NVIDIA cuDNN

API Reference | NVIDIA Docs
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Chapter 1. Introduction

NVIDIA® CUDAN® Deep Neural Network (cuDNN) library offers a context-based API that allows for easy multithreading and (optional) interoperability with CUDA streams. This API Reference lists the datatypes and functions per library. Specifically, this reference consists of a cuDNN datatype reference section that describes the types of enums and a cuDNN API reference section that describes all routines in the cuDNN library API.

The cuDNN library as well as this API document has been split into the following libraries:

**cudnn_ops_infer**
This entity contains the routines related to cuDNN context creation and destruction, tensor descriptor management, tensor utility routines, and the inference portion of common machine learning algorithms such as batch normalization, softmax, dropout, and so on.

**cudnn_ops_train**
This entity contains common training routines and algorithms, such as batch normalization, softmax, dropout, and so on. The cudnn_ops_train library depends on cudnn_ops_infer.

**cudnn_cnn_infer**
This entity contains all routines related to convolutional neural networks needed at inference time. The cudnn_cnn_infer library depends on cudnn_ops_infer.

**cudnn_cnn_train**
This entity contains all routines related to convolutional neural networks needed during training time. The cudnn_cnn_train library depends on cudnn_ops_infer, cudnn_ops_train, and cudnn_cnn_infer.

**cudnn_adv_infer**
This entity contains all other features and algorithms. This includes RNNs, CTC loss, and multi-head attention. The cudnn_adv_infer library depends on cudnn_ops_infer.

**cudnn_adv_train**
This entity contains all the training counterparts of cudnn_adv_infer. The cudnn_adv_train library depends on cudnn_ops_infer, cudnn_ops_train, and cudnn_adv_infer.

**cudnnBackend**
Introduced in cuDNN version 8.x, this entity contains a list of valid cuDNN backend descriptor types, a list of valid attributes, a subset of valid attribute values, and a full description of each backend descriptor type and their attributes.

**cudnn**
This is an optional shim layer between the application layer and the cuDNN code. This layer opportunistically opens the correct library for the API at runtime.
Chapter 2. Added, Deprecated, and Removed API Functions

2.1. API Changes for cuDNN 8.7.0

The following tables show which API functions were added, deprecated, and removed for the cuDNN 8.7.0.

Table 1. API functions and data types that were added in cuDNN 8.7.0

<table>
<thead>
<tr>
<th>Backend descriptor types</th>
</tr>
</thead>
<tbody>
<tr>
<td>cudnnRngDistribution_t</td>
</tr>
<tr>
<td>CUDNN_BACKEND_OPERATION_RNG_DESCRIPTOR</td>
</tr>
<tr>
<td>CUDNN_BACKEND_RNG_DESCRIPTOR</td>
</tr>
</tbody>
</table>

2.2. API Changes for cuDNN 8.5.0

The following tables show which API functions were added, deprecated, and removed for the cuDNN 8.5.0.

Table 2. API functions and data types that were added in cuDNN 8.5.0

<table>
<thead>
<tr>
<th>Backend descriptor types</th>
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<tbody>
<tr>
<td>cudnnBackendNormFwdPhase_t</td>
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<tr>
<td>cudnnBackendNormMode_t</td>
</tr>
<tr>
<td>CUDNN_BACKEND_OPERATION_CONCAT_DESCRIPTOR</td>
</tr>
<tr>
<td>CUDNN_BACKEND_OPERATION_NORM_BACKWARD_DESCRIPTOR</td>
</tr>
<tr>
<td>CUDNN_BACKEND_OPERATION_NORM_FORWARD_DESCRIPTOR</td>
</tr>
</tbody>
</table>
2.3. API Changes for cuDNN 8.4.0

The following tables show which API functions were added, deprecated, and removed for the cuDNN 8.4.0.

Table 3. API functions and data types that were added in cuDNN 8.4.0

<table>
<thead>
<tr>
<th>Backend descriptor types</th>
</tr>
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</table>
| cudnnBackendBehaviorNote_t          
| CUDNN_BACKEND_OPERATION_REDUCTION_DESCRIPTOR |
| CUDNN_BACKEND_POINTWISE_DESCRIPTOR |
| CUDNN_BACKEND_REDUCTION_DESCRIPTOR |
| cudnnBackendTensorReordering_t |
| cudnnBnFinalizeStatsMode_t |
| cudnnPaddingMode_t |
| cudnnResampleMode_t |

2.4. API Changes for cuDNN 8.3.0

The following tables show which API functions were added, deprecated, and removed for the cuDNN 8.3.0.

Table 4. API functions and data types that were added in cuDNN 8.3.0

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<thead>
<tr>
<th>Backend descriptor types</th>
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<tbody>
<tr>
<td>CUDNN_BACKEND_OPERATION_RESAMPLE_BWD_DESCRIPTOR</td>
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<tr>
<td>CUDNN_BACKEND_OPERATION_RESAMPLE_FWD_DESCRIPTOR</td>
</tr>
<tr>
<td>CUDNN_BACKEND_RESAMPLE_DESCRIPTOR</td>
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</tbody>
</table>
2.5. API Changes for cuDNN 8.2.0

The following tables show which API functions were added, deprecated, and removed for the cuDNN 8.2.0.

Table 5. API functions and data types that were added in cuDNN 8.2.0

<table>
<thead>
<tr>
<th>New functions</th>
</tr>
</thead>
<tbody>
<tr>
<td>cudnnGetActivationDescriptorSwishBeta()</td>
</tr>
<tr>
<td>cudnnSetActivationDescriptorSwishBeta()</td>
</tr>
</tbody>
</table>

2.6. API Changes for cuDNN 8.1.0

The following tables show which API functions were added, deprecated, and removed for the cuDNN 8.1.0.

Table 6. API functions and data types that were added in cuDNN 8.1.0

<table>
<thead>
<tr>
<th>Backend descriptor types</th>
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</thead>
<tbody>
<tr>
<td>CUDNN_BACKEND_MATMUL_DESCRIPTOR</td>
</tr>
<tr>
<td>CUDNN_BACKEND_OPERATION_MATMUL_DESCRIPTOR</td>
</tr>
</tbody>
</table>

2.7. API Changes for cuDNN 8.0.3

The following tables show which API functions were added, deprecated, and removed for the cuDNN 8.0.3.

Table 7. API functions and data types that were added in cuDNN 8.0.3

<table>
<thead>
<tr>
<th>Backend descriptor types</th>
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</thead>
<tbody>
<tr>
<td>CUDNN_BACKEND_CONVOLUTION_DESCRIPTOR</td>
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<tr>
<td>CUDNN_BACKEND_ENGINE_DESCRIPTOR</td>
</tr>
<tr>
<td>CUDNN_BACKEND_ENGINECFG_DESCRIPTOR</td>
</tr>
<tr>
<td>CUDNN_BACKENDENGINEHEUR_DESCRIPTOR</td>
</tr>
<tr>
<td>CUDNN_BACKEND_EXECUTION_PLAN_DESCRIPTOR</td>
</tr>
</tbody>
</table>
2.8. API Changes for cuDNN 8.0.2

The following tables show which API functions were added, deprecated, and removed for the cuDNN 8.0.2.

Table 8. API functions and data types that were added in cuDNN 8.0.2

<table>
<thead>
<tr>
<th>New functions and data types</th>
</tr>
</thead>
<tbody>
<tr>
<td>cudnnRNNBackwardData_v8()</td>
</tr>
<tr>
<td>cudnnRNNBackwardWeights_v8()</td>
</tr>
</tbody>
</table>

2.9. API Changes for cuDNN 8.0.0 Preview

The following tables show which API functions were added, deprecated, and removed for the cuDNN 8.0.0 Preview Release.

Table 9. API functions and data types that were added in cuDNN 8.0.0 Preview

<table>
<thead>
<tr>
<th>New functions and data types</th>
</tr>
</thead>
<tbody>
<tr>
<td>cudnnAdvInferVersionCheck()</td>
</tr>
<tr>
<td>cudnnAdvTrainVersionCheck()</td>
</tr>
</tbody>
</table>
### New functions and data types

- `cudnnBackendAttributeName_t`
- `cudnnBackendAttributeType_t`
- `cudnnBackendCreateDescriptor()`
- `cudnnBackendDescriptor_t`
- `cudnnBackendDescriptorType_t`
- `cudnnBackendDestroyDescriptor()`
- `cudnnBackendExecute()`
- `cudnnBackendFinalize()`
- `cudnnBackendGetAttribute()`
- `cudnnBackendHeurMode_t`
- `cudnnBackendInitialize()`
- `cudnnBackendKnobType_t`
- `cudnnBackendLayoutType_t`
- `cudnnBackendNumericalNote_t`
- `cudnnBackendSetAttribute()`
- `cudnnBuildRNNDynamic()`
- `cudnnCTCLoss_v8()`
- `cudnnDeriveNormTensorDescriptor()`
- `cudnnForwardMode_t`
- `cudnnGenStatsMode_t`
- `cudnnGetCTCLossDescriptor_v8()`
- `cudnnGetCTCLossDescriptorEx()`
- `cudnnGetCTCLossWorkspaceSize_v8`
- `cudnnGetFilterSizeInBytes()`
- `cudnnGetFoldedConvBackwardDataDescriptors()`
- `cudnnGetNormalizationBackwardWorkspaceSize()`
- `cudnnGetNormalizationForwardTrainingWorkspaceSize()`
- `cudnnGetNormalizationTrainingReserveSpaceSize()`
- `cudnnGetRNNDescriptor_v8()`
- `cudnnGetRNNMatrixMathType()`
- `cudnnGetRNNTempSpaceSizes()`
- `cudnnGetRNNWeightParams()`
- `cudnnGetRNNWeightSpaceSize()`
- `cudnnLRNDescriptor_t`
- `cudnnNormAlgo_t`
- `cudnnNormalizationBackward()`
- `cudnnNormalizationForwardInference()`
- `cudnnNormalizationForwardTraining()`
### New functions and data types

- `cudnnNormMode_t`
- `cudnnNormOps_t`
- `cudnnOpsInferVersionCheck()`
- `cudnnOpsTrainVersionCheck()`
- `cudnnPointwiseMode_t`
- `cudnnRNNForward()`
- `cudnnRNNGetClip_v8()`
- `cudnnRNNGetClip_v8()`
- `cudnnSetCTCLossDescriptor_v8()`
- `cudnnSetRNNDescriptor_v8()`
- `cudnnSeverity_t`

For our deprecation policy, refer to the [Backward Compatibility And Deprecation Policy](#).

### Table 10. API functions and data types that were deprecated in cuDNN 8.0.0 Preview

<table>
<thead>
<tr>
<th>Deprecated functions and data types</th>
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<tbody>
<tr>
<td><code>cudnnCopyAlgorithmDescriptor()</code></td>
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<tr>
<td><code>cudnnCreateAlgorithmDescriptor()</code></td>
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</tr>
<tr>
<td><code>cudnnCreatePersistentRNNPlan()</code></td>
<td><code>cudnnBuildRNNDynamic()</code></td>
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<td><code>cudnnDestroyAlgorithmDescriptor()</code></td>
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<tr>
<td><code>cudnnDestroyPersistentRNNPlan()</code></td>
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</tr>
<tr>
<td><code>cudnnFindRNNBackwardDataAlgorithmEx()</code></td>
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<td><code>cudnnFindRNNBackwardWeightsAlgorithmEx()</code></td>
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<td><code>cudnnGetRNNProjectionLayers()</code></td>
<td><code>cudnnGetRNNDescriptor_v8()</code></td>
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<tr>
<td>Deprecated functions and data types</td>
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<td>cudnnSetRNNProjectionLayers()</td>
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Table 11. API functions and data types that were removed in cuDNN 8.0.0 Preview

<table>
<thead>
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<th>Removed functions and data types</th>
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<tbody>
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<td>cudnnConvolutionBwdDataPreference_t</td>
</tr>
<tr>
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Chapter 3. cudnn_ops_infer.so Library

This entity contains the routines related to cuDNN context creation and destruction, tensor descriptor management, tensor utility routines, and the inference portion of common machine learning algorithms such as batch normalization, softmax, dropout, and so on.

3.1. Data Type References

These are the data type references in the cudnn_ops_infer.so library.

3.1.1. Pointer To Opaque Struct Types

These are the pointers to the opaque struct types in the cudnn_ops_infer.so library.

3.1.1.1. cudnnActivationDescriptor_t

CudnnActivationDescriptor_t is a pointer to an opaque structure holding the description of an activation operation. cudnnCreateActivationDescriptor() is used to create one instance, and cudnnSetActivationDescriptor() must be used to initialize this instance.

3.1.1.2. cudnnCTCLossDescriptor_t

CudnnCTCLossDescriptor_t is a pointer to an opaque structure holding the description of a CTC loss operation. cudnnCreateCTCLossDescriptor() is used to create one instance, cudnnSetCTCLossDescriptor() is used to initialize this instance, and cudnnDestroyCTCLossDescriptor() is used to destroy this instance.

3.1.1.3. cudnnDropoutDescriptor_t

CudnnDropoutDescriptor_t is a pointer to an opaque structure holding the description of a dropout operation. cudnnCreateDropoutDescriptor() is used to create one instance, cudnnSetDropoutDescriptor() is used to initialize this instance, cudnnDestroyDropoutDescriptor() is used to destroy this instance,
cudnnGetDropoutDescriptor() is used to query fields of a previously initialized instance, cudnnRestoreDropoutDescriptor() is used to restore an instance to a previously saved off state.

### 3.1.1.4. cudnnFilterDescriptor_t

CudnnFilterDescriptor_t is a pointer to an opaque structure holding the description of a filter dataset. cudnnCreateFilterDescriptor() is used to create one instance, and cudnnSetFilter4dDescriptor() or cudnnSetFilterNdDescriptor() must be used to initialize this instance.

### 3.1.1.5. cudnnHandle_t

CudnnHandle_t is a pointer to an opaque structure holding the cuDNN library context. The cuDNN library context must be created using cudnnCreate() and the returned handle must be passed to all subsequent library function calls. The context should be destroyed at the end using cudnnDestroy(). The context is associated with only one GPU device, the current device at the time of the call to cudnnCreate(). However, multiple contexts can be created on the same GPU device.

### 3.1.1.6. cudnnLRNDescriptor_t

CudnnLRNDescriptor_t is a pointer to an opaque structure holding the parameters of a local response normalization. cudnnCreateLRNDescriptor() is used to create one instance, and the routine cudnnSetLRNDescriptor() must be used to initialize this instance.

### 3.1.1.7. cudnnOpTensorDescriptor_t

CudnnOpTensorDescriptor_t is a pointer to an opaque structure holding the description of a Tensor Core operation, used as a parameter to cudnnOpTensor(). cudnnCreateOpTensorDescriptor() is used to create one instance, and cudnnSetOpTensorDescriptor() must be used to initialize this instance.

### 3.1.1.8. cudnnPoolingDescriptor_t

CudnnPoolingDescriptor_t is a pointer to an opaque structure holding the description of a pooling operation. cudnnCreatePoolingDescriptor() is used to create one instance, and cudnnSetPoolingNdDescriptor() or cudnnSetPooling2dDescriptor() must be used to initialize this instance.

### 3.1.1.9. cudnnReduceTensorDescriptor_t

CudnnReduceTensorDescriptor_t is a pointer to an opaque structure holding the description of a tensor reduction operation, used as a parameter to cudnnReduceTensor(). cudnnCreateReduceTensorDescriptor() is used to create one instance, and cudnnSetReduceTensorDescriptor() must be used to initialize this instance.
3.1.1.10. **cudnnSpatialTransformerDescriptor_t**

cudnnSpatialTransformerDescriptor_t is a pointer to an opaque structure holding the description of a spatial transformation operation. 
cudnnCreateSpatialTransformerDescriptor() is used to create one instance, cudnnSetSpatialTransformerNdDescriptor() is used to initialize this instance, and cudnnDestroySpatialTransformerDescriptor() is used to destroy this instance.

3.1.1.11. **cudnnTensorDescriptor_t**

cudnnTensorDescriptor_t is a pointer to an opaque structure holding the description of a generic n-D dataset. cudnnCreateTensorDescriptor() is used to create one instance, and one of the routines cudnnSetTensorNdDescriptor(), cudnnSetTensor4dDescriptor() or cudnnSetTensor4dDescriptorEx() must be used to initialize this instance.

3.1.1.12. **cudnnTensorTransformDescriptor_t**

cudnnTensorTransformDescriptor_t is an opaque structure containing the description of the tensor transform. Use the cudnnCreateTensorTransformDescriptor() function to create an instance of this descriptor, and cudnnDestroyTensorTransformDescriptor() function to destroy a previously created instance.

3.1.2. **Enumeration Types**

These are the enumeration types in the cudnn_ops_infer.so library.

3.1.2.1. **cudnnActivationMode_t**

cudnnActivationMode_t is an enumerated type used to select the neuron activation function used in cudnnActivationForward(), cudnnActivationBackward(), and cudnnConvolutionBiasActivationForward().

**Values**

- **CUDNN_ACTIVATION_SIGMOID**
  - Selects the sigmoid function.
- **CUDNN_ACTIVATION_RELU**
  - Selects the rectified linear function.
- **CUDNN_ACTIVATION_TANH**
  - Selects the hyperbolic tangent function.
- **CUDNN_ACTIVATION_CLIPPED_RELU**
  - Selects the clipped rectified linear function.
- **CUDNN_ACTIVATION_ELU**
  - Selects the exponential linear function.
**CUDNN_ACTIVATION_IDENTITY**

Selects the identity function, intended for bypassing the activation step in `cudnnConvolutionBiasActivationForward()`. (The `cudnnConvolutionBiasActivationForward()` function must use `CUDNN_CONVOLUTION_FWD_ALGO_IMPLICIT_PRECOMP_GEMM`.) Does not work with `cudnnActivationForward()` or `cudnnActivationBackward()`.

**CUDNN_ACTIVATION_SWISH**

Selects the swish function.

### 3.1.2.2. cudnnAlgorithm_t

This function has been deprecated in cuDNN 8.0.

### 3.1.2.3. cudnnBatchNormMode_t

`cudnnBatchNormMode_t` is an enumerated type used to specify the mode of operation in `cudnnBatchNormalizationForwardInference()`, `cudnnBatchNormalizationForwardTraining()`, `cudnnBatchNormalizationBackward()` and `cudnnDeriveBNTensorDescriptor()` routines.

**Values**

**CUDNN_BATCHNORM_PER_ACTIVATION**

Normalization is performed per-activation. This mode is intended to be used after the non-convolutional network layers. In this mode, the tensor dimensions of `bnBias` and `bnScale` and the parameters used in the `cudnnBatchNormalization*` functions are `1xCxHxW`.

**CUDNN_BATCHNORM_SPATIAL**

Normalization is performed over `N`+spatial dimensions. This mode is intended for use after convolutional layers (where spatial invariance is desired). In this mode the `bnBias` and `bnScale` tensor dimensions are `1xCx1x1`.

**CUDNN_BATCHNORM_SPATIAL_PERSISTENT**

This mode is similar to `CUDNN_BATCHNORM_SPATIAL` but it can be faster for some tasks.

An optimized path may be selected for `CUDNN_DATA_FLOAT` and `CUDNN_DATA_HALF` types, compute capability 6.0 or higher for the following two batch normalization API calls: `cudnnBatchNormalizationForwardTraining()` and `cudnnBatchNormalizationBackward()`. In the case of `cudnnBatchNormalizationBackward()`, the `savedMean` and `savedInvVariance` arguments should not be `NULL`.

**The rest of this section applies to NCHW mode only:** This mode may use a scaled atomic integer reduction that is deterministic but imposes more restrictions on the input data range. When a numerical overflow occurs, the algorithm may produce NaN-s or Inf-s (infinity) in output buffers.
When Inf-s/NaN-s are present in the input data, the output in this mode is the same as from a pure floating-point implementation.

For finite but very large input values, the algorithm may encounter overflows more frequently due to a lower dynamic range and emit Inf-s/NaN-s while CUDNN_BATCNORM_SPATIAL will produce finite results. The user can invoke cudnnQueryRuntimeError() to check if a numerical overflow occurred in this mode.

### 3.1.2.4. cudnnBatchNormOps_t

CudnnBatchNormOps_t is an enumerated type used to specify the mode of operation in cudnnGetBatchNormalizationForwardTrainingExWorkspaceSize(), cudnnBatchNormalizationForwardTrainingEx(), cudnnGetBatchNormalizationBackwardExWorkspaceSize(), cudnnBatchNormalizationBackwardEx(), and cudnnGetBatchNormalizationTrainingExReserveSpaceSize() functions.

**Values**

- **CUDNN_BATCHNORM_OPS_BN**
  - Only batch normalization is performed, per-activation.

- **CUDNN_BATCHNORM_OPS_BN_ACTIVATION**
  - First, the batch normalization is performed, and then the activation is performed.

- **CUDNN_BATCHNORM_OPS_BN_ADD_ACTIVATION**
  - Performs the batch normalization, then element-wise addition, followed by the activation operation.

### 3.1.2.5. cudnnCTCLossAlgo_t

CudnnCTCLossAlgo_t is an enumerated type that exposes the different algorithms available to execute the CTC loss operation.

**Values**

- **CUDNN_CTC_LOSS_ALGO_DETERMINISTIC**
  - Results are guaranteed to be reproducible.

- **CUDNN_CTC_LOSS_ALGO_NON_DETERMINISTIC**
  - Results are not guaranteed to be reproducible.

### 3.1.2.6. cudnnDataType_t

CudnnDataType_t is an enumerated type indicating the data type to which a tensor descriptor or filter descriptor refers.

**Values**

- **CUDNN_DATA_FLOAT**
  - The data is a 32-bit single-precision floating-point (float).
The data is a 64-bit double-precision floating-point (double).

The data is a 16-bit floating-point.

The data is an 8-bit signed integer.

The data is a 32-bit signed integer.

The data is 32-bit elements each composed of 4 8-bit signed integers. This data type is only supported with the tensor format CUDNN_TENSOR_NCHW_VECT_C.

The data is an 8-bit unsigned integer.

The data is 32-bit elements each composed of 4 8-bit unsigned integers. This data type is only supported with the tensor format CUDNN_TENSOR_NCHW_VECT_C.

The data is 32-element vectors, each element being an 8-bit signed integer. This data type is only supported with the tensor format CUDNN_TENSOR_NCHW_VECT_C. Moreover, this data type can only be used with algo 1, meaning, CUDNN_CONVOLUTION_FWD_ALGO_IMPLICIT_PRECOMP_GEMM. For more information, refer to cudnnConvolutionFwdAlgo_t.

The data is a 16-bit quantity, with 7 mantissa bits, 8 exponent bits, and 1 sign bit.

The data is a 64-bit signed integer.

The data is a boolean (bool).

Note that for type CUDNN_TYPE_BOOLEAN, elements are expected to be "packed": that is, one byte contains 8 elements of type CUDNN_TYPE_BOOLEAN. Further, within each byte, elements are indexed from the least significant bit to the most significant bit. For example, a 1 dimensional tensor of 8 elements containing 01001111 has value 1 for elements 0 through 3, 0 for elements 4 and 5, 1 for element 6 and 0 for element 7.

Tensors with more than 8 elements simply use more bytes, where the order is also from least significant to most significant byte. Note, CUDA is little-endian, meaning that the least significant byte has the lower memory address address. For example, in the case of 16 elements, 01001111 11111100 has value 1 for elements 0 through 3, 0 for elements 4 and 5, 1 for element 6 and 0 for element 7, value 0 for elements 8 and 9, 1 for elements 10 through 15.

The data is an 8-bit quantity, with 3 mantissa bits, 4 exponent bits, and 1 sign bit.
CUDNN_DATA_FP8_E5M2
   The data is an 8-bit quantity, with 2 mantissa bits, 5 exponent bits, and 1 sign bit.
CUDNN_DATA_FAST_FLOAT_FOR_FP8
   The data type is a higher throughput but lower precision compute type (compared to
   CUDNN_DATA_FLOAT) used for FP8 tensor core operations

3.1.2.7. cudnnDeterminism_t

   cudnnDeterminism_t is an enumerated type used to indicate if the computed results are
deterministic (reproducible). For more information, refer to Reproducibility (Determinism).

Values

CUDNN_NON_DETERMINISTIC
   Results are not guaranteed to be reproducible.
CUDNN_DETERMINISTIC
   Results are guaranteed to be reproducible.

3.1.2.8. cudnnDivNormMode_t

   cudnnDivNormMode_t is an enumerated type used to specify the mode of operation in
   cudnnDivisiveNormalizationForward() and cudnnDivisiveNormalizationBackward().

Values

CUDNN_DIVNORM_PRECOMPUTED_MEANS
   The means tensor data pointer is expected to contain means or other kernel
   convolution values precomputed by the user. The means pointer can also be NULL, in
   that case, it’s considered to be filled with zeroes. This is equivalent to spatial LRN.

   Note: In the backward pass, the means are treated as independent inputs and
   the gradient over means is computed independently. In this mode, to yield a net
   gradient over the entire LCN computational graph, the destDiffMeans result should
   be backpropagated through the user’s means layer (which can be implemented
   using average pooling) and added to the destDiffData tensor produced by
   cudnnDivisiveNormalizationBackward().

3.1.2.9. cudnnErrQueryMode_t

   cudnnErrQueryMode_t is an enumerated type passed to cudnnQueryRuntimeError() to
   select the remote kernel error query mode.

Values

CUDNN_ERRQUERY_RAWCODE
   Read the error storage location regardless of the kernel completion status.
CUDNN_ERRQUERY_NONBLOCKING
Report if all tasks in the user stream of the cuDNN handle were completed. If that is the case, report the remote kernel error code.

CUDNN_ERRQUERY_BLOCKING
Wait for all tasks to complete in the user stream before reporting the remote kernel error code.

3.1.2.10. cudnnFoldingDirection_t
cudnnFoldingDirection_t is an enumerated type used to select the folding direction. For more information, refer to cudnnTensorTransformDescriptor_t.

Data Member

CUDNN_TRANSFORM_FOLD = 0U
Selects folding.

CUDNN_TRANSFORM_UNFOLD = 1U
Selects unfolding.

3.1.2.11. cudnnIndicesType_t
cudnnIndicesType_t is an enumerated type used to indicate the data type for the indices to be computed by the cudnnReduceTensor() routine. This enumerated type is used as a field for the cudnnReduceTensorDescriptor_t descriptor.

Values

CUDNN_32BIT_INDICES
Compute unsigned int indices.

CUDNN_64BIT_INDICES
Compute unsigned long indices.

CUDNN_16BIT_INDICES
Compute unsigned short indices.

CUDNN_8BIT_INDICES
Compute unsigned char indices.

3.1.2.12. cudnnLRNMode_t
cudnnLRNMode_t is an enumerated type used to specify the mode of operation in cudnnLRNCrossChannelForward() and cudnnLRNCrossChannelBackward().

Values

CUDNN_LRN_CROSS_CHANNEL_DIM1
LRN computation is performed across the tensor’s dimension dimA[1].
3.1.2.13. **cudnnMathType_t**

*cudnnMathType_t* is an enumerated type used to indicate if the use of Tensor Core operations is permitted in a given library routine.

**Values**

- **CUDNN_DEFAULT_MATH**
  Tensor Core operations are not used on pre-NVIDIA A100 GPU devices. On A100 GPU architecture devices, Tensor Core TF32 operation is permitted.

- **CUDNN_TENSOR_OP_MATH**
  The use of Tensor Core operations is permitted but will not actively perform datatype down conversion on tensors in order to utilize Tensor Cores.

- **CUDNN_TENSOR_OP_MATH_ALLOW_CONVERSION**
  The use of Tensor Core operations is permitted and will actively perform datatype down conversion on tensors in order to utilize Tensor Cores.

- **CUDNN_FMA_MATH**
  Restricted to only kernels that use FMA instructions.

On pre-NVIDIA A100 GPU devices, CUDNN_DEFAULT_MATH and CUDNN_FMA_MATH have the same behavior: Tensor Core kernels will not be selected. With NVIDIA Ampere architecture and CUDA toolkit 11, CUDNN_DEFAULT_MATH permits TF32 Tensor Core operation and CUDNN_FMA_MATH does not. The TF32 behavior for CUDNN_DEFAULT_MATH and the other Tensor Core math types can be explicitly disabled by the environment variable NVIDIA_TF32_OVERRIDE=0.

3.1.2.14. **cudnnNanPropagation_t**

*cudnnNanPropagation_t* is an enumerated type used to indicate if a given routine should propagate Nan numbers. This enumerated type is used as a field for the cudnnActivationDescriptor_t descriptor and cudnnPoolingDescriptor_t descriptor.

**Values**

- **CUDNN_NOT_PROPAGATE_NAN**
  Nan numbers are not propagated.

- **CUDNN_PROPAGATE_NAN**
  Nan numbers are propagated.

3.1.2.15. **cudnnNormAlgo_t**

*cudnnNormAlgo_t* is an enumerated type used to specify the algorithm to execute the normalization operation.

**Values**

- **CUDNN_NORM_ALGO_STANDARD**
  Standard normalization is performed.
**CUDNN_NORM_ALGO_PERSIST**

This mode is similar to CUDNN_NORM_ALGO_STANDARD, however it only supports CUDNN_NORM_PER_CHANNEL and can be faster for some tasks.

An optimized path may be selected for CUDNN_DATA_FLOAT and CUDNN_DATA_HALF types, compute capability 6.0 or higher for the following two normalization API calls: cudnnNormalizationForwardTraining() and cudnnNormalizationBackward(). In the case of cudnnNormalizationBackward(), the savedMean and savedInvVariance arguments should not be NULL.

**The rest of this section applies to NCHW mode only:** This mode may use a scaled atomic integer reduction that is deterministic but imposes more restrictions on the input data range. When a numerical overflow occurs, the algorithm may produce NaN-s or Inf-s (infinity) in output buffers.

When Inf-s/NaN-s are present in the input data, the output in this mode is the same as from a pure floating-point implementation.

For finite but very large input values, the algorithm may encounter overflows more frequently due to a lower dynamic range and emit Inf-s/NaN-s while CUDNN_NORM_ALGO_STANDARD will produce finite results. The user can invoke cudnnQueryRuntimeError() to check if a numerical overflow occurred in this mode.

### 3.1.2.16. cudnnNormMode_t

cudnnNormMode_t is an enumerated type used to specify the mode of operation in cudnnNormalizationForwardInference(), cudnnNormalizationForwardTraining(), cudnnBatchNormalizationBackward(), cudnnGetNormalizationForwardTrainingWorkspaceSize(), cudnnGetNormalizationBackwardWorkspaceSize(), and cudnnGetNormalizationTrainingReserveSpaceSize() routines.

**Values**

**CUDNN_NORM_PER_ACTIVATION**

Normalization is performed per-activation. This mode is intended to be used after the non-convolutional network layers. In this mode, the tensor dimensions of normBias and normScale and the parameters used in the cudnnNormalization* functions are 1xCxHxW.

**CUDNN_NORM_PER_CHANNEL**

Normalization is performed per-channel over N+spatial dimensions. This mode is intended for use after convolutional layers (where spatial invariance is desired). In this mode, the normBias and normScale tensor dimensions are 1xCx1x1.

### 3.1.2.17. cudnnNormOps_t

cudnnNormOps_t is an enumerated type used to specify the mode of operation in cudnnGetNormalizationForwardTrainingWorkspaceSize().
cudnnNormalizationForwardTraining(),
cudnnGetNormalizationBackwardWorkspaceSize(), cudnnNormalizationBackward(),
and cudnnGetNormalizationTraining ReserveSpaceSize() functions.

Values

**CUDNN_NORM_OPS_NORM**
  Only normalization is performed.

**CUDNN_NORM_OPS_NORM_ACTIVATION**
  First, the normalization is performed, then the activation is performed.

**CUDNN_NORM_OPS_NORM_ADD_ACTIVATION**
  Performs the normalization, then element-wise addition, followed by the activation operation.

3.1.2.18. **cudnnOpTensorOp_t**
cudnnOpTensorOp_t is an enumerated type used to indicate the Tensor Core operation to be used by the cudnnOpTensor() routine. This enumerated type is used as a field for the cudnnOpTensorDescriptor_t descriptor.

Values

**CUDNN_OP_TENSOR_ADD**
  The operation to be performed is addition.

**CUDNN_OP_TENSOR_MUL**
  The operation to be performed is multiplication.

**CUDNN_OP_TENSOR_MIN**
  The operation to be performed is a minimum comparison.

**CUDNN_OP_TENSOR_MAX**
  The operation to be performed is a maximum comparison.

**CUDNN_OP_TENSOR_SQRT**
  The operation to be performed is square root, performed on only the A tensor.

**CUDNN_OP_TENSOR_NOT**
  The operation to be performed is negation, performed on only the A tensor.

3.1.2.19. **cudnnPoolingMode_t**
cudnnPoolingMode_t is an enumerated type passed to cudnnSetPooling2dDescriptor() to select the pooling method to be used by cudnnPoolingForward() and cudnnPoolingBackward().

Values

**CUDNN_POOLING_MAX**
  The maximum value inside the pooling window is used.
CUDNN_POOLING_AVERAGE_COUNT_INCLUDE_PADDING
Values inside the pooling window are averaged. The number of elements used to calculate the average includes spatial locations falling in the padding region.

CUDNN_POOLING_AVERAGE_COUNT_EXCLUDE_PADDING
Values inside the pooling window are averaged. The number of elements used to calculate the average excludes spatial locations falling in the padding region.

CUDNN_POOLING_MAX_DETERMINISTIC
The maximum value inside the pooling window is used. The algorithm used is deterministic.

3.1.2.20. cudnnReduceTensorIndices_t

cudnnReduceTensorIndices_t is an enumerated type used to indicate whether indices are to be computed by the cudnnReduceTensor() routine. This enumerated type is used as a field for the cudnnReduceTensorDescriptor_t descriptor.

Values

CUDNN_REDUCE_TENSOR_NO_INDICES
Do not compute indices.

CUDNN_REDUCE_TENSOR_FLATTENED_INDICES
Compute indices. The resulting indices are relative, and flattened.

3.1.2.21. cudnnReduceTensorOp_t

cudnnReduceTensorOp_t is an enumerated type used to indicate the Tensor Core operation to be used by the cudnnReduceTensor() routine. This enumerated type is used as a field for the cudnnReduceTensorDescriptor_t descriptor.

Values

CUDNN_REDUCE_TENSOR_ADD
The operation to be performed is addition.

CUDNN_REDUCE_TENSOR_MUL
The operation to be performed is multiplication.

CUDNN_REDUCE_TENSOR_MIN
The operation to be performed is a minimum comparison.

CUDNN_REDUCE_TENSOR_MAX
The operation to be performed is a maximum comparison.

CUDNN_REDUCE_TENSOR_AMAX
The operation to be performed is a maximum comparison of absolute values.

CUDNN_REDUCE_TENSOR_AVG
The operation to be performed is averaging.

CUDNN_REDUCE_TENSOR_NORM1
The operation to be performed is addition of absolute values.

CUDNN_REDUCE_TENSOR_NORM2
The operation to be performed is a square root of the sum of squares.
CUDNN_REDUCE_TENSOR_MUL_NO_ZEROS
The operation to be performed is multiplication, not including elements of value zero.

3.1.2.22. cudnnRNNAlgo_t

cudnnRNNAlgo_t is an enumerated type used to specify the algorithm used in the cudnnRNNForwardInference(), cudnnRNNForwardTraining(), cudnnRNNBackwardData(), and cudnnRNNBackwardWeights() routines.

Values

CUDNN_RNN_ALGO_STANDARD
Each RNN layer is executed as a sequence of operations. This algorithm is expected to have robust performance across a wide range of network parameters.

CUDNN_RNN_ALGO_PERSIST_STATIC
The recurrent parts of the network are executed using a persistent kernel approach. This method is expected to be fast when the first dimension of the input tensor is small (meaning, a small minibatch).

CUDNN_RNN_ALGO_PERSIST_STATIC is only supported on devices with compute capability >= 6.0.

CUDNN_RNN_ALGO_PERSIST_DYNAMIC
The recurrent parts of the network are executed using a persistent kernel approach. This method is expected to be fast when the first dimension of the input tensor is small (meaning, a small minibatch). When using CUDNN_RNN_ALGO_PERSIST_DYNAMIC persistent kernels are prepared at runtime and are able to optimize using the specific parameters of the network and active GPU. As such, when using CUDNN_RNN_ALGO_PERSIST_DYNAMIC a one-time plan preparation stage must be executed. These plans can then be reused in repeated calls with the same model parameters.

The limits on the maximum number of hidden units supported when using CUDNN_RNN_ALGO_PERSIST_DYNAMIC are significantly higher than the limits when using CUDNN_RNN_ALGO_PERSIST_STATIC, however throughput is likely to significantly reduce when exceeding the maximums supported by CUDNN_RNN_ALGO_PERSIST_STATIC. In this regime, this method will still outperform CUDNN_RNN_ALGO_STANDARD for some cases.

CUDNN_RNN_ALGO_PERSIST_DYNAMIC is only supported on devices with compute capability >= 6.0 on Linux machines.

3.1.2.23. cudnnSamplerType_t

cudnnSamplerType_t is an enumerated type passed to cudnnSetSpatialTransformerNdDescriptor() to select the sampler type to be used by cudnnSpatialTfSamplerForward() and cudnnSpatialTfSamplerBackward().
Values

CUDNN_SAMPLER_BILINEAR
Selects the bilinear sampler.

3.1.2.24. cudnnSeverity_t

cudnnSeverity_t is an enumerated type passed to the customized callback function for logging that users may set. This enumerate describes the severity level of the item, so the customized logging call back may react differently.

Values

CUDNN_SEV_FATAL
This value indicates a fatal error emitted by cuDNN.

CUDNN_SEV_ERROR
This value indicates a normal error emitted by cuDNN.

CUDNN_SEV_WARNING
This value indicates a warning emitted by cuDNN.

CUDNN_SEV_INFO
This value indicates a piece of information (for example, API log) emitted by cuDNN.

3.1.2.25. cudnnSoftmaxAlgorithm_t
cudnnSoftmaxAlgorithm_t is used to select an implementation of the softmax function used in cudnnSoftmaxForward() and cudnnSoftmaxBackward().

Values

CUDNN_SOFTMAX_FAST
This implementation applies the straightforward softmax operation.

CUDNN_SOFTMAX_ACCURATE
This implementation scales each point of the softmax input domain by its maximum value to avoid potential floating point overflows in the softmax evaluation.

CUDNN_SOFTMAX_LOG
This entry performs the log softmax operation, avoiding overflows by scaling each point in the input domain as in CUDNN_SOFTMAX_ACCURATE.

3.1.2.26. cudnnSoftmaxMode_t
cudnnSoftmaxMode_t is used to select over which data the cudnnSoftmaxForward() and cudnnSoftmaxBackward() are computing their results.

Values

CUDNN_SOFTMAX_MODE_INSTANCE
The softmax operation is computed per image (N) across the dimensions C, H, W.
**CUDNN_SOFTMAX_MODE_CHANNEL**

The softmax operation is computed per spatial location \((H, W)\) per image \((N)\) across dimension \(C\).

**3.1.2.27. cudnnStatus_t**

`cudnnStatus_t` is an enumerated type used for function status returns. All cuDNN library functions return their status, which can be one of the following values:

**Values**

**CUDNN_STATUS_SUCCESS**

The operation was completed successfully.

**CUDNN_STATUS_NOT_INITIALIZED**

The cuDNN library was not initialized properly. This error is usually returned when a call to `cudnnCreate()` fails or when `cudnnCreate()` has not been called prior to calling another cuDNN routine. In the former case, it is usually due to an error in the CUDA Runtime API called by `cudnnCreate()` or by an error in the hardware setup.

**CUDNN_STATUS_ALLOC_FAILED**

Resource allocation failed inside the cuDNN library. This is usually caused by an internal `cudaMalloc()` failure.

To correct, prior to the function call, deallocate previously allocated memory as much as possible.

**CUDNN_STATUS_BAD_PARAM**

An incorrect value or parameter was passed to the function.

To correct, ensure that all the parameters being passed have valid values.

**CUDNN_STATUS_ARCH_MISMATCH**

The function requires a feature absent from the current GPU device. Note that cuDNN only supports devices with compute capabilities greater than or equal to 3.0.

To correct, compile and run the application on a device with appropriate compute capability.

**CUDNN_STATUS_MAPPING_ERROR**

An access to GPU memory space failed, which is usually caused by a failure to bind a texture.

To correct, prior to the function call, unbind any previously bound textures.

Otherwise, this may indicate an internal error/bug in the library.

**CUDNN_STATUS_EXECUTION_FAILED**

The GPU program failed to execute. This is usually caused by a failure to launch some cuDNN kernel on the GPU, which can occur for multiple reasons.
To correct, check that the hardware, an appropriate version of the driver, and the cuDNN library are correctly installed.

Otherwise, this may indicate an internal error/bug in the library.

**CUDNN_STATUS_INTERNAL_ERROR**
An internal cuDNN operation failed.

**CUDNN_STATUS_NOT_SUPPORTED**
The functionality requested is not presently supported by cuDNN.

**CUDNN_STATUS_LICENSE_ERROR**
The functionality requested requires some license and an error was detected when trying to check the current licensing. This error can happen if the license is not present or is expired or if the environment variable `NVIDIA_LICENSE_FILE` is not set properly.

**CUDNN_STATUS_RUNTIME_PREREQUISITE_MISSING**
A runtime library required by cuDNN cannot be found in the predefined search paths. These libraries are `libcuda.so (nvcuda.dll)` and `libnvrtc.so (nvrtc64_<Major Release Version>_0.dll)` and `nvrtc-builtins64_<Major Release Version>.dll`.

**CUDNN_STATUS_RUNTIME_IN_PROGRESS**
Some tasks in the user stream are not completed.

**CUDNN_STATUS.Runtime FP OVERFLOW**
Numerical overflow occurred during the GPU kernel execution.

### 3.1.2.28. `cudnnTensorFormat_t`

`cudnnTensorFormat_t` is an enumerated type used by `cudnnSetTensor4dDescriptor()` to create a tensor with a pre-defined layout. For a detailed explanation of how these tensors are arranged in memory, refer to [Data Layout Formats](#).

#### Values

**CUDNN_TENSOR_NCHW**
This tensor format specifies that the data is laid out in the following order: batch size, feature maps, rows, columns. The strides are implicitly defined in such a way that the data are contiguous in memory with no padding between images, feature maps, rows, and columns; the columns are the inner dimension and the images are the outermost dimension.

**CUDNN_TENSOR_NHWC**
This tensor format specifies that the data is laid out in the following order: batch size, rows, columns, feature maps. The strides are implicitly defined in such a way that the data are contiguous in memory with no padding between images, rows, columns, and feature maps; the feature maps are the inner dimension and the images are the outermost dimension.

**CUDNN_TENSOR_NCHW_VECT_C**
This tensor format specifies that the data is laid out in the following order: batch size, feature maps, rows, columns. However, each element of the tensor is a vector...
of multiple feature maps. The length of the vector is carried by the data type of the tensor. The strides are implicitly defined in such a way that the data are contiguous in memory with no padding between images, feature maps, rows, and columns; the columns are the inner dimension and the images are the outermost dimension. This format is only supported with tensor data types CUDNN_DATA_INT8x4, CUDNN_DATA_INT8x32, and CUDNN_DATA_UINT8x4.

The CUDNN_TENSOR_NCHW_VECT_C can also be interpreted in the following way: The NCHW INT8x32 format is really N x (C/32) x H x W x 32 (32 Cs for every W), just as the NCHW INT8x4 format is N x (C/4) x H x W x 4 (4 Cs for every W). Hence, the VECT_C name - each W is a vector (4 or 32) of Cs.

3.2. API Functions

These are the API functions in the cudnn_ops_infer.so library.

3.2.1. cudnnActivationForward()

This routine applies a specified neuron activation function element-wise over each input value.

```c
cludnStatus_t cudnnActivationForward(
    cudnnHandle_t handle,
    cudnnActivationDescriptor_t     activationDesc,
    const void                     *alpha,
    const cudnnTensorDescriptor_t   xDesc,
    const void                     *x,
    const void                     *beta,
    const cudnnTensorDescriptor_t   yDesc,
    void                           *y)
```

In-place operation is allowed for this routine; meaning, xData and yData pointers may be equal. However, this requires xDesc and yDesc descriptors to be identical (particularly, the strides of the input and output must match for an in-place operation to be allowed).

All tensor formats are supported for 4 and 5 dimensions, however, the best performance is obtained when the strides of xDesc and yDesc are equal and HW-packed. For more than 5 dimensions the tensors must have their spatial dimensions packed.

Parameters

**handle**

*Input*. Handle to a previously created cuDNN context. For more information, refer to [cudnnHandle_t](#).

**activationDesc**

*Input*. Activation descriptor. For more information, refer to [cudnnActivationDescriptor_t](#).
alpha, beta

*Input*. Pointers to scaling factors (in host memory) used to blend the computation result with prior value in the output layer as follows:

\[
dstValue = \alpha[0] \times \text{result} + \beta[0] \times \text{priorDstValue}
\]

For more information, refer to [Scaling Parameters](#).

xDesc

*Input*. Handle to the previously initialized input tensor descriptor. For more information, refer to `cudnnTensorDescriptor_t`.

x

*Input*. Data pointer to GPU memory associated with the tensor descriptor `xDesc`.

yDesc

*Input*. Handle to the previously initialized output tensor descriptor.

y

*Output*. Data pointer to GPU memory associated with the output tensor descriptor `yDesc`.

**Returns**

**CUDNN_STATUS_SUCCESS**

The function launched successfully.

**CUDNN_STATUS_NOT_SUPPORTED**

The function does not support the provided configuration.

**CUDNN_STATUS_BAD_PARAM**

At least one of the following conditions are met:

- The parameter `mode` has an invalid enumerant value.
- The dimensions `n`, `c`, `h`, and `w` of the input tensor and output tensor differ.
- The `datatype` of the input tensor and output tensor differs.
- The strides `nStride`, `cStride`, `hStride`, and `wStride` of the input tensor and output tensor differ and in-place operation is used (meaning, `x` and `y` pointers are equal).

**CUDNN_STATUS_EXECUTION_FAILED**

The function failed to launch on the GPU.

### 3.2.2. `cudnnAddTensor()`

This function adds the scaled values of a bias tensor to another tensor. Each dimension of the bias tensor `A` must match the corresponding dimension of the destination tensor `C` or must be equal to 1. In the latter case, the same value from the bias tensor for those dimensions will be used to blend into the `C` tensor.

```c

cudnnStatus_t cudnnAddTensor(
    cudnnHandle_t                     handle,
    const void                       *alpha,
    const cudnnTensorDescriptor_t     aDesc,
    const void                       *A,
    const void                       *beta,
    const cudnnTensorDescriptor_t     cDesc,
);
```
Only 4D and 5D tensors are supported. Beyond these dimensions, this routine is not supported.

Parameters

**handle**

*Input*. Handle to a previously created cuDNN context. For more information, refer to `cudnnHandle_t`.

**alpha, beta**

*Input*. Pointers to scaling factors (in host memory) used to blend the source value with the prior value in the destination tensor as follows:

\[ \text{dstValue} = \alpha[0] \ast \text{srcValue} + \beta[0] \ast \text{priorDstValue} \]

For more information, refer to Scaling Parameters.

**aDesc**

*Input*. Handle to a previously initialized tensor descriptor. For more information, refer to `cudnnTensorDescriptor_t`.

**A**

*Input*. Pointer to data of the tensor described by the `aDesc` descriptor.

**cDesc**

*Input*. Handle to a previously initialized tensor descriptor.

**C**

*Input/Output*. Pointer to data of the tensor described by the `cDesc` descriptor.

Returns

**CUDNN_STATUS_SUCCESS**

The function executed successfully.

**CUDNN_STATUS_NOT_SUPPORTED**

The function does not support the provided configuration.

**CUDNN_STATUS_BAD_PARAM**

The dimensions of the bias tensor refer to an amount of data that is incompatible with the output tensor dimensions or the `dataType` of the two tensor descriptors are different.

**CUDNN_STATUS_EXECUTION_FAILED**

The function failed to launch on the GPU.

3.2.3. **cudnnBatchNormalizationForwardInference()**

This function performs the forward batch normalization layer computation for the inference phase. This layer is based on the [Batch Normalization: Accelerating Deep Network Training by Reducing Internal Covariate Shift](https://arxiv.org/abs/1502.03167) paper.

```c
void cudnnBatchNormalizationForwardInference(
    cudnnHandle_t handle,
    cudnnBatchNormMode_t mode,
    const void *alpha,
    const void *beta,
    cudnnTensorDescriptor_t aDesc,
    const void *a,
    cudnnTensorDescriptor_t cDesc,
    void *C)
```
Only 4D and 5D tensors are supported.

The input transformation performed by this function is defined as:

\[ y = \beta \cdot y + \alpha \cdot \left[ \text{bnBias} + (\text{bnScale} \cdot (x - \text{estimatedMean})/\sqrt{\text{epsilon} + \text{estimatedVariance}}) \right] \]

For the training phase, refer to `cudnnBatchNormalizationForwardTraining()`.

Higher performance can be obtained when HW-packed tensors are used for all of \( x \) and \( dx \).

For more information, refer to `cudnnDeriveBNTensorDescriptor()` for the secondary tensor descriptor generation for the parameters used in this function.

**Parameters**

- **handle**
  
  *Input*. Handle to a previously created cuDNN library descriptor. For more information, refer to `cudnnHandle_t`.

- **mode**
  
  *Input*. Mode of operation (spatial or per-activation). For more information, refer to `cudnnBatchNormMode_t`.

- **alpha**, **beta**
  
  *Inputs*. Pointers to scaling factors (in host memory) used to blend the layer output value with prior value in the destination tensor as follows:

  \[ \text{dstValue} = \alpha[0] \cdot \text{resultValue} + \beta[0] \cdot \text{priorDstValue} \]

  For more information, refer to Scaling Parameters.

- **xDesc**, **yDesc**
  
  *Input*. Handles to the previously initialized tensor descriptors.

- **x**
  
  *Input*. Data pointer to GPU memory associated with the tensor descriptor \( x\text{Desc} \), for the layer's \( x \) input data.

- **y**
  
  *Input/Output*. Data pointer to GPU memory associated with the tensor descriptor \( y\text{Desc} \), for the \( y \)output of the batch normalization layer.

- **bnScaleBiasMeanVarDesc**, **bnScale**, **bnBias**
  
  *Inputs*. Tensor descriptors and pointers in device memory for the batch normalization scale and bias parameters (in the Batch Normalization: Accelerating Deep Network)
Training by Reducing Internal Covariate Shift paper, bias is referred to as beta and scale as gamma).

**estimatedMean, estimatedVariance**

Inputs. Mean and variance tensors (these have the same descriptor as the bias and scale). The `resultRunningMean` and `resultRunningVariance`, accumulated during the training phase from the `cudnnBatchNormalizationForwardTraining()` call, should be passed as inputs here.

**epsilon**

Input. Epsilon value used in the batch normalization formula. Its value should be equal to or greater than the value defined for `CUDNN_BN_MIN_EPSILON` in `cudnn.h`.

## Supported configurations

This function supports the following combinations of data types for various descriptors.

### Table 12. Supported Configurations for `cudnnBatchNormalizationForwardInference()`

<table>
<thead>
<tr>
<th>Data Type Configurations</th>
<th>xDesc</th>
<th>bnScaleBiasMean</th>
<th>alpha, beta</th>
<th>yDesc</th>
</tr>
</thead>
<tbody>
<tr>
<td>INT8_CONFIG</td>
<td>CUDNN_DATA_INT8</td>
<td>CUDNN_DATA_FLOAT</td>
<td>CUDNN_DATA_FLOAT</td>
<td>CUDNN_DATA_INT8</td>
</tr>
<tr>
<td>PSEUDO_HALF_CONFIG</td>
<td>CUDNN_DATA_HALF</td>
<td>CUDNN_DATA_FLOAT</td>
<td>CUDNN_DATA_FLOAT</td>
<td>CUDNN_DATA_HALF</td>
</tr>
<tr>
<td>FLOAT_CONFIG</td>
<td>CUDNN_DATA_FLOAT</td>
<td>CUDNN_DATA_FLOAT</td>
<td>CUDNN_DATA_FLOAT</td>
<td>CUDNN_DATA_FLOAT</td>
</tr>
<tr>
<td>DOUBLE_CONFIG</td>
<td>CUDNN_DATA_DOUBLE</td>
<td>CUDNN_DATA_DOUBLE</td>
<td>CUDNN_DATA_DOUBLE</td>
<td>CUDNN_DATA_DOUBLE</td>
</tr>
<tr>
<td>BFLOAT16_CONFIG</td>
<td>CUDNN_DATA_BFLOAT16</td>
<td>CUDNN_DATA_FLOAT</td>
<td>CUDNN_DATA_FLOAT</td>
<td>CUDNN_DATA_BFLOAT16</td>
</tr>
</tbody>
</table>

## Returns

**CUDNN_STATUS_SUCCESS**

The computation was performed successfully.

**CUDNN_STATUS_NOT_SUPPORTED**

The function does not support the provided configuration.

**CUDNN_STATUS_BAD_PARAM**

At least one of the following conditions are met:

- One of the pointers `alpha, beta, x, y, bnScale, bnBias, estimatedMean, and estimatedInvVariance` is NULL.

- The number of `xDesc` or `yDesc` tensor descriptor dimensions is not within the range of [4, 5] (only 4D and 5D tensors are supported.)

- `bnScaleBiasMeanVarDesc` dimensions are not 1xCx1x1 for 4D and 1xCx1x1x1 for 5D for spatial, and are not 1xCxHxW for 4D and 1xCxDxHxW for 5D for per-activation mode.
- Epsilon value is less than \texttt{CUDNN\_BN\_MIN\_EPSILON}.
- Dimensions or data types mismatch for \texttt{xDesc}, \texttt{yDesc}.

### 3.2.4. \texttt{cudnnCopyAlgorithmDescriptor()}
This function has been deprecated in cuDNN 8.0.

### 3.2.5. \texttt{cudnnCreate()}
This function initializes the cuDNN library and creates a handle to an opaque structure holding the cuDNN library context. It allocates hardware resources on the host and device and must be called prior to making any other cuDNN library calls.

```c
void cudnnStatus_t cudnnCreate(cudnnHandle_t *handle)
```

The cuDNN library handle is tied to the current CUDA device (context). To use the library on multiple devices, one cuDNN handle needs to be created for each device.

For a given device, multiple cuDNN handles with different configurations (for example, different current CUDA streams) may be created. Because \texttt{cudnnCreate()} allocates some internal resources, the release of those resources by calling \texttt{cudnnDestroy()} will implicitly call \texttt{cudaDeviceSynchronize()}; therefore, the recommended best practice is to call \texttt{cudnnCreate/cudnnDestroy} outside of performance-critical code paths.

For multithreaded applications that use the same device from different threads, the recommended programming model is to create one (or a few, as is convenient) cuDNN handle(s) per thread and use that cuDNN handle for the entire life of the thread.

**Parameters**

- \texttt{handle}
  - Output. Pointer to pointer where to store the address to the allocated cuDNN handle. For more information, refer to \texttt{cudnnHandle_t}.

**Returns**

- \texttt{CUDNN\_STATUS\_BAD\_PARAM}
  - Invalid (\texttt{NULL}) input pointer supplied.
- \texttt{CUDNN\_STATUS\_NOT\_INITIALIZED}
  - No compatible GPU found, CUDA driver not installed or disabled, CUDA runtime API initialization failed.
- \texttt{CUDNN\_STATUS\_ARCH\_MISMATCH}
  - NVIDIA GPU architecture is too old.
- \texttt{CUDNN\_STATUS\_ALLOC\_FAILED}
  - Host memory allocation failed.
- \texttt{CUDNN\_STATUS\_INTERNAL\_ERROR}
  - CUDA resource allocation failed.
- \texttt{CUDNN\_STATUS\_LICENSE\_ERROR}
  - cuDNN license validation failed (only when the feature is enabled).
CUDNN STATUS_SUCCESS
   cuDNN handle was created successfully.

3.2.6. cudnnCreateActivationDescriptor()

This function creates an activation descriptor object by allocating the memory needed to hold its opaque structure. For more information, refer to cudnnActivationDescriptor_t.

```c
void cudnnCreateActivationDescriptor(
   cudnnActivationDescriptor_t *activationDesc)
```

Returns

CUDNN STATUS_SUCCESS
   The object was created successfully.

CUDNN.setStatus_ALLOC_FAILED
   The resources could not be allocated.

3.2.7. cudnnCreateAlgorithmDescriptor()

This function has been deprecated in cuDNN 8.0.

This function creates an algorithm descriptor object by allocating the memory needed to hold its opaque structure.

```c
void cudnnCreateAlgorithmDescriptor(
   cudnnAlgorithmDescriptor_t *algoDesc)
```

Returns

CUDNN STATUS_SUCCESS
   The object was created successfully.

CUDNN.setStatus_ALLOC_FAILED
   The resources could not be allocated.

3.2.8. cudnnCreateAlgorithmPerformance()

This function creates multiple algorithm performance objects by allocating the memory needed to hold their opaque structures.

```c
void cudnnCreateAlgorithmPerformance(
   cudnnAlgorithmPerformance_t *algoPerf,
   int numberToCreate)
```

Returns

CUDNN STATUS_SUCCESS
   The object was created successfully.

CUDNN.setStatus_ALLOC_FAILED
   The resources could not be allocated.
3.2.9. **cudnnCreateDropoutDescriptor()**

This function creates a generic dropout descriptor object by allocating the memory needed to hold its opaque structure. For more information, refer to `cudnnDropoutDescriptor_t`.

```c
   cudnnStatus_t cudnnCreateDropoutDescriptor(
       cudnnDropoutDescriptor_t    *dropoutDesc)
```

**Returns**

- **CUDNN_STATUS_SUCCESS**
  The object was created successfully.
- **CUDNN_STATUS_ALLOC_FAILED**
  The resources could not be allocated.

3.2.10. **cudnnCreateFilterDescriptor()**

This function creates a filter descriptor object by allocating the memory needed to hold its opaque structure. For more information, refer to `cudnnFilterDescriptor_t`.

```c
   cudnnStatus_t cudnnCreateFilterDescriptor(
       cudnnFilterDescriptor_t *filterDesc)
```

**Returns**

- **CUDNN_STATUS_SUCCESS**
  The object was created successfully.
- **CUDNN_STATUS_ALLOC_FAILED**
  The resources could not be allocated.

3.2.11. **cudnnCreateLRNDescriptor()**

This function allocates the memory needed to hold the data needed for LRN and DivisiveNormalization layers operation and returns a descriptor used with subsequent layer forward and backward calls.

```c
   cudnnStatus_t cudnnCreateLRNDescriptor(
       cudnnLRNDescriptor_t    *poolingDesc)
```

**Returns**

- **CUDNN_STATUS_SUCCESS**
  The object was created successfully.
- **CUDNN_STATUS_ALLOC_FAILED**
  The resources could not be allocated.

3.2.12. **cudnnCreateOpTensorDescriptor()**

This function creates a tensor pointwise math descriptor. For more information, refer to `cudnnOpTensorDescriptor_t`.

```c
   cudnnStatus_t cudnnCreateOpTensorDescriptor(
```

Black box function
cudnnOpTensorDescriptor_t*  opTensorDesc)

Parameters

opTensorDesc
  Output. Pointer to the structure holding the description of the tensor pointwise math such as add, multiply, and more.

Returns

CUDNN_STATUS_SUCCESS
  The function returned successfully.

CUDNN_STATUS_BAD_PARAM
  Tensor pointwise math descriptor passed to the function is invalid.

CUDNN_STATUS_ALLOC_FAILED
  Memory allocation for this tensor pointwise math descriptor failed.

3.2.13. cudnnCreatePoolingDescriptor()

This function creates a pooling descriptor object by allocating the memory needed to hold its opaque structure.

cudnnStatus_t cudnnCreatePoolingDescriptor(
              cudnnPoolingDescriptor_t    *poolingDesc)

Returns

CUDNN_STATUS_SUCCESS
  The object was created successfully.

CUDNN_STATUS_ALLOC_FAILED
  The resources could not be allocated.

3.2.14. cudnnCreateReduceTensorDescriptor()

This function creates a reduced tensor descriptor object by allocating the memory needed to hold its opaque structure.

cudnnStatus_t cudnnCreateReduceTensorDescriptor(
              cudnnReduceTensorDescriptor_t* reduceTensorDesc)

Returns

CUDNN_STATUS_SUCCESS
  The object was created successfully.

CUDNN_STATUS_BAD_PARAM
  reduceTensorDesc is a NULL pointer.

CUDNN_STATUS_ALLOC_FAILED
  The resources could not be allocated.
3.2.15. `cudnnCreateSpatialTransformerDescriptor()`

This function creates a generic spatial transformer descriptor object by allocating the memory needed to hold its opaque structure.

```c
cudnnStatus_t cudnnCreateSpatialTransformerDescriptor(
    cudnnSpatialTransformerDescriptor_t *stDesc)
```

**Returns**

- **CUDNN_STATUS_SUCCESS**
  The object was created successfully.
- **CUDNN_STATUS_ALLOC_FAILED**
  The resources could not be allocated.

3.2.16. `cudnnCreateTensorDescriptor()`

This function creates a generic tensor descriptor object by allocating the memory needed to hold its opaque structure. The data is initialized to all zeros.

```c
cudnnStatus_t cudnnCreateTensorDescriptor(
    cudnnTensorDescriptor_t *tensorDesc)
```

**Parameters**

- **tensorDesc**
  *Output*. Pointer to pointer where the address to the allocated tensor descriptor object should be stored.

**Returns**

- **CUDNN_STATUS_BAD_PARAM**
  Invalid input argument.
- **CUDNN_STATUS_ALLOC_FAILED**
  The resources could not be allocated.
- **CUDNN_STATUS_SUCCESS**
  The object was created successfully.

3.2.17. `cudnnCreateTensorTransformDescriptor()`

This function creates a tensor transform descriptor object by allocating the memory needed to hold its opaque structure. The tensor data is initialized to all zero. Use the `cudnnSetTensorTransformDescriptor()` function to initialize the descriptor created by this function.

```c
cudnnStatus_t cudnnCreateTensorTransformDescriptor(
    cudnnTensorTransformDescriptor_t *transformDesc);
```

**Parameters**

- **transformDesc**
  *Output*. A pointer to an uninitialized tensor transform descriptor.
3.2.18. cudnnDeriveBNTensorDescriptor()

This function derives a secondary tensor descriptor for the batch normalization scale, invVariance, bnBias, and bnScale subtensors from the layer’s x data descriptor.

```c
    cudnnStatus_t cudnnDeriveBNTensorDescriptor(
        cudnnTensorDescriptor_t         derivedBnDesc,
        const cudnnTensorDescriptor_t   xDesc,
        cudnnBatchNormMode_t            mode)
```

Use the tensor descriptor produced by this function as the bnScaleBiasMeanVarDesc parameter for the `cudnnBatchNormalizationForwardInference()` and `cudnnBatchNormalizationForwardTraining()` functions, and as the bnScaleBiasDiffDesc parameter in the `cudnnBatchNormalizationBackward()` function.

The resulting dimensions will be:

- 1xCx1x1 for 4D and 1xCx1x1x1 for 5D for `BATCHNORM_MODE_SPATIAL`
- 1xCxHxW for 4D and 1xCxDxHxW for 5D for `BATCHNORM_MODE_PER_ACTIVATION` mode

For `HALF` input data type the resulting tensor descriptor will have a `FLOAT` type. For other data types, it will have the same type as the input data.

**Note:**

- Only 4D and 5D tensors are supported.
- The derivedBnDesc should be first created using `cudnnCreateTensorDescriptor()`.
- xDesc is the descriptor for the layer’s x data and has to be set up with proper dimensions prior to calling this function.

**Parameters**

- **derivedBnDesc**
  - Output. Handle to a previously created tensor descriptor.
- **xDesc**
  - Input. Handle to a previously created and initialized layer’s x data descriptor.
- **mode**
  - Input. Batch normalization layer mode of operation.
Returns

**CUDNN_STATUS_SUCCESS**
The computation was performed successfully.

**CUDNN_STATUS_BAD_PARAM**
Invalid batch normalization mode.

### 3.2.19. `cudnnDeriveNormTensorDescriptor()`

This function derives tensor descriptors for the normalization **mean**, **invariance**, **normBias**, and **normScale** subtensors from the layer’s `x` data descriptor and norm mode. **normalization**, **mean**, and **invariance** share the same descriptor while **bias** and **scale** share the same descriptor.

```c
extern "C" {
  cudnnStatus_t CUDNNWINAPI cudnnDeriveNormTensorDescriptor(cudnnTensorDescriptor_t derivedNormScaleBiasDesc,
                                                             cudnnTensorDescriptor_t derivedNormMeanVarDesc,
                                                             const cudnnTensorDescriptor_t xDesc,
                                                             cudnnNormMode_t mode,
                                                             int groupCnt);
}
```

Use the tensor descriptor produced by this function as the **normScaleBiasDesc** or **normMeanVarDesc** parameter for the `cudnnNormalizationForwardInference()` and `cudnnNormalizationForwardTraining()` functions, and as the **dNormScaleBiasDesc** and **normMeanVarDesc** parameters in the `cudnnNormalizationBackward()` function.

The resulting dimensions will be:

- 1xCx1x1 for 4D and 1xCx1x1x1 for 5D for **CUDNN_NORM_PER_ACTIVATION**
- 1xCxHxW for 4D and 1xCxDxHxW for 5D for **CUDNN_NORM_PER_CHANNEL** mode

For **HALF** input data type the resulting tensor descriptor will have a **FLOAT** type. For other data types, it will have the same type as the input data.

- Only 4D and 5D tensors are supported.
- The **derivedNormScaleBiasDesc** and **derivedNormMeanVarDesc** should be created first using `cudnnCreateTensorDescriptor()`.
- **xDesc** is the descriptor for the layer’s `x` data and has to be set up with proper dimensions prior to calling this function.

#### Parameters

- **derivedNormScaleBiasDesc**
  - *Output*. Handle to a previously created tensor descriptor.
- **derivedNormMeanVarDesc**
  - *Output*. Handle to a previously created tensor descriptor.
- **xDesc**
  - *Input*. Handle to a previously created and initialized layer’s `x` data descriptor.
- **mode**
  - *Input*. The normalization layer mode of operation.
groupCnt

Input. The number of grouped convolutions. Currently, only 1 is supported.

Returns

CUDNN_STATUS_SUCCESS
The computation was performed successfully.

CUDNN_STATUS_BAD_PARAM
Invalid batch normalization mode.

3.2.20. cudnnDestroy()

This function releases the resources used by the cuDNN handle. Because cudnnCreate() allocates some internal resources, the release of those resources by calling cudnnDestroy() will implicitly call cudaDeviceSynchronize(); therefore, the recommended best practice is to call cudnnCreate/cudnnDestroy outside of performance-critical code paths and before any CUDA context destroy operation.

Parameters

handle
Input. The cuDNN handle to be destroyed.

Returns

CUDNN_STATUS_SUCCESS
The cuDNN context destruction was successful.

3.2.21. cudnnDestroyActivationDescriptor()

This function destroys a previously created activation descriptor object.

Returns

CUDNN_STATUS_SUCCESS
The object was destroyed successfully.

3.2.22. cudnnDestroyAlgorithmDescriptor()

This function has been deprecated in cuDNN 8.0.

This function destroys a previously created algorithm descriptor object.
Returns

**CUDNN_STATUS_SUCCESS**
The object was destroyed successfully.

### 3.2.23. **cudnnDestroyAlgorithmPerformance()**

This function destroys a previously created algorithm descriptor object.

```c
 LibcudnnDestroyAlgorithmPerformance(
     cudnnAlgorithmPerformance_t  algoPerf)
```

Returns

**CUDNN_STATUS_SUCCESS**
The object was destroyed successfully.

### 3.2.24. **cudnnDestroyDropoutDescriptor()**

This function destroys a previously created dropout descriptor object.

```c
 LibcudnnDestroyDropoutDescriptor(
     cudnnDropoutDescriptor_t dropoutDesc)
```

Returns

**CUDNN_STATUS_SUCCESS**
The object was destroyed successfully.

### 3.2.25. **cudnnDestroyFilterDescriptor()**

This function destroys a filter object.

```c
 LibcudnnDestroyFilterDescriptor(
     cudnnFilterDescriptor_t filterDesc)
```

Returns

**CUDNN_STATUS_SUCCESS**
The object was destroyed successfully.

### 3.2.26. **cudnnDestroyLRNDescriptor()**

This function destroys a previously created LRN descriptor object.

```c
 LibcudnnDestroyLRNDescriptor(
     cudnnLRNDescriptor_t lrnDesc)
```

Returns

**CUDNN_STATUS_SUCCESS**
The object was destroyed successfully.
3.2.27. **cudnnDestroyOpTensorDescriptor()**

This function deletes a tensor pointwise math descriptor object.

```c
void cudnnDestroyOpTensorDescriptor(
    cudnnOpTensorDescriptor_t opTensorDesc);
```

**Parameters**

- `opTensorDesc` 
  - *Input*. Pointer to the structure holding the description of the tensor pointwise math to be deleted.

**Returns**

- **CUDNN_STATUS_SUCCESS** 
  - The function returned successfully.

3.2.28. **cudnnDestroyPoolingDescriptor()**

This function destroys a previously created pooling descriptor object.

```c
void cudnnDestroyPoolingDescriptor(
    cudnnPoolingDescriptor_t poolingDesc);
```

**Returns**

- **CUDNN_STATUS_SUCCESS** 
  - The object was destroyed successfully.

3.2.29. **cudnnDestroyReduceTensorDescriptor()**

This function destroys a previously created reduce tensor descriptor object. When the input pointer is `NULL`, this function performs no destroy operation.

```c
void cudnnDestroyReduceTensorDescriptor(
    cudnnReduceTensorDescriptor_t tensorDesc);
```

**Parameters**

- `tensorDesc` 
  - *Input*. Pointer to the reduce tensor descriptor object to be destroyed.

**Returns**

- **CUDNN_STATUS_SUCCESS** 
  - The object was destroyed successfully.

3.2.30. **cudnnDestroySpatialTransformerDescriptor()**

This function destroys a previously created spatial transformer descriptor object.

```c
void cudnnDestroySpatialTransformerDescriptor(
    cudnnSpatialTransformerDescriptor_t stDesc);
```
3.2.31. **cudnnDestroyTensorDescriptor()**

This function destroys a previously created tensor descriptor object. When the input pointer is `NULL`, this function performs no destroy operation.

```c
int cudnnDestroyTensorDescriptor(cudnnTensorDescriptor_t tensorDesc);
```

**Parameters**

- `tensorDesc`  
  *Input*. Pointer to the tensor descriptor object to be destroyed.

**Returns**

- **CUDNN_STATUS_SUCCESS**  
  The object was destroyed successfully.

3.2.32. **cudnnDestroyTensorTransformDescriptor()**

Destroys a previously created tensor transform descriptor.

```c
int cudnnDestroyTensorTransformDescriptor(cudnnTensorTransformDescriptor_t transformDesc);
```

**Parameters**

- `transformDesc`  
  *Input*. The tensor transform descriptor to be destroyed.

**Returns**

- **CUDNN_STATUS_SUCCESS**  
  The descriptor was destroyed successfully.

3.2.33. **cudnnDivisiveNormalizationForward()**

This function performs the forward spatial DivisiveNormalization layer computation. It divides every value in a layer by the standard deviation of its spatial neighbors as described in the [What is the Best Multi-Stage Architecture for Object Recognition](#) paper. Note that DivisiveNormalization only implements the \( \frac{x}{\max(c, \sigma_x)} \) portion of the computation, where \( \sigma_x \) is the variance over the spatial neighborhood of \( x \).

```c
int cudnnDivisiveNormalizationForward(
    cudnnHandle_t        handle,  
    cudnnLRNDescriptor_t normDesc,  
    cudnnDivNormMode_t   mode,  
    const void           *alpha,  
    const cudnnTensorDescriptor_t xDesc,
);`
The full LCN (Local Contrastive Normalization) computation can be implemented as a two-step process:

\[
x_m = x - \text{mean}(x);
\]
\[
y = \frac{x_m}{\text{max}(c, \text{sigma}(x_m))};
\]

The \(x - \text{mean}(x)\) which is often referred to as "subtractive normalization" portion of the computation can be implemented using cuDNN average pooling layer followed by a call to \text{addTensor}.

\textbf{Note:} Supported tensor formats are NCHW for 4D and NCDHW for 5D with any non-overlapping non-negative strides. Only 4D and 5D tensors are supported.

\textbf{Parameters}

\textbf{handle}

*Input.* Handle to a previously created cuDNN library descriptor.

\textbf{normDesc}

*Input.* Handle to a previously initialized LRN parameter descriptor. This descriptor is used for both LRN and \text{DivisiveNormalization} layers.

\textbf{divNormMode}

*Input.* \text{DivisiveNormalization} layer mode of operation. Currently only \text{CUDNN_DIVNORM_PRECOMPUTED_MEANS} is implemented. Normalization is performed using the means input tensor that is expected to be precomputed by the user.

\textbf{alpha, beta}

*Input.* Pointers to scaling factors (in host memory) used to blend the layer output value with prior value in the destination tensor as follows:

\[
dstValue = alpha[0] \times \text{resultValue} + beta[0] \times \text{priorDstValue}
\]

For more information, refer to \text{Scaling Parameters}.

\textbf{xDesc, yDesc}

*Input.* Tensor descriptor objects for the input and output tensors. Note that \text{xDesc} is shared between \text{x}, \text{means}, \text{temp}, and \text{temp2} tensors.

\textbf{x}

*Input.* Input tensor data pointer in device memory.

\textbf{means}

*Input.* Input means tensor data pointer in device memory. Note that this tensor can be \text{NULL} (in that case its values are assumed to be zero during the computation). This tensor also doesn’t have to contain \text{means}, these can be any values, a frequently used variation is a result of convolution with a normalized positive kernel (such as Gaussian).
temp, temp2

*Workspace*. Temporary tensors in device memory. These are used for computing intermediate values during the forward pass. These tensors do not have to be preserved as inputs from forward to the backward pass. Both use xDesc as their descriptor.

y

*Output*. Pointer in device memory to a tensor for the result of the forward DivisiveNormalization computation.

Returns

**CUDNN_STATUS_SUCCESS**

The computation was performed successfully.

**CUDNN_STATUS_BAD_PARAM**

At least one of the following conditions are met:

- One of the tensor pointers x, y, temp, and temp2 is NULL.
- Number of input tensor or output tensor dimensions is outside of [4, 5] range.
- A mismatch in dimensions between any two of the input or output tensors.
- For in-place computation when pointers x == y, a mismatch in strides between the input data and output data tensors.
- Alpha or beta pointer is NULL.
- LRN descriptor parameters are outside of their valid ranges.
- Any of the tensor strides are negative.

**CUDNN_STATUS_UNSUPPORTED**

The function does not support the provided configuration, for example, any of the input and output tensor strides mismatch (for the same dimension) is a non-supported configuration.

3.2.34. `cudnnDropoutForward()`

This function performs forward dropout operation over x returning results in y. If dropout was used as a parameter to `cudnnSetDropoutDescriptor()`, the approximate dropout fraction of x values will be replaced by a 0, and the rest will be scaled by 1/(1-dropout). This function should not be running concurrently with another `cudnnDropoutForward()` function using the same states.

```c
void cudnnDropoutForward(
    cudnnHandle_t handle,
    const cudnnDropoutDescriptor_t dropoutDesc,
    const cudnnTensorDescriptor_t xdesc,
    const void *x,
    const cudnnTensorDescriptor_t ydesc,
    void *y,
    void *reserveSpace,
)
```
size_t reserveSpaceSizeInBytes

Note:
- Better performance is obtained for fully packed tensors.
- This function should not be called during inference.

Parameters

handle
  *Input*. Handle to a previously created cuDNN context.

dropoutDesc
  *Input*. Previously created dropout descriptor object.

xDesc
  *Input*. Handle to a previously initialized tensor descriptor.

x
  *Input*. Pointer to data of the tensor described by the xDesc descriptor.

yDesc
  *Input*. Handle to a previously initialized tensor descriptor.

y
  *Output*. Pointer to data of the tensor described by the yDesc descriptor.

reserveSpace
  *Output*. Pointer to user-allocated GPU memory used by this function. It is expected that the contents of reserveSpace does not change between cudnnDropoutForward() and cudnnDropoutBackward() calls.

reserveSpaceSizeInBytes
  *Input*. Specifies the size in bytes of the provided memory for the reserve space.

Returns

CUDNN_STATUS_SUCCESS
  The call was successful.

CUDNN_STATUS_NOT_SUPPORTED
  The function does not support the provided configuration.

CUDNN_STATUS_BAD_PARAM
  At least one of the following conditions are met:
  - The number of elements of input tensor and output tensors differ.
  - The datatype of the input tensor and output tensors differs.
  - The strides of the input tensor and output tensors differ and in-place operation is used (meaning, x and y pointers are equal).
  - The provided reserveSpaceSizeInBytes is less than the value returned by cudnnDropoutGetReserveSpaceSize().
  - cudnnSetDropoutDescriptor() has not been called on dropoutDesc with the non-NULL states argument.
CUDNN_STATUS_EXECUTION_FAILED
The function failed to launch on the GPU.

3.2.35. cudnnDropoutGetReserveSpaceSize()
This function is used to query the amount of reserve needed to run dropout with the
input dimensions given by xDesc. The same reserve space is expected to be passed to
cudnnDropoutForward() and cudnnDropoutBackward(), and its contents is expected to
remain unchanged between cudnnDropoutForward() and cudnnDropoutBackward() calls.

```
cudnnStatus_t cudnnDropoutGetReserveSpaceSize(
    cudnnTensorDescriptor_t     xDesc,
    size_t                     *sizeInBytes)
```

Parameters

xDesc
Input. Handle to a previously initialized tensor descriptor, describing input to a dropout
operation.

sizeInBytes
Output. Amount of GPU memory needed as reserve space to be able to run dropout
with an input tensor descriptor specified by xDesc.

Returns

CUDNN_STATUS_SUCCESS
The query was successful.

3.2.36. cudnnDropoutGetStatesSize()
This function is used to query the amount of space required to store the states of the
random number generators used by the cudnnDropoutForward() function.

```
cudnnStatus_t cudnnDropoutGetStatesSize(
    cudnnHandle_t       handle,
    size_t             *sizeInBytes)
```

Parameters

handle
Input. Handle to a previously created cuDNN context.

sizeInBytes
Output. Amount of GPU memory needed to store random generator states.

Returns

CUDNN_STATUS_SUCCESS
The query was successful.
3.2.37. **cudnnGetActivationDescriptor()**

This function queries a previously initialized generic activation descriptor object.

```c
const cudnnActivationDescriptor_t activationDesc,
    cudnnActivationMode_t *mode,
    cudnnNanPropagation_t *reluNanOpt,
    double *coef)
```

**Parameters**

- **activationDesc**  
  *Input*. Handle to a previously created activation descriptor.

- **mode**  
  *Output*. Enumerant to specify the activation mode.

- **reluNanOpt**  
  *Output*. Enumerant to specify the Nan propagation mode.

- **coef**  
  *Output*. Floating point number to specify the clipping threshold when the activation mode is set to CUDNN_ACTIVATION_CLIPPED_RELU or to specify the alpha coefficient when the activation mode is set to CUDNN_ACTIVATION_ELU.

**Returns**

- **CUDNN_STATUS_SUCCESS**  
  The object was queried successfully.

3.2.38. **cudnnGetActivationDescriptorSwishBeta()**

This function queries the current beta parameter set for SWISH activation.

```c
cudnnStatus_t cudnnGetActivationDescriptorSwishBeta(cudnnActivationDescriptor_t activationDesc, double* swish_beta)
```

**Parameters**

- **activationDesc**  
  *Input*. Handle to a previously created activation descriptor.

- **swish_beta**  
  *Output*. Pointer to a double value that will receive the currently configured SWISH beta parameter.

**Returns**

- **CUDNN_STATUS_SUCCESS**  
  The beta parameter was queried successfully.

- **CUDNN_STATUS_BAD_PARAM**  
  At least one of activationDesc or swish_beta were NULL.
3.2.39. **cudnnGetAlgorithmDescriptor()**

This function has been deprecated in cuDNN 8.0.

This function queries a previously initialized generic algorithm descriptor object.

```c
const cudnnStatus_t cudnnGetAlgorithmDescriptor(  
    const cudnnAlgorithmDescriptor_t    algoDesc,  
    cudnnAlgorithm_t                    *algorithm)
```

**Parameters**

- **algoDesc**
  - *Input*. Handle to a previously created algorithm descriptor.
- **algorithm**
  - *Input*. Struct to specify the algorithm.

**Returns**

- **CUDNN_STATUS_SUCCESS**
  - The object was queried successfully.

3.2.40. **cudnnGetAlgorithmPerformance()**

This function has been deprecated in cuDNN 8.0.

This function queries a previously initialized generic algorithm performance object.

```c
const cudnnStatus_t cudnnGetAlgorithmPerformance(  
    const cudnnAlgorithmPerformance_t   algoPerf,  
    cudnnAlgorithmDescriptor_t*         algoDesc,  
    cudnnStatus_t*                      status,  
    float*                              time,  
    size_t*                             memory)
```

**Parameters**

- **algoPerf**
  - *Input/Output*. Handle to a previously created algorithm performance object.
- **algoDesc**
  - *Output*. The algorithm descriptor which the performance results describe.
- **status**
  - *Output*. The cuDNN status returned from running the `algoDesc` algorithm.
- **time**
  - *Output*. The GPU time spent running the `algoDesc` algorithm.
- **memory**
  - *Output*. The GPU memory needed to run the `algoDesc` algorithm.

**Returns**

- **CUDNN_STATUS_SUCCESS**
  - The object was queried successfully.
3.2.41. cudnnGetAlgorithmSpaceSize()

This function has been deprecated in cuDNN 8.0.

This function queries for the amount of host memory needed to call `cudnnSaveAlgorithm()`, much like the `get workspace size` function query for the amount of device memory needed.

```
cudnnStatus_t cudnnGetAlgorithmSpaceSize(
    cudnnHandle_t               handle,
    cudnnAlgorithmDescriptor_t  algoDesc,
    size_t*                     algoSpaceSizeInBytes)
```

**Parameters**

- **handle**
  - *Input*. Handle to a previously created cuDNN context.

- **algoDesc**
  - *Input*. A previously created algorithm descriptor.

- **algoSpaceSizeInBytes**
  - *Output*. Amount of host memory needed as a workspace to be able to save the metadata from the specified `algoDesc`.

**Returns**

- **CUDNN_STATUS_SUCCESS**
  - The function launched successfully.

- **CUDNN_STATUS_BAD_PARAM**
  - At least one of the arguments is `NULL`.

3.2.42. cudnnGetCallback()

This function queries the internal states of cuDNN error reporting functionality.

```
cudnnStatus_t cudnnGetCallback(
    unsigned            mask,
    void                **udata,
    cudnnCallback_t     fptr)
```

**Parameters**

- **mask**
  - *Output*. Pointer to the address where the current internal error reporting message bit mask will be outputted.

- **udata**
  - *Output*. Pointer to the address where the current internally stored `udata` address will be stored.

- **fptr**
  - *Output*. Pointer to the address where the current internally stored `callback` function pointer will be stored. When the built-in default callback function is used, `NULL` will be outputted.
Returns

CUDNN_STATUS_SUCCESS
The function launched successfully.

CUDNN_STATUS_BAD_PARAM
If any of the input parameters are NULL.

3.2.43. cudnnGetCudartVersion()
The same version of a given cuDNN library can be compiled against different CUDA toolkit versions. This routine returns the CUDA toolkit version that the currently used cuDNN library has been compiled against.

size_t cudnnGetCudartVersion()

3.2.44. cudnnGetDropoutDescriptor()
This function queries the fields of a previously initialized dropout descriptor.

cudnnStatus_t cudnnGetDropoutDescriptor(
cudnnDropoutDescriptor_t dropoutDesc,
cudnnHandle_t handle,
float *dropout,
void **states,
unsigned long long *seed)

Parameters

dropoutDesc
Input. Previously initialized dropout descriptor.

handle
Input. Handle to a previously created cuDNN context.

dropout
Output. The probability with which the value from input is set to 0 during the dropout layer.

states
Output. Pointer to user-allocated GPU memory that holds random number generator states.

seed
Output. Seed used to initialize random number generator states.

Returns

CUDNN_STATUS_SUCCESS
The call was successful.

CUDNN_STATUS_BAD_PARAM
One or more of the arguments was an invalid pointer.
3.2.45. **cudnnGetErrorString()**

This function converts the cuDNN status code to a NULL terminated (ASCIIZ) static string. For example, when the input argument is `CUDNN_STATUS_SUCCESS`, the returned string is `CUDNN_STATUS_SUCCESS`. When an invalid status value is passed to the function, the returned string is `CUDNN_UNKNOWN_STATUS`.

```c
const char * cudnnGetErrorString(cudnnStatus_t status)
```

**Parameters**

- **status**
  - *Input*. cuDNN enumerant status code.

**Returns**

Pointer to a static, NULL terminated string with the status name.

3.2.46. **cudnnGetFilter4dDescriptor()**

This function queries the parameters of the previously initialized `Filter4d` descriptor object.

```c
cudnnStatus_t cudnnGetFilter4dDescriptor(  
    const cudnnFilterDescriptor_t     filterDesc,
    cudnnDataType_t            *dataType,
    cudnnTensorFormat_t        *format,
    int                        *k,
    int                        *c,
    int                        *h,
    int                        *w)
```

**Parameters**

- **filterDesc**
  - *Input*. Handle to a previously created filter descriptor.
- **datatype**
  - *Output*. Data type.
- **format**
  - *Output*. Type of format.
- **k**
  - *Output*. Number of output feature maps.
- **c**
  - *Output*. Number of input feature maps.
- **h**
  - *Output*. Height of each filter.
- **w**
  - *Output*. Width of each filter.
3.2.47. **cudnnGetFilterNdDescriptor()**

This function queries a previously initialized FilterNd descriptor object.

```c
const cudnnFilterDescriptor_t wDesc,
int nbDimsRequested,
cudnnDataType_t *dataType,
cudnnTensorFormat_t *format,
int *nbDims,
int filterDimA[])
```

### Parameters

- **wDesc**
  - *Input*. Handle to a previously initialized filter descriptor.

- **nbDimsRequested**
  - *Input*. Dimension of the expected filter descriptor. It is also the minimum size of the arrays `filterDimA` in order to be able to hold the results.

- **dataType**
  - *Output*. Data type.

- **format**
  - *Output*. Type of format.

- **nbDims**
  - *Output*. Actual dimension of the filter.

- **filterDimA**
  - *Output*. Array of dimensions of at least `nbDimsRequested` that will be filled with the filter parameters from the provided filter descriptor.

### Returns

- **CUDNN_STATUS_SUCCESS**
  - The object was set successfully.

- **CUDNN_STATUS_BAD_PARAM**
  - The parameter `nbDimsRequested` is negative.

3.2.48. **cudnnGetFilterSizeInBytes()**

This function returns the size of the filter tensor in memory with respect to the given descriptor. It can be used to know the amount of GPU memory to be allocated to hold that filter tensor.

```c
cudnnStatus_t cudnnGetFilterSizeInBytes(const cudnnFilterDescriptor_t filterDesc, size_t *size) ;
```
Parameters

**filterDesc**
*Input*. Handle to a previously initialized filter descriptor.

**size**
*Output*. Size in bytes needed to hold the tensor in GPU memory.

Returns

**CUDNN_STATUS_SUCCESS**
*filterDesc* is valid.

**CUDNN_STATUS_BAD_PARAM**
*filterDesc* is invalid.

### 3.2.49. `cudnnGetLRNDescriptor()`

This function retrieves values stored in the previously initialized LRN descriptor object.

```c

int cudnnGetLRNDescriptor(    cudnnLRNDescriptor_t    normDesc,    unsigned               *lrnN,    double                 *lrnAlpha,    double                 *lrnBeta,    double                 *lrnK)
```

Parameters

**normDesc**
*Input*. Handle to a previously created LRN descriptor.

**lrnN, lrnAlpha, lrnBeta, lrnK**
*Output*. Pointers to receive values of parameters stored in the descriptor object. For more information, refer to `cudnnSetLRNDescriptor()`. Any of these pointers can be NULL (no value is returned for the corresponding parameter).

Returns

**CUDNN_STATUS_SUCCESS**
Function completed successfully.

### 3.2.50. `cudnnGetOpTensorDescriptor()`

This function returns the configuration of the passed tensor pointwise math descriptor.

```c

int cudnnGetOpTensorDescriptor(    const cudnnOpTensorDescriptor_t opTensorDesc,    cudnnOpTensorOp_t    *opTensorOp,    cudnnDataType_t    *opTensorCompType,    cudnnNanPropagation_t    *opTensorNanOpt)
```

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Parameters

**opTensorDesc**
*Input.* Tensor pointwise math descriptor passed to get the configuration from.

**opTensorOp**
*Output.* Pointer to the tensor pointwise math operation type, associated with this tensor pointwise math descriptor.

**opTensorCompType**
*Output.* Pointer to the cuDNN data-type associated with this tensor pointwise math descriptor.

**opTensorNanOpt**
*Output.* Pointer to the NAN propagation option associated with this tensor pointwise math descriptor.

Returns

**CUDNN_STATUS_SUCCESS**
The function returned successfully.

**CUDNN_STATUS_BAD_PARAM**
Input tensor pointwise math descriptor passed is invalid.

### 3.2.51. cudnnGetPooling2dDescriptor()

This function queries a previously created Pooling2D descriptor object.

```c
const cudnnPoolingDescriptor_t poolingDesc,
cudnnPoolingMode_t *mode, 
cudnnNanPropagation_t *maxpoolingNanOpt,
int *windowHeight, 
int *windowWidth, 
int *verticalPadding, 
int *horizontalPadding, 
int *verticalStride, 
int *horizontalStride)
```

Parameters

**poolingDesc**
*Input.* Handle to a previously created pooling descriptor.

**mode**
*Output.* Enumerant to specify the pooling mode.

**maxpoolingNanOpt**
*Output.* Enumerant to specify the Nan propagation mode.

**windowHeight**
*Output.* Height of the pooling window.

**windowWidth**
*Output.* Width of the pooling window.
**verticalPadding**
*Output*. Size of vertical padding.

**horizontalPadding**
*Output*. Size of horizontal padding.

**verticalStride**
*Output*. Pooling vertical stride.

**horizontalStride**
*Output*. Pooling horizontal stride.

### Returns

**CUDNN_STATUS_SUCCESS**
The object was set successfully.

#### 3.2.52. *cudnnGetPooling2dForwardOutputDim()*

This function provides the output dimensions of a tensor after Pooling2D has been applied.

```c
void cudnnGetPooling2dForwardOutputDim(
    const cudnnPoolingDescriptor_t      poolingDesc,
    const cudnnTensorDescriptor_t       inputDesc,
    int                                *outN,
    int                                *outC,
    int                                *outH,
    int                                *outW)
```

Each dimension $h$ and $w$ of the output images is computed as follows:

$$
\text{outputDim} = 1 + \frac{(\text{inputDim} + 2\times \text{padding} - \text{windowDim})}{\text{poolingStride}};
$$

### Parameters

**poolingDesc**
*Input*. Handle to a previously initialized pooling descriptor.

**inputDesc**
*Input*. Handle to the previously initialized input tensor descriptor.

**N**
*Output*. Number of images in the output.

**C**
*Output*. Number of channels in the output.

**H**
*Output*. Height of images in the output.

**W**
*Output*. Width of images in the output.

### Returns

**CUDNN_STATUS_SUCCESS**
The function launched successfully.
CUDNN_STATUS_BAD_PARAM

At least one of the following conditions are met:

- poolingDesc has not been initialized.
- poolingDesc or inputDesc has an invalid number of dimensions (2 and 4 respectively are required).

3.2.53. **cudnnGetPoolingNdDescriptor()**

This function queries a previously initialized generic PoolingNd descriptor object.

```
cudnnStatus_t cudnnGetPoolingNdDescriptor(  
    const cudnnPoolingDescriptor_t poolingDesc,  
    int nbDimsRequested,  
    cudnnPoolingMode_t *mode,  
    cudnnNanPropagation_t *maxpoolingNanOpt,  
    int *nbDims,  
    int windowDimA[],  
    int paddingA[],  
    int strideA[])  
)
```

**Parameters**

- **poolingDesc**
  - *Input*. Handle to a previously created pooling descriptor.

- **nbDimsRequested**
  - *Input*. Dimension of the expected pooling descriptor. It is also the minimum size of the arrays windowDimA, paddingA, and strideA in order to be able to hold the results.

- **mode**
  - *Output*. Enumerant to specify the pooling mode.

- **maxpoolingNanOpt**
  - *Output*. Enumerant to specify the Nan propagation mode.

- **nbDims**
  - *Output*. Actual dimension of the pooling descriptor.

- **windowDimA**
  - *Output*. Array of dimension of at least nbDimsRequested that will be filled with the window parameters from the provided pooling descriptor.

- **paddingA**
  - *Output*. Array of dimension of at least nbDimsRequested that will be filled with the padding parameters from the provided pooling descriptor.

- **strideA**
  - *Output*. Array of dimension at least nbDimsRequested that will be filled with the stride parameters from the provided pooling descriptor.

**Returns**

- **CUDNN_STATUS_SUCCESS**
  - The object was queried successfully.

- **CUDNN_STATUS_NOT_SUPPORTED**
  - The parameter nbDimsRequested is greater than CUDNN_DIM_MAX.
3.2.54. `cudnnGetPoolingNdForwardOutputDim()`

This function provides the output dimensions of a tensor after PoolingNd has been applied.

```c
#include <cudnn.h>

result = cudnnGetPoolingNdForwardOutputDim(
    poolingDesc, inputDesc, nbDims, outDimA[]);
```

Each dimension of the \((\text{nbDims}-2)\)-D images of the output tensor is computed as follows:

```
outputDim = 1 + (inputDim + 2*padding - windowDim)/poolingStride;
```

### Parameters

- **poolingDesc**
  - *Input*. Handle to a previously initialized pooling descriptor.

- **inputDesc**
  - *Input*. Handle to the previously initialized input tensor descriptor.

- **nbDims**
  - *Input*. Number of dimensions in which pooling is to be applied.

- **outDimA**
  - *Output*. Array of \(\text{nbDims}\) output dimensions.

### Returns

- **CUDNN_STATUS_SUCCESS**
  - The function launched successfully.

- **CUDNN_STATUS_BAD_PARAM**
  - At least one of the following conditions are met:
    - poolingDesc has not been initialized.
    - The value of nbDims is inconsistent with the dimensionality of poolingDesc and inputDesc.

3.2.55. `cudnnGetProperty()`

This function writes a specific part of the cuDNN library version number into the provided host storage.

```c
#include <cudnn.h>

result = cudnnGetProperty(
    type, *value);
```
Parameters

**type**
*Input.* Enumerant type that instructs the function to report the numerical value of the cuDNN major version, minor version, or the patch level depending on whether **type** is set to `MAJOR_VERSION`, `MINOR_VERSION`, or `PATCH_LEVEL`.

**value**
*Output.* Host pointer where the version information should be written.

Returns

**CUDNN_STATUS_INVALID_VALUE**
Invalid value of the **type** argument.

**CUDNN_STATUS_SUCCESS**
Version information was stored successfully at the provided address.

### 3.2.56. *cudnnGetReduceTensorDescriptor()*

This function queries a previously initialized reduce tensor descriptor object.

```c
const cudnnReduceTensorDescriptor_t reduceTensorDesc,
cudnnReduceTensorOp_t *reduceTensorOp,
cudnnDataType_t *reduceTensorCompType,
cudnnNanPropagation_t *reduceTensorNanOpt,
cudnnReduceTensorIndices_t *reduceTensorIndices,
cudnnIndicesType_t *reduceTensorIndicesType)
```

Parameters

**reduceTensorDesc**
*Input.* Pointer to a previously initialized reduce tensor descriptor object.

**reduceTensorOp**
*Output.* Enumerant to specify the reduced tensor operation.

**reduceTensorCompType**
*Output.* Enumerant to specify the computation datatype of the reduction.

**reduceTensorNanOpt**
*Output.* Enumerant to specify the Nan propagation mode.

**reduceTensorIndices**
*Output.* Enumerant to specify the reduced tensor indices.

**reduceTensorIndicesType**
*Output.* Enumerant to specify the reduced tensor indices type.

Returns

**CUDNN_STATUS_SUCCESS**
The object was queried successfully.

**CUDNN_STATUS_BAD_PARAM**
reduceTensorDesc is NULL.
3.2.57. **cudnnGetReductionIndicesSize()**

This is a helper function to return the minimum size of the index space to be passed to the reduction given the input and output tensors.

```c
#include <cudnn.h>

cudnnStatus_t cudnnGetReductionIndicesSize(
    cudnnHandle_t handle,
    const cudnnReduceTensorDescriptor_t reduceDesc,
    const cudnnTensorDescriptor_t aDesc,
    const cudnnTensorDescriptor_t cDesc,
    size_t *sizeInBytes)
```

**Parameters**

- **handle**
  - *Input*. Handle to a previously created cuDNN library descriptor.
- **reduceDesc**
  - *Input*. Pointer to a previously initialized reduce tensor descriptor object.
- **aDesc**
  - *Input*. Pointer to the input tensor descriptor.
- **cDesc**
  - *Input*. Pointer to the output tensor descriptor.
- **sizeInBytes**
  - *Output*. Minimum size of the index space to be passed to the reduction.

**Returns**

- **CUDNN_STATUS_SUCCESS**
  - The index space size is returned successfully.

3.2.58. **cudnnGetReductionWorkspaceSize()**

This is a helper function to return the minimum size of the workspace to be passed to the reduction given the input and output tensors.

```c
#include <cudnn.h>

cudnnStatus_t cudnnGetReductionWorkspaceSize(
    cudnnHandle_t handle,
    const cudnnReduceTensorDescriptor_t reduceDesc,
    const cudnnTensorDescriptor_t aDesc,
    const cudnnTensorDescriptor_t cDesc,
    size_t *sizeInBytes)
```

**Parameters**

- **handle**
  - *Input*. Handle to a previously created cuDNN library descriptor.
- **reduceDesc**
  - *Input*. Pointer to a previously initialized reduce tensor descriptor object.
- **aDesc**
  - *Input*. Pointer to the input tensor descriptor.
cDesc
   Input. Pointer to the output tensor descriptor.

sizeInBytes
   Output. Minimum size of the index space to be passed to the reduction.

Returns

CUDNN_STATUS_SUCCESS
   The workspace size is returned successfully.

3.2.59. cudnnGetStream()
This function retrieves the user CUDA stream programmed in the cuDNN handle. When the user's CUDA stream is not set in the cuDNN handle, this function reports the null-stream.

cudnnStatus_t cudnnGetStream(
   cudnnHandle_t   handle,
   cudaStream_t   *streamId)

Parameters

handle
   Input. Pointer to the cuDNN handle.

streamID
   Output. Pointer where the current CUDA stream from the cuDNN handle should be stored.

Returns

CUDNN_STATUS_BAD_PARAM
   Invalid (NULL) handle.

CUDNN_STATUS_SUCCESS
   The stream identifier was retrieved successfully.

3.2.60. cudnnGetTensor4dDescriptor()
This function queries the parameters of the previously initialized Tensor4d descriptor object.

cudnnStatus_t cudnnGetTensor4dDescriptor(
   const cudnnTensorDescriptor_t _tensorDesc,
   cudnnDataType_t   *dataType,
   int n,
   int c,
   int h,
   int w,
   int *nStride,
   int *cStride,
   int *hStride,
   int *wStride)
Parameters

tensorDesc
   Input. Handle to a previously initialized tensor descriptor.

datatype
   Output. Data type.

n
   Output. Number of images.

c
   Output. Number of feature maps per image.

h
   Output. Height of each feature map.

w
   Output. Width of each feature map.
nStride
   Output. Stride between two consecutive images.
cStride
   Output. Stride between two consecutive feature maps.
hStride
   Output. Stride between two consecutive rows.
wStride
   Output. Stride between two consecutive columns.

Returns

CUDNN_STATUS_SUCCESS
   The operation succeeded.

3.2.61. cudnnGetTensorNdDescriptor()

This function retrieves values stored in a previously initialized TensorNd descriptor object.
cudnnStatus_t cudnnGetTensorNdDescriptor(
   const cudnnTensorDescriptor_t   tensorDesc,
   int                             nbDimsRequested,
   cudnnDataType_t                *dataType,
   int                             *nbDims,
   int                             dimA[],
   int                             strideA[])

Parameters

tensorDesc
   Input. Handle to a previously initialized tensor descriptor.

nbDimsRequested
   Input. Number of dimensions to extract from a given tensor descriptor. It is also the minimum size of the arrays dimA and strideA. If this number is greater than the resulting nbDims[0], only nbDims[0] dimensions will be returned.
datatype
Output. Data type.

nbDims
Output. Actual number of dimensions of the tensor will be returned in nbDims[0].

dimA
Output. Array of dimensions of at least nbDimsRequested that will be filled with the dimensions from the provided tensor descriptor.

strideA
Output. Array of dimensions of at least nbDimsRequested that will be filled with the strides from the provided tensor descriptor.

Returns

CUDNN_STATUS_SUCCESS
The results were returned successfully.

CUDNN_STATUS_BAD_PARAM
Either tensorDesc or nbDims pointer is NULL.

3.2.62. cudnnGetTensorSizeInBytes()

This function returns the size of the tensor in memory in respect to the given descriptor. This function can be used to know the amount of GPU memory to be allocated to hold that tensor.

cudnnStatus_t cudnnGetTensorSizeInBytes(
    const cudnnTensorDescriptor_t   tensorDesc,
    size_t                         *size)

Parameters

tensorDesc
Input. Handle to a previously initialized tensor descriptor.

size
Output. Size in bytes needed to hold the tensor in GPU memory.

Returns

CUDNN_STATUS_SUCCESS
The results were returned successfully.

3.2.63. cudnnGetTensorTransformDescriptor()

This function returns the values stored in a previously initialized tensor transform descriptor.

cudnnStatus_t cudnnGetTensorTransformDescriptor(
    cudnnTensorTransformDescriptor_t transformDesc,
    uint32_t nbDimsRequested,
    cudnnTensorFormat_t *destFormat,
    int32_t padBeforeA[],
    int32_t padAfterA[],
    uint32_t foldA[],)
cudnnFoldingDirection_t *direction);

**Parameters**

transformDesc  
*Input.* A previously initialized tensor transform descriptor.

nbDimsRequested  
*Input.* The number of dimensions to consider. For more information, refer to `TensorDescriptor`.

destFormat  
*Output.* The transform format that will be returned.

padBeforeA[]  
*Output.* An array filled with the amount of padding to add before each dimension. The dimension of this padBeforeA[] parameter is equal to nbDimsRequested.

padAfterA[]  
*Output.* An array filled with the amount of padding to add after each dimension. The dimension of this padBeforeA[] parameter is equal to nbDimsRequested.

foldA[]  
*Output.* An array that was filled with the folding parameters for each spatial dimension. The dimension of this foldA[] array is nbDimsRequested-2.

direction  
*Output.* The setting that selects folding or unfolding. For more information, refer to `cudnnFoldingDirection_t`.

**Returns**

CUDNN_STATUS_SUCCESS  
The results were obtained successfully.

CUDNN_STATUS_BAD_PARAM  
If transformDesc is NULL or if nbDimsRequested is less than 3 or greater than CUDNN_DIM_MAX.

### 3.2.64. cudnnGetVersion()

This function returns the version number of the cuDNN library. It returns the CUDNN_VERSION defined present in the cudnn.h header file. Starting with release R2, the routine can be used to identify dynamically the current cuDNN library used by the application. The defined CUDNN_VERSION can be used to have the same application linked against different cuDNN versions using conditional compilation statements.

```c
size_t cudnnGetVersion()
```

### 3.2.65. cudnnInitTransformDest()

This function initializes and returns a destination tensor descriptor destDesc for tensor transform operations. The initialization is done with the desired parameters described in the transform descriptor cudnnTensorDescriptor_t.

```c
const cudnnTensorTransformDescriptor_t transformDesc,
```
```c
const cudnnTensorDescriptor_t srcDesc,
cudnnTensorDescriptor_t destDesc,
size_t *destSizeInBytes);
```

**Note:** The returned tensor descriptor will be packed.

**Parameters**

- **transformDesc**
  
  *Input.* Handle to a previously initialized tensor transform descriptor.

- **srcDesc**
  
  *Input.* Handle to a previously initialized tensor descriptor.

- **destDesc**
  
  *Output.* Handle of the tensor descriptor that will be initialized and returned.

- **destSizeInBytes**
  
  *Output.* A pointer to hold the size, in bytes, of the new tensor.

**Returns**

- **CUDNN_STATUS_SUCCESS**
  
  The tensor descriptor was initialized successfully.

- **CUDNN_STATUS_BAD_PARAM**
  
  If either `srcDesc` or `destDesc` is NULL, or if the tensor descriptor's `nbDims` is incorrect. For more information, refer to [Tensor Descriptor](#).

- **CUDNN_STATUS_NOT_SUPPORTED**
  
  If the provided configuration is not 4D.

- **CUDNN_STATUS_EXECUTION_FAILED**
  
  Function failed to launch on the GPU.

### 3.2.66. `cudnnLRNCrossChannelForward()`

This function performs the forward LRN layer computation.

```c
cudnnStatus_t cudnnLRNCrossChannelForward(
    cudnnHandle_t handle,
    cudnnLRNDescriptor_t normDesc,
    cudnnLRNMode_t lrnMode,
    const void *alpha,
    const cudnnTensorDescriptor_t xDesc,
    const void *x,
    const void *beta,
    const cudnnTensorDescriptor_t yDesc,
    void *y)
```

**Note:** Supported formats are: positive-strided, NCHW and NHWC for 4D `x` and `y`, and only NCDHW DHW-packed for 5D (for both `x` and `y`). Only non-overlapping 4D and 5D tensors are supported. NCHW layout is preferred for performance.
Parameters

**handle**

*Input.* Handle to a previously created cuDNN library descriptor.

**normDesc**

*Input.* Handle to a previously initialized LRN parameter descriptor.

**lrnMode**

*Input.* LRN layer mode of operation. Currently only `CUDNN_LRN_CROSS_CHANNEL_DIM1` is implemented. Normalization is performed along the tensor's `dimA[1]`.

**alpha, beta**

*Input.* Pointers to scaling factors (in host memory) used to blend the layer output value with prior value in the destination tensor as follows:

\[
\text{dstValue} = \alpha[0] \times \text{resultValue} + \beta[0] \times \text{priorDstValue}
\]

For more information, refer to Scaling Parameters.

**xDesc, yDesc**

*Input.* Tensor descriptor objects for the input and output tensors.

**x**

*Input.* Input tensor data pointer in device memory.

**y**

*Output.* Output tensor data pointer in device memory.

Returns

**CUDNN_STATUS_SUCCESS**

The computation was performed successfully.

**CUDNN_STATUS_BAD_PARAM**

At least one of the following conditions are met:

- One of the tensor pointers `x`, `y` is `NULL`.
- Number of input tensor dimensions is 2 or less.
- LRN descriptor parameters are outside of their valid ranges.
- One of the tensor parameters is 5D but is not in NCDHW DHW-packed format.

**CUDNN_STATUS_NOT_SUPPORTED**

The function does not support the provided configuration. Refer to the following examples of non-supported configurations:

- Any of the input tensor datatypes is not the same as any of the output tensor datatype.
- `x` and `y` tensor dimensions mismatch.
- Any tensor parameters strides are negative.
3.2.67. **cudnnNormalizationForwardInference()**

This function performs the forward normalization layer computation for the inference phase. Per-channel normalization layer is based on the [Batch Normalization: Accelerating Deep Network Training by Reducing Internal Covariate Shift](https://arxiv.org/abs/1502.03167) paper.

```c
void cudnnNormalizationForwardInference(cudnnHandle_t handle,
cudnnNormMode_t mode,
cudnnNormOps_t normOps,
cudnnNormAlgo_t algo,
const void *alpha,
const void *beta,
const cudnnTensorDescriptor_t xDesc,
const void *x,
const cudnnTensorDescriptor_t normScaleBiasDesc,
const void *normScale,
const void *normBias,
const cudnnTensorDescriptor_t normMeanVarDesc,
const void *estimatedMean,
const void *estimatedVariance,
const cudnnTensorDescriptor_t zDesc,
const void *z,
cudnnActivationDescriptor_t activationDesc,
const cudnnTensorDescriptor_t yDesc,
void *y,
double epsilon,
int groupCnt);
```

Only 4D and 5D tensors are supported.

The input transformation performed by this function is defined as:

\[
y = \beta y + \alpha \left[ \text{normBias} + \left( \text{normScale} (x - \text{estimatedMean}) / \sqrt{\text{epsilon + estimatedVariance}} \right) \right]
\]

The **epsilon** value has to be the same during training, backpropagation, and inference.

For the training phase, refer to **cudnnNormalizationForwardTraining()**.

Higher performance can be obtained when HW-packed tensors are used for all of \(x\) and \(y\).

**Parameters**

**handle**

*Input*. Handle to a previously created cuDNN library descriptor. For more information, refer to **cudnnHandle_t**.

**mode**

*Input*. Mode of operation (per-channel or per-activation). For more information, refer to **cudnnNormMode_t**.

**normOps**

*Input*. Mode of post-operative. Currently, **CUDNN_NORM_OPS_NORM_ACTIVATION** and **CUDNN_NORM_OPS_NORM_ADD_ACTIVATION** are not supported.

**algo**

*Input*. Algorithm to be performed. For more information, refer to **cudnnNormAlgo_t**.
alpha, beta

*Inputs.* Pointers to scaling factors (in host memory) used to blend the layer output value with prior value in the destination tensor as follows:

\[
dstValue = \text{alpha}[0] \ast \text{resultValue} + \text{beta}[0] \ast \text{priorDstValue}
\]

For more information, refer to Scaling Parameters.

xDesc, yDesc

*Input.* Handles to the previously initialized tensor descriptors.

*x

*Input.* Data pointer to GPU memory associated with the tensor descriptor xDesc, for the layer’s x input data.

*y

*Output.* Data pointer to GPU memory associated with the tensor descriptor yDesc, for the y output of the normalization layer.

zDesc, *z

*Input.* Tensor descriptors and pointers in device memory for residual addition to the result of the normalization operation, prior to the activation. zDesc and *z are optional and are only used when normOps is CUDNN_NORM_OPS_NORM_ADD_ACTIVATION, otherwise users may pass NULL. When in use, z should have exactly the same dimension as x and the final output y. For more information, refer to cudnnTensorDescriptor_t.

Since normOps is only supported for CUDNN_NORM_OPS_NORM, we can set these to NULL for now.

normScaleBiasDesc, normScale, normBias

*Inputs.* Tensor descriptors and pointers in device memory for the normalization scale and bias parameters (in the Batch Normalization: Accelerating Deep Network Training by Reducing Internal Covariate Shift paper, bias is referred to as beta and scale as gamma).

normMeanVarDesc, estimatedMean, estimatedVariance

*Inputs.* Mean and variance tensors and their tensor descriptors. The estimatedMean and estimatedVariance inputs, accumulated during the training phase from the cudnnNormalizationForwardTraining() call, should be passed as inputs here.

activationDesc

*Input.* Descriptor for the activation operation. When the normOps input is set to either CUDNN_NORM_OPS_NORM_ACTIVATION or CUDNN_NORM_OPS_NORM_ADD_ACTIVATION then this activation is used, otherwise the user may pass NULL. Since normOps is only supported for CUDNN_NORM_OPS_NORM, we can set these to NULL for now.

epsilon

*Input.* Epsilon value used in the normalization formula. Its value should be equal to or greater than zero.

groupCnt

*Input.* The number of grouped convolutions. Currently, only 1 is supported.
Returns

**CUDNN_STATUS_SUCCESS**
The computation was performed successfully.

**CUDNN_STATUS_NOT_SUPPORTED**
A compute or data type other than what is supported was chosen, or an unknown algorithm type was chosen.

**CUDNN_STATUS_BAD_PARAM**
At least one of the following conditions are met:
- One of the pointers alpha, beta, x, y, normScale, normBias, estimatedMean, and estimatedInvVariance is NULL.
- The number of xDesc or yDesc tensor descriptor dimensions is not within the range of [4,5] (only 4D and 5D tensors are supported).
- normScaleBiasDesc and normMeanVarDesc dimensions are not 1xCx1x1 for 4D and 1xCx1x1x1 for 5D for per-channel, and are not 1xCxHxW for 4D and 1xCxDxHxW for 5D for per-activation mode.
- epsilon value is less than zero.
- Dimensions or data types mismatch for xDesc and yDesc.

**CUDNN_STATUS_NOT_SUPPORTED**
A compute or data type other than FLOAT was chosen, or an unknown algorithm type was chosen.

**CUDNN_STATUS_EXECUTION_FAILED**
The function failed to launch on the GPU.

### 3.2.68. cudnnOpsInferVersionCheck()

This function is the first of a series of corresponding functions that check for consistent library versions among DLL files for different modules.

```c
void cudnnOpsInferVersionCheck()
```

Returns

**CUDNN_STATUS_SUCCESS**
The version of this DLL file is consistent with cuDNN DLLs on which it depends.

**CUDNN_STATUS_VERSION_MISMATCH**
The version of this DLL file does not match that of a cuDNN DLLs on which it depends.

### 3.2.69. cudnnOpTensor()

This function implements the equation \( C = \text{op}(\alpha_1[0] \ast A, \alpha_2[0] \ast B) + \beta[0] \ast C \), given the tensors \( A, B, \) and \( C \) and the scaling factors \( \alpha_1, \alpha_2, \) and \( \beta. \) The \text{op} to use is indicated by the descriptor `cudnnOpTensorDescriptor_t`, meaning,
the type of opTensorDesc. Currently-supported ops are listed by the cudnnOpTensorOp_t enum.

cudnnStatus_t cudnnOpTensor(
    cudnnHandle_t                     handle,
    const cudnnOpTensorDescriptor_t   opTensorDesc,
    const void                       *alpha1,
    const cudnnTensorDescriptor_t     aDesc,
    const void                       *A,
    const void                       *alpha2,
    const cudnnTensorDescriptor_t     bDesc,
    const void                       *B,
    const void                       *beta,
    const cudnnTensorDescriptor_t     cDesc,
    void                             *C)

The following restrictions on the input and destination tensors apply:

- Each dimension of the input tensor A must match the corresponding dimension of the destination tensor C, and each dimension of the input tensor B must match the corresponding dimension of the destination tensor C or must be equal to 1. In the latter case, the same value from the input tensor B for those dimensions will be used to blend into the C tensor.
- The data types of the input tensors A and B, and the destination tensor C, must satisfy Table 13.

Table 13. Supported Datatypes for cudnnOpTensor()

<table>
<thead>
<tr>
<th>opTensorCompType in opTensorDesc</th>
<th>A</th>
<th>B</th>
<th>C (destination)</th>
</tr>
</thead>
<tbody>
<tr>
<td>FLOAT</td>
<td>FLOAT</td>
<td>FLOAT</td>
<td>FLOAT</td>
</tr>
<tr>
<td>FLOAT</td>
<td>INT8</td>
<td>INT8</td>
<td>FLOAT</td>
</tr>
<tr>
<td>FLOAT</td>
<td>HALF</td>
<td>HALF</td>
<td>FLOAT</td>
</tr>
<tr>
<td>FLOAT</td>
<td>BFLOAT16</td>
<td>BFLOAT16</td>
<td>FLOAT</td>
</tr>
<tr>
<td>DOUBLE</td>
<td>DOUBLE</td>
<td>DOUBLE</td>
<td>DOUBLE</td>
</tr>
<tr>
<td>FLOAT</td>
<td>FLOAT</td>
<td>FLOAT</td>
<td>HALF</td>
</tr>
<tr>
<td>FLOAT</td>
<td>HALF</td>
<td>HALF</td>
<td>HALF</td>
</tr>
<tr>
<td>FLOAT</td>
<td>INT8</td>
<td>INT8</td>
<td>INT8</td>
</tr>
<tr>
<td>FLOAT</td>
<td>FLOAT</td>
<td>FLOAT</td>
<td>INT8</td>
</tr>
<tr>
<td>FLOAT</td>
<td>BFLOAT16</td>
<td>BFLOAT16</td>
<td>BFLOAT16</td>
</tr>
</tbody>
</table>

Note: CUDNN_TENSOR_NCHW_VECT_C is not supported as input tensor format. All tensors up to dimension five (5) are supported. This routine does not support tensor formats beyond these dimensions.
Parameters

handle
   Input. Handle to a previously created cuDNN context.

opTensorDesc
   Input. Handle to a previously initialized op tensor descriptor.

alpha1, alpha2, beta
   Input. Pointers to scaling factors (in host memory) used to blend the source value with prior value in the destination tensor as follows:
   \[ \text{dstValue} = \alpha[0] \times \text{resultValue} + \beta[0] \times \text{priorDstValue} \]
   For more information, refer to Scaling Parameters.

aDesc, bDesc, cDesc
   Input. Handle to a previously initialized tensor descriptor.

A, B
   Input. Pointer to data of the tensors described by the aDesc and bDesc descriptors, respectively.

C
   Input/Output. Pointer to data of the tensor described by the cDesc descriptor.

Returns

CUDNN_STATUS_SUCCESS
   The function executed successfully.

CUDNN_STATUS_NOT_SUPPORTED
   The function does not support the provided configuration. Refer to the following examples of non-supported configurations:
   ▶ The dimensions of the bias tensor and the output tensor dimensions are above 5.
   ▶ opTensorCompType is not set as stated above.

CUDNN_STATUS_BAD_PARAM
   The data type of the destination tensor C is unrecognized, or the restrictions on the input and destination tensors, stated above, are not met.

CUDNN_STATUS_EXECUTION_FAILED
   The function failed to launch on the GPU.

3.2.70. cudnnPoolingForward()

This function computes pooling of input values (meaning, the maximum or average of several adjacent values) to produce an output with smaller height and/or width.

```c
void cudnnPoolingForward(
    cudnnHandle_t               handle,
    const cudnnPoolingDescriptor_t  poolingDesc,
    const void                  *alpha,
    const cudnnTensorDescriptor_t cDesc,
    const void                  *x,
    const void                  *beta,
);```

const cudnnTensorDescriptor_t    yDesc,
void                            *y)

All tensor formats are supported, best performance is expected when using HW-packed tensors. Only 2 and 3 spatial dimensions are allowed. Vectorized tensors are only supported if they have 2 spatial dimensions.

The dimensions of the output tensor yDesc can be smaller or bigger than the dimensions advised by the routine cudnnGetPooling2dForwardOutputDim() or cudnnGetPoolingNdForwardOutputDim() .

For average pooling, the compute type is float even for integer input and output data type. Output round is nearest-even and clamp to the most negative or most positive value of type if out of range.

Parameters

handle
   Input. Handle to a previously created cuDNN context.

poolingDesc
   Input. Handle to a previously initialized pooling descriptor.

alpha, beta
   Input. Pointers to scaling factors (in host memory) used to blend the computation result with prior value in the output layer as follows:
   
   dstValue = \alpha[0]*resultValue + \beta[0]*priorDstValue

   For more information, refer to Scaling Parameters.

xDesc
   Input. Handle to the previously initialized input tensor descriptor. Must be of type FLOAT, DOUBLE, HALF, INT8, INT8x4, INT8x32, or BFLOAT16. For more information, refer to cudnnDataType_t.

x
   Input. Data pointer to GPU memory associated with the tensor descriptor xDesc.

yDesc
   Input. Handle to the previously initialized output tensor descriptor. Must be of type FLOAT, DOUBLE, HALF, INT8, INT8x4, INT8x32, or BFLOAT16. For more information, refer to cudnnDataType_t.

y
   Output. Data pointer to GPU memory associated with the output tensor descriptor yDesc.

Returns

CUDNN_STATUS_SUCCESS
   The function launched successfully.

CUDNN_STATUS_BAD_PARAM
   At least one of the following conditions are met:
      ▶ The dimensions n, c of the input tensor and output tensors differ.
The datatype of the input tensor and output tensors differs.

**CUDNN_STATUS_NOT_SUPPORTED**
The function does not support the provided configuration.

**CUDNN_STATUS_EXECUTION_FAILED**
The function failed to launch on the GPU.

### 3.2.71. `cudnnQueryRuntimeError()`

cuDNN library functions perform extensive input argument checking before launching GPU kernels. The last step is to verify that the GPU kernel actually started. When a kernel fails to start, **CUDNN_STATUS_EXECUTION_FAILED** is returned by the corresponding API call. Typically, after a GPU kernel starts, no runtime checks are performed by the kernel itself - numerical results are simply written to output buffers.

```c
int cudnnQueryRuntimeError(
    cudnnHandle_t            handle,
    cudnnStatus_t           *rstatus,
    cudnnErrQueryMode_t      mode,
    cudnnRuntimeTag_t       *tag)
```

When the **CUDNN_BATCHNORM_SPATIAL_PERSISTENT** mode is selected in **cudnnBatchNormalizationForwardTraining()** or **cudnnBatchNormalizationBackward()**, the algorithm may encounter numerical overflows where **CUDNN_BATCHNORM_SPATIAL** performs just fine albeit at a slower speed. The user can invoke **cudnnQueryRuntimeError()** to make sure numerical overflows did not occur during the kernel execution. Those issues are reported by the kernel that performs computations.

**cudnnQueryRuntimeError()** can be used in polling and blocking software control flows. There are two polling modes (**CUDNN_ERRQUERY_RAWCODE** and **CUDNN_ERRQUERY_NONBLOCKING**) and one blocking mode **CUDNN_ERRQUERY_BLOCKING**.

**CUDNN_ERRQUERY_RAWCODE** reads the error storage location regardless of the kernel completion status. The kernel might not even start and the error storage (allocated per cuDNN handle) might be used by an earlier call.

**CUDNN_ERRQUERY_NONBLOCKING** checks if all tasks in the user stream are completed. The **cudnnQueryRuntimeError()** function will return immediately and report **CUDNN_STATUS_RUNTIME_IN_PROGRESS** in `rstatus` if some tasks in the user stream are pending. Otherwise, the function will copy the remote kernel error code to `rstatus`.

In the blocking mode (**CUDNN_ERRQUERY_BLOCKING**), the function waits for all tasks to drain in the user stream before reporting the remote kernel error code. The blocking flavor can be further adjusted by calling `cudaSetDeviceFlags` with the `cudaDeviceScheduleSpin`, `cudaDeviceScheduleYield`, or `cudaDeviceScheduleBlockingSync` flag.

**CUDNN_ERRQUERY_NONBLOCKING** and **CUDNN_ERRQUERY_BLOCKING** modes should not be used when the user stream is changed in the cuDNN handle, meaning, **cudnnSetStream()** is invoked between functions that report runtime kernel errors and the **cudnnQueryRuntimeError()** function.
The remote error status reported in `rstatus` can be set to: `CUDNN_STATUS_SUCCESS`, `CUDNN_STATUS_RUNTIME_IN_PROGRESS`, or `CUDNN_STATUS_RUNTIME_FP_OVERFLOW`. The remote kernel error is automatically cleared by `cudnnQueryRuntimeError()`.

**Note:** The `cudnnQueryRuntimeError()` function should be used in conjunction with `cudnnBatchNormalizationForwardTraining()` and `cudnnBatchNormalizationBackward()` when the `cudnnBatchNormMode_t` argument is `CUDNN_BATCHNORM_SPATIAL_PERSISTENT`.

### Parameters

- **handle**
  - *Input*. Handle to a previously created cuDNN context.

- **rstatus**
  - *Output*. Pointer to the user's error code storage.

- **mode**

- **tag**
  - *Input/Output*. Currently, this argument should be `NULL`.

### Returns

- **`CUDNN_STATUS_SUCCESS`**
  - No errors detected (`rstatus` holds a valid value).

- **`CUDNN_STATUS_BAD_PARAM`**
  - Invalid input argument.

- **`CUDNN_STATUS_INTERNAL_ERROR`**
  - A stream blocking synchronization or a non-blocking stream query failed.

- **`CUDNN_STATUS_MAPPING_ERROR`**
  - The device cannot access zero-copy memory to report kernel errors.

#### 3.2.72. `cudnnReduceTensor()`

This function reduces tensor `A` by implementing the equation $C = \alpha \times \text{reduce op} (A) + \beta \times C$, given tensors `A` and `C` and scaling factors `alpha` and `beta`. The reduction op to use is indicated by the descriptor `reduceTensorDesc`. Currently-supported ops are listed by the `cudnnReduceTensorOp_t` enum.

```c
void cudnnReduceTensor(  
    cudnnHandle_t handle,  
    const cudnnReduceTensorDescriptor_t reduceTensorDesc,  
    void *indices,  
    size_t indicesSizeInBytes,  
    void *workspace,  
    size_t workspaceSizeInBytes,  
    const void *alpha,  
    const cudnnTensorDescriptor_t aDesc,  
    const void *A,  
    const void *beta,  
    const cudnnTensorDescriptor_t cDesc,  
    void *C)  
);  
```
Each dimension of the output tensor $C$ must match the corresponding dimension of the input tensor $A$ or must be equal to 1. The dimensions equal to 1 indicate the dimensions of $A$ to be reduced.

The implementation will generate indices for the min and max ops only, as indicated by the `cudnnReduceTensorIndices_t` enum of the `reduceTensorDesc`. Requesting indices for the other reduction ops results in an error. The data type of the indices is indicated by the `cudnnIndicesType_t` enum; currently only the 32-bit (unsigned int) type is supported.

The indices returned by the implementation are not absolute indices but relative to the dimensions being reduced. The indices are also flattened, meaning, not coordinate tuples.

The data types of the tensors $A$ and $C$ must match if of type double. In this case, $\alpha$ and $\beta$ and the computation enum of $reduceTensorDesc$ are all assumed to be of type double.

The `HALF` and `INT8` data types may be mixed with the `FLOAT` data types. In these cases, the computation enum of $reduceTensorDesc$ is required to be of type `FLOAT`.

Note: Up to dimension 8, all tensor formats are supported. Beyond those dimensions, this routine is not supported.

Parameters

```handle```
Input. Handle to a previously created cuDNN context.

```reduceTensorDesc```
Input. Handle to a previously initialized reduce tensor descriptor.

```indices```
Output. Handle to a previously allocated space for writing indices.

```indicesSizeInBytes```
Input. Size of the above previously allocated space.

```workspace```
Input. Handle to a previously allocated space for the reduction implementation.

```workspaceSizeInBytes```
Input. Size of the above previously allocated space.

```alpha, beta```
Input. Pointers to scaling factors (in host memory) used to blend the source value with prior value in the destination tensor as follows:

$$dstValue = \alpha[0]\ast resultValue + \beta[0]\ast priorDstValue$$

For more information, refer to Scaling Parameters.

```aDesc, cDesc```
Input. Handle to a previously initialized tensor descriptor.

```A```
Input. Pointer to data of the tensor described by the `aDesc` descriptor.

```C```
Input/Output. Pointer to data of the tensor described by the `cDesc` descriptor.
Returns

**CUDNN_STATUS_SUCCESS**
The function executed successfully.

**CUDNN_STATUS_NOT_SUPPORTED**
The function does not support the provided configuration. See the following for some examples of non-supported configurations:

- The dimensions of the input tensor and the output tensor are above 8.
- reduceTensorCompType is not set as stated above.

**CUDNN_STATUS_BAD_PARAM**
The corresponding dimensions of the input and output tensors all match, or the conditions in the above paragraphs are unmet.

**CUDNN_INVALID_VALUE**
The allocations for the indices or workspace are insufficient.

**CUDNN_STATUS_EXECUTION_FAILED**
The function failed to launch on the GPU.

### 3.2.73. `cudnnRestoreAlgorithm()`

This function has been deprecated in cuDNN 8.0.

This function reads algorithm metadata from the host memory space provided by the user in `algoSpace`, allowing the user to use the results of RNN finds from previous cuDNN sessions.

```c
#include <cudnn.h>

// This function reads algorithm metadata from the host memory space provided by the user in `algoSpace`, allowing
// the user to use the results of RNN finds from previous cuDNN sessions.

cudnnStatus_t cudnnRestoreAlgorithm(
    cudnnHandle_t handle,
    void* algoSpace,
    size_t algoSpaceSizeInBytes,
    cudnnAlgorithmDescriptor_t algoDesc
)
```

**Parameters**

**handle**

*Input*. Handle to a previously created cuDNN context.

**algoDesc**

*Input*. A previously created algorithm descriptor.

**algoSpace**

*Input*. Pointer to the host memory to be read.

**algoSpaceSizeInBytes**

*Input*. Amount of host memory needed as a workspace to be able to hold the metadata from the specified `algoDesc`.

**Returns**

**CUDNN_STATUS_SUCCESS**
The function launched successfully.
CUDNN_STATUS_NOT_SUPPORTED
The metadata is from a different cuDNN version.

CUDNN_STATUS_BAD_PARAM
At least one of the following conditions is met:
- One of the arguments is NULL.
- The metadata is corrupted.

3.2.74. cudnnRestoreDropoutDescriptor()

This function restores a dropout descriptor to a previously saved-off state.

```c
#include "cuDNN.h"

// cudnnRestoreDropoutDescriptor()

int cudnnRestoreDropoutDescriptor(
    cudnnDropoutDescriptor_t dropoutDesc,
    cudnnHandle_t            handle,
    float                    dropout,
    void                    *states,
    size_t                   stateSizeInBytes,
    unsigned long long       seed)
```

Parameters

- **dropoutDesc**
  - Input/Output. Previously created dropout descriptor.

- **handle**
  - Input. Handle to a previously created cuDNN context.

- **dropout**
  - Input. Probability with which the value from an input tensor is set to 0 when performing dropout.

- **states**
  - Input. Pointer to GPU memory that holds random number generator states initialized by a prior call to cudnnSetDropoutDescriptor().

- **stateSizeInBytes**
  - Input. Size in bytes of buffer holding random number generator states. States.

- **seed**
  - Input. Seed used in prior calls to cudnnSetDropoutDescriptor() that initialized states buffer. Using a different seed from this has no effect. A change of seed, and subsequent update to random number generator states can be achieved by calling cudnnSetDropoutDescriptor().

Returns

- **CUDNN_STATUS_SUCCESS**
  - The call was successful.

- **CUDNN_STATUS_INVALID_VALUE**
  - The states buffer size (as indicated in stateSizeInBytes) is too small.
3.2.75. cudnnSaveAlgorithm()

This function has been deprecated in cuDNN 8.0.

This function writes algorithm metadata into the host memory space provided by the user in algoSpace, allowing the user to preserve the results of RNN finds after cuDNN exits.

```c
void cudnnSaveAlgorithm(
    cudnnHandle_t handle,
    cudnnAlgorithmDescriptor_t algoDesc,
    void* algoSpace
    size_t algoSpaceSizeInBytes)
```

**Parameters**

- **handle**
  Input. Handle to a previously created cuDNN context.
- **algoDesc**
  Input. A previously created algorithm descriptor.
- **algoSpace**
  Input. Pointer to the host memory to be written.
- **algoSpaceSizeInBytes**
  Input. Amount of host memory needed as a workspace to be able to save the metadata from the specified algoDesc.

**Returns**

- **CUDNN_STATUS_SUCCESS**
  The function launched successfully.
- **CUDNN_STATUS_BAD_PARAM**
  At least one of the following conditions is met:
  - One of the arguments is NULL.
  - algoSpaceSizeInBytes is too small.

3.2.76. cudnnScaleTensor()

This function scales all the elements of a tensor by a given factor.

```c
void cudnnScaleTensor(
    cudnnHandle_t handle,
    const cudnnTensorDescriptor_t yDesc,
    void* y,
    const void* alpha)
```

**Parameters**

- **handle**
  Input. Handle to a previously created cuDNN context.
- **yDesc**
  Input. Handle to a previously initialized tensor descriptor.
cudnnSetActivationDescriptor()

This function initializes a previously created generic activation descriptor object.

```c
int cudnnSetActivationDescriptor(
cudnnActivationDescriptor_t activationDesc,
cudnnActivationMode_t mode,
cudnnNanPropagation_t reluNanOpt,
float coef)
```

Parameters

- **activationDesc**
  - *Input/Output*. Handle to a previously created activation descriptor.

- **mode**
  - *Input*. Enumerant to specify the activation mode.

- **reluNanOpt**
  - *Input*. Enumerant to specify the Nan propagation mode.

- **coef**
  - *Input*. Floating point number. When the activation mode (refer to `cudnnActivationMode_t`) is set to CUDNN_ACTIVATION_CLIPPED_RELU, this input specifies the clipping threshold; and when the activation mode is set to CUDNN_ACTIVATION_RELU, this input specifies the upper bound.

Returns

- **CUDNN_STATUS_SUCCESS**
  - The object was set successfully.

- **CUDNN_STATUS_BAD_PARAM**
  - `mode` or `reluNanOpt` has an invalid enumerant value.
3.2.78. **cudnnSetActivationDescriptorSwishBeta()**

This function sets the beta parameter of the SWISH activation function to `swish_beta`.

```c
    cudnnStatus_t cudnnSetActivationDescriptorSwishBeta(cudnnActivationDescriptor_t activationDesc, double swish_beta)
```

**Parameters**

- `activationDesc` _Input/Output_. Handle to a previously created activation descriptor.
- `swish_beta` _Input_. The value to set the SWISH activations' beta parameter to.

**Returns**

- **CUDNN_STATUS_SUCCESS**
  The value was set successfully.
- **CUDNN_STATUS_BAD_PARAM**
  The activation descriptor is a NULL pointer.

3.2.79. **cudnnSetAlgorithmDescriptor()**

This function has been deprecated in cuDNN 8.0.

This function initializes a previously created generic algorithm descriptor object.

```c
    cudnnStatus_t cudnnSetAlgorithmDescriptor(cudnnAlgorithmDescriptor_t algorithmDesc, cudnnAlgorithm_t algorithm)
```

**Parameters**

- `algorithmDesc` _Input/Output_. Handle to a previously created algorithm descriptor.
- `algorithm` _Input_. Struct to specify the algorithm.

**Returns**

- **CUDNN_STATUS_SUCCESS**
  The object was set successfully.

3.2.80. **cudnnSetAlgorithmPerformance()**

This function has been deprecated in cuDNN 8.0.

This function initializes a previously created generic algorithm performance object.

```c
    cudnnStatus_t cudnnSetAlgorithmPerformance(cudnnAlgorithmPerformance_t algoPerf, cudnnAlgorithmDescriptor_t algoDesc, cudnnStatus_t status, float time,
```

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#### cudnnGetPerformance() Parameters

- **algoPerf**
  - *Input/Output*. Handle to a previously created algorithm performance object.

- **algoDesc**
  - *Input*. The algorithm descriptor which the performance results describe.

- **status**
  - *Input*. The cuDNN status returned from running the `algoDesc` algorithm.

- **time**
  - *Input*. The GPU time spent running the `algoDesc` algorithm.

- **memory**
  - *Input*. The GPU memory needed to run the `algoDesc` algorithm.

#### cudnnGetPerformance() Returns

- **CUDNN_STATUS_SUCCESS**
  - The object was set successfully.

- **CUDNN_STATUS_BAD_PARAM**
  - `mode` or `reluNanOpt` has an invalid enumerate value.

#### 3.2.81. cudnnSetCallback()

This function sets the internal states of cuDNN error reporting functionality.

```c
void cudnnSetCallback(
    cudnnStatus_t cudnnSetCallback(
        unsigned mask,
        void *udata,
        cudnnCallback_t fptr)
```

#### cudnnSetCallback() Parameters

- **mask**
  - *Input*. An unsigned integer. The four least significant bits (LSBs) of this unsigned integer are used for switching on and off the different levels of error reporting messages. This applies for both the default callbacks, and for the customized callbacks. The bit position is in correspondence with the enum of `cudnnSeverity_t`. The user may utilize the predefined macros `CUDNN_SEV_ERROR_EN`, `CUDNN_SEV_WARNING_EN`, and `CUDNN_SEV_INFO_EN` to form the bit mask. When a bit is set to 1, the corresponding message channel is enabled.

  For example, when bit 3 is set to 1, the API logging is enabled. Currently, only the log output of level `CUDNN_SEV_INFO` is functional; the others are not yet implemented. When used for turning on and off the logging with the default callback, the user may pass `NULL` to `udata` and `fptr`. In addition, the environment variable `CUDNN_LOGDEST_DBG` must be set. For more information, refer to [Deprecation Policy](#).

  ▶ `CUDNN_SEV_INFO_EN = 0b1000` (functional).
- `CUDNN_SEV_ERROR_EN` = 0b0010 (not yet functional).
- `CUDNN_SEV_WARNING_EN` = 0b0100 (not yet functional).

The output of `CUDNN_SEV_FATAL` is always enabled and cannot be disabled.

**udata**

*Input.* A pointer provided by the user. This pointer will be passed to the user’s custom logging callback function. The data it points to will not be read, nor be changed by cuDNN. This pointer may be used in many ways, such as in a mutex or in a communication socket for the user’s callback function for logging. If the user is utilizing the default callback function, or doesn’t want to use this input in the customized callback function, they may pass in `NULL`.

**fptr**

*Input.* A pointer to a user-supplied callback function. When `NULL` is passed to this pointer, then cuDNN switches back to the built-in default callback function. The user-supplied callback function prototype must be similar to the following (also defined in the header file):

```c
void customizedLoggingCallback (cudnnSeverity_t sev, void *udata, const cudnnDebug_t *dbg, const char *msg);
```

- The structure `cudnnDebug_t` is defined in the header file. It provides the metadata, such as time, time since start, stream ID, process and thread ID, that the user may choose to print or store in their customized callback.
- The variable `msg` is the logging message generated by cuDNN. Each line of this message is terminated by `\0`, and the end of the message is terminated by `\0\0`. Users may select what is necessary to show in the log, and may reformat the string.

**Returns**

**CUDNN_STATUS_SUCCESS**

The function launched successfully.

### 3.2.82. `cudnnSetDropoutDescriptor()`

This function initializes a previously created dropout descriptor object. If the `states` argument is equal to `NULL`, then the random number generator states won’t be initialized, and only the `dropout` value will be set. The user is expected not to change the memory pointed at by `states` for the duration of the computation.

```c
void cudnnSetDropoutDescriptor (cudnnDropoutDescriptor_t dropoutDesc, cudnnHandle_t handle, float dropout, void *states, size_t stateSizeInBytes, unsigned long long seed);
```

When the `states` argument is not `NULL`, a cuRAND initialization kernel is invoked by `cudnnSetDropoutDescriptor()`. This kernel requires a substantial amount of GPU memory for the stack. Memory is released when the kernel finishes. The
CUDNN_STATUS_ALLOC_FAILED status is returned when no sufficient free memory is available for the GPU stack.

Parameters

dropoutDesc
   Input/Output. Previously created dropout descriptor object.

handle
   Input. Handle to a previously created cuDNN context.

dropout
   Input. The probability with which the value from input is set to zero during the dropout layer.

states
   Output. Pointer to user-allocated GPU memory that will hold random number generator states.

stateSizeInBytes
   Input. Specifies the size in bytes of the provided memory for the states.

seed
   Input. Seed used to initialize random number generator states.

Returns

CUDNN_STATUS_SUCCESS
   The call was successful.

CUDNN_STATUS_INVALID_VALUE
   The sizeInBytes argument is less than the value returned by cudnnDropoutGetStatesSize().

CUDNN_STATUS_ALLOC_FAILED
   The function failed to temporarily extend the GPU stack.

CUDNN_STATUS_EXECUTION_FAILED
   The function failed to launch on the GPU.

CUDNN_STATUS_INTERNAL_ERROR
   Internally used CUDA functions returned an error status.

3.2.83. cudnnSetFilter4dDescriptor()

This function initializes a previously created filter descriptor object into a 4D filter. The layout of the filters must be contiguous in memory.

```c
int cudnnSetFilter4dDescriptor(
    cudnnFilterDescriptor_t    filterDesc,
    cudnnDataType_t            dataType,
    cudnnTensorFormat_t        format,
    int                        k,
    int                        c,
    int                        h,
    int                        w)
```

Tensor format CUDNN_TENSOR_NHWC has limited support in cudnnConvolutionForward(), cudnnConvolutionBackwardData(), and cudnnConvolutionBackwardFilter().
Parameters

**filterDesc**
*Input/Output.* Handle to a previously created filter descriptor.

**datatype**
*Input.* Data type.

**format**
*Input.* Type of the filter layout format. If this input is set to `CUDNN_TENSOR_NCHW`, which is one of the enumerant values allowed by `cudnnTensorFormat_t` descriptor, then the layout of the filter is in the form of `KCRS`, where:

- `K` represents the number of output feature maps
- `C` is the number of input feature maps
- `R` is the number of rows per filter
- `S` is the number of columns per filter

If this input is set to `CUDNN_TENSOR_NHWC`, then the layout of the filter is in the form of `KRSC`. For more information, refer to `cudnnTensorFormat_t`.

**k**
*Input.* Number of output feature maps.

**c**
*Input.* Number of input feature maps.

**h**
*Input.* Height of each filter.

**w**
*Input.* Width of each filter.

Returns

**CUDNN_STATUS_SUCCESS**
The object was set successfully.

**CUDNN_STATUS_BAD_PARAM**
At least one of the parameters `k`, `c`, `h`, `w` is negative or `dataType` or `format` has an invalid enumerant value.

### 3.2.84. **cudnnSetFilterNdDescriptor()**

This function initializes a previously created filter descriptor object. The layout of the filters must be contiguous in memory.

```c
#include <cudnn.h>

cudnnStatus_t cudnnSetFilterNdDescriptor(
    cudnnFilterDescriptor_t filterDesc,
    cudnnDataType_t         dataType,
    cudnnTensorFormat_t     format,
    int                     nbDims,
    const int               filterDimA[])
```
The tensor format CUDNN_TENSOR_NHWC has limited support in cudnnConvolutionForward(), cudnnConvolutionBackwardData(), and cudnnConvolutionBackwardFilter().

Parameters

filterDesc
   Input/Output. Handle to a previously created filter descriptor.

datatype
   Input. Data type.

format
   Input. Type of the filter layout format. If this input is set to CUDNN_TENSOR_NCHW, which is one of the enumerant values allowed by cudnnTensorFormat_t descriptor, then the layout of the filter is as follows:
   ▶ For N=4, a 4D filter descriptor, the filter layout is in the form of KCRS:
      ▶ K represents the number of output feature maps
      ▶ C is the number of input feature maps
      ▶ R is the number of rows per filter
      ▶ S is the number of columns per filter
   ▶ For N=3, a 3D filter descriptor, the number S (number of columns per filter) is omitted.
   ▶ For N=5 and greater, the layout of the higher dimensions immediately follows RS.

On the other hand, if this input is set to CUDNN_TENSOR_NHWC, then the layout of the filter is as follows:
   ▶ For N=4, a 4D filter descriptor, the filter layout is in the form of KRSC.
   ▶ For N=3, a 3D filter descriptor, the number S (number of columns per filter) is omitted and the layout of C immediately follows R.
   ▶ For N=5 and greater, the layout of the higher dimensions are inserted between S and C. For more information, refer to cudnnTensorFormat_t.

nbDims
   Input. Dimension of the filter.

filterDimA
   Input. Array of dimension nbDims containing the size of the filter for each dimension.

Returns

CUDNN_STATUS_SUCCESS
   The object was set successfully.

CUDNN_STATUS_BAD_PARAM
   At least one of the elements of the array filterDimA is negative or dataType or format has an invalid enumerant value.
CUDNN_STATUS_NOT_SUPPORTED
The parameter nbDims exceeds CUDNN_DIM_MAX.

3.2.85. cudnnSetLRNDescriptor()

This function initializes a previously created LRN descriptor object.

<table>
<thead>
<tr>
<th>cudnnStatus_t</th>
<th>cudnnSetLRNDescriptor(</th>
</tr>
</thead>
<tbody>
<tr>
<td>cudnnLRNDescriptor_t</td>
<td>normDesc,</td>
</tr>
<tr>
<td>unsigned</td>
<td>lrnN,</td>
</tr>
<tr>
<td>double</td>
<td>lrnAlpha,</td>
</tr>
<tr>
<td>double</td>
<td>lrnBeta,</td>
</tr>
<tr>
<td>double</td>
<td>lrnK)</td>
</tr>
</tbody>
</table>

Note:
- Macros CUDNN_LRN_MIN_N, CUDNN_LRN_MAX_N, CUDNN_LRN_MIN_K, CUDNN_LRN_MIN_BETA defined in cudnn.h specify valid ranges for parameters.
- Values of double parameters will be cast down to the tensor datatype during computation.

Parameters

- **normDesc**
  - Output. Handle to a previously created LRN descriptor.

- **lrnN**
  - Input. Normalization window width in elements. The LRN layer uses a window [center-lookBehind, center+lookAhead], where lookBehind = floor( (lrnN-1)/2 ), lookAhead = lrnN-lookBehind-1. So for n=10, the window is [k-4...k...k+5] with a total of 10 samples. For the DivisiveNormalization layer, the window has the same extent as above in all spatial dimensions (dimA[2], dimA[3], dimA[4]). By default, lrnN is set to 5 in cudnnCreateLRNDescriptor().

- **lrnAlpha**
  - Input. Value of the alpha variance scaling parameter in the normalization formula. Inside the library code, this value is divided by the window width for LRN and by (window width)^#spatialDimensions for DivisiveNormalization. By default, this value is set to 1e-4 in cudnnCreateLRNDescriptor().

- **lrnBeta**
  - Input. Value of the beta power parameter in the normalization formula. By default, this value is set to 0.75 in cudnnCreateLRNDescriptor().

- **lrnK**
  - Input. Value of the k parameter in the normalization formula. By default, this value is set to 2.0.

Returns

- **CUDNN_STATUS_SUCCESS**
  - The object was set successfully.
CUDNN_STATUS_BAD_PARAM
One of the input parameters was out of valid range as described above.

3.2.86. cudnnSetOpTensorDescriptor()
This function initializes a tensor pointwise math descriptor.

```c
void cudnnSetOpTensorDescriptor(
    cudnnOpTensorDescriptor_t   opTensorDesc,
    cudnnOpTensorOp_t           opTensorOp,
    cudnnDataType_t             opTensorCompType,
    cudnnNanPropagation_t       opTensorNanOpt)
```

Parameters

**opTensorDesc**
*Output*. Pointer to the structure holding the description of the tensor pointwise math descriptor.

**opTensorOp**
*Input*. Tensor pointwise math operation for this tensor pointwise math descriptor.

**opTensorCompType**
*Input*. Computation datatype for this tensor pointwise math descriptor.

**opTensorNanOpt**
*Input*. NAN propagation policy.

Returns

**CUDNN_STATUS_SUCCESS**
The function returned successfully.

**CUDNN_STATUS_BAD_PARAM**
At least one of the input parameters passed is invalid.

3.2.87. cudnnSetPooling2dDescriptor()
This function initializes a previously created generic pooling descriptor object into a 2D description.

```c
void cudnnSetPooling2dDescriptor(
    cudnnPoolingDescriptor_t    poolingDesc,
    cudnnPoolingMode_t          mode,
    cudnnNanPropagation_t       maxpoolingNanOpt,
    int                         windowHeight,
    int                         windowWidth,
    int                         verticalPadding,
    int                         horizontalPadding,
    int                         verticalStride,
    int                         horizontalStride)
```

Parameters

**poolingDesc**
*Input/Output*. Handle to a previously created pooling descriptor.
mode
   Input. Enumerant to specify the pooling mode.

maxpoolingNanOpt
   Input. Enumerant to specify the Nan propagation mode.

windowHeight
   Input. Height of the pooling window.

windowWidth
   Input. Width of the pooling window.

verticalPadding
   Input. Size of vertical padding.

horizontalPadding
   Input. Size of horizontal padding.

verticalStride
   Input. Pooling vertical stride.

horizontalStride
   Input. Pooling horizontal stride.

Returns

CUDNN_STATUS_SUCCESS
   The object was set successfully.

CUDNN_STATUS_BAD_PARAM
   At least one of the parameters windowHeight, windowWidth, verticalStride, horizontalStride is negative or mode or maxpoolingNanOpt has an invalid enumerate value.

3.2.88. cudnnSetPoolingNdDescriptor()

This function initializes a previously created generic pooling descriptor object.

```c
void cudnnSetPoolingNdDescriptor(
    cudnnPoolingDescriptor_t poolingDesc,
    const cudnnPoolingMode_t mode,
    const cudnnNanPropagation_t maxpoolingNanOpt,
    int nbDims,
    const int windowHeightA[],
    const int paddingA[],
    const int strideA[])
```

Parameters

poolingDesc
   Input/Output. Handle to a previously created pooling descriptor.

mode
   Input. Enumerant to specify the pooling mode.

maxpoolingNanOpt
   Input. Enumerant to specify the Nan propagation mode.

nbDims
   Input. Dimension of the pooling operation. Must be greater than zero.
windowDimA

*Input.* Array of dimension `nbDims` containing the window size for each dimension. The value of array elements must be greater than zero.

paddingA

*Input.* Array of dimension `nbDims` containing the padding size for each dimension. Negative padding is allowed.

strideA

*Input.* Array of dimension `nbDims` containing the striding size for each dimension. The value of array elements must be greater than zero (meaning, negative striding size is not allowed).

**Returns**

**CUDNN_STATUS_SUCCESS**

The object was initialized successfully.

**CUDNN_STATUS_NOT_SUPPORTED**

If (`nbDims > CUDNN_DIM_MAX-2`).

**CUDNN_STATUS_BAD_PARAM**

Either `nbDims`, or at least one of the elements of the arrays `windowDimA` or `strideA` is negative, or `mode` or `maxpoolingNanOpt` has an invalid enumerate value.

### 3.2.89. cudnnSetReduceTensorDescriptor()

This function initializes a previously created reduce tensor descriptor object.

```c
#include <cudnn.h>

cudnnStatus_t cudnnSetReduceTensorDescriptor(cudnnReduceTensorDescriptor_t reduceTensorDesc,
                                          cudnnReduceTensorOp_t reduceTensorOp,
                                          cudnnDataType_t reduceTensorCompType,
                                          cudnnNanPropagation_t reduceTensorNanOpt,
                                          cudnnReduceTensorIndices_t reduceTensorIndices,
                                          cudnnIndicesType_t reduceTensorIndicesType);
```

**Parameters**

**reduceTensorDesc**

*Input/Output.* Handle to a previously created reduce tensor descriptor.

**reduceTensorOp**

*Input.* Enumerant to specify the reduce tensor operation.

**reduceTensorCompType**

*Input.* Enumerant to specify the computation datattype of the reduction.

**reduceTensorNanOpt**

*Input.* Enumerant to specify the Nan propagation mode.

**reduceTensorIndices**

*Input.* Enumerant to specify the reduced tensor indices.

**reduceTensorIndicesType**

*Input.* Enumerant to specify the reduce tensor indices type.
Returns

CUDNN_STATUS_SUCCESS
The object was set successfully.

CUDNN_STATUS_BAD_PARAM
reduceTensorDesc is NULL (reduceTensorOp, reduceTensorCompType,
reduceTensorNanOpt, reduceTensorIndices or reduceTensorIndicesType has an
invalid enumerant value).

3.2.90. cudnnSetSpatialTransformerNdDescriptor()

This function initializes a previously created generic spatial transformer descriptor object.

```c
 cunnStatus_t cudnnSetSpatialTransformerNdDescriptor(
   cudnnSpatialTransformerDescriptor_t  stDesc,
   cudnnSamplerType_t                  samplerType,
   cudnnDataType_t                     dataType,
   const int                           nbDims,
   const int                           dimA[
```

Parameters

**stDesc**
*Input/Output.* Previously created spatial transformer descriptor object.

**samplerType**
*Input.* Enumerant to specify the sampler type.

**dataType**
*Input.* Data type.

**nbDims**
*Input.* Dimension of the transformed tensor.

**dimA**
*Input.* Array of dimension nbDims containing the size of the transformed tensor for
every dimension.

Returns

CUDNN_STATUS_SUCCESS
The call was successful.

CUDNN_STATUS_BAD_PARAM
At least one of the following conditions are met:

- Either stDesc or dimA is NULL.
- Either dataType or samplerType has an invalid enumerant value.

3.2.91. cudnnSetStream()

This function sets the user’s CUDA stream in the cuDNN handle. The new stream will be
used to launch cuDNN GPU kernels or to synchronize to this stream when cuDNN kernels
are launched in the internal streams. If the cuDNN library stream is not set, all kernels
use the default (NULL) stream. Setting the user stream in the cuDNN handle guarantees the issue-order execution of cuDNN calls and other GPU kernels launched in the same stream.

```c
    cudnnStatus_t cudnnSetStream(
        cudnnHandle_t   handle,
        cudaStream_t    streamId)
```

With CUDA 11.x or later, internal streams have the same priority as the stream set by the last call to this function. In CUDA graph capture mode, CUDA 11.8 or later is required in order for the stream priorities to match.

**Parameters**

- **handle**
  - *Input*. Pointer to the cuDNN handle.

- **streamID**
  - *Input*. New CUDA stream to be written to the cuDNN handle.

**Returns**

- **CUDNN_STATUS_BAD_PARAM**
  - Invalid (NULL) handle.

- **CUDNN_STATUS_MAPPING_ERROR**
  - Mismatch between the user stream and the cuDNN handle context.

- **CUDNN_STATUS_SUCCESS**
  - The new stream was set successfully.

### 3.2.92. `cudnnSetTensor()`

This function sets all the elements of a tensor to a given value.

```c
    cudnnStatus_t cudnnSetTensor(
        cudnnHandle_t                   handle,
        const cudnnTensorDescriptor_t   yDesc,
        void                           *y,
        const void                     *valuePtr)
```

**Parameters**

- **handle**
  - *Input*. Handle to a previously created cuDNN context.

- **yDesc**
  - *Input*. Handle to a previously initialized tensor descriptor.

- **y**
  - *Input/Output*. Pointer to data of the tensor described by the yDesc descriptor.

- **valuePtr**
  - *Input*. Pointer in host memory to a single value. All elements of the y tensor will be set to value[0]. The data type of the element in value[0] has to match the data type of tensor y.
### Returns

**CUDNN_STATUS_SUCCESS**
- The function launched successfully.

**CUDNN_STATUS_NOT_SUPPORTED**
- The function does not support the provided configuration.

**CUDNN_STATUS_BAD_PARAM**
- One of the provided pointers is **NIL**.

**CUDNN_STATUS_EXECUTION_FAILED**
- The function failed to launch on the GPU.

### 3.2.93. `cudnnSetTensor4dDescriptor()`

This function initializes a previously created generic tensor descriptor object into a 4D tensor. The strides of the four dimensions are inferred from the format parameter and set in such a way that the data is contiguous in memory with no padding between dimensions.

```c
int cudnnSetTensor4dDescriptor(
    cudnnTensorDescriptor_t tensorDesc,
    cudnnTensorFormat_t     format,
    cudnnDataType_t         dataType,
    int                     n,
    int                     c,
    int                     h,
    int                     w)
```

The total size of a tensor including the potential padding between dimensions is limited to 2 Giga-elements of type `datatype`.

### Parameters

- **tensorDesc**
  - *Input/Output*. Handle to a previously created tensor descriptor.

- **format**
  - *Input*. Type of format.

- **datatype**
  - *Input*. Data type.

- **n**
  - *Input*. Number of images.

- **c**
  - *Input*. Number of feature maps per image.

- **h**
  - *Input*. Height of each feature map.

- **w**
  - *Input*. Width of each feature map.
Returns

**CUDNN_STATUS_SUCCESS**
The object was set successfully.

**CUDNN_STATUS_BAD_PARAM**
At least one of the parameters \( n, c, h, w \) was negative or \( \text{format} \) has an invalid enumerant value or \( \text{dataType} \) has an invalid enumerant value.

**CUDNN_STATUS_NOT_SUPPORTED**
The total size of the tensor descriptor exceeds the maximum limit of 2 Giga-elements.

3.2.94. **cudnnSetTensor4dDescriptorEx()**

This function initializes a previously created generic tensor descriptor object into a 4D tensor, similarly to \( \text{cudnnSetTensor4dDescriptor}() \) but with the strides explicitly passed as parameters. This can be used to lay out the 4D tensor in any order or simply to define gaps between dimensions.

```c
#include <cudnn.h>

cudnnStatus_t cudnnSetTensor4dDescriptorEx(
  cudnnTensorDescriptor_t tensorDesc,
  cudnnDataType_t dataType,
  int n,
  int c,
  int h,
  int w,
  int nStride,
  int cStride,
  int hStride,
  int wStride)
```

At present, some cuDNN routines have limited support for strides. Those routines will return **CUDNN_STATUS_NOT_SUPPORTED** if a 4D tensor object with an unsupported stride is used. **cudnnTransformTensor()** can be used to convert the data to a supported layout.

The total size of a tensor including the potential padding between dimensions is limited to 2 Giga-elements of type \( \text{datatype} \).

**Parameters**

- **tensorDesc**
  *Input/Output*. Handle to a previously created tensor descriptor.

- **datatype**
  *Input*. Data type.

- **n**
  *Input*. Number of images.

- **c**
  *Input*. Number of feature maps per image.

- **h**
  *Input*. Height of each feature map.

- **w**
  *Input*. Width of each feature map.
nStride
   Input. Stride between two consecutive images.

cStride
   Input. Stride between two consecutive feature maps.

hStride
   Input. Stride between two consecutive rows.

wStride
   Input. Stride between two consecutive columns.

Returns

CUDNN_STATUS_SUCCESS
   The object was set successfully.

CUDNN_STATUS_BAD_PARAM
   At least one of the parameters n, c, h, w or nStride, cStride, hStride, wStride is negative or dataType has an invalid enumerant value.

CUDNN_STATUS_NOT_SUPPORTED
   The total size of the tensor descriptor exceeds the maximum limit of 2 Giga-elements.

3.2.95. cudnnSetTensorNdDescriptor()

This function initializes a previously created generic tensor descriptor object.

cudnnStatus_t cudnnSetTensorNdDescriptor(
   cudnnTensorDescriptor_t tensorDesc,
   cudnnDataType_t         dataType,
   int                     nbDims,
   const int               dimA[],
   const int               strideA[])

The total size of a tensor including the potential padding between dimensions is limited to 2 Giga-elements of type dataType. Tensors are restricted to having at least 4 dimensions, and at most CUDNN_DIM_MAX dimensions (defined in cudnn.h). When working with lower dimensional data, it is recommended that the user create a 4D tensor, and set the size along unused dimensions to 1.

Parameters

tensorDesc
   Input/Output. Handle to a previously created tensor descriptor.

datatype
   Input. Data type.

nbDims
   Input. Dimension of the tensor.

Note: Do not use 2 dimensions. Due to historical reasons, the minimum number of dimensions in the filter descriptor is three. For more information, refer to cudnnGetRNNLinLayerBiasParams().
dimA

*Input.* Array of dimension nbDims that contain the size of the tensor for every dimension. The size along unused dimensions should be set to 1. By convention, the ordering of dimensions in the array follows the format - \([N, C, D, H, W]\), with \(W\) occupying the smallest index in the array.

strideA

*Input.* Array of dimension nbDims that contain the stride of the tensor for every dimension. By convention, the ordering of the strides in the array follows the format - \([N\text{stride}, C\text{stride}, D\text{stride}, H\text{stride}, W\text{stride}]\), with \(W\text{stride}\) occupying the smallest index in the array.

Returns

**CUDNN_STATUS_SUCCESS**

The object was set successfully.

**CUDNN_STATUS_BAD_PARAM**

At least one of the elements of the array dimA was negative or zero, or dataType has an invalid enumerator value.

**CUDNN_STATUS_NOT_SUPPORTED**

The parameter nbDims is outside the range \([4, \text{CUDNN\_DIM\_MAX}]\), or the total size of the tensor descriptor exceeds the maximum limit of 2 Giga-elements.

### 3.2.96. cudnnSetTensorNdDescriptorEx()

This function initializes an Nd tensor descriptor.

```c

extern cudnnStatus_t cudnnSetTensorNdDescriptorEx(
  cudnnTensorDescriptor_t tensorDesc,
  cudnnTensorFormat_t     format,
  cudnnDataType_t         dataType,
  int                     nbDims,
  const int               dimA[])

```

Parameters

**tensorDesc**

*Output.* Pointer to the tensor descriptor struct to be initialized.

**format**

*Input.* Tensor format.

**dataType**

*Input.* Tensor data type.

**nbDims**

*Input.* Dimension of the tensor.

Note: Do not use 2 dimensions. Due to historical reasons, the minimum number of dimensions in the filter descriptor is three. For more information, refer to cudnnGetRNNLinLayerBiasParams().
dimA

*Input*. Array containing the size of each dimension.

**Returns**

**CUDNN_STATUS_SUCCESS**

The function was successful.

**CUDNN_STATUS_BAD_PARAM**

Tensor descriptor was not allocated properly; or input parameters are not set correctly.

**CUDNN_STATUS_NOT_SUPPORTED**

Dimension size requested is larger than maximum dimension size supported.

### 3.2.97. `cudnnSetTensorTransformDescriptor()`

This function initializes a tensor transform descriptor that was previously created using the `cudnnCreateTensorTransformDescriptor()` function.

```c
void cudnnSetTensorTransformDescriptor(
  cudnnTensorTransformDescriptor_t transformDesc,
  const uint32_t nbDims,
  const cudnnTensorFormat_t destFormat,
  const int32_t padBeforeA[],
  const int32_t padAfterA[],
  const uint32_t foldA[],
  const cudnnFoldingDirection_t direction);
```

**Parameters**

**transformDesc**

*Output*. The tensor transform descriptor to be initialized.

**nbDims**

*Input*. The dimensionality of the transform operands. Must be greater than 2. For more information, refer to Tensor Descriptor.

**destFormat**

*Input*. The desired destination format.

**padBeforeA[]**

*Input*. An array that contains the amount of padding that should be added before each dimension. Set to `NULL` for no padding.

**padAfterA[]**

*Input*. An array that contains the amount of padding that should be added after each dimension. Set to `NULL` for no padding.

**foldA[]**

*Input*. An array that contains the folding parameters for each spatial dimension (dimensions 2 and up). Set to `NULL` for no folding.

**direction**

*Input*. Selects folding or unfolding. This input has no effect when folding parameters are all <= 1. For more information, refer to `cudnnFoldingDirection_t`. 
Returns

CUDNN_STATUS_SUCCESS
The function was launched successfully.

CUDNN_STATUS_BAD_PARAM
The parameter `transformDesc` is NULL, or if `direction` is invalid, or `nbDims` is <= 2.

CUDNN_STATUS_NOT_SUPPORTED
If the dimension size requested is larger than maximum dimension size supported (meaning, one of the `nbDims` is larger than `CUDNN_DIM_MAX`), or if `destFromat` is something other than NCHW or NHWC.

3.2.98. `cudnnSoftmaxForward()`

This routine computes the softmax function.

```c
void cudnnSoftmaxForward(    cudnnHandle_t                    handle,
        cudnnSoftmaxAlgorithm_t          algorithm,
        cudnnSoftmaxMode_t               mode,
        const void                      *alpha,
        const cudnnTensorDescriptor_t    xDesc,
        const void                      *x,
        const void                      *beta,
        const cudnnTensorDescriptor_t    yDesc,
        void                            *y)
```

All tensor formats are supported for all modes and algorithms with 4 and 5D tensors. Performance is expected to be highest with NCHW fully-packed tensors. For more than 5 dimensions tensors must be packed in their spatial dimensions.

Data Types

This function supports the following data types:

- CUDNN_DATA_FLOAT
- CUDNN_DATA_DOUBLE
- CUDNN_DATA_HALF
- CUDNN_DATA_BFLOAT16
- CUDNN_DATA_INT8

Parameters

- **handle**
  - *Input*. Handle to a previously created cuDNN context.

- **algorithm**
  - *Input*. Enumerant to specify the softmax algorithm.

- **mode**
  - *Input*. Enumerant to specify the softmax mode.
**alpha, beta**

*Input*. Pointers to scaling factors (in host memory) used to blend the computation result with prior value in the output layer as follows:

\[
dstValue = \text{alpha}[0] \times \text{result} + \text{beta}[0] \times \text{priorDstValue}
\]

For more information, refer to Scaling Parameters.

**xDesc**

*Input*. Handle to the previously initialized input tensor descriptor.

**x**

*Input*. Data pointer to GPU memory associated with the tensor descriptor `xDesc`.

**yDesc**

*Input*. Handle to the previously initialized output tensor descriptor.

**y**

*Output*. Data pointer to GPU memory associated with the output tensor descriptor `yDesc`.

**Returns**

- **CUDNN_STATUS_SUCCESS**
  The function launched successfully.

- **CUDNN_STATUS_NOT_SUPPORTED**
  The function does not support the provided configuration.

- **CUDNN_STATUS_BAD_PARAM**
  At least one of the following conditions are met:
  
  - The dimensions \(n, c, h, w\) of the input tensor and output tensors differ.
  - The datatype of the input tensor and output tensors differ.
  - The parameters `algorithm` or `mode` have an invalid enumerant value.

**CUDNN_STATUS_EXECUTION_FAILED**

The function failed to launch on the GPU.

### 3.2.99. `cudnnSpatialTfGridGeneratorForward()`

This function generates a grid of coordinates in the input tensor corresponding to each pixel from the output tensor.

```c
#include <cudnn.h>

// Parameters

const cudnnSpatialTransformerDescriptor_t stDesc;
const void *theta;
void *grid;

// Call the function

status_t result = cudnnSpatialTfGridGeneratorForward(
    handle, stDesc, theta, grid);
```

Only 2D transformation is supported.

**Parameters**

- **handle**
  *Input*. Handle to a previously created cuDNN context.
stDesc

*Input.* Previously created spatial transformer descriptor object.

theta

*Input.* Affine transformation matrix. It should be of size $n \times 2 \times 3$ for a 2d transformation, where $n$ is the number of images specified in stDesc.

grid

*Output.* A grid of coordinates. It is of size $n \times h \times w \times 2$ for a 2d transformation, where $n$, $h$, $w$ is specified in stDesc. In the 4th dimension, the first coordinate is $x$, and the second coordinate is $y$.

**Returns**

**CUDNN_STATUS_SUCCESS**

The call was successful.

**CUDNN_STATUS_BAD_PARAM**

At least one of the following conditions are met:

- handle is NULL.
- One of the parameters grid or theta is NULL.

**CUDNN_STATUS_NOT_SUPPORTED**

The function does not support the provided configuration. Refer to the following examples of non-supported configurations:

- The dimension of the transformed tensor specified in stDesc > 4.

**CUDNN_STATUS_EXECUTION_FAILED**

The function failed to launch on the GPU.

### 3.2.100. cudnnSpatialTfSamplerForward()

This function performs a sampler operation and generates the output tensor using the grid given by the grid generator.

```
cudnnStatus_t cudnnSpatialTfSamplerForward(
    cudnnHandle_t                              handle,
    const cudnnSpatialTransformerDescriptor_t  stDesc,
    const void                                *alpha,
    const cudnnTensorDescriptor_t              xDesc,
    const void                                *x,
    const void                                *grid,
    const void                                *beta,
    cudnnTensorDescriptor_t                    yDesc,
    void                                      *y)
```

Only 2D transformation is supported.

**Parameters**

**handle**

*Input.* Handle to a previously created cuDNN context.
stDesc

*Input*. Previously created spatial transformer descriptor object.

alpha, beta

*Input*. Pointers to scaling factors (in host memory) used to blend the source value with prior value in the destination tensor as follows:
\[
dstValue = alpha[0] \times srcValue + beta[0] \times priorDstValue
\]
For more information, refer to [Scaling Parameters](#).

xDesc

*Input*. Handle to the previously initialized input tensor descriptor.

x

*Input*. Data pointer to GPU memory associated with the tensor descriptor xDesc.

grid

*Input*. A grid of coordinates generated by `cudnnSpatialTfGridGeneratorForward()`.

yDesc

*Input*. Handle to the previously initialized output tensor descriptor.

y

*Output*. Data pointer to GPU memory associated with the output tensor descriptor yDesc.

Returns

**CUDNN_STATUS_SUCCESS**

The call was successful.

**CUDNN_STATUS_BAD_PARAM**

At least one of the following conditions are met:

- handle is NULL.
- One of the parameters x, y or grid is NULL.

**CUDNN_STATUS_NOT_SUPPORTED**

The function does not support the provided configuration. Refer to the following examples of non-supported configurations:

- The dimension of transformed tensor > 4.

**CUDNN_STATUS_EXECUTION_FAILED**

The function failed to launch on the GPU.

3.2.101. cudnnTransformFilter()

This function converts the filter between different formats, data types, or dimensions based on the described transformation. It can be used to convert a filter with an unsupported layout format to a filter with a supported layout format.

```c

cudnnStatus_t cudnnTransformFilter(  
    cudnnHandle_t handle,  
    const cudnnTensorTransformDescriptor_t transDesc,  
    const void *alpha,  

```
This function copies the scaled data from the input filter `srcDesc` to the output tensor `destDesc` with a different layout. If the filter descriptors of `srcDesc` and `destDesc` have different dimensions, they must be consistent with folding and padding amount and order specified in `transDesc`.

The `srcDesc` and `destDesc` tensors must not overlap in any way (that is, tensors cannot be transformed in place).

```
const cudnnFilterDescriptor_t srcDesc,
const void *srcData,
const void *beta,
const cudnnFilterDescriptor_t destDesc,
void *destData);
```

**Parameters**

**handle**

*Input*. Handle to a previously created cuDNN context. For more information, refer to `cudnnHandle_t`.

**transDesc**

*Input*. A descriptor containing the details of the requested filter transformation. For more information, refer to `cudnnTensorTransformDescriptor_t`.

**alpha, beta**

*Input*. Pointers, in the host memory, to the scaling factors used to scale the data in the input tensor `srcDesc`. `beta` is used to scale the destination tensor, while `alpha` is used to scale the source tensor. For more information, refer to **Scaling Parameters**.

The beta scaling value is not honored in the folding and zero-padding cases. Unfolding supports any `(alpha, beta)`.

**srcDesc, destDesc**

*Input*. Handles to the previously initiated filter descriptors. `srcDesc` and `destDesc` must not overlap. For more information, refer to `cudnnTensorDescriptor_t`.

**srcData**

*Input*. Pointers, in the host memory, to the data of the tensor described by `srcDesc`.

**destData**

*Output*. Pointers, in the host memory, to the data of the tensor described by `destDesc`.

**Returns**

**CUDNN_STATUS_SUCCESS**

The function launched successfully.

**CUDNN_STATUS_BAD_PARAM**

A parameter is uninitialized or initialized incorrectly, or the number of dimensions is different between `srcDesc` and `destDesc`.  

Note: When performing a folding transform or a zero-padding transform, the scaling factors `(alpha, beta)` should be set to (1, 0). However, unfolding transforms support any `(alpha, beta)` values. This function is thread safe.
**CUDNN_STATUS_NOT_SUPPORTED**

The function does not support the provided configuration. Also, in the folding and padding paths, any value other than A=1 and B=0 will result in a **CUDNN_STATUS_NOT_SUPPORTED**.

**CUDNN_STATUS_EXECUTION_FAILED**

The function failed to launch on the GPU.

### 3.2.102. *cudnnTransformTensor()*

This function copies the scaled data from one tensor to another tensor with a different layout. Those descriptors need to have the same dimensions but not necessarily the same strides. The input and output tensors must not overlap in any way (meaning, tensors cannot be transformed in place). This function can be used to convert a tensor with an unsupported format to a supported one.

```c
void cudnnTransformTensor(cudnnHandle_t handle,
                          const void *alpha,
                          const cudnnTensorDescriptor_t xDesc,
                          const void *x,
                          const void *beta,
                          const cudnnTensorDescriptor_t yDesc,
                          void *y)
```

**Parameters**

- **handle**
  - *Input*. Handle to a previously created cuDNN context.

- **alpha, beta**
  - *Input*. Pointers to scaling factors (in host memory) used to blend the source value with prior value in the destination tensor as follows:

    \[
    \text{dstValue} = \text{alpha}[0]\times\text{srcValue} + \text{beta}[0]\times\text{priorDstValue}
    \]

    For more information, refer to Scaling Parameters.

- **xDesc**
  - *Input*. Handle to a previously initialized tensor descriptor. For more information, refer to cudnnTensorDescriptor_t.

- **x**
  - *Input*. Pointer to data of the tensor described by the xDesc descriptor.

- **yDesc**
  - *Input*. Handle to a previously initialized tensor descriptor. For more information, refer to cudnnTensorDescriptor_t.

- **y**
  - *Output*. Pointer to data of the tensor described by the yDesc descriptor.

**Returns**

- **CUDNN_STATUS_SUCCESS**
  - The function launched successfully.
CUDNN_STATUS_NOT_SUPPORTED
The function does not support the provided configuration.

CUDNN_STATUS_BAD_PARAM
The dimensions n, c, h, w or the dataType of the two tensor descriptors are different.

CUDNN_STATUS_EXECUTION_FAILED
The function failed to launch on the GPU.

3.2.103. cudnnTransformTensorEx()
This function converts the tensor layouts between different formats. It can be used to convert a tensor with an unsupported layout format to a tensor with a supported layout format.

```c
CUDA_STATUS_t cudnnTransformTensorEx(
    cudnnHandle_t handle,
    const cudnnTensorTransformDescriptor_t transDesc,
    const void *alpha,
    const cudnnTensorDescriptor_t srcDesc,
    const void *srcData,
    const void *beta,
    const cudnnTensorDescriptor_t destDesc,
    void *destData);
```

This function copies the scaled data from the input tensor srcDesc to the output tensor destDesc with a different layout. The tensor descriptors of srcDesc and destDesc should have the same dimensions but need not have the same strides.

The srcDesc and destDesc tensors must not overlap in any way (that is, tensors cannot be transformed in place).

Note: When performing a folding transform or a zero-padding transform, the scaling factors (alpha, beta) should be set to (1, 0). However, unfolding transforms support any (alpha, beta) values. This function is thread safe.

Parameters

handle
Input. Handle to a previously created cuDNN context. For more information, refer to cudnnHandle_t.

transDesc
Input. A descriptor containing the details of the requested tensor transformation. For more information, refer to cudnnTensorTransformDescriptor_t.

alpha, beta
Input. Pointers, in the host memory, to the scaling factors used to scale the data in the input tensor srcDesc. beta is used to scale the destination tensor, while alpha is used to scale the source tensor. For more information, refer to Scaling Parameters.

The beta scaling value is not honored in the folding and zero-padding cases. Unfolding supports any (alpha, beta).
srcDesc, destDesc

*Input.* Handles to the previously initiated tensor descriptors. srcDesc and destDesc must not overlap. For more information, refer to cudnnTensorDescriptor_t.

srcData

*Input.* Pointers, in the host memory, to the data of the tensor described by srcDesc.

destData

*Output.* Pointers, in the host memory, to the data of the tensor described by destDesc.

**Returns**

**CUDNN_STATUS_SUCCESS**

The function was launched successfully.

**CUDNN_STATUS_BAD_PARAM**

A parameter is uninitialized or initialized incorrectly, or the number of dimensions is different between srcDesc and destDesc.

**CUDNN_STATUS_NOT_SUPPORTED**

Function does not support the provided configuration. Also, in the folding and padding paths, any value other than A=1 and B=0 will result in a CUDNN_STATUS_NOT_SUPPORTED.

**CUDNN_STATUS_EXECUTION_FAILED**

Function failed to launch on the GPU.
Chapter 4.  
cudnn_ops_train.so Library

This entity contains common training routines and algorithms, such as batch normalization, softmax, dropout, and so on. The cudnn_ops_train library depends on cudnn_ops_infer.

4.1.  API Functions

These are the API functions in the cudnn_ops_train.so library.

4.1.1.  cudnnActivationBackward()

This routine computes the gradient of a neuron activation function.

```c
    cudnnStatus_t cudnnActivationBackward(
        cudnnHandle_t                    handle,
        cudnnActivationDescriptor_t      activationDesc,
        const void                      *alpha,
        const cudnnTensorDescriptor_t    yDesc,       
        const void                      *y,
        const cudnnTensorDescriptor_t    dyDesc,      
        const void                      *dy,
        const cudnnTensorDescriptor_t    xDesc,       
        const void                      *x,
        const void                      *beta,
        const cudnnTensorDescriptor_t    dxDesc,      
        void                            *dx)
```

In-place operation is allowed for this routine; meaning dy and dx pointers may be equal. However, this requires the corresponding tensor descriptors to be identical (particularly, the strides of the input and output must match for an in-place operation to be allowed).

All tensor formats are supported for 4 and 5 dimensions, however, the best performance is obtained when the strides of yDesc and xDesc are equal and HW-packed. For more than 5 dimensions the tensors must have their spatial dimensions packed.

Parameters

- **handle**
  
  *Input*. Handle to a previously created cuDNN context. For more information, refer to cudnnHandle_t.
activationDesc

*Input.* Activation descriptor. For more information, refer to `cudnnActivationDescriptor_t`.

\[ \text{alpha, beta} \]

*Input.* Pointers to scaling factors (in host memory) used to blend the computation result with prior value in the output layer as follows:

\[ \text{dstValue} = \text{alpha}[0]*result + \text{beta}[0]*\text{priorDstValue} \]

For more information, refer to Scaling Parameters.

\[ \text{yDesc} \]

*Input.* Handle to the previously initialized input tensor descriptor. For more information, refer to `cudnnTensorDescriptor_t`.

\[ \text{y} \]

*Input.* Data pointer to GPU memory associated with the tensor descriptor `yDesc`.

\[ \text{dyDesc} \]

*Input.* Handle to the previously initialized input differential tensor descriptor.

\[ \text{dy} \]

*Input.* Data pointer to GPU memory associated with the tensor descriptor `dyDesc`.

\[ \text{xDesc} \]

*Input.* Handle to the previously initialized output tensor descriptor.

\[ \text{x} \]

*Input.* Data pointer to GPU memory associated with the output tensor descriptor `xDesc`.

\[ \text{dxDesc} \]

*Input.* Handle to the previously initialized output differential tensor descriptor.

\[ \text{dx} \]

*Output.* Data pointer to GPU memory associated with the output tensor descriptor `dxDesc`.

**Returns**

**CUDNN_STATUS_SUCCESS**

The function launched successfully.

**CUDNN_STATUS_BAD_PARAM**

At least one of the following conditions are met:

- The strides `nStride`, `cStride`, `hStride` and `wStride` of the input differential tensor and output differential tensor differ and in-place operation is used.

**CUDNN_STATUS_NOT_SUPPORTED**

The function does not support the provided configuration. Refer to the following examples of non-supported configurations:

- The dimensions `n`, `c`, `h`, and `w` of the input tensor and output tensor differ.
- The datatype of the input tensor and output tensor differs.
- The strides \( n\text{Stride}, c\text{Stride}, h\text{Stride}, \) and \( w\text{Stride} \) of the input tensor and the input differential tensor differ.
- The strides \( n\text{Stride}, c\text{Stride}, h\text{Stride}, \) and \( w\text{Stride} \) of the output tensor and the output differential tensor differ.

**CUDNN\_STATUS\_EXECUTION\_FAILED**

The function failed to launch on the GPU.

### 4.1.2. `cudnnBatchNormalizationBackward()`

This function performs the backward batch normalization layer computation. This layer is based on the *Batch Normalization: Accelerating Deep Network Training by Reducing Internal Covariate Shift* paper.

```c
inline cudnnStatus_t cudnnBatchNormalizationBackward(
    cudnnHandle_t                    handle,
    cudnnBatchNormMode_t             mode,
    const void                      *alphaDataDiff,
    const void                      *betaDataDiff,
    const void                      *alphaParamDiff,
    const void                      *betaParamDiff,
    const cudnnTensorDescriptor_t    xDesc,    
    const void                      *x,
    const cudnnTensorDescriptor_t    dyDesc,   
    const void                      *dy,
    const cudnnTensorDescriptor_t    dxDesc,   
    void                            *dx,
    const cudnnTensorDescriptor_t    bnScaleBiasDiffDesc, 
    const void                      *bnScale,   
    void                            *resultBnScaleDiff, 
    void                            *resultBnBiasDiff, 
    double                          epsilon,   
    const void                      *savedMean, 
    const void                      *savedInvVariance)
```

Only 4D and 5D tensors are supported.

The \( \epsilon \) value has to be the same during training, backpropagation, and inference.

Higher performance can be obtained when HW-packed tensors are used for all of \( x, dy, \) and \( dx \).

For more information, refer to `cudnnDeriveBNTensorDescriptor()` for the secondary tensor descriptor generation for the parameters used in this function.

**Parameters**

- **handle**
  
  *Input*. Handle to a previously created cuDNN library descriptor. For more information, refer to `cudnnHandle_t`.

- **mode**
  
  *Input*. Mode of operation (spatial or per-activation). For more information, refer to `cudnnBatchNormMode_t`.
*alphaDataDiff, *betaDataDiff

*Inputs.* Pointers to scaling factors (in host memory) used to blend the gradient output \( dx \) with a prior value in the destination tensor as follows:

\[
dstValue = \text{alphaDataDiff}[0] \times \text{resultValue} + \text{betaDataDiff}[0] \times \text{priorDstValue}
\]

For more information, refer to [Scaling Parameters](#).

*alphaParamDiff, *betaParamDiff

*Inputs.* Pointers to scaling factors (in host memory) used to blend the gradient outputs \( \text{resultBnScaleDiff} \) and \( \text{resultBnBiasDiff} \) with prior values in the destination tensor as follows:

\[
dstValue = \text{alphaParamDiff}[0] \times \text{resultValue} + \text{betaParamDiff}[0] \times \text{priorDstValue}
\]

For more information, refer to [Scaling Parameters](#).

\( x\text{Desc}, dx\text{Desc}, dy\text{Desc} \)

*Inputs.* Handles to the previously initialized tensor descriptors.

*\( x \)

*Inputs.* Data pointer to GPU memory associated with the tensor descriptor \( x\text{Desc} \), for the layer’s \( x \) data.

*\( dy \)

*Inputs.* Data pointer to GPU memory associated with the tensor descriptor \( dy\text{Desc} \), for the backpropagated differential \( dy \) input.

*\( dx \)

*Inputs/Outputs.* Data pointer to GPU memory associated with the tensor descriptor \( dx\text{Desc} \), for the resulting differential output with respect to \( x \).

\( \text{bnScaleBiasDiffDesc} \)

*Input.* Shared tensor descriptor for the following five tensors: \( \text{bnScale} \), \( \text{resultBnScaleDiff} \), \( \text{resultBnBiasDiff} \), \( \text{savedMean} \), and \( \text{savedInvVariance} \). The dimensions for this tensor descriptor are dependent on normalization mode. For more information, refer to [cudnnDeriveBNTensorDescriptor()](#).

**Note:** The data type of this tensor descriptor must be float for FP16 and FP32 input tensors, and double for FP64 input tensors.

\( \text{bnScale} \)

*Input.* Pointer in the device memory for the batch normalization scale parameter (in the original paper the quantity scale is referred to as gamma).

**Note:** The bnBias parameter is not needed for this layer's computation.

\( \text{resultBnScaleDiff}, \text{resultBnBiasDiff} \)

*Outputs.* Pointers in device memory for the resulting scale and bias differentials computed by this routine. Note that these scale and bias gradients are weight gradients specific to this batch normalization operation, and by definition are not backpropagated.
**epsilon**

*Input*. Epsilon value used in batch normalization formula. Its value should be equal to or greater than the value defined for `CUDNN_BN_MIN_EPSILON` in `cudnn.h`. The same epsilon value should be used in forward and backward functions.

**savedMean, *savedInvVariance**

*Inputs*. Optional cache parameters containing saved intermediate results that were computed during the forward pass. For this to work correctly, the layer’s `x` and `bnScale` data have to remain unchanged until this backward function is called.

**Note**: Both these parameters can be `NULL` but only at the same time. It is recommended to use this cache since the memory overhead is relatively small.

**Supported configurations**

This function supports the following combinations of data types for various descriptors.

<table>
<thead>
<tr>
<th>Data Type Configurations</th>
<th>xDesc</th>
<th>bnScaleBiasMean</th>
<th>alpha, beta</th>
<th>yDesc</th>
</tr>
</thead>
<tbody>
<tr>
<td>PSEUDO_HALF_CONFIG</td>
<td>CUDNN_DATA_HALF</td>
<td>CUDNN_DATA_FLOAT</td>
<td>CUDNN_DATA_FLOAT</td>
<td>CUDNN_DATA_HALF</td>
</tr>
<tr>
<td>FLOAT_CONFIG</td>
<td>CUDNN_DATA_FLOAT</td>
<td>CUDNN_DATA_FLOAT</td>
<td>CUDNN_DATA_FLOAT</td>
<td>CUDNN_DATA_FLOAT</td>
</tr>
<tr>
<td>DOUBLE_CONFIG</td>
<td>CUDNN_DATA_DOUBLE</td>
<td>CUDNN_DATA_DOUBLE</td>
<td>CUDNN_DATA_DOUBLE</td>
<td>CUDNN_DATA_DOUBLE</td>
</tr>
<tr>
<td>PSEUDO_BFLOAT16</td>
<td>CUDNN_DATA_BFLOAT16</td>
<td>CUDNN_DATA_FLOAT</td>
<td>CUDNN_DATA_FLOAT</td>
<td>CUDNN_DATA_BFLOAT16</td>
</tr>
</tbody>
</table>

**Returns**

**CUDNN_STATUS_SUCCESS**

The computation was performed successfully.

**CUDNN_STATUS_NOT_SUPPORTED**

The function does not support the provided configuration.

**CUDNN_STATUS_BAD_PARAM**

At least one of the following conditions are met:

- Any of the pointers `alpha, beta, x, dy, dx, bnScale, resultBnScaleDiff, and resultBnBiasDiff` is `NULL`.
- The number of `xDesc, yDesc` or `dxDesc` tensor descriptor dimensions is not within the range of `[4, 5]` (only 4D and 5D tensors are supported).
- `bnScaleBiasDiffDesc` dimensions are not `1xCx1x1` for 4D and `1xCx1x1x1` for 5D for spatial, and are not `1xCxHxW` for 4D and `1xCxDxHxW` for 5D for per-activation mode.
4.1.3. cudnnBatchNormalizationBackwardEx()

This function is an extension of the cudnnBatchNormalizationBackward() for performing the backward batch normalization layer computation with a fast NHWC semi-persistent kernel.

```c
void cudnnBatchNormalizationBackwardEx (
    cudnnHandle_t       handle,               
    cudnnBatchNormMode_t mode,                
    cudnnBatchNormOps_t bnOps,                
    const void          *alphaDataDiff,      
    const void          *betaDataDiff,       
    const void          *alphaParamDiff,     
    const void          *betaParamDiff,      
    const cudnnTensorDescriptor_t xDesc,      
    const void          *xData,              
    const cudnnTensorDescriptor_t yDesc,      
    const void          *yData,              
    const cudnnTensorDescriptor_t dyDesc,     
    const void          *dyData,             
    const cudnnTensorDescriptor_t dzDesc,     
    void                 *dzData,             
    const cudnnTensorDescriptor_t dxDesc,     
    void                 *dxData,             
    const cudnnTensorDescriptor_t dBnScaleBiasDesc,  
    void                 *dBnScaleData, 
    const void          *bnBiasData,         
    void                 *dBnBiasData, 
    double               epsilon,             
    const void          *savedMean,          
    const void          *savedInvVariance,    
    const cudnnActivationDescriptor_t activationDesc,  
    void                 *workspace,        
    size_t               workSpaceSizeInBytes 
    void                 *reserveSpace,      
    size_t               reserveSpaceSizeInBytes); 
```

This API will trigger the new semi-persistent NHWC kernel when the following conditions are true:

- Exactly one of savedMean, savedInvVariance pointers is NULL.
- epsilon value is less than CUDNN_BN_MIN_EPSILON.
- Dimensions or data types mismatch for any pair of xDesc, dyDesc, and dxDesc.

- All tensors, namely, x, y, dz, dy and dx must be NHWC-fully packed, and must be of the type CUDNN_DATA_HALF.
- The input parameter mode must be set to CUDNN_BATCHNORM_SPATIAL_PERSISTENT.
- workspace is not NULL.
- Before cuDNN version 8.2.0, the tensor C dimension should always be a multiple of 4. After 8.2.0, the tensor C dimension should be a multiple of 4 only when bnOps is CUDNN_BATCHNORM_OPS_BN_ADD_ACTIVATION.
- workSpaceSizeInBytes is equal to or larger than the amount required by cudnnGetBatchNormalizationBackwardExWorkspaceSize().
- reserveSpaceSizeInBytes is equal to or larger than the amount required by cudnnGetBatchNormalizationTrainingExReserveSpaceSize().
The content in reserveSpace stored by cudnnBatchNormalizationForwardTrainingEx() must be preserved.

If workspace is NULL and workSpaceSizeInBytes of zero is passed in, this API will function exactly like the non-extended function cudnnBatchNormalizationBackward.

This workspace is not required to be clean. Moreover, the workspace does not have to remain unchanged between the forward and backward pass, as it is not used for passing any information.

This extended function can accept a workspace pointer to the GPU workspace, and workSpaceSizeInBytes, the size of the workspace, from the user.

The bnOps input can be used to set this function to perform either only the batch normalization, or batch normalization followed by activation, or batch normalization followed by element-wise addition and then activation.

Only 4D and 5D tensors are supported. The epsilon value has to be the same during the training, the backpropagation, and the inference.

When the tensor layout is NCHW, higher performance can be obtained when HW-packed tensors are used for x, dy, and dx.

**Parameters**

handle
- *Input*. Handle to a previously created cuDNN library descriptor. For more information, refer to cudnnHandle_t.

mode
- *Input*. Mode of operation (spatial or per-activation). For more information, refer to cudnnBatchNormMode_t.

bnOps
- *Input*. Mode of operation. Currently, CUDNN_BATCHNORM_OPS_BN_ACTIVATION and CUDNN_BATCHNORM_OPS_BN_ADD_ACTIVATION are only supported in the NHWC layout. For more information, refer to cudnnBatchNormOps_t. This input can be used to set this function to perform either only the batch normalization, or batch normalization followed by activation, or batch normalization followed by element-wise addition and then activation.

*alphaDataDiff, *betaDataDiff
- *Inputs*. Pointers to scaling factors (in host memory) used to blend the gradient output dx with a prior value in the destination tensor as follows:
  \[ \text{dstValue} = \alpha[0] \times \text{resultValue} + \beta[0] \times \text{priorDstValue} \]

  For more information, refer to Scaling Parameters.

*alphaParamDiff, *betaParamDiff
- *Inputs*. Pointers to scaling factors (in host memory) used to blend the gradient outputs dBnScaleData and dBnBiasData with prior values in the destination tensor as follows:
  \[ \text{dstValue} = \alpha[0] \times \text{resultValue} + \beta[0] \times \text{priorDstValue} \]

  For more information, refer to Scaling Parameters.
**Inputs.** Tensor descriptors and pointers in the device memory for the layer's \( x \) data, backpropagated gradient input \( dy \), the original forward output \( y \) data. \( y\text{Desc} \) and \( y\text{Data} \) are not needed if \( \text{bnOps} \) is set to \text{CUDNN\_BATCHNORM\_OPS\_BN}, users may pass \text{NULL}. For more information, refer to \text{cudnnTensorDescriptor\_t}. 

**Outputs.** Tensor descriptors and pointers in the device memory for the computed gradient output \( dz \), and \( dx \). \( dz\text{Desc} \) is not needed when \( \text{bnOps} \) is \text{CUDNN\_BATCHNORM\_OPS\_BN} or \text{CUDNN\_BATCHNORM\_OPS\_BN\_ACTIVATION}, users may pass \text{NULL}. For more information, refer to \text{cudnnTensorDescriptor\_t}. 

**d\text{BnScaleBiasDesc}**

\text{Input.} Shared tensor descriptor for the following six tensors: \text{bnScaleData}, \text{bnBiasData}, \text{dBnScaleData}, \text{dBnBiasData}, \text{savedMean}, and \text{savedInvVariance}. For more information, refer to \text{cudnnDeriveBNTensorDescriptor()}. 

The dimensions for this tensor descriptor are dependent on normalization mode.

---

**Note:** The data type of this tensor descriptor must be \text{float} for FP16 and FP32 input tensors and \text{double} for FP64 input tensors.

For more information, refer to \text{cudnnTensorDescriptor\_t}.

**\text{bnScaleData}**

\text{Input.} Pointer in the device memory for the batch normalization scale parameter (in the \text{Batch Normalization: Accelerating Deep Network Training by Reducing Internal Covariate Shift} paper, the quantity scale is referred to as gamma).

**\text{bnBiasData}**

\text{Input.} Pointers in the device memory for the batch normalization bias parameter (in the \text{Batch Normalization: Accelerating Deep Network Training by Reducing Internal Covariate Shift} paper, bias is referred to as beta). This parameter is used only when activation should be performed.

**\text{dBnScaleData, dBnBiasData}**

\text{Outputs.} Pointers in the device memory for the gradients of \text{bnScaleData} and \text{bnBiasData}, respectively.

**\epsilon**

\text{Input.} Epsilon value used in batch normalization formula. Its value should be equal to or greater than the value defined for \text{CUDNN\_BN\_MIN\_EPSILON} in \text{cudn.h}. The same epsilon value should be used in forward and backward functions.
*savedMean, *savedInvVariance

*Inputs. Optional cache parameters containing saved intermediate results computed during the forward pass. For this to work correctly, the layer’s x and bnScaleData, bnBiasData data has to remain unchanged until this backward function is called. Note that both these parameters can be NULL but only at the same time. It is recommended to use this cache since the memory overhead is relatively small.

activationDesc

*Input. Descriptor for the activation operation. When the bnOps input is set to either CUDNN_BATCHNORM_OPS_BN_ACTIVATION or CUDNN_BATCHNORM_OPS_BN_ADD_ACTIVATION then this activation is used, otherwise the user may pass NULL.

workspace

*Input. Pointer to the GPU workspace. If workspace is NULL and workSpaceSizeInBytes of zero is passed in, then this API will function exactly like the non-extended function cudnnBatchNormalizationBackward().

workSpaceSizeInBytes

*Input. The size of the workspace. It must be large enough to trigger the fast NHWC semi-persistent kernel by this function.

*reserveSpace

*Input. Pointer to the GPU workspace for the reserveSpace.

reserveSpaceSizeInBytes

*Input. The size of the reserveSpace. It must be equal or larger than the amount required by cudnnGetBatchNormalizationTrainingExReserveSpaceSize().

Supported configurations

This function supports the following combinations of data types for various descriptors.

Table 15. Supported Configurations for cudnnBatchNormalizationBackwardEx()

<table>
<thead>
<tr>
<th>Data Type Configurations</th>
<th>xDesc</th>
<th>bnScaleBiasMeanVarDesc</th>
<th>alpha, beta</th>
<th>yDesc</th>
</tr>
</thead>
<tbody>
<tr>
<td>PSEUDO_HALF_CONFIG</td>
<td>CUDNN_DATA_HALF</td>
<td>CUDNN_DATA_FLOAT</td>
<td>CUDNN_DATA_FLOAT</td>
<td>CUDNN_DATA_HALF</td>
</tr>
<tr>
<td>FLOAT_CONFIG</td>
<td>CUDNN_DATA_FLOAT</td>
<td>CUDNN_DATA_FLOAT</td>
<td>CUDNN_DATA_FLOAT</td>
<td>CUDNN_DATA_FLOAT</td>
</tr>
<tr>
<td>DOUBLE_CONFIG</td>
<td>CUDNN_DATA_DOUBLE</td>
<td>CUDNN_DATA_DOUBLE</td>
<td>CUDNN_DATA_DOUBLE</td>
<td>CUDNN_DATA_DOUBLE</td>
</tr>
<tr>
<td>PSEUDO_BFLOAT16_CONFIG</td>
<td>CUDNN_DATA_BFLOAT16</td>
<td>CUDNN_DATA_FLOAT</td>
<td>CUDNN_DATA_FLOAT</td>
<td>CUDNN_DATA_BFLOAT16</td>
</tr>
</tbody>
</table>

Returns

CUDNN_STATUS_SUCCESS

The computation was performed successfully.

CUDNN_STATUS_NOT_SUPPORTED

The function does not support the provided configuration.
**CUDNN_STATUS_BAD_PARAM**

At least one of the following conditions are met:

- Any of the pointers `alphaDataDiff, betaDataDiff, alphaParamDiff, betaParamDiff, x, dy, dx, bnScale, resultBnScaleDiff, and resultBnBiasDiff` is NULL.
- The number of `xDesc, yDesc, or dxDesc` tensor descriptor dimensions is not within the range of `[4, 5]` (only 4D and 5D tensors are supported).
- `dBnScaleBiasDesc` dimensions not `1xCx1x1` for 4D and `1xCx1x1x1` for 5D for spatial, and are not `1xCxHxW` for 4D and `1xCxDxHxW` for 5D for per-activation mode.
- Exactly one of `savedMean, savedInvVariance` pointers is NULL.
- `epsilon` value is less than `CUDNN_BN_MIN_EPSILON`.
- Dimensions or data types mismatch for any pair of `xDesc, dyDesc, or dxDesc`.

### 4.1.4. `cudnnBatchNormalizationForwardTraining()`

This function performs the forward batch normalization layer computation for the training phase. This layer is based on the Batch Normalization: Accelerating Deep Network Training by Reducing Internal Covariate Shift paper.

```c
#include <cuda_runtime.h>
#include <cudnn.h>

int cudnnStatus_t cudnnBatchNormalizationForwardTraining(
    cudnnHandle_t                    handle,
    cudnnBatchNormMode_t             mode,
    const void                      *alpha,
    const void                      *beta,
    const cudnnTensorDescriptor_t    xDesc,
    const void                      *x,
    const cudnnTensorDescriptor_t    yDesc,
    void                            *y,
    const cudnnTensorDescriptor_t    bnScaleBiasMeanVarDesc,
    const void                      *bnScale,
    const void                      *bnBias,
    double                           exponentialAverageFactor,
    void                            *resultRunningMean,
    void                            *resultRunningVariance,
    double                           epsilon,
    void                            *resultSaveMean,
    void                            *resultSaveInvVariance)
```

Only 4D and 5D tensors are supported.

The `epsilon` value has to be the same during training, backpropagation, and inference.

For the inference phase, use `cudnnBatchNormalizationForwardInference`.

Higher performance can be obtained when HW-packed tensors are used for both `x` and `y`.

Refer to `cudnnDeriveBNTensorDescriptor()` for the secondary tensor descriptor generation for the parameters used in this function.
Parameters

**handle**
Handle to a previously created cuDNN library descriptor. For more information, refer to `cudnnHandle_t`.

**mode**
Mode of operation (spatial or per-activation). For more information, refer to `cudnnBatchNormMode_t`.

**alpha, beta**
*Inputs.* Pointers to scaling factors (in host memory) used to blend the layer output value with prior value in the destination tensor as follows:

\[
dstValue = alpha[0] \times \text{resultValue} + beta[0] \times \text{priorDstValue}
\]

For more information, refer to Scaling Parameters.

**xDesc, yDesc**
Tensor descriptors and pointers in device memory for the layer’s x and y data. For more information, refer to `cudnnTensorDescriptor_t`.

*x*
*Input.* Data pointer to GPU memory associated with the tensor descriptor xDesc, for the layer’s x input data.

*y*
*Input.* Data pointer to GPU memory associated with the tensor descriptor yDesc, for the y output of the batch normalization layer.

**bnScaleBiasMeanVarDesc**
Shared tensor descriptor desc for the secondary tensor that was derived by `cudnnDeriveBNTensorDescriptor()`. The dimensions for this tensor descriptor are dependent on the normalization mode.

**bnScale, bnBias**
*Inputs.* Pointers in device memory for the batch normalization scale and bias parameters (in the Batch Normalization: Accelerating Deep Network Training by Reducing Internal Covariate Shift paper, bias is referred to as beta and scale as gamma). Note that bnBias parameter can replace the previous layer’s bias parameter for improved efficiency.

**exponentialAverageFactor**
*Input.* Factor used in the moving average computation as follows:

\[
\text{runningMean} = \text{runningMean} \times (1 - \text{factor}) + \text{newMean} \times \text{factor}
\]

Use a factor=$1/(1+n)$ at N-th call to the function to get the Cumulative Moving Average (CMA) behavior, for example:

\[
\text{CMA}[n] = (x[1]+...+x[n])/n
\]

For example:

\[
\begin{align*}
\text{CMA}[n+1] &= (n \times \text{CMA}[n] + x[n+1])/(n+1) \\
&= ((n+1) \times \text{CMA}[n] - \text{CMA}[n])/(n+1) + x[n+1]/(n+1) \\
&= \text{CMA}[n] \times (1 - 1/(n+1)) + x[n+1]*1/(n+1) \\
&= \text{CMA}[n] \times (1 - \text{factor}) + x(n+1)*\text{factor}
\end{align*}
\]
resultRunningMean, resultRunningVariance

**Inputs/Outputs.** Running mean and variance tensors (these have the same descriptor as the bias and scale). Both of these pointers can be NULL but only at the same time. The value stored in resultRunningVariance (or passed as an input in inference mode) is the sample variance and is the moving average of variance[x] where the variance is computed either over batch or spatial+batch dimensions depending on the mode. If these pointers are not NULL, the tensors should be initialized to some reasonable values or to 0.

epsilon

**Input.** Epsilon value used in the batch normalization formula. Its value should be equal to or greater than the value defined for CUDNN_BN_MIN_EPSILON in cudnn.h. The same epsilon value should be used in forward and backward functions.

resultSaveMean, resultSaveInvVariance

**Outputs.** Optional cache to save intermediate results computed during the forward pass. These buffers can be used to speed up the backward pass when supplied to the cudnnBatchNormalizationBackward() function. The intermediate results stored in resultSaveMean and resultSaveInvVariance buffers should not be used directly by the user. Depending on the batch normalization mode, the results stored in resultSaveInvVariance may vary. For the cache to work correctly, the input layer data must remain unchanged until the backward function is called. Note that both parameters can be NULL but only at the same time. In such a case, intermediate statistics will not be saved, and cudnnBatchNormalizationBackward() will have to re-compute them. It is recommended to use this cache as the memory overhead is relatively small because these tensors have a much lower product of dimensions than the data tensors.

**Supported configurations**

This function supports the following combinations of data types for various descriptors.

**Table 16. Supported Configurations for cudnnBatchNormalizationForwardTraining()**

<table>
<thead>
<tr>
<th>Data Type Configurations</th>
<th>xDesc</th>
<th>bnScaleBiasMean</th>
<th>alpha, beta</th>
<th>yDesc</th>
</tr>
</thead>
<tbody>
<tr>
<td>PSEUDO_HALF_CONFIG</td>
<td>CUDNN_DATA_HALF</td>
<td>CUDNN_DATA_FLOAT</td>
<td>CUDNN_DATA_FLOAT</td>
<td>CUDNN_DATA_HALF</td>
</tr>
<tr>
<td>FLOAT_CONFIG</td>
<td>CUDNN_DATA_FLOAT</td>
<td>CUDNN_DATA_FLOAT</td>
<td>CUDNN_DATA_FLOAT</td>
<td>CUDNN_DATA_FLOAT</td>
</tr>
<tr>
<td>DOUBLE_CONFIG</td>
<td>CUDNN_DATA_DOUBLE</td>
<td>CUDNN_DATA_DOUBLE</td>
<td>CUDNN_DATA_DOUBLE</td>
<td>CUDNN_DATA_DOUBLE</td>
</tr>
<tr>
<td>PSEUDO_BFLOAT16_CONFIG</td>
<td>CUDNN_DATA_BFLOAT16</td>
<td>CUDNN_DATA_FLOAT</td>
<td>CUDNN_DATA_FLOAT</td>
<td>CUDNN_DATA_BFLOAT16</td>
</tr>
</tbody>
</table>
Returns

CUDNN_STATUS_SUCCESS
The computation was performed successfully.

CUDNN_STATUS_NOT_SUPPORTED
The function does not support the provided configuration.

CUDNN_STATUS_BAD_PARAM
At least one of the following conditions are met:

- One of the pointers alpha, beta, x, y, bnScale, and bnBias is NULL.
- The number of xDesc or yDesc tensor descriptor dimensions is not within the range of [4,5] (only 4D and 5D tensors are supported).
- bnScaleBiasMeanVarDesc dimensions are not 1xCx1x1 for 4D and 1xCx1x1x1 for 5D for spatial, and are not 1xCxHxW for 4D and 1xCxDxHxW for 5D for per-activation mode.
- Exactly one of resultSaveMean, resultSaveInvVariance pointers are NULL.
- Exactly one of resultRunningMean, resultRunningInvVariance pointers are NULL.
- epsilon value is less than CUDNN_BN_MIN_EPSILON.
- Dimensions or data types mismatch for xDesc or yDesc.

4.1.5. cudnnBatchNormalizationForwardTrainingEx()

This function is an extension of the cudnnBatchNormalizationForwardTraining() for performing the forward batch normalization layer computation.

```c
void cudnnStatus_t cudnnBatchNormalizationForwardTrainingEx(
  cudnnHandle_t handle,
  cudnnBatchNormMode_t mode,
  cudnnBatchNormOps_t bnOps,
  const void *alpha,
  const void *beta,
  const cudnnTensorDescriptor_t xDesc,
  const void *xData,
  const cudnnTensorDescriptor_t zDesc,
  const void *zData,
  const cudnnTensorDescriptor_t yDesc,
  void *yData,
  const cudnnTensorDescriptor_t bnScaleBiasMeanVarDesc,
  const void *bnScaleData,
  const void *bnBiasData,
  double exponentialAverageFactor,
  void *resultRunningMeanData,
  void *resultRunningVarianceData,
  double epsilon,
  void *saveMean,
  void *saveInvVariance,
  const cudnnActivationDescriptor_t activationDesc,
  void *workspace,
  size_t workSpaceSizeInBytes
);
```

This API will trigger the new semi-persistent NHWC kernel when the following conditions are true:
- All tensors, namely, x, y, dz, dy and dx must be NHWC-fully packed and must be of the type CUDNN_DATA_HALF.
- The input parameter mode must be set to CUDNN_BATCHNORM_SPATIAL_PERSISTENT.
- workspace is not NULL.
- Before cuDNN version 8.2.0, the tensor C dimension should always be a multiple of 4. After 8.2.0, the tensor C dimension should be a multiple of 4 only when bnOps is CUDNN_BATCHNORM_OPS_BN_ADD_ACTIVATION.
- workSpaceSizeInBytes is equal to or larger than the amount required by cudnnGetBatchNormalizationForwardTrainingExWorkspaceSize().
- reserveSpaceSizeInBytes is equal to or larger than the amount required by cudnnGetBatchNormalizationTrainingExReserveSpaceSize().
- The content in reserveSpace stored by cudnnBatchNormalizationForwardTrainingEx() must be preserved.

If workspace is NULL and workSpaceSizeInBytes of zero is passed in, this API will function exactly like the non-extended function cudnnBatchNormalizationForwardTraining().

This workspace is not required to be clean. Moreover, the workspace does not have to remain unchanged between the forward and backward pass, as it is not used for passing any information.

This extended function can accept a *workspace pointer to the GPU workspace, and workSpaceSizeInBytes, the size of the workspace, from the user.

The bnOps input can be used to set this function to perform either only the batch normalization, or batch normalization followed by activation, or batch normalization followed by element-wise addition and then activation.

Only 4D and 5D tensors are supported. The epsilon value has to be the same during the training, the backpropagation, and the inference.

When the tensor layout is NCHW, higher performance can be obtained when HW-packed tensors are used for x, dy, and dx.

**Parameters**

- **handle**
  Handle to a previously created cuDNN library descriptor. For more information, refer to cudnnHandle_t.
- **mode**
  Mode of operation (spatial or per-activation). For more information, refer to cudnnBatchNormMode_t.
- **bnOps**
  Input. Mode of operation for the fast NHWC kernel. For more information, refer to cudnnBatchNormOps_t. This input can be used to set this function to perform either only the batch normalization, or batch normalization followed by activation, or batch normalization followed by element-wise addition and then activation.
*alpha, *beta

*Inputs.* Pointers to scaling factors (in host memory) used to blend the layer output value with prior value in the destination tensor as follows:

dstValue = alpha[0]*resultValue + beta[0]*priorDstValue

For more information, refer to Scaling Parameters.

**xDesc, *xData, zDesc, *zData, yDesc, *yData**

Tensor descriptors and pointers in device memory for the layer’s input \( x \) and output \( y \), and for the optional \( z \) tensor input for residual addition to the result of the batch normalization operation, prior to the activation. The optional \( z\)Des and \( *zData \) descriptors are only used when \( bnOps \) is \( CUDNN\_BATCHNORM\_OPS\_BN\_ADD\_ACTIVATION \), otherwise users may pass NULL. When in use, \( z \) should have exactly the same dimension as \( x \) and the final output \( y \). For more information, refer to \( cudnnTensorDescriptor_t \).

**bnScaleBiasMeanVarDesc**

Shared tensor descriptor \( desc \) for the secondary tensor that was derived by \( cudnnDeriveBNTensorDescriptor() \). The dimensions for this tensor descriptor are dependent on the normalization mode.

***bnScaleData, *bnBiasData**

*Inputs.* Pointers in device memory for the batch normalization scale and bias parameters (in the Batch Normalization: Accelerating Deep Network Training by Reducing Internal Covariate Shift paper, bias is referred to as beta and scale as gamma). Note that \( bnBiasData \) parameter can replace the previous layer’s bias parameter for improved efficiency.

**exponentialAverageFactor**

*Input.* Factor used in the moving average computation as follows:

\[
\text{runningMean} = \text{runningMean} \times (1 - \text{factor}) + \frac{\text{newMean} \times \text{factor}}{1}
\]

Use a \( \text{factor} = 1/(1+n) \) at \( n \)-th call to the function to get the Cumulative Moving Average (CMA) behavior, for example:

\[
\text{CMA}[n] = \frac{x[1]+...+x[n]}{n}
\]

For example:

\[
\text{CMA}[n+1] = \frac{(n \times \text{CMA}[n]+x[n+1])/(n+1)}{1+n} + x[n+1]/(n+1) = \frac{CMA[n] \times (1-1/(n+1))+x[n+1]*1/(n+1)}{1} = \text{CMA}[n] \times (1-1/(n+1))+x[n+1]*1/(n+1) = CMA[n] \times (1-1/(n+1))+x[n+1]*1/(n+1)
\]

***resultRunningMeanData, *resultRunningVarianceData**

*Inputs/Outputs.* Pointers to the running mean and running variance data. Both these pointers can be NULL but only at the same time. The value stored in \( \text{resultRunningVarianceData} \) (or passed as an input in inference mode) is the sample variance and is the moving average of \( \text{variance}[x] \) where the variance is computed either over batch or spatial+batch dimensions depending on the mode. If these pointers are not NULL, the tensors should be initialized to some reasonable values or to 0.
**epsilon**

*Input.* Epsilon value used in the batch normalization formula. Its value should be equal to or greater than the value defined for `CUDNN_BN_MIN_EPSILON` in `cudnn.h`. The same epsilon value should be used in forward and backward functions.

***saveMean, *saveInvVariance**

*Outputs.* Optional cache parameters containing saved intermediate results computed during the forward pass. For this to work correctly, the layer's `x` and `bnScaleData`, `bnBiasData` data has to remain unchanged until this backward function is called. Note that both these parameters can be `NULL` but only at the same time. It is recommended to use this cache since the memory overhead is relatively small.

**activationDesc**

*Input.* The tensor descriptor for the activation operation. When the `bnOps` input is set to either `CUDNN_BATCHNORM_OPS_BN_ACTIVATION` or `CUDNN_BATCHNORM_OPS_BN_ADD_ACTIVATION` then this activation is used, otherwise user may pass `NULL`.

**workspace, workSpaceSizeInBytes**

*Inputs.* `workspace` is a pointer to the GPU workspace, and `workSpaceSizeInBytes` is the size of the workspace. When `workspace` is not `NULL` and `workSpaceSizeInBytes` is large enough, and the tensor layout is NHWC and the data type configuration is supported, then this function will trigger a new semi-persistent NHWC kernel for batch normalization. The workspace is not required to be clean. Also, the workspace does not need to remain unchanged between the forward and backward passes.

***reserveSpace**

*Input.* Pointer to the GPU workspace for the `reserveSpace`.

**reserveSpaceSizeInBytes**

*Input.* The size of the `reserveSpace`. Must be equal or larger than the amount required by `cudnnGetBatchNormalizationTrainingExReserveSpaceSize()`.

**Supported configurations**

This function supports the following combinations of data types for various descriptors.

**Table 17. Supported Configurations for `cudnnBatchNormalizationForwardTrainingEx()`**

<table>
<thead>
<tr>
<th>Data Type Configurations</th>
<th>xDesc</th>
<th>bnScaleBiasMean</th>
<th>alpha, beta</th>
<th>yDesc</th>
</tr>
</thead>
<tbody>
<tr>
<td>PSEUDO_HALF_CONFIG</td>
<td>CUDNN_DATA_HALF</td>
<td>CUDNN_DATA_FLOAT</td>
<td>CUDNN_DATA_FLOAT</td>
<td>CUDNN_DATA_HALF</td>
</tr>
<tr>
<td>FLOAT_CONFIG</td>
<td>CUDNN_DATA_FLOAT</td>
<td>CUDNN_DATA_FLOAT</td>
<td>CUDNN_DATA_FLOAT</td>
<td>CUDNN_DATA_FLOAT</td>
</tr>
<tr>
<td>DOUBLE_CONFIG</td>
<td>CUDNN_DATA_DOUBLE</td>
<td>CUDNN_DATA_DOUBLE</td>
<td>CUDNN_DATA_DOUBLE</td>
<td>CUDNN_DATA_DOUBLE</td>
</tr>
<tr>
<td>PSEUDO_BFLOAT16_CONFIG</td>
<td>CUDNN_DATA_BFLOAT16</td>
<td>CUDNN_DATA_FLOAT</td>
<td>CUDNN_DATA_FLOAT</td>
<td>CUDNN_DATA_BFLOAT16</td>
</tr>
</tbody>
</table>
Returns

**CUDNN_STATUS_SUCCESS**
The computation was performed successfully.

**CUDNN_STATUS_NOT_SUPPORTED**
The function does not support the provided configuration.

**CUDNN_STATUS_BAD_PARAM**
At least one of the following conditions are met:

- One of the pointers $alpha$, $beta$, $x$, $y$, $bnScaleData$, and $bnBiasData$ is NULL.
- The number of $xDesc$ or $yDesc$ tensor descriptor dimensions is not within the $[4, 5]$ range (only 4D and 5D tensors are supported).
- $bnScaleBiasMeanVarDesc$ dimensions are not $1\times C \times 1 \times 1$ for 4D and $1\times C \times 1 \times 1 \times 1$ for 5D for spatial, and are not $1\times C \times H \times W$ for 4D and $1\times C \times D \times H \times W$ for 5D for per-activation mode.
- Exactly one of $saveMean$, $saveInvVariance$ pointers are NULL.
- Exactly one of $resultRunningMeanData$, $resultRunningInvVarianceData$ pointers are NULL.
- $epsilon$ value is less than $CUDNN_BN_MIN_EPSILON$.
- Dimensions or data types mismatch for $xDesc$ and $yDesc$.

4.1.6. **cudnnDivisiveNormalizationBackward()**

This function performs the backward DivisiveNormalization layer computation.

```c
int cudnnDivisiveNormalizationBackward(
    cudnnHandle_t                    handle,
    cudnnLRNDescriptor_t             normDesc,
    cudnnDivNormMode_t               mode,
    const void                      *alpha,
    const cudnnTensorDescriptor_t    xDesc,
    const void                      *x,
    const void                      *means,
    const void                      *dy,
    void                            *temp,
    void                            *temp2,
    const void                      *beta,
    const cudnnTensorDescriptor_t    dxDesc,
    void                            *dx,
    void                            *dMeans)
```

Supported tensor formats are NCHW for 4D and NCDHW for 5D with any non-overlapping non-negative strides. Only 4D and 5D tensors are supported.

Parameters

**handle**

*Input:* Handle to a previously created cuDNN library descriptor.
**normDesc**
*Input.* Handle to a previously initialized LRN parameter descriptor (this descriptor is used for both LRN and DivisiveNormalization layers).

**mode**
*Input.* DivisiveNormalization layer mode of operation. Currently only `CUDNN_DIVNORM_PRECOMPUTED_MEANS` is implemented. Normalization is performed using the means input tensor that is expected to be precomputed by the user.

**alpha, beta**
*Input.* Pointers to scaling factors (in host memory) used to blend the layer output value with prior value in the destination tensor as follows:

\[
dstValue = alpha[0]*resultValue + beta[0]*priorDstValue
\]

For more information, refer to Scaling Parameters.

**xDesc, x, means**
*Input.* Tensor descriptor and pointers in device memory for the layer’s x and means data. Note that the means tensor is expected to be precomputed by the user. It can also contain any valid values (not required to be actual means, and can be for instance a result of a convolution with a Gaussian kernel).

**dy**
*Input.* Tensor pointer in device memory for the layer’s dy cumulative loss differential data (error backpropagation).

**temp, temp2**
*Workspace.* Temporary tensors in device memory. These are used for computing intermediate values during the backward pass. These tensors do not have to be preserved from forward to backward pass. Both use xDesc as a descriptor.

**dxDesc**
*Input.* Tensor descriptor for dx and dMeans.

**dx, dMeans**
*Output.* Tensor pointers (in device memory) for the layers resulting in cumulative gradients dx and dMeans (dLoss/dx and dLoss/dMeans). Both share the same descriptor.

**Returns**

**CUDNN_STATUS_SUCCESS**
The computation was performed successfully.

**CUDNN_STATUS_BAD_PARAM**
At least one of the following conditions are met:

- One of the tensor pointers x, dx, temp, temp2, and dy is NULL.
- Number of any of the input or output tensor dimensions is not within the \([4, 5]\) range.
- Either alpha or beta pointer is NULL.
- A mismatch in dimensions between xDesc and dxDesc.
- LRN descriptor parameters are outside of their valid ranges.
- Any of the tensor strides is negative.

**CUDNN_STATUS_UNSUPPORTED**

The function does not support the provided configuration, for example, any of the input and output tensor strides mismatch (for the same dimension) is a non-supported configuration.

### 4.1.7. cudnnDropoutBackward()

This function performs backward dropout operation over \(dy\) returning results in \(dx\). If during forward dropout operation value from \(x\) was propagated to \(y\) then during backward operation value from \(dy\) will be propagated to \(dx\), otherwise, \(dx\) value will be set to 0.

```c
#include <cudnn.h>

/*
 * cudnnDropoutBackward() returns the error code.
 */
cudnnStatus_t cudnnDropoutBackward(
    cudnnHandle_t                   handle,
    const cudnnDropoutDescriptor_t  dropoutDesc,
    const cudnnTensorDescriptor_t   dyDesc,
    const void                     *dy,
    const cudnnTensorDescriptor_t   dxDesc,
    void                           *dx,
    void                           *reserveSpace,
    size_t                          reserveSpaceSizeInBytes)
```

Better performance is obtained for fully packed tensors.

**Parameters**

- **handle**
  - Input. Handle to a previously created cuDNN context.

- **dropoutDesc**
  - Input. Previously created dropout descriptor object.

- **dyDesc**
  - Input. Handle to a previously initialized tensor descriptor.

- **dy**
  - Input. Pointer to data of the tensor described by the dyDesc descriptor.

- **dxDesc**
  - Input. Handle to a previously initialized tensor descriptor.

- **dx**
  - Output. Pointer to data of the tensor described by the dxDesc descriptor.

- **reserveSpace**
  - Input. Pointer to user-allocated GPU memory used by this function. It is expected that reserveSpace was populated during a call to cudnnDropoutForward and has not been changed.

- **reserveSpaceSizeInBytes**
  - Input. Specifies the size in bytes of the provided memory for the reserve space.
Returns

**CUDNN_STATUS_SUCCESS**
The call was successful.

**CUDNN_STATUS_NOT_SUPPORTED**
The function does not support the provided configuration.

**CUDNN_STATUS_BAD_PARAM**
At least one of the following conditions are met:

- The number of elements of input tensor and output tensors differ.
- The datatype of the input tensor and output tensors differs.
- The strides of the input tensor and output tensors differ and in-place operation is used (i.e., x and y pointers are equal).
- The provided reserveSpaceSizeInBytes is less than the value returned by cudnnDropoutGetReserveSpaceSize.
- cudnnSetDropoutDescriptor has not been called on dropoutDesc with the non-NULL states argument.

**CUDNN_STATUS_EXECUTION_FAILED**
The function failed to launch on the GPU.

### 4.1.8. cudnnGetBatchNormalizationBackwardExWorkspaceSize()

This function returns the amount of GPU memory workspace the user should allocate to be able to call cudnnGetBatchNormalizationBackwardExWorkspaceSize() function for the specified bnOps input setting. The workspace allocated will then be passed to the function cudnnGetBatchNormalizationBackwardExWorkspaceSize().

```c
void cudnnStatus_t cudnnGetBatchNormalizationBackwardExWorkspaceSize(cudnnHandle_t handle, cudnnBatchNormMode_t mode, cudnnBatchNormOps_t bnOps, const cudnnTensorDescriptor_t xDesc, const cudnnTensorDescriptor_t yDesc, const cudnnTensorDescriptor_t dyDesc, const cudnnTensorDescriptor_t dzDesc, const cudnnTensorDescriptor_t dxDesc, const cudnnTensorDescriptor_t dBnScaleBiasDesc, const cudnnActivationDescriptor_t activationDesc, size_t *sizeInBytes);
```

**Parameters**

- **handle**
  *Input.* Handle to a previously created cuDNN library descriptor. For more information, refer to [cudnnHandle_t](#).

- **mode**
  *Input.* Mode of operation (spatial or per-activation). For more information, refer to [cudnnBatchNormMode_t](#).
bnOps

Input. Mode of operation for the fast NHWC kernel. For more information, refer to `cudnnBatchNormOps_t`. This input can be used to set this function to perform either only the batch normalization, or batch normalization followed by activation, or batch normalization followed by element-wise addition and then activation.

xDesc, yDesc, dyDesc, dzDesc, dxDesc

Tensor descriptors and pointers in the device memory for the layer’s x data, back propagated differential dy (inputs), the optional y input data, the optional dz output, and the dx output, which is the resulting differential with respect to x. For more information, refer to `cudnnTensorDescriptor_t`.

dBnScaleBiasDesc

Input. Shared tensor descriptor for the following six tensors: bnScaleData, bnBiasData, dBnScaleData, dBnBiasData, savedMean, and savedInvVariance. This is the shared tensor descriptor desc for the secondary tensor that was derived by `cudnnDeriveBNTensorDescriptor()`. The dimensions for this tensor descriptor are dependent on normalization mode. Note that the data type of this tensor descriptor must be float for FP16 and FP32 input tensors, and double for FP64 input tensors.

activationDesc

Input. Descriptor for the activation operation. When the bnOps input is set to either CUDNN_BATCHNORM_OPS_BN_ACTIVATION or CUDNN_BATCHNORM_OPS_BN_ADD_ACTIVATION, then this activation is used, otherwise user may pass NULL.

*sizeInBytes

Output. Amount of GPU memory required for the workspace, as determined by this function, to be able to execute the `cudnnGetBatchNormalizationForwardTrainingExWorkspaceSize()` function with the specified bnOps input setting.

Returns

CUDNN_STATUS_SUCCESS

The computation was performed successfully.

CUDNN_STATUS_NOT_SUPPORTED

The function does not support the provided configuration.

CUDNN_STATUS_BAD_PARAM

At least one of the following conditions are met:

- Number of xDesc, yDesc or dxDesc tensor descriptor dimensions is not within the range of [4, 5] (only 4D and 5D tensors are supported).
- dBnScaleBiasDesc dimensions not 1xCx1x1 for 4D and 1xCx1x1x1 for 5D for spatial, and are not 1xCxHxW for 4D and 1xCxDxHxW for 5D for per-activation mode.
- Dimensions or data types mismatch for any pair of xDesc, dyDesc, or dxDesc.
4.1.9. **cudnnGetBatchNormalizationForwardTrainingExWorkspaceSize**

This function returns the amount of GPU memory workspace the user should allocate to be able to call `cudnnGetBatchNormalizationForwardTrainingExWorkspaceSize()` function for the specified `bnOps` input setting. The workspace allocated should then be passed by the user to the function `cudnnGetBatchNormalizationForwardTrainingExWorkspaceSize()`.

```c
    cudnnStatus_t cudnnGetBatchNormalizationForwardTrainingExWorkspaceSize(
        cudnnHandle_t                           handle,
        cudnnBatchNormMode_t                    mode,
        cudnnBatchNormOps_t                     bnOps,
        const cudnnTensorDescriptor_t           xDesc,
        const cudnnTensorDescriptor_t           zDesc,
        const cudnnTensorDescriptor_t           yDesc,
        const cudnnTensorDescriptor_t           bnScaleBiasMeanVarDesc,
        const cudnnActivationDescriptor_t       activationDesc,
        size_t                                  *sizeInBytes);
```

**Parameters**

- **handle**
  
  *Input*. Handle to a previously created cuDNN library descriptor. For more information, refer to `cudnnHandle_t`.

- **mode**
  
  *Input*. Mode of operation (spatial or per-activation). For more information, refer to `cudnnBatchNormMode_t`.

- **bnOps**
  
  *Input*. Mode of operation for the fast NHWC kernel. For more information, refer to `cudnnBatchNormOps_t`. This input can be used to set this function to perform either only the batch normalization, or batch normalization followed by activation, or batch normalization followed by element-wise addition and then activation.

- **xDesc, zDesc, yDesc**
  
  Tensor descriptors and pointers in the device memory for the layer’s `x` data, the optional `z` input data, and the `y` output. `zDesc` is only needed when `bnOps` is `CUDNN_BATCHNORM_OPS_BN_ADD_ACTIVATION`, otherwise the user may pass NULL. For more information, refer to `cudnnTensorDescriptor_t`.

- **bnScaleBiasMeanVarDesc**
  
  *Input*. Shared tensor descriptor for the following six tensors: `bnScaleData`, `bnBiasData`, `dBNScaleData`, `dBNBiasData`, `savedMean`, and `savedInvVariance`. This is the shared tensor descriptor desc for the secondary tensor that was derived by `cudnnDeriveBNTensorDescriptor()`. The dimensions for this tensor descriptor are dependent on normalization mode. Note that the data type of this tensor descriptor must be `float` for FP16 and FP32 input tensors, and `double` for FP64 input tensors.

- **activationDesc**
  
  *Input*. Descriptor for the activation operation. When the `bnOps` input is set to either `CUDNN_BATCHNORM_OPS_BN_ACTIVATION` or `CUDNN_BATCHNORM_OPS_BN_ADD_ACTIVATION` then this activation is used, otherwise the user may pass NULL.
*sizeInBytes

Output. Amount of GPU memory required for the workspace, as determined by this function, to be able to execute the cudnnGetBatchNormalizationForwardTrainingExWorkspaceSize() function with the specified bnOps input setting.

Returns

CUDNN_STATUS_SUCCESS
The computation was performed successfully.

CUDNN_STATUS_NOT_SUPPORTED
The function does not support the provided configuration.

CUDNN_STATUS_BAD_PARAM
At least one of the following conditions are met:

- Number of xDesc, yDesc or dxDesc tensor descriptor dimensions is not within the range of [4, 5] (only 4D and 5D tensors are supported).
- dBnScaleBiasDesc dimensions not 1xCx1x1 for 4D and 1xCx1x1x1 for 5D for spatial, and are not 1xCxHxW for 4D and 1xCxDxHxW for 5D for per-activation mode.
- Dimensions or data types mismatch for xDesc or yDesc.

4.1.10. cudnnGetBatchNormalizationTrainingExReserveSpaceSize()

This function returns the amount of reserve GPU memory workspace the user should allocate for the batch normalization operation, for the specified bnOps input setting. In contrast to the workspace, the reserved space should be preserved between the forward and backward calls, and the data should not be altered.

```c
int cudnnGetBatchNormalizationTrainingExReserveSpaceSize(
    cudnnHandle_t                       handle,
    cudnnBatchNormMode_t                mode,
    cudnnBatchNormOps_t                 bnOps,
    const cudnnActivationDescriptor_t   activationDesc,
    const cudnnTensorDescriptor_t       xDesc,
    size_t                              *sizeInBytes);
```

Parameters

handle
Input. Handle to a previously created cuDNN library descriptor. For more information, refer to cudnnHandle_t.

mode
Input. Mode of operation (spatial or per-activation). For more information, refer to cudnnBatchNormMode_t.

bnOps
Input. Mode of operation for the fast NHWC kernel. For more information, refer to cudnnBatchNormOps_t. This input can be used to set this function to perform either
only the batch normalization, or batch normalization followed by activation, or batch normalization followed by element-wise addition and then activation.

**xDesc**  
Tensor descriptors for the layer’s x data. For more information, refer to `cudnnTensorDescriptor_t`.

**activationDesc**  
*Input*. Descriptor for the activation operation. When the bnOps input is set to either `CUDNN_BATCHNORM_OPS_BN_ACTIVATION` or `CUDNN_BATCHNORM_OPS_BN_ADD_ACTIVATION` then this activation is used, otherwise user may pass NULL.

**sizeInBytes**  
*Output*. Amount of GPU memory reserved.

**Returns**

- **CUDNN_STATUS_SUCCESS**  
The computation was performed successfully.

- **CUDNN_STATUS_NOT_SUPPORTED**  
The function does not support the provided configuration.

- **CUDNN_STATUS_BAD_PARAM**  
At least one of the following conditions are met:

  - The xDesc tensor descriptor dimension is not within the [4, 5] range (only 4D and 5D tensors are supported).

**4.1.11. cudnnGetNormalizationBackwardWorkspaceSize()**

This function returns the amount of GPU memory workspace the user should allocate to be able to call `cudnnNormalizationBackward()` function for the specified `normOps` and `algo` input setting. The workspace allocated will then be passed to the function `cudnnNormalizationBackward()`.

```c
void cudnnGetNormalizationBackwardWorkspaceSize(cudnnHandle_t handle,  
cudnnNormMode_t mode,  
cudnnNormOps_t normOps,  
cudnnNormAlgo_t algo,  
const cudnnTensorDescriptor_t xDesc,  
const cudnnTensorDescriptor_t yDesc,  
const cudnnTensorDescriptor_t dyDesc,  
const cudnnTensorDescriptor_t dzDesc,  
const cudnnTensorDescriptor_t dxDesc,  
const cudnnTensorDescriptor_t dNormScaleBiasDesc,  
const cudnnActivationDescriptor_t activationDesc,  
const cudnnTensorDescriptor_t normMeanVarDesc,  
size_t *sizeInBytes,  
int groupCnt);
```
Parameters

**handle**

*Input.* Handle to a previously created cuDNN library descriptor. For more information, refer to [cudnnHandle_t](#).

**mode**

*Input.* Mode of operation (per-channel or per-activation). For more information, refer to [cudnnNormMode_t](#).

**normOps**

*Input.* Mode of post-operative. Currently `CUDNN_NORM_OPS_NORM_ACTIVATION` and `CUDNN_NORM_OPS_NORM_ADD_ACTIVATION` are only supported in the NHWC layout. For more information, refer to [cudnnNormOps_t](#). This input can be used to set this function to perform either only the normalization, or normalization followed by activation, or normalization followed by element-wise addition and then activation.

**algo**

*Input.* Algorithm to be performed. For more information, refer to [cudnnNormAlgo_t](#).

**xDesc, yDesc, dyDesc, dzDesc, dxDesc**

Tensor descriptors and pointers in the device memory for the layer’s x data, back propagated differential dy (inputs), the optional y input data, the optional dz output, and the dx output, which is the resulting differential with respect to x. For more information, refer to [cudnnTensorDescriptor_t](#).

**dNormScaleBiasDesc**

*Input.* Shared tensor descriptor for the following four tensors: normScaleData, normBiasData, dNormScaleData, dNormBiasData. The dimensions for this tensor descriptor are dependent on normalization mode. Note that the data type of this tensor descriptor must be float for FP16 and FP32 input tensors, and double for FP64 input tensors.

**activationDesc**

*Input.* Descriptor for the activation operation. When the normOps input is set to either `CUDNN_NORM_OPS_NORM_ACTIVATION` or `CUDNN_NORM_OPS_NORM_ADD_ACTIVATION`, then this activation is used, otherwise the user may pass NULL.

**normMeanVarDesc**

*Input.* Shared tensor descriptor for the following tensors: savedMean and savedInvVariance. The dimensions for this tensor descriptor are dependent on normalization mode. Note that the data type of this tensor descriptor must be float for FP16 and FP32 input tensors, and double for FP64 input tensors.

**sizeInBytes**

*Output.* Amount of GPU memory required for the workspace, as determined by this function, to be able to execute the [cudnnGetNormalizationForwardTrainingWorkspaceSize()](#) function with the specified normOps input setting.

**groupCnt**

*Input.* The number of grouped convolutions. Currently, only 1 is supported.
Returns

**CUDNN_STATUS_SUCCESS**
The computation was performed successfully.

**CUDNN_STATUS_NOT_SUPPORTED**
The function does not support the provided configuration.

**CUDNN_STATUS_BAD_PARAM**
At least one of the following conditions are met:

- Number of xDesc, yDesc or dxDesc tensor descriptor dimensions is not within the range of [4,5] (only 4D and 5D tensors are supported).
- dNormScaleBiasDesc dimensions not 1x1x1 for 4D and 1x1x1x1 for 5D for per-channel, and are not 1x1xHxW for 4D and 1xCxDxHxW for 5D for per-activation mode.
- Dimensions or data types mismatch for any pair of xDesc, dyDesc, or dxDesc.

### 4.1.12. cudnnGetNormalizationForwardTrainingWorkspaceSize()

This function returns the amount of GPU memory workspace the user should allocate to be able to call `cudnnNormalizationForwardTraining()` function for the specified `normOps` and `algo` input setting. The workspace allocated should then be passed by the user to the function `cudnnNormalizationForwardTraining()`.

```c

cudnnStatus_t
cudnnGetNormalizationForwardTrainingWorkspaceSize(cudnnHandle_t handle,
                                              cudnnNormMode_t mode,
                                              cudnnNormOps_t normOps,
                                              cudnnNormAlgo_t algo,
                                              const cudnnTensorDescriptor_t xDesc,
                                              const cudnnTensorDescriptor_t zDesc,
                                              const cudnnTensorDescriptor_t yDesc,
                                              const cudnnTensorDescriptor_t normScaleBiasDesc,
                                              const cudnnActivationDescriptor_t activationDesc,
                                              const cudnnTensorDescriptor_t normMeanVarDesc,
                                              size_t *sizeInBytes,
                                              int groupCnt);
```

**Parameters**

**handle**

*Input.* Handle to a previously created cuDNN library descriptor. For more information, refer to `cudnnHandle_t`.

**mode**

*Input.* Mode of operation (per-channel or per-activation). For more information, refer to `cudnnNormMode_t`. 
**normOps**

*Input.* Mode of post-operative. Currently CUDNN_NORM_OPS_NORM_ACTIVATION and CUDNN_NORM_OPS_NORM_ADD_ACTIVATION are only supported in the NHWC layout. For more information, refer to cudnnNormOps_t. This input can be used to set this function to perform either only the normalization, or normalization followed by activation, or normalization followed by element-wise addition and then activation.

**algo**

*Input.* Algorithm to be performed. For more information, refer to cudnnNormAlgo_t.

**xDesc, zDesc, yDesc**

Tensor descriptors and pointers in the device memory for the layer’s x data, the optional z input data, and the y output. zDesc is only needed when normOps is CUDNN_NORM_OPS_NORM_ADD_ACTIVATION, otherwise the user may pass NULL. For more information, refer to cudnnTensorDescriptor_t.

**normScaleBiasDesc**

*Input.* Shared tensor descriptor for the following tensors: normScaleData and normBiasData. The dimensions for this tensor descriptor are dependent on normalization mode. Note that the data type of this tensor descriptor must be float for FP16 and FP32 input tensors, and double for FP64 input tensors.

**activationDesc**

*Input.* Descriptor for the activation operation. When the normOps input is set to either CUDNN_NORM_OPS_NORM_ACTIVATION or CUDNN_NORM_OPS_NORM_ADD_ACTIVATION, then this activation is used, otherwise the user may pass NULL.

**normMeanVarDesc**

*Input.* Shared tensor descriptor for the following tensors: savedMean and savedInvVariance. The dimensions for this tensor descriptor are dependent on normalization mode. Note that the data type of this tensor descriptor must be float for FP16 and FP32 input tensors, and double for FP64 input tensors.

**sizeInBytes**

*Output.* Amount of GPU memory required for the workspace, as determined by this function, to be able to execute the cudnnGetNormalizationForwardTrainingWorkspaceSize() function with the specified normOps input setting.

**groupCnt**

*Input.* The number of grouped convolutions. Currently, only 1 is supported.

**Returns**

**CUDNN_STATUS_SUCCESS**

The computation was performed successfully.

**CUDNN_STATUS_NOT_SUPPORTED**

The function does not support the provided configuration.

**CUDNN_STATUS_BAD_PARAM**

At least one of the following conditions are met:
- Number of xDesc, yDesc or zDesc tensor descriptor dimensions is not within the range of [4,5] (only 4D and 5D tensors are supported).
- normScaleBiasDesc dimensions not 1xCx1x1 for 4D and 1xCx1x1x1 for 5D for per-channel, and are not 1xCxHxW for 4D and 1xCxDxHxW for 5D for per-activation mode.
- Dimensions or data types mismatch for xDesc or yDesc.

## 4.1.13. cudnnGetNormalizationTrainingReserveSpaceSize
This function returns the amount of reserve GPU memory workspace the user should allocate for the normalization operation, for the specified normOps input setting. In contrast to the workspace, the reserved space should be preserved between the forward and backward calls, and the data should not be altered.

```c
void cudnnGetNormalizationTrainingReserveSpaceSize(cudnnHandle_t handle, cudnnNormMode_t mode, cudnnNormOps_t normOps, cudnnNormAlgo_t algo, const cudnnActivationDescriptor_t activationDesc, const cudnnTensorDescriptor_t xDesc, size_t *sizeInBytes, int groupCnt);
```

### Parameters

- **handle**
  - *Input*. Handle to a previously created cuDNN library descriptor. For more information, refer to [cudnnHandle_t](pr-09702-001_v8.9.5.pdf).

- **mode**
  - *Input*. Mode of operation (per-channel or per-activation). For more information, refer to [cudnnNormMode_t](pr-09702-001_v8.9.5.pdf).

- **normOps**
  - *Input*. Mode of post-operative. Currently **CUDNN_NORM_OPS_NORM_ACTIVATION** and **CUDNN_NORM_OPS_NORM_ADD_ACTIVATION** are only supported in the NHWC layout. For more information, refer to [cudnnNormOps_t](pr-09702-001_v8.9.5.pdf). This input can be used to set this function to perform either only the normalization, or normalization followed by activation, or normalization followed by element-wise addition and then activation.

- **algo**
  - *Input*. Algorithm to be performed. For more information, refer to [cudnnNormAlgo_t](pr-09702-001_v8.9.5.pdf).

- **xDesc**
  - Tensor descriptors for the layer’s x data. For more information, refer to [cudnnTensorDescriptor_t](pr-09702-001_v8.9.5.pdf).

- **activationDesc**
  - *Input*. Descriptor for the activation operation. When the normOps input is set to either **CUDNN_NORM_OPS_NORM_ACTIVATION** or **CUDNN_NORM_OPS_NORM_ADD_ACTIVATION** then this activation is used, otherwise the user may pass NULL.
*sizeInBytes

Output. Amount of GPU memory reserved.

groupCnt

Input. The number of grouped convolutions. Currently, only 1 is supported.

Returns

CUDNN_STATUS_SUCCESS

The computation was performed successfully.

CUDNN_STATUS_NOT_SUPPORTED

The function does not support the provided configuration.

CUDNN_STATUS_BAD_PARAM

At least one of the following conditions are met:

- The xDesc tensor descriptor dimension is not within the [4,5] range (only 4D and 5D tensors are supported).

4.1.14. cudnnLRNCrossChannelBackward()

This function performs the backward LRN layer computation.

```c
void cudnnLRNCrossChannelBackward(
    cudnnHandle_t               handle,
    cudnnLRNDescriptor_t        normDesc,
    cudnnLRNMode_t              lrnMode,
    const void                  *alpha,
    const cudnnTensorDescriptor_t yDesc,
    const void                  *y,
    const cudnnTensorDescriptor_t dyDesc,
    const void                  *dy,
    const cudnnTensorDescriptor_t xDesc,
    const void                  *x,
    const void                  *beta,
    const cudnnTensorDescriptor_t dxDesc,
    void                        *dx)
```

Supported formats are: positive-strided, NCHW and NHWC for 4D x and y, and only NCDHW DHW-packed for 5D (for both x and y). Only non-overlapping 4D and 5D tensors are supported. NCHW layout is preferred for performance.

Parameters

handle

Input. Handle to a previously created cuDNN library descriptor.

normDesc

Input. Handle to a previously initialized LRN parameter descriptor.

lrnMode

Input. LRN layer mode of operation. Currently, only CUDNN_LRN_CROSS_CHANNEL_DIM1 is implemented. Normalization is performed along the tensor’s dimA[1].
**alpha, beta**

*Input*. Pointers to scaling factors (in host memory) used to blend the layer output value with prior value in the destination tensor as follows:

\[
\text{dstValue} = \alpha[0] \times \text{resultValue} + \beta[0] \times \text{priorDstValue}
\]

For more information, refer to [Scaling Parameters](#).

**yDesc, y**

*Input*. Tensor descriptor and pointer in device memory for the layer’s \( y \) data.

**dyDesc, dy**

*Input*. Tensor descriptor and pointer in device memory for the layer’s input cumulative loss differential data \( dy \) (including error backpropagation).

**xDesc, x**

*Input*. Tensor descriptor and pointer in device memory for the layer’s \( x \) data. Note that these values are not modified during backpropagation.

**dxDesc, dx**

*Output*. Tensor descriptor and pointer in device memory for the layer’s resulting cumulative loss differential data \( dx \) (including error backpropagation).

**Returns**

**CUDNN_STATUS_SUCCESS**

The computation was performed successfully.

**CUDNN_STATUS_BAD_PARAM**

At least one of the following conditions are met:

- One of the tensor pointers \( x, y \) is **NULL**.
- Number of input tensor dimensions is 2 or less.
- LRN descriptor parameters are outside of their valid ranges.
- One of the tensor parameters is 5D but is not in NCDHW DHW-packed format.

**CUDNN_STATUS_NOT_SUPPORTED**

The function does not support the provided configuration. See the following for some examples of non-supported configurations:

- Any of the input tensor datatypes is not the same as any of the output tensor datatype.
- Any pairwise tensor dimensions mismatch for \( x, y, dx, \) or \( dy \).
- Any tensor parameters strides are negative.

### 4.1.15. cudnnNormalizationBackward()

This function performs backward normalization layer computation that is specified by mode. Per-channel normalization layer is based on the *Batch Normalization: Accelerating Deep Network Training by Reducing Internal Covariate Shift* paper.
cudnnNormMode_t mode,
cudnnNormOps_t normOps,
cudnnNormAlgo_t algo,
const void *alphaDataDiff,
const void *betaDataDiff,
const void *alphaParamDiff,
const void *betaParamDiff,
const cudnnTensorDescriptor_t xDesc,
const void *xData,
const cudnnTensorDescriptor_t yDesc,
const void *yData,
const cudnnTensorDescriptor_t dyDesc,
const void *dyData,
const cudnnTensorDescriptor_t dzDesc,
void *dzData,
const cudnnTensorDescriptor_t dxDesc,
void *dxData,
const cudnnTensorDescriptor_t dNormScaleBiasDesc,
void *dNormScaleData,
const void *normBiasData,
void *dNormScaleData,
void *dNormBiasData,
double epsilon,
const cudnnTensorDescriptor_t normMeanVarDesc,
const void *savedMean,
const void *savedInvVariance,
cudnnActivationDescriptor_t activationDesc,
void *workSpace,
size_t workspaceSizeInBytes,
void *reserveSpace,
size_t reserveSpaceSizeInBytes,
int groupCnt)

Only 4D and 5D tensors are supported. The epsilon value has to be the same during training, backpropagation, and inference. This workspace is not required to be clean. Moreover, the workspace does not have to remain unchanged between the forward and backward pass, as it is not used for passing any information.

This function can accept a *workspace pointer to the GPU workspace, and workspaceSizeInBytes, the size of the workspace, from the user.

The normOps input can be used to set this function to perform either only the normalization, or normalization followed by activation, or normalization followed by element-wise addition and then activation.

When the tensor layout is NCHW, higher performance can be obtained when HW-packed tensors are used for x, dy, or dx.

Higher performance for CUDNN_NORM_PER_CHANNEL mode can be obtained when the following conditions are true:

- All tensors, namely, x, y, dz, dy, and dx must be NHWC-fully packed, and must be of the type CUDNN_DATA_HALF.
- The tensor C dimension should be a multiple of 4.
- The input parameter mode must be set to CUDNN_NORM_PER_CHANNEL.
- The input parameter algo must be set to CUDNN_NORM_ALGO_PERSIST.
- Workspace is not NULL.
- `workSpaceSizeInBytes` is equal to or larger than the amount required by `cudnnGetNormalizationBackwardWorkspaceSize()`.
- `reserveSpaceSizeInBytes` is equal to or larger than the amount required by `cudnnGetNormalizationTrainingReserveSpaceSize()`.
- The content in `reserveSpace` stored by `cudnnNormalizationForwardTraining()` must be preserved.

**Parameters**

**handle**

*Input.* Handle to a previously created cuDNN library descriptor. For more information, refer to `cudnnHandle_t`.

**mode**

*Input.* Mode of operation (per-channel or per-activation). For more information, refer to `cudnnNormMode_t`.

**normOps**

*Input.* Mode of post-operative. Currently `CUDNN_NORM_OPS_NORM_ACTIVATION` and `CUDNN_NORM_OPS_NORM_ADD_ACTIVATION` are only supported in the NHWC layout. For more information, refer to `cudnnNormOps_t`. This input can be used to set this function to perform either only the normalization, or normalization followed by activation, or normalization followed by element-wise addition and then activation.

**algo**

*Input.* Algorithm to be performed. For more information, refer to `cudnnNormAlgo_t`.

**alphaDataDiff,** **betaDataDiff**

*Inputs.* Pointers to scaling factors (in host memory) used to blend the gradient output `dx` with a prior value in the destination tensor as follows:

```
dstValue = alpha[0]*resultValue + beta[0]*priorDstValue
```

For more information, refer to Scaling Parameters.

**alphaParamDiff,** **betaParamDiff**

*Inputs.* Pointers to scaling factors (in host memory) used to blend the gradient outputs `dNormScaleData` and `dNormBiasData` with prior values in the destination tensor as follows:

```
dstValue = alpha[0]*resultValue + beta[0]*priorDstValue
```

For more information, refer to Scaling Parameters.

**xDesc,** **xData,** **yDesc,** **yData,** **dyDesc,** **dyData**

*Inputs.* Tensor descriptors and pointers in the device memory for the layer’s `x` data, backpropagated gradient input `dy`, the original forward output `y` data. `yDesc` and `yData` are not needed if `normOps` is set to `CUDNN_NORM_OPS_NORM`, users may pass `NULL`. For more information, refer to `cudnnTensorDescriptor_t`.
**dzDesc, dxDesc**
*Inputs.* Tensor descriptors and pointers in the device memory for the computed gradient output dz and dx. *dzDesc is not needed when normOps is CUDNN_NORM_OPS_NORM or CUDNN_NORM_OPS_NORM_ACTIVATION, users may pass NULL. For more information, refer to cudnnTensorDescriptor_t.

**dxData, *dxData**
*Outputs.* Tensor descriptors and pointers in the device memory for the computed gradient output dz and dx. *dzData is not needed when normOps is CUDNN_NORM_OPS_NORM or CUDNN_NORM_OPS_NORM_ACTIVATION, users may pass NULL. For more information, refer to cudnnTensorDescriptor_t.

**dNormScaleBiasDesc**
*Input.* Shared tensor descriptor for the following six tensors: normScaleData, normBiasData, dNormScaleData, and dNormBiasData. The dimensions for this tensor descriptor are dependent on normalization mode.

---

**Note:** The data type of this tensor descriptor must be float for FP16 and FP32 input tensors and double for FP64 input tensors.

For more information, refer to cudnnTensorDescriptor_t.

**normScaleData**
*Input.* Pointer in the device memory for the normalization scale parameter (in the Batch Normalization: Accelerating Deep Network Training by Reducing Internal Covariate Shift paper, the quantity scale is referred to as gamma).

**normBiasData**
*Input.* Pointers in the device memory for the normalization bias parameter (in the Batch Normalization: Accelerating Deep Network Training by Reducing Internal Covariate Shift paper, bias is referred to as beta). This parameter is used only when activation should be performed.

**dNormScaleData, *dNormBiasData**
*Outputs.* Pointers in the device memory for the gradients of normScaleData and normBiasData, respectively.

**epsilon**
*Input.* Epsilon value used in normalization formula. Its value should be equal to or greater than zero. The same epsilon value should be used in forward and backward functions.

**normMeanVarDesc**
*Input.* Shared tensor descriptor for the following tensors: savedMean and savedInvVariance. The dimensions for this tensor descriptor are dependent on normalization mode.

---

**Note:** The data type of this tensor descriptor must be float for FP16 and FP32 input tensors and double for FP64 input tensors.
For more information, refer to cudnnTensorDescriptor_t.

*savedMean, *savedInvVariance

*Inputs. Optional cache parameters containing saved intermediate results computed during the forward pass. For this to work correctly, the layer’s x and normScaleData, normBiasData data has to remain unchanged until this backward function is called. Note that both these parameters can be NULL but only at the same time. It is recommended to use this cache since the memory overhead is relatively small.

activationDesc

*Input. Descriptor for the activation operation. When the normOps input is set to either CUDNN_NORM_OPS_NORM_ACTIVATION or CUDNN_NORM_OPS_NORM_ADD_ACTIVATION then this activation is used, otherwise the user may pass NULL.

workspace

*Input. Pointer to the GPU workspace.

workSpaceSizeInBytes

*Input. The size of the workspace. It must be large enough to trigger the fast NHWC semi-persistent kernel by this function.

*reserveSpace

*Input. Pointer to the GPU workspace for the reserveSpace.

reserveSpaceSizeInBytes

*Input. The size of the reserveSpace. It must be equal or larger than the amount required by cudnnGetNormalizationTrainingReserveSpaceSize().

groupCnt

*Input. The number of grouped convolutions. Currently, only 1 is supported.

Returns

CUDNN_STATUS_SUCCESS
The computation was performed successfully.

CUDNN_STATUS_NOT_SUPPORTED
The function does not support the provided configuration.

CUDNN_STATUS_BAD_PARAM
At least one of the following conditions are met:

- Any of the pointers alphaDataDiff, betaDataDiff, alphaParamDiff, betaParamDiff, xData, dyData, dxData, normScaleData, dNormScaleData, and dNormBiasData is NULL.
- The number of xDesc, yDesc, or dxDesc tensor descriptor dimensions is not within the range of [4,5] (only 4D and 5D tensors are supported).
- dNormScaleBiasDesc dimensions not 1Cx1x1 for 4D and 1xCx1x1x1 for 5D for per-channel, and are not 1xCxHxW for 4D and 1xCxDxHxW for 5D for per-activation mode.
- Exactly one of savedMean, savedInvVariance pointers is NULL.
- epsilon value is less than zero.
- Dimensions or data types mismatch for any pair of xDesc, dyDesc, dxDesc, dNormScaleBiasDesc, or normMeanVarDesc.

4.1.16. cudnnNormalizationForwardTraining()

This function performs the forward normalization layer computation for the training phase. Depending on mode, different normalization operations will be performed. Per-channel layer is based on the Batch Normalization: Accelerating Deep Network Training by Reducing Internal Covariate Shift paper.

cudnnStatus_t cudnnNormalizationForwardTraining(cudnnHandle_t handle,
cudnnNormMode_t mode,
cudnnNormOps_t normOps,
cudnnNormAlgo_t algo,
const void *alpha,
const void *beta,
const cudnnTensorDescriptor_t xDesc,
const void *xData,
const cudnnTensorDescriptor_t normScaleBiasDesc,
const void *normScale,
const void *normBias,
double exponentialAverageFactor,
const cudnnTensorDescriptor_t normMeanVarDesc,
void *resultRunningMean,
void *resultRunningVariance,
void *resultSaveMean,
void *resultSaveInvVariance,
cudnnActivationDescriptor_t activationDesc,
const cudnnTensorDescriptor_t zDesc,
const void *zData,
const cudnnTensorDescriptor_t yDesc,
void *yData,
void *workspace,
size_t workSpaceSizeInBytes,
void *reserveSpace,
size_t reserveSpaceSizeInBytes,
int groupCnt);

Only 4D and 5D tensors are supported.

The epsilon value has to be the same during training, back propagation, and inference.

For the inference phase, refer to cudnnNormalizationForwardInference().

Higher performance can be obtained when HW-packed tensors are used for both x and y.

This API will trigger the new semi-persistent NHWC kernel when the following conditions are true:

- All tensors, namely, xData, yData must be NHWC-fully packed and must be of the type CUDNN_DATA_HALF.
- The tensor C dimension should be a multiple of 4.
- The input parameter mode must be set to CUDNN_NORM_PER_CHANNEL.
- The input parameter algo must be set to CUDNN_NORM_ALGO_PERSIST.
- workspace is not NULL.
- workSpaceSizeInBytes is equal to or larger than the amount required by cudnnGetNormalizationForwardTrainingWorkspaceSize().
reserveSpaceSizeInBytes is equal to or larger than the amount required by cudnnGetNormalizationTrainingReserveSpaceSize().

The content in reserveSpace stored by cudnnNormalizationForwardTraining() must be preserved.

This workspace is not required to be clean. Moreover, the workspace does not have to remain unchanged between the forward and backward pass, as it is not used for passing any information. This extended function can accept a *workspace pointer to the GPU workspace, and workSpaceSizeInBytes, the size of the workspace, from the user.

The normOps input can be used to set this function to perform either only the normalization, or normalization followed by activation, or normalization followed by element-wise addition and then activation.

Only 4D and 5D tensors are supported. The epsilon value has to be the same during the training, the backpropagation, and the inference.

When the tensor layout is NCHW, higher performance can be obtained when HW-packed tensors are used for xData, yData.

### Parameters

**handle**

*Input.* Handle to a previously created cuDNN library descriptor. For more information, refer to cudnnHandle_t.

**mode**

*Input.* Mode of operation (per-channel or per-activation). For more information, refer to cudnnNormMode_t.

**normOps**

*Input.* Mode of post-operative. Currently CUDNN NORM_OPS_NORM_ACTIVATION and CUDNN NORM_OPS_NORM_ADD_ACTIVATION are only supported in the NHWC layout. For more information, refer to cudnnNormOps_t. This input can be used to set this function to perform either only the normalization, or normalization followed by activation, or normalization followed by element-wise addition and then activation.

**algo**

*Input.* Algorithm to be performed. For more information, refer to cudnnNormAlgo_t.

**alpha, beta**

*Inputs.* Pointers to scaling factors (in host memory) used to blend the layer output value with prior value in the destination tensor as follows:

\[
\text{dstValue} = \alpha[0] \times \text{resultValue} + \beta[0] \times \text{priorDstValue}
\]

For more information, refer to Scaling Parameters.

**xDesc, yDesc**

*Input.* Handles to the previously initialized tensor descriptors.

**xData**

*Input.* Data pointer to GPU memory associated with the tensor descriptor xDesc, for the layer's x input data.
*yData

*Output. Data pointer to GPU memory associated with the tensor descriptor yDesc, for the y output of the normalization layer.

zDesc, *zData

*Input. Tensor descriptors and pointers in device memory for residual addition to the result of the normalization operation, prior to the activation. zDesc and *zData are optional and are only used when normOps is CUDNN_NORM_OPS_NORM_ADD_ACTIVATION, otherwise the user may pass NULL. When in use, z should have exactly the same dimension as xData and the final output yData. For more information, refer to cudnnTensorDescriptor_t.

normScaleBiasDesc, normScale, normBias

*Inputs. Tensor descriptors and pointers in device memory for the normalization scale and bias parameters (in the Batch Normalization: Accelerating Deep Network Training by Reducing Internal Covariate Shift paper, bias is referred to as beta and scale as gamma). The dimensions for the tensor descriptor are dependent on the normalization mode.

exponentialAverageFactor

*Input. Factor used in the moving average computation as follows:

\[
\text{runningMean} = \text{runningMean} \times (1-\text{factor}) + \text{newMean} \times \text{factor}
\]

Use a factor=1/(1+n) at N-th call to the function to get the Cumulative Moving Average (CMA) behavior, for example:

\[
\text{CMA}[n] = (x[1]+...+x[n])/n
\]

For example:

\[
\text{CMA}[n+1] = (n*\text{CMA}[n]+x[n+1])/(n+1)
= ((n+1)*\text{CMA}[n]-\text{CMA}[n])/n+1 + x[n+1]/(n+1)
= \text{CMA}[n]*(1-1/(n+1))+x[n+1]/(n+1)
= \text{CMA}[n]*(1-\text{factor}) + x[n+1] \times \text{factor}
\]

normMeanVarDesc

*Inputs. Tensor descriptor used for following tensors: resultRunningMean, resultRunningVariance, resultSaveMean, resultSaveInvVariance.

*resultRunningMean, *resultRunningVariance

*Inputs/Outputs. Pointers to the running mean and running variance data. Both these pointers can be NULL but only at the same time. The value stored in resultRunningVariance (or passed as an input in inference mode) is the sample variance and is the moving average of \(\text{variance}[x]\) where the variance is computed either over batch or spatial+batch dimensions depending on the mode. If these pointers are not NULL, the tensors should be initialized to some reasonable values or to 0.

epsilon

*Input. Epsilon value used in the normalization formula. Its value should be equal to or greater than zero.

*resultSaveMean, *resultSaveInvVariance

*Outputs. Optional cache parameters containing saved intermediate results computed during the forward pass. For this to work correctly, the layer’s x and normScale, normBias, and epsilon should be passed in the same way.
normBias data has to remain unchanged until this backward function is called. Note that both these parameters can be NULL but only at the same time. It is recommended to use this cache since the memory overhead is relatively small.

**activationDesc**

*Input*. The tensor descriptor for the activation operation. When the normOps input is set to either CUDNN_NORM_OPS_NORM_ACTIVATION or CUDNN_NORM_OPS_NORM_ADD_ACTIVATION then this activation is used, otherwise the user may pass NULL.

**workspace, workSpaceSizeInBytes**

*Inputs*. `workspace` is a pointer to the GPU workspace, and `workSpaceSizeInBytes` is the size of the workspace. When `workspace` is not NULL and `workSpaceSizeInBytes` is large enough, and the tensor layout is NHWC and the data type configuration is supported, then this function will trigger a semi-persistent NHWC kernel for normalization. The workspace is not required to be clean. Also, the workspace does not need to remain unchanged between the forward and backward passes.

**reserveSpace**

*Input*. Pointer to the GPU workspace for the `reserveSpace`.

**reserveSpaceSizeInBytes**

*Input*. The size of the `reserveSpace`. Must be equal or larger than the amount required by `cudnnGetNormalizationTrainingReserveSpaceSize()`.

**groupCnt**

*Input*. The number of grouped convolutions. Currently, only 1 is supported.

**Supported configurations**

This function supports the following combinations of data types for various descriptors.

**Table 18. Supported Configurations for cudnnNormalizationForwardTraining()**

<table>
<thead>
<tr>
<th>Data Type Configurations</th>
<th>xDesc, yDesc, zDesc</th>
<th>normScaleBiasDesc, normMeanVarDesc</th>
</tr>
</thead>
<tbody>
<tr>
<td>PSEUDO_HALF_CONFIG</td>
<td>CUDNN_DATA_HALF</td>
<td>CUDNN_DATA_FLOAT</td>
</tr>
<tr>
<td>FLOAT_CONFIG</td>
<td>CUDNN_DATA_FLOAT</td>
<td>CUDNN_DATA_FLOAT</td>
</tr>
<tr>
<td>DOUBLE_CONFIG</td>
<td>CUDNN_DATA_DOUBLE</td>
<td>CUDNN_DATA_DOUBLE</td>
</tr>
<tr>
<td>PSEUDO_BFLOAT16_CONFIG</td>
<td>CUDNN_DATA_BFLOAT16</td>
<td>CUDNN_DATA_FLOAT</td>
</tr>
</tbody>
</table>

**Returns**

**CUDNN_STATUS_SUCCESS**

The computation was performed successfully.

**CUDNN_STATUS_NOT_SUPPORTED**

The function does not support the provided configuration.
cudnn_ops_train.so Library

**CUDNN_STATUS_BAD_PARAM**
At least one of the following conditions are met:

- One of the pointers alpha, beta, xData, yData, normScale, and normBias is NULL.
- The number of xDesc or yDesc tensor descriptor dimensions is not within the [4,5] range (only 4D and 5D tensors are supported).
- normScaleBiasDesc dimensions are not 1x1x1x1 for 4D and 1xCx1x1x1 for 5D for per-channel mode, and are not 1xCxHxW for 4D and 1xCxDxHxW for 5D for per-activation mode.
- Exactly one of resultSaveMean, resultSaveInvVariance pointers are NULL.
- Exactly one of resultRunningMean, resultRunningInvVariance pointers are NULL.
- epsilon value is less than zero.
- Dimensions or data types mismatch for xDesc or yDesc.

### 4.1.17. `cudnnOpsTrainVersionCheck()`

This function checks whether the version of the OpsTrain subset of the library is consistent with the other sub-libraries.

```c
cudnnStatus_t cudnnOpsTrainVersionCheck(void)
```

**Returns**

**CUDNN_STATUS_SUCCESS**
The version is consistent with other sub-libraries.

**CUDNN_STATUS_VERSION_MISMATCH**
The version of OpsTrain is not consistent with other sub-libraries. Users should check the installation and make sure all sub-component versions are consistent.

### 4.1.18. `cudnnPoolingBackward()`

This function computes the gradient of a pooling operation.

```c
cudnnStatus_t cudnnPoolingBackward(  
  cudnnHandle_t                        handle,  
  const cudnnPoolingDescriptor_t      poolingDesc,  
  const void                          *alpha,  
  const cudnnTensorDescriptor_t       yDesc,  
  const void                          *y,  
  const cudnnTensorDescriptor_t       dyDesc,  
  const void                          *dy,  
  const cudnnTensorDescriptor_t       xDesc,  
  const void                          *xData,  
  const void                          *beta,  
  const cudnnTensorDescriptor_t       dxDesc,  
  void                                *dx)
```

As of cuDNN version 6.0, a deterministic algorithm is implemented for max backwards pooling. This algorithm can be chosen via the pooling mode enum of poolingDesc. The
a deterministic algorithm has been measured to be up to 50% slower than the legacy max backwards pooling algorithm, or up to 20% faster, depending upon the use case.

**Note:** Tensor vectorization is not supported for any tensor descriptor arguments in this function. Best performance is expected when using HW-packed tensors. Only 2 and 3 spatial dimensions are supported.

cudnnPoolingBackward() allows both \( x \) and \( y \) data pointers (together with the related tensor descriptor handles) to be NULL for avg-pooling. This could save memory footprint and bandwidth.

**Parameters**

**handle**

*Input.* Handle to a previously created cuDNN context.

**poolingDesc**

*Input.* Handle to the previously initialized pooling descriptor.

**alpha, beta**

*Input.* Pointers to scaling factors (in host memory) used to blend the computation result with prior value in the output layer as follows:

\[
dstValue = alpha[0]*resultValue + beta[0]*priorDstValue
\]

For more information, refer to **Scaling Parameters**.

**yDesc**

*Input.* Handle to the previously initialized input tensor descriptor. Can be NULL for average pooling.

**y**

*Input.* Data pointer to GPU memory associated with the tensor descriptor `yDesc`. Can be NULL for average pooling.

**dyDesc**

*Input.* Handle to the previously initialized input differential tensor descriptor. Must be of type `FLOAT`, `DOUBLE`, `HALF`, or `BFLOAT16`. For more information, refer to [cudnnDataType_t](#).

**dy**

*Input.* Data pointer to GPU memory associated with the tensor descriptor `dyData`.

**xDesc**

*Input.* Handle to the previously initialized output tensor descriptor. Can be NULL for average pooling.

**x**

*Input.* Data pointer to GPU memory associated with the output tensor descriptor `xDesc`. Can be NULL for average pooling.

**dxDesc**

*Input.* Handle to the previously initialized output differential tensor descriptor. Must be of type `FLOAT`, `DOUBLE`, `HALF`, or `BFLOAT16`. For more information, refer to [cudnnDataType_t](#).
dx

Output. Data pointer to GPU memory associated with the output tensor descriptor dxDesc.

Returns

CUDNN_STATUS_SUCCESS
The function launched successfully.

CUDNN_STATUS_BAD_PARAM
At least one of the following conditions are met:

- The dimensions n, c, h, w of the yDesc and dyDesc tensors differ.
- The strides nStride, cStride, hStride, wStride of the yDesc and dyDesc tensors differ.
- The dimensions n, c, h, w of the dxDesc and dxDesc tensors differ.
- The strides nStride, cStride, hStride, wStride of the xDesc and dxDesc tensors differ.
- The datatype of the four tensors differ.

CUDNN_STATUS_NOT_SUPPORTED
The function does not support the provided configuration. See the following for some examples of non-supported configurations:

- The wStride of input tensor or output tensor is not 1.

CUDNN_STATUS_EXECUTION_FAILED
The function failed to launch on the GPU.

4.1.19. cudnnSoftmaxBackward()

This routine computes the gradient of the softmax function.

```c
  cudnnStatus_t cudnnSoftmaxBackward(
    cudnnHandle_t                    handle,
    cudnnSoftmaxAlgorithm_t          algorithm,
    cudnnSoftmaxMode_t               mode,
    const void                      *alpha,
    const cudnnTensorDescriptor_t    yDesc,
    const void                      *yData,
    const cudnnTensorDescriptor_t    dyDesc,
    const void                      *dy,
    const void                      *beta,
    const cudnnTensorDescriptor_t    dxDesc,
    void                            *dx)
```

In-place operation is allowed for this routine; meaning, dy and dx pointers may be equal. However, this requires dyDesc and dxDesc descriptors to be identical (particularly, the strides of the input and output must match for in-place operation to be allowed).

All tensor formats are supported for all modes and algorithms with 4 and 5D tensors. Performance is expected to be highest with NCHW fully-packed tensors. For more than 5 dimensions tensors must be packed in their spatial dimensions.
Data Types

This function supports the following data types:

- CUDNN_DATA_FLOAT
- CUDNN_DATA_DOUBLE
- CUDNN_DATA_HALF
- CUDNN_DATA_BFLOAT16

Parameters

**handle**

*Input*. Handle to a previously created cuDNN context.

**algorithm**

*Input*. Enumerant to specify the softmax algorithm.

**mode**

*Input*. Enumerant to specify the softmax mode.

**alpha, beta**

*Input*. Pointers to scaling factors (in host memory) used to blend the computation result with prior value in the output layer as follows:

\[
dstValue = \alpha[0] \times \text{result} + \beta[0] \times \text{priorDstValue}
\]

For more information, refer to [Scaling Parameters](#).

**yDesc**

*Input*. Handle to the previously initialized input tensor descriptor.

**y**

*Input*. Data pointer to GPU memory associated with the tensor descriptor *yDesc*.

**dyDesc**

*Input*. Handle to the previously initialized input differential tensor descriptor.

**dy**

*Input*. Data pointer to GPU memory associated with the tensor descriptor *dyData*.

**dxDesc**

*Input*. Handle to the previously initialized output differential tensor descriptor.

**dx**

*Output*. Data pointer to GPU memory associated with the output tensor descriptor *dxDesc*.

Returns

**CUDNN_STATUS_SUCCESS**

The function launched successfully.

**CUDNN_STATUS_NOT_SUPPORTED**

The function does not support the provided configuration.
CUDNN_STATUS_BAD_PARAM
At least one of the following conditions are met:

- The dimensions \( n, c, h, w \) of the \( yDesc \), \( dyDesc \) and \( dxDesc \) tensors differ.
- The strides \( nStride, cStride, hStride, wStride \) of the \( yDesc \) and \( dyDesc \) tensors differ.
- The datatype of the three tensors differs.

CUDNN_STATUS_EXECUTION_FAILED
The function failed to launch on the GPU.

4.1.20. cudnnSpatialTfGridGeneratorBackward()

This function computes the gradient of a grid generation operation.

```c
int cudnnSpatialTfGridGeneratorBackward(
    cudnnHandle_t handle,
    const cudnnSpatialTransformerDescriptor_t stDesc,
    const void *dgrid,
    void *dtheta
)
```

Only 2d transformation is supported.

Parameters

**handle**

*Input*. Handle to a previously created cuDNN context.

**stDesc**

*Input*. Previously created spatial transformer descriptor object.

**dgrid**

*Input*. Data pointer to GPU memory contains the input differential data.

**dtheta**

*Output*. Data pointer to GPU memory contains the output differential data.

Returns

CUDNN_STATUS_SUCCESS
The call was successful.

CUDNN_STATUS_BAD_PARAM
At least one of the following conditions are met:

- handle is NULL.
- One of the parameters dgrid or dtheta is NULL.

CUDNN_STATUS_NOT_SUPPORTED
The function does not support the provided configuration. See the following for some examples of non-supported configurations:

- The dimension of the transformed tensor specified in \( stDesc > 4 \).
The function failed to launch on the GPU.

4.1.21. **cudnnSpatialTfSamplerBackward()**

This function computes the gradient of a sampling operation.

```c
void cudnnSpatialTfSamplerBackward(
    cudnnHandle_t handle,
    const cudnnSpatialTransformerDescriptor_t stDesc,
    const void *alpha,
    const cudnnTensorDescriptor_t xDesc,
    const void *x,
    const void *beta,
    const cudnnTensorDescriptor_t dxDesc,
    void *dx,
    const void *alphaDgrid,
    const cudnnTensorDescriptor_t dyDesc,
    const void *dy,
    const void *grid,
    const void *betaDgrid,
    void *dgrid)
```

Only 2d transformation is supported.

**Parameters**

**handle**

*Input*. Handle to a previously created cuDNN context.

**stDesc**

*Input*. Previously created spatial transformer descriptor object.

**alpha, beta**

*Input*. Pointers to scaling factors (in host memory) used to blend the source value with prior value in the destination tensor as follows:

\[ \text{dstValue} = \alpha[0] \times \text{srcValue} + \beta[0] \times \text{priorDstValue} \]

For more information, refer to [Scaling Parameters](#).

**xDesc**

*Input*. Handle to the previously initialized input tensor descriptor.

**x**

*Input*. Data pointer to GPU memory associated with the tensor descriptor xDesc.

**dxDesc**

*Input*. Handle to the previously initialized output differential tensor descriptor.

**dx**

*Output*. Data pointer to GPU memory associated with the output tensor descriptor dxDesc.

**alphaDgrid, betaDgrid**

*Input*. Pointers to scaling factors (in host memory) used to blend the gradient outputs dgrid with prior value in the destination pointer as follows:

\[ \text{dstValue} = \alpha[0] \times \text{srcValue} + \beta[0] \times \text{priorDstValue} \]

For more information, refer to [Scaling Parameters](#).
dyDesc

*Input.* Handle to the previously initialized input differential tensor descriptor.

dy

*Input.* Data pointer to GPU memory associated with the tensor descriptor dyDesc.

grid

*Input.* A grid of coordinates generated by cudnnSpatialTfGridGeneratorForward().

dgrid

*Output.* Data pointer to GPU memory contains the output differential data.

**Returns**

**CUDNN_STATUS_SUCCESS**

The call was successful.

**CUDNN_STATUS_BAD_PARAM**

At least one of the following conditions are met:

- handle is NULL.
- One of the parameters x, dx, y, dy, grid, dgrid is NULL.
- The dimension of dy differs from those specified in stDesc.

**CUDNN_STATUS_NOT_SUPPORTED**

The function does not support the provided configuration. See the following for some examples of non-supported configurations:

- The dimension of transformed tensor > 4.

**CUDNN_STATUS_EXECUTION_FAILED**

The function failed to launch on the GPU.
Chapter 5. cudnn_cnn_infer.so Library

This entity contains all routines related to convolutional neural networks needed at inference time. The cudnn_cnn_infer library depends on cudnn_ops_infer.

For the backend data and descriptor types, refer to the cuDNN Backend API section.

5.1. Data Type References

These are the data type references in the cudnn_cnn_infer.so library.

5.1.1. Pointer To Opaque Struct Types

These are the pointers to the opaque struct types in the cudnn_cnn_infer.so library.

5.1.1.1. cudnnConvolutionDescriptor_t

cudnnConvolutionDescriptor_t is a pointer to an opaque structure holding the description of a convolution operation. cudnnCreateConvolutionDescriptor() is used to create one instance, and cudnnSetConvolutionNdDescriptor() or cudnnSetConvolution2dDescriptor() must be used to initialize this instance.

5.1.2. Struct Types

These are the struct types in the cudnn_cnn_infer.so library.

5.1.2.1. cudnnConvolutionBwdDataAlgoPerf_t

cudnnConvolutionBwdDataAlgoPerf_t is a structure containing performance results returned by cudnnFindConvolutionBackwardDataAlgorithm() or heuristic results returned by cudnnGetConvolutionBackwardDataAlgorithm_v7().

Data Members

- cudnnConvolutionBwdDataAlgo_t algo
  - The algorithm runs to obtain the associated performance metrics.
cudnnStatus_t status
If any error occurs during the workspace allocation or timing of
cudnnConvolutionBackwardData(), this status will represent that error. Otherwise,
this status will be the return status of cudnnConvolutionBackwardData().

- CUDNN_STATUS_ALLOC_FAILED if any error occurred during workspace allocation or if
  the provided workspace is insufficient.
- CUDNN_STATUS_INTERNAL_ERROR if any error occurred during timing calculations or
  workspace deallocation.
- Otherwise, this will be the return status of cudnnConvolutionBackwardData().

float time
The execution time of cudnnConvolutionBackwardData() (in milliseconds).

size_t memory
The workspace size (in bytes).

cudnnDeterminism_t determinism
The determinism of the algorithm.

cudnnMathType_t mathType
The math type provided to the algorithm.

int reserved[3]
Reserved space for future properties.

5.1.2.2. cudnnConvolutionFwdAlgoPerf_t

cudnnConvolutionFwdAlgoPerf_t is a structure containing performance results
returned by cudnnFindConvolutionForwardAlgorithm() or heuristic results returned by
cudnnGetConvolutionForwardAlgorithm_v7().

Data Members

cudnnConvolutionFwdAlgo_t algo
The algorithm runs to obtain the associated performance metrics.

cudnnStatus_t status
If any error occurs during the workspace allocation or timing of
cudnnConvolutionForward(), this status will represent that error. Otherwise, this
status will be the return status of cudnnConvolutionForward().

- CUDNN_STATUS_ALLOC_FAILED if any error occurred during workspace allocation or if
  the provided workspace is insufficient.
- CUDNN_STATUS_INTERNAL_ERROR if any error occurred during timing calculations or
  workspace deallocation.
- Otherwise, this will be the return status of cudnnConvolutionForward().

float time
The execution time of cudnnConvolutionForward() (in milliseconds).
size_t memory
    The workspace size (in bytes).
cudnnDeterminism_t determinism
    The determinism of the algorithm.
cudnnMathType_t mathType
    The math type provided to the algorithm.
int reserved[3]
    Reserved space for future properties.

5.1.3.  Enumeration Types
These are the enumeration types in the cudnn_cnn_infer.so library.

5.1.3.1.  cudnnConvolutionBwdDataAlgo_t

cudnnConvolutionBwdDataAlgo_t is an enumerated type that exposes the different algorithms available to execute the backward data convolution operation.

Values

CUDNN_CONVOLUTION_BWD_DATA_ALGO_0
    This algorithm expresses the convolution as a sum of matrix products without actually explicitly forming the matrix that holds the input tensor data. The sum is done using the atomic add operation, thus the results are non-deterministic.

CUDNN_CONVOLUTION_BWD_DATA_ALGO_1
    This algorithm expresses the convolution as a matrix product without actually explicitly forming the matrix that holds the input tensor data. The results are deterministic.

CUDNN_CONVOLUTION_BWD_DATA_ALGO_FFT
    This algorithm uses a Fast-Fourier Transform approach to compute the convolution. A significant memory workspace is needed to store intermediate results. The results are deterministic.

CUDNN_CONVOLUTION_BWD_DATA_ALGO_FFT_TILING
    This algorithm uses the Fast-Fourier Transform approach but splits the inputs into tiles. A significant memory workspace is needed to store intermediate results but less than CUDNN_CONVOLUTION_BWD_DATA_ALGO_FFT for large size images. The results are deterministic.

CUDNN_CONVOLUTION_BWD_DATA_ALGO_WINOGRAD
    This algorithm uses the Winograd Transform approach to compute the convolution. A reasonably sized workspace is needed to store intermediate results. The results are deterministic.

CUDNN_CONVOLUTION_BWD_DATA_ALGO_WINOGRAD_NONFUSED
    This algorithm uses the Winograd Transform approach to compute the convolution. A significant workspace may be needed to store intermediate results. The results are deterministic.
5.1.3.2. cudnnConvolutionBwdFilterAlgo_t

cudnnConvolutionBwdFilterAlgo_t is an enumerated type that exposes the different algorithms available to execute the backward filter convolution operation.

Values

**CUDNN_CONVOLUTION_BWD_FILTER_ALGO_0**
This algorithm expresses the convolution as a sum of matrix products without actually explicitly forming the matrix that holds the input tensor data. The sum is done using the atomic add operation, thus the results are non-deterministic.

**CUDNN_CONVOLUTION_BWD_FILTER_ALGO_1**
This algorithm expresses the convolution as a matrix product without actually explicitly forming the matrix that holds the input tensor data. The results are deterministic.

**CUDNN_CONVOLUTION_BWD_FILTER_ALGO_FFT**
This algorithm uses the Fast-Fourier Transform approach to compute the convolution. A significant workspace is needed to store intermediate results. The results are deterministic.

**CUDNN_CONVOLUTION_BWD_FILTER_ALGO_3**
This algorithm is similar to CUDNN_CONVOLUTION_BWD_FILTER_ALGO_0 but uses some small workspace to precompute some indices. The results are also non-deterministic.

**CUDNN_CONVOLUTION_BWD_FILTER_WINOGRAD_NONFUSED**
This algorithm uses the Winograd Transform approach to compute the convolution. A significant workspace may be needed to store intermediate results. The results are deterministic.

**CUDNN_CONVOLUTION_BWD_FILTER_ALGO_FFT_TILING**
This algorithm uses the Fast-Fourier Transform approach to compute the convolution but splits the input tensor into tiles. A significant workspace may be needed to store intermediate results. The results are deterministic.

5.1.3.3. cudnnConvolutionFwdAlgo_t

cudnnConvolutionFwdAlgo_t is an enumerated type that exposes the different algorithms available to execute the forward convolution operation.

Values

**CUDNN_CONVOLUTION_FWD_ALGO_IMPLICIT_GEMM**
This algorithm expresses the convolution as a matrix product without actually explicitly forming the matrix that holds the input tensor data.

**CUDNN_CONVOLUTION_FWD_ALGO_IMPLICIT_PRECOMP_GEMM**
This algorithm expresses convolution as a matrix product without actually explicitly forming the matrix that holds the input tensor data, but still needs some memory workspace to precompute some indices in order to facilitate the implicit construction of the matrix that holds the input tensor data.
**CUDNN_CONVOLUTION_FWD_ALGO_GEMM**
This algorithm expresses the convolution as an explicit matrix product. A significant memory workspace is needed to store the matrix that holds the input tensor data.

**CUDNN_CONVOLUTION_FWD_ALGO_DIRECT**
This algorithm expresses the convolution as a direct convolution (for example, without implicitly or explicitly doing a matrix multiplication).

**CUDNN_CONVOLUTION_FWD_ALGO_FFT**
This algorithm uses the Fast-Fourier Transform approach to compute the convolution. A significant memory workspace is needed to store intermediate results.

**CUDNN_CONVOLUTION_FWD_ALGO_FFT_TILING**
This algorithm uses the Fast-Fourier Transform approach but splits the inputs into tiles. A significant memory workspace is needed to store intermediate results but less than **CUDNN_CONVOLUTION_FWD_ALGO_FFT** for large size images.

**CUDNN_CONVOLUTION_FWD_ALGO_WINOGRAD**
This algorithm uses the Winograd Transform approach to compute the convolution. A reasonably sized workspace is needed to store intermediate results.

**CUDNN_CONVOLUTION_FWD_ALGO_WINOGRAD_NONFUSED**
This algorithm uses the Winograd Transform approach to compute the convolution. A significant workspace may be needed to store intermediate results.

### 5.1.3.4. cudnnConvolutionMode_t

cudnnConvolutionMode_t is an enumerated type used by cudnnSetConvolution2dDescriptor() to configure a convolution descriptor. The filter used for the convolution can be applied in two different ways, corresponding mathematically to a convolution or to a cross-correlation. (A cross-correlation is equivalent to a convolution with its filter rotated by 180 degrees.)

**Values**

**CUDNN_CONVOLUTION**
In this mode, a convolution operation will be done when applying the filter to the images.

**CUDNN_CROSS_CORRELATION**
In this mode, a cross-correlation operation will be done when applying the filter to the images.

### 5.1.3.5. cudnnReorderType_t

cudnnReorderType_t is an enumerated type to set the convolution reordering type. The reordering type can be set by cudnnSetConvolutionReorderType() and its status can be read by cudnnGetConvolutionReorderType().

```c
typedef enum {
    CUDNN_DEFAULT_REORDER = 0,
    CUDNN_NO_REORDER      = 1,
} cudnnReorderType_t;
```
5.2. **API Functions**

These are the API functions in the **cudnn_cnn_infer.so** library.

### 5.2.1. **cudnnCnnInferVersionCheck()**

This function checks whether the version of the CnnInfer subset of the library is consistent with the other sub-libraries.

```c
void cudnnCnnInferVersionCheck()
```

**Returns**

- **CUDNN_STATUS_SUCCESS**
  - The version is consistent with other sub-libraries.
- **CUDNN_STATUS_VERSION_MISMATCH**
  - The version of CnnInfer is not consistent with other sub-libraries. Users should check the installation and make sure all sub-component versions are consistent.

### 5.2.2. **cudnnConvolutionBackwardData()**

This function computes the convolution data gradient of the tensor `dy`, where `y` is the output of the forward convolution in **cudnnConvolutionForward()**. It uses the specified `algo`, and returns the results in the output tensor `dx`. Scaling factors `alpha` and `beta` can be used to scale the computed result or accumulate with the current `dx`.

```c
void cudnnConvolutionBackwardData(    
    cudnnHandle_t                       handle,    
    const void                         *alpha,    
    const cudnnFilterDescriptor_t       wDesc,    
    const void                         *w,    
    const cudnnTensorDescriptor_t       dyDesc,    
    const void                         *dy,    
    const cudnnConvolutionDescriptor_t  convDesc,    
    cudnnConvolutionBwdDataAlgo_t       algo,    
    void                               *workSpace,    
    size_t                              workSpaceSizeInBytes,    
    const void                         *beta,    
    const cudnnTensorDescriptor_t       dxDesc,    
    void                               *dx)
```

**Parameters**

- **handle**
  - *Input*. Handle to a previously created cuDNN context. For more information, refer to **cudnnHandle_t**.

- **alpha, beta**
  - *Input*. Pointers to scaling factors (in host memory) used to blend the computation result with prior value in the output layer as follows:
    ```c
    dstValue = alpha[0]*result + beta[0]*priorDstValue
    ```
  - For more information, refer to **Scaling Parameters**.
**wDesc**

*Input.* Handle to a previously initialized filter descriptor. For more information, refer to `cudnnFilterDescriptor_t`.

**w**

*Input.* Data pointer to GPU memory associated with the filter descriptor `wDesc`.

**dyDesc**

*Input.* Handle to the previously initialized input differential tensor descriptor. For more information, refer to `cudnnTensorDescriptor_t`.

**dy**

*Input.* Data pointer to GPU memory associated with the input differential tensor descriptor `dyDesc`.

**convDesc**

*Input.* Previously initialized convolution descriptor. For more information, refer to `cudnnConvolutionDescriptor_t`.

**algo**

*Input.* Enumerant that specifies which backward data convolution algorithm should be used to compute the results. For more information, refer to `cudnnConvolutionBwdDataAlgo_t`.

**workSpace**

*Input.* Data pointer to GPU memory to a workspace needed to be able to execute the specified algorithm. If no workspace is needed for a particular algorithm, that pointer can be **NIL**.

**workSpaceSizeInBytes**

*Input.* Specifies the size in bytes of the provided `workSpace`.

**dxDesc**

*Input.* Handle to the previously initialized output tensor descriptor.

**dx**

*Input/Output.* Data pointer to GPU memory associated with the output tensor descriptor `dxDesc` that carries the result.

---

### Supported configurations

This function supports the following combinations of data types for `wDesc`, `dyDesc`, `convDesc`, and `dxDesc`.

#### Table 19. Supported Configurations for `cudnnConvolutionBackwardData()`

<table>
<thead>
<tr>
<th>Data Type Configurations</th>
<th><strong>wDesc</strong>, <strong>dyDesc</strong> and <strong>dxDesc</strong> Data Type</th>
<th><strong>convDesc</strong> Data Type</th>
</tr>
</thead>
<tbody>
<tr>
<td>TRUE_HALF_CONFIG (only supported on architectures with true FP16 support,)</td>
<td>CUDNN_DATA_HALF</td>
<td>CUDNN_DATA_HALF</td>
</tr>
</tbody>
</table>
### Data Type Configurations

<table>
<thead>
<tr>
<th>Data Type Configuration</th>
<th>( w\text{Desc}, dy\text{Desc} ) and ( dx\text{Desc} ) Data Type</th>
<th>convDesc Data Type</th>
</tr>
</thead>
<tbody>
<tr>
<td>PSEUDO_HALF_CONFIG</td>
<td>CUDNN_DATA_HALF</td>
<td>CUDNN_DATA_FLOAT</td>
</tr>
<tr>
<td>PSEUDO_BFLOAT16_CONFIG</td>
<td>CUDNN_DATA_BFLOAT16</td>
<td>CUDNN_DATA_FLOAT</td>
</tr>
<tr>
<td>FLOAT_CONFIG</td>
<td>CUDNN_DATA_FLOAT</td>
<td>CUDNN_DATA_FLOAT</td>
</tr>
<tr>
<td>DOUBLE_CONFIG</td>
<td>CUDNN_DATA_DOUBLE</td>
<td>CUDNN_DATA_DOUBLE</td>
</tr>
</tbody>
</table>

### Supported algorithms

Note: Specifying a separate algorithm can cause changes in performance, support and computation determinism. See the following for a list of algorithm options, and their respective supported parameters and deterministic behavior.

The table below shows the list of the supported 2D and 3D convolutions. The 2D convolutions are described first, followed by the 3D convolutions.

For the following terms, the short-form versions shown in the parentheses are used in the table below, for brevity:

- CUDNN\_CONVOLUTION\_BWD\_DATA\_ALGO\_0 \(_{\text{ALGO}_0}\)
- CUDNN\_CONVOLUTION\_BWD\_DATA\_ALGO\_1 \(_{\text{ALGO}_1}\)
- CUDNN\_CONVOLUTION\_BWD\_DATA\_ALGO\_FFT \(_{\text{FFT}}\)
- CUDNN\_CONVOLUTION\_BWD\_DATA\_ALGO\_FFT\_TILING \(_{\text{FFT\_TILING}}\)
- CUDNN\_CONVOLUTION\_BWD\_DATA\_ALGO\_WINOGRAD \(_{\text{WINOGRAD}}\)
- CUDNN\_CONVOLUTION\_BWD\_DATA\_ALGO\_WINOGRAD\_NONFUSED \(_{\text{WINOGRAD\_NONFUSED}}\)
- CUDNN\_TENSOR\_NCHW \(_{\text{NCHW}}\)
- CUDNN\_TENSOR\_NHWC \(_{\text{NHWC}}\)
- CUDNN\_TENSOR\_NCHW\_VECT\_C \(_{\text{NCHW\_VECT\_C}}\)
## Table 20. Supported Algorithms for `cudnnConvolutionBackwardData()` 2D Convolutions: wDesc: _NHWC

The **Filter descriptor** wDesc: _NHWC (refer to `cudnnTensorFormat_t`)

<table>
<thead>
<tr>
<th>Algo Name</th>
<th>Deterministic (Yes or No)</th>
<th>Tensor Formats Supported for dyDesc</th>
<th>Tensor Formats Supported for dxDesc</th>
<th>Data Type Configuration Supported</th>
<th>Important</th>
</tr>
</thead>
<tbody>
<tr>
<td>_ALGO_0</td>
<td></td>
<td>NHWC HWC-packed</td>
<td>NHWC HWC-packed</td>
<td>TRUE_HALF_CONFIG</td>
<td></td>
</tr>
<tr>
<td>_ALGO_1</td>
<td></td>
<td></td>
<td></td>
<td>PSEUDO_HALF_CONFIG</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>PSEUDO_BFLOAT16_CONFIG</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>FLOAT_CONFIG</td>
<td></td>
</tr>
</tbody>
</table>

## Table 21. Supported Algorithms for `cudnnConvolutionBackwardData()` 2D Convolutions: wDesc: _NCHW

The **Filter descriptor** wDesc: _NCHW.

<table>
<thead>
<tr>
<th>Algo Name</th>
<th>Deterministic (Yes or No)</th>
<th>Tensor Formats Supported for dyDesc</th>
<th>Tensor Formats Supported for dxDesc</th>
<th>Data Type Configuration Supported</th>
<th>Important</th>
</tr>
</thead>
<tbody>
<tr>
<td>_ALGO_0</td>
<td>No</td>
<td>NCHW CHW-packed</td>
<td>All except _NCHW_VECT_C</td>
<td>TRUE_HALF_CONFIG</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>PSEUDO_HALF_CONFIG</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>PSEUDO_BFLOAT16_CONFIG</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>FLOAT_CONFIG</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>DOUBLE_CONFIG</td>
<td></td>
</tr>
</tbody>
</table>

| _ALGO_1   | Yes                       | NCHW CHW-packed                     | All except _NCHW_VECT_C             | TRUE_HALF_CONFIG                 |           |
|           |                           |                                     |                                     | PSEUDO_HALF_CONFIG               |           |
|           |                           |                                     |                                     | PSEUDO_BFLOAT16_CONFIG           |           |
|           |                           |                                     |                                     | FLOAT_CONFIG                      |           |
|           |                           |                                     |                                     | DOUBLE_CONFIG                     |           |

**Dilation:** greater than 0 for all dimensions

**convDesc:** Group Count Support: Greater than 0

**Dilation:** greater than 0 for all dimensions

**convDesc:** Group Count Support: Greater than 0
<table>
<thead>
<tr>
<th>Algo Name</th>
<th>Deterministic (Yes or No)</th>
<th>Tensor Formats Supported for dyDesc</th>
<th>Tensor Formats Supported for dxDesc</th>
<th>Data Type Configuration Supported</th>
<th>Important</th>
</tr>
</thead>
<tbody>
<tr>
<td>_FFT</td>
<td>Yes</td>
<td>NCHW CHW-packed</td>
<td>NCHW HW-packed</td>
<td>PSEUDO_HALF_CONFIG, FLOAT_CONFIG</td>
<td>Dilation: 1 for all dimensions convDesc Group Count Support: Greater than 0 dxDesc feature map height + 2 * convDesc zero-padding height must equal 256 or less dxDesc feature map width + 2 * convDesc zero-padding width must equal 256 or less convDesc vertical and horizontal filter stride must equal 1 wDesc filter height must be greater than convDesc zero-padding height wDesc filter width must be greater than convDesc zero-padding width</td>
</tr>
</tbody>
</table>
**Filter descriptor** \( wDesc: \text{ NCHW} \).

<table>
<thead>
<tr>
<th>Algo Name</th>
<th>Deterministic (Yes or No)</th>
<th>Tensor Formats Supported for dyDesc</th>
<th>Tensor Formats Supported for dxDesc</th>
<th>Data Type Configuration Supported</th>
<th>Important</th>
</tr>
</thead>
<tbody>
<tr>
<td>_FFT_TILING</td>
<td>Yes</td>
<td>NCHW CHW-packed</td>
<td>NCHW HW-packed</td>
<td>PSEUDO_HALF_CONFIG, FLOAT_CONFIG, DOUBLE_CONFIG</td>
<td>1 for all dimensions when the task can be handled by 1D FFT, meaning, one of the filter dimensions, width or height is 1. ConvDesc Group Count Support: Greater than 0. When neither of ( wDesc ) filter dimension is 1, the filter width and height must not be larger than 32. When either of ( wDesc ) filter dimension is 1, the largest filter dimension should not exceed 256. ConvDesc vertical and horizontal filter stride must equal 1 when either the filter width or filter height is 1, otherwise, the...</td>
</tr>
</tbody>
</table>
Filter descriptor \texttt{wDesc: _NCHW}.

<table>
<thead>
<tr>
<th>Algo Name</th>
<th>Deterministic (Yes or No)</th>
<th>Tensor Formats Supported for dyDesc</th>
<th>Tensor Formats Supported for dxDesc</th>
<th>Data Type Configuration Supported</th>
<th>Important</th>
</tr>
</thead>
<tbody>
<tr>
<td>_WINOGRAD</td>
<td>Yes</td>
<td>NCHW CHW-packed</td>
<td>All except _NCHW_VECT_C, PSEUDO_HALF_CONFIG, FLOAT_CONFIG</td>
<td>PSEUDO_HALF_CONFIG</td>
<td>\textbf{Dilation}: 1 for all dimensions</td>
</tr>
<tr>
<td>_WINOGRAD_NONFUSED</td>
<td>Yes</td>
<td>NCHW CHW-packed</td>
<td>All except _NCHW_VECT_C, TRUE_HALF_CONFIG, PSEUDO_HALF_CONFIG, PSEUDO_BFLOAT16_CONFIG</td>
<td>TRUE_HALF_CONFIG</td>
<td>\textbf{Dilation}: 1 for all dimensions</td>
</tr>
</tbody>
</table>
**Filter descriptor** $w_{\text{Desc}}$: _NCHW_.

<table>
<thead>
<tr>
<th>Algo Name</th>
<th>Deterministic (Yes or No)</th>
<th>Tensor Formats Supported for $dy_{\text{Desc}}$</th>
<th>Tensor Formats Supported for $dx_{\text{Desc}}$</th>
<th>Data Type Configuration Supported</th>
<th>Important</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>FLOAT_CONFIG</td>
<td>convDesc</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Group Count Support: Greater than 0</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>convDesc vertical and horizontal filter stride must equal 1</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>$w_{\text{Desc}}$ filter (height, width) must be (3,3) or (5,5)</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>If $w_{\text{Desc}}$ filter (height, width) is (5,5) then the data type config TRUE_HALF_CONFIG is not supported</td>
<td></td>
</tr>
</tbody>
</table>

Table 22. Supported Algorithms for `cudnnConvolutionBackwardData()`

**3D Convolutions:** $w_{\text{Desc}}$: _NCHW_

**Filter descriptor** $w_{\text{Desc}}$: _NCHW_.

<table>
<thead>
<tr>
<th>Algo Name</th>
<th>Deterministic (Yes or No)</th>
<th>Tensor Formats Supported for $dy_{\text{Desc}}$</th>
<th>Tensor Formats Supported for $dx_{\text{Desc}}$</th>
<th>Data Type Configuration Supported</th>
<th>Important</th>
</tr>
</thead>
<tbody>
<tr>
<td>_ALGO_0</td>
<td>Yes</td>
<td>NCDHW CDHW-packed</td>
<td>All except _NCDHW_VECT_C PSEUDO_HALF_CONFIG PSEUDO_BFLOAT16_CONFIG FLOAT_CONFIG</td>
<td>PSEUDO_HALF_CONFIG</td>
<td>Dilation: greater than 0 for all dimensions</td>
</tr>
</tbody>
</table>
**Filter descriptor** \( \text{wDesc: } _\text{NCHW}. \)

<table>
<thead>
<tr>
<th>Algo Name</th>
<th>Deterministic (Yes or No)</th>
<th>Tensor Formats Supported for dyDesc</th>
<th>Tensor Formats Supported for dxDesc</th>
<th>Data Type Configuration Supported</th>
<th>Important</th>
</tr>
</thead>
<tbody>
<tr>
<td>_ALGO_1</td>
<td>Yes</td>
<td>NCDHW</td>
<td>NCDHW</td>
<td>TRUE_HALF_CONFIG</td>
<td><strong>Group Count Support:</strong> Greater than 0</td>
</tr>
<tr>
<td></td>
<td></td>
<td>CDHW-packed</td>
<td>CDHW-packed</td>
<td>PSEUDO_HALF_CONFIG</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>PSEUDO_FLOAT_CONFIG</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>DOUBLE_CONFIG</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td><strong>Dilation:</strong> 1 for all dimensions</td>
<td></td>
</tr>
<tr>
<td>_FFT_TILING</td>
<td>Yes</td>
<td>NCDHW</td>
<td>NCDHW</td>
<td>PSEUDO_HALF_CONFIG</td>
<td><strong>Group Count Support:</strong> Greater than 0</td>
</tr>
<tr>
<td></td>
<td></td>
<td>CDHW-packed</td>
<td>CDHW-packed</td>
<td>FLOAT_CONFIG</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>DOUBLE_CONFIG</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td><strong>Dilation:</strong> 1 for all dimensions</td>
<td></td>
</tr>
</tbody>
</table>

\( \text{convDesc} \)

\( \text{wDesc} \) filter height must equal 16 or less

\( \text{wDesc} \) filter width must equal 16 or less

\( \text{wDesc} \) filter depth must equal 16 or less

\( \text{convDesc} \) must have all filter strides equal to 1

\( \text{wDesc} \) filter height must
### Filter descriptor wDesc: _NCHW.

<table>
<thead>
<tr>
<th>Algo Name (3D Convolutions)</th>
<th>Deterministic (Yes or No)</th>
<th>Tensor Formats Supported for dyDesc</th>
<th>Tensor Formats Supported for dxDesc</th>
<th>Data Type Configuration Supported</th>
<th>Important</th>
</tr>
</thead>
<tbody>
<tr>
<td>_ALGO_1</td>
<td>Yes</td>
<td>NDHWC</td>
<td>NDHWC</td>
<td>TRUE_HALF_CONFIG</td>
<td>Dilation:</td>
</tr>
<tr>
<td></td>
<td></td>
<td>DHWC-packed</td>
<td>DHWC-packed</td>
<td>PSEUDO_HALF_CONFIG</td>
<td>Greater than 0 for all dimensions</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>PSEUDO_BFLOAT16_CONFIG</td>
<td>convDesc</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>FLOAT_CONFIG</td>
<td>Group Count Support:</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Greater than 0</td>
</tr>
</tbody>
</table>

Table 23. Supported Algorithms for cudnnConvolutionBackwardData() 3D Convolutions: wDesc: _NHWC
Returns

**CUDNN_STATUS_SUCCESS**
The operation was launched successfully.

**CUDNN_STATUS_BAD_PARAM**
At least one of the following conditions are met:

- At least one of the following is NULL: handle, dyDesc, wDesc, convDesc, dxDesc, dy, w, dx, alpha, and beta
- wDesc and dyDesc have a non-matching number of dimensions
- wDesc and dxDesc have a non-matching number of dimensions
- wDesc has fewer than three number of dimensions
- wDesc, dxDesc, and dyDesc have a non-matching data type.
- wDesc and dxDesc have a non-matching number of input feature maps per image (or group in case of grouped convolutions).
- dyDesc spatial sizes do not match with the expected size as determined by cudnnGetConvolutionNdForwardOutputDim

**CUDNN_STATUS_NOT_SUPPORTED**
At least one of the following conditions are met:

- dyDesc or dxDesc have a negative tensor striding
- dyDesc, wDesc or dxDesc has a number of dimensions that is not 4 or 5
- The chosen algo does not support the parameters provided; see above for an exhaustive list of parameters that support each algo
- dyDesc or wDesc indicate an output channel count that isn’t a multiple of group count (if group count has been set in convDesc).

**CUDNN_STATUS_MAPPING_ERROR**
An error occurs during the texture binding of texture object creation associated with the filter data or the input differential tensor data.

**CUDNN_STATUS_EXECUTION_FAILED**
The function failed to launch on the GPU.

5.2.3. **cudnnConvolutionBiasActivationForward()**
This function applies a bias and then an activation to the convolutions or cross-correlations of **cudnnConvolutionForward()**, returning results in y. The full computation follows the equation \( y = \text{act} ( \alpha_1 \cdot \text{conv}(x) + \alpha_2 \cdot z + \text{bias} ) \).

```c
void cudnnConvolutionBiasActivationForward( 
    cudnnHandle_t handle, 
    const void *alpha1, 
    const cudnnTensorDescriptor_t xDesc, 
    const void *x, 
    const cudnnFilterDescriptor_t wDesc, 
    const void *w, 
    const cudnnConvolutionDescriptor_t convDesc, 
); 
```
cudnnConvolutionFwdAlgo_t algo,
void *workSpace, size_t workSpaceSizeInBytes, const void *alpha2,
const cudnnTensorDescriptor_t zDesc, const void *z,
const cudnnTensorDescriptor_t biasDesc, const void *bias,
const cudnnActivationDescriptor_t activationDesc,
const cudnnTensorDescriptor_t yDesc, void *y)}

The routine `cudnnGetConvolution2dForwardOutputDim()` or `cudnnGetConvolutionNdForwardOutputDim()` can be used to determine the proper dimensions of the output tensor descriptor `yDesc` with respect to `xDesc`, `convDesc`, and `wDesc`.

Only the `CUDNN_CONVOLUTION_FWD_ALGO_IMPLICIT_PRECOMP_GEMM` algo is enabled with `CUDNN_ACTIVATION_IDENTITY`. In other words, in the `cudnnActivationDescriptor_t` structure of the input `activationDesc`, if the mode of the `cudnnActivationMode_t` field is set to the enum value `CUDNN_ACTIVATION_IDENTITY`, then the input `cudnnConvolutionFwdAlgo_t` of this function `cudnnConvolutionBiasActivationForward()` must be set to the enum value `CUDNN_CONVOLUTION_FWD_ALGO_IMPLICIT_PRECOMP_GEMM`. For more information, refer to `cudnnSetActivationDescriptor()`.

Device pointer `z` and `y` may be pointing to the same buffer, however, `x` cannot point to the same buffer as `z` or `y`.

**Parameters**

**handle**

*Input*. Handle to a previously created cuDNN context. For more information, refer to `cudnnHandle_t`.

**alpha1, alpha2**

*Input*. Pointers to scaling factors (in host memory) used to blend the computation result of convolution with `z` and bias as follows:

\[ y = \text{act} \left( \alpha_1 \ast \text{conv}(x) + \alpha_2 \ast z + \text{bias} \right) \]

For more information, refer to Scaling Parameters.

**xDesc**

*Input*. Handle to a previously initialized tensor descriptor. For more information, refer to `cudnnTensorDescriptor_t`.

**x**

*Input*. Data pointer to GPU memory associated with the tensor descriptor `xDesc`.

**wDesc**

*Input*. Handle to a previously initialized filter descriptor. For more information, refer to `cudnnFilterDescriptor_t`.

**w**

*Input*. Data pointer to GPU memory associated with the filter descriptor `wDesc`. 

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**convDesc**
*Input*. Previously initialized convolution descriptor. For more information, refer to `cudnnConvolutionDescriptor_t`.

**algo**
*Input*. Enumerant that specifies which convolution algorithm should be used to compute the results. For more information, refer to `cudnnConvolutionFwdAlgo_t`.

**workSpace**
*Input*. Data pointer to GPU memory to a workspace needed to be able to execute the specified algorithm. If no workspace is needed for a particular algorithm, that pointer can be NIL.

**workSpaceSizeInBytes**
*Input*. Specifies the size in bytes of the provided `workSpace`.

**zDesc**
*Input*. Handle to a previously initialized tensor descriptor.

**z**
*Input*. Data pointer to GPU memory associated with the tensor descriptor `zDesc`.

**biasDesc**
*Input*. Handle to a previously initialized tensor descriptor.

**bias**
*Input*. Data pointer to GPU memory associated with the tensor descriptor `biasDesc`.

**activationDesc**
*Input*. Handle to a previously initialized activation descriptor. For more information, refer to `cudnnActivationDescriptor_t`.

**yDesc**
*Input*. Handle to a previously initialized tensor descriptor.

**y**
*Input/Output*. Data pointer to GPU memory associated with the tensor descriptor `yDesc` that carries the result of the convolution.

For the convolution step, this function supports the specific combinations of data types for `xDesc, wDesc, convDesc, and yDesc` as listed in the documentation of `cudnnConvolutionForward()`. The following table specifies the supported combinations of data types for `x, y, z, bias, and alpha1/alpha2`.

**Table 24. Supported Combinations of Data Types (x = CUDNN_DATA) for cudnnConvolutionBiasActivationForward()**

<table>
<thead>
<tr>
<th>x</th>
<th>w</th>
<th>convDesc</th>
<th>y and z</th>
<th>bias</th>
<th>alpha1/alpha2</th>
</tr>
</thead>
<tbody>
<tr>
<td>X_DOUBLE</td>
<td>X_DOUBLE</td>
<td>X_DOUBLE</td>
<td>X_DOUBLE</td>
<td>X_DOUBLE</td>
<td>X_DOUBLE</td>
</tr>
<tr>
<td>X_FLOAT</td>
<td>X_FLOAT</td>
<td>X_FLOAT</td>
<td>X_FLOAT</td>
<td>X_FLOAT</td>
<td>X_FLOAT</td>
</tr>
<tr>
<td>X_HALF</td>
<td>X_HALF</td>
<td>X_FLOAT</td>
<td>X_HALF</td>
<td>X_HALF</td>
<td>X_FLOAT</td>
</tr>
</tbody>
</table>
### cudnnCnnInfer.so

<table>
<thead>
<tr>
<th>x</th>
<th>w</th>
<th>convDesc</th>
<th>y and z</th>
<th>bias</th>
<th>alpha1/alpha2</th>
</tr>
</thead>
<tbody>
<tr>
<td>X_BFLOAT16</td>
<td>X_BFLOAT16</td>
<td>X_FLOAT</td>
<td>X_BFLOAT16</td>
<td>X_BFLOAT16</td>
<td>X_FLOAT</td>
</tr>
<tr>
<td>X_INT8</td>
<td>X_INT8</td>
<td>X_INT32</td>
<td>X_INT8</td>
<td>X_FLOAT</td>
<td>X_FLOAT</td>
</tr>
<tr>
<td>X_INT8</td>
<td>X_INT8</td>
<td>X_INT32</td>
<td>X_FLOAT</td>
<td>X_FLOAT</td>
<td>X_FLOAT</td>
</tr>
<tr>
<td>X_INT8x4</td>
<td>X_INT8x4</td>
<td>X_INT32</td>
<td>X_INT8x4</td>
<td>X_FLOAT</td>
<td>X_FLOAT</td>
</tr>
<tr>
<td>X_INT8x4</td>
<td>X_INT8x4</td>
<td>X_INT32</td>
<td>X_FLOAT</td>
<td>X_FLOAT</td>
<td>X_FLOAT</td>
</tr>
<tr>
<td>X_UINT8</td>
<td>X_INT8</td>
<td>X_INT32</td>
<td>X_INT8</td>
<td>X_FLOAT</td>
<td>X_FLOAT</td>
</tr>
<tr>
<td>X_UINT8</td>
<td>X_INT8</td>
<td>X_INT32</td>
<td>X_FLOAT</td>
<td>X_FLOAT</td>
<td>X_FLOAT</td>
</tr>
<tr>
<td>X_UINT8x4</td>
<td>X_INT8x4</td>
<td>X_INT32</td>
<td>X_INT8x4</td>
<td>X_FLOAT</td>
<td>X_FLOAT</td>
</tr>
<tr>
<td>X_UINT8x4</td>
<td>X_INT8x4</td>
<td>X_INT32</td>
<td>X_FLOAT</td>
<td>X_FLOAT</td>
<td>X_FLOAT</td>
</tr>
<tr>
<td>X_INT8x32</td>
<td>X_INT8x32</td>
<td>X_INT32</td>
<td>X_INT8x32</td>
<td>X_FLOAT</td>
<td>X_FLOAT</td>
</tr>
</tbody>
</table>

### Returns

In addition to the error values listed by the documentation of `cudnnConvolutionForward()`, the possible error values returned by this function and their meanings are listed below.

**CUDNN_STATUS_SUCCESS**

The operation was launched successfully.

**CUDNN_STATUS_BAD_PARAM**

At least one of the following conditions are met:

- At least one of the following is `NULL`: handle, xDesc, wDesc, convDesc, yDesc, zDesc, biasDesc, activationDesc, xData, wData, yData, zData, bias, alpha1, and alpha2.

- The number of dimensions of xDesc, wDesc, yDesc, and zDesc is not equal to the array length of convDesc + 2.

**CUDNN_STATUS_NOT_SUPPORTED**

The function does not support the provided configuration. Some examples of non-supported configurations are as follows:

- The mode of activationDesc is not `CUDNN_ACTIVATION_RELU` or `CUDNN_ACTIVATION.IDENTITY`.

- The reluNanOpt of activationDesc is not `CUDNN_NOT_PROPAGATE_NAN`.

- The second stride of biasDesc is not equal to one.

- The first dimension of biasDesc is not equal to one.

- The second dimension of biasDesc and the first dimension of filterDesc are not equal.

- The data type of biasDesc does not correspond to the data type of yDesc as listed in the above data types table.
zDesc and destDesc do not match.

**CUDNN_STATUS_EXECUTION_FAILED**
The function failed to launch on the GPU.

### 5.2.4. `cudnnConvolutionForward()`

This function executes convolutions or cross-correlations over \( x \) using filters specified with \( w \), returning results in \( y \). Scaling factors \( \alpha \) and \( \beta \) can be used to scale the input tensor and the output tensor respectively.

```
cudnnStatus_t cudnnConvolutionForward(  
  cudnnHandle_t handle,  
  const void *alpha,  
  const cudnnTensorDescriptor_t xDesc,  
  const void *x,  
  const cudnnFilterDescriptor_t wDesc,  
  const void *w,  
  const cudnnConvolutionDescriptor_t convDesc,  
  cudnnConvolutionFwdAlgo_t algo,  
  void *workSpace,  
  size_t workSpaceSizeInBytes,  
  const void *beta,  
  const cudnnTensorDescriptor_t yDesc,  
  void *y)  
```

The routine `cudnnGetConvolution2dForwardOutputDim()` or `cudnnGetConvolutionNdForwardOutputDim()` can be used to determine the proper dimensions of the output tensor descriptor \( yDesc \) with respect to \( xDesc \), \( convDesc \), and \( wDesc \).

**Parameters**

- **handle**
  *Input.* Handle to a previously created cuDNN context. For more information, refer to `cudnnHandle_t`.

- **alpha**, **beta**
  *Input.* Pointers to scaling factors (in host memory) used to blend the computation result with prior value in the output layer as follows:
  
  \[
  \text{dstValue} = \alpha[0] \times \text{result} + \beta[0] \times \text{priorDstValue}
  \]

  For more information, refer to Scaling Parameters.

- **xDesc**
  *Input.* Handle to a previously initialized tensor descriptor. For more information, refer to `cudnnTensorDescriptor_t`.

- **x**
  *Input.* Data pointer to GPU memory associated with the tensor descriptor \( xDesc \).

- **wDesc**
  *Input.* Handle to a previously initialized filter descriptor. For more information, refer to `cudnnFilterDescriptor_t`.

- **w**
  *Input.* Data pointer to GPU memory associated with the filter descriptor \( wDesc \).
**convDesc**

*Input*. Previously initialized convolution descriptor. For more information, refer to `cudnnConvolutionDescriptor_t`.

**algo**

*Input*. Enumerant that specifies which convolution algorithm should be used to compute the results. For more information, refer to `cudnnConvolutionFwdAlgo_t`.

**workSpace**

*Input*. Data pointer to GPU memory to a workspace needed to be able to execute the specified algorithm. If no workspace is needed for a particular algorithm, that pointer can be `NIL`.

**workSpaceSizeInBytes**

*Input*. Specifies the size in bytes of the provided `workSpace`.

**yDesc**

*Input*. Handle to a previously initialized tensor descriptor.

**y**

*Input/Output*. Data pointer to GPU memory associated with the tensor descriptor `yDesc` that carries the result of the convolution.

### Supported configurations

This function supports the following combinations of data types for `xDesc`, `wDesc`, `convDesc`, and `yDesc`.

### Table 25. Supported Configurations for `cudnnConvolutionForward()`

<table>
<thead>
<tr>
<th>Data Type Configurations</th>
<th><code>xDesc</code> and <code>wDesc</code></th>
<th><code>convDesc</code></th>
<th><code>yDesc</code></th>
</tr>
</thead>
<tbody>
<tr>
<td>TRUE_HALF_CONFIG (only supported on architectures with true FP16 support, meaning, compute capability 5.3 and later)</td>
<td>CUDNN_DATA_HALF</td>
<td>CUDNN_DATA_HALF</td>
<td>CUDNN_DATA_HALF</td>
</tr>
<tr>
<td>PSEUDO_HALF_CONFIG</td>
<td>CUDNN_DATA_HALF</td>
<td>CUDNN_DATA_FLOAT</td>
<td>CUDNN_DATA_HALF</td>
</tr>
<tr>
<td>PSEUDO_BFLOAT16_CONFIG (only support on architecture with bfloat16 support, meaning, compute capability 8.0 and later)</td>
<td>CUDNN_DATA_FLOAT</td>
<td>CUDNN_DATA_HALF</td>
<td></td>
</tr>
</tbody>
</table>
### Data Type Configurations

<table>
<thead>
<tr>
<th>Data Type Configurations</th>
<th>xDesc and wDesc</th>
<th>convDesc</th>
<th>yDesc</th>
</tr>
</thead>
<tbody>
<tr>
<td>FLOAT_CONFIG</td>
<td>CUDNN_DATA_FLOAT</td>
<td>CUDNN_DATA_FLOAT</td>
<td>CUDNN_DATA_FLOAT</td>
</tr>
<tr>
<td>DOUBLE_CONFIG</td>
<td>CUDNN_DATA_DOUBLE</td>
<td>CUDNN_DATA_DOUBLE</td>
<td>CUDNN_DATA_DOUBLE</td>
</tr>
<tr>
<td>INT8 CONFIG (only supported on architectures with DP4A support, meaning, compute capability 6.1 and later)</td>
<td>CUDNN_DATA_INT8</td>
<td>CUDNN_DATA_INT32</td>
<td>CUDNN_DATA_INT8</td>
</tr>
<tr>
<td>INT8_EXT_CONFIG (only supported on architectures with DP4A support, meaning, compute capability 6.1 and later)</td>
<td>CUDNN_DATA_INT8</td>
<td>CUDNN_DATA_INT32</td>
<td>CUDNN_DATA_FLOAT</td>
</tr>
<tr>
<td>INT8x4_CONFIG (only supported on architectures with DP4A support, meaning, compute capability 6.1 and later)</td>
<td>CUDNN_DATA_INT8x4</td>
<td>CUDNN_DATA_INT32</td>
<td>CUDNN_DATA_INT8x4</td>
</tr>
<tr>
<td>INT8x4_EXT_CONFIG (only supported on architectures with DP4A support, meaning, compute capability 6.1 and later)</td>
<td>CUDNN_DATA_INT8x4</td>
<td>CUDNN_DATA_INT32</td>
<td>CUDNN_DATA_FLOAT</td>
</tr>
<tr>
<td>UINT8 CONFIG (only supported on architectures with DP4A support, meaning, compute capability 6.1 and later)</td>
<td>xDesc: CUDNN_DATA_UINT8</td>
<td>convDesc: CUDNN_DATA_INT32</td>
<td>yDesc: CUDNN_DATA_INT8</td>
</tr>
<tr>
<td>UINT8x4 CONFIG (only supported on architectures with DP4A support, meaning, compute capability 6.1 and later)</td>
<td>xDesc: CUDNN_DATA_UINT8x4</td>
<td>convDesc: CUDNN_DATA_INT32</td>
<td>yDesc: CUDNN_DATA_INT8x4</td>
</tr>
</tbody>
</table>
Data Type Configurations | xDesc and wDesc | convDesc | yDesc |
--- | --- | --- | --- |
on architectures with DP4A support, meaning, compute capability 6.1 and later) | wDesc: CUDNN_DATA_INT8x4 | | |
UINT8_EXT_CONFIG (only supported on architectures with DP4A support, meaning, compute capability 6.1 and later) | xDesc: CUDNN_DATA_UINT8 | convDesc: CUDNN_DATA_INT32 | yDesc: CUDNN_DATA_FLOAT |
wDesc: CUDNN_DATA_INT8 |
| CUDNN_DATA_INT8 |
UINT8x4_EXT_CONFIG (only supported on architectures with DP4A support, meaning, compute capability 6.1 and later) | xDesc: CUDNN_DATA_UINT8x4 | convDesc: CUDNN_DATA_INT32 | yDesc: CUDNN_DATA_FLOAT |
wDesc: CUDNN_DATA_INT8x4 |
| CUDNN_DATA_INT8x4 |
INT8x32_CONFIG (only supported on architectures with IMMA support, meaning compute capability 7.5 and later) | CUDNN_DATA_INT8x32 | convDesc: CUDNN_DATA_INT32 | yDesc: CUDNN_DATA_INT8x32 |

Supported algorithms

Note: For this function, all algorithms perform deterministic computations. Specifying a separate algorithm can cause changes in performance and support.

The table below shows the list of the supported 2D and 3D convolutions. The 2D convolutions are described first, followed by the 3D convolutions.

For the following terms, the short-form versions shown in the parenthesis are used in the table below, for brevity:
- CUDNN_CONVOLUTION_FWD_ALGO_IMPLICIT_GEMM (_IMPLICIT_GEMM)
- CUDNN_CONVOLUTION_FWD_ALGO_IMPLICIT_PRECOMP_GEMM (_IMPLICIT_PRECOMP_GEMM)
- CUDNN_CONVOLUTION_FWD_ALGO_GEMM (_GEMM)
- CUDNN_CONVOLUTION_FWD_ALGO_DIRECT (_DIRECT)
- CUDNN_CONVOLUTION_FWD_ALGO_FFT (_FFT)
- CUDNN_CONVOLUTION_FWD_ALGO_FFT_TILING (_FFT_TILING)
- CUDNN_CONVOLUTION_FWD_ALGO_WINograd (_WINOGRAD)
- CUDNN_CONVOLUTION_FWD_ALGO_WINograd_nonfused (_WINOGRAD_NONFUSED)
- CUDNN_TENSOR_NCHW (_NCHW)
- CUDNN_TENSOR_NHWC (_NHWC)
- CUDNN_TENSOR_NCHW_VECT_C (_NCHW_VECT_C)

Table 26. Supported Algorithms for cudnnConvolutionForward() 2D Convolutions: wDesc: _NCHW

Filter descriptor wDesc: _NCHW (refer to cudnnTensorFormat_t)

<table>
<thead>
<tr>
<th>Algo Name</th>
<th>Tensor Formats Supported for xDesc</th>
<th>Tensor Formats Supported for yDesc</th>
<th>Data Type Configurations Supported</th>
<th>Important</th>
</tr>
</thead>
<tbody>
<tr>
<td>_IMPLICIT_GEMM</td>
<td>All except _NCHW_VECT_C.</td>
<td>All except _NCHW_VECT_C.</td>
<td>TRUE_HALF_CONFIG</td>
<td>Dilation: Greater than 0 for all dimensions</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>PSEUDO_HALF_CONFIG</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>PSEUDO_HALF_CONFIG</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>PSEUDO_BFLOAT16_CONFIG</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>FLOAT_CONFIG</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>DOUBLE_CONFIG</td>
<td></td>
</tr>
<tr>
<td>_IMPLICIT_PRECOMP_GEMM</td>
<td>All except _NCHW_VECT_C.</td>
<td>All except _NCHW_VECT_C.</td>
<td>TRUE_HALF_CONFIG</td>
<td>Dilation: 1 for all dimensions</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>PSEUDO_HALF_CONFIG</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>PSEUDO_HALF_CONFIG</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>PSEUDO_BFLOAT16_CONFIG</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>FLOAT_CONFIG</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>DOUBLE_CONFIG</td>
<td></td>
</tr>
<tr>
<td>_GEMM</td>
<td>All except _NCHW_VECT_C.</td>
<td>All except _NCHW_VECT_C.</td>
<td>PSEUDO_HALF_CONFIG</td>
<td>Dilation: 1 for all dimensions</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>FLOAT_CONFIG</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>DOUBLE_CONFIG</td>
<td></td>
</tr>
<tr>
<td>_FFT</td>
<td>NCHW HW-packed</td>
<td>NCHW HW-packed</td>
<td>PSEUDO_HALF_CONFIG</td>
<td>Dilation: 1 for all dimensions</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>FLOAT_CONFIG</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>xDesc feature</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>map height + 2</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>* convDesc zero-</td>
<td></td>
</tr>
</tbody>
</table>
**Filter descriptor** \( wDesc: \_NCHW \) (refer to [cudnnTensorFormat_t](#))

\( convDesc \) Group count support: Greater than 0, for all algos.

<table>
<thead>
<tr>
<th>Algo Name</th>
<th>Tensor Formats Supported for ( xDesc )</th>
<th>Tensor Formats Supported for ( yDesc )</th>
<th>Data Type Configurations Supported</th>
<th>Important</th>
</tr>
</thead>
<tbody>
<tr>
<td>_FFT_TILING</td>
<td></td>
<td></td>
<td></td>
<td>padding height must equal 256 or less</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>( xDesc ) feature map width + 2 * ( convDesc ) zero-padding width must equal 256 or less</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>( convDesc ) vertical and horizontal filter stride must equal 1</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>( wDesc ) filter height must be greater than ( convDesc ) zero-padding height</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>( wDesc ) filter width must be greater than ( convDesc ) zero-padding width</td>
<td></td>
</tr>
</tbody>
</table>

**Dilation:** 1 for all dimensions

When neither of \( wDesc \) filter dimension is 1, the filter width and height must not be larger than 32

When either of \( wDesc \) filter
Filter descriptor \texttt{wDesc}: \texttt{NCHW} (refer to \texttt{cudnnTensorFormat_t})

\texttt{convDesc} Group count support: Greater than 0, for all algos.

<table>
<thead>
<tr>
<th>Algo Name</th>
<th>Tensor Formats Supported for \texttt{xDesc}</th>
<th>Tensor Formats Supported for \texttt{yDesc}</th>
<th>Data Type Configurations Supported</th>
<th>Important</th>
</tr>
</thead>
<tbody>
<tr>
<td>\texttt{WINOGRAD}</td>
<td>All except \texttt{NCHW Vect}</td>
<td>All except \texttt{NCHW Vect}</td>
<td>PSEUDO_HALF_CONFIG FLOAT_CONFIG</td>
<td>Dilation: 1 for all dimensions \texttt{convDesc} vertical and horizontal filter stride must equal 1 when either the filter width or filter height is 1, otherwise the stride can be a 1 or 2 \texttt{wDesc} filter height must be greater than \texttt{convDesc} zero-padding height \texttt{wDesc} filter width must be greater than \texttt{convDesc} zero-padding width</td>
</tr>
</tbody>
</table>
Filter descriptor \( wDesc: \_NCHW \) (refer to \texttt{cudnnTensorFormat\_t})

\texttt{convDesc} Group count support: Greater than 0, for all algs.

<table>
<thead>
<tr>
<th>Algo Name</th>
<th>Tensor Formats Supported for ( xDesc )</th>
<th>Tensor Formats Supported for ( yDesc )</th>
<th>Data Type Configurations Supported</th>
<th>Important</th>
</tr>
</thead>
<tbody>
<tr>
<td>_WINOGRAD_NONFUSED</td>
<td></td>
<td></td>
<td>TRUE_HALF_CONFIG</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>PSEUDO_HALF_CONFIG</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>PSEUDO_BFLOAT16_CONFIG</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>FLOAT_CONFIG</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td><strong>Dilation:</strong> 1 for all dimensions</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>convDesc vertical and horizontal filter stride must equal 1</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>wDesc filter (height, width) must be (3,3) or (5,5)</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>If wDesc filter (height, width) is (5,5), then data type config TRUE_HALF_CONFIG is not supported.</td>
<td></td>
</tr>
<tr>
<td>_DIRECT</td>
<td>Currently not implemented in cuDNN.</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Table 27. Supported Algorithms for \texttt{cudnnConvolutionForward()} 2D Convolutions: \( wDesc: \_NCHWC \)

Filter descriptor \( wDesc: \_NCHWC \)

\texttt{convDesc} Group count support: Greater than 0.

<table>
<thead>
<tr>
<th>Algo Name</th>
<th>( xDesc )</th>
<th>( yDesc )</th>
<th>Data Type Configurations Supported</th>
<th>Important</th>
</tr>
</thead>
<tbody>
<tr>
<td>_IMPLICIT_GEMM</td>
<td>_NCHW_VECT_C</td>
<td>_NCHW_VECT_C</td>
<td>INT8x4_CONFIG</td>
<td></td>
</tr>
<tr>
<td>_IMPLICIT_PRECOMP_GEMM</td>
<td>_NCHW_VECT_C</td>
<td>_NCHW_VECT_C</td>
<td>UINT8x4_CONFIG</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>INT8x32_CONFIG</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td><strong>Dilation:</strong> 1 for all dimensions</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Requires compute</td>
<td></td>
</tr>
</tbody>
</table>
Filter descriptor `wDesc:` **_NCHWC**

`convDesc` Group count support: Greater than 0.

<table>
<thead>
<tr>
<th>Algo Name</th>
<th>xDesc</th>
<th>yDesc</th>
<th>Data Type Configurations Supported</th>
<th>Important</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td>capability 7.2 or above.</td>
<td></td>
</tr>
</tbody>
</table>

Table 28. **Supported Algorithms for** `cudnnConvolutionForward()` **2D Convolutions:** `wDesc:` **_NHWC**

Filter descriptor `wDesc:` **_NHWC**

`convDesc` Group count support: Greater than 0.

<table>
<thead>
<tr>
<th>Algo Name</th>
<th>xDesc</th>
<th>yDesc</th>
<th>Data Type Configurations Supported</th>
<th>Important</th>
</tr>
</thead>
<tbody>
<tr>
<td>_IMPLICIT_GEMM</td>
<td>NHWC fully-packed</td>
<td>NHWC fully-packed</td>
<td>INT8_CONFIG</td>
<td>Dilation: 1 for all dimensions&lt;br&gt;Input and output feature maps must be a multiple of 4. Output features maps can be non-multiple in the case of INT8_EXT_CONFIG or UINT8_EXT_CONFIG.</td>
</tr>
<tr>
<td>_IMPLICIT_PRECOMP_GEMM</td>
<td>NHWC HWC-packed.</td>
<td>NHWC HWC-packed.</td>
<td>TRUE_HALF_CONFIG</td>
<td>PSEUDO_HALF_CONFIG</td>
</tr>
<tr>
<td></td>
<td>NCHW CHW-packed</td>
<td></td>
<td>PSEUDO_BFLOAT16_CONFIG</td>
<td>FLOAT_CONFIG</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>DOUBLE_CONFIG</td>
<td></td>
</tr>
</tbody>
</table>
Table 29. Supported Algorithms for `cudnnConvolutionForward()` 3D Convolutions: \(\text{wDesc: \_NCHW}\)

**Filter descriptor wDesc: \_NCHW**

**convDesc** Group count support: Greater than 0, for all algos.

<table>
<thead>
<tr>
<th>Algo Name</th>
<th>xDesc</th>
<th>yDesc</th>
<th>Data Type Configurations Supported</th>
<th>Important</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td><code>_IMPLICIT_GEMM</code></td>
<td>All except _NCHW_VECT_C.</td>
<td>All except _NCHW_VECT_C.</td>
<td>PSEUDO_HALF_CONFIG</td>
<td></td>
<td>Dilation: Greater than 0 for all dimensions</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>PSEUDO_BFLOAT16_CONFIG</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>FLOAT_CONFIG</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>DOUBLE_CONFIG</td>
<td></td>
<td></td>
</tr>
<tr>
<td><code>_IMPLICIT_PRECOMP_GEMM</code></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><code>_FFT_TILING</code></td>
<td>NCDHW DHW-packed</td>
<td>NCDHW DHW-packed</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

---

- ConvDesc filter height must equal 16 or less
- ConvDesc filter width must equal 16 or less
- ConvDesc filter depth must equal 16 or less
- ConvDesc must have all filter strides equal to 1
- ConvDesc filter height must be greater than ConvDesc zero-padding height
- ConvDesc filter width must be greater than ConvDesc zero-padding width
Filter descriptor \( wDesc: \_NCHW \)

\( \text{convDesc} \) Group count support: Greater than 0, for all algos.

<table>
<thead>
<tr>
<th>Algo Name</th>
<th>xDesc</th>
<th>yDesc</th>
<th>Data Type Configurations Supported</th>
<th>Important</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td>wDesc filter depth must be greater than ( \text{convDesc} ) zero-padding depth</td>
<td></td>
</tr>
</tbody>
</table>

Table 30. Supported Algorithms for \texttt{cudnnConvolutionForward()} 3D Convolutions: \( wDesc: \_NHWC \)

Filter descriptor \( wDesc: \_NHWC \)

\( \text{convDesc} \) Group count support: Greater than 0, for all algos.

<table>
<thead>
<tr>
<th>Algo Name</th>
<th>xDesc</th>
<th>yDesc</th>
<th>Data Type Configurations Supported</th>
<th>Important</th>
</tr>
</thead>
<tbody>
<tr>
<td>_IMPLICIT_PRECOMP_GEMM</td>
<td>NDHWC</td>
<td>NDHWC</td>
<td>PSEUDO_HALF_CONFIG</td>
<td></td>
</tr>
<tr>
<td></td>
<td>DHWC-packed</td>
<td>DHWC-packed</td>
<td>PSEUDO_BFLOAT16_CONFIG</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>FLOAT_CONFIG</td>
<td></td>
</tr>
</tbody>
</table>

Dilation: Greater than 0 for all dimensions

Note: Tensors can be converted to and from \texttt{CUDNN_TENSOR_NCHW_VECT_C} with 
\texttt{cudnnTransformTensor()}.

Returns

**CUDNN_STATUS_SUCCESS**

The operation was launched successfully.

**CUDNN_STATUS_BAD_PARAM**

At least one of the following conditions are met:

- At least one of the following is NULL: handle, xDesc, wDesc, convDesc, yDesc, xData, w, yData, alpha, and beta
- xDesc and yDesc have a non-matching number of dimensions
- xDesc and wDesc have a non-matching number of dimensions
- xDesc has fewer than three number of dimensions
- xDesc's number of dimensions is not equal to \( \text{convDesc} \) array length + 2
- xDesc and wDesc have a non-matching number of input feature maps per image (or group in case of grouped convolutions)
- yDesc or wDesc indicate an output channel count that isn’t a multiple of group count (if group count has been set in convDesc).
- xDesc, wDesc, and yDesc have a non-matching data type
- For some spatial dimension, wDesc has a spatial size that is larger than the input spatial size (including zero-padding size)

**CUDNN_STATUS_NOT_SUPPORTED**
At least one of the following conditions are met:
- xDesc or yDesc have negative tensor striding
- xDesc, wDesc, or yDesc has a number of dimensions that is not 4 or 5
- yDesc spatial sizes do not match with the expected size as determined by cudnnGetConvolutionNdForwardOutputDim()
- The chosen algo does not support the parameters provided; see above for an exhaustive list of parameters supported for each algo

**CUDNN_STATUS_MAPPING_ERROR**
An error occurs during the texture object creation associated with the filter data.

**CUDNN_STATUS_EXECUTION_FAILED**
The function failed to launch on the GPU.

### 5.2.5. cudnnCreateConvolutionDescriptor()
This function creates a convolution descriptor object by allocating the memory needed to hold its opaque structure. For more information, refer to cudnnConvolutionDescriptor_t.

```c
#include <cudnn.h>

void cudnnConvolutionDesc = cudnnCreateConvolutionDescriptor(1, 1, 1, 1, 1, 1, 1);
```

**Returns**

**CUDNN_STATUS_SUCCESS**
The object was created successfully.

**CUDNN_STATUS_ALLOC_FAILED**
The resources could not be allocated.

### 5.2.6. cudnnDestroyConvolutionDescriptor()
This function destroys a previously created convolution descriptor object.

```c
#include <cudnn.h>

void cudnnConvolutionDesc = cudnnDestroyConvolutionDescriptor(1, 1, 1, 1, 1, 1, 1);
```
Returns

**CUDNN_STATUS_SUCCESS**

The descriptor was destroyed successfully.

### 5.2.7. cudnnFindConvolutionBackwardDataAlgorithm()

This function attempts all algorithms available for `cudnnConvolutionBackwardData()`. It will attempt both the provided `convDesc` `mathType` and `CUDNN_DEFAULT_MATH` (assuming the two differ).

```c
void cudnnFindConvolutionBackwardDataAlgorithm(
    const cudnnHandle_t handle,
    const cudnnFilterDescriptor_t wDesc,
    const cudnnTensorDescriptor_t dyDesc,
    const cudnnConvolutionDescriptor_t convDesc,
    const cudnnTensorDescriptor_t dxDesc,
    const int requestedAlgoCount,
    int *returnedAlgoCount,
    cudnnConvolutionBwdDataAlgoPerf_t *perfResults)
```

Algorithms without the **CUDNN_TENSOR_OP_MATH** availability will only be tried with `CUDNN_DEFAULT_MATH`, and returned as such.

Memory is allocated via `cudaMalloc()`. The performance metrics are returned in the user-allocated array of `cudnnConvolutionBwdDataAlgoPerf_t`. These metrics are written in a sorted fashion where the first element has the lowest compute time. The total number of resulting algorithms can be queried through the API `cudnnGetConvolutionBackwardDataAlgorithmMaxCount()`.

**Note:**
- This function is host blocking.
- It is recommended to run this function prior to allocating layer data; doing otherwise may needlessly inhibit some algorithm options due to resource usage.

**Parameters**

- **handle**
  - *Input*. Handle to a previously created cuDNN context.

- **wDesc**
  - *Input*. Handle to a previously initialized filter descriptor.

- **dyDesc**
  - *Input*. Handle to the previously initialized input differential tensor descriptor.

- **convDesc**
  - *Input*. Previously initialized convolution descriptor.

- **dxDesc**
  - *Input*. Handle to the previously initialized output tensor descriptor.

- **requestedAlgoCount**
  - *Input*. The maximum number of elements to be stored in `perfResults`. 
**returnedAlgoCount**

*Output.* The number of output elements stored in `perfResults`.

**perfResults**

*Output.* A user-allocated array to store performance metrics sorted ascending by compute time.

**Returns**

**CUDNN_STATUS_SUCCESS**

The query was successful.

**CUDNN_STATUS_BAD_PARAM**

At least one of the following conditions are met:

- `handle` is not allocated properly.
- `wDesc`, `dyDesc`, or `dxDesc` is not allocated properly.
- `wDesc`, `dyDesc`, or `dxDesc` has fewer than 1 dimension.
- Either `returnedCount` or `perfResults` is NIL.
- `requestedCount` is less than 1.

**CUDNN_STATUS_ALLOC_FAILED**

This function was unable to allocate memory to store sample input, filters and output.

**CUDNN_STATUS_INTERNAL_ERROR**

At least one of the following conditions are met:

- The function was unable to allocate necessary timing objects.
- The function was unable to deallocate necessary timing objects.
- The function was unable to deallocate sample input, filters and output.

### 5.2.8. cudnnFindConvolutionBackwardDataAlgorithmEx()

This function attempts all algorithms available for `cudnnConvolutionBackwardData()`, it will attempt both the provided `convDesc` `mathType` and `CUDNN_DEFAULT_MATH` (assuming the two differ).

```c
#include <cudnn.h>

void cudnnConvolutionBackwardDataAlgorithmEx(
    cudnnHandle_t                      handle,
    const cudnnFilterDescriptor_t     wDesc,
    const void*                        w,
    const cudnnTensorDescriptor_t     dyDesc,
    const void*                        dy,
    const cudnnConvolutionDescriptor_t convDesc,
    const cudnnTensorDescriptor_t     dxDesc,
    void*                              dx,
    const int                          requestedAlgoCount,
    int*                               returnedAlgoCount,
    cudnnConvolutionBwdDataAlgoPerf_t  *perfResults,
    void*                              workspace,
    size_t                             workSpaceSizeInBytes)
```

Algorithms without the `CUDNN_TENSOR_OP_MATH` availability will only be tried with `CUDNN_DEFAULT_MATH`, and returned as such.
Memory is allocated via `cudaMalloc()`. The performance metrics are returned in the user-allocated array of `cudnnConvolutionBwdDataAlgoPerf_t`. These metrics are written in a sorted fashion where the first element has the lowest compute time. The total number of resulting algorithms can be queried through the API `cudnnGetConvolutionBackwardDataAlgorithmMaxCount()`.

**Note:** This function is host blocking.

**Parameters**

- **handle**
  - *Input*. Handle to a previously created cuDNN context.

- **wDesc**
  - *Input*. Handle to a previously initialized filter descriptor.

- **w**
  - *Input*. Data pointer to GPU memory associated with the filter descriptor `wDesc`.

- **dyDesc**
  - *Input*. Handle to the previously initialized input differential tensor descriptor.

- **dy**
  - *Input*. Data pointer to GPU memory associated with the filter descriptor `dyDesc`.

- **convDesc**
  - *Input*. Previously initialized convolution descriptor.

- **dxDesc**
  - *Input*. Handle to the previously initialized output tensor descriptor.

- **dxDesc**
  - *Input/Output*. Data pointer to GPU memory associated with the tensor descriptor `dxDesc`. The content of this tensor will be overwritten with arbitrary values.

- **requestedAlgoCount**
  - *Input*. The maximum number of elements to be stored in `perfResults`.

- **returnedAlgoCount**
  - *Output*. The number of output elements stored in `perfResults`.

- **perfResults**
  - *Output*. A user-allocated array to store performance metrics sorted ascending by compute time.

- **workSpace**
  - *Input*. Data pointer to GPU memory is a necessary workspace for some algorithms. The size of this workspace will determine the availability of algorithms. A nil pointer is considered a `workSpace` of 0 bytes.

- **workSpaceSizeInBytes**
  - *Input*. Specifies the size in bytes of the provided `workSpace`.

**Returns**

- **CUDNN_STATUS_SUCCESS**
  - The query was successful.
CUDNN_STATUS_BAD_PARAM
At least one of the following conditions are met:

- handle is not allocated properly.
- wDesc, dyDesc, or dxDesc is not allocated properly.
- wDesc, dyDesc, or dxDesc has fewer than 1 dimension.
- w, dy, or dx is NIL.
- Either returnedCount or perfResults is NIL.
- requestedCount is less than 1.

CUDNN_STATUS_INTERNAL_ERROR
At least one of the following conditions are met:

- The function was unable to allocate necessary timing objects.
- The function was unable to deallocate necessary timing objects.
- The function was unable to deallocate sample input, filters and output.

5.2.9. cudnnFindConvolutionForwardAlgorithm()
This function attempts all algorithms available for cudnnConvolutionForward(). It will attempt both the provided convDesc mathType and CUDNN_DEFAULT_MATH (assuming the two differ).

```c
int cudnnFindConvolutionForwardAlgorithm(  
    cudnnHandle_t                     handle,  
    const cudnnTensorDescriptor_t    xDesc,   
    const cudnnFilterDescriptor_t    wDesc,   
    const cudnnConvolutionDescriptor_t convDesc,  
    const cudnnTensorDescriptor_t    yDesc,   
    const int                        requestedAlgoCount,  
    int *                            returnedAlgoCount,  
    cudnnConvolutionFwdAlgoPerf_t    *perfResults)
```

Algorithms without the CUDNN_TENSOR_OP_MATH availability will only be tried with CUDNN_DEFAULT_MATH, and returned as such.

Memory is allocated via cudaMalloc(). The performance metrics are returned in the user-allocated array of cudnnConvolutionFwdAlgoPerf_t. These metrics are written in a sorted fashion where the first element has the lowest compute time. The total number of resulting algorithms can be queried through the API cudnnGetConvolutionForwardAlgorithmMaxCount().

Note:

- This function is host blocking.
- It is recommended to run this function prior to allocating layer data; doing otherwise may needlessly inhibit some algorithm options due to resource usage.
Parameters

**handle**
 *Input.* Handle to a previously created cuDNN context.

**xDesc**
 *Input.* Handle to the previously initialized input tensor descriptor.

**wDesc**
 *Input.* Handle to a previously initialized filter descriptor.

**convDesc**
 *Input.* Previously initialized convolution descriptor.

**yDesc**
 *Input.* Handle to the previously initialized output tensor descriptor.

**requestedAlgoCount**
 *Input.* The maximum number of elements to be stored in `perfResults`.

**returnedAlgoCount**
 *Output.* The number of output elements stored in `perfResults`.

**perfResults**
 *Output.* A user-allocated array to store performance metrics sorted ascending by compute time.

Returns

**CUDNN_STATUS_SUCCESS**
 The query was successful.

**CUDNN_STATUS_BAD_PARAM**
 At least one of the following conditions are met:

- `handle` is not allocated properly.
- `xDesc`, `wDesc`, or `yDesc` are not allocated properly.
- `xDesc`, `wDesc`, or `yDesc` has fewer than 1 dimension.
- Either `returnedCount` or `perfResults` is NIL.
- `requestedCount` is less than 1.

**CUDNN_STATUS_ALLOC_FAILED**
 This function was unable to allocate memory to store sample input, filters and output.

**CUDNN_STATUS_INTERNAL_ERROR**
 At least one of the following conditions are met:

- The function was unable to allocate necessary timing objects.
- The function was unable to deallocate necessary timing objects.
- The function was unable to deallocate sample input, filters and output.
5.2.10. **cudnnFindConvolutionForwardAlgorithmEx()**

This function attempts all algorithms available for `cudnnConvolutionForward()`. It will attempt both the provided `convDesc` `mathType` and `CUDNN_DEFAULT_MATH` (assuming the two differ).

```c
void cudnnFindConvolutionForwardAlgorithmEx(
    cudnnHandle_t                      handle,
    const cudnnTensorDescriptor_t      xDesc,
    const void                        *x,
    const cudnnFilterDescriptor_t      wDesc,
    const void                        *w,
    const cudnnConvolutionDescriptor_t convDesc,
    const cudnnTensorDescriptor_t      yDesc,
    void *y,
    const int                          requestedAlgoCount,
    int *returnedAlgoCount,
    cudnnConvolutionFwdAlgoPerf_t     *perfResults,
    void                              *workSpace,
    size_t                             workSpaceSizeInBytes)
```

Algorithms without the `CUDNN_TENSOR_OP_MATH` availability will only be tried with `CUDNN_DEFAULT_MATH`, and returned as such.

Memory is allocated via `cudaMalloc()`. The performance metrics are returned in the user-allocated array of `cudnnConvolutionFwdAlgoPerf_t`. These metrics are written in a sorted fashion where the first element has the lowest compute time. The total number of resulting algorithms can be queried through the API `cudnnGetConvolutionForwardAlgorithmMaxCount()`.

**Note:** This function is host blocking.

### Parameters

- **handle**
  - *Input*. Handle to a previously created cuDNN context.
- **xDesc**
  - *Input*. Handle to the previously initialized input tensor descriptor.
- **x**
  - *Input*. Data pointer to GPU memory associated with the tensor descriptor `xDesc`.
- **wDesc**
  - *Input*. Handle to a previously initialized filter descriptor.
- **w**
  - *Input*. Data pointer to GPU memory associated with the filter descriptor `wDesc`.
- **convDesc**
  - *Input*. Previously initialized convolution descriptor.
- **yDesc**
  - *Input*. Handle to the previously initialized output tensor descriptor.
- **y**
  - *Input/Output*. Data pointer to GPU memory associated with the tensor descriptor `yDesc`. The content of this tensor will be overwritten with arbitrary values.
requestedAlgoCount
  Input. The maximum number of elements to be stored in perfResults.

returnedAlgoCount
  Output. The number of output elements stored in perfResults.

perfResults
  Output. A user-allocated array to store performance metrics sorted ascending by compute time.

workSpace
  Input. Data pointer to GPU memory is a necessary workspace for some algorithms. The size of this workspace will determine the availability of algorithms. A nil pointer is considered a workSpace of 0 bytes.

workSpaceSizeInBytes
  Input. Specifies the size in bytes of the provided workSpace.

Returns

CUDNN_STATUS_SUCCESS
  The query was successful.

CUDNN_STATUS_BAD_PARAM
  At least one of the following conditions are met:
  ▶ handle is not allocated properly.
  ▶ xDesc, wDesc, or yDesc are not allocated properly.
  ▶ xDesc, wDesc, or yDesc has fewer than 1 dimension.
  ▶ x, w, or y is NIL.
  ▶ Either returnedCount or perfResults is NIL.
  ▶ requestedCount is less than 1.

CUDNN_STATUS_INTERNAL_ERROR
  At least one of the following conditions are met:
  ▶ The function was unable to allocate necessary timing objects.
  ▶ The function was unable to deallocate necessary timing objects.
  ▶ The function was unable to deallocate sample input, filters and output.

5.2.11. cudnnGetConvolution2dDescriptor()

This function queries a previously initialized 2D convolution descriptor object.
Parameters

convDesc
Input. Handle to a previously created convolution descriptor.

pad_h
Output. Zero-padding height: number of rows of zeros implicitly concatenated onto the
top and onto the bottom of input images.

pad_w
Output. Zero-padding width: number of columns of zeros implicitly concatenated onto
the left and onto the right of input images.

u
Output. Vertical filter stride.

v
Output. Horizontal filter stride.

dilation_h
Output. Filter height dilation.

dilation_w
Output. Filter width dilation.

mode
Output. Convolution mode.

computeType
Output. Compute precision.

Returns

CUDNN_STATUS_SUCCESS
The operation was successful.

CUDNN_STATUS_BAD_PARAM
The parameter convDesc is NIL.

5.2.12. cudnnGetConvolution2dForwardOutputDim()

This function returns the dimensions of the resulting 4D tensor of a 2D convolution,
given the convolution descriptor, the input tensor descriptor and the filter descriptor. This
function can help to setup the output tensor and allocate the proper amount of memory
prior to launch the actual convolution.

cudnnStatus_t cudnnGetConvolution2dForwardOutputDim(
    const cudnnConvolutionDescriptor_t  convDesc,
    const cudnnTensorDescriptor_t       inputTensorDesc,
    const cudnnFilterDescriptor_t       filterDesc,
    int                                *n,
    int                                *c,
    int                                *h,
    int                                *w)

Each dimension h and w of the output images is computed as follows:

    outputDim = 1 + ( inputDim + 2*pad - (((filterDim-1)*dilation)+1) )/convolutionStride;
**Note:** The dimensions provided by this routine must be strictly respected when calling `cudnnConvolutionForward()` or `cudnnConvolutionBackwardBias()`. Providing a smaller or larger output tensor is not supported by the convolution routines.

### Parameters

- **convDesc**
  - *Input*. Handle to a previously created convolution descriptor.

- **inputTensorDesc**
  - *Input*. Handle to a previously initialized tensor descriptor.

- **filterDesc**
  - *Input*. Handle to a previously initialized filter descriptor.

- **n**
  - *Output*. Number of output images.

- **c**
  - *Output*. Number of output feature maps per image.

- **h**
  - *Output*. Height of each output feature map.

- **w**
  - *Output*. Width of each output feature map.

### Returns

- **CUDNN_STATUS_BAD_PARAM**
  - One or more of the descriptors has not been created correctly or there is a mismatch between the feature maps of `inputTensorDesc` and `filterDesc`.

- **CUDNN_STATUS_SUCCESS**
  - The object was set successfully.

### 5.2.13. `cudnnGetConvolutionBackwardDataAlgorithmMaxCount()`

This function returns the maximum number of algorithms which can be returned from `cudnnFindConvolutionBackwardDataAlgorithm()` and `cudnnGetConvolutionForwardAlgorithm_v7()`. This is the sum of all algorithms plus the sum of all algorithms with Tensor Core operations supported for the current device.

```c
#include <cudnn.h>

cudnnStatus_t cudnnGetConvolutionBackwardDataAlgorithmMaxCount(
    cudnnHandle_t       handle,
    int                 *count)
```

### Parameters

- **handle**
  - *Input*. Handle to a previously created cuDNN context.

- **count**
  - *Output*. The resulting maximum number of algorithms.
Returns

**CUDNN_STATUS_SUCCESS**
The function was successful.

**CUDNN_STATUS_BAD_PARAM**
The provided handle is not allocated properly.

### 5.2.14. `cudnnGetConvolutionBackwardDataAlgorithm_v7()`

This function serves as a heuristic for obtaining the best suited algorithm for `cudnnConvolutionBackwardData()` for the given layer specifications. This function will return all algorithms (including CUDA_TENSOR_OP_MATH and CUDA_DEFAULT_MATH versions of algorithms where CUDA_TENSOR_OP_MATH may be available) sorted by expected (based on internal heuristic) relative performance with the fastest being index 0 of perfResults. For an exhaustive search for the fastest algorithm, use `cudnnFindConvolutionBackwardDataAlgorithm()`. The total number of resulting algorithms can be queried through the returnedAlgoCount variable.

```c
inline cudnnStatus_t cudnnGetConvolutionBackwardDataAlgorithm_v7(
    cudnnHandle_t                          handle,
    const cudnnFilterDescriptor_t          wDesc,
    const cudnnTensorDescriptor_t          dyDesc,
    const cudnnConvolutionDescriptor_t     convDesc,
    const cudnnTensorDescriptor_t          dxDesc,
    const int                              requestedAlgoCount,
    int                                   *returnedAlgoCount,
    cudnnConvolutionBwdDataAlgoPerf_t     *perfResults)
```

**Parameters**

- **handle**
  - Input. Handle to a previously created cuDNN context.

- **wDesc**
  - Input. Handle to a previously initialized filter descriptor.

- **dyDesc**
  - Input. Handle to the previously initialized input differential tensor descriptor.

- **convDesc**
  - Input. Previously initialized convolution descriptor.

- **dxDesc**
  - Input. Handle to the previously initialized output tensor descriptor.

- **requestedAlgoCount**
  - Input. The maximum number of elements to be stored in perfResults.

- **returnedAlgoCount**
  - Output. The number of output elements stored in perfResults.

- **perfResults**
  - Output. A user-allocated array to store performance metrics sorted ascending by compute time.
Returns

**CUDNN_STATUS_SUCCESS**
The query was successful.

**CUDNN_STATUS_BAD_PARAM**
At least one of the following conditions are met:

- One of the parameters `handle`, `wDesc`, `dyDesc`, `convDesc`, `dxDesc`, `perfResults`, or `returnedAlgoCount` is NULL.
- The numbers of feature maps of the input tensor and output tensor differ.
- The `dataType` of the two tensor descriptors or the filters are different.
- `requestedAlgoCount` is less than or equal to 0.

5.2.15. **cudnnGetConvolutionBackwardDataWorkspaceSize()**

This function returns the amount of GPU memory workspace the user needs to allocate to be able to call `cudnnConvolutionBackwardData()` with the specified algorithm. The workspace allocated will then be passed to the routine `cudnnConvolutionBackwardData()`. The specified algorithm can be the result of the call to `cudnnGetConvolutionBackwardDataAlgorithm_v7()` or can be chosen arbitrarily by the user. Note that not every algorithm is available for every configuration of the input tensor and/or every configuration of the convolution descriptor.

```c
void cudnnGetConvolutionBackwardDataWorkspaceSize(
    cudnnHandle_t                       handle,
    const cudnnFilterDescriptor_t       wDesc,
    const cudnnTensorDescriptor_t       dyDesc,
    const cudnnConvolutionDescriptor_t  convDesc,
    const cudnnTensorDescriptor_t       dxDesc,
    cudnnConvolutionBwdDataAlgo_t       algo,
    size_t                             *sizeInBytes)
```

**Parameters**

- **handle**
  - *Input*. Handle to a previously created cuDNN context.

- **wDesc**
  - *Input*. Handle to a previously initialized filter descriptor.

- **dyDesc**
  - *Input*. Handle to the previously initialized input differential tensor descriptor.

- **convDesc**
  - *Input*. Previously initialized convolution descriptor.

- **dxDesc**
  - *Input*. Handle to the previously initialized output tensor descriptor.

- **algo**
  - *Input*. Enumerant that specifies the chosen convolution algorithm.
sizeInBytes

*Output.* Amount of GPU memory needed as workspace to be able to execute a forward convolution with the specified `algo`.

**Returns**

**CUDNN_STATUS_SUCCESS**

The query was successful.

**CUDNN_STATUS_BADgetParam**

At least one of the following conditions are met:

- The numbers of feature maps of the input tensor and output tensor differ.
- The `dataType` of the two tensor descriptors or the filter are different.

**CUDNN_STATUS_NOT_SUPPORTED**

The combination of the tensor descriptors, filter descriptor and convolution descriptor is not supported for the specified algorithm.

### 5.2.16. `cudnnGetConvolutionForwardAlgorithmMaxCount()`

This function returns the maximum number of algorithms which can be returned from `cudnnFindConvolutionForwardAlgorithm()` and `cudnnGetConvolutionForwardAlgorithm_v7()`. This is the sum of all algorithms plus the sum of all algorithms with Tensor Core operations supported for the current device.

```c
#include <cudnn.h>

static cudnnStatus_t cudnnGetConvolutionForwardAlgorithmMaxCount(
    cudnnHandle_t handle,
    int *count)
```

**Parameters**

`handle`

*Input.* Handle to a previously created cuDNN context.

`count`

*Output.* The resulting maximum number of algorithms.

**Returns**

**CUDNN_STATUS_SUCCESS**

The function was successful.

**CUDNN_STATUS_BAD_PARAM**

The provided handle is not allocated properly.

### 5.2.17. `cudnnGetConvolutionForwardAlgorithm_v7()`

This function serves as a heuristic for obtaining the best suited algorithm for `cudnnConvolutionForward()` for the given layer specifications. This function will return all algorithms (including `CUDNN_TENSOR_OP_MATH` and `CUDNN_DEFAULT_MATH` versions of algorithms where `CUDNN_TENSOR_OP_MATH` may be available) sorted by expected (based on internal heuristic) relative performance with the fastest being...
index 0 of perfResults. For an exhaustive search for the fastest algorithm, use cudnnFindConvolutionForwardAlgorithm(). The total number of resulting algorithms can be queried through the returnedAlgoCount variable.

```c
    cudnnStatus_t cudnnGetConvolutionForwardAlgorithm_v7(
        cudnnHandle_t handle,
        const cudnnTensorDescriptor_t xDesc,
        const cudnnFilterDescriptor_t wDesc,
        const cudnnConvolutionDescriptor_t convDesc,
        const cudnnTensorDescriptor_t yDesc,
        const int requestedAlgoCount,
        int *returnedAlgoCount,
        cudnnConvolutionFwdAlgoPerf_t *perfResults)
```

**Parameters**

- **handle**
  - *Input*. Handle to a previously created cuDNN context.

- **xDesc**
  - *Input*. Handle to the previously initialized input tensor descriptor.

- **wDesc**
  - *Input*. Handle to a previously initialized convolution filter descriptor.

- **convDesc**
  - *Input*. Previously initialized convolution descriptor.

- **yDesc**
  - *Input*. Handle to the previously initialized output tensor descriptor.

- **requestedAlgoCount**
  - *Input*. The maximum number of elements to be stored in perfResults.

- **returnedAlgoCount**
  - *Output*. The number of output elements stored in perfResults.

- **perfResults**
  - *Output*. A user-allocated array to store performance metrics sorted ascending by compute time.

**Returns**

- **CUDNN_STATUS_SUCCESS**
  - The query was successful.

- **CUDNN_STATUS_BAD_PARAM**
  - At least one of the following conditions are met:
    - One of the parameters handle, xDesc, wDesc, convDesc, yDesc, perfResults, or returnedAlgoCount is NULL.
    - Either yDesc or wDesc have different dimensions from xDesc.
    - The data types of tensors xDesc, yDesc or wDesc are not all the same.
    - The number of feature maps in xDesc and wDesc differs.
    - The tensor xDesc has a dimension smaller than 3.
    - requestedAlgoCount is less than or equal to 0.
5.2.18. `cudnnGetConvolutionForwardWorkspaceSize()`

This function returns the amount of GPU memory workspace the user needs to allocate to be able to call `cudnnConvolutionForward()` with the specified algorithm. The workspace allocated will then be passed to the routine `cudnnConvolutionForward()`. The specified algorithm can be the result of the call to `cudnnGetConvolutionForwardAlgorithm_v7()` or can be chosen arbitrarily by the user.

Note that not every algorithm is available for every configuration of the input tensor and/or every configuration of the convolution descriptor.

```c
    cudnnStatus_t cudnnGetConvolutionForwardWorkspaceSize(
        cudnnHandle_t handle,
        const cudnnTensorDescriptor_t xDesc,
        const cudnnFilterDescriptor_t wDesc,
        const cudnnConvolutionDescriptor_t convDesc,
        const cudnnTensorDescriptor_t yDesc,
        cudnnConvolutionFwdAlgo_t algo,
        size_t *sizeInBytes)
```

**Parameters**

**handle**
- *Input*. Handle to a previously created cuDNN context.

**xDesc**
- *Input*. Handle to the previously initialized \( x \) tensor descriptor.

**wDesc**
- *Input*. Handle to a previously initialized filter descriptor.

**convDesc**
- *Input*. Previously initialized convolution descriptor.

**yDesc**
- *Input*. Handle to the previously initialized \( y \) tensor descriptor.

**algo**
- *Input*. Enumerant that specifies the chosen convolution algorithm.

**sizeInBytes**
- *Output*. Amount of GPU memory needed as workspace to be able to execute a forward convolution with the specified `algo`.

**Returns**

**CUDNN_STATUS_SUCCESS**
- The query was successful.

**CUDNN_STATUS_BAD_PARAM**
- At least one of the following conditions are met:
  - One of the parameters `handle`, `xDesc`, `wDesc`, `convDesc`, or `yDesc` is NULL.
  - The tensor `yDesc` or `wDesc` are not of the same dimension as `xDesc`.
  - The tensor `xDesc`, `yDesc` or `wDesc` are not of the same data type.
  - The numbers of feature maps of the tensor `xDesc` and `wDesc` differ.
The tensor xDesc has a dimension smaller than 3.

**CUDNN_STATUS_NOT_SUPPORTED**

The combination of the tensor descriptors, filter descriptor and convolution descriptor is not supported for the specified algorithm.

### 5.2.19. **cudnnGetConvolutionGroupCount()**

This function returns the group count specified in the given convolution descriptor.

```c
int cudnnGetConvolutionGroupCount(
    cudnnConvolutionDescriptor_t    convDesc,
    int                            *groupCount)
```

**Returns**

**CUDNN_STATUS_SUCCESS**

The group count was returned successfully.

**CUDNN_STATUS_BAD_PARAM**

An invalid convolution descriptor was provided.

### 5.2.20. **cudnnGetConvolutionMathType()**

This function returns the math type specified in a given convolution descriptor.

```c
int cudnnGetConvolutionMathType(
    cudnnConvolutionDescriptor_t    convDesc,
    cudnnMathType_t                *mathType)
```

**Returns**

**CUDNN_STATUS_SUCCESS**

The math type was returned successfully.

**CUDNN_STATUS_BAD_PARAM**

An invalid convolution descriptor was provided.

### 5.2.21. **cudnnGetConvolutionNdDescriptor()**

This function queries a previously initialized convolution descriptor object.

```c
int cudnnGetConvolutionNdDescriptor(
    const cudnnConvolutionDescriptor_t  convDesc,
    int arrayLengthRequested,
    int *arrayLength,
    int padA[],
    int filterStrideA[],
    int dilationA[],
    cudnnConvolutionMode_t             *mode,
    cudnnDataType_t                    *dataType)
```

**Parameters**

**convDesc**

*Input/Output.* Handle to a previously created convolution descriptor.
arrayLengthRequested

Input. Dimension of the expected convolution descriptor. It is also the minimum size of the arrays padA, filterStrideA, and dilationA in order to be able to hold the results.

arrayLength

Output. Actual dimension of the convolution descriptor.

padA

Output. Array of dimension of at least arrayLengthRequested that will be filled with the padding parameters from the provided convolution descriptor.

filterStrideA

Output. Array of dimension of at least arrayLengthRequested that will be filled with the filter stride from the provided convolution descriptor.

dilationA

Output. Array of dimension of at least arrayLengthRequested that will be filled with the dilation parameters from the provided convolution descriptor.

mode

Output. Convolution mode of the provided descriptor.

datatype

Output. Datatype of the provided descriptor.

Returns

CUDA STATUS SUCCESS

The query was successful.

CUDA STATUS BAD PARAM

At least one of the following conditions are met:

- The descriptor convDesc is NIL.
- The arrayLengthRequest is negative.

CUDA STATUS NOT SUPPORTED

The arrayLengthRequested is greater than CUDNN_DIM_MAX-2.

5.2.22. cudnnGetConvolutionNdForwardOutputDim()

This function returns the dimensions of the resulting Nd tensor of a nbDims-2-D convolution, given the convolution descriptor, the input tensor descriptor and the filter descriptor. This function can help to setup the output tensor and allocate the proper amount of memory prior to launch the actual convolution.

cudnnStatus_t cudnnGetConvolutionNdForwardOutputDim(
    const cudnnConvolutionDescriptor_t  convDesc,
    const cudnnTensorDescriptor_t       inputTensorDesc,
    const cudnnFilterDescriptor_t       filterDesc,
    int                                 nbDims,
    int                                 tensorOutputDimA[])

Each dimension of the (nbDims-2)-D images of the output tensor is computed as follows:

\[
outputDim = 1 + (inputDim + 2*pad - (((filterDim-1)*dilation)+1)) / convolutionStride;
\]
Note: The dimensions provided by this routine must be strictly respected when calling cudnnConvolutionForward() or cudnnConvolutionBackwardBias(). Providing a smaller or larger output tensor is not supported by the convolution routines.

Parameters

- **convDesc**
  - *Input*. Handle to a previously created convolution descriptor.

- **inputTensorDesc**
  - *Input*. Handle to a previously initialized tensor descriptor.

- **filterDesc**
  - *Input*. Handle to a previously initialized filter descriptor.

- **nbDims**
  - *Input*. Dimension of the output tensor.

- **tensorOuputDimA**
  - *Output*. Array of dimensions nbDims that contains on exit of this routine the sizes of the output tensor.

Returns

- **CUDNN_STATUS_BAD_PARAM**
  - At least one of the following conditions are met:
    - One of the parameters convDesc, inputTensorDesc, and filterDesc is nil.
    - The dimension of the filter descriptor filterDesc is different from the dimension of input tensor descriptor inputTensorDesc.
    - The dimension of the convolution descriptor is different from the dimension of input tensor descriptor inputTensorDesc-2.
    - The features map of the filter descriptor filterDesc is different from the one of input tensor descriptor inputTensorDesc.
    - The size of the dilated filter filterDesc is larger than the padded sizes of the input tensor.
    - The dimension nbDims of the output array is negative or greater than the dimension of input tensor descriptor inputTensorDesc.

- **CUDNN_STATUS_SUCCESS**
  - The routine exited successfully.

5.2.23. **cudnnGetConvolutionReorderType()**

This function retrieves the convolution reorder type from the given convolution descriptor.

```c
void cudnnGetConvolutionReorderType(
    cudnnConvolutionDescriptor_t convDesc,
    cudnnReorderType_t *reorderType);
```
Parameters

convDesc
   *Input*. The convolution descriptor from which the reorder type should be retrieved.

reorderType
   *Output*. The retrieved reorder type. For more information, refer to cudnnReorderType_t.

Returns

CUDNN_STATUS_BAD_PARAM
   One of the inputs to this function is not valid.

CUDNN_STATUS_SUCCESS
   The reorder type is retrieved successfully.

5.2.24. cudnnGetFoldedConvBackwardDataDescriptors()

This function calculates folding descriptors for backward data gradients. It takes as input the data descriptors along with the convolution descriptor and computes the folded data descriptors and the folding transform descriptors. These can then be used to do the actual folding transform.

```c
const cudnnStatus_t cudnnGetFoldedConvBackwardDataDescriptors(const cudnnHandle_t handle, 
   const cudnnFilterDescriptor_t filterDesc, 
   const cudnnTensorDescriptor_t diffDesc, 
   const cudnnConvolutionDescriptor_t convDesc, 
   const cudnnTensorDescriptor_t gradDesc, 
   const cudnnTensorFormat_t transformFormat, 
   cudnnFilterDescriptor_t foldedFilterDesc, 
   cudnnTensorDescriptor_t paddedDiffDesc, 
   cudnnConvolutionDescriptor_t foldedConvDesc, 
   cudnnTensorDescriptor_t foldedGradDesc, 
   cudnnTensorTransformDescriptor_t filterFoldTransDesc, 
   cudnnTensorTransformDescriptor_t diffPadTransDesc, 
   cudnnTensorTransformDescriptor_t gradFoldTransDesc, 
   cudnnTensorTransformDescriptor_t gradUnfoldTransDesc); 
```

Parameters

handle
   *Input*. Handle to a previously created cuDNN context.

filterDesc
   *Input*. Filter descriptor before folding.

diffDesc
   *Input*. Diff descriptor before folding.
convDesc
   Input. Convolution descriptor before folding.
gradDesc
   Input. Gradient descriptor before folding.
transformFormat
   Input. Transform format for folding.
foldedFilterDesc
   Output. Folded filter descriptor.
paddedDiffDesc
   Output. Padded Diff descriptor.
foldedConvDesc
   Output. Folded convolution descriptor.
foldedGradDesc
   Output. Folded gradient descriptor.
filterFoldTransDesc
   Output. Folding transform descriptor for filter.
diffPadTransDesc
   Output. Folding transform descriptor for Desc.
gradFoldTransDesc
   Output. Folding transform descriptor for gradient.
gradUnfoldTransDesc
   Output. Unfolding transform descriptor for folded gradient.

Returns

CUDNN_STATUS_SUCCESS
   Folded descriptors were computed successfully.
CUDNN_STATUS_BAD_PARAM
   If any of the input parameters is NULL or if the input tensor has more than 4
   dimensions.
CUDNN_STATUS_EXECUTION_FAILED
   Computing the folded descriptors failed.

5.2.25. cudnnIm2Col()

This function constructs the A matrix necessary to perform a forward pass of GEMM
convolution.

```
cudnnStatus_t cudnnIm2Col(
   cudnnHandle_t                   handle,
   cudnnTensorDescriptor_t         srcDesc,
   const void                      *srcData,
   cudnnFilterDescriptor_t         filterDesc,
   cudnnConvolutionDescriptor_t    convDesc,
   void                            *colBuffer)
```

This A matrix has a height of batch_size*y_height*y_width and width of
input_channels*filter_height*filter_width, where:
batch_size is srcDesc first dimension
y_height/y_width are computed from cudnnGetConvolutionNdForwardOutputDim()
input_channels is srcDesc second dimension (when in NCHW layout)
filter_height/filter_width are wDesc third and fourth dimension

The A matrix is stored in format HW fully-packed in GPU memory.

Parameters

handle
   Input. Handle to a previously created cuDNN context.

srcDesc
   Input. Handle to a previously initialized tensor descriptor.

srcData
   Input. Data pointer to GPU memory associated with the input tensor descriptor.

filterDesc
   Input. Handle to a previously initialized filter descriptor.

convDesc
   Input. Handle to a previously initialized convolution descriptor.

colBuffer
   Output. Data pointer to GPU memory storing the output matrix.

Returns

CUDNN_STATUS_BAD_PARAM
   srcData or colBuffer is NULL.

CUDNN_STATUS_NOT_SUPPORTED
   Any of srcDesc, filterDesc, convDesc has dataType of CUDNN_DATA_INT8, CUDNN_DATA_INT8x4, CUDNN_DATA_INT8 or CUDNN_DATA_INT8x4 convDesc has groupCount larger than 1.

CUDNN_STATUS_EXECUTION_FAILED
   The CUDA kernel execution was unsuccessful.

CUDNN_STATUS_SUCCESS
   The output data array is successfully generated.

5.2.26. cudnnReorderFilterAndBias()

This function cudnnReorderFilterAndBias(), reorders the filter and bias values for tensors with data type CUDNN_DATA_INT8x32 and tensor format CUDNN_TENSOR_NCHW_VECT_C. It can be used to enhance the inference time by separating the reordering operation from convolution. Currently, only 2D filters are supported.

```c
  cudnnStatus_t cudnnReorderFilterAndBias(
    cudnnHandle_t handle,
    const cudnnFilterDescriptor_t filterDesc,
    cudnnReorderType_t reorderType,
    const void *filterData,
    void *reorderedFilterData,
    int reorderBias,
  )
```
Filter and bias tensors with data type `CUDNN_DATA_INT8x32` (also implying tensor format `CUDNN_TENSOR_NCHW_VECT_C`) requires permutation of output channel axes in order to take advantage of the Tensor Core IMMA instruction. This is done in every `cudnnConvolutionForward()` and `cudnnConvolutionBiasActivationForward()` call when the reorder type attribute of the convolution descriptor is set to `CUDNN_DEFAULT_REORDER`. Users can avoid the repeated reordering kernel call by first using this call to reorder the filter and bias tensor and call the convolution forward APIs with reorder type set to `CUDNN_NO_REORDER`.

For example, convolutions in a neural network of multiple layers can require reordering of kernels at every layer, which can take up a significant fraction of the total inference time. Using this function, the reordering can be done one time on the filter and bias data. This is followed by the convolution operations at the multiple layers, which enhance the inference time.

### Parameters

- **handle**
  - *Input*. Handle to a previously created cuDNN context.

- **filterDesc**
  - *Input*. Descriptor for the kernel dataset.

- **reorderType**
  - *Input*. Setting to either perform reordering or not. For more information, refer to `cudnnReorderType_t`.

- **filterData**
  - *Input*. Pointer to the filter (kernel) data location in the device memory.

- **reorderedFilterData**
  - *Output*. Pointer to the location in the device memory where the reordered filter data will be written to, by this function. This tensor has the same dimensions as `filterData`.

- **reorderBias**
  - *Input*. If > 0, then reorders the bias data also. If <= 0 then does not perform reordering operations on the bias data.

- **biasData**
  - *Input*. Pointer to the bias data location in the device memory.

- **reorderedBiasData**
  - *Output*. Pointer to the location in the device memory where the reordered bias data will be written to, by this function. This tensor has the same dimensions as `biasData`.

### Returns

- **CUDNN_STATUS_SUCCESS**
  - Reordering was successful.

- **CUDNN_STATUS_EXECUTION_FAILED**
  - Either the reordering of the filter data or of the bias data failed.
**CUDNN_STATUS_BAD_PARAM**

The handle, filter descriptor, filter data, or reordered data is NULL. Or, if the bias reordering is requested ($\text{reorderBias} > 0$), the bias data or reordered bias data is NULL. This status can also be returned if the filter dimension size is not 4.

**CUDNN_STATUS_NOT_SUPPORTED**

Filter descriptor data type is not CUDNN_DATA_INT8x32; the filter descriptor tensor is not in a vectorized layout (CUDNN_TENSOR_NCHW_VECT_C).

### 5.2.27. cudnnSetConvolution2dDescriptor()

This function initializes a previously created convolution descriptor object into a 2D correlation. This function assumes that the tensor and filter descriptors correspond to the forward convolution path and checks if their settings are valid. That same convolution descriptor can be reused in the backward path provided it corresponds to the same layer.

```c
__host__ __device__ cudnnStatus_t cudnnSetConvolution2dDescriptor(
    cudnnConvolutionDescriptor_t    convDesc,
    int                             pad_h,
    int                             pad_w,
    int                             u,
    int                             v,
    int                             dilation_h,
    int                             dilation_w,
    cudnnConvolutionMode_t          mode,
    cudnnDataType_t                 computeType)
```

**Parameters**

**convDesc**

*Input/Output.* Handle to a previously created convolution descriptor.

**pad_h**

*Input.* Zero-padding height: number of rows of zeros implicitly concatenated onto the top and onto the bottom of input images.

**pad_w**

*Input.* Zero-padding width: number of columns of zeros implicitly concatenated onto the left and onto the right of input images.

**u**

*Input.* Vertical filter stride.

**v**

*Input.* Horizontal filter stride.

**dilation_h**

*Input.* Filter height dilation.

**dilation_w**

*Input.* Filter width dilation.

**mode**

*Input.* Selects between CUDNN_CONVOLUTION and CUDNN_CROSS_CORRELATION.

**computeType**

*Input.* Compute precision.
Returns

**CUDNN_STATUS_SUCCESS**
   The object was set successfully.

**CUDNN_STATUS_BAD_PARAM**
   At least one of the following conditions are met:
   • The descriptor `convDesc` is NIL.
   • One of the parameters `pad_h`, `pad_w` is strictly negative.
   • One of the parameters `u`, `v` is negative or zero.
   • One of the parameters `dilation_h`, `dilation_w` is negative or zero.
   • The parameter `mode` has an invalid enumerant value.

5.2.28. **cudnnSetConvolutionGroupCount()**

This function allows the user to specify the number of groups to be used in the associated convolution.

```c
void cudnnSetConvolutionGroupCount(
    cudnnConvolutionDescriptor_t convDesc,
    int groupCount);
```

Returns

**CUDNN_STATUS_SUCCESS**
   The group count was set successfully.

**CUDNN_STATUS_BAD_PARAM**
   An invalid convolution descriptor was provided.

5.2.29. **cudnnSetConvolutionMathType()**

This function allows the user to specify whether or not the use of tensor op is permitted in the library routines associated with a given convolution descriptor.

```c
void cudnnSetConvolutionMathType(
    cudnnConvolutionDescriptor_t convDesc,
    cudnnMathType_t mathType);
```

Returns

**CUDNN_STATUS_SUCCESS**
   The math type was set successfully.

**CUDNN_STATUS_BAD_PARAM**
   Either an invalid convolution descriptor was provided or an invalid math type was specified.

5.2.30. **cudnnSetConvolutionNdDescriptor()**

This function initializes a previously created generic convolution descriptor object into a Nd correlation. That same convolution descriptor can be reused in the backward path.
provided it corresponds to the same layer. The convolution computation will be done in
the specified dataType, which can be potentially different from the input/output tensors.

```c
void cudnnSetConvolutionNdDescriptor(cudnnConvolutionDescriptor_t convDesc,
                                     int arrayLength,
                                     const int* padA,
                                     const int* filterStrideA,
                                     const int* dilationA,
                                     cudnnConvolutionMode_t mode,
                                     cudnnDataType_t dataType)
```

**Parameters**

**convDesc**
- Input/Output. Handle to a previously created convolution descriptor.

**arrayLength**
- Input. Dimension of the convolution.

**padA**
- Input. Array of dimension arrayLength containing the zero-padding size for each
dimension. For every dimension, the padding represents the number of extra zeros
implicitly concatenated at the start and at the end of every element of that dimension.

**filterStrideA**
- Input. Array of dimension arrayLength containing the filter stride for each dimension.
  For every dimension, the filter stride represents the number of elements to slide to
reach the next start of the filtering window of the next point.

**dilationA**
- Input. Array of dimension arrayLength containing the dilation factor for each
dimension.

**mode**
- Input. Selects between CUDNN_CONVOLUTION and CUDNN_CROSS_CORRELATION.

**dataType**
- Input. Selects the data type in which the computation will be done.

**Note:** CUDNN_DATA_HALF in cudnnSetConvolutionNdDescriptor() with
HALF_CONVOLUTION_BWD_FILTER is **not recommended** as it is known to not
be useful for any practical use case for training and will be considered to
be blocked in a future cuDNN release. The use of CUDNN_DATA_HALF for
input tensors in cudnnSetTensorNdDescriptor() and CUDNN_DATA_FLOAT in
cudnnSetConvolutionNdDescriptor() with HALF_CONVOLUTION_BWD_FILTER is
recommended and is used with the automatic mixed precision (AMP) training in many
well known deep learning frameworks.

**Returns**

**CUDNN_STATUS_SUCCESS**
- The object was set successfully.
CUDNN_STATUS_BAD_PARAM
At least one of the following conditions are met:

- The descriptor `convDesc` is NIL.
- The `arrayLengthRequest` is negative.
- The enumerant `mode` has an invalid value.
- The enumerant `datatype` has an invalid value.
- One of the elements of `padA` is strictly negative.
- One of the elements of `strideA` is negative or zero.
- One of the elements of `dilationA` is negative or zero.

CUDNN_STATUS_NOT_SUPPORTED
At least one of the following conditions are met:

- The `arrayLengthRequest` is greater than `CUDNN_DIM_MAX`.

5.2.31. **cudnnSetConvolutionReorderType()**
This function sets the convolution reorder type for the given convolution descriptor.

```c
void cudnnSetConvolutionReorderType(
  cudnnConvolutionDescriptor_t convDesc,
  cudnnReorderType_t reorderType);
```

**Parameters**

- `convDesc`
  - *Input*. The convolution descriptor for which the reorder type should be set.

- `reorderType`
  - *Input*. Set the reorder type to this value. For more information, refer to `cudnnReorderType_t`.

**Returns**

- **CUDNN_STATUS_BAD_PARAM**
  - The reorder type supplied is not supported.

- **CUDNN_STATUS_SUCCESS**
  - Reorder type is set successfully.
Chapter 6.  cudnn_cnn_train.so Library

This entity contains all routines related to convolutional neural networks needed during training time. The cudnn_cnn_train library depends on cudnn_ops_infer, cudnn_ops_train, and cudnn_cnn_infer.

For the backend data and descriptor types, refer to the cuDNN Backend API section.

6.1.  Data Type References

These are the data type references in the cudnn_cnn_train.so library.

6.1.1.  Pointer To Opaque Struct Types

These are the pointers to the opaque struct types in the cudnn_cnn_train.so library.

6.1.1.1.  cudnnFusedOpsConstParamPack_t

cudnnFusedOpsConstParamPack_t is a pointer to an opaque structure holding the description of the cudnnFusedOps constant parameters. Use the function cudnnCreateFusedOpsConstParamPack() to create one instance of this structure, and the function cudnnDestroyFusedOpsConstParamPack() to destroy a previously-created descriptor.

6.1.1.2.  cudnnFusedOpsPlan_t

cudnnFusedOpsPlan_t is a pointer to an opaque structure holding the description of the cudnnFusedOpsPlan. This descriptor contains the plan information, including the problem type and size, which kernels should be run, and the internal workspace partition. Use the function cudnnCreateFusedOpsPlan() to create one instance of this structure, and the function cudnnDestroyFusedOpsPlan() to destroy a previously-created descriptor.

6.1.1.3.  cudnnFusedOpsVariantParamPack_t

cudnnFusedOpsVariantParamPack_t is a pointer to an opaque structure holding the description of the cudnnFusedOps variant parameters. Use the function
cudnnCreateFusedOpsVariantParamPack() to create one instance of this structure, and the function cudnnDestroyFusedOpsVariantParamPack() to destroy a previously-created descriptor.

6.1.2. Struct Types
These are the struct types in the cudnn_cnn_train.so library.

6.1.2.1. cudnnConvolutionBwdFilterAlgoPerf_t

cudnnConvolutionBwdFilterAlgoPerf_t is a structure containing performance results returned by cudnnFindConvolutionBackwardFilterAlgorithm() or heuristic results returned by cudnnGetConvolutionBackwardFilterAlgorithm_v7().

Data Members

cudnnConvolutionBwdFilterAlgo_t algo
The algorithm runs to obtain the associated performance metrics.

cudnnStatus_t status
If any error occurs during the workspace allocation or timing of cudnnConvolutionBackwardFilter(), this status will represent that error. Otherwise, this status will be the return status of cudnnConvolutionBackwardFilter().

▶ CUDNN_STATUS_ALLOC_FAILED if any error occurred during workspace allocation or if the provided workspace is insufficient.
▶ CUDNN_STATUS_INTERNAL_ERROR if any error occurred during timing calculations or workspace deallocation.
▶ Otherwise, this will be the return status of cudnnConvolutionBackwardFilter().

float time
The execution time of cudnnConvolutionBackwardFilter() (in milliseconds).

size_t memory
The workspace size (in bytes).

cudnnDeterminism_t determinism
The determinism of the algorithm.

cudnnMathType_t mathType
The math type provided to the algorithm.

int reserved[3]
Reserved space for future properties.

6.1.3. Enumeration Types
These are the enumeration types in the cudnn_cnn_train.so library.
6.1.3.1. **cudnnFusedOps_t**

The `cudnnFusedOps_t` type is an enumerated type to select a specific sequence of computations to perform in the fused operations.

**Members and Descriptions**

- **CUDNN_FUSED_SCALE_BIAS_ACTIVATION_CONV_BNSTATS = 0**
  
  On a per-channel basis, it performs these operations in this order: scale, add bias, activation, convolution, and generate batchnorm statistics.

- **Figure 1. Operations Per Channel For CUDNN_FUSED_SCALE_BIAS_ACTIVATION_CONV_BNSTATS**

- **CUDNN_FUSED_SCALE_BIAS_ACTIVATION_WGRAD = 1**
  
  On a per-channel basis, it performs these operations in this order: scale, add bias, activation, convolution backward weights, and generate batchnorm statistics.

- **CUDNN_FUSED_BN_FINALIZE_STATISTICS_TRAINING = 2**
  
  Computes the equivalent scale and bias from ySum, ySqSum and learned scale, bias. Optionally, update running statistics and generate saved stats.

- **CUDNN_FUSED_BN_FINALIZE_STATISTICS_INFERENCE = 3**
  
  Computes the equivalent scale and bias from the learned running statistics and the learned scale, bias.
CUDNN_FUSED_CONV_SCALE_BIAS_ADD_ACTIVATION = 4

On a per-channel basis, performs these operations in this order: convolution, scale, add bias, element-wise addition with another tensor, and activation.

CUDNN_FUSEDSCALE_BIAS_ADD_ACTIVATION_GEN_BITMASK = 5

On a per-channel basis, performs these operations in this order: scale and bias on one tensor, scale and bias on a second tensor, element-wise addition of these two tensors, and on the resulting tensor performs activation and generates activation bit mask.

CUDNN_FUSEDACTIVATION_FORK_DBATCHNORM = 6

On a per-channel basis, performs these operations in this order: backward activation, fork (meaning, write out gradient for the residual branch), and backward batch norm.

6.1.3.2. cudnnFusedOpsConstParamLabel_t

The cudnnFusedOpsConstParamLabel_t is an enumerated type for the selection of the type of the cudnnFusedOps descriptor. For more information, refer to cudnnSetFusedOpsConstParamPackAttribute().

typedef enum {
    CUDNN_PARAM_XDESC = 0,
    CUDNN_PARAM_XDATA_PLACEHOLDER = 1,
    CUDNN_PARAM_BN_MODE = 2,
    CUDNN_PARAM_BN_EQSCALEBIAS_DESC = 3,
    CUDNN_PARAM_BN_EQSCALE_PLACEHOLDER = 4,
    CUDNN_PARAM_BN_EQBIAS_PLACEHOLDER = 5,
    CUDNN_PARAM_ACTIVATION_DESC = 6,
    CUDNN_PARAM_CONV_DESC = 7,
    CUDNN_PARAM_WDESC = 8,
    CUDNN_PARAM_WDATA_PLACEHOLDER = 9,
    CUDNN_PARAM_DWDESC = 10,
    CUDNN_PARAM_DWDATA_PLACEHOLDER = 11,
    CUDNN_PARAM_YDESC = 12,
    CUDNN_PARAM_YDATA_PLACEHOLDER = 13,
    CUDNN_PARAM_DYDESC = 14,
    CUDNN_PARAM_DYDATA_PLACEHOLDER = 15,
    CUDNN_PARAM_YSTATS_DESC = 16,
    CUDNN_PARAM_YSUM_PLACEHOLDER = 17,
    CUDNN_PARAM_YSQSUM_PLACEHOLDER = 18,
    CUDNN_PARAM_BN_SCALEGAMMA_MEANVAR_DESC = 19,
    CUDNN_PARAM_BN_SCALE_PLACEHOLDER = 20,
    CUDNN_PARAM_BN_BIAS_PLACEHOLDER = 21,
    CUDNN_PARAM_BN_SAVED_MEAN_PLACEHOLDER = 22,
    CUDNN_PARAM_BN_SAVED_INVSTD_PLACEHOLDER = 23,
    CUDNN_PARAM_BN_RUNNING_MEAN_PLACEHOLDER = 24,
    CUDNN_PARAM_BN_RUNNING_VAR_PLACEHOLDER = 25,
    CUDNN_PARAM_ZDESC = 26,
    CUDNN_PARAM_ZDATA_PLACEHOLDER = 27,
    CUDNN_PARAM_BN_Z_EQSCALEBIAS_DESC = 28,
    CUDNN_PARAM_BN_Z_EQSCALE_PLACEHOLDER = 29,
    CUDNN_PARAM_BN_Z_EQBIAS_PLACEHOLDER = 30,
    CUDNN_PARAM_ACTIVATION_BITMASK_DESC = 31,
    CUDNN_PARAM_ACTIVATION_BITMASK_PLACEHOLDER = 32,
    CUDNN_PARAM_DXDESC = 33,
    CUDNN_PARAM_DXDATA_PLACEHOLDER = 34,
    CUDNN_PARAM_DZDESC = 35,
    CUDNN_PARAM_DZDATA_PLACEHOLDER = 36,
    CUDNN_PARAM_BN_DSCALE_PLACEHOLDER = 37,
    CUDNN_PARAM_BN_DBIAS_PLACEHOLDER = 38,
} cudnnFusedOpsConstParamLabel_t;
### Table 31. Legend For Tables in cudnnFusedOpsConstParamLabel_t

<table>
<thead>
<tr>
<th>Short Form Used</th>
<th>Stands For</th>
</tr>
</thead>
<tbody>
<tr>
<td>Setter</td>
<td>cudnnSetFusedOpsConstParamPackAttribute()</td>
</tr>
<tr>
<td>Getter</td>
<td>cudnnGetFusedOpsConstParamPackAttribute()</td>
</tr>
<tr>
<td>X_PointerPlaceHolder_t</td>
<td>cudnnFusedOpsPointerPlaceHolder_t</td>
</tr>
<tr>
<td>x_ prefix in the Attribute column</td>
<td>Stands for CUDNN_PARAM_ in the enumerator name</td>
</tr>
</tbody>
</table>

### Table 32. CUDNN_FUSED_SCALE_BIAS_ACTIVATION_CONV_BNSTATS In cudnnFusedOpsConstParamLabel_t

<table>
<thead>
<tr>
<th>Attribute</th>
<th>Expected Descriptor Type Passed in, in the Setter</th>
<th>Description</th>
<th>Default Value After Creation</th>
</tr>
</thead>
<tbody>
<tr>
<td>X_XDESC</td>
<td>In the setter, the *param should be xDesc, a pointer to a previously initialized cudnnTensorDescriptor_t.</td>
<td>Tensor descriptor describing the size, layout, and datatype of the x (input) tensor.</td>
<td>NULL</td>
</tr>
<tr>
<td>X_XDATA_PLACEHOLDER</td>
<td>In the setter, the *param should be a pointer to a previously initialized X_PointerPlaceHolder</td>
<td>Describes whether xData pointer in the VariantParamPack will be NULL, or if not, user promised pointer alignment*.</td>
<td>CUDNN_PTR_NULL</td>
</tr>
<tr>
<td>X_BN_MODE</td>
<td>In the setter, the <em>param should be a pointer to a previously initialized cudnnBatchNormMode_t</em>.</td>
<td>Describes the mode of operation for the scale, bias and the statistics. As of cuDNN 7.6.0, only CUDNN_BATCHNORM_SPATIAL and CUDNN_BATCHNORM_SPATIAL_PERSISTENT are supported, meaning, scale, bias, and statistics are all per-channel.</td>
<td>CUDNN_BATCHNORM_PER_ACTIVATION</td>
</tr>
<tr>
<td>X_BN_EQSCALEBIAS_DESC</td>
<td>In the setter, the *param should be a pointer to a previously initialized cudnnTensorDescriptor_t.</td>
<td>Tensor descriptor describing the size, layout, and datatype of the batchNorm equivalent scale and bias tensors. The shapes must match</td>
<td>NULL</td>
</tr>
</tbody>
</table>
For the attribute `CUDNN_FUSED_SCALE_BIAS_ACTIVATION_CONV_BNSTATS` in `cudnnFusedOpsConstParamLabel_t`

<table>
<thead>
<tr>
<th>Attribute</th>
<th>Expected Descriptor Type Passed in, in the Setter</th>
<th>Description</th>
<th>Default Value After Creation</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>the mode specified in <code>CUDNN_PARAM_BN_MODE</code>. If set to <code>NULL</code>, both scale and bias operation will become a NOP.</td>
<td></td>
<td></td>
</tr>
<tr>
<td><code>X_BN_EQSCALE_PLACEHOLDER</code></td>
<td>In the setter, the *param should be a pointer to a previously initialized <code>X_PointerPlaceHolder</code></td>
<td>Describes whether batchnorm equivalent scale pointer in the VariantParamPack will be <code>NULL</code>, or if not, user promised pointer alignment *. If set to <code>CUDNN_PTR_NULL</code>, then the scale operation becomes a NOP.</td>
<td><code>CUDNN_PTR_NULL</code></td>
</tr>
<tr>
<td><code>X_BN_EQBIAS_PLACEHOLDER</code></td>
<td>In the setter, the *param should be a pointer to a previously initialized <code>X_PointerPlaceHolder</code></td>
<td>Describes whether batchnorm equivalent bias pointer in the VariantParamPack will be <code>NULL</code>, or if not, user promised pointer alignment *. If set to <code>CUDNN_PTR_NULL</code>, then the bias operation becomes a NOP.</td>
<td><code>CUDNN_PTR_NULL</code></td>
</tr>
<tr>
<td><code>X_ACTIVATION_DESC</code></td>
<td>In the setter, the *param should be a pointer to a previously initialized <code>cudnnActivationDescriptor_t</code></td>
<td>Describes the activation operation. As of cuDNN 7.6.0, only activation modes of <code>CUDNN_ACTIVATION_RELU</code> and <code>CUDNN_ACTIVATION_IDENTITY</code> are supported. If set to <code>NULL</code> or if the activation mode is set to <code>CUDNN_ACTIVATION_IDENTITY</code>, then the activation in the op sequence becomes a NOP.</td>
<td><code>NULL</code></td>
</tr>
</tbody>
</table>
For the attribute **CUDNN_FUSED_SCALE_BIAS_ACTIVATION_CONV_BNSTATS** in `cudnnFusedOpsConstParamLabel_t`

<table>
<thead>
<tr>
<th>Attribute</th>
<th>Expected Descriptor Type Passed in, in the Setter</th>
<th>Description</th>
<th>Default Value After Creation</th>
</tr>
</thead>
<tbody>
<tr>
<td>X_CONV_DESC</td>
<td>In the setter, the *param should be a pointer to a previously initialized <code>cudnnConvolutionDescriptor_t*</code></td>
<td>Describes the convolution operation.</td>
<td>NULL</td>
</tr>
<tr>
<td>X_WDESC</td>
<td>In the setter, the *param should be a pointer to a previously initialized <code>cudnnFilterDescriptor_t*</code></td>
<td>Filter descriptor describing the size, layout and datatype of the w (filter) tensor.</td>
<td>NULL</td>
</tr>
<tr>
<td>X_WDATA_PLACEHOLDER</td>
<td>In the setter, the *param should be a pointer to a previously initialized <code>X_PointerPlaceHolder</code></td>
<td>Describes whether w (filter) tensor pointer in the VariantParamPack will be NULL, or if not, user promised pointer alignment *.</td>
<td>CUDNN_PTR_NULL</td>
</tr>
<tr>
<td>X_YDESC</td>
<td>In the setter, the *param should be a pointer to a previously initialized <code>cudnnTensorDescriptor_t*</code></td>
<td>Tensor descriptor describing the size, layout and datatype of the y (output) tensor.</td>
<td>NULL</td>
</tr>
<tr>
<td>X_YDATA_PLACEHOLDER</td>
<td>In the setter, the *param should be a pointer to a previously initialized <code>X_PointerPlaceHolder</code></td>
<td>Describes whether y (output) tensor pointer in the VariantParamPack will be NULL, or if not, user promised pointer alignment *.</td>
<td>CUDNN_PTR_NULL</td>
</tr>
<tr>
<td>X_YSTATS_DESC</td>
<td>In the setter, the *param should be a pointer to a previously initialized <code>cudnnTensorDescriptor_t*</code></td>
<td>Tensor descriptor describing the size, layout and datatype of the sum of y and sum of y square tensors. The shapes need to match the mode specified in <code>CUDNN_PARAM_BN_MODE</code>. If set to NULL, the y statistics generation operation will become a NOP.</td>
<td>NULL</td>
</tr>
<tr>
<td>X_YSUM_PLACEHOLDER</td>
<td>In the setter, the *param should be a pointer to a previously initialized <code>X_PointerPlaceHolder</code></td>
<td>Describes whether sum of y pointer in the</td>
<td>CUDNN_PTR_NULL</td>
</tr>
</tbody>
</table>
For the attribute CUDNN_FUSED_SCALE_BIAS_ACTIVATION_CONV_BNSTATS in cudnnFusedOpsConstParamLabel_t

<table>
<thead>
<tr>
<th>Attribute</th>
<th>Expected Descriptor Type Passed in, in the Setter</th>
<th>Description</th>
<th>Default Value After Creation</th>
</tr>
</thead>
</table>
| be a pointer to a previously initialized X_PointerPlaceHolder | VariantParamPack will be NULL, or if not, user promised pointer alignment *.
If set to CUDNN_PTR_NULL, the y statistics generation operation will become a NOP. | | |
| X_YSQSUM_PLACEHOLDER | In the setter, the *param should be a pointer to a previously initialized X_PointerPlaceHolder | Describes whether sum of y square pointer in the VariantParamPack will be NULL, or if not, user promised pointer alignment *.
If set to CUDNN_PTR_NULL, the y statistics generation operation will become a NOP. | CUDNN_PTR_NULL |

Note:
- If the corresponding pointer placeholder in ConstParamPack is set to CUDNN_PTR_NULL, then the device pointer in the VariantParamPack needs to be NULL as well.
- If the corresponding pointer placeholder in ConstParamPack is set to CUDNN_PTR_ELEM_ALIGNED or CUDNN_PTR_16B_ALIGNED, then the device pointer in the VariantParamPack may not be NULL and need to be at least element-aligned or 16 bytes-aligned, respectively.

As of cuDNN 7.6.0, if the conditions in Table 33 are met, then the fully fused fast path will be triggered. Otherwise, a slower partially fused path will be triggered.

Table 33. Conditions for Fully Fused Fast Path (Forward) for cudnnFusedOpsConstParamLabel_t

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Condition</th>
</tr>
</thead>
<tbody>
<tr>
<td>Device compute capability</td>
<td>Need to be one of 7.0, 7.2 or 7.5.</td>
</tr>
<tr>
<td>CUDNN_PARAM_XDESC</td>
<td>Tensor is 4 dimensional</td>
</tr>
<tr>
<td>CUDNN_PARAM_XDATA_PLACEHOLDER</td>
<td>Datatype is CUDNN_DATA_HALF</td>
</tr>
<tr>
<td>Parameter</td>
<td>Condition</td>
</tr>
<tr>
<td>-----------------------------------</td>
<td>---------------------------------------------------------------------------</td>
</tr>
<tr>
<td>cudnn_cnn_train.so</td>
<td></td>
</tr>
<tr>
<td>Library</td>
<td></td>
</tr>
<tr>
<td>Parameter</td>
<td>Condition</td>
</tr>
<tr>
<td>Parameter</td>
<td></td>
</tr>
<tr>
<td>cudnn_param_bn_eqscalebias_desc</td>
<td>If either one of scale and bias operation is not turned into a NOP:</td>
</tr>
<tr>
<td>cudnn_param_bn_eqscale_placeholder</td>
<td>Tensor is 4 dimensional with shape 1xCx1x1</td>
</tr>
<tr>
<td>cudnn_param_bn_eqbias_placeholder</td>
<td>Datatype is cudnn_data_half</td>
</tr>
<tr>
<td>cudnn_param_bn_eqscalebias_desc</td>
<td>Layout is fully packed</td>
</tr>
<tr>
<td>cudnn_param_bn_eqscale_placeholder</td>
<td>Alignment is cudnn_ptr_16b_aligned</td>
</tr>
<tr>
<td>cudnn_param_bn_eqbias_placeholder</td>
<td></td>
</tr>
<tr>
<td>cudnn_param_conv_desc</td>
<td>Convolution descriptor’s mode needs to be cudnn_cross_correlation.</td>
</tr>
<tr>
<td>cudnn_param_wdesc</td>
<td>Convolution descriptor’s dataType needs to be cudnn_data_float.</td>
</tr>
<tr>
<td>cudnn_param_wdata_placeholder</td>
<td>Convolution descriptor’s dilationA is (1,1).</td>
</tr>
<tr>
<td>cudnn_param_conv_desc</td>
<td>Convolution descriptor’s group count needs to be 1.</td>
</tr>
<tr>
<td>cudnn_param_wdesc</td>
<td>Convolution descriptor’s mathType needs to be cudnn_tensor_op_math or</td>
</tr>
<tr>
<td>cudnn_param_wdata_placeholder</td>
<td>cudnn_tensor_op_math_allow_conversion.</td>
</tr>
<tr>
<td>cudnn_param_conv_desc</td>
<td>Filter is in NHWC layout</td>
</tr>
<tr>
<td>cudnn_param_wdesc</td>
<td>Filter’s dataType is cudnn_data_half</td>
</tr>
<tr>
<td>cudnn_param_wdata_placeholder</td>
<td>Filter’s K dimension is a multiple of 32</td>
</tr>
<tr>
<td>cudnn_param_conv_desc</td>
<td>Filter size RxS is either 1x1 or 3x3</td>
</tr>
<tr>
<td>cudnn_param_wdesc</td>
<td>If filter size RxS is 1x1, convolution descriptor’s padA needs to be (0,0)</td>
</tr>
<tr>
<td>cudnn_param_wdata_placeholder</td>
<td>and filterStrideA needs to be (1,1).</td>
</tr>
<tr>
<td>cudnn_param_wdesc</td>
<td>Filter’s alignment is cudnn_ptr_16b_aligned</td>
</tr>
<tr>
<td>cudnn_param_wdata_placeholder</td>
<td></td>
</tr>
<tr>
<td>cudnn_param_ydesc</td>
<td>Tensor is 4 dimensional</td>
</tr>
<tr>
<td>cudnn_param_ydata_placeholder</td>
<td>Datatype is cudnn_data_half</td>
</tr>
<tr>
<td>cudnn_param_ydesc</td>
<td>Layout is NHWC fully packed</td>
</tr>
<tr>
<td>cudnn_param_ydata_placeholder</td>
<td>Alignment is cudnn_ptr_16b_aligned</td>
</tr>
<tr>
<td>cudnn_param_ydesc</td>
<td></td>
</tr>
<tr>
<td>cudnn_param_ystats_desc</td>
<td>If the generate statistics operation is not turned into a NOP:</td>
</tr>
<tr>
<td>cudnn_param_ysum_placeholder</td>
<td>Tensor is 4 dimensional with shape 1xKx1x1</td>
</tr>
<tr>
<td>cudnn_param_ysqsum_placeholder</td>
<td>Datatype is cudnn_data_float</td>
</tr>
<tr>
<td>cudnn_param_ystats_desc</td>
<td>Layout is fully packed</td>
</tr>
<tr>
<td>cudnn_param_ysum_placeholder</td>
<td>Alignment is cudnn_ptr_16b_aligned</td>
</tr>
<tr>
<td>cudnn_param_ysqsum_placeholder</td>
<td></td>
</tr>
</tbody>
</table>
Table 34. **CUDNN_FUSED_SCALE_BIAS_ACTIVATION_WGRAD** in `cudnnFusedOpsConstParamLabel_t`

<table>
<thead>
<tr>
<th>Attribute</th>
<th>Expected Descriptor Type Passed in, in the Setter</th>
<th>Description</th>
<th>Default Value After Creation</th>
</tr>
</thead>
<tbody>
<tr>
<td>X_XDESC</td>
<td>In the setter, the <code>*param</code> should be <code>xDesc</code>, a pointer to a previously initialized <code>cudnnTensorDescriptor_t</code>.</td>
<td>Tensor descriptor describing the size, layout and datatype of the <code>x</code> (input) tensor</td>
<td>NULL</td>
</tr>
<tr>
<td>X_XDATA_PLACEHOLDER</td>
<td>In the setter, the <code>*param</code> should be a pointer to a previously initialized <code>X_PointerPlaceHolder_t*</code>.</td>
<td>Describes whether <code>xData</code> pointer in the VariantParamPack will be <code>NULL</code>, or if not, user promised pointer alignment.</td>
<td>CUDNN_PTR_NULL</td>
</tr>
<tr>
<td>X_BN_MODE</td>
<td>In the setter, the <code>*param</code> should be a pointer to a previously initialized <code>cudnnBatchNormMode_t*</code>.</td>
<td>Describes the mode of operation for the scale, bias and the statistics.</td>
<td>CUDNN_BATCHNORM_PER_ACTIVATION</td>
</tr>
<tr>
<td>X_BN_EQSCALEBIAS_DESC</td>
<td>In the setter, the <code>*param</code> should be a pointer to a previously initialized <code>cudnnTensorDescriptor_t</code>.</td>
<td>Tensor descriptor describing the size, layout and datatype of the batchNorm equivalent scale and bias tensors. The shapes must match</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>the mode specified in CUDNN_PARAM_BN_MODE. If set to <code>NULL</code>, both scale and bias operation will become a NOP.</td>
<td>NULL</td>
</tr>
<tr>
<td>X_BN_EQSCALE_PLACEHOLDER</td>
<td>In the setter, the <code>*param</code> should be a pointer to a previously initialized <code>cudnnTensorDescriptor_t</code>.</td>
<td>Describes whether batchnorm equivalent scale</td>
<td>CUDNN_PTR_NULL</td>
</tr>
<tr>
<td>Attribute</td>
<td>Expected Descriptor Type Passed in, in the Setter</td>
<td>Description</td>
<td>Default Value After Creation</td>
</tr>
<tr>
<td>-----------</td>
<td>-----------------------------------------------</td>
<td>-------------</td>
<td>-------------------------------</td>
</tr>
<tr>
<td><code>CUDNN_FUSED_SCALE_BIAS_ACTIVATION_WGRAD</code> in cudnnFusedOpsConstParamLabel_t</td>
<td>previously initialized <code>X_PointerPlaceHolder_t*</code></td>
<td>pointer in the VariantParamPack will be NULL, or if not, user promised pointer alignment <code>*</code>. If set to <code>CUDNN_PTR_NULL</code>, then the scale operation becomes a NOP.</td>
<td></td>
</tr>
<tr>
<td><code>X_BN_EQBIAS_PLACEHOLDER</code></td>
<td>In the setter, the <code>*param</code> should be a pointer to a previously initialized <code>X_PointerPlaceHolder_t*</code></td>
<td>Describes whether batchnorm equivalent bias pointer in the VariantParamPack will be NULL, or if not, user promised pointer alignment <code>*</code>. If set to <code>CUDNN_PTR_NULL</code>, then the bias operation becomes a NOP.</td>
<td><code>CUDNN_PTR_NULL</code></td>
</tr>
<tr>
<td><code>X_ACTIVATION_DESC</code></td>
<td>In the setter, the <code>*param</code> should be a pointer to a previously initialized cudnnActivationDescriptor_t</td>
<td>Describes the activation operation. As of cuDNN 7.6.0, only the activation mode of <code>CUDNN_ACTIVATION_RELU</code> and <code>CUDNN_ACTIVATION_IDENTITY</code> is supported. If set to <code>NULL</code> or if the activation mode is set to <code>CUDNN_ACTIVATION_IDENTITY</code>, then the activation in the op sequence becomes a NOP.</td>
<td><code>NULL</code></td>
</tr>
<tr>
<td><code>X_CONV_DESC</code></td>
<td>In the setter, the <code>*param</code> should be a pointer to a previously initialized cudnnConvolutionDescriptor_t</td>
<td>Describes the convolution operation.</td>
<td><code>NULL</code></td>
</tr>
</tbody>
</table>
For the attribute `CUDNN_FUSED_SCALE_BIAS_ACTIVATION_WGRAD` in the `cudnnFusedOpsConstParamLabel_t`:

<table>
<thead>
<tr>
<th>Attribute</th>
<th>Expected Descriptor Type Passed in, in the Setter</th>
<th>Description</th>
<th>Default Value After Creation</th>
</tr>
</thead>
<tbody>
<tr>
<td>X_DWDESC</td>
<td>Previously initialized <code>cudnnConvolutionDescriptor_t*</code>.</td>
<td>Filter descriptor describing the size, layout and datatype of the ( dw ) (filter gradient output) tensor.</td>
<td>NULL</td>
</tr>
<tr>
<td>X_DWDATA_PLACEHOLDER</td>
<td>In the setter, the *param should be a pointer to a previously initialized <code>cudnnFilterDescriptor_t*</code>.</td>
<td>Describes whether ( dw ) (filter gradient output) tensor pointer in the <code>VariantParamPack</code> will be <code>NULL</code>, or if not, user promised pointer alignment *).</td>
<td><code>CUDNN_PTR_NULL</code></td>
</tr>
<tr>
<td>X_DYDESC</td>
<td>In the setter, the *param should be a pointer to a previously initialized <code>cudnnTensorDescriptor_t*</code>.</td>
<td>Tensor descriptor describing the size, layout and datatype of the ( dy ) (gradient input) tensor.</td>
<td>NULL</td>
</tr>
<tr>
<td>X_DYDATA_PLACEHOLDER</td>
<td>In the setter, the *param should be a pointer to a previously initialized <code>cudnnTensorDescriptor_t*</code>.</td>
<td>Describes whether ( dy ) (gradient input) tensor pointer in the <code>VariantParamPack</code> will be <code>NULL</code>, or if not, user promised pointer alignment *).</td>
<td><code>CUDNN_PTR_NULL</code></td>
</tr>
</tbody>
</table>

**Note:**

- If the corresponding pointer placeholder in `ConstParamPack` is set to `CUDNN_PTR_NULL`, then the device pointer in the `VariantParamPack` needs to be `NULL` as well.
- If the corresponding pointer placeholder in `ConstParamPack` is set to `CUDNN_PTR_ELEM_ALIGNED` or `CUDNN_PTR_16B_ALIGNED`, then the device pointer in the `VariantParamPack` may not be `NULL` and needs to be at least element-aligned or 16 bytes-aligned, respectively.

As of cuDNN 7.6.0, if the conditions in Table 35 are met, then the fully fused fast path will be triggered. Otherwise a slower partially fused path will be triggered.
Table 35. Conditions for Fully Fused Fast Path (Backward) for cudnnFusedOpsConstParamLabel_t

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Condition</th>
</tr>
</thead>
<tbody>
<tr>
<td>Device compute capability</td>
<td>Needs to be one of 7.0, 7.2 or 7.5.</td>
</tr>
<tr>
<td>CUDNN_PARAM_XDESC</td>
<td>Tensor is 4 dimensional</td>
</tr>
<tr>
<td>CUDNN_PARAM_XDATA_PLACEHOLDER</td>
<td>Datatype is CUDNN_DATA_HALF</td>
</tr>
<tr>
<td></td>
<td>Layout is NHWC fully packed</td>
</tr>
<tr>
<td></td>
<td>Alignment is CUDNN_PTR_16B_ALIGNED</td>
</tr>
<tr>
<td></td>
<td>Tensor’s C dimension is a multiple of 8.</td>
</tr>
<tr>
<td>CUDNN_PARAM_BN_EQSCALEBIAS_DESC</td>
<td>If either one of scale and bias operation is not turned into a NOP:</td>
</tr>
<tr>
<td>CUDNN_PARAM_BN_EQSCALE_PLACEHOLDER</td>
<td>Tensor is 4 dimensional with shape 1xCx1x1</td>
</tr>
<tr>
<td>CUDNN_PARAM_BN_EQBIAS_PLACEHOLDER</td>
<td>Datatype is CUDNN_DATA_HALF</td>
</tr>
<tr>
<td></td>
<td>Layout is fully packed</td>
</tr>
<tr>
<td></td>
<td>Alignment is CUDNN_PTR_16B_ALIGNED</td>
</tr>
<tr>
<td>CUDNN_PARAM_CONV_DESC</td>
<td>Convolution descriptor’s mode needs to be CUDNN_CROSS_CORRELATION.</td>
</tr>
<tr>
<td>CUDNN_PARAM_DWDESC</td>
<td>Convolution descriptor’s dataType needs to be CUDNN_DATA_FLOAT.</td>
</tr>
<tr>
<td>CUDNN_PARAM_DWDATA_PLACEHOLDER</td>
<td>Convolution descriptor’s dilationA is (1,1)</td>
</tr>
<tr>
<td></td>
<td>Convolution descriptor’s group count needs to be 1.</td>
</tr>
<tr>
<td></td>
<td>Convolution descriptor’s mathType needs to be CUDNN_TENSOR_OP_MATH</td>
</tr>
<tr>
<td></td>
<td>or CUDNN_TENSOR_OP_MATH_ALLOW_CONVERSION.</td>
</tr>
<tr>
<td></td>
<td>Filter gradient is in NHWC layout</td>
</tr>
<tr>
<td></td>
<td>Filter gradient’s data type is CUDNN_DATA_HALF</td>
</tr>
<tr>
<td></td>
<td>Filter gradient’s x dimension is a multiple of 32.</td>
</tr>
<tr>
<td></td>
<td>Filter gradient size RxS is either 1x1 or 3x3</td>
</tr>
<tr>
<td></td>
<td>If filter gradient size RxS is 1x1, convolution descriptor’s padA needs to be (0,0) and filterStrideA needs to be (1,1).</td>
</tr>
<tr>
<td></td>
<td>Filter gradient’s alignment is CUDNN_PTR_16B_ALIGNED</td>
</tr>
<tr>
<td>CUDNN_PARAM_DYDESC</td>
<td>Tensor is 4 dimensional</td>
</tr>
<tr>
<td>CUDNN_PARAM_DYDATA_PLACEHOLDER</td>
<td>Datatype is CUDNN_DATA_HALF</td>
</tr>
<tr>
<td></td>
<td>Layout is NHWC fully packed</td>
</tr>
<tr>
<td></td>
<td>Alignment is CUDNN_PTR_16B_ALIGNED</td>
</tr>
</tbody>
</table>
Table 36. **CUDNN_FUSED_BN_FINALIZE_STATISTICS_TRAINING** in `cudnnFusedOpsConstParamLabel_t`

For the attribute **CUDNN_FUSED_BN_FINALIZE_STATISTICS_TRAINING** in `cudnnFusedOpsConstParamLabel_t`

<table>
<thead>
<tr>
<th>Attribute</th>
<th>Expected Descriptor Type Passed in, in the Setter</th>
<th>Description</th>
<th>Default Value After Creation</th>
</tr>
</thead>
<tbody>
<tr>
<td>X_BN_MODE</td>
<td>In the setter, the *param should be a pointer to a previously initialized <code>cudnnBatchNormMode_t*</code></td>
<td>Describes the mode of operation for the scale, bias and the statistics. As of cuDNN 7.6.0, only CUDNN_BATCHNORM_SPATIAL and CUDNN_BATCHNORM_SPATIAL_PERSISTENT are supported, meaning, scale, bias and statistics are all per-channel.</td>
<td>CUDNN_BATCHNORM_PER_ACTIVATION</td>
</tr>
<tr>
<td>X_YSTATS_DESC</td>
<td>In the setter, the *param should be a pointer to a previously initialized <code>cudnnTensorDescriptor_t*</code></td>
<td>Tensor descriptor describing the size, layout and datatype of the sum of y and sum of y square tensors. The shapes need to match the mode specified in CUDNN_PARAM_BN_MODE.</td>
<td>NULL</td>
</tr>
</tbody>
</table>
| X_YSUM_PLACEHOLDER   | In the setter, the *param should be a pointer to a previously initialized `X_PointerPlaceHolder_t*` | Describes whether sum of y pointer in the VariantParamPack will be NULL, or if not, user promised pointer alignment *.
| X_YSQSUM_PLACEHOLDER | In the setter, the *param should be a pointer to a previously initialized `X_PointerPlaceHolder_t*` | Describes whether sum of y square pointer in the VariantParamPack will be NULL, or if not, user promised pointer alignment *.
| X_BN_SCALEBIAS_MEANVAR_DESC | In the setter, the *param should be a pointer to a previously initialized A common tensor descriptor describing the size, layout and datatype of | NULL                                          |
For the attribute **CUDNN_FUSED_BN_FINALIZE_STATISTICS_TRAINING** in `cudnnFusedOpsConstParamLabel_t`

<table>
<thead>
<tr>
<th>Attribute</th>
<th>Expected Descriptor Type Passed in, in the Setter</th>
<th>Description</th>
<th>Default Value After Creation</th>
</tr>
</thead>
<tbody>
<tr>
<td>X_BN_SCALE_PLACEHOLDER</td>
<td>previously initialized <code>cudnnTensorDescriptor_t</code></td>
<td>the batchNorm trained scale, bias and statistics tensors. The shapes need to match the mode specified in CUDNN_PARAM_BN_MODE (similar to the bnScaleBiasMeanVarDesc field in the cudnnBatchNormalization* API).</td>
<td>CUDNN_PTR_NULL</td>
</tr>
<tr>
<td></td>
<td>In the setter, the *param should be a pointer to a previously initialized <code>X\_PointerPlaceHolder_t</code></td>
<td>Describes whether the batchNorm trained scale pointer in the VariantParamPack will be NULL, or if not, user promised pointer alignment *. If the output of BN_EQSCALE is not needed, then this is not needed and may be NULL.</td>
<td>CUDNN_PTR_NULL</td>
</tr>
<tr>
<td>X_BN_BIAS_PLACEHOLDER</td>
<td>In the setter, the *param should be a pointer to a previously initialized <code>X\_PointerPlaceHolder_t</code></td>
<td>Describes whether the batchNorm trained bias pointer in the VariantParamPack will be NULL, or if not, user promised pointer alignment *. If neither output of BN_EQSCALE or BN_EQBIAS is needed, then this is not needed and may be NULL.</td>
<td>CUDNN_PTR_NULL</td>
</tr>
<tr>
<td>X_BN_SAVED_MEAN_PLACEHOLDER</td>
<td>In the setter, the *param should be a pointer to a previously initialized <code>X\_PointerPlaceHolder_t</code></td>
<td>Describes whether the batchNorm saved mean pointer in the VariantParamPack will be NULL, or if</td>
<td>CUDNN_PTR_NULL</td>
</tr>
</tbody>
</table>
For the attribute **CUDNN_FUSED_BNFINALIZE_STATISTICS_TRAINING** in cudnnFusedOpsConstParamLabel_t

<table>
<thead>
<tr>
<th>Attribute</th>
<th>Expected Descriptor Type Passed in, in the Setter</th>
<th>Description</th>
<th>Default Value After Creation</th>
</tr>
</thead>
<tbody>
<tr>
<td>CUDNN_PTR_NULL</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

| X_BN_SAVED_INVSTD_PLACEHOLDER | In the setter, the *param should be a pointer to a previously initialized X_PointerPlaceHolder | Describes whether the batchNorm saved inverse standard deviation pointer in the VariantParamPack will be NULL, or if not, user promised pointer alignment *. If set to CUDNN_PTR_NULL, then the computation for this output becomes a NOP. | CUDNN_PTR_NULL |
| X_BN_RUNNING_MEAN_PLACEHOLDER | In the setter, the *param should be a pointer to a previously initialized X_PointerPlaceHolder | Describes whether the batchNorm running mean pointer in the VariantParamPack will be NULL, or if not, user promised pointer alignment *. If set to CUDNN_PTR_NULL, then the computation for this output becomes a NOP. | CUDNN_PTR_NULL |
| X_BN_RUNNING_VAR_PLACEHOLDER | In the setter, the *param should be a pointer to a previously initialized X_PointerPlaceHolder | Describes whether the batchNorm running variance pointer in the VariantParamPack will be NULL, or if not, user promised pointer alignment *. If set to CUDNN_PTR_NULL, then the computation for this output becomes a NOP. | CUDNN_PTR_NULL |
For the attribute **CUDNN_FUSED_BN_FINALIZE_STATISTICS_TRAINING** in **cudnnFusedOpsConstParamLabel_t**

<table>
<thead>
<tr>
<th>Attribute</th>
<th>Expected Descriptor Type Passed in, in the Setter</th>
<th>Description</th>
<th>Default Value After Creation</th>
</tr>
</thead>
<tbody>
<tr>
<td>X_BN_EQSCALEBIAS_DESC</td>
<td>In the setter, the <em>param should be a pointer to a previously initialized cudnnTensorDescriptor_t</em></td>
<td>Tensor descriptor describing the size, layout and datatype of the batchNorm equivalent scale and bias tensors. The shapes need to match the mode specified in CUDNN_PARAM_BN_MODE. If neither output of BN_EQSCALE or BN_EQBIAS is needed, then this is not needed and may be NULL.</td>
<td>NULL</td>
</tr>
<tr>
<td>X_BN_EQSCALE_PLACEHOLDER</td>
<td>In the setter, the <em>param should be a pointer to a previously initialized X_PointerPlaceHolder_t</em></td>
<td>Describes whether batchnorm equivalent scale pointer in the VariantParamPack will be NULL, or if not, user promised pointer alignment *. If set to CUDNN_PTR_NULL, then the computation for this output becomes a NOP.</td>
<td>CUDNN_PTR_NULL</td>
</tr>
<tr>
<td>X_BN_EQBIAS_PLACEHOLDER</td>
<td>In the setter, the <em>param should be a pointer to a previously initialized X_PointerPlaceHolder_t</em></td>
<td>Describes whether batchnorm equivalent bias pointer in the VariantParamPack will be NULL, or if not, user promised pointer alignment *. If set to CUDNN_PTR_NULL, then the computation for this output becomes a NOP.</td>
<td>CUDNN_PTR_NULL</td>
</tr>
</tbody>
</table>
### Table 37. CUDNN_FUSED_BN_FINALIZE_STATISTICS_INFERENCE in cudnnFusedOpsConstParamLabel_t

<table>
<thead>
<tr>
<th>Attribute</th>
<th>Expected Descriptor Type Passed in, in the Setter</th>
<th>Description</th>
<th>Default Value After Creation</th>
</tr>
</thead>
<tbody>
<tr>
<td>X_BN_MODE</td>
<td>In the setter, the <em>param should be a pointer to a previously initialized cudnnBatchNormMode_t.</em></td>
<td>Describes the mode of operation for the scale, bias and the statistics.</td>
<td>CUDNN_BATCHNORM_PER_ACTIVATION</td>
</tr>
<tr>
<td>X_BN_SCALEBIAS_MEANVAR_DESC</td>
<td>In the setter, the *param should be a pointer to a previously initialized cudnnTensorDescriptor_t</td>
<td>A common tensor descriptor describing the size, layout and datatype of the batchNorm trained scale, bias and statistics tensors. The shapes need to match the</td>
<td>NULL</td>
</tr>
</tbody>
</table>
For the attribute `CUDNN_FUSED_BN_FINALIZE_STATISTICS_INFERNE` in `cudnnFusedOpsConstParamLabel_t`

<table>
<thead>
<tr>
<th>Attribute</th>
<th>Expected Descriptor Type Passed in, in the Setter</th>
<th>Description</th>
<th>Default Value After Creation</th>
</tr>
</thead>
<tbody>
<tr>
<td><code>X_BN_SCALE_PLACEHOLDER</code></td>
<td>In the setter, the *param should be a pointer to a previously initialized <code>X_PointerPlaceHolder_t</code></td>
<td>Describes whether the batchNorm trained scale pointer in the <code>VariantParamPack</code> will be <code>NULL</code>, or if not, user promised pointer alignment *</td>
<td><code>CUDNN_PTR_NULL</code></td>
</tr>
<tr>
<td><code>X_BN_BIAS_PLACEHOLDER</code></td>
<td>In the setter, the *param should be a pointer to a previously initialized <code>X_PointerPlaceHolder_t</code></td>
<td>Describes whether the batchNorm trained bias pointer in the <code>VariantParamPack</code> will be <code>NULL</code>, or if not, user promised pointer alignment *</td>
<td><code>CUDNN_PTR_NULL</code></td>
</tr>
<tr>
<td><code>X_BN_RUNNING_MEAN_PLACEHOLDER</code></td>
<td>In the setter, the *param should be a pointer to a previously initialized <code>X_PointerPlaceHolder_t</code></td>
<td>Describes whether the batchNorm running mean pointer in the <code>VariantParamPack</code> will be <code>NULL</code>, or if not, user promised pointer alignment *</td>
<td><code>CUDNN_PTR_NULL</code></td>
</tr>
<tr>
<td><code>X_BN_RUNNING_VAR_PLACEHOLDER</code></td>
<td>In the setter, the *param should be a pointer to a previously initialized <code>X_PointerPlaceHolder_t</code></td>
<td>Describes whether the batchNorm running variance pointer in the <code>VariantParamPack</code> will be <code>NULL</code>, or if not, user promised pointer alignment *</td>
<td><code>CUDNN_PTR_NULL</code></td>
</tr>
<tr>
<td><code>X_BN_EQSCALEBIAS_DESC</code></td>
<td>In the setter, the *param should be a pointer to a previously initialized <code>cudnnTensorDescriptor_t</code></td>
<td>Tensor descriptor describing the size, layout and datatype of the batchNorm equivalent scale</td>
<td><code>NULL</code></td>
</tr>
</tbody>
</table>
## For the attribute CUDNN_FUSED_BNFINALIZE_STATISTICS_INFERENCE in cudnnFusedOpsConstParamLabel_t

<table>
<thead>
<tr>
<th>Attribute</th>
<th>Expected Descriptor Type Passed in, in the Setter</th>
<th>Description</th>
<th>Default Value After Creation</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>and bias tensors. The shapes need to match the mode specified in CUDNN_PARAM_BN_MODE.</td>
<td>X_BN_EQSCALE_PLACEHOLDER: In the setter, the *param should be a pointer to a previously initialized X_PointerPlaceHolder</td>
<td>CUDNN_PTR_NULL</td>
</tr>
<tr>
<td>X_BN_EQSCALE_PLACEHOLDER</td>
<td>Describes whether batchnorm equivalent scale pointer in the VariantParamPack will be NULL, or if not, user promised pointer alignment *. If set to CUDNN_PTR_NULL, then the computation for this output becomes a NOP.</td>
<td>X_BN_EQBIAS_PLACEHOLDER: In the setter, the *param should be a pointer to a previously initialized X_PointerPlaceHolder</td>
<td>CUDNN_PTR_NULL</td>
</tr>
<tr>
<td>X_BN_EQBIAS_PLACEHOLDER</td>
<td>Describes whether batchnorm equivalent bias pointer in the VariantParamPack will be NULL, or if not, user promised pointer alignment *. If set to CUDNN_PTR_NULL, then the computation for this output becomes a NOP.</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Table 38. CUDNN_FUSED_CONVOLUTION_SCALE_BIAS_ADD_RELU in cudnnFusedOpsConstParamLabel_t

For the attribute CUDNN_FUSED_CONVOLUTION_SCALE_BIAS_ADD_RELU in cudnnFusedOpsConstParamLabel_t

This operation performs the following computation, where * denotes convolution operator:

\[ y = (w \ast x) + 2z + b \]

<table>
<thead>
<tr>
<th>Attribute</th>
<th>Expected Descriptor Type Passed in, in the Setter</th>
<th>Description</th>
<th>Default Value After Creation</th>
</tr>
</thead>
<tbody>
<tr>
<td>X_XDESC</td>
<td>In the setter, the *param should be xDesc, a pointer to a previously initialized cudnnTensorDescriptor_t.</td>
<td>Tensor descriptor describing the size, layout and datatype of the x (input) tensor.</td>
<td>NULL</td>
</tr>
<tr>
<td>X_XDATA_PLACEHOLDER</td>
<td>In the setter, the *param should be a pointer to a previously initialized X_PointerPlaceHolder</td>
<td>describes whether xData pointer in the VariantParamPack will be NULL, or if not, user promised pointer alignment *</td>
<td>CUDNN_PTR_NULL</td>
</tr>
<tr>
<td>X_CONV_DESC</td>
<td>In the setter, the <em>param should be a pointer to a previously initialized cudnnConvolutionDescriptor_t</em></td>
<td>Describes the convolution operation.</td>
<td>NULL</td>
</tr>
<tr>
<td>X_WDESC</td>
<td>In the setter, the <em>param should be a pointer to a previously initialized cudnnFilterDescriptor_t</em></td>
<td>Filter descriptor describing the size, layout and datatype of the w (filter) tensor.</td>
<td>NULL</td>
</tr>
<tr>
<td>X_WDATA_PLACEHOLDER</td>
<td>In the setter, the *param should be a pointer to a previously initialized X_PointerPlaceHolder</td>
<td>Describes whether w (filter) tensor pointer in the VariantParamPack will be NULL, or if not, user promised pointer alignment *</td>
<td>CUDNN_PTR_NULL</td>
</tr>
<tr>
<td>X_BN_EQSCALEBIAS_DESC</td>
<td>In the setter, the *param should be a pointer to a previously initialized cudnnTensorDescriptor</td>
<td>Tensor descriptor describing the size, layout and datatype of the #1 scale and bias tensors. The tensor should have shape (1,K,1,1), K is the number of output features.</td>
<td>NULL</td>
</tr>
<tr>
<td>X_BN_EQSCALE_PLACEHOLDER</td>
<td>In the setter, the *param should</td>
<td>Describes whether batchnorm equivalent</td>
<td>CUDNN_PTR_NULL</td>
</tr>
</tbody>
</table>
For the attribute `CUDNN_FUSED_CONVOLUTION_SCALE_BIAS_ADD_RELU` in `cudnnFusedOpsConstParamLabel_t`

This operation performs the following computation, where * denotes convolution operator: \( y = 1(w \star x) + 2z + b \)

<table>
<thead>
<tr>
<th>Attribute</th>
<th>Expected Descriptor Type Passed in, in the Setter</th>
<th>Description</th>
<th>Default Value After Creation</th>
</tr>
</thead>
<tbody>
<tr>
<td>X_ZDESC</td>
<td>In the setter, the *param should be xDesc, a pointer to a previously initialized cudnnTensorDescriptor_t.</td>
<td>Tensor descriptor describing the size, layout and datatype of the ( z ) tensor. If unset, then ( z ) scale-add term becomes a NOP.</td>
<td>NULL</td>
</tr>
<tr>
<td>CUDNN_PARAM_ZDATA_PLACEHOLDER</td>
<td>In the setter, the <em>param should be a pointer to a previously initialized X_PointerPlaceHolder_t</em>.</td>
<td>Describes whether ( z ) tensor pointer in the VariantParamPack will be NULL, or if not, user promised pointer alignment *. If set to CUDNN_PTR_NULL, then ( z ) scale-add term becomes a NOP.</td>
<td>CUDNN_PTR_NULL</td>
</tr>
<tr>
<td>CUDNN_PARAM_BN_Z_EQSCALEBIAS_DESC</td>
<td>In the setter, the <em>param should be a pointer to a previously initialized cudnnTensorDescriptor_t</em>.</td>
<td>Tensor descriptor describing the size, layout and datatype of the ( \alpha_2 ) tensor. If set to NULL then scaling for input ( z ) becomes a NOP.</td>
<td>NULLPTR</td>
</tr>
<tr>
<td>CUDNN_PARAM_BN_Z_EQSCALE_PLACEHOLDER</td>
<td>In the setter, the <em>param should be a pointer to a previously initialized X_PointerPlaceHolder_t</em>.</td>
<td>Describes whether batchnorm ( z )-equivalent scaling pointer in the VariantParamPack will be NULL, or if not,</td>
<td>CUDNN_PTR_NULL</td>
</tr>
</tbody>
</table>
For the attribute **CUDNN_FUSED_CONVOLUTION_SCALE_BIAS_ADD_RELU** in 
cudnnFusedOpsConstParamLabel_t

This operation performs the following computation, where * denotes convolution 
operator: \( y = 1(w*x) + 2 \ z + b \)

<table>
<thead>
<tr>
<th>Attribute</th>
<th>Expected Descriptor Type Passed in, in the Setter</th>
<th>Description</th>
<th>Default Value After Creation</th>
</tr>
</thead>
<tbody>
<tr>
<td>X_ACTIVATION_DESC</td>
<td>In the setter, the <em>param should be a pointer to a previously initialized cudnnActivationDescriptor_t</em></td>
<td>Describes the activation operation. As of 7.6.0, only activation modes of CUDNN_ACTIVATION_RELU and CUDNN_ACTIVATION_IDENTITY are supported. If set to NULL or if the activation mode is set to CUDNN_ACTIVATION_IDENTITY, then the activation in the op sequence becomes a NOP.</td>
<td>NULL</td>
</tr>
<tr>
<td>X_YDESC</td>
<td>In the setter, the <em>param should be a pointer to a previously initialized cudnnTensorDescriptor_t</em></td>
<td>Tensor descriptor describing the size, layout and datatype of the ( y ) (output) tensor.</td>
<td>NULL</td>
</tr>
<tr>
<td>X_YDATA_PLACEHOLDER</td>
<td>In the setter, the *param should be a pointer to a previously initialized X_PointerPlaceHolder</td>
<td>Describes whether ( y ) (output) tensor pointer in the VariantParamPack will be NULL, or if not, user promised pointer alignment *.</td>
<td>CUDNN_PTR_NULL</td>
</tr>
</tbody>
</table>

### 6.1.3.3. cudnnFusedOpsPointerPlaceHolder_t

`cudnnFusedOpsPointerPlaceHolder_t` is an enumerated type used to select the alignment type of the cudnnFusedOps descriptor pointer.
<table>
<thead>
<tr>
<th>Member</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>CUDNN_PTR_NULL = 0</td>
<td>Indicates that the pointer to the tensor in the variantPack will be NULL.</td>
</tr>
<tr>
<td>CUDNN_PTR_ELEM_ALIGNED = 1</td>
<td>Indicates that the pointer to the tensor in the variantPack will not be NULL, and will have element alignment.</td>
</tr>
<tr>
<td>CUDNN_PTR_16B_ALIGNED = 2</td>
<td>Indicates that the pointer to the tensor in the variantPack will not be NULL, and will have 16 byte alignment.</td>
</tr>
</tbody>
</table>

### 6.1.3.4. cudnnFusedOpsVariantParamLabel_t

The `cudnnFusedOpsVariantParamLabel_t` is an enumerated type that is used to set the buffer pointers. These buffer pointers can be changed in each iteration.

```c
typedef enum {
    CUDNN_PTR_XDATA = 0,
    CUDNN_PTR_BN_EQSCALE = 1,
    CUDNN_PTR_BN_EQBIAS = 2,
    CUDNN_PTR_WDATA = 3,
    CUDNN_PTR_DWDATA = 4,
    CUDNN_PTR_YDATA = 5,
    CUDNN_PTR_DYDATA = 6,
    CUDNN_PTR_YSUM = 7,
    CUDNN_PTR_YSQSUM = 8,
    CUDNN_PTR_WORKSPACE = 9,
    CUDNN_PTR_BN_SCALE = 10,
    CUDNN_PTR_BN_BIAS = 11,
    CUDNN_PTR_BN_SAVED_MEAN = 12,
    CUDNN_PTR_BN_SAVED_INVSTD = 13,
    CUDNN_PTR_BN_RUNNING_MEAN = 14,
    CUDNN_PTR_BN_RUNNING_VAR = 15,
    CUDNN_PTR_ZDATA = 16,
    CUDNN_PTR_BN_Z_EQSCALE = 17,
    CUDNN_PTR_BN_Z_EQBIAS = 18,
    CUDNN_PTR_ACTIVATION_BITMASK = 19,
    CUDNN_PTR_DXDATA = 20,
    CUDNN_PTR_DZDATA = 21,
    CUDNN_PTR_BN_DSCALE = 22,
    CUDNN_PTR_BN_DBIAS = 23,
    CUDNN_SCALAR_SIZE_T_WORKSPACE_SIZE_IN_BYTES = 100,
    CUDNN_SCALAR_INT64_T_BN_ACCUMULATION_COUNT = 101,
    CUDNN_SCALAR_DOUBLE_BN_EXP_AVG_FACTOR = 102,
    CUDNN_SCALAR_DOUBLE_BN_EPSILON = 103,
} cudnnFusedOpsVariantParamLabel_t;
```

### Table 39. Legend For Tables in cudnnFusedOpsVariantParamLabel_t

<table>
<thead>
<tr>
<th>Short-Form Used</th>
<th>Stands For</th>
</tr>
</thead>
<tbody>
<tr>
<td>Setter</td>
<td><code>cudnnSetFusedOpsVariantParamPackAttribute()</code></td>
</tr>
<tr>
<td>Getter</td>
<td><code>cudnnGetFusedOpsVariantParamPackAttribute()</code></td>
</tr>
<tr>
<td>x_prefix in the Attribute key column</td>
<td>Stands for CUDNN_PTR_ or CUDNN_SCALAR_ in the enumerator name.</td>
</tr>
</tbody>
</table>
Table 40. **CUDNN_FUSED_SCALE_BIAS_ACTIVATION_CONV_BNSTATS** in cudnnFusedOpsVariantParamLabel_t

<table>
<thead>
<tr>
<th>Attribute key</th>
<th>Expected Descriptor Type Passed in, in the Setter</th>
<th>I/O Type</th>
<th>Description</th>
<th>Default Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>X_XDATA</td>
<td>void *</td>
<td>input</td>
<td>Pointer to (x) (input) tensor on device, need to agree with previously set CUDNN_PARAM_XDATA_PLACEHOLDER attribute *.</td>
<td>NULL</td>
</tr>
<tr>
<td>X_BN_EQSCALE</td>
<td>void *</td>
<td>input</td>
<td>Pointer to batchnorm equivalent scale tensor on device, need to agree with previously set CUDNN_PARAM_BN_EQSCALE_PLACEHOLDER attribute *.</td>
<td>NULL</td>
</tr>
<tr>
<td>X_BN_EQBIAS</td>
<td>void *</td>
<td>input</td>
<td>Pointer to batchnorm equivalent bias tensor on device, need to agree with previously set CUDNN_PARAM_BN_EQBIAS_PLACEHOLDER attribute *.</td>
<td>NULL</td>
</tr>
<tr>
<td>X_WDATA</td>
<td>void *</td>
<td>input</td>
<td>Pointer to (w) (filter) tensor on device, need to agree with previously set CUDNN_PARAM_WDATA_PLACEHOLDER attribute *.</td>
<td>NULL</td>
</tr>
<tr>
<td>X_YDATA</td>
<td>void *</td>
<td>output</td>
<td>Pointer to (y) (output) tensor on device, need to agree with previously set CUDNN_PARAM_YDATA_PLACEHOLDER attribute *.</td>
<td>NULL</td>
</tr>
<tr>
<td>X_YSUM</td>
<td>void *</td>
<td>output</td>
<td>Pointer to sum of (y) tensor on device, need to agree with previously set CUDNN_PARAM_YSUM_PLACEHOLDER attribute *.</td>
<td>NULL</td>
</tr>
<tr>
<td>X_YSQSUM</td>
<td>void *</td>
<td>output</td>
<td>Pointer to sum of (y) square tensor on device, need to agree with previously set CUDNN_PARAM_YSQSUM_PLACEHOLDER attribute *.</td>
<td>NULL</td>
</tr>
</tbody>
</table>
For the attribute `CUDNN_FUSED_SCALE_BIAS_ACTIVATION_CONV_BNSTATS` in `cudnnFusedOpsVariantParamLabel_t`

<table>
<thead>
<tr>
<th>Attribute key</th>
<th>Expected Descriptor Type Passed in, in the Setter</th>
<th>I/O Type</th>
<th>Description</th>
<th>Default Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>X_WORKSPACE</td>
<td>void *</td>
<td>input</td>
<td>Pointer to user allocated workspace on device. Can be NULL if the workspace size requested is 0.</td>
<td>NULL</td>
</tr>
<tr>
<td>X_SIZE_T_WORKSPACE_SIZE</td>
<td>size_t *</td>
<td>input</td>
<td>Pointer to a size_t value in host memory describing the user allocated workspace size in bytes. The amount needs to be equal or larger than the amount requested in <code>cudnnMakeFusedOpsPlan</code>.</td>
<td>0</td>
</tr>
</tbody>
</table>

Note:
- If the corresponding pointer placeholder in `ConstParamPack` is set to `CUDNN_PTR_NULL`, then the device pointer in the `VariantParamPack` needs to be NULL as well.
- If the corresponding pointer placeholder in `ConstParamPack` is set to `CUDNN_PTR_ELEM_ALIGNED` or `CUDNN_PTR_16B_ALIGNED`, then the device pointer in the `VariantParamPack` may not be NULL and needs to be at least element-aligned or 16 bytes-aligned, respectively.

Table 41. `CUDNN_FUSED_SCALE_BIAS_ACTIVATION_WGRAD` in `cudnnFusedOpsVariantParamLabel_t`

<table>
<thead>
<tr>
<th>Attribute key</th>
<th>Expected Descriptor Type Passed in, in the Setter</th>
<th>I/O Type</th>
<th>Description</th>
<th>Default Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>X_XDATA</td>
<td>void *</td>
<td>input</td>
<td>Pointer to x (input) tensor on device, need to agree with previously set <code>CUDNN_PARAM_XDATA_PLACEHOLDER</code> attribute *</td>
<td>NULL</td>
</tr>
<tr>
<td>X_BN_EQSCALE</td>
<td>void *</td>
<td>input</td>
<td>Pointer to batchnorm equivalent scale tensor</td>
<td>NULL</td>
</tr>
<tr>
<td>Attribute key</td>
<td>Expected Descriptor Type Passed in, in the Setter</td>
<td>I/O Type</td>
<td>Description</td>
<td>Default Value</td>
</tr>
<tr>
<td>---------------------</td>
<td>--------------------------------------------------</td>
<td>----------</td>
<td>-------------------------------------------------------------------------------</td>
<td>---------------</td>
</tr>
<tr>
<td>X_BN_EQBIAS</td>
<td>void *</td>
<td>input</td>
<td>Pointer to batchnorm equivalent bias tensor on device, need to agree with previously set CUDNN_PARAM_BN_EQSCALE_PLACEHOLDER attribute *</td>
<td>NULL</td>
</tr>
<tr>
<td>X_DWDATA</td>
<td>void *</td>
<td>output</td>
<td>Pointer to $dw$ (filter gradient output) tensor on device, need to agree with previously set CUDNN_PARAM_WDATA_PLACEHOLDER attribute *</td>
<td>NULL</td>
</tr>
<tr>
<td>X_DYDATA</td>
<td>void *</td>
<td>input</td>
<td>Pointer to $dy$ (gradient input) tensor on device, need to agree with previously set CUDNN_PARAM_YDATA_PLACEHOLDER attribute *</td>
<td>NULL</td>
</tr>
<tr>
<td>X_WORKSPACE</td>
<td>void *</td>
<td>input</td>
<td>Pointer to user allocated workspace on device. Can be NULL if the workspace size requested is 0.</td>
<td>NULL</td>
</tr>
<tr>
<td>X_SIZE_T_WORKSPACE_SIZE_INBYTES_t</td>
<td>void *</td>
<td>input</td>
<td>Pointer to a size_t value in host memory describing the user allocated workspace size in bytes. The amount needs to be equal or larger than the amount requested in cudnnMakeFusedOpsPlan.</td>
<td>0</td>
</tr>
</tbody>
</table>

**Note:**
- If the corresponding pointer placeholder in ConstParamPack is set to CUDNN_PTR_NULL, then the device pointer in the VariantParamPack needs to be NULL as well.
- If the corresponding pointer placeholder in ConstParamPack is set to CUDNN_PTR_ELEM_ALIGNED or CUDNN_PTR_16B_ALIGNED, then the device pointer in the...
VariantParamPack may not be NULL and needs to be at least element-aligned or 16 bytes-aligned, respectively.

Table 42. CUDNN_FUSED_BN_FINALIZE_STATISTICS_TRAINING in cudnnFusedOpsVariantParamLabel_t

<table>
<thead>
<tr>
<th>Attribute key</th>
<th>Expected Descriptors Type Passed in, in the Setter</th>
<th>I/O Type</th>
<th>Description</th>
<th>Default Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>X_YSUM</td>
<td>void *</td>
<td>input</td>
<td>Pointer to sum of $y$ tensor on device, need to agree with previously set CUDNN_PARAM_YSUM_PLACEHOLDER attribute *</td>
<td>NULL</td>
</tr>
<tr>
<td>X_YSQSUM</td>
<td>void *</td>
<td>input</td>
<td>Pointer to sum of $y$ square tensor on device, need to agree with previously set CUDNN_PARAM_YSQSUM_PLACEHOLDER attribute *</td>
<td>NULL</td>
</tr>
<tr>
<td>X_BN_SCALE</td>
<td>void *</td>
<td>input</td>
<td>Pointer to sum of $y$ square tensor on device, need to agree with previously set CUDNN_PARAM_BN_SCALE_PLACEHOLDER attribute *</td>
<td>NULL</td>
</tr>
<tr>
<td>X_BN_BIAS</td>
<td>void *</td>
<td>input</td>
<td>Pointer to sum of $y$ square tensor on device, need to agree with previously set CUDNN_PARAM_BN_BIAS_PLACEHOLDER attribute *</td>
<td>NULL</td>
</tr>
<tr>
<td>X_BN_SAVED_MEAN</td>
<td>void *</td>
<td>output</td>
<td>Pointer to sum of $y$ square tensor on device, need to agree with previously set CUDNN_PARAM_BN_SAVED_MEAN_PLACEHOLDER attribute *</td>
<td>NULL</td>
</tr>
<tr>
<td>X_BN_SAVED_INVSTD</td>
<td>void *</td>
<td>output</td>
<td>Pointer to sum of $y$ square tensor on device, need to agree with previously set CUDNN_PARAM_BN_SAVED_INVSTD_PLACEHOLDER attribute *</td>
<td>NULL</td>
</tr>
<tr>
<td>X_BN_RUNNING_MEAN</td>
<td>void *</td>
<td>input/output</td>
<td>Pointer to sum of $y$ square tensor on device, need to agree with previously set CUDNN_PARAM_BN_RUNNING_MEAN_PLACEHOLDER attribute *</td>
<td>NULL</td>
</tr>
</tbody>
</table>
For the attribute **CUDNN_FUSED_BN_FINALIZE_STATISTICS_TRAINING** in **cudnnFusedOpsVariantParamLabel_t**

<table>
<thead>
<tr>
<th>Attribute key</th>
<th>Expected Type Passed in, in the Setter</th>
<th>I/O Type</th>
<th>Description</th>
<th>Default Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>X_BN_RUNNING_VAR</td>
<td>void *</td>
<td>input/output</td>
<td>Pointer to sum of $y$ square tensor on device, need to agree with previously set CUDNN_PARAM_BN_RUNNING_VAR_PLACEHOLDER attribute *.</td>
<td>NULL</td>
</tr>
<tr>
<td>X_BN_EQSCALE</td>
<td>void *</td>
<td>output</td>
<td>Pointer to batchnorm equivalent scale tensor on device, need to agree with previously set CUDNN_PARAM_BN_EQSCALE_PLACEHOLDER attribute *.</td>
<td>NULL</td>
</tr>
<tr>
<td>X_BN_EQBIAS</td>
<td>void *</td>
<td>output</td>
<td>Pointer to batchnorm equivalent bias tensor on device, need to agree with previously set CUDNN_PARAM_BN_EQBIAS_PLACEHOLDER attribute *.</td>
<td>NULL</td>
</tr>
<tr>
<td>X_INT64_T_BN_ACCUMULATION_COUNT</td>
<td>int64_t *</td>
<td>input</td>
<td>Pointer to a scalar value in int64_t on host memory. This value should describe the number of tensor elements accumulated in the sum of $y$ and sum of $y$ square tensors. For example, in the single GPU use case, if the mode is CUDNN_BATCHNORM_SPATIAL or CUDNN_BATCHNORM_SPATIAL_PERSISTENT, the value should be equal to $N^*H^*W$ of the tensor from which the statistics are calculated. In multi-GPU use case, if all-reduce has been performed on the sum of $y$ and sum of $y$ square tensors, this value should be the sum of the single GPU accumulation count on each of the GPUs.</td>
<td>0</td>
</tr>
</tbody>
</table>
For the attribute **CUDNN_FUSED_BNFINALIZE_STATISTICS_TRAINING** in cudnnFusedOpsVariantParamLabel_t

<table>
<thead>
<tr>
<th>Attribute key</th>
<th>Expected Type Passed in, in the Setter</th>
<th>I/O Type</th>
<th>Description</th>
<th>Default Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>X_DOUBLE_BN_EXP_AVG_FACTOR</td>
<td>double *</td>
<td>input</td>
<td>Pointer to a scalar value in double on host memory. Factor used in the moving average computation. See exponentialAverageFactor in cudnnBatchNormalization* APIs.</td>
<td>0.0</td>
</tr>
<tr>
<td>X_DOUBLE_BN_EPSILON</td>
<td>double *</td>
<td>input</td>
<td>Pointer to a scalar value in double on host memory. A conditioning constant used in the batch normalization formula. Its value should be equal to or greater than the value defined for CUDNN_BN_MIN_EPSILON in cudnn.h. See exponentialAverageFactor in cudnnBatchNormalization* APIs.</td>
<td>0.0</td>
</tr>
<tr>
<td>X_WORKSPACE</td>
<td>void *</td>
<td>input</td>
<td>Pointer to user allocated workspace on device. Can be NULL if the workspace size requested is 0.</td>
<td>NULL</td>
</tr>
<tr>
<td>X_SIZE_T_WORKSPACE_SIZE_IN_BYTES</td>
<td>void *</td>
<td>input</td>
<td>Pointer to a size_t value in host memory describing the user allocated workspace size in bytes. The amount needs to be equal or larger than the amount requested in cudnnMakeFusedOpsPlan.</td>
<td>0</td>
</tr>
</tbody>
</table>

Note:

- If the corresponding pointer placeholder in ConstParamPack is set to CUDNN_PTR_NULL, then the device pointer in the VariantParamPack needs to be NULL as well.
- If the corresponding pointer placeholder in ConstParamPack is set to CUDNN_PTR_ELEMAligned or CUDNN_PTR_16BAligned, then the device pointer in the...
VariantParamPack may not be NULL and needs to be at least element-aligned or 16 bytes-aligned, respectively.

Table 43. CUDNN_FUSED_BN_FINALIZE_STATISTICS_INFERENCE in cudnnFusedOpsVariantParamLabel_t

<table>
<thead>
<tr>
<th>Attribute key</th>
<th>Expected Descriptor Type Passed in, in the Setter</th>
<th>I/O Type</th>
<th>Description</th>
<th>Default Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>X_BN_SCALE</td>
<td>void *</td>
<td>input</td>
<td>Pointer to sum of $y$ square tensor on device, need to agree with previously set CUDNN_PARAM_BN_SCALE_PLACEHOLDER attribute *.</td>
<td>NULL</td>
</tr>
<tr>
<td>X_BN_BIAS</td>
<td>void *</td>
<td>input</td>
<td>Pointer to sum of $y$ square tensor on device, need to agree with previously set CUDNN_PARAM_BN_BIAS_PLACEHOLDER attribute *.</td>
<td>NULL</td>
</tr>
<tr>
<td>X_BN_RUNNING_MEAN</td>
<td>void *</td>
<td>input/output</td>
<td>Pointer to sum of $y$ square tensor on device, need to agree with previously set CUDNN_PARAM_BN_RUNNING_MEAN_PLACEHOLDER attribute *.</td>
<td>NULL</td>
</tr>
<tr>
<td>X_BN_RUNNING_VAR</td>
<td>void *</td>
<td>input/output</td>
<td>Pointer to sum of $y$ square tensor on device, need to agree with previously set CUDNN_PARAM_BN_RUNNING_VAR_PLACEHOLDER attribute *.</td>
<td>NULL</td>
</tr>
<tr>
<td>X_BN_EQSCALE</td>
<td>void *</td>
<td>output</td>
<td>Pointer to batchnorm equivalent scale tensor on device, need to agree with previously set CUDNN_PARAM_BN_EQSCALE_PLACEHOLDER attribute *.</td>
<td>NULL</td>
</tr>
<tr>
<td>X_BN_EQBIAS</td>
<td>void *</td>
<td>output</td>
<td>Pointer to batchnorm equivalent bias tensor on device, need to agree with previously set CUDNN_PARAM_BN_EQBIAS_PLACEHOLDER attribute *.</td>
<td>NULL</td>
</tr>
</tbody>
</table>
For the attribute **CUDNN_FUSED_BN_FINALIZE_STATISTICS_INFER**
ence in cudnnFusedOpsVariantParamLabel_t

<table>
<thead>
<tr>
<th>Attribute key</th>
<th>Expected Descriptor Type Passed in, in the Setter</th>
<th>I/O Type</th>
<th>Description</th>
<th>Default Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>X_DOUBLE_BN_EPSILON</td>
<td>double *</td>
<td>input</td>
<td>Pointer to a scalar value in double on host memory. A conditioning constant used in the batch normalization formula. Its value should be equal to or greater than the value defined for CUDNN_BN_MIN_EPSILON in cudnn.h. See exponentialAverageFactor in cudnnBatchNormalization* APIs.</td>
<td>0.0</td>
</tr>
<tr>
<td>X_WORKSPACE</td>
<td>void *</td>
<td>input</td>
<td>Pointer to user allocated workspace on device. Can be NULL if the workspace size requested is 0.</td>
<td>NULL</td>
</tr>
<tr>
<td>X_SIZE_T_WORKSPACE_SIZE_IN_BYTES</td>
<td>size_t *</td>
<td>input</td>
<td>Pointer to a size_t value in host memory describing the user allocated workspace size in bytes. The amount needs to be equal or larger than the amount requested in cudnnMakeFusedOpsPlan.</td>
<td>0</td>
</tr>
</tbody>
</table>

**Note:**
- If the corresponding pointer placeholder in ConstParamPack is set to CUDNN_PTR_NULL, then the device pointer in the VariantParamPack needs to be NULL as well.
- If the corresponding pointer placeholder in ConstParamPack is set to CUDNN_PTR_ELEM_ALIGNED or CUDNN_PTR_16B_ALIGNED, then the device pointer in the VariantParamPack may not be NULL and needs to be at least element-aligned or 16 bytes-aligned, respectively.
Table 44. CUDNN_FUSED_BN_FINALIZE_STATISTICS_INFERENCE in cudnnFusedOpsVariantParamLabel_t

<table>
<thead>
<tr>
<th>Attribute key</th>
<th>Expected Descriptor Type Passed in, in the Setter</th>
<th>I/O Type</th>
<th>Description</th>
<th>Default Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>X_XDATA</td>
<td>void *</td>
<td>input</td>
<td>Pointer to (x) (image) tensor on device, need to agree with previously set CUDNN_PARAM_XDATA_PLACEHOLDER attribute *</td>
<td>NULL</td>
</tr>
<tr>
<td>X_WDATA</td>
<td>void *</td>
<td>input</td>
<td>Pointer to (w) (filter) tensor on device, need to agree with previously set CUDNN_PARAM_WDATA_PLACEHOLDER attribute *</td>
<td>NULL</td>
</tr>
<tr>
<td>X_BN_EQSCALE</td>
<td>void *</td>
<td>input</td>
<td>Pointer to (\alpha_1) or batchnorm equivalent scale tensor on device; need to agree with previously set CUDNN_PARAM_BN_EQSCALE_PLACEHOLDER attribute *</td>
<td>NULL</td>
</tr>
<tr>
<td>X_ZDATA</td>
<td>void *</td>
<td>input</td>
<td>Pointer to (z) (tensor on device; Need to agree with previously set CUDNN_PARAM_YDATA_PLACEHOLDER attribute *</td>
<td>NULL</td>
</tr>
<tr>
<td>X_BN_Z_EQSCALE</td>
<td>void *</td>
<td>input</td>
<td>Pointer to (\alpha_2), NULL equivalent scale tensor for (z); Need to agree with previously set CUDNN_PARAM_BN_Z_EQSCALE_PLACEHOLDER attribute *</td>
<td>NULL</td>
</tr>
<tr>
<td>X_BN_Z_EQBIAS</td>
<td>void *</td>
<td>input</td>
<td>Pointer to batchnorm equivalent bias tensor on</td>
<td>NULL</td>
</tr>
</tbody>
</table>
For the attribute `CUDNN_FUSED_BN_FINALIZE_STATISTICS_INFERENCE` in `cudnnFusedOpsVariantParamLabel_t`

<table>
<thead>
<tr>
<th>Attribute key</th>
<th>Expected Descriptor Type Passed in, in the Setter</th>
<th>I/O Type</th>
<th>Description</th>
<th>Default Value</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>device, need to agree with previously set <code>CUDNN_PARAM_BN_Z_EQBIAS_PLACEHOLDER</code> attribute *</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><code>X_YDATA</code></td>
<td>void *</td>
<td>output</td>
<td>Pointer to ( y ) (output) tensor on device, need to agree with previously set <code>CUDNN_PARAM_YDATA_PLACEHOLDER</code> attribute *</td>
<td>NULL</td>
</tr>
<tr>
<td><code>X_WORKSPACE</code></td>
<td>void *</td>
<td>input</td>
<td>Pointer to user allocated workspace on device. Can be NULL if the workspace size requested is 0.</td>
<td>NULL</td>
</tr>
<tr>
<td><code>X_SIZE_T_WORKSPACE_SIZE_IN_BYTES</code></td>
<td>size_t *</td>
<td>input</td>
<td>Pointer to a <code>size_t</code> value in host memory describing the user allocated workspace size in bytes. The amount needs to be equal or larger than the amount requested in <code>cudnnMakeFusedOpsPlan</code>.</td>
<td>0</td>
</tr>
</tbody>
</table>

**Note:**
- If the corresponding pointer placeholder in `ConstParamPack` is set to `CUDNN_PTR_NULL`, then the device pointer in the `VariantParamPack` needs to be NULL as well.
- If the corresponding pointer placeholder in `ConstParamPack` is set to `CUDNN_PTR_ELEM_ALIGNED` or `CUDNN_PTR_16B_ALIGNED`, then the device pointer in the `VariantParamPack` may not be NULL and needs to be at least element-aligned or 16 bytes-aligned, respectively.
6.2. API Functions

These are the API functions in the cudnn_cnn_train.so library.

6.2.1. **cudnnCnnTrainVersionCheck()**

This function checks whether the version of the CnnTrain subset of the library is consistent with the other sub-libraries.

```c
void cudnnCnnTrainVersionCheck()
```

**Returns**

**CUDNN_STATUS_SUCCESS**

The version is consistent with other sub-libraries.

**CUDNN_STATUS_VERSION_MISMATCH**

The version of CnnTrain is not consistent with other sub-libraries. Users should check the installation and make sure all sub-component versions are consistent.

6.2.2. **cudnnConvolutionBackwardBias()**

This function computes the convolution function gradient with respect to the bias, which is the sum of every element belonging to the same feature map across all of the images of the input tensor. Therefore, the number of elements produced is equal to the number of features maps of the input tensor.

```c
void cudnnConvolutionBackwardBias(
    cudnnStatus_t cudnnConvolutionBackwardBias(
        cudnnHandle_t handle,
        const void *alpha,
        const cudnnTensorDescriptor_t dyDesc,
        const void *beta,
        const cudnnTensorDescriptor_t dbDesc,
        void *db)
```

**Parameters**

**handle**

*Input*. Handle to a previously created cuDNN context. For more information, refer to [cudnnHandle_t](#).

**alpha, beta**

*Input*. Pointers to scaling factors (in host memory) used to blend the computation result with prior value in the output layer as follows:

\[
\text{dstValue} = \alpha[0]*\text{resultValue} + \beta[0]*\text{priorDstValue}
\]

For more information, refer to [Scaling Parameters](#).

**dyDesc**

*Input*. Handle to the previously initialized input tensor descriptor. For more information, refer to [cudnnTensorDescriptor_t](#).
dy
   Input. Data pointer to GPU memory associated with the tensor descriptor dyDesc.

dbDesc
   Input. Handle to the previously initialized output tensor descriptor.

db
   Output. Data pointer to GPU memory associated with the output tensor descriptor dbDesc.

Returns

CUDNN_STATUS_SUCCESS
   The operation was launched successfully.

CUDNN_STATUS_NOT_SUPPORTED
   The function does not support the provided configuration.

CUDNN_STATUS_BAD_PARAM
   At least one of the following conditions are met:
   ▶ One of the parameters n, height, or width of the output tensor is not 1.
   ▶ The numbers of feature maps of the input tensor and output tensor differ.
   ▶ The dataType of the two tensor descriptors is different.

6.2.3. cudnnConvolutionBackwardFilter()

This function computes the convolution weight (filter) gradient of the tensor dy, where y is the output of the forward convolution in cudnnConvolutionForward(). It uses the specified algo, and returns the results in the output tensor dw. Scaling factors alpha and beta can be used to scale the computed result or accumulate with the current dw.

```c
#include <cuda.h>

void cudnnConvolutionBackwardFilter(
  cudnnHandle_t handle,
  const void *alpha,
  const cudnnTensorDescriptor_t xDesc,
  const void *x,
  const cudnnTensorDescriptor_t dyDesc,
  const void *dy,
  const cudnnConvolutionDescriptor_t convDesc,
  cudnnConvolutionBwdFilterAlgo_t algo,
  void *workSpace,
  size_t workSpaceSizeInBytes,
  const void *beta,
  const cudnnFilterDescriptor_t dwDesc,
  void *dw);
```

Parameters

handle
   Input. Handle to a previously created cuDNN context. For more information, refer to cudnnHandle_t.
**alpha, beta**

*Input*. Pointers to scaling factors (in host memory) used to blend the computation result with prior value in the output layer as follows:

\[ \text{dstValue} = \text{alpha}[0] \times \text{result} + \text{beta}[0] \times \text{priorDstValue} \]

For more information, refer to [Scaling Parameters](#).

**xDesc**

*Input*. Handle to a previously initialized tensor descriptor. For more information, refer to [cudnnTensorDescriptor_t](#).

**x**

*Input*. Data pointer to GPU memory associated with the tensor descriptor xDesc.

**dyDesc**

*Input*. Handle to the previously initialized input differential tensor descriptor.

**dy**

*Input*. Data pointer to GPU memory associated with the backpropagation gradient tensor descriptor dyDesc.

**convDesc**

*Input*. Previously initialized convolution descriptor. For more information, refer to [cudnnConvolutionDescriptor_t](#).

**algo**

*Input*. Enumerant that specifies which convolution algorithm should be used to compute the results. For more information, refer to [cudnnConvolutionBwdFilterAlgo_t](#).

**workSpace**

*Input*. Data pointer to GPU memory to a workspace needed to be able to execute the specified algorithm. If no workspace is needed for a particular algorithm, that pointer can be NIL.

**workSpaceSizeInBytes**

*Input*. Specifies the size in bytes of the provided workSpace.

**dwDesc**

*Input*. Handle to a previously initialized filter gradient descriptor. For more information, refer to [cudnnFilterDescriptor_t](#).

**dw**

*Input/Output*. Data pointer to GPU memory associated with the filter gradient descriptor dwDesc that carries the result.

**Supported configurations**

This function supports the following combinations of data types for xDesc, dyDesc, convDesc, and dwDesc.
Table 45. Supported Configurations for cudnnConvolutionBackwardFilter()

<table>
<thead>
<tr>
<th>Data Type Configurations</th>
<th>xDesc, dyDesc, and dwDesc Data Type</th>
<th>convDesc Data Type</th>
</tr>
</thead>
<tbody>
<tr>
<td>TRUE_HALF_CONFIG (only supported on architectures with true FP16 support, meaning, compute capability 5.3 and later)</td>
<td>CUDNN_DATA_HALF</td>
<td>CUDNN_DATA_HALF</td>
</tr>
<tr>
<td>PSEUDO_HALF_CONFIG</td>
<td>CUDNN_DATA_HALF</td>
<td>CUDNN_DATA_FLOAT</td>
</tr>
<tr>
<td>PSEUDO_BFLOAT16_CONFIG</td>
<td>CUDNN_DATA_BFLOAT16</td>
<td>CUDNN_DATA_FLOAT</td>
</tr>
<tr>
<td>FLOAT_CONFIG</td>
<td>CUDNN_DATA_FLOAT</td>
<td>CUDNN_DATA_FLOAT</td>
</tr>
<tr>
<td>DOUBLE_CONFIG</td>
<td>CUDNN_DATA_DOUBLE</td>
<td>CUDNN_DATA_DOUBLE</td>
</tr>
</tbody>
</table>

Supported algorithms

Note: Specifying a separate algorithm can cause changes in performance, support and computation determinism. Refer to the following table for an exhaustive list of algorithm options and their respective supported parameters and deterministic behavior.

The table below shows the list of the supported 2D and 3D convolutions. The 2D convolutions are described first, followed by the 3D convolutions.

For the following terms, the short-form versions shown in the parentheses are used in the table below, for brevity:

- CUDNN_CONVOLUTION_BWD_FILTER_ALGO_0 (_ALGO_0)
- CUDNN_CONVOLUTION_BWD_FILTER_ALGO_1 (_ALGO_1)
- CUDNN_CONVOLUTION_BWD_FILTER_ALGO_3 (_ALGO_3)
- CUDNN_CONVOLUTION_BWD_FILTER_ALGO_FFT (_FFT)
- CUDNN_CONVOLUTION_BWD_FILTER_ALGO_FFT_TILING (_FFT_TILING)
- CUDNN_CONVOLUTION_BWD_FILTER_ALGO_WINOGRAD_NONFUSED (_WINOGRAD_NONFUSED)
- CUDNN_TENSOR_NCHW (_NCHW)
- CUDNN_TENSOR_NHWC (_NHWC)
- CUDNN_TENSOR_NCHW_VECT_C (_NCHW_VECT_C)
Table 46. Supported Algorithms for cudnnConvolutionBackwardFilter() 2D Convolutions:
dwDesc: _NHWC

Filter descriptor dwDesc: _NHWC (refer to cudnnTensorFormat_t)

<table>
<thead>
<tr>
<th>Algo Name</th>
<th>Deterministic (Yes or No)</th>
<th>Tensor Formats Supported for dyDesc</th>
<th>Tensor Formats Supported for dxDesc</th>
<th>Data Type Configuration Supported</th>
<th>Important</th>
</tr>
</thead>
<tbody>
<tr>
<td>_ALGO_0 and _ALGO_1</td>
<td></td>
<td>NHWC HWC-packed.</td>
<td>NHWC HWC-packed</td>
<td>PSEUDO_HALF_CONFIG</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>PSEUDO_BFLOAT16_CONFIG</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>FLOAT_CONFIG</td>
<td></td>
</tr>
</tbody>
</table>

Table 47. Supported Algorithms for cudnnConvolutionBackwardFilter() 2D Convolutions:
dwDesc: _NCHW

Filter descriptor dwDesc: _NCHW

<table>
<thead>
<tr>
<th>Algo Name</th>
<th>Deterministic (Yes or No)</th>
<th>Tensor Formats Supported for dyDesc</th>
<th>Tensor Formats Supported for dxDesc</th>
<th>Data Type Configuration Supported</th>
<th>Important</th>
</tr>
</thead>
<tbody>
<tr>
<td>_ALGO_0</td>
<td>No</td>
<td>All except _NCHW_VECT_C</td>
<td>NCHW CHW-packed</td>
<td>PSEUDO_HALF_CONFIG</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>PSEUDO_BFLOAT16_CONFIG</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>FLOAT_CONFIG</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>DOUBLE_CONFIG</td>
<td></td>
</tr>
</tbody>
</table>

| _ALGO_1            | Yes                       | All except _NCHW_VECT_C             | NCHW CHW-packed                     | PSEUDO_HALF_CONFIG              |                             |
|                    |                           |                                     |                                     | TRUE_HALF_CONFIG                |                             |
|                    |                           |                                     |                                     | PSEUDO_BFLOAT16_CONFIG          |                             |
|                    |                           |                                     |                                     | FLOAT_CONFIG                    |                             |
|                    |                           |                                     |                                     | DOUBLE_CONFIG                   |                             |

Dilation: greater than 0 for all dimensions
convDesc Group Count Support: Greater than 0
Filter descriptor **dwDesc: _NCHW**

<table>
<thead>
<tr>
<th>Algo Name</th>
<th>Deterministic (Yes or No)</th>
<th>Tensor Formats Supported for dyDesc</th>
<th>Tensor Formats Supported for dxDesc</th>
<th>Data Type Configuration Supported</th>
<th>Important</th>
</tr>
</thead>
<tbody>
<tr>
<td>_FFT</td>
<td>Yes</td>
<td>NCHW CHW-packed</td>
<td>NCHW CHW-packed</td>
<td>PSEUDO_HALF_CONFIG</td>
<td>Dilation: 1 for all dimensions of convDesc. Group Count Support: Greater than 0. xDesc feature map height + 2 * convDesc zero-padding should be less than or equal to 256. xDesc feature map width + 2 * convDesc zero-padding should be less than or equal to 256. convDesc vertical and horizontal filter stride must be equal to 1. dwDesc filter height must be greater than convDesc zero-padding height. dwDesc filter width must be greater than convDesc zero-padding height.</td>
</tr>
</tbody>
</table>
# Filter descriptor **dwDesc**: _NCHW_

<table>
<thead>
<tr>
<th>Algo Name</th>
<th>Deterministic (Yes or No)</th>
<th>Tensor Formats Supported for dyDesc</th>
<th>Tensor Formats Supported for dxDesc</th>
<th>Data Type Configuration Supported</th>
<th>Important</th>
</tr>
</thead>
<tbody>
<tr>
<td>_ALGO_3</td>
<td>No</td>
<td>All except _NCHW_VECT_C</td>
<td>NCHW CHW-packed</td>
<td>PSEUDO_HALF_CONFIG, PSEUDO_BFLOAT16_CONFIG, FLOAT_CONFIG, DOUBLE_CONFIG</td>
<td>Dilation: 1 for all dimensions, convDesc Group Count Support: Greater than 0</td>
</tr>
<tr>
<td>_WINOGRAD_NONFUSED</td>
<td>Yes</td>
<td>All except _NCHW_VECT_C</td>
<td>NCHW CHW-packed</td>
<td>TRUE_HALF_CONFIG, PSEUDO_HALF_CONFIG, PSEUDO_BFLOAT16_CONFIG, FLOAT_CONFIG</td>
<td>Dilation: 1 for all dimensions, convDesc Group Count Support: Greater than 0</td>
</tr>
<tr>
<td>_FFT_TILING</td>
<td>Yes</td>
<td>NCHW CHW-packed</td>
<td>NCHW CHW-packed</td>
<td>PSEUDO_HALF_CONFIG, FLOAT_CONFIG</td>
<td>Dilation: 1 for all dimensions</td>
</tr>
</tbody>
</table>

- **_WINOGRAD_NONFUSED_**
  - Vertical and horizontal filter stride must equal 1
  - dwDesc filter (height, width) must be (3,3) or (5,5)
  - If dwDesc filter (height, width) is (5,5), then the data type config **TRUE_HALF_CONFIG** is not supported.
### Filter descriptor \texttt{dwDesc}: \_NCHW

<table>
<thead>
<tr>
<th>Algo Name</th>
<th>Deterministic (\text{(Yes or No)})</th>
<th>Tensor Formats Supported for (\text{dyDesc})</th>
<th>Tensor Formats Supported for (\text{dxDesc})</th>
<th>Data Type Configuration Supported</th>
<th>Important</th>
</tr>
</thead>
</table>

- **Deterministic**: (Yes or No)
- **Tensor Formats Supported for \(\text{dyDesc}\)**
- **Tensor Formats Supported for \(\text{dxDesc}\)**
- **Data Type Configuration Supported**: \(\text{convDesc}\)
- **Important**:
  - **Group Count Support**: Greater than 0
  - **dyDesc width or height must equal 1** (the same dimension as in \(\text{xDesc}\)). The other dimension must be less than or equal to 256, meaning, the largest 1D tile size currently supported.
  - **convDesc**: vertical and horizontal filter stride must equal 1
  - **dwDesc filter height must be greater than convDesc zero-padding height**
  - **dwDesc filter width must be greater than convDesc zero-padding width**
### Table 48: Supported Algorithms for `cudnnConvolutionBackwardFilter()` 3D Convolutions:

Filter descriptor `dwDesc: _NCHW`

<table>
<thead>
<tr>
<th>Algo Name (3D Convolutions)</th>
<th>Deterministic (Yes or No)</th>
<th>Tensor Formats Supported for <code>dyDesc</code></th>
<th>Tensor Formats Supported for <code>dxDesc</code></th>
<th>Data Type Configurations Supported</th>
<th>Important</th>
</tr>
</thead>
<tbody>
<tr>
<td>_ALGO_0</td>
<td>No</td>
<td>All except _NCDHW_VECT_C</td>
<td>▶ NCDHW CDHW-packed</td>
<td>PSEUDO_HALF_CONFIG, PSEUDO_BFLOAT16_CONFIG, FLOAT_CONFIG, DOUBLE_CONFIG</td>
<td>Dilation: greater than 0 for all dimensions convDesc Group Count Support: Greater than 0</td>
</tr>
<tr>
<td>_ALGO_1</td>
<td>No</td>
<td>All except _NCDHW_VECT_C</td>
<td>▶ NCDHW CDHW-packed</td>
<td>PSEUDO_HALF_CONFIG, PSEUDO_BFLOAT16_CONFIG, FLOAT_CONFIG, DOUBLE_CONFIG</td>
<td>Dilation: greater than 0 for all dimensions convDesc Group Count Support: Greater than 0</td>
</tr>
<tr>
<td>_ALGO_3</td>
<td>No</td>
<td>NCDHW fully-packed</td>
<td>NCDHW fully-packed</td>
<td>PSEUDO_HALF_CONFIG, PSEUDO_BFLOAT16_CONFIG, FLOAT_CONFIG, DOUBLE_CONFIG</td>
<td>Dilation: greater than 0 for all dimensions convDesc Group Count Support: Greater than 0</td>
</tr>
</tbody>
</table>
Table 49. Supported Algorithms for 
cudnnConvolutionBackwardFilter() 3D Convolutions:
dwDesc: _NHWC

<table>
<thead>
<tr>
<th>Filter descriptor dwDesc: _NHWC</th>
<th>Tensor Formats Supported for xDesc</th>
<th>Tensor Formats Supported for dyDesc</th>
<th>Data Type Configuration Supported</th>
<th>Important</th>
</tr>
</thead>
<tbody>
<tr>
<td>_ALGO_1</td>
<td>NDHWC HWC-packed</td>
<td>NDHWC HWC-packed</td>
<td>PSEUDO_HALF_CONFIG, PSEUDO_BFLO16_CONFIG, FLOAT_CONFIG, TRUE_HALF_CONFIG</td>
<td>Dilation: greater than 0 for all dimensions</td>
</tr>
</tbody>
</table>

Returns

**CUDNN_STATUS_SUCCESS**

The operation was launched successfully.

**CUDNN_STATUS_BAD_PARAM**

At least one of the following conditions are met:

- At least one of the following is NULL: handle, xDesc, dyDesc, convDesc, dwDesc, xData, dyData, dwData, alpha, or beta
- xDesc and dyDesc have a non-matching number of dimensions
- xDesc and dwDesc have a non-matching number of dimensions
- xDesc has fewer than three number of dimensions
- xDesc, dyDesc, and dwDesc have a non-matching data type.
- xDesc and dwDesc have a non-matching number of input feature maps per image (or group in case of grouped convolutions).
- yDesc or dwDesc indicate an output channel count that isn’t a multiple of group count (if group count has been set in convDesc).

**CUDNN_STATUS_NOT_SUPPORTED**

At least one of the following conditions are met:

- xDesc or dyDesc have negative tensor striding
- xDesc, dyDesc or dwDesc has a number of dimensions that is not 4 or 5
- The chosen algo does not support the parameters provided; see above for exhaustive list of parameter support for each algo
**CUDNN_STATUS_MAPPING_ERROR**
An error occurs during the texture object creation associated with the filter data.

**CUDNN_STATUS_EXECUTION_FAILED**
The function failed to launch on the GPU.

### 6.2.4. `cudnnCreateFusedOpsConstParamPack()`

This function creates an opaque structure to store the various problem size information, such as the shape, layout and the type of tensors, and the descriptors for convolution and activation, for the selected sequence of `cudnnFusedOps` computations.

```c

cudnnStatus_t cudnnCreateFusedOpsConstParamPack(  
cudnnFusedOpsConstParamPack_t *constPack,  
cudnnFusedOps_t ops);
```

**Parameters**

- **constPack**
  - *Input*. The opaque structure that is created by this function. For more information, refer to `cudnnFusedOpsConstParamPack_t`.

- **ops**
  - *Input*. The specific sequence of computations to perform in the `cudnnFusedOps` computations, as defined in the enumerant type `cudnnFusedOps_t`.

**Returns**

- **CUDNN_STATUS_BAD_PARAM**
  - If either `constPack` or `ops` is NULL.

- **CUDNN_STATUS_ALLOC_FAILED**
  - The resources could not be allocated.

- **CUDNN_STATUS_SUCCESS**
  - If the descriptor is created successfully.

### 6.2.5. `cudnnCreateFusedOpsPlan()`

This function creates the plan descriptor for the `cudnnFusedOps` computation. This descriptor contains the plan information, including the problem type and size, which kernels should be run, and the internal workspace partition.

```c

cudnnStatus_t cudnnCreateFusedOpsPlan(  
cudnnFusedOpsPlan_t *plan,  
cudnnFusedOps_t ops);
```

**Parameters**

- **plan**
  - *Input*. A pointer to the instance of the descriptor created by this function.

- **ops**
  - *Input*. The specific sequence of fused operations computations for which this plan descriptor should be created. For more information, refer to `cudnnFusedOps_t`.
Returns

**CUDNN_STATUS_BAD_PARAM**
If either the input *plan* is NULL or the *ops* input is not a valid *cudnnFusedOp* enum.

**CUDNN_STATUS_ALLOC_FAILED**
The resources could not be allocated.

**CUDNN_STATUS_SUCCESS**
The plan descriptor is created successfully.

### 6.2.6. cudnnCreateFusedOpsVariantParamPack()

This function creates the variant pack descriptor for the *cudnnFusedOps* computation.

```c
void cudnnCreateFusedOpsVariantParamPack(
  cudnnFusedOpsVariantParamPack_t *varPack,
  cudnnFusedOps_t ops);
```

**Parameters**

*varPack*  
*Input*. Pointer to the descriptor created by this function. For more information, refer to *cudnnFusedOpsVariantParamPack_t*.

*ops*  
*Input*. The specific sequence of fused operations computations for which this descriptor should be created.

Returns

**CUDNN_STATUS_SUCCESS**
The descriptor is successfully created.

**CUDNN_STATUS_ALLOC_FAILED**
The resources could not be allocated.

**CUDNN_STATUS_BAD_PARAM**
If any input is invalid.

### 6.2.7. cudnnDestroyFusedOpsConstParamPack()

This function destroys a previously-created *cudnnFusedOpsConstParamPack_t* structure.

```c
void cudnnDestroyFusedOpsConstParamPack(
  cudnnFusedOpsConstParamPack_t constPack);
```

**Parameters**

*constPack*  
*Input*. The *cudnnFusedOpsConstParamPack_t* structure that should be destroyed.
Returns

**CUDNN_STATUS_SUCCESS**
If the descriptor is destroyed successfully.

**CUDNN_STATUS_INTERNAL_ERROR**
If the ops enum value is not supported or invalid.

### 6.2.8. **cudnnDestroyFusedOpsPlan()**

This function destroys the plan descriptor provided.

```c
#include <cudnn.h>

cudnnStatus_t cudnnDestroyFusedOpsPlan(cudnnFusedOpsPlan_t plan);
```

**Parameters**

- `plan` 
  *Input*. The descriptor that should be destroyed by this function.

**Returns**

**CUDNN_STATUS_SUCCESS**
If either the plan descriptor is **NULL** or the descriptor is successfully destroyed.

### 6.2.9. **cudnnDestroyFusedOpsVariantParamPack()**

This function destroys a previously-created descriptor for `cudnnFusedOps` constant parameters.

```c
#include <cudnn.h>

cudnnStatus_t cudnnDestroyFusedOpsVariantParamPack(cudnnFusedOpsVariantParamPack_t varPack);
```

**Parameters**

- `varPack` 
  *Input*. The descriptor that should be destroyed.

**Returns**

**CUDNN_STATUS_SUCCESS**
The descriptor is successfully destroyed.

### 6.2.10. **cudnnFindConvolutionBackwardFilterAlgorithm()**

This function attempts all algorithms available for `cudnnConvolutionBackwardFilter()`. It will attempt both the provided `convDesc` `mathType` and `CUDNN_DEFAULT_MATH` (assuming the two differ).

```c
#include <cudnn.h>

cudnnStatus_t cudnnFindConvolutionBackwardFilterAlgorithm(
    cudnnHandle_t handle,
    const cudnnTensorDescriptor_t xDesc,
    const cudnnTensorDescriptor_t dyDesc,
    const cudnnConvolutionDescriptor_t convDesc,
);
```
```c
const cudnnFilterDescriptor_t          dwDesc,
const int                              requestedAlgoCount,
int                                   *returnedAlgoCount,
cudnnConvolutionBwdFilterAlgoPerf_t   *perfResults)
```

**Note:** Algorithms without the CUDNN_TENSOR_OP_MATH availability will only be tried with CUDNN_DEFAULT_MATH, and returned as such.

Memory is allocated via `cudaMalloc()`. The performance metrics are returned in the user-allocated array of `cudnnConvolutionBwdFilterAlgoPerf_t`. These metrics are written in a sorted fashion where the first element has the lowest compute time. The total number of resulting algorithms can be queried through the API `cudnnGetConvolutionBackwardFilterAlgorithmMaxCount()`.

**Note:**
- This function is host blocking.
- It is recommended to run this function prior to allocating layer data; doing otherwise may needlessly inhibit some algorithm options due to resource usage.

**Parameters**

- **handle**
  - *Input*. Handle to a previously created cuDNN context.
- **xDesc**
  - *Input*. Handle to the previously initialized input tensor descriptor.
- **dyDesc**
  - *Input*. Handle to the previously initialized input differential tensor descriptor.
- **convDesc**
  - *Input*. Previously initialized convolution descriptor.
- **dwDesc**
  - *Input*. Handle to a previously initialized filter descriptor.
- **requestedAlgoCount**
  - *Input*. The maximum number of elements to be stored in `perfResults`.
- **returnedAlgoCount**
  - *Output*. The number of output elements stored in `perfResults`.
- **perfResults**
  - *Output*. A user-allocated array to store performance metrics sorted ascending by compute time.

**Returns**

- **CUDNN_STATUS_SUCCESS**
  - The query was successful.
- **CUDNN_STATUS_BAD_PARAM**
  - At least one of the following conditions are met:
    - `handle` is not allocated properly.
xDesc, dyDesc, or dwDesc are not allocated properly.

xDesc, dyDesc, or dwDesc has fewer than 1 dimension.

Either returnedCount or perfResults is NIL.

requestedCount is less than 1.

**CUDNN_STATUS_ALLOC_FAILED**

This function was unable to allocate memory to store sample input, filters and output.

**CUDNN_STATUS_INTERNAL_ERROR**

At least one of the following conditions are met:

- The function was unable to allocate necessary timing objects.
- The function was unable to deallocate necessary timing objects.
- The function was unable to deallocate sample input, filters and output.

### 6.2.11. cudnnFindConvolutionBackwardFilterAlgorithmEx()

This function attempts all algorithms available for cudnnConvolutionBackwardFilter(). It will attempt both the provided convDesc mathType and CUDNN_DEFAULT_MATH (assuming the two differ).

```c
void cudnnFindConvolutionBackwardFilterAlgorithmEx(
    cudnnHandle_t                          handle,
    const cudnnTensorDescriptor_t          xDesc,
    const void                            *x,
    const cudnnTensorDescriptor_t          dyDesc,
    const void                            *dy,
    const cudnnConvolutionDescriptor_t     convDesc,
    const cudnnFilterDescriptor_t          dwDesc,
    void                                  *dw,
    const int                              requestedAlgoCount,
    int                                   *returnedAlgoCount,
    cudnnConvolutionBwdFilterAlgoPerf_t   *perfResults,
    void                                  *workSpace,
    size_t                                 workSpaceSizeInBytes)
```

**Note:** Algorithms without the CUDNN_TENSOR_OP_MATH availability will only be tried with CUDNN_DEFAULT_MATH, and returned as such.

Memory is allocated via cudaMalloc(). The performance metrics are returned in the user-allocated array of cudnnConvolutionBwdFilterAlgoPerf_t. These metrics are written in a sorted fashion where the first element has the lowest compute time. The total number of resulting algorithms can be queried through the API cudnnGetConvolutionBackwardFilterAlgorithmMaxCount().

**Note:** This function is host blocking.

**Parameters**

**handle**

*Input.* Handle to a previously created cuDNN context.
xDesc
   Input. Handle to the previously initialized input tensor descriptor.

x
   Input. Data pointer to GPU memory associated with the filter descriptor xDesc.

dyDesc
   Input. Handle to the previously initialized input differential tensor descriptor.

dy
   Input. Data pointer to GPU memory associated with the tensor descriptor dyDesc.

convDesc
   Input. Previously initialized convolution descriptor.

dwDesc
   Input. Handle to a previously initialized filter descriptor.

dw
   Input/Output. Data pointer to GPU memory associated with the filter descriptor dwDesc. The content of this tensor will be overwritten with arbitrary values.

requestedAlgoCount
   Input. The maximum number of elements to be stored in perfResults.

returnedAlgoCount
   Output. The number of output elements stored in perfResults.

perfResults
   Output. A user-allocated array to store performance metrics sorted ascending by compute time.

workSpace
   Input. Data pointer to GPU memory is a necessary workspace for some algorithms. The size of this workspace will determine the availability of algorithms. A NIL pointer is considered a workSpace of 0 bytes.

workSpaceSizeInBytes
   Input. Specifies the size in bytes of the provided workSpace.

Returns

CUDNN_STATUS_SUCCESS
   The query was successful.

CUDNN_STATUS_BAD_PARAM
   At least one of the following conditions are met:
   ▶ handle is not allocated properly.
   ▶ xDesc, dyDesc, or dwDesc are not allocated properly.
   ▶ xDesc, dyDesc, or dwDesc has fewer than 1 dimension.
   ▶ x, dy, or dw is NIL.
   ▶ Either returnedCount or perfResults is NIL.
   ▶ requestedCount is less than 1.
CUDNN\_STATUS\_INTERNAL\_ERROR
At least one of the following conditions are met:

- The function was unable to allocate necessary timing objects.
- The function was unable to deallocate necessary timing objects.
- The function was unable to deallocate sample input, filters and output.

6.2.12. cudnnFusedOpsExecute()
This function executes the sequence of cudnnFusedOps operations.

```c

cudnnStatus_t cudnnFusedOpsExecute(
    cudnnHandle_t handle,
    const cudnnFusedOpsPlan_t plan,
    cudnnFusedOpsVariantParamPack_t varPack);
```

Parameters

- **handle**
  *Input*. Pointer to the cuDNN library context.
- **plan**
  *Input*. Pointer to a previously-created and initialized plan descriptor.
- **varPack**
  *Input*. Pointer to the descriptor to the variant parameters pack.

Returns

CUDNN\_STATUS\_BAD\_PARAM
If the type of cudnnFusedOps_t in the plan descriptor is unsupported.

6.2.13. cudnnGetConvolutionBackwardFilterAlgorithmMaxCount()
This function returns the maximum number of algorithms which can be returned from cudnnFindConvolutionBackwardFilterAlgorithm() and cudnnGetConvolutionForwardAlgorithm_v7(). This is the sum of all algorithms plus the sum of all algorithms with Tensor Core operations supported for the current device.

```c

cudnnStatus_t cudnnGetConvolutionBackwardFilterAlgorithmMaxCount(
    cudnnHandle_t handle,
    int *count)
```

Parameters

- **handle**
  *Input*. Handle to a previously created cuDNN context.
- **count**
  *Output*. The resulting maximum count of algorithms.
Returns

**CUDNN_STATUS_SUCCESS**
The function was successful.

**CUDNNSTATUS_BAD_PARAM**
The provided handle is not allocated properly.

6.2.14. **cudnnGetConvolutionBackwardFilterAlgorithm_v7()**
This function serves as a heuristic for obtaining the best suited algorithm for
`cudnnConvolutionBackwardFilter()` for the given layer specifications. This function
will return all algorithms (including `CUDNN_TENSOR_OP_MATH` and `CUDNN_DEFAULT_MATH`
versions of algorithms where `CUDNN_TENSOR_OP_MATH` may be available) sorted by
expected (based on internal heuristic) relative performance with fastest being
index 0 of `perfResults`. For an exhaustive search for the fastest algorithm, use
`cudnnFindConvolutionBackwardFilterAlgorithm()`. The total number of resulting
algorithms can be queried through the `returnedAlgoCount` variable.

```c
    cudnnStatus_t cudnnGetConvolutionBackwardFilterAlgorithm_v7(
        cudnnHandle_t                          handle,
        const cudnnTensorDescriptor_t          xDesc,
        const cudnnTensorDescriptor_t          dyDesc,
        const cudnnConvolutionDescriptor_t     convDesc,
        const cudnnFilterDescriptor_t          dwDesc,
        const int                              requestedAlgoCount,
        int                                   *returnedAlgoCount,
        cudnnConvolutionBwdFilterAlgoPerf_t   *perfResults)
```

Parameters

**handle**
*Input*. Handle to a previously created cuDNN context.

**xDesc**
*Input*. Handle to the previously initialized input tensor descriptor.

**dyDesc**
*Input*. Handle to the previously initialized input differential tensor descriptor.

**convDesc**
*Input*. Previously initialized convolution descriptor.

**dwDesc**
*Input*. Handle to a previously initialized filter descriptor.

**requestedAlgoCount**
*Input*. The maximum number of elements to be stored in `perfResults`.

**returnedAlgoCount**
*Output*. The number of output elements stored in `perfResults`.

**perfResults**
*Output*. A user-allocated array to store performance metrics sorted ascending by
compute time.
Returns

**CUDNN_STATUS_SUCCESS**

The query was successful.

**CUDNN_STATUS_BAD_PARAM**

At least one of the following conditions are met:

- One of the parameters `handle`, `xDesc`, `dyDesc`, `convDesc`, `dwDesc`, `perfResults`, or `returnedAlgoCount` is NULL.
- The numbers of feature maps of the input tensor and output tensor differ.
- The `dataType` of the two tensor descriptors or the filter are different.
- `requestedAlgoCount` is less than or equal to 0.

### 6.2.15. cudnnGetConvolutionBackwardFilterWorkspaceSize

This function returns the amount of GPU memory workspace the user needs to allocate to be able to call `cudnnConvolutionBackwardFilter()` with the specified algorithm. The workspace allocated will then be passed to the routine `cudnnConvolutionBackwardFilter()`. The specified algorithm can be the result of the call to `cudnnGetConvolutionBackwardFilterAlgorithm_v7()` or can be chosen arbitrarily by the user. Note that not every algorithm is available for every configuration of the input tensor and/or every configuration of the convolution descriptor.

```c
void cudnnGetConvolutionBackwardFilterWorkspaceSize(
    cudnnHandle_t handle,
    const cudnnTensorDescriptor_t xDesc,
    const cudnnTensorDescriptor_t dyDesc,
    const cudnnConvolutionDescriptor_t convDesc,
    const cudnnFilterDescriptor_t dwDesc,
    cudnnConvolutionBwdFilterAlgo_t algo,
    size_t *sizeInBytes)
```

**Parameters**

**handle**

*Input*. Handle to a previously created cuDNN context.

**xDesc**

*Input*. Handle to the previously initialized input tensor descriptor.

**dyDesc**

*Input*. Handle to the previously initialized input differential tensor descriptor.

**convDesc**

*Input*. Previously initialized convolution descriptor.

**dwDesc**

*Input*. Handle to a previously initialized filter descriptor.

**algo**

*Input*. Enumerant that specifies the chosen convolution algorithm.
**sizeInBytes**

*Output.* Amount of GPU memory needed as workspace to be able to execute a forward convolution with the specified `algo`.

**Returns**

**CUDNN_STATUS_SUCCESS**

The query was successful.

**CUDNN_STATUS_BAD_PARAM**

At least one of the following conditions are met:

- The numbers of feature maps of the input tensor and output tensor differ.
- The `dataType` of the two tensor descriptors or the filter are different.

**CUDNN_STATUS_NOT_SUPPORTED**

The combination of the tensor descriptors, filter descriptor and convolution descriptor is not supported for the specified algorithm.

### 6.2.16. `cudnnGetFusedOpsConstParamPackAttribute()`

This function retrieves the values of the descriptor pointed to by the `param` pointer input. The type of the descriptor is indicated by the enum value of `paramLabel` input.

```c
const cudnnStatus_t cudnnGetFusedOpsConstParamPackAttribute(
    const cudnnFusedOpsConstParamPack_t constPack,
    cudnnFusedOpsConstParamLabel_t paramLabel,
    void *param,
    int *isNULL);
```

**Parameters**

**constPack**

*Input.* The opaque `cudnnFusedOpsConstParamPack_t` structure that contains the various problem size information, such as the shape, layout and the type of tensors, and the descriptors for convolution and activation, for the selected sequence of `cudnnFusedOps_t` computations.

**paramLabel**

*Input.* Several types of descriptors can be retrieved by this getter function. The `param` input points to the descriptor itself, and this input indicates the type of the descriptor pointed to by the `param` input. The `cudnnFusedOpsConstParamLabel_t` enumerant type enables the selection of the type of the descriptor. Refer to the `param` description below.

**param**

*Input.* Data pointer to the host memory associated with the descriptor that should be retrieved. The type of this descriptor depends on the value of `paramLabel`. For the given `paramLabel`, if the associated value inside the `constPack` is set to `NULL` or by default `NULL`, then cuDNN will copy the value or the opaque structure in the `constPack` to the host memory buffer pointed to by `param`. For more information, see the table in `cudnnFusedOpsConstParamLabel_t`. 
isNULL

*Input/Output.* Users must pass a pointer to an integer in the host memory in this field. If the value in the *constPack* associated with the given *paramLabel* is by default NULL or previously set by the user to NULL, then cuDNN will write a non-zero value to the location pointed by *is* isNULL.

**Returns**

**CUDNN_STATUS_SUCCESS**

The descriptor values are retrieved successfully.

**CUDNN_STATUS_BAD_PARAM**

If either *constPack*, *param* or *isNULL* is NULL; or if *paramLabel* is invalid.

### 6.2.17. `cudnnGetFusedOpsVariantParamPackAttribute()`

This function retrieves the settings of the variable parameter pack descriptor.

```c
cudnnStatus_t cudnnGetFusedOpsVariantParamPackAttribute(
    const cudnnFusedOpsVariantParamPack_t varPack,
    cudnnFusedOpsVariantParamLabel_t paramLabel,
    void *ptr);
```

**Parameters**

**varPack**

*Input.* Pointer to the `cudnnFusedOps` variant parameter pack (*varPack*) descriptor.

**paramLabel**

*Input.* Type of the buffer pointer parameter (in the *varPack* descriptor). For more information, refer to `cudnnFusedOpsConstParamLabel_t`. The retrieved descriptor values vary according to this type.

**ptr**

*Output.* Pointer to the host or device memory where the retrieved value is written by this function. The data type of the pointer, and the host/device memory location, depend on the *paramLabel* input selection. For more information, refer to `cudnnFusedOpsVariantParamLabel_t`.

**Returns**

**CUDNN_STATUS_SUCCESS**

The descriptor values are retrieved successfully.

**CUDNN_STATUS_BAD_PARAM**

If either *varPack* or *ptr* is NULL, or if *paramLabel* is set to invalid value.

### 6.2.18. `cudnnMakeFusedOpsPlan()`

This function determines the optimum kernel to execute, and the workspace size the user should allocate, prior to the actual execution of the fused operations by `cudnnFusedOpsExecute()`. 

```c
cudnnStatus_t cudnnMakeFusedOpsPlan(
```

NVIDIA cuDNN
cudnnHandle_t handle,
cudnnFusedOpsPlan_t plan,
const cudnnFusedOpsConstParamPack_t constPack,
size_t *workspaceSizeInBytes);

Parameters

handle
  Input. Pointer to the cuDNN library context.

plan
  Input. Pointer to a previously-created and initialized plan descriptor.

constPack
  Input. Pointer to the descriptor to the const parameters pack.

workspaceSizeInBytes
  Output. The amount of workspace size the user should allocate for the execution of this plan.

Returns

CUDNN_STATUS_BAD_PARAM
  If any of the inputs is NULL, or if the type of cudnnFusedOps_t in the constPack descriptor is unsupported.

CUDNN_STATUS_SUCCESS
  The function executed successfully.

6.2.19. cudnnSetFusedOpsConstParamPackAttribute()

This function sets the descriptor pointed to by the param pointer input. The type of the descriptor to be set is indicated by the enum value of the paramName input.

cudnnStatus_t cudnnSetFusedOpsConstParamPackAttribute(
  cudnnFusedOpsConstParamPack_t constPack,
  cudnnFusedOpsConstParamLabel_t paramName,
  const void *param);

Parameters

constPack
  Input. The opaque cudnnFusedOpsConstParamPack_t structure that contains the various problem size information, such as the shape, layout and the type of tensors, the descriptors for convolution and activation, and settings for operations such as convolution and activation.

paramLabel
  Input. Several types of descriptors can be set by this setter function. The param input points to the descriptor itself, and this input indicates the type of the descriptor pointed to by the param input. The cudnnFusedOpsConstParamLabel_t enumerant type enables the selection of the type of the descriptor.
param

Input. Data pointer to the host memory, associated with the specific descriptor. The type of the descriptor depends on the value of paramLabel. For more information, refer to the table in cudnnFusedOpsConstParamLabel_t.

If this pointer is set to NULL, then the cuDNN library will record as such. If not, then the values pointed to by this pointer (meaning, the value or the opaque structure underneath) will be copied into the constPack during cudnnSetFusedOpsConstParamPackAttribute() operation.

Returns

CUDNN_STATUS_SUCCESS
The descriptor is set successfully.

CUDNN_STATUS_BAD_PARAM
If constPack is NULL, or if paramLabel or the ops setting for constPack is invalid.

6.2.20. cudnnSetFusedOpsVariantParamPackAttribute()

This function sets the variable parameter pack descriptor.

```c
void *ptr);
```

Parameters

varPack

Input. Pointer to the cudnnFusedOps variant parameter pack (varPack) descriptor.

paramLabel

Input. Type to which the buffer pointer parameter (in the varPack descriptor) is set by this function. For more information, refer to cudnnFusedOpsConstParamLabel_t.

ptr

Input. Pointer, to the host or device memory, to the value to which the descriptor parameter is set. The data type of the pointer, and the host/device memory location, depend on the paramLabel input selection. For more information, refer to cudnnFusedOpsVariantParamLabel_t.

Returns

CUDNN_STATUS_BAD_PARAM
If varPack is NULL or if paramLabel is set to an unsupported value.

CUDNN_STATUS_SUCCESS
The descriptor was set successfully.
Chapter 7. cudnn_adv_infer.so Library

This entity contains all other features and algorithms. This includes RNNs, CTC loss, and multi-head attention. The cudnn_adv_infer library depends on cudnn_ops_infer.

7.1. Data Type References
These are the data type references in the cudnn_adv_infer.so library.

7.1.1. Pointer To Opaque Struct Types
These are the pointers to the opaque struct types in the cudnn_adv_infer.so library.

7.1.1.1. cudnnAttnDescriptor_t

cudnnAttnDescriptor_t is a pointer to an opaque structure holding parameters of the multi-head attention layer such as:

- weight and bias tensor shapes (vector lengths before and after linear projections)
- parameters that can be set in advance and do not change when invoking functions to evaluate forward responses and gradients (number of attention heads, softmax smoothing/sharpening coefficient)
- other settings that are necessary to compute temporary buffer sizes.

Use the cudnnCreateAttnDescriptor() function to create an instance of the attention descriptor object and cudnnDestroyAttnDescriptor() to delete the previously created descriptor. Use the cudnnSetAttnDescriptor() function to configure the descriptor.

7.1.1.2. cudnnPersistentRNNPlan_t

This function is deprecated starting in cuDNN 8.0.0.

cudnnPersistentRNNPlan_t is a pointer to an opaque structure holding a plan to execute a dynamic persistent RNN. cudnnCreatePersistentRNNPlan() is used to create and initialize one instance.
7.1.1.3. **cudnnRNNDataDescriptor_t**

cudnnRNNDataDescriptor_t is a pointer to an opaque structure holding the description of an RNN data set. The function cudnnCreateRNNDataDescriptor() is used to create one instance, and cudnnSetRNNDataDescriptor() must be used to initialize this instance.

7.1.1.4. **cudnnRNNDescriptor_t**

cudnnRNNDescriptor_t is a pointer to an opaque structure holding the description of an RNN operation. cudnnCreateRNNDescriptor() is used to create one instance.

7.1.1.5. **cudnnSeqDataDescriptor_t**

cudnnSeqDataDescriptor_t is a pointer to an opaque structure holding parameters of the sequence data container or buffer. The sequence data container is used to store fixed size vectors defined by the VECT dimension. Vectors are arranged in additional three dimensions: TIME, BATCH and BEAM.

The TIME dimension is used to bundle vectors into sequences of vectors. The actual sequences can be shorter than the TIME dimension, therefore, additional information is needed about each sequence length and how unused (padding) vectors should be saved.

It is assumed that the sequence data container is fully packed. The TIME, BATCH and BEAM dimensions can be in any order when vectors are traversed in the ascending order of addresses. Six data layouts (permutation of TIME, BATCH and BEAM) are possible.

The cudnnSeqDataDescriptor_t object holds the following parameters:

- data type used by vectors
- TIME, BATCH, BEAM and VECT dimensions
- data layout
- the length of each sequence along the TIME dimension
- an optional value to be copied to output padding vectors

Use the cudnnCreateSeqDataDescriptor() function to create one instance of the sequence data descriptor object and cudnnDestroySeqDataDescriptor() to delete a previously created descriptor. Use the cudnnSetSeqDataDescriptor() function to configure the descriptor.

This descriptor is used by multi-head attention API functions.

7.1.2. **Enumeration Types**

These are the enumeration types in the cudnn_adv_infer.so library.
7.1.2.1. cudnnDirectionMode_t

cudnnDirectionMode_t is an enumerated type used to specify the recurrence pattern in the cudnnRNNForwardInference(), cudnnRNNForwardTraining(), cudnnRNNBackwardData() and cudnnRNNBackwardWeights() routines.

Values

**CUDNN_UNIDIRECTIONAL**
- The network iterates recurrently from the first input to the last.

**CUDNN_BIDIRECTIONAL**
- Each layer of the network iterates recurrently from the first input to the last and separately from the last input to the first. The outputs of the two are concatenated at each iteration giving the output of the layer.

7.1.2.2. cudnnForwardMode_t

cudnnForwardMode_t is an enumerated type to specify inference or training mode in RNN API. This parameter allows the cuDNN library to tune more precisely the size of the workspace buffer that could be different in inference and training regimens.

Values

**CUDNN_FWD_MODE_INFERENCE**
- Selects the inference mode.

**CUDNN_FWD_MODE_TRAINING**
- Selects the training mode.

7.1.2.3. cudnnMultiHeadAttnWeightKind_t

cudnnMultiHeadAttnWeightKind_t is an enumerated type that specifies a group of weights or biases in the cudnnGetMultiHeadAttnWeights() function.

Values

**CUDNN_MH_ATTN_Q_WEIGHTS**
- Selects the input projection weights for queries.

**CUDNN_MH_ATTN_K_WEIGHTS**
- Selects the input projection weights for keys.

**CUDNN_MH_ATTN_V_WEIGHTS**
- Selects the input projection weights for values.

**CUDNN_MH_ATTN_O_WEIGHTS**
- Selects the output projection weights.

**CUDNN_MH_ATTN_Q_BIASES**
- Selects the input projection biases for queries.

**CUDNN_MH_ATTN_K_BIASES**
- Selects the input projection biases for keys.
CUDNN_MH_ATTN_V_BIASES
Selects the input projection biases for values.

CUDNN_MH_ATTN_O_BIASES
Selects the output projection biases.

7.1.2.4. cudnnRNNBiasMode_t

cudnnRNNBiasMode_t is an enumerated type used to specify the number of bias vectors for RNN functions. Refer to the description of the cudnnRNNMode_t enumerated type for the equations for each cell type based on the bias mode.

Values

CUDNN_RNN_NO_BIAS
Applies RNN cell formulas that do not use biases.

CUDNN_RNN_SINGLE_INP_BIAS
Applies RNN cell formulas that use one input bias vector in the input GEMM.

CUDNN_RNN_DOUBLE_BIAS
Applies RNN cell formulas that use two bias vectors.

CUDNN_RNN_SINGLE_REC_BIAS
Applies RNN cell formulas that use one recurrent bias vector in the recurrent GEMM.

7.1.2.5. cudnnRNNClipMode_t

cudnnRNNClipMode_t is an enumerated type used to select the LSTM cell clipping mode. It is used with cudnnRNNSetClip(), cudnnRNNGetClip() functions, and internally within LSTM cells.

Values

CUDNN_RNN_CLIP_NONE
Disables LSTM cell clipping.

CUDNN_RNN_CLIP_MINMAX
Enables LSTM cell clipping.

7.1.2.6. cudnnRNNDataLayout_t

cudnnRNNDataLayout_t is an enumerated type used to select the RNN data layout. It is used in the API calls cudnnGetRNNDataDescriptor() and cudnnSetRNNDataDescriptor().

Values

CUDNN_RNN_DATA_LAYOUT_SEQ_MAJOR_UNPACKED
Data layout is padded, with outer stride from one time-step to the next.

CUDNN_RNN_DATA_LAYOUT_SEQ_MAJOR_PACKED
The sequence length is sorted and packed as in the basic RNN API.
**CUDNN_RNN_DATA_LAYOUT_BATCH_MAJOR_UNPACKED**

Data layout is padded, with outer stride from one batch to the next.

### 7.1.2.7. cudnnRNNInputMode_t

CudnnRNNInputMode_t is an enumerated type used to specify the behavior of the first layer in the cudnnRNNForwardInference(), cudnnRNNForwardTraining(), cudnnRNNBackwardData() and cudnnRNNBackwardWeights() routines.

**Values**

- **CUDNN_LINEAR_INPUT**
  A biased matrix multiplication is performed at the input of the first recurrent layer.

- **CUDNN_SKIP_INPUT**
  No operation is performed at the input of the first recurrent layer. If CUDNN_SKIP_INPUT is used the leading dimension of the input tensor must be equal to the hidden state size of the network.

### 7.1.2.8. cudnnRNNMode_t

CudnnRNNMode_t is an enumerated type used to specify the type of network used in the cudnnRNNForwardInference, cudnnRNNForwardTraining, cudnnRNNBackwardData and cudnnRNNBackwardWeights routines.

**Values**

- **CUDNN_RNN_RELU**
  A single-gate recurrent neural network with a ReLU activation function.

  In the forward pass, the output \( h_t \) for a given iteration can be computed from the recurrent input \( h_{t-1} \) and the previous layer input \( x_t \), given the matrices \( W, R \) and the bias vectors, where \( \text{ReLU}(x) = \max(x, 0) \).

  If cudnnRNNBiasMode_t biasMode in rnnDesc is CUDNN_RNN_DOUBLE_BIAS (default mode), then the following equation with biases \( b_W \) and \( b_R \) applies:

  \[
  h_t = \text{ReLU}(W x_t + R h_{t-1} + b_W + b_R)
  \]

  If cudnnRNNBiasMode_t biasMode in rnnDesc is CUDNN_RNN_SINGLE_inp_BIAS or CUDNN_RNN_SINGLE_rec_BIAS, then the following equation with bias \( b \) applies:

  \[
  h_t = \text{ReLU}(W x_t + R h_{t-1} + b)
  \]

  If cudnnRNNBiasMode_t biasMode in rnnDesc is CUDNN_RNN_NO_BIAS, then the following equation applies:

  \[
  h_t = \text{ReLU}(W x_t + R h_{t-1})
  \]
**CUDNN_RNN_TANH**

A single-gate recurrent neural network with a \( \tanh \) activation function.

In the forward pass, the output \( h_t \) for a given iteration can be computed from the recurrent input \( h_{t-1} \) and the previous layer input \( x_t \), given the matrices \( W, R \) and the bias vectors, and where \( \tanh \) is the hyperbolic tangent function.

If `cudnnRNNBiasMode_t biasMode in rnnDesc` is `CUDNN_RNN_DOUBLE_BIAS` (default mode), then the following equation with biases \( b_W \) and \( b_R \) applies:

\[
h_t = \tanh(W x_t + R h_{t-1} + b_W + b_R)
\]

If `cudnnRNNBiasMode_t biasMode in rnnDesc` is `CUDNN_RNN_SINGLE_INP_BIAS` or `CUDNN_RNN_SINGLE_REC_BIAS`, then the following equation with bias \( b \) applies:

\[
h_t = \tanh(W x_t + R h_{t-1} + b)
\]

If `cudnnRNNBiasMode_t biasMode in rnnDesc` is `CUDNN_RNN_NO_BIAS`, then the following equation applies:

\[
h_t = \tanh(W x_t + R h_{t-1})
\]

**CUDNN_LSTM**

A four-gate Long Short-Term Memory (LSTM) network with no peephole connections.

In the forward pass, the output \( h_t \) and cell output \( c_t \) for a given iteration can be computed from the recurrent input \( h_{t-1} \), the cell input \( c_{t-1} \) and the previous layer input \( x_t \), given the matrices \( W, R \) and the bias vectors.

In addition, the following applies:

- \( \sigma \) is the sigmoid operator such that: \( \sigma(x) = 1 / (1 + e^x) \),
- \( \cdot \) represents a point-wise multiplication,
- \( \tanh \) is the hyperbolic tangent function, and
- \( i_t, f_t, o_t, c'_t \) represent the input, forget, output and new gates respectively.

If `cudnnRNNBiasMode_t biasMode in rnnDesc` is `CUDNN_RNN_DOUBLE_BIAS` (default mode), then the following equations with biases \( b_W \) and \( b_R \) apply:

\[
i_t = \sigma(W x_t + R h_{t-1} + b_W + b_R)
\]
\[
f_t = \sigma(W f x_t + R f h_{t-1} + b_W + b_R)
\]
\[
o_t = \sigma(W o x_t + R o h_{t-1} + b_W + b_R)
\]
\[
c'_t = \tanh(W c x_t + R c h_{t-1} + b_W + b_R)
\]
\[
c_t = f_t \cdot c_{t-1} + i_t \cdot c'_t
\]
\[
h_t = o_t \cdot \tanh(c_t)
\]
If cudnnRNNBiasMode_t biasMode in rnnDesc is CUDNN_RNN_SINGLE_inp_BIAS or CUDNN_RNN_SINGLE_rec_BIAS, then the following equations with bias $b$ apply:

$$i_t = \sigma \left( W x_t + R_t h_{t-1} + b \right)$$
$$f_t = \sigma \left( W_f x_t + R_f h_{t-1} + b_f \right)$$
$$o_t = \sigma \left( W_o x_t + R_o h_{t-1} + b_o \right)$$
$$c'_t = \tanh \left( W_c x_t + R_c h_{t-1} + b_c \right)$$
$$c_t = f_t \cdot c_{t-1} + i_t \cdot c'_t$$
$$h_t = o_t \cdot \tanh \left( c_t \right)$$

If cudnnRNNBiasMode_t biasMode in rnnDesc is CUDNN_RNN_NO_BIAS, then the following equations apply:

$$i_t = \sigma \left( W x_t + R h_{t-1} \right)$$
$$f_t = \sigma \left( W_f x_t + R_f h_{t-1} \right)$$
$$o_t = \sigma \left( W_o x_t + R_o h_{t-1} \right)$$
$$c'_t = \tanh \left( W_c x_t + R_c h_{t-1} \right)$$
$$c_t = f_t \cdot c_{t-1} + i_t \cdot c'_t$$
$$h_t = o_t \cdot \tanh \left( c_t \right)$$

**CUDNN_GRU**

A three-gate network consisting of Gated Recurrent Units.

In the forward pass, the output $h_t$ for a given iteration can be computed from the recurrent input $h_{t-1}$ and the previous layer input $x_t$ given matrices $W, R$ and the bias vectors.

In addition, the following applies:

- $\sigma$ is the sigmoid operator such that: $\sigma(x) = 1 / (1 + e^{-x})$,
- $\cdot$ represents a point-wise multiplication,
- $\tanh$ is the hyperbolic tangent function, and
- $i_t, r_t, h_t$ represent the input, reset, and new gates respectively.

If cudnnRNNBiasMode_t biasMode in rnnDesc is CUDNN_RNN_DOUBLE_BIAS (default mode), then the following equations with biases $b_W$ and $b_R$ apply:

$$i_t = \sigma \left( W x_t + R h_{t-1} + b_W + b_R \right)$$
$$r_t = \sigma \left( W_f x_t + R_f h_{t-1} + b_W + b_R \right)$$
\[ H'_t = \tanh(W_x x_t + r_t \cdot (R_h h_{t-1} + b_R) + b_W) \]
\[ h_t = (1-i_t) \cdot H'_t + i_t \cdot h_{t-1} \]

If `cudnnRNNBiasMode_t biasMode in rnnDesc is CUDNN_RNN_SINGLE_INP_BIAS`, then the following equations with bias \( b \) apply:

\[ i_t = \sigma \left( W_x x_t + R_i h_{t-1} + b \right) \]
\[ r_t = \sigma \left( W_x x_t + R_r h_{t-1} + b \right) \]
\[ H'_t = \tanh(W_x x_t + r_t \cdot (R_r h_{t-1} + b) + b_W) \]
\[ h_t = (1-i_t) \cdot H'_t + i_t \cdot h_{t-1} \]

If `cudnnRNNBiasMode_t biasMode in rnnDesc is CUDNN_RNN_SINGLE_REC_BIAS`, then the following equations with bias \( b \) apply:

\[ i_t = \sigma \left( W_x x_t + R_i h_{t-1} + b \right) \]
\[ r_t = \sigma \left( W_x x_t + R_r h_{t-1} + b \right) \]
\[ H'_t = \tanh(W_x x_t + r_t \cdot (R_r h_{t-1} + b_R) + b_W) \]
\[ h_t = (1-i_t) \cdot H'_t + i_t \cdot h_{t-1} \]

If `cudnnRNNBiasMode_t biasMode in rnnDesc is CUDNN_RNN_NO_BIAS`, then the following equations apply:

\[ i_t = \sigma \left( W_x x_t + R_i h_{t-1} \right) \]
\[ r_t = \sigma \left( W_x x_t + R_r h_{t-1} \right) \]
\[ H'_t = \tanh(W_x x_t + r_t \cdot (R_r h_{t-1}) \right) \]
\[ h_t = (1-i_t) \cdot H'_t + i_t \cdot h_{t-1} \]

### 7.1.2.9. `cudnnRNNPaddingMode_t`

`cudnnRNNPaddingMode_t` is an enumerated type used to enable or disable the padded input/output.

#### Values

- **CUDNN_RNN_PADDED_IO_DISABLED**
  - Disables the padded input/output.
- **CUDNN_RNN_PADDED_IO_ENABLED**
  - Enables the padded input/output.
7.1.2.10. `cudnnSeqDataAxis_t`

`cudnnSeqDataAxis_t` is an enumerated type that indexes active dimensions in the `dimA[]` argument that is passed to the `cudnnSetSeqDataDescriptor()` function to configure the sequence data descriptor of type `cudnnSeqDataDescriptor_t`.

`cudnnSeqDataAxis_t` constants are also used in the `axis[]` argument of the `cudnnSetSeqDataDescriptor()` call to define the layout of the sequence data buffer in memory.

Refer to `cudnnSetSeqDataDescriptor()` for a detailed description on how to use the `cudnnSeqDataAxis_t` enumerated type.

The `CUDNN_SEQDATA_DIM_COUNT` macro defines the number of constants in the `cudnnSeqDataAxis_t` enumerated type. This value is currently set to 4.

**Values**

- `CUDNN_SEQDATA_TIME_DIM`
  Identifies the `TIME` (sequence length) dimension or specifies the `TIME` in the data layout.

- `CUDNN_SEQDATA_BATCH_DIM`
  Identifies the `BATCH` dimension or specifies the `BATCH` in the data layout.

- `CUDNN_SEQDATA_BEAM_DIM`
  Identifies the `BEAM` dimension or specifies the `BEAM` in the data layout.

- `CUDNN_SEQDATA_VECT_DIM`
  Identifies the `VECT` (vector) dimension or specifies the `VECT` in the data layout.

### 7.2. API Functions

These are the API functions in the `cudnn_adv_infer.so` library.

#### 7.2.1. `cudnnAdvInferVersionCheck()`

This function checks to see whether the version of the AdvInfer subset of the library is consistent with the other sub-libraries.

```c
cudnnStatus_t cudnnAdvInferVersionCheck(void)
```

**Returns**

- `CUDNN_STATUS_SUCCESS`
  The version is consistent with other sub-libraries.

- `CUDNN_STATUS_VERSION_MISMATCH`
  The version of AdvInfer is not consistent with other sub-libraries. Users should check the installation and make sure all sub-component versions are consistent.
7.2.2. **cudnnBuildRNNDynamic()**

This function compiles the RNN persistent code using CUDA runtime compilation library (NVRTC) when the `CUDNN_RNN_ALGO_PERSIST_DYNAMIC` algo is selected. The code is tailored to the current GPU and specific hyperparameters (miniBatch). This call is expected to be expensive in terms of runtime and should be invoked infrequently. Note that the `CUDNN_RNN_ALGO_PERSIST_DYNAMIC` algo does not support variable length sequences within the batch.

```c
extern "C" cudnnStatus_t cudnnBuildRNNDynamic(
  cudnnHandle_t handle,
  cudnnRNNDescriptor_t rnnDesc,
  int32_t miniBatch);
```

**Parameters**

- **handle**
  - *Input*. Handle to a previously created cuDNN context.

- **rnnDesc**
  - *Input*. A previously initialized RNN descriptor.

- **miniBatch**
  - *Input*. The exact number of sequences in a batch.

**Returns**

- **CUDNN_STATUS_SUCCESS**
  - The code was built and linked successfully.

- **CUDNN_STATUS_MAPPING_ERROR**
  - A GPU/CUDA resource, such as a texture object, shared memory, or zero-copy memory is not available in the required size or there is a mismatch between the user resource and cuDNN internal resources. A resource mismatch may occur, for example, when calling `cudnnSetStream()`. There could be a mismatch between the user provided CUDA stream and the internal CUDA events instantiated in the cuDNN handle when `cudnnCreate()` was invoked.

  This error status may not be correctable when it is related to texture dimensions, shared memory size, or zero-copy memory availability. If `CUDNN_STATUS_MAPPING_ERROR` is returned by `cudnnSetStream()`, then it is typically correctable, however, it means that the cuDNN handle was created on one GPU and the user stream passed to this function is associated with another GPU.

- **CUDNN_STATUS_ALLOC_FAILED**
  - The resources could not be allocated.

- **CUDNN_STATUS_RUNTIME_PREREQUISITE_MISSING**
  - The prerequisite runtime library could not be found.

- **CUDNN_STATUS_NOT_SUPPORTED**
  - The current hyper-parameters are invalid.
7.2.3.  cudnnCreateAttnDescriptor()

This function creates one instance of an opaque attention descriptor object by allocating
the host memory for it and initializing all descriptor fields. The function writes NULL to
attnDesc when the attention descriptor object cannot be allocated.

\[
\text{cudnnStatus_t \ cudnnCreateAttnDescriptor(cudnnAttnDescriptor_t *attnDesc);}\]

Use the \text{cudnnSetAttnDescriptor()} function to configure the attention descriptor and
\text{cudnnDestroyAttnDescriptor()} to destroy it and release the allocated memory.

Parameters

\textbf{attnDesc}  
\textit{Output}. Pointer where the address to the newly created attention descriptor should be
written.

Returns

\textbf{CUDNN_STATUS_SUCCESS}  
The descriptor object was created successfully.

\textbf{CUDNN_STATUS_BAD_PARAM}  
An invalid input argument was encountered (attnDesc=NULL).

\textbf{CUDNN_STATUS_ALLOC_FAILED}  
The memory allocation failed.

7.2.4.  cudnnCreatePersistentRNNPlan()

This function has been deprecated in cuDNN 8.0. Use \text{cudnnBuildRNNDynamic()} instead
of \text{cudnnCreatePersistentRNNPlan()}.

\[
\text{cudnnStatus_t \ cudnnCreatePersistentRNNPlan(}
\begin{array}{ll}
\text{cudnnRNNDescriptor_t} & \text{rnnDesc}, \\
\text{const int} & \text{minibatch}, \\
\text{const cudnnDataType_t} & \text{dataType}, \\
\text{cudnnPersistentRNNPlan_t} & \text{plan}
\end{array}
\)

This function creates a plan to execute persistent RNNs when using the
\text{CUDNN_RNN_ALGO_PERSIST_DYNAMIC} algo. This plan is tailored to the current GPU
and RNN model hyperparameters. This function call is expected to be expensive in
terms of runtime and should be used infrequently. However, the user must invoke
\text{cudnnCreatePersistentRNNPlan()} every time the number of input vectors changes in a
minibatch. For more information, refer to \text{cudnnRNNDescriptor_t}, \text{cudnnDataType_t}, and
\text{cudnnPersistentRNNPlan_t}.

Parameters

\textbf{rnnDesc}  
\textit{Input}. A previously initialized RNN descriptor.

\textbf{minibatch}  
\textit{Input}. The exact number of vectors in a batch.
**dataType**

*Input.* Specifies data type for RNN weights/biases and input and output data.

**plan**

*Output.* Pointer to where the address to the newly created RNN persistent plan should be written.

**Returns**

**CUDNN_STATUS_SUCCESS**

The object was created successfully.

**CUDNN_STATUS_MAPPING_ERROR**

A GPU/CUDA resource, such as a texture object, shared memory, or zero-copy memory is not available in the required size or there is a mismatch between the user resource and cuDNN internal resources. A resource mismatch may occur, for example, when calling `cudnnSetStream()`. There could be a mismatch between the user provided CUDA stream and the internal CUDA events instantiated in the cuDNN handle when `cudnnCreate()` was invoked.

This error status may not be correctable when it is related to texture dimensions, shared memory size, or zero-copy memory availability. If **CUDNN_STATUS_MAPPING_ERROR** is returned by `cudnnSetStream()`, then it is typically correctable, however, it means that the cuDNN handle was created on one GPU and the user stream passed to this function is associated with another GPU.

**CUDNN_STATUSALLOC_FAILED**

The resources could not be allocated.

**CUDNN_STATUS_RUNTIME_PREREQUISITE_MISSING**

A prerequisite runtime library cannot be found.

**CUDNN_STATUS_NOT_SUPPORTED**

The current hyperparameters are invalid.

### 7.2.5. *cudnnCreateRNNDataDescriptor()*

This function creates a RNN data descriptor object by allocating the memory needed to hold its opaque structure.

```c
cudaStatus_t cudnnCreateRNNDataDescriptor(
    cudnnRNNDataDescriptor_t *RNNDataDesc)
```

**Parameters**

**RNNDataDesc**

*Output.* Pointer to where the address to the newly created RNN data descriptor should be written.
Returns

**CUDNN_STATUS_SUCCESS**
The RNN data descriptor object was created successfully.

**CUDNN_STATUS_BAD_PARAM**
The `RNNDataDesc` argument is NULL.

**CUDNN_STATUS_ALLOC_FAILED**
The resources could not be allocated.

### 7.2.6. cudnnCreateRNNDescriptor()

This function creates a generic RNN descriptor object by allocating the memory needed to hold its opaque structure.

```c
    cudnnStatus_t cudnnCreateRNNDescriptor(cudnnRNNDescriptor_t *rnnDesc)
```

**Parameters**

- `rnnDesc`
  
  *Output*. Pointer to where the address to the newly created RNN descriptor should be written.

**Returns**

- **CUDNN_STATUS_SUCCESS**
The object was created successfully.
- **CUDNN_STATUS_BAD_PARAM**
The `rnnDesc` argument is NULL.
- **CUDNN_STATUS_ALLOC_FAILED**
The resources could not be allocated.

### 7.2.7. cudnnCreateSeqDataDescriptor()

This function creates one instance of an opaque sequence data descriptor object by allocating the host memory for it and initializing all descriptor fields. The function writes NULL to `seqDataDesc` when the sequence data descriptor object cannot be allocated.

```c
    cudnnStatus_t cudnnCreateSeqDataDescriptor(cudnnSeqDataDescriptor_t *seqDataDesc);
```

Use the `cudnnSetSeqDataDescriptor()` function to configure the sequence data descriptor and `cudnnDestroySeqDataDescriptor()` to destroy it and release the allocated memory.

**Parameters**

- `seqDataDesc`
  
  *Output*. Pointer where the address to the newly created sequence data descriptor should be written.
Returns

**CUDNN_STATUS_SUCCESS**
The descriptor object was created successfully.

**CUDNN_STATUS_BAD_PARAM**
An invalid input argument was encountered (seqDataDesc=NULL).

**CUDNN_STATUS_ALLOC_FAILED**
The memory allocation failed.

### 7.2.8. cudnnDestroyAttnDescriptor()

This function destroys the attention descriptor object and releases its memory. The `attnDesc` argument can be NULL. Invoking `cudnnDestroyAttnDescriptor()` with a NULL argument is a no operation (NOP).

```c
    cudnnStatus_t cudnnDestroyAttnDescriptor(cudnnAttnDescriptor_t attnDesc);
```

The `cudnnDestroyAttnDescriptor()` function is not able to detect if the `attnDesc` argument holds a valid address. Undefined behavior will occur in case of passing an invalid pointer, not returned by the `cudnnCreateAttnDescriptor()` function, or in the double deletion scenario of a valid address.

**Parameters**

- **attnDesc**
  
  *Input.* Pointer to the attention descriptor object to be destroyed.

**Returns**

**CUDNN_STATUS_SUCCESS**
The descriptor was destroyed successfully.

### 7.2.9. cudnnDestroyPersistentRNNPlan()

This function has been deprecated in cuDNN 8.0.

This function destroys a previously created persistent RNN plan object. Invoking `cudnnDestroyPersistentRNNPlan()` with the NULL argument is a no operation (NOP).

```c
    cudnnStatus_t cudnnDestroyPersistentRNNPlan(
        cudnnPersistentRNNPlan_t plan);
```

The `cudnnDestroyPersistentRNNPlan()` function is not able to detect if the `plan` argument holds a valid address. Undefined behavior will occur in case of passing an invalid pointer, not returned by the `cudnnCreatePersistentRNNPlan()` function, or in the double deletion scenario of a valid address.

**Parameters**

- **plan**
  
  *Input.* Pointer to the RNN persistent plan object to be destroyed.
Returns

**CUDNN_STATUS_SUCCESS**

The object was destroyed successfully.

### 7.2.10. cudnnDestroyRNNDataDescriptor()

This function destroys a previously created RNN data descriptor object. Invoking `cudnnDestroyRNNDataDescriptor()` with the NULL argument is a no operation (NOP).

```c

cudnnStatus_t cudnnDestroyRNNDataDescriptor(
    cudnnRNNDataDescriptor_t RNNDataDesc)
```

The `cudnnDestroyRNNDataDescriptor()` function is not able to detect if the `RNNDataDesc` argument holds a valid address. Undefined behavior will occur in cases of passing an invalid pointer, not returned by the `cudnnCreateRNNDataDescriptor()` function, or in the double deletion scenario of a valid address.

**Parameters**

- **RNNDataDesc**
  
  *Input.* Pointer to the RNN data descriptor object to be destroyed.

Returns

**CUDNN_STATUS_SUCCESS**

The RNN data descriptor object was destroyed successfully.

### 7.2.11. cudnnDestroyRNNDescriptor()

This function destroys a previously created RNN descriptor object. Invoking `cudnnDestroyRNNDescriptor()` with the NULL argument is a no operation (NOP).

```c

cudnnStatus_t cudnnDestroyRNNDescriptor(
    cudnnRNNDescriptor_t rnnDesc)
```

The `cudnnDestroyRNNDescriptor()` function is not able to detect if the `rnnDesc` argument holds a valid address. Undefined behavior will occur in cases of passing an invalid pointer, not returned by the `cudnnCreateRNNDescriptor()` function, or in the double deletion scenario of a valid address.

**Parameters**

- **rnnDesc**
  
  *Input.* Pointer to the RNN descriptor object to be destroyed.

Returns

**CUDNN_STATUS_SUCCESS**

The object was destroyed successfully.
7.2.12. **cudnnDestroySeqDataDescriptor()**

This function destroys the sequence data descriptor object and releases its memory. The `seqDataDesc` argument can be NULL. Invoking `cudnnDestroySeqDataDescriptor()` with a NULL argument is a no operation (NOP).

```c
int cudnnDestroySeqDataDescriptor(cudnnSeqDataDescriptor_t seqDataDesc);
```

The `cudnnDestroySeqDataDescriptor()` function is not able to detect if the `seqDataDesc` argument holds a valid address. Undefined behavior will occur in case of passing an invalid pointer, not returned by the `cudnnCreateSeqDataDescriptor()` function, or in the double deletion scenario of a valid address.

**Parameters**

`seqDataDesc`

*Input.* Pointer to the sequence data descriptor object to be destroyed.

**Returns**

`CUDNN_STATUS_SUCCESS`

The descriptor was destroyed successfully.

7.2.13. **cudnnFindRNNForwardInferenceAlgorithmEx()**

This function has been deprecated in cuDNN 8.0.

This function attempts all available cuDNN algorithms for `cudnnRNNForwardInference()`, using user-allocated GPU memory. It outputs the parameters that influence the performance of the algorithm to a user-allocated array of `cudnnAlgorithmPerformance_t`. These parameter metrics are written in sorted fashion where the first element has the lowest compute time.

```c
int cudnnFindRNNForwardInferenceAlgorithmEx(  
    cudnnHandle_t handle,  
    const cudnnRNNDescriptor_t rnnDesc,  
    const int seqLength,  
    const cudnnTensorDescriptor_t *xDesc,  
    const void *x,  
    const cudnnTensorDescriptor_t *hxDesc,  
    const void *hx,  
    const cudnnTensorDescriptor_t *cxDesc,  
    const void *cx,  
    const cudnnFilterDescriptor_t *wDesc,  
    const void *w,  
    const cudnnTensorDescriptor_t *yDesc,  
    void *y,  
    const cudnnTensorDescriptor_t *hyDesc,  
    const void *hy,  
    const cudnnTensorDescriptor_t *cyDesc,  
    const void *cy,  
    const float findIntensity,  
    const int requestedAlgoCount,  
    int *returnedAlgoCount,  
    cudnnAlgorithmPerformance_t *perfResults,  
    void *workspace,  
    size_t workSpaceSizeInBytes)
```
Parameters

**handle**

*Input*. Handle to a previously created cuDNN context.

**rnnDesc**

*Input*. A previously initialized RNN descriptor.

**seqLength**

*Input*. Number of iterations to unroll over. The value of this `seqLength` must not exceed the value that was used in the `cudnnGetRNNWorkspaceSize()` function for querying the workspace size required to execute the RNN.

**xDesc**

*Input*. An array of fully packed tensor descriptors describing the input to each recurrent iteration (one descriptor per iteration). The first dimension (batch size) of the tensors may decrease from element \(n\) to element \(n+1\) but may not increase. Each tensor descriptor must have the same second dimension (vector length).

**x**

*Input*. Data pointer to GPU memory associated with the tensor descriptors in the array `xDesc`. The data are expected to be packed contiguously with the first element of iteration \(n+1\) following directly from the last element of iteration \(n\).

**hxDesc**

*Input*. A fully packed tensor descriptor describing the initial hidden state of the RNN. The first dimension of the tensor depends on the `direction` argument used to initialize `rnnDesc`:

- If `direction` is `CUDNN_UNIDIRECTIONAL` the first dimension should match the `numLayers` argument.
- If `direction` is `CUDNN_BIDIRECTIONAL` the first dimension should match double the `numLayers` argument.

The second dimension must match the first dimension of the tensors described in `xDesc`. The third dimension must match the `hiddenSize` argument used to initialize `rnnDesc`. The tensor must be fully packed.

**hx**

*Input*. Data pointer to GPU memory associated with the tensor descriptor `hxDesc`. If a `NULL` pointer is passed, the initial hidden state of the network will be initialized to zero.

**cxDesc**

*Input*. A fully packed tensor descriptor describing the initial cell state for LSTM networks. The first dimension of the tensor depends on the `direction` argument used to initialize `rnnDesc`:

- If `direction` is `CUDNN_UNIDIRECTIONAL` the first dimension should match the `numLayers` argument.
If `direction` is `CUDNN_BIDIRECTIONAL` the first dimension should match double the `numLayers` argument.

The second dimension must match the first dimension of the tensors described in `xDesc`. The third dimension must match the `hiddenSize` argument used to initialize `rnnDesc`. The tensor must be fully packed.

**cx**

*Input.* Data pointer to GPU memory associated with the tensor descriptor `cxDesc`. If a NULL pointer is passed, the initial cell state of the network will be initialized to zero.

**wDesc**

*Input.* Handle to a previously initialized filter descriptor describing the weights for the RNN.

**w**

*Input.* Data pointer to GPU memory associated with the filter descriptor `wDesc`.

**yDesc**

*Input.* An array of fully packed tensor descriptors describing the output from each recurrent iteration (one descriptor per iteration). The second dimension of the tensor depends on the `direction` argument used to initialize `rnnDesc`:

- If `direction` is `CUDNN_UNIDIRECTIONAL` the second dimension should match the `hiddenSize` argument.
- If `direction` is `CUDNN_BIDIRECTIONAL` the second dimension should match double the `hiddenSize` argument.

The first dimension of the tensor `n` must match the first dimension of the tensor `n` in `xDesc`.

**y**

*Output.* Data pointer to GPU memory associated with the output tensor descriptor `yDesc`. The data are expected to be packed contiguously with the first element of iteration `n+1` following directly from the last element of iteration `n`.

**hyDesc**

*Input.* A fully packed tensor descriptor describing the final hidden state of the RNN. The first dimension of the tensor depends on the `direction` argument used to initialize `rnnDesc`:

- If `direction` is `CUDNN_UNIDIRECTIONAL` the first dimension should match the `numLayers` argument.
- If `direction` is `CUDNN_BIDIRECTIONAL` the first dimension should match double the `numLayers` argument.

The second dimension must match the first dimension of the tensors described in `xDesc`. The third dimension must match the `hiddenSize` argument used to initialize `rnnDesc`. The tensor must be fully packed.
**hy**

*Output.* Data pointer to GPU memory associated with the tensor descriptor `hyDesc`. If a `NULL` pointer is passed, the final hidden state of the network will not be saved.

**cyDesc**

*Input.* A fully packed tensor descriptor describing the final cell state for LSTM networks. The first dimension of the tensor depends on the `direction` argument used to initialize `rnnDesc`:

- If `direction` is `CUDNN_UNIDIRECTIONAL` the first dimension should match the `numLayers` argument.
- If `direction` is `CUDNN_BIDIRECTIONAL` the first dimension should match double the `numLayers` argument.

The second dimension must match the first dimension of the tensors described in `xDesc`. The third dimension must match the `hiddenSize` argument used to initialize `rnnDesc`. The tensor must be fully packed.

**cy**

*Output.* Data pointer to GPU memory associated with the tensor descriptor `cyDesc`. If a `NULL` pointer is passed, the final cell state of the network will not be saved.

**findIntensity**

*Input.* This input was previously unused in versions prior to 7.2.0. It is used in cuDNN 7.2.0 and later versions to control the overall runtime of the RNN find algorithms, by selecting the percentage of a large Cartesian product space to be searched.

- Setting `findIntensity` within the range `(0,1.]` will set a percentage of the entire RNN search space to search. When `findIntensity` is set to 1.0, a full search is performed over all RNN parameters.
- When `findIntensity` is set to 0.0, a quick, minimal search is performed. This setting has the best runtime. However, in this case the parameters returned by this function will not correspond to the best performance of the algorithm; a longer search might discover better parameters. This option will execute up to three instances of the configured RNN problem. Runtime will vary proportionally to RNN problem size, as it will in the other cases, hence no guarantee of an explicit time bound can be given.
- Setting `findIntensity` within the range `[-1.0)` sets a percentage of a reduced Cartesian product space to be searched. This reduced search space has been heuristically selected to have good performance. The setting of -1.0 represents a full search over this reduced search space.
- Values outside the range `[-1,1]` are truncated to the range `[-1,1]`, and then interpreted as per the above.
- Setting `findIntensity` to 1.0 in cuDNN 7.2 and later versions is equivalent to the behavior of this function in versions prior to cuDNN 7.2.0.
This function times the single RNN executions over large parameter spaces - one execution per parameter combination. The times returned by this function are latencies.

**requestedAlgoCount**
*Input.* The maximum number of elements to be stored in `perfResults`.

**returnedAlgoCount**
*Output.* The number of output elements stored in `perfResults`.

**perfResults**
*Output.* A user-allocated array to store performance metrics sorted ascending by compute time.

**workspace**
*Input.* Data pointer to GPU memory to be used as a workspace for this call.

**workSpaceSizeInBytes**
*Input.* Specifies the size in bytes of the provided `workspace`.

**Returns**

**CUDNN_STATUS_SUCCESS**
The function launched successfully.

**CUDNN_STATUS_NOT_SUPPORTED**
The function does not support the provided configuration.

**CUDNN_STATUS_BAD_PARAM**
At least one of the following conditions are met:

- The descriptor `rnnDesc` is invalid.
- At least one of the descriptors `hxDesc, cxDesc, wDesc, hyDesc` or `cyDesc`, or one of the descriptors in `xDesc` or `yDesc` is invalid.
- The descriptors in one of `xDesc, hxDesc, cxDesc, wDesc`, `yDesc, hyDesc` or `cyDesc` have incorrect strides or dimensions.
- `workSpaceSizeInBytes` is too small.

**CUDNN_STATUS_EXECUTION_FAILED**
The function failed to launch on the GPU.

**CUDNN_STATUS_ALLOC_FAILED**
The function was unable to allocate memory.

### 7.2.14. `cudnnGetAttnDescriptor()`

This function retrieves settings from the previously created attention descriptor. The user can assign `NULL` to any pointer except `attnDesc` when the retrieved value is not needed.

```c
extern cudnnStatus_t cudnnGetAttnDescriptor(  
    cudnnAttnDescriptor_t attnDesc,  
    unsigned *attnMode,  
    int *nHeads,  
    double *smScaler,  
    cudnnDataType_t *dataType,  
    cudnnDataType_t *computePrec,
```

NVIDIA cuDNN
cudnnMathType_t *mathType,
cudnnDropoutDescriptor_t *attnDropoutDesc,
cudnnDropoutDescriptor_t *postDropoutDesc,
int *qSize,
int *kSize,
int *vSize,
int *qProjSize,
int *kProjSize,
int *vProjSize,
int *oProjSize,
int *qoMaxSeqLength,
int *kvMaxSeqLength,
int *maxBatchSize,
int *maxBeamSize);

Parameters

attnDesc
  Input. Attention descriptor.

attnMode
  Output. Pointer to the storage for binary attention flags.

nHeads
  Output. Pointer to the storage for the number of attention heads.

smScaler
  Output. Pointer to the storage for the softmax smoothing/sharpening coefficient.

dataType
  Output. Data type for attention weights, sequence data inputs, and outputs.

computePrec
  Output. Pointer to the storage for the compute precision.

mathType
  Output. NVIDIA Tensor Core settings.

attnDropoutDesc
  Output. Descriptor of the dropout operation applied to the softmax output.

postDropoutDesc
  Output. Descriptor of the dropout operation applied to the multi-head attention output.

qSize, kSize, vSize
  Output. Q, K, and V embedding vector lengths.

qProjSize, kProjSize, vProjSize
  Output. Q, K, and V embedding vector lengths after input projections.

oProjSize
  Output. Pointer to store the output vector length after projection.

qoMaxSeqLength
  Output. Largest sequence length expected in sequence data descriptors related to Q, O, dQ, dO inputs and outputs.

kvMaxSeqLength
  Output. Largest sequence length expected in sequence data descriptors related to K, V, dK, dV inputs and outputs.
maxBatchSize

*Output.* Largest batch size expected in the `cudnnSeqDataDescriptor_t` container.

maxBeamSize

*Output.* Largest beam size expected in the `cudnnSeqDataDescriptor_t` container.

**Returns**

**CUDNN_STATUS_SUCCESS**

Requested attention descriptor fields were retrieved successfully.

**CUDNN_STATUS_BAD_PARAM**

An invalid input argument was found.

### 7.2.15. cudnnGetMultiHeadAttnBuffers()

This function computes weight, work, and reserve space buffer sizes used by the following functions:

- `cudnnMultiHeadAttnForward()`
- `cudnnMultiHeadAttnBackwardData()`
- `cudnnMultiHeadAttnBackwardWeights()`

```c
    cudnnStatus_t cudnnGetMultiHeadAttnBuffers(
        cudnnHandle_t handle,
        const cudnnAttnDescriptor_t attnDesc,
        size_t *weightSizeInBytes,
        size_t *workSpaceSizeInBytes,
        size_t *reserveSpaceSizeInBytes);
```

Assigning NULL to the `reserveSpaceSizeInBytes` argument indicates that the user does not plan to invoke multi-head attention gradient functions: `cudnnMultiHeadAttnBackwardData()` and `cudnnMultiHeadAttnBackwardWeights()`. This situation occurs in the inference mode.

**Note:** NULL cannot be assigned to `weightSizeInBytes` and `workSpaceSizeInBytes` pointers.

The user must allocate weight, work, and reserve space buffer sizes in the GPU memory using `cudaMalloc()` with the reported buffer sizes. The buffers can be also carved out from a larger chunk of allocated memory but the buffer addresses must be at least 16B aligned.

The work-space buffer is used for temporary storage. Its content can be discarded or modified after all GPU kernels launched by the corresponding API complete. The reserve-space buffer is used to transfer intermediate results from `cudnnMultiHeadAttnForward()` to `cudnnMultiHeadAttnBackwardData()`, and from `cudnnMultiHeadAttnBackwardData()` to `cudnnMultiHeadAttnBackwardWeights()`. The content of the reserve-space buffer cannot be modified until all GPU kernels launched by the above three multi-head attention API functions finish.

All multi-head attention weight and bias tensors are stored in a single weight buffer. For speed optimizations, the cuDNN API may change tensor layouts and their relative
locations in the weight buffer based on the provided attention parameters. Use the
`cudnnGetMultiHeadAttnWeights()` function to obtain the start address and the shape of
each weight or bias tensor.

**Parameters**

**handle**
- *Input.* The current cuDNN context handle.

**attnDesc**
- *Input.* Pointer to a previously initialized attention descriptor.

**weightSizeInBytes**
- *Output.* Minimum buffer size required to store all multi-head attention trainable
  parameters.

**workSpaceSizeInBytes**
- *Output.* Minimum buffer size required to hold all temporary surfaces used by the
  forward and gradient multi-head attention API calls.

**reserveSpaceSizeInBytes**
- *Output.* Minimum buffer size required to store all intermediate data exchanged
  between forward and backward (gradient) multi-head attention functions. Set this
  parameter to `NULL` in the inference mode indicating that gradient API calls will not be
  invoked.

**Returns**

**CUDNN_STATUS_ARCH_MISMATCH**
- The GPU device does not support the input data type.

**CUDNN_STATUS_SUCCESS**
- The requested buffer sizes were computed successfully.

**CUDNN_STATUS_BAD_PARAM**
- An invalid input argument was found.

### 7.2.16. `cudnnGetMultiHeadAttnWeights()`

This function obtains the shape of the weight or bias tensor. It also retrieves the start
address of tensor data located in the weight buffer. Use the `wKind` argument to select a
particular tensor. For more information, refer to `cudnnMultiHeadAttnWeightKind_t` for
the description of the enumerant type.

```c
#include <cudnn.h>

cudnnStatus_t cudnnGetMultiHeadAttnWeights(
    cudnnHandle_t handle,
    const cudnnAttnDescriptor_t attnDesc,
    cudnnMultiHeadAttnWeightKind_t wKind,
    size_t weightSizeInBytes,
    const void *weights,
    cudnnTensorDescriptor_t wDesc,
    void **wAddr);
```

Biases are used in the input and output projections when the
`CUDNN_ATTN_ENABLE_PROJ_BIASES` flag is set in the attention descriptor. Refer to
`cudnnSetAttnDescriptor()` for the description of flags to control projection biases.
When the corresponding weight or bias tensor does not exist, the function writes
NULL to the storage location pointed by wAddr and returns zeros in the wDesc tensor
descriptor. The return status of the cudnnGetMultiHeadAttnWeights() function is
CUDNN_STATUS_SUCCESS in this case.

The cuDNN multiHeadAttention sample code demonstrates how to access multi-
head attention weights. Although the buffer with weights and biases should be
allocated in the GPU memory, the user can copy it to the host memory and invoke the
cudnnGetMultiHeadAttnWeights() function with the host weights address to obtain
tensor pointers in the host memory. This scheme allows the user to inspect trainable
parameters directly in the CPU memory.

Parameters

handle
  Input. The current cuDNN context handle.

attnDesc
  Input. A previously configured attention descriptor.

wKind
  Input. Enumerant type to specify which weight or bias tensor should be retrieved.

weightSizeInBytes
  Input. Buffer size that stores all multi-head attention weights and biases.

weights
  Input. Pointer to the weight buffer in the host or device memory.

wDesc
  Output. The descriptor specifying weight or bias tensor shape. For weights, the
  wDesc.dimA[] array has three elements: [nHeads, projected size, original size].
  For biases, the wDesc.dimA[] array also has three elements: [nHeads, projected
  size, 1]. The wDesc.strideA[] array describes how tensor elements are arranged in
  memory.

wAddr
  Output. Pointer to a location where the start address of the requested tensor should
  be written. When the corresponding projection is disabled, the address written to
  wAddr is NULL.

Returns

CUDNN_STATUS_SUCCESS
  The weight tensor descriptor and the address of data in the device memory were
  successfully retrieved.

CUDNN_STATUS_BAD_PARAM
  An invalid or incompatible input argument was encountered. For example, wKind did
  not have a valid value or weightSizeInBytes was too small.

7.2.17. cudnnGetRNNBackwardWeightsAlgorithmMaxCount()  
This function has been deprecated in cuDNN 8.0.
7.2.18. **cudnnGetRNNBiasMode()**

This function has been deprecated in cuDNN 8.0. Use `cudnnGetRNNDescriptor_v8()` instead of `cudnnGetRNNBiasMode()`.

```
cudnnStatus_t cudnnGetRNNBiasMode(
    cudnnRNNDescriptor_t rnnDesc,
    cudnnRNNBiasMode_t *biasMode)
```

This function retrieves the RNN bias mode that was configured by `cudnnSetRNNBiasMode()`. The default value of `biasMode` in `rnnDesc` after `cudnnCreateRNNDescriptor()` is `CUDNN_RNN_DOUBLE_BIAS`.

**Parameters**

- **rnnDesc**
  - *Input*. A previously created RNN descriptor.

- ***biasMode**
  - *Output*. Pointer to where RNN bias mode should be saved.

**Returns**

- **CUDNN_STATUS_BAD_PARAM**
  - Either the `rnnDesc` or `*biasMode` is NULL.

- **CUDNN_STATUS_SUCCESS**
  - The `biasMode` parameter was retrieved successfully.

7.2.19. **cudnnGetRNNDataDescriptor()**

This function retrieves a previously created RNN data descriptor object.

```
cudnnStatus_t cudnnGetRNNDataDescriptor(
    cudnnRNNDATA_DESCRIPTOR_t RNNDesc,
    cudnnDataType_t *dataType,
    cudnnRNNDataLayout_t *layout,
    int *maxSeqLength,
    int *batchSize,
    int *vectorSize,
    int arrayLengthRequested,
    void *paddingFill);
```

**Parameters**

- **RNNDesc**
  - *Input*. A previously created and initialized RNN descriptor.

- **dataType**
  - *Output*. Pointer to the host memory location to store the datatype of the RNN data tensor.
cudnn_adv_infer.so Library

7.2.20. cudnnGetRNNDescriptor_v6()

This function has been deprecated in cuDNN 8.0. Use cudnnGetRNNDescriptor_v8() instead of cudnnGetRNNDescriptor_v6().

```
cudnnStatus_t cudnnGetRNNDescriptor_v6(
  cudnnHandle_t handle,
  cudnnRNNDescriptor_t rnnDesc,
  int *hiddenSize,
  int *numLayers,
  cudnnDropoutDescriptor_t *dropoutDesc,
  cudnnRNNInputMode_t *inputMode,
  cudnnDirectionMode_t *direction,
  cudnnRNNMode_t *cellMode,
  cudnnRNNAlgo_t *algo,
  cudnnDataType_t *mathPrec) {
```

layout
   Output. Pointer to the host memory location to store the memory layout of the RNN data tensor.

maxSeqLength
   Output. The maximum sequence length within this RNN data tensor, including the padding vectors.

batchSize
   Output. The number of sequences within the mini-batch.

vectorSize
   Output. The vector length (meaning, embedding size) of the input or output tensor at each time-step.

arrayLengthRequested
   Input. The number of elements that the user requested for seqLengthArray.

seqLengthArray
   Output. Pointer to the host memory location to store the integer array describing the length (meaning, number of time-steps) of each sequence. This is allowed to be a NULL pointer if arrayLengthRequested is 0.

paddingFill
   Output. Pointer to the host memory location to store the user defined symbol. The symbol should be interpreted as the same data type as the RNN data tensor.

Returns

CUDNN_STATUS_SUCCESS
   The parameters are fetched successfully.

CUDNN_STATUS_BAD_PARAM
   Any one of these have occurred:
     ▶ Any of RNNDataDesc, dataType, layout, maxSeqLength, batchSize, vectorSize, or paddingFill is NULL.
     ▶ seqLengthArray is NULL while arrayLengthRequested is greater than zero.
     ▶ arrayLengthRequested is less than zero.
This function retrieves RNN network parameters that were configured by cudnnSetRNNDescriptor_v6(). All pointers passed to the function should be not-NULL or CUDNN_STATUS_BAD_PARAM is reported. The function does not check the validity of retrieved parameters.

**Parameters**

**handle**
*Input*. Handle to a previously created cuDNN library descriptor.

**rnnDesc**
*Input*. A previously created and initialized RNN descriptor.

**hiddenSize**
*Output*. Pointer to where the size of the hidden state should be stored (the same value is used in every RNN layer).

**numLayers**
*Output*. Pointer to where the number of RNN layers should be stored.

**dropoutDesc**
*Output*. Pointer to where the handle to a previously configured dropout descriptor should be stored.

**inputMode**
*Output*. Pointer to where the mode of the first RNN layer should be saved.

**direction**
*Output*. Pointer to where RNN unidirectional/bidirectional mode should be saved.

**mode**
*Output*. Pointer to where RNN cell type should be saved.

**algo**
*Output*. Pointer to where RNN algorithm type should be stored.

**mathPrec**
*Output*. Pointer to where the math precision type should be stored.

**Returns**

**CUDNN_STATUS_SUCCESS**
RNN parameters were successfully retrieved from the RNN descriptor.

**CUDNN_STATUS_BAD_PARAM**
At least one pointer passed to the function is NULL.

### 7.2.21. cudnnGetRNNDescriptor_v8()

This function retrieves RNN network parameters that were configured by cudnnSetRNNDescriptor_v8(). The user can assign NULL to any pointer except rnnDesc when the retrieved value is not needed. The function does not check the validity of retrieved parameters.

```c
#include <cudnn.h>

typedef cudnnStatus_t cudnnGetRNNDescriptor_v8(
    cudnnRNNDescriptor_t rnnDesc,
    cudnnRNNAlgo_t *algo,
    cudnnRNNMode_t *cellMode,
    cudnnRNNBiasMode_t *biasMode,
);``
cudnnDirectionMode_t *dirMode,
cudnnRNNInputMode_t *inputMode,
cudnnDataType_t *dataType,
cudnnDataType_t *mathPrec,
cudnnMathType_t *mathType,
int32_t *inputSize,
int32_t *hiddenSize,
int32_t *projSize,
int32_t *numLayers,
    cudnnDropoutDescriptor_t *dropoutDesc,
uint32_t *auxFlags);

Parameters

rnnDesc
Input. A previously created and initialized RNN descriptor.

algo
Output. Pointer to where RNN algorithm type should be stored.

cellMode
Output. Pointer to where RNN cell type should be saved.

biasMode
Output. Pointer to where RNN bias mode cudnnRNNBiasMode_t should be saved.

dirMode
Output. Pointer to where RNN unidirectional/bidirectional mode should be saved.

inputMode
Output. Pointer to where the mode of the first RNN layer should be saved.

dataType
Output. Pointer to where the data type of RNN weights/biases should be stored.

mathPrec
Output. Pointer to where the math precision type should be stored.

mathType
Output. Pointer to where the preferred option for Tensor Cores are saved.

inputSize
Output. Pointer to where the RNN input vector size is stored.

hiddenSize
Output. Pointer to where the size of the hidden state should be stored (the same value is used in every RNN layer).

projSize
Output. Pointer to where the LSTM cell output size after the recurrent projection is stored.

numLayers
Output. Pointer to where the number of RNN layers should be stored.

dropoutDesc
Output. Pointer to where the handle to a previously configured dropout descriptor should be stored.

auxFlags
Output. Pointer to miscellaneous RNN options (flags) that do not require passing additional numerical values to configure.
Returns

**CUDNN_STATUS_SUCCESS**

RNN parameters were successfully retrieved from the RNN descriptor.

**CUDNN_STATUS_BAD_PARAM**

An invalid input argument was found (rnnDesc was NULL).

**CUDNN_STATUS_NOT_INITIALIZED**

The RNN descriptor was configured with the legacy `cudnnSetRNNDescriptor_v6()` call.

### 7.2.22. `cudnnGetRNNForwardInferenceAlgorithmMaxCount()`

This function has been deprecated in cuDNN 8.0.

### 7.2.23. `cudnnGetRNNLinLayerBiasParams()`

This function has been deprecated in cuDNN 8.0. Use `cudnnGetRNNWeightParams()` instead of `cudnnGetRNNLinLayerBiasParams()`.

```c
#include <cudnn.h>

cudnnStatus_t cudnnGetRNNLinLayerBiasParams(
    cudnnHandle_t                   handle,
    const cudnnRNNDescriptor_t      rnnDesc,
    const int                       pseudoLayer,
    const cudnnTensorDescriptor_t   xDesc,
    const cudnnFilterDescriptor_t   wDesc,
    const void                     *w,
    const int                       linLayerID,
    cudnnFilterDescriptor_t         linLayerBiasDesc,
    void                           **linLayerBias)
```

This function is used to obtain a pointer and a descriptor of every RNN bias column vector in each pseudo-layer within the recurrent network defined by `rnnDesc` and its input width specified in `xDesc`.

**Note:** The `cudnnGetRNNLinLayerBiasParams()` function was changed in cuDNN version 7.1.1 to match the behavior of `cudnnGetRNNLinLayerMatrixParams()`.

The `cudnnGetRNNLinLayerBiasParams()` function returns the RNN bias vector size in two dimensions: rows and columns.

Due to historical reasons, the minimum number of dimensions in the filter descriptor is three. In previous versions of the cuDNN library, the function returns the total number of vector elements in `linLayerBiasDesc` as follows:

```
filterDimA[0]=total_size,
filterDimA[1]=1,
```

For more information, see the description of the `cudnnGetFilterNdDescriptor()` function.

In cuDNN 7.1.1, the format was changed to:

```
filterDimA[0]=1,
filterDimA[1]=rows,
```

In both cases, the format field of the filter descriptor should be ignored when retrieved by `cudnnGetFilterNdDescriptor()`.
The RNN implementation in cuDNN uses two bias vectors before the cell non-linear function. Note that the RNN implementation in cuDNN depends on the number of bias vectors before the cell non-linear function. Refer to the equations in the `cudnnRNNMode_t` description, for the enumerant type based on the value of `cudnnRNNBiasMode_t biasMode` in `rnnDesc`. If nonexistent biases are referenced by `linLayerID`, then this function sets `linLayerBiasDesc` to a zeroed filter descriptor where:

```
filterDimA[0]=0,
filterDimA[1]=0, and
```
and sets `linLayerBias` to NULL. Refer to the details for the function parameter `linLayerID` to determine the relevant values of `linLayerID` based on `biasMode`.

**Parameters**

**handle**

*Input.* Handle to a previously created cuDNN library descriptor.

**rnnDesc**

*Input.* A previously initialized RNN descriptor.

**pseudoLayer**

*Input.* The pseudo-layer to query. In unidirectional RNNs, a pseudo-layer is the same as a physical layer (pseudoLayer=0 is the RNN input layer, pseudoLayer=1 is the first hidden layer). In bidirectional RNNs, there are twice as many pseudo-layers in comparison to physical layers.

- pseudoLayer=0 refers to the forward part of the physical input layer
- pseudoLayer=1 refers to the backward part of the physical input layer
- pseudoLayer=2 is the forward part of the first hidden layer, and so on

**xDesc**

*Input.* A fully packed tensor descriptor describing the input to one recurrent iteration (to retrieve the RNN input width).

**wDesc**

*Input.* Handle to a previously initialized filter descriptor describing the weights for the RNN.

**w**

*Input.* Data pointer to GPU memory associated with the filter descriptor `wDesc`.

**linLayerID**

*Input.* Linear ID index of the weight matrix.

If `cellMode` in `rnnDesc` was set to `CUDNN_RNN_RELU` or `CUDNN_RNN_TANH`:

- Value 0 references the weight matrix used in conjunction with the input from the previous layer or input to the RNN model.
- Value 1 references the weight matrix used in conjunction with the hidden state from the previous time step or the initial hidden state.

If `cellMode` in `rnnDesc` was set to `CUDNN_LSTM`: 

---

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Values 0, 1, 2, and 3 reference weight matrices used in conjunction with the input from the previous layer or input to the RNN model.

Values 4, 5, 6, and 7 reference weight matrices used in conjunction with the hidden state from the previous time step or the initial hidden state.

Value 8 corresponds to the projection matrix, if enabled.

Values and their LSTM gates:

- `linLayerID0` and 4 correspond to the input gate.
- `linLayerID1` and 5 correspond to the forget gate.
- `linLayerID2` and 6 correspond to the new cell state calculations with a hyperbolic tangent.
- `linLayerID3` and 7 correspond to the output gate.

If `cellMode` in `rnnDesc` was set to `CUDNN_GRU`:

- Values 0, 1, and 2 reference weight matrices used in conjunction with the input from the previous layer or input to the RNN model.
- Values 3, 4, and 5 reference weight matrices used in conjunction with the hidden state from the previous time step or the initial hidden state.

Values and their GRU gates:

- `linLayerID0` and 3 correspond to the reset gate.
- `linLayerID1` and 4 references to the update gate.
- `linLayerID2` and 5 correspond to the new hidden state calculations with a hyperbolic tangent.

`linLayerBiasDesc`

- **Output**: Handle to a previously created filter descriptor.

`linLayerBias`

- **Output**: Data pointer to GPU memory associated with the filter descriptor `linLayerBiasDesc`.

**Returns**

**CUDNN_STATUS_SUCCESS**

The query was successful.

**CUDNN_STATUS_NOT_SUPPORTED**

The function does not support the provided configuration.

**CUDNN_STATUS_BAD_PARAM**

At least one of the following conditions are met:

- One of the following arguments is NULL: `handle`, `rnnDesc`, `xDesc`, `wDesc`, `linLayerBiasDesc`, or `linLayerBias`.
- A data type mismatch was detected between `rnnDesc` and other descriptors.
- Minimum requirement for the $w$ pointer alignment is not satisfied.
- The value of `pseudoLayer` or `linLayerID` is out of range.

**CUDNN_STATUS_INVALID_VALUE**

Some elements of the `linLayerBias` vector are outside the $w$ buffer boundaries as specified by the $w$Desc descriptor.

### 7.2.24. `cudnnGetRNNLinLayerMatrixParams()`

This function has been deprecated in cuDNN 8.0. Use `cudnnGetRNNWeightParams()` instead of `cudnnGetRNNLinLayerMatrixParams()`.

```c
#include <cudnn.h>

int cudnnGetRNNLinLayerMatrixParams(
    cudnnHandle_t                   handle,
    const cudnnRNNDescriptor_t      rnnDesc,
    const int                       pseudoLayer,
    const cudnnTensorDescriptor_t   xDesc,
    const cudnnFilterDescriptor_t   wDesc,
    const void                      *w,
    const int                       linLayerID,
    cudnnFilterDescriptor_t         linLayerMatDesc,
    void                            **linLayerMat)
```

This function is used to obtain a pointer and a descriptor of every RNN weight matrix in each pseudo-layer within the recurrent network defined by `rnnDesc` and its input width specified in `xDesc`.

**Note:** The `cudnnGetRNNLinLayerMatrixParams()` function was enhanced in cuDNN version 7.1.1 without changing its prototype. Instead of reporting the total number of elements in each weight matrix in the `linLayerMatDesc` filter descriptor, the function returns the matrix size as two dimensions: rows and columns. Moreover, when a weight matrix does not exist, for example, due to `CUDNN_SKIP_INPUT` mode, the function returns `NULL` in `linLayerMat` and all fields of `linLayerMatDesc` are zero.

The `cudnnGetRNNLinLayerMatrixParams()` function returns the RNN matrix size in two dimensions: rows and columns. This allows the user to easily print and initialize RNN weight matrices. Elements in each weight matrix are arranged in the row-major order. Due to historical reasons, the minimum number of dimensions in the filter descriptor is three. In previous versions of the cuDNN library, the function returned the total number of weights in `linLayerMatDesc` as follows: `filterDimA[0]=total_size`, `filterDimA[1]=1`, `filterDimA[2]=1` (see the description of the `cudnnGetFilterNdDescriptor()` function). In cuDNN 7.1.1, the format was changed to: `filterDimA[0]=1`, `filterDimA[1]=rows`, `filterDimA[2]=columns`. In both cases, the "format" field of the filter descriptor should be ignored when retrieved by `cudnnGetFilterNdDescriptor()`.

**Parameters**

- **handle**
  - `Input`. Handle to a previously created cuDNN library descriptor.
- **rnnDesc**
  - `Input`. A previously initialized RNN descriptor.
**pseudoLayer**

*Input.* The pseudo-layer to query. In unidirectional RNNs, a pseudo-layer is the same as a physical layer (*pseudoLayer*=0 is the RNN input layer, *pseudoLayer*=1 is the first hidden layer). In bidirectional RNNs, there are twice as many pseudo-layers in comparison to physical layers.

- *pseudoLayer*=0 refers to the forward part of the physical input layer
- *pseudoLayer*=1 refers to the backward part of the physical input layer
- *pseudoLayer*=2 is the forward part of the first hidden layer, and so on

**xDesc**

*Input.* A fully packed tensor descriptor describing the input to one recurrent iteration (to retrieve the RNN input width).

**wDesc**

*Input.* Handle to a previously initialized filter descriptor describing the weights for the RNN.

**w**

*Input.* Data pointer to GPU memory associated with the filter descriptor *wDesc.*

**linLayerID**

*Input.* The linear layer to obtain information about:

- If *mode* in *rnnDesc* was set to **CUDNN_RNN_RELU** or **CUDNN_RNN_TANH**:
  - Value 0 references the bias applied to the input from the previous layer (relevant if *biasMode* in *rnnDesc* is **CUDNN_RNN_SINGLE_INF_BIAS** or **CUDNN_RNN_DOUBLE_BIAS**).
  - Value 1 references the bias applied to the recurrent input (relevant if *biasMode* in *rnnDesc* is **CUDNN_RNN_DOUBLE_BIAS** or **CUDNN_RNN_SINGLE_REC_BIAS**).

- If *mode* in *rnnDesc* was set to **CUDNN_LSTM**:
  - Values of 0, 1, 2 and 3 reference bias applied to the input from the previous layer (relevant if *biasMode* in *rnnDesc* is **CUDNN_RNN_SINGLE_INF_BIAS** or **CUDNN_RNN_DOUBLE_BIAS**).
  - Values of 4, 5, 6 and 7 reference bias applied to the recurrent input (relevant if *biasMode* in *rnnDesc* is **CUDNN_RNN_DOUBLE_BIAS** or **CUDNN_RNN_SINGLE_REC_BIAS**).
  - Values and their associated gates:
    - Values 0 and 4 reference the input gate.
    - Values 1 and 5 reference the forget gate.
    - Values 2 and 6 reference the new memory gate.
    - Values 3 and 7 reference the output gate.

- If *mode* in *rnnDesc* was set to **CUDNN_GRU**:
Values of 0, 1 and 2 reference bias applied to the input from the previous layer (relevant if \texttt{biasMode} in \texttt{rnnDesc} is \texttt{CUDNN_RNN_SINGLE_inp_BIAS} or \texttt{CUDNN_RNN_DOUBLE_BIAS}).

Values of 3, 4 and 5 reference bias applied to the recurrent input (relevant if \texttt{biasMode} in \texttt{rnnDesc} is \texttt{CUDNN_RNN_DOUBLE_BIAS} or \texttt{CUDNN_RNN_SINGLE_rec_BIAS}).

Values and their associated gates:

- Values 0 and 3 reference the reset gate.
- Values 1 and 4 reference the update gate.
- Values 2 and 5 reference the new memory gate.

For more information on modes and bias modes, refer to \texttt{cudnnRNNMode_t}.

\textbf{linLayerMatDesc}

\textit{Output}. Handle to a previously created filter descriptor. When the weight matrix does not exist, the returned filter descriptor has all fields set to zero.

\textbf{linLayerMat}

\textit{Output}. Data pointer to GPU memory associated with the filter descriptor \texttt{linLayerMatDesc}. When the weight matrix does not exist, the returned pointer is \texttt{NULL}.

\textbf{Returns}

\textbf{CUDNN_STATUS_SUCCESS}

The query was successful.

\textbf{CUDNN_STATUS_NOT_SUPPORTED}

The function does not support the provided configuration.

\textbf{CUDNN_STATUS_BAD_PARAM}

At least one of the following conditions are met:

- One of the following arguments is \texttt{NULL}: \texttt{handle}, \texttt{rnnDesc}, \texttt{xDesc}, \texttt{wDesc}, \texttt{linLayerMatDesc}, or \texttt{linLayerMat}.
- A data type mismatch was detected between \texttt{rnnDesc} and other descriptors.
- Minimum requirement for the \texttt{w} pointer alignment is not satisfied.
- The value of \texttt{pseudoLayer} or \texttt{linLayerID} is out of range.

\textbf{CUDNN_STATUS.INVALID.VALUE}

Some elements of the \texttt{linLayerMat} vector are outside the \texttt{w} buffer boundaries as specified by the \texttt{wDesc} descriptor.

---

\textbf{7.2.25. cudnnGetRNNMatrixMathType()}

This function has been deprecated in cuDNN 8.0. Use \texttt{cudnnGetRNNDescriptor_v8()} instead of \texttt{cudnnGetRNNMatrixMathType()}.
This function retrieves the preferred settings for NVIDIA Tensor Cores on NVIDIA Volta™ (SM 7.0) or higher GPUs. Refer to the cudnnMathType_t description for more details.

Parameters

rnnDesc
   Input. A previously created and initialized RNN descriptor.

mType
   Output. Address where the preferred Tensor Core settings should be stored.

Returns

CUDNN_STATUS_SUCCESS
   The requested RNN descriptor field was retrieved successfully.

CUDNN_STATUS_BAD_PARAM
   An invalid input argument was found (rnnDesc or mType was NULL).

7.2.26. cudnnGetRNNPaddingMode()

This function has been deprecated in cuDNN 8.0. Use cudnnGetRNNDescriptor_v8() instead of cudnnGetRNNPaddingMode().

cudnnStatus_t cudnnGetRNNPaddingMode(
   cudnnRNNDescriptor_t        rnnDesc,
   cudnnRNNPaddingMode_t       *paddingMode)

This function retrieves the RNN padding mode from the RNN descriptor.

Parameters

rnnDesc
   Input/Output. A previously created RNN descriptor.

*paddingMode
   Input. Pointer to the host memory where the RNN padding mode is saved.

Returns

CUDNN_STATUS_SUCCESS
   The RNN padding mode parameter was retrieved successfully.

CUDNN_STATUS_BAD_PARAM
   Either the rnnDesc or *paddingMode is NULL.

7.2.27. cudnnGetRNNParamsSize()

This function has been deprecated in cuDNN 8.0. Use cudnnGetRNNWeightSpaceSize() instead of cudnnGetRNNParamsSize().

cudnnStatus_t cudnnGetRNNParamsSize(
   cudnnHandle_t                handle,
   const cudnnRNNDescriptor_t   rnnDesc,
   const cudnnTensorDescriptor_t xDesc,
   size_t                        *sizeInBytes,
   cudnnDataType_t               dataType)
This function is used to query the amount of parameter space required to execute the RNN described by `rnnDesc` with input dimensions defined by `xDesc`.

Parameters

**handle**
*Input*. Handle to a previously created cuDNN library descriptor.

**rnnDesc**
*Input*. A previously initialized RNN descriptor.

**xDesc**
*Input*. A fully packed tensor descriptor describing the input to one recurrent iteration.

**sizeInBytes**
*Output*. Minimum amount of GPU memory needed as parameter space to be able to execute an RNN with the specified descriptor and input tensors.

**dataType**
*Input*. The data type of the parameters.

Returns

**CUDNN_STATUS_SUCCESS**
The query was successful.

**CUDNN_STATUS_BAD_PARAM**
At least one of the following conditions are met:

- The descriptor `rnnDesc` is invalid.
- The descriptor `xDesc` is invalid.
- The descriptor `xDesc` is not fully packed.
- The combination of `dataType` and tensor descriptor data type is invalid.

**CUDNN_STATUS_NOT_SUPPORTED**
The combination of the RNN descriptor and tensor descriptors is not supported.

### 7.2.28. cudnnGetRNNProjectionLayers()

This function has been deprecated in cuDNN 8.0. Use `cudnnGetRNNDescriptor_v8()` instead of `cudnnGetRNNProjectionLayers()`.

cudnnStatus_t cudnnGetRNNProjectionLayers(
    cudnnHandle_t           handle,
    cudnnRNNDescriptor_t    rnnDesc,
    int                     *recProjSize,
    int                     *outProjSize
)

This function retrieves the current RNN projection parameters. By default, the projection feature is disabled so invoking this function will yield `recProjSize` equal to `hiddenSize` and `outProjSize` set to zero. The `cudnnSetRNNProjectionLayers()` method enables the RNN projection.
Parameters

**handle**
*Input.* Handle to a previously created cuDNN library descriptor.

**rnnDesc**
*Input.* A previously created and initialized RNN descriptor.

**recProjSize**
*Output.* Pointer where the recurrent projection size should be stored.

**outProjSize**
*Output.* Pointer where the output projection size should be stored.

Returns

**CUDNN_STATUS_SUCCESS**
RNN projection parameters were retrieved successfully.

**CUDNN_STATUS_BAD_PARAM**
A NULL pointer was passed to the function.

### 7.2.29. **cudnnGetRNNTempSpaceSizes()**

This function computes the work and reserve space buffer sizes based on the RNN network geometry stored in `rnnDesc`, designated usage (inference or training) defined by the `fMode` argument, and the current RNN data dimensions (`maxSeqLength`, `batchSize`) retrieved from `xDesc`. When RNN data dimensions change, the `cudnnGetRNNTempSpaceSizes()` must be called again because RNN temporary buffer sizes are not monotonic.

```c
inline cudnnStatus_t cudnnGetRNNTempSpaceSizes(
    cudnnHandle_t handle,  
cudnnRNNDescriptor_t rnnDesc,  
cudnnForwardMode_t fMode,  
cudnnRNNDataDescriptor_t xDesc,  
    size_t *workSpaceSize,  
    size_t *reserveSpaceSize);
```

The user can assign `NULL` to `workSpaceSize` or `reserveSpaceSize` pointers when the corresponding value is not needed.

Parameters

**handle**
*Input.* The current cuDNN context handle.

**rnnDesc**
*Input.* A previously initialized RNN descriptor.

**fMode**
*Input.* Specifies whether temporary buffers are used in inference or training modes. The reserve-space buffer is not used during inference. Therefore, the returned size of the reserve space buffer will be zero when the `fMode` argument is `CUDNN_FWD_MODE_INFERENCE`. 

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xDesc
Input. A single RNN data descriptor that specifies current RNN data dimensions:
maxSeqLength and batchSize.

workSpaceSize
Output. Minimum amount of GPU memory in bytes needed as a workspace buffer.
The workspace buffer is not used to pass intermediate results between APIs but as a
temporary read/write buffer.

reserveSpaceSize
Output. Minimum amount of GPU memory in bytes needed as the reserve-
space buffer. The reserve space buffer is used to pass intermediate results from
cudnnRNNForward() to RNN BackwardData and BackwardWeights routines that
compute first order derivatives with respect to RNN inputs or trainable weight and
biases.

Returns

CUDNN_STATUS_SUCCESS
RNN temporary buffer sizes were computed successfully.

CUDNN_STATUS_BAD_PARAM
An invalid input argument was detected.

CUDNN_STATUS_NOT_SUPPORTED
An incompatible or unsupported combination of input arguments was detected.

7.2.30. cudnnGetRNNTrainingReserveSize()
This function has been deprecated in cuDNN 8.0. Use cudnnGetRNNTempSpaceSizes() instead of cudnnGetRNNTrainingReserveSize().
cudnnStatus_t cudnnGetRNNTrainingReserveSize(
cudnnHandle_t                   handle,
const cudnnRNNDescriptor_t      rnnDesc,
const int                       seqLength,
const cudnnTensorDescriptor_t   *xDesc,
size_t                         *sizeInBytes)

This function is used to query the amount of reserved space required for training the
RNN described by rnnDesc with input dimensions defined by xDesc. The same reserved
space buffer must be passed to cudnnRNNForwardTraining(), cudnnRNNBackwardData(),
and cudnnRNNBackwardWeights(). Each of these calls overwrites the contents of the
reserved space, however it can safely be backed up and restored between calls if reuse of
the memory is desired.

Parameters

handle
Input. Handle to a previously created cuDNN library descriptor.

rnnDesc
Input. A previously initialized RNN descriptor.
seqLength

*Input*. Number of iterations to unroll over. The value of this `seqLength` must not exceed the value that was used in the `cudnnGetRNNWorkspaceSize()` function for querying the workspace size required to execute the RNN.

xDesc

*Input*. An array of tensor descriptors describing the input to each recurrent iteration (one descriptor per iteration). The first dimension (batch size) of the tensors may decrease from element $n$ to element $n+1$ but may not increase. Each tensor descriptor must have the same second dimension (vector length).

sizeInBytes

*Output*. Minimum amount of GPU memory needed as reserve space to be able to train an RNN with the specified descriptor and input tensors.

Returns

**CUDNN_STATUS_SUCCESS**

The query was successful.

**CUDNN_STATUS_BAD_PARAM**

At least one of the following conditions are met:

- The descriptor `rnnDesc` is invalid.
- At least one of the descriptors in `xDesc` is invalid.
- The descriptors in `xDesc` have inconsistent second dimensions, strides or data types.
- The descriptors in `xDesc` have increasing first dimensions.
- The descriptors in `xDesc` are not fully packed.

**CUDNN_STATUS_NOT_SUPPORTED**

The data types in tensors described by `xDesc` are not supported.

### 7.2.31. `cudnnGetRNNWeightParams()`

This function is used to obtain the start address and shape of every RNN weight matrix and bias vector in each pseudo-layer within the recurrent network.

```c
extern "C" {
    cudnnStatus_t cudnnGetRNNWeightParams(
        cudnnHandle_t handle,
        cudnnRNNDescriptor_t rnnDesc,
        int32_t pseudoLayer,
        size_t weightSpaceSize,
        const void *weightSpace,
        int32_t linLayerID,
        cudnnTensorDescriptor_t mDesc,
        void **mAddr,
        cudnnTensorDescriptor_t bDesc,
        void **bAddr);
}
```
### Parameters

**handle**

*Input.* Handle to a previously created cuDNN library descriptor.

**rnnDesc**

*Input.* A previously initialized RNN descriptor.

**pseudoLayer**

*Input.* The pseudo-layer to query. In unidirectional RNNs, a pseudo-layer is the same as a physical layer (*pseudoLayer=0* is the RNN input layer, *pseudoLayer=1* is the first hidden layer). In bidirectional RNNs, there are twice as many pseudo-layers in comparison to physical layers:

- *pseudoLayer=0* refers to the forward direction sub-layer of the physical input layer
- *pseudoLayer=1* refers to the backward direction sub-layer of the physical input layer
- *pseudoLayer=2* is the forward direction sub-layer of the first hidden layer, and so on

**weightSpaceSize**

*Input.* Size of the weight space buffer in bytes.

**weightSpace**

*Input.* Pointer to the weight space buffer.

**linLayerID**

*Input.* Weight matrix or bias vector linear ID index.

If `cellMode` in `rnnDesc` was set to `CUDNN_RNN_RELU` or `CUDNN_RNN_TANH`:

- Value 0 references the weight matrix or bias vector used in conjunction with the input from the previous layer or input to the RNN model.
- Value 1 references the weight matrix or bias vector used in conjunction with the hidden state from the previous time step or the initial hidden state.

If `cellMode` in `rnnDesc` was set to `CUDNN_LSTM`:

- Values 0, 1, 2 and 3 reference weight matrices or bias vectors used in conjunction with the input from the previous layer or input to the RNN model.
- Values 4, 5, 6 and 7 reference weight matrices or bias vectors used in conjunction with the hidden state from the previous time step or the initial hidden state.
- Value 8 corresponds to the projection matrix, if enabled (there is no bias in this operation).

Values and their LSTM gates:

- `linLayerID0` and 4 correspond to the input gate.
- `linLayerID1` and 5 correspond to the forget gate.
linLayerID2 and 6 correspond to the new cell state calculations with hyperbolic tangent.

linLayerID3 and 7 correspond to the output gate.

If cellMode in rnnDesc was set to CUDNN_GRU:

- Values 0, 1 and 2 reference weight matrices or bias vectors used in conjunction with the input from the previous layer or input to the RNN model.
- Values 3, 4 and 5 reference weight matrices or bias vectors used in conjunction with the hidden state from the previous time step or the initial hidden state.

Values and their GRU gates:

- linLayerID0 and 3 correspond to the reset gate.
- linLayerID1 and 4 reference to the update gate.
- linLayerID2 and 5 correspond to the new hidden state calculations with hyperbolic tangent.

For more information on modes and bias modes, refer to cudnnRNNMode_t.

mDesc
Output. Handle to a previously created tensor descriptor. The shape of the corresponding weight matrix is returned in this descriptor in the following format: dimA[3] = {1, rows, cols}. The reported number of tensor dimensions is zero when the weight matrix does not exist. This situation occurs for input GEMM matrices of the first layer when CUDNN_SKIP_INPUT is selected or for the LSTM projection matrix when the feature is disabled.

mAddr
Output. Pointer to the beginning of the weight matrix within the weight space buffer. When the weight matrix does not exist, the returned address is NULL.

bDesc
Output. Handle to a previously created tensor descriptor. The shape of the corresponding bias vector is returned in this descriptor in the following format: dimA[3] = {1, rows, 1}. The reported number of tensor dimensions is zero when the bias vector does not exist.

bAddr
Output. Pointer to the beginning of the bias vector within the weight space buffer. When the bias vector does not exist, the returned address is NULL.

Returns

CUDNN_STATUS_SUCCESS
The query was completed successfully.

CUDNN_STATUS_BAD_PARAM
An invalid input argument was encountered. For example, the value of pseudoLayer is out of range or linLayerID is negative or larger than 8.
CUDNN_STATUS_INVALID_VALUE
Some weight/bias elements are outside the weight space buffer boundaries.

CUDNN_STATUS_NOT_INITIALIZED
The RNN descriptor was configured with the legacy cudnnSetRNNDescriptor_v6() call.

7.2.32. cudnnGetRNNWeightSpaceSize()

This function reports the required size of the weight space buffer in bytes. The weight space buffer holds all RNN weight matrices and bias vectors.

```c
#include <cudnn.h>

cudnnStatus_t cudnnGetRNNWeightSpaceSize(
  cudnnHandle_t handle,
  cudnnRNNDescriptor_t rnnDesc,
  size_t *weightSpaceSize);
```

Parameters

handle
Input. The current cuDNN context handle.

rnnDesc
Input. A previously initialized RNN descriptor.

weightSpaceSize
Output. Minimum size in bytes of GPU memory needed for all RNN trainable parameters.

Returns

CUDNN_STATUS_SUCCESS
The query was successful.

CUDNN_STATUS_BAD_PARAM
An invalid input argument was encountered. For example, any input argument was NULL.

CUDNN_STATUS_NOT_INITIALIZED
The RNN descriptor was configured with the legacy cudnnSetRNNDescriptor_v6() call.

7.2.33. cudnnGetRNNWorkspaceSize()

This function has been deprecated in cuDNN 8.0. Use cudnnGetRNNTempSpaceSizes() instead of cudnnGetRNNWorkspaceSize().

```c
#include <cudnn.h>

cudnnStatus_t cudnnGetRNNWorkspaceSize(
  cudnnHandle_t handle,
  const cudnnRNNDescriptor_t rnnDesc,
  const int seqLength,
  const cudnnTensorDescriptor_t *xDesc,
  size_t *sizeInBytes);
```

This function is used to query the amount of work space required to execute the RNN described by rnnDesc with input dimensions defined by xDesc.
Parameters

**handle**
- *Input*. Handle to a previously created cuDNN library descriptor.

**rnnDesc**
- *Input*. A previously initialized RNN descriptor.

**seqLength**
- *Input*. Number of iterations to unroll over. Workspace that is allocated, based on the size that this function provides, cannot be used for sequences longer than `seqLength`.

**xDesc**
- *Input*. An array of tensor descriptors describing the input to each recurrent iteration (one descriptor per iteration). The first dimension (batch size) of the tensors may decrease from element `n` to element `n+1` but may not increase. For example, if you have multiple time series in a batch, they can be different lengths. This dimension is the batch size for the particular iteration of the sequence, and so it should decrease when a sequence in the batch has been terminated.

  Each tensor descriptor must have the same second dimension (vector length).

**sizeInBytes**
- *Output*. Minimum amount of GPU memory needed as workspace to be able to execute an RNN with the specified descriptor and input tensors.

Returns

- **CUDNN_STATUS_SUCCESS**
  - The query was successful.

- **CUDNN_STATUS_BAD_PARAM**
  - At least one of the following conditions are met:
    - The descriptor `rnnDesc` is invalid.
    - At least one of the descriptors in `xDesc` is invalid.
    - The descriptors in `xDesc` have inconsistent second dimensions, strides or data types.
    - The descriptors in `xDesc` have increasing first dimensions.
    - The descriptors in `xDesc` are not fully packed.

- **CUDNN_STATUS_NOT_SUPPORTED**
  - The data types in tensors described by `xDesc` are not supported.

### 7.2.34. `cudnnGetSeqDataDescriptor()`

This function retrieves settings from a previously created sequence data descriptor. The user can assign `NULL` to any pointer except `seqDataDesc` when the retrieved value is not needed. The `nbDimsRequested` argument applies to both `dimA[]` and `axes[]` arrays. A
The `cudnnGetSeqDataDescriptor()` function does not report the actual strides in the sequence data buffer. Those strides can be handy in computing the offset to any sequence data element. The user must precompute strides based on the `axes[]` and `dimA[]` arrays reported by the `cudnnGetSeqDataDescriptor()` function. Below is sample code that performs this task:

```c
// Array holding sequence data strides.
size_t strA[CUDNN_SEQDATA_DIM_COUNT] = {0};

// Compute strides from dimension and order arrays.
size_t stride = 1;
for (int i = nbDims - 1; i >= 0; i--) {
  int j = int(axes[i]);
  if (unsigned(j) < CUDNN_SEQDATA_DIM_COUNT-1 && strA[j] == 0) {
    strA[j] = stride;
    stride *= dimA[j];
  } else {
    fprintf(stderr, "ERROR: invalid axes[%d]=%d

", i, j);
    abort();
  }
}
```

Now, the `strA[]` array can be used to compute the index to any sequence data element, for example:

```c
// Using four indices (batch, beam, time, vect) with ranges already checked.
size_t base = strA[CUDNN_SEQDATA_BATCH_DIM] * batch
+ strA[CUDNN_SEQDATA_BEAM_DIM] * beam
+ strA[CUDNN_SEQDATA_TIME_DIM] * time;
val = seqDataPtr[base + vect];
```

The above code assumes that all four indices (batch, beam, time, vect) are less than the corresponding value in the `dimA[]` array. The sample code also omits the `strA[CUDNN_SEQDATA_VECT_DIM]` stride because its value is always 1, meaning, elements of one vector occupy a contiguous block of memory.

**Parameters**

- `seqDataDesc` *Input*. Sequence data descriptor.
- `dataType` *Output*. Data type used in the sequence data buffer.
- `nbDims` *Output*. The number of active dimensions in the `dimA[]` and `axes[]` arrays.
**nbDimsRequested**

*Input.* The maximum number of consecutive elements that can be written to `dimA[]` and `axes[]` arrays starting from index zero. The recommended value for this argument is `CUDNN_SEQDATA_DIM_COUNT`.

**dimA[]**

*Output.* Integer array holding sequence data dimensions.

**axes[]**

*Output.* Array of `cudnnSeqDataAxis_t` that defines the layout of sequence data in memory.

**seqLengthArraySize**

*Output.* The number of required elements in `seqLengthArray[]` to save all sequence lengths.

**seqLengthSizeRequested**

*Input.* The maximum number of consecutive elements that can be written to the `seqLengthArray[]` array starting from index zero.

**seqLengthArray[]**

*Output.* Integer array holding sequence lengths.

**paddingFill**

*Output.* Pointer to a storage location of `dataType` with the fill value that should be written to all padding vectors. Use `NULL` when an explicit initialization of output padding vectors was not requested.

**Returns**

**CUDNN_STATUS_SUCCESS**

Requested sequence data descriptor fields were retrieved successfully.

**CUDNN_STATUS_BAD_PARAM**

An invalid input argument was found.

**CUDNN_STATUS_INTERNAL_ERROR**

An inconsistent internal state was encountered.

### 7.2.35. `cudnnMultiHeadAttnForward()`

The `cudnnMultiHeadAttnForward()` function computes the forward responses of the multi-head attention layer. When `reserveSpaceSizeInBytes=0` and `reserveSpace=NULL`, the function operates in the inference mode in which backward (gradient) functions are not invoked, otherwise, the training mode is assumed. In the training mode, the reserve space is used to pass intermediate results from `cudnnMultiHeadAttnForward()` to `cudnnMultiHeadAttnBackwardData()` and from `cudnnMultiHeadAttnBackwardData()` to `cudnnMultiHeadAttnBackwardWeights()`.

```c
const cudnnMultiHeadAttnForward_t cudnnMultiHeadAttnForward(
    cudnnHandle_t handle,
    const cudnnAttnDescriptor_t attnDesc,
    int currIdx,
    const int loWinIdx[],
    const int hiWinIdx[],
    const int devSeqLengthsQO[],
    const int devSeqLengthsKV[],
```
In the inference mode, the `currIdx` specifies the time-step or sequence index of the embedding vectors to be processed. In this mode, the user can perform one iteration for time-step zero (`currIdx=0`), then update `Q, K, V` vectors and the attention window, and execute the next step (`currIdx=1`). The iterative process can be repeated for all time-steps.

When all `Q` time-steps are available (for example, in the training mode or in the inference mode on the encoder side in self-attention), the user can assign a negative value to `currIdx` and the `cudnnMultiHeadAttnForward()` API will automatically sweep through all `Q` time-steps.

The `loWinIdx[]` and `hiWinIdx[]` host arrays specify the attention window size for each `Q` time-step. In a typical self-attention case, the user must include all previously visited embedding vectors but not the current or future vectors. In this situation, the user should set:

```
currIdx=0: loWinIdx[0]=0; hiWinIdx[0]=0;  // initial time-step, no attention window
currIdx=1: loWinIdx[1]=0; hiWinIdx[1]=1;  // attention window spans one vector
currIdx=2: loWinIdx[2]=0; hiWinIdx[2]=2;  // attention window spans two vectors
(...)```

When `currIdx` is negative in `cudnnMultiHeadAttnForward()`, the `loWinIdx[]` and `hiWinIdx[]` arrays must be fully initialized for all time-steps. When `cudnnMultiHeadAttnForward()` is invoked with `currIdx=0, currIdx=1, currIdx=2, etc.,` then the user can update `loWinIdx[currIdx]` and `hiWinIdx[currIdx]` elements only before invoking the forward response function. All other elements in the `loWinIdx[]` and `hiWinIdx[]` arrays will not be accessed. Any adaptive attention window scheme can be implemented that way.

Use the following settings when the attention window should be the maximum size, for example, in cross-attention:

```
currIdx=0: loWinIdx[0]=0; hiWinIdx[0]=maxSeqLenK;
currIdx=1: loWinIdx[1]=0; hiWinIdx[1]=maxSeqLenK;
(...)```

The `maxSeqLenK` value above should be equal to or larger than `dimA[CUDNN_SEQDATA_TIME_DIM]` in the `kDesc` descriptor. A good choice is to use `maxSeqLenK=INT_MAX` from `limits.h`.

Note: The actual length of any `K` sequence defined in `seqLengthArray[]` in `cudnnSetSeqDataDescriptor()` can be shorter than `maxSeqLenK`. The effective attention
The window span is computed based on `seqLengthArray[]` stored in the K sequence descriptor and indices held in `loWinIdx[]` and `hiWinIdx[]` arrays.

`devSeqLengthsQO[]` and `devSeqLengthsKV[]` are pointers to device (not host) arrays with Q, O, and K, V sequence lengths. Note that the same information is also passed in the corresponding descriptors of type `cudnnSeqDataDescriptor_t` on the host side. The need for extra device arrays comes from the asynchronous nature of cuDNN calls and limited size of the constant memory dedicated to GPU kernel arguments. When the `cudnnMultiHeadAttnForward()` API returns, the sequence length arrays stored in the descriptors can be immediately modified for the next iteration. However, the GPU kernels launched by the forward call may not have started at this point. For this reason, copies of sequence arrays are needed on the device side to be accessed directly by GPU kernels. Those copies cannot be created inside the `cudnnMultiHeadAttnForward()` function for very large K, V inputs without the device memory allocation and CUDA stream synchronization.

To reduce the `cudnnMultiHeadAttnForward()` API overhead, `devSeqLengthsQO[]` and `devSeqLengthsKV[]` device arrays are not validated to contain the same settings as `seqLengthArray[]` in the sequence data descriptors.

Sequence lengths in the `kDesc` and `vDesc` descriptors should be the same. Similarly, sequence lengths in the `qDesc` and `oDesc` descriptors should match. The user can define six different data layouts in the `qDesc`, `kDesc`, `vDesc` and `oDesc` descriptors. Refer to the `cudnnSetSeqDataDescriptor()` function for the discussion of those layouts. All multi-head attention API calls require that the same layout is used in all sequence data descriptors.

In the transformer model, the multi-head attention block is tightly coupled with the layer normalization and residual connections. `cudnnMultiHeadAttnForward()` does not encompass the layer normalization but it can be used to handle residual connections as depicted in the following figure.

**Figure 2.** Multi-Head Attention Block is Tightly Coupled with the Layer Normalization and Residual Connections
Queries and residuals share the same qDesc descriptor in cudnnMultiHeadAttnForward(). When residual connections are disabled, the residuals pointer should be NULL. When residual connections are enabled, the vector length in qDesc should match the vector length specified in the oDesc descriptor, so that a vector addition is feasible.

The queries, keys, and values pointers are not allowed to be NULL, even when K and V are the same inputs or Q, K, V are the same inputs.

**Parameters**

**handle**

*Input.* The current cuDNN context handle.

**attnDesc**

*Input.* A previously initialized attention descriptor.

**currIdx**

*Input.* Time-step in queries to process. When the currIdx argument is negative, all Q time-steps are processed. When currIdx is zero or positive, the forward response is computed for the selected time-step only. The latter input can be used in inference mode only, to process one time-step while updating the next attention window and Q, R, K, V inputs in-between calls.

**loWinIdx[], hiWinIdx[]**

*Input.* Two host integer arrays specifying the start and end indices of the attention window for each Q time-step. The start index in K, V sets is inclusive, and the end index is exclusive.

**devSeqLengthsQO[]**

*Input.* Device array specifying sequence lengths of query, residual, and output sequence data.

**devSeqLengthsKV[]**

*Input.* Device array specifying sequence lengths of key and value input data.

**qDesc**

*Input.* Descriptor for the query and residual sequence data.

**queries**

*Input.* Pointer to queries data in the device memory.

**residuals**

*Input.* Pointer to residual data in device memory. Set this argument to NULL if no residual connections are required.

**kDesc**

*Input.* Descriptor for the keys sequence data.

**keys**

*Input.* Pointer to keys data in device memory.

**vDesc**

*Input.* Descriptor for the values sequence data.

**values**

*Input.* Pointer to values data in device memory.
oDesc
  Input. Descriptor for the multi-head attention output sequence data.

out
  Output. Pointer to device memory where the output response should be written.

weightSizeInBytes
  Input. Size of the weight buffer in bytes where all multi-head attention trainable
  parameters are stored.

weights
  Input. Pointer to the weight buffer in device memory.

workSpaceSizeInBytes
  Input. Size of the work-space buffer in bytes used for temporary API storage.

workSpace
  Input/Output. Pointer to the work-space buffer in device memory.

reserveSpaceSizeInBytes
  Input. Size of the reserve-space buffer in bytes used for data exchange between
  forward and backward (gradient) API calls. This parameter should be zero in the
  inference mode and non-zero in the training mode.

reserveSpace
  Input/Output. Pointer to the reserve-space buffer in device memory. This argument
  should be NULL in inference mode and non-NULL in the training mode.

Returns

CUDNN_STATUS_SUCCESS
  No errors were detected while processing API input arguments and launching GPU
  kernels.

CUDNN_STATUS_BAD_PARAM
  An invalid or incompatible input argument was encountered. Some examples include:
    ▶ a required input pointer was NULL
    ▶ curIdx was out of bound
    ▶ the descriptor value for attention, query, key, value, and output were
      incompatible with one another

CUDNN_STATUS_EXECUTION_FAILED
  The process of launching a GPU kernel returned an error, or an earlier kernel did not
  complete successfully.

CUDNN_STATUS_INTERNAL_ERROR
  An inconsistent internal state was encountered.

CUDNN_STATUS_NOT_SUPPORTED
  A requested option or a combination of input arguments is not supported.

CUDNN_STATUS_ALLOC_FAILED
  Insufficient amount of shared memory to launch a GPU kernel.
7.2.36. **cudnnRNNForward()**

This routine computes the forward response of the recurrent neural network described by `rnnDesc` with inputs in `x`, `hx`, `cx`, and weights/biases in the `weightSpace` buffer. RNN outputs are written to `y`, `hy`, and `cy` buffers. Locations of `x`, `y`, `hx`, `cx`, `hy`, and `cy` signals in the multi-layer RNN model are shown in the following figure. Note that internal RNN signals between time-steps and between layers are not exposed to the user.

```c
void cudnnRNNForward(
    cudnnHandle_t handle,
    cudnnRNNDescriptor_t rnnDesc,
    cudnnForwardMode_t fwdMode,
    const int32_t devSeqLengths[],
    cudnnRNNDataDescriptor_t xDesc,
    const void *x,
    cudnnRNNDataDescriptor_t yDesc,
    void *y,
    cudnnTensorDescriptor_t hDesc,
    const void *hx,
    void *hy,
    cudnnTensorDescriptor_t cDesc,
    const void *cx,
    void *cy,
    size_t weightSpaceSize,
    const void *weightSpace,
    size_t workSpaceSize,
    void *workSpace,
    size_t reserveSpaceSize,
    void *reserveSpace);
```

The next figure depicts data flow when the RNN model is bidirectional. In this mode each RNN physical layer consists of two consecutive pseudo-layers, each with its own weights, biases, the initial hidden state `hx`, and for LSTM, also the initial cell state `cx`.
Even pseudo-layers 0, 2, 4 process input vectors from left to right or in the forward (F) direction. Odd pseudo-layers 1, 3, 5 process input vectors from right to left or in the reverse (R) direction. Two successive pseudo-layers operate on the same input vectors, just in a different order. Pseudo-layers 0 and 1 access the original sequences stored in the x buffer. Outputs of F and R cells are concatenated so vectors fed to the next two pseudo-layers have lengths of $2 \times \text{hiddenSize}$ or $2 \times \text{projSize}$. Input GEMMs in subsequent pseudo-layers adjust vector lengths to $1 \times \text{hiddenSize}$.

**Figure 4. Data Flow when the RNN Model is Bidirectional**

When the `fwdMode` parameter is set to `CUDNN_FWD_MODE_TRAINING`, the `cudnnRNNForward()` function stores intermediate data required to compute first order derivatives in the reserve space buffer. Work and reserve space buffer sizes should be computed by the `cudnnGetRNNTempSpaceSizes()` function with the same `fwdMode` setting as used in the `cudnnRNNForward()` call.

The same layout type must be specified in `xDesc` and `yDesc` descriptors. The same sequence lengths must be configured in `xDesc`, `yDesc` and in the device array `devSeqLengths`. Starting in cuDNN 8.9.1, the `devSeqLengths` parameter is no longer required and can be set to `NULL`. The variable sequence length array is transferred automatically to GPU memory by the `cudnnRNNForward()` function.

The `cudnnRNNForward()` function does not verify that sequence lengths stored in `devSeqLengths` in GPU memory are the same as in `xDesc` and `yDesc` descriptors in CPU memory. Sequence length arrays from `xDesc` and `yDesc` descriptors are checked for consistency, however.
Parameters

handle
   Input. The current cuDNN context handle.

rnnDesc
   Input. A previously initialized RNN descriptor.

fwdMode
   Input. Specifies inference or training mode (CUDNN_FWD_MODE_INFER and
   CUDNN_FWD_MODE_TRAIN). In the training mode, additional data is stored in the
   reserve space buffer. This information is used in the backward pass to compute
   derivatives.

devSeqLengths
   Input. A copy of seqLengthArray from xDesc or yDesc RNN data descriptor. The
devSeqLengths array must be stored in GPU memory as it is accessed asynchronously
by GPU kernels, possibly after the cudnnRNNForward() function exists. In cuDNN 8.9.1
and later versions, devSeqLengths should be NULL.

xDesc
   Input. A previously initialized descriptor corresponding to the RNN model primary
input. The dataType, layout, maxSeqLength, batchSize, and seqLengthArray must
match that of yDesc. The parameter vectorSize must match the inputSize argument
passed to the cudnnSetRNNDescriptor_v8() function.

x
   Input. Data pointer to the GPU memory associated with the RNN data descriptor
xDesc. The vectors are expected to be arranged in memory according to the layout
specified by xDesc. The elements in the tensor (including padding vectors) must be
densely packed.

yDesc
   Input. A previously initialized RNN data descriptor. The dataType, layout,
maxSeqLength, batchSize, and seqLengthArray must match that of xDesc. The
parameter vectorSize depends on whether LSTM projection is enabled and whether
the network is bi-directional. Specifically:

   ▶ For uni-directional models, the parameter vectorSize must match the hiddenSize
argument passed to cudnnSetRNNDescriptor_v8(). If the LSTM projection is
enabled, the vectorSize must be the same as the projSize argument passed to
   cudnnSetRNNDescriptor_v8().

   ▶ For bi-directional models, if the RNN cellMode is CUDNN_LSTM and the projection
feature is enabled, the parameter vectorSize must be 2x the projSize argument
passed to cudnnSetRNNDescriptor_v8(). Otherwise, it should be 2x the
   hiddenSize value.

y
   Output. Data pointer to the GPU memory associated with the RNN data descriptor
yDesc. The vectors are expected to be laid out in memory according to the layout
specified by yDesc. The elements in the tensor (including elements in the padding vector) must be densely packed, and no strides are supported.

**hDesc**

*Input*. A tensor descriptor describing the initial or final hidden state of RNN. Hidden state data are fully packed. The first dimension of the tensor depends on the dirMode argument passed to the `cudnnSetRNNDescriptor_v8()` function.

- If dirMode is CUDNN_UNIDIRECTIONAL, then the first dimension should match the numLayers argument passed to `cudnnSetRNNDescriptor_v8()`.
- If dirMode is CUDNN_BIDIRECTIONAL, then the first dimension should be double the numLayers argument passed to `cudnnSetRNNDescriptor_v8()`.

The second dimension must match the batchSize parameter described in xDesc. The third dimension depends on whether RNN mode is CUDNN_LSTM and whether the LSTM projection is enabled. Specifically:

- If RNN mode is CUDNN_LSTM and LSTM projection is enabled, the third dimension must match the projSize argument passed to the `cudnnSetRNNProjectionLayers()` call.
- Otherwise, the third dimension must match the hiddenSize argument passed to the `cudnnSetRNNDescriptor_v8()` call used to initialize rnnDesc.

**hx**

*Input*. Pointer to the GPU buffer with the RNN initial hidden state. Data dimensions are described by the hDesc tensor descriptor. If a NULL pointer is passed, the initial hidden state of the network will be initialized to zero.

**hy**

*Output*. Pointer to the GPU buffer where the final RNN hidden state should be stored. Data dimensions are described by the hDesc tensor descriptor. If a NULL pointer is passed, the final hidden state of the network will not be saved.

**cDesc**

*Input*. For LSTM networks only. A tensor descriptor describing the initial or final cell state for LSTM networks only. Cell state data are fully packed. The first dimension of the tensor depends on the dirMode argument passed to the `cudnnSetRNNDescriptor_v8()` call.

- If dirMode is CUDNN_UNIDIRECTIONAL the first dimension should match the numLayers argument passed to `cudnnSetRNNDescriptor_v8()`.
- If dirMode is CUDNN_BIDIRECTIONAL the first dimension should match double the numLayers argument passed to `cudnnSetRNNDescriptor_v8()`.

The second tensor dimension must match the batchSize parameter in xDesc. The third dimension must match the hiddenSize argument passed to the `cudnnSetRNNDescriptor_v8()` call.
cx
*Input*. For LSTM networks only. Pointer to the GPU buffer with the initial LSTM state data. Data dimensions are described by the `cDesc` tensor descriptor. If a `NULL` pointer is passed, the initial cell state of the network will be initialized to zero.

`cy`
*Output*. For LSTM networks only. Pointer to the GPU buffer where final LSTM state data should be stored. Data dimensions are described by the `cDesc` tensor descriptor. If a `NULL` pointer is passed, the final LSTM cell state will not be saved.

`weightSpaceSize`
*Input*. Specifies the size in bytes of the provided weight-space buffer.

`weightSpace`
*Input*. Address of the weight space buffer in GPU memory.

`workSpaceSize`
*Input*. Specifies the size in bytes of the provided workspace buffer.

`workSpace`
*Input/Output*. Address of the workspace buffer in GPU memory to store temporary data.

`reserveSpaceSize`
*Input*. Specifies the size in bytes of the reserve-space buffer.

`reserveSpace`
*Input/Output*. Address of the reserve-space buffer in GPU memory.

**Returns**

**CUDNN_STATUS_SUCCESS**
No errors were detected while processing API input arguments and launching GPU kernels.

**CUDNN_STATUS_NOT_SUPPORTED**
At least one of the following conditions are met:

- variable sequence length input is passed while `CUDNN_RNN_ALGO_PERSIST_STATIC` or `CUDNN_RNN_ALGO_PERSIST_DYNAMIC` is specified
- `CUDNN_RNN_ALGO_PERSIST_STATIC` or `CUDNN_RNN_ALGO_PERSIST_DYNAMIC` is requested on pre-Pascal devices
- the 'double' floating point type is used for input/output and the `CUDNN_RNN_ALGO_PERSIST_STATIC` algo

**CUDNN_STATUS_BAD_PARAM**
An invalid or incompatible input argument was encountered. For example:

- some input descriptors are `NULL`
- at least one of the settings in `rnnDesc`, `xDesc`, `yDesc`, `hDesc`, or `cDesc` descriptors is invalid
- `weightSpaceSize`, `workSpaceSize`, or `reserveSpaceSize` is too small
**CUDNN_STATUS_EXECUTION_FAILED**

The process of launching a GPU kernel returned an error, or an earlier kernel did not complete successfully.

**CUDNN_STATUS_ALLOC_FAILED**

The function was unable to allocate CPU memory.

### 7.2.37. cudnnRNNForwardInference()

This function has been deprecated in cuDNN 8.0. Use [cudnnRNNForward()](#) instead of cudnnRNNForwardInference().

```c
    cudnnStatus_t cudnnRNNForwardInference(
        cudnnHandle_t                   handle,
        const cudnnRNNDescriptor_t      rnnDesc,  
        const int                       seqLength,  
        const cudnnTensorDescriptor_t  *xDesc,    
        const void                     *x,         
        const cudnnTensorDescriptor_t   hxDesc,    
        const void                     *hx,        
        const cudnnTensorDescriptor_t   cxDesc,    
        const void                     *cx,        
        const cudnnFilterDescriptor_t   wDesc,     
        const void                     *w,         
        const cudnnTensorDescriptor_t   *yDesc,     
        void                           *y,         
        const cudnnTensorDescriptor_t   hyDesc,    
        void                           *hy,        
        const cudnnTensorDescriptor_t   cyDesc,    
        void                           *cy,         
        void                           *workspace,
        size_t                         workSpaceSizeInBytes)
```

This routine executes the recurrent neural network described by `rnnDesc` with inputs `x`, `hx`, and `cx`, weights `w` and outputs `y`, `hy`, and `cy`. `workspace` is required for intermediate storage. This function does not store intermediate data required for training; [cudnnRNNForwardTraining()](#) should be used for that purpose.

**Parameters**

- **handle**
  - *Input*. Handle to a previously created cuDNN context.

- **rnnDesc**
  - *Input*. A previously initialized RNN descriptor.

- **seqLength**
  - *Input*. Number of iterations to unroll over. The value of this `seqLength` must not exceed the value that was used in the [cudnnGetRNNWorkspaceSize()](#) function for querying the workspace size required to execute the RNN.

- **xDesc**
  - *Input*. An array of `seqLength` fully packed tensor descriptors. Each descriptor in the array should have three dimensions that describe the input data format to one recurrent iteration (one descriptor per RNN time-step). The first dimension (batch size) of the tensors may decrease from iteration `n` to iteration `n+1` but may not increase. Each tensor descriptor must have the same second dimension (RNN input vector length, `inputSize`). The third dimension of each tensor should be 1. Input data are...
expected to be arranged in the column-major order so strides in xDesc should be set as follows:

```
```

**x**

*Input.* Data pointer to GPU memory associated with the array of tensor descriptors xDesc. The input vectors are expected to be packed contiguously with the first vector of iteration (time-step) \(n+1\) following directly from the last vector of iteration \(n\). In other words, input vectors for all RNN time-steps should be packed in the contiguous block of GPU memory with no gaps between the vectors.

**hxDesc**

*Input.* A fully packed tensor descriptor describing the initial hidden state of the RNN. The first dimension of the tensor depends on the direction argument used to initialize rnnDesc:

- If direction is CUDNN_UNIDIRECTIONAL the first dimension should match the numLayers argument.
- If direction is CUDNN_BIDIRECTIONAL the first dimension should match double the numLayers argument.

The second dimension must match the first dimension of the tensors described in xDesc. The third dimension must match the hiddenSize argument used to initialize rnnDesc. The tensor must be fully packed.

**hx**

*Input.* Data pointer to GPU memory associated with the tensor descriptor hxDesc. If a NULL pointer is passed, the initial hidden state of the network will be initialized to zero.

**cxDesc**

*Input.* A fully packed tensor descriptor describing the initial cell state for LSTM networks. The first dimension of the tensor depends on the direction argument used to initialize rnnDesc:

- If direction is CUDNN_UNIDIRECTIONAL the first dimension should match the numLayers argument.
- If direction is CUDNN_BIDIRECTIONAL the first dimension should match double the numLayers argument.

The second dimension must match the first dimension of the tensors described in xDesc. The third dimension must match the hiddenSize argument used to initialize rnnDesc. The tensor must be fully packed.

**cx**

*Input.* Data pointer to GPU memory associated with the tensor descriptor cxDesc. If a NULL pointer is passed, the initial cell state of the network will be initialized to zero.

**wDesc**

*Input.* Handle to a previously initialized filter descriptor describing the weights for the RNN.
Input. Data pointer to GPU memory associated with the filter descriptor wDesc.

yDesc

Input. An array of fully packed tensor descriptors describing the output from each recurrent iteration (one descriptor per iteration). The second dimension of the tensor depends on the direction argument used to initialize rnnDesc:

- If direction is CUDNN_UNIDIRECTIONAL the second dimension should match the hiddenSize argument.
- If direction is CUDNN_BIDIRECTIONAL the second dimension should match double the hiddenSize argument.

The first dimension of the tensor n must match the first dimension of the tensor n in xDesc.

y

Output. Data pointer to GPU memory associated with the output tensor descriptor yDesc. The data are expected to be packed contiguously with the first element of iteration n+1 following directly from the last element of iteration n.

hyDesc

Input. A fully packed tensor descriptor describing the final hidden state of the RNN. The first dimension of the tensor depends on the direction argument used to initialize_rnnDesc:

- If direction is CUDNN_UNIDIRECTIONAL the first dimension should match the numLayers argument.
- If direction is CUDNN_BIDIRECTIONAL the first dimension should match double the numLayers argument.

The second dimension must match the first dimension of the tensors described in xDesc. The third dimension must match the hiddenSize argument used to initialize rnnDesc. The tensor must be fully packed.

hy

Output. Data pointer to GPU memory associated with the tensor descriptor hyDesc. If a NULL pointer is passed, the final hidden state of the network will not be saved.

cyDesc

Input. A fully packed tensor descriptor describing the final cell state for LSTM networks. The first dimension of the tensor depends on the direction argument used to initialize rnnDesc:

- If direction is CUDNN_UNIDIRECTIONAL the first dimension should match the numLayers argument.
- If direction is CUDNN_BIDIRECTIONAL the first dimension should match double the numLayers argument.
The second dimension must match the first dimension of the tensors described in xDesc. The third dimension must match the hiddenSize argument used to initialize rnnDesc. The tensor must be fully packed.

\textbf{cy}

\textit{Output}. Data pointer to GPU memory associated with the tensor descriptor cyDesc. If a NULL pointer is passed, the final cell state of the network will not be saved.

\textbf{workspace}

\textit{Input}. Data pointer to GPU memory to be used as a workspace for this call.

\textbf{workSpaceSizeInBytes}

\textit{Input}. Specifies the size in bytes of the provided workspace.

\textbf{Returns}

\textbf{CUDNN_STATUS_SUCCESS}

The function launched successfully.

\textbf{CUDNN_STATUS_NOT_SUPPORTED}

The function does not support the provided configuration.

\textbf{CUDNN_STATUS_BAD_PARAM}

At least one of the following conditions are met:

- The descriptor rnnDesc is invalid.
- At least one of the descriptors hxDesc, cxDesc, wDesc, hyDesc, cyDesc or one of the descriptors in xDesc, or yDesc is invalid.
- The descriptors in one of xDesc, hxDesc, cxDesc, wDesc, yDesc, hyDesc, or cyDesc have incorrect strides or dimensions.
- workSpaceSizeInBytes is too small.

\textbf{CUDNN_STATUS_INVALID_VALUE}

\texttt{cudnnSetPersistentRNNPlan()} was not called prior to the current function when CUDNN_RNN_ALGO_PERSIST_DYNAMIC was selected in the RNN descriptor.

\textbf{CUDNN_STATUS_EXECUTION_FAILED}

The function failed to launch on the GPU.

\textbf{CUDNN_STATUS_ALLOC_FAILED}

The function was unable to allocate memory.

\textbf{7.2.38. \texttt{cudnnRNNForwardInferenceEx()}}

This function has been deprecated in cuDNN 8.0. Use \texttt{cudnnRNNForward()} instead of \texttt{cudnnRNNForwardInferenceEx()}.
This routine is the extended version of the `cudnnRNNForwardInference()` function. The `cudnnRNNForwardTrainingEx()` function allows the user to use an unpacked (padded) layout for input `x` and output `y`. In the unpacked layout, each sequence in the mini-batch is considered to be of fixed length, specified by `maxSeqLength` in its corresponding `RNNDataDescriptor`. Each fixed-length sequence, for example, the `n`th sequence in the mini-batch, is composed of a valid segment, specified by the `seqLengthArray[n]` in its corresponding `RNNDataDescriptor`, and a padding segment to make the combined sequence length equal to `maxSeqLength`.

With an unpacked layout, both sequence major (meaning, time major) and batch major are supported. For backward compatibility, the packed sequence major layout is supported. However, similar to the non-extended function `cudnnRNNForwardInference()`, the sequences in the mini-batch need to be sorted in descending order according to length.

**Parameters**

**handle**
*Input.* Handle to a previously created cuDNN context.

**rnnDesc**
*Input.* A previously initialized RNN descriptor.

**xDesc**
*Input.* A previously initialized RNN Data descriptor. The `dataType`, `layout`, `maxSeqLength`, `batchSize`, and `seqLengthArray` need to match that of `yDesc`.

**x**
*Input.* Data pointer to the GPU memory associated with the RNN data descriptor `xDesc`. The vectors are expected to be laid out in memory according to the layout specified by `xDesc`. The elements in the tensor (including elements in the padding vector) must be densely packed, and no strides are supported.

**hxDesc**
*Input.* A fully packed tensor descriptor describing the initial hidden state of the RNN. The first dimension of the tensor depends on the `direction` argument used to initialize `rnnDesc`:
If `direction` is **CUDNN_UNIDIRECTIONAL** the first dimension should match the `numLayers` argument.

If `direction` is **CUDNN_BIDIRECTIONAL** the first dimension should match double the `numLayers` argument.

The second dimension must match the `batchSize` parameter described in `xDesc`. The third dimension depends on whether RNN mode is **CUDNN_LSTM** and whether LSTM projection is enabled. Specifically:

- If RNN mode is **CUDNN_LSTM** and LSTM projection is enabled, the third dimension must match the `recProjSize` argument passed to `cudnnSetRNNProjectionLayers()` call used to set `rnnDesc`.
- Otherwise, the third dimension must match the `hiddenSize` argument used to initialize `rnnDesc`.

**hx**

*Input*. Data pointer to GPU memory associated with the tensor descriptor `hxDesc`. If a NULL pointer is passed, the initial hidden state of the network will be initialized to zero.

**cxDesc**

*Input*. A fully packed tensor descriptor describing the initial cell state for LSTM networks. The first dimension of the tensor depends on the `direction` argument used to initialize `rnnDesc`:

- If `direction` is **CUDNN_UNIDIRECTIONAL** the first dimension should match the `numLayers` argument.
- If `direction` is **CUDNN_BIDIRECTIONAL** the first dimension should match double the `numLayers` argument.

The second dimension must match the `batchSize` parameter in `xDesc`. The third dimension must match the `hiddenSize` argument used to initialize `rnnDesc`.

**cx**

*Input*. Data pointer to GPU memory associated with the tensor descriptor `cxDesc`. If a NULL pointer is passed, the initial cell state of the network will be initialized to zero.

**wDesc**

*Input*. Handle to a previously initialized filter descriptor describing the weights for the RNN.

**w**

*Input*. Data pointer to GPU memory associated with the filter descriptor `wDesc`.

**yDesc**

*Input*. A previously initialized RNN data descriptor. The `dataType`, `layout`, `maxSeqLength`, `batchSize`, and `seqLengthArray` must match that of `dyDesc` and `dxDesc`. The parameter `vectorSize` depends on whether RNN mode is **CUDNN_LSTM** and whether LSTM projection is enabled and whether the network is bidirectional. Specifically:
For uni-directional network, if the RNN mode is \texttt{CUDNN_LSTM} and LSTM projection is enabled, the parameter \texttt{vectorSize} must match the \texttt{recProjSize} argument passed to \texttt{cudnnSetRNNProjectionLayers()} call used to set \texttt{rnnDesc}. If the network is bidirectional, then multiply the value by 2.

Otherwise, for a uni-directional network, the parameter \texttt{vectorSize} must match the \texttt{hiddenSize} argument used to initialize \texttt{rnnDesc}. If the network is bidirectional, then multiply the value by 2.

\texttt{y}
\textit{Output}. Data pointer to the GPU memory associated with the RNN data descriptor \texttt{yDesc}. The vectors are expected to be laid out in memory according to the layout specified by \texttt{yDesc}. The elements in the tensor (including elements in the padding vector) must be densely packed, and no strides are supported.

\texttt{hyDesc}
\textit{Input}. A fully packed tensor descriptor describing the final hidden state of the RNN. The descriptor must be set exactly the same way as \texttt{hxDesc}.

\texttt{hy}
\textit{Output}. Data pointer to GPU memory associated with the tensor descriptor \texttt{hyDesc}. If a \texttt{NULL} pointer is passed, the final hidden state of the network will not be saved.

\texttt{cyDesc}
\textit{Input}. A fully packed tensor descriptor describing the final cell state for LSTM networks. The descriptor must be set exactly the same way as \texttt{cxDesc}.

\texttt{cy}
\textit{Output}. Data pointer to GPU memory associated with the tensor descriptor \texttt{cyDesc}. If a \texttt{NULL} pointer is passed, the final cell state of the network will not be saved.

\texttt{kDesc}
Reserved. User may pass in \texttt{NULL}.

\texttt{keys}
Reserved. Users may pass in \texttt{NULL}.

\texttt{cDesc}
Reserved. Users may pass in \texttt{NULL}.

\texttt{cAttn}
Reserved. Users may pass in \texttt{NULL}.

\texttt{iDesc}
Reserved. Users may pass in \texttt{NULL}.

\texttt{iAttn}
Reserved. Users may pass in \texttt{NULL}.

\texttt{qDesc}
Reserved. Users may pass in \texttt{NULL}.

\texttt{queries}
Reserved. Users may pass in \texttt{NULL}.

\texttt{workspace}
\textit{Input}. Data pointer to GPU memory to be used as a workspace for this call.
**workSpaceSizeInBytes**

*Input.* Specifies the size in bytes of the provided *workspace.*

**Returns**

**CUDNN_STATUS_SUCCESS**

The function launched successfully.

**CUDNN_STATUS_NOT_SUPPORTED**

At least one of the following conditions are met:

- Variable sequence length input is passed in while `CUDNN_RNN_ALGO_PERSIST_STATIC` or `CUDNN_RNN_ALGO_PERSIST_DYNAMIC` is used.
- `CUDNN_RNN_ALGO_PERSIST_STATIC` or `CUDNN_RNN_ALGO_PERSIST_DYNAMIC` is used on pre-Pascal devices.
- Double input/output is used for `CUDNN_RNN_ALGO_PERSIST_STATIC`.

**CUDNN_STATUS_BAD_PARAM**

At least one of the following conditions are met:

- The descriptor `rnnDesc` is invalid.
- At least one of the descriptors in `xDesc`, `yDesc`, `hxDesc`, `cxDesc`, `wDesc`, `hyDesc`, or `cyDesc` is invalid, or has incorrect strides or dimensions.
- `reserveSpaceSizeInBytes` is too small.
- `workSpaceSizeInBytes` is too small.

**CUDNN_STATUS_INVALID_VALUE**

`cudnnSetPersistentRNNPlan()` was not called prior to the current function when `CUDNN_RNN_ALGO_PERSIST_DYNAMIC` was selected in the RNN descriptor.

**CUDNN_STATUS_EXECUTION_FAILED**

The function failed to launch on the GPU.

**CUDNN_STATUS_ALLOC_FAILED**

The function was unable to allocate memory.

### 7.2.39. `cudnnRNNGetClip()`

This function has been deprecated in cuDNN 8.0. Use `cudnnRNNGetClip_v8()` instead of `cudnnRNNGetClip()`.

```c
cudnnStatus_t cudnnRNNGetClip(
    cudnnHandle_t              handle,
    cudnnRNNDescriptor_t       rnnDesc,
    cudnnRNNClipMode_t         *clipMode,
    cudnnNanPropagation_t      *clipNanOpt,
    double                      lclip,
    double                      rclip);
```

Retrieves the current LSTM cell clipping parameters, and stores them in the arguments provided.
Parameters

*clipMode
  Output. Pointer to the location where the retrieved clipMode is stored. The clipMode can be CUDNN_RNN_CLIP_NONE in which case no LSTM cell state clipping is being performed; or CUDNN_RNN_CLIP_MINMAX, in which case the cell state activation to other units are being clipped.

*lclip, *rclip
  Output. Pointers to the location where the retrieved LSTM cell clipping range [lclip, rclip] is stored.

*clipNanOpt
  Output. Pointer to the location where the retrieved clipNanOpt is stored.

Returns

CUDNN_STATUS_SUCCESS
  The function launched successfully.

CUDNN_STATUS_BAD_PARAM
  If any of the pointer arguments provided are NULL.

7.2.40. cudnnRNNGetClip_v8()

Retrieves the current LSTM cell clipping parameters, and stores them in the arguments provided. The user can assign NULL to any pointer except rnnDesc when the retrieved value is not needed. The function does not check the validity of retrieved parameters.

cudnnStatus_t cudnnRNNGetClip_v8(
  cudnnRNNDescriptor_t rnnDesc,
  cudnnRNNClipMode_t *clipMode,
  cudnnNanPropagation_t *clipNanOpt,
  double *lclip,
  double *rclip);

Parameters

rnnDesc
  Input. A previously initialized RNN descriptor.

clipMode
  Output. Pointer to the location where the retrieved cudnnRNNClipMode_t value is stored. The clipMode can be CUDNN_RNN_CLIP_NONE in which case no LSTM cell state clipping is being performed; or CUDNN_RNN_CLIP_MINMAX, in which case the cell state activation to other units are being clipped.

clipNanOpt
  Output. Pointer to the location where the retrieved cudnnNanPropagation_t value is stored.

lclip, rclip
  Output. Pointers to the location where the retrieved LSTM cell clipping range [lclip, rclip] is stored.
Returns

**CUDNN_STATUS_SUCCESS**

LSTM clipping parameters were successfully retrieved from the RNN descriptor.

**CUDNN_STATUS_BAD_PARAM**

An invalid input argument was found (rnnDesc was NULL).

7.2.41. **cudnnRNNSetClip()**

This function has been deprecated in cuDNN 8.0. Use **cudnnRNNSetClip_v8()** instead of cudnnRNNSetClip().

```c
void cudnnRNNSetClip(
    cudnnHandle_t handle,
    cudnnRNNDescriptor_t rnnDesc,
    cudnnRNNClipMode_t clipMode,
    cudnnNanPropagation_t clipNanOpt,
    double lclip,
    double rclip);
```

Sets the LSTM cell clipping mode. The LSTM clipping is disabled by default. When enabled, clipping is applied to all layers. This cudnnRNNSetClip() function may be called multiple times.

**Parameters**

**clipMode**

*Input.* Enables or disables the LSTM cell clipping. When clipMode is set to

- **CUDNN_RNN_CLIP_NONE** no LSTM cell state clipping is performed. When clipMode is
- **CUDNN_RNN_CLIP_MINMAX** the cell state activation to other units is clipped.

**lclip, rclip**

*Input.* The range \([lclip, rclip]\) to which the LSTM cell clipping should be set.

**clipNanOpt**

*Input.* When set to **CUDNN_PROPAGATE_NAN** (see the description for

- **cudnnNanPropagation_t**), NaN is propagated from the LSTM cell, or it can be set to one
  of the clipping range boundary values, instead of propagating.

**Returns**

**CUDNN_STATUS_SUCCESS**

The function launched successfully.

**CUDNN_STATUS_BAD_PARAM**

Returns this value if \(lclip > rclip\); or if either \(lclip\) or \(rclip\) is NaN.
7.2.42. cudnnRNNSetClip_v8()

Sets the LSTM cell clipping mode. The LSTM clipping is disabled by default. When enabled, clipping is applied to all layers. This cudnnRNNSetClip() function does not affect the work, reserve, and weight-space buffer sizes and may be called multiple times.

```
cudnnStatus_t cudnnRNNSetClip_v8(
    cudnnRNNDescriptor_t rnnDesc,
    cudnnRNNClipMode_t clipMode,
    cudnnNanPropagation_t clipNanOpt,
    double lclip,
    double rclip);
```

Parameters

- **rnnDesc**
  - *Input*. A previously initialized RNN descriptor.

- **clipMode**
  - *Input*. Enables or disables the LSTM cell clipping. When `clipMode` is set to `CUDNN_RNN_CLIP_NONE` no LSTM cell state clipping is performed. When `clipMode` is `CUDNN_RNN_CLIP_MINMAX` the cell state activation to other units is clipped.

- **clipNanOpt**
  - *Input*. When set to `CUDNN_PROPAGATE_NAN` (see the description for `cudnnNanPropagation_t`), NaN is propagated from the LSTM cell, or it can be set to one of the clipping range boundary values, instead of propagating.

- **lclip, rclip**
  - *Input*. The range `[lclip, rclip]` to which the LSTM cell clipping should be set.

Returns

- **CUDNN_STATUS_SUCCESS**
  - The function completed successfully.

- **CUDNN_STATUS_BAD_PARAM**
  - An invalid input argument was found, for example:
    - `rnnDesc` was NULL
    - `lclip > rclip`
    - either `lclip` or `rclip` is NaN

7.2.43. cudnnSetAttnDescriptor()

This function configures a multi-head attention descriptor that was previously created using the cudnnCreateAttnDescriptor() function. The function sets attention parameters that are necessary to compute internal buffer sizes, dimensions of weight and bias tensors, or to select optimized code paths.

```
cudnnStatus_t cudnnSetAttnDescriptor(
    cudnnAttnDescriptor_t attnDesc,
    unsigned attnMode,
    int nHeads,
    double smScaler,
);```
Input sequence data descriptors in `cudnnMultiHeadAttnForward()`, `cudnnMultiHeadAttnBackwardData()` and `cudnnMultiHeadAttnBackwardWeights()` functions are checked against the configuration parameters stored in the attention descriptor. Some parameters must match exactly while max arguments such as `maxBatchSize` or `qoMaxSeqLength` establish upper limits for the corresponding dimensions.

The multi-head attention model can be described by the following equations:

\[ h_i = \text{softmax}(\text{smScaler}(K^T W^T_i)(W_Q q)), \text{ for } i = 0 \ldots \text{nHeads} - 1 \]

\[ \text{MultiHeadAttn}(q, K, V, W_Q, W_K, W_V, W_O) = \sum_{i=0}^{\text{nHeads} - 1} W_O h_i \]

Where:
- `nHeads` is the number of independent attention heads that evaluate `h_i` vectors.
- `q` is a primary input, a single query column vector.
- `K, V` are two matrices of key and value column vectors.

For simplicity, the above equations are presented using a single embedding vector `q` but the cuDNN API can handle multiple `q` candidates in the beam search scheme, process `q` vectors from multiple sequences bundled into a batch, or automatically iterate through all embedding vectors (time-steps) of a sequence. Thus, in general, `q, K, V` inputs are tensors with additional pieces of information such as the active length of each sequence or how unused padding vectors should be saved.

In some publications, `W_Oi` matrices are combined into one output projection matrix and `h_i` vectors are merged explicitly into a single vector. This is an equivalent notation. In the cuDNN library, `W_Oi` matrices are conceptually treated the same way as `W_Qi`, `W_Ki` or `W_Vi` input projection weights. See the description of the `cudnnGetMultiHeadAttnWeights()` function for more details.

Weight matrices `W_Qi`, `W_Ki`, `W_Vi` and `W_Oi` play similar roles, adjusting vector lengths in `q`, `K, V` inputs and in the multi-head attention final output. The user can disable any or all projections by setting `qProjSize`, `kProjSize`, `vProjSize` or `oProjSize` arguments to zero.

Embedding vector sizes in `q, K, V` and the vector lengths after projections need to be selected in such a way that matrix multiplications described above are feasible. Otherwise,
CUDNN_STATUS_BAD_PARAM is returned by the cudnnSetAttnDescriptor() function. All four weight matrices are used when it is desirable to maintain rank deficiency of $W_{kQ} = W_{kJ} W_{Qj}$ or $W_{Ov} = W_{Oj} W_{vj}$ matrices to eliminate one or more dimensions during linear transformations in each head. This is a form of feature extraction. In such cases, the projected sizes are smaller than the original vector lengths.

For each attention head, weight matrix sizes are defined as follows:

- $W_{Qj}$ - size $[qProjSize \times qSize]$, $i = 0..nHeads - 1$
- $W_{kJ}$ - size $[kProjSize \times kSize]$, $i = 0..nHeads - 1$, $kProjSize = qProjSize$
- $W_{vj}$ - size $[vProjSize \times vSize]$, $i = 0..nHeads - 1$
- $W_{Oj}$ - size $[oProjSize \times (vProjSize > 0 ? vProjSize : vSize)]$, $i = 0..nHeads - 1$

When the output projection is disabled ($oProjSize = 0$), the output vector length is $nHeads \times (vProjSize > 0 ? vProjSize : vSize)$, meaning, the output is a concatenation of all $h$ vectors. In the alternative interpretation, a concatenated matrix $W_O = [W_{O0} W_{O1} W_{O2} ...]$ forms the identity matrix.

Softmax is a normalized, exponential vector function that takes and outputs vectors of the same size. The multi-head attention API utilizes softmax of the CUDNN_SOFTMAX_ACCURATE type to reduce the likelihood of the floating-point overflow.

The smScaler parameter is the softmax sharpening/smoothing coefficient. When smScaler=1.0, softmax uses the natural exponential function $\exp(x)$ or $2.7183^x$. When smScaler<1.0, for example smScaler=0.2, the function used by the softmax block will not grow as fast because $\exp(0.2x) \approx 1.2214^x$.

The smScaler parameter can be adjusted to process larger ranges of values fed to softmax. When the range is too large (or smScaler is not sufficiently small for the given range), the output vector of the softmax block becomes categorical, meaning, one vector element is close to 1.0 and other outputs are zero or very close to zero. When this occurs, the Jacobian matrix of the softmax block is also close to zero so deltas are not back-propagated during training from output to input except through residual connections, if these connections are enabled. The user can set smScaler to any positive floating-point value or even zero. The smScaler parameter is not trainable.

The qoMaxSeqLength, kvMaxSeqLength, maxBatchSize, and maxBeamSize arguments declare the maximum sequence lengths, maximum batch size, and maximum beam size respectively, in the cudnnSeqDataDescriptor_t containers. The actual dimensions supplied to forward and backward (gradient) API functions should not exceed the max limits. The max arguments should be set carefully because too large values will result in excessive memory usage due to oversized work and reserve space buffers.

The attnMode argument is treated as a binary mask where various on/off options are set. These options can affect the internal buffer sizes, enforce certain argument checks, select optimized code execution paths, or enable attention variants that do not require additional numerical arguments. An example of such options is the inclusion of biases in input and output projections.

The attnDropoutDesc and postDropoutDesc arguments are descriptors that define two dropout layers active in the training mode. The first dropout operation defined...
by `attnDropoutDesc`, is applied directly to the softmax output. The second dropout operation, specified by `postDropoutDesc`, alters the multi-head attention output, just before the point where residual connections are added.

Note: The `cudnnSetAttnDescriptor()` function performs a shallow copy of `attnDropoutDesc` and `postDropoutDesc`, meaning, the addresses of both dropout descriptors are stored in the attention descriptor and not the entire structure. Therefore, the user should keep dropout descriptors during the entire life of the attention descriptor.

Parameters

- **attnDesc**
  - Output. Attention descriptor to be configured.

- **attnMode**
  - Input. Enables various attention options that do not require additional numerical values. See the table below for the list of supported flags. The user should assign a preferred set of bitwise OR-ed flags to this argument.

- **nHeads**
  - Input. Number of attention heads.

- **smScaler**
  - Input. Softmax smoothing \( (1.0 \geq \text{smScaler} \geq 0.0) \) or sharpening \( (\text{smScaler} > 1.0) \) coefficient. Negative values are not accepted.

- **dataType**
  - Input. Data type used to represent attention inputs, attention weights and attention outputs.

- **computePrec**
  - Input. Compute precision.

- **mathType**
  - Input. NVIDIA Tensor Core settings.

- **attnDropoutDesc**
  - Input. Descriptor of the dropout operation applied to the softmax output. See the table below for a list of unsupported features.

- **postDropoutDesc**
  - Input. Descriptor of the dropout operation applied to the multi-head attention output, just before the point where residual connections are added. See the table below for a list of unsupported features.

- **qSize, kSize, vSize**
  - Input. Q, K, V embedding vector lengths.

- **qProjSize, kProjSize, vProjSize**
  - Input. Q, K, V embedding vector lengths after input projections. Use zero to disable the corresponding projection.

- **oProjSize**
  - Input. The \( h \) vector length after the output projection. Use zero to disable this projection.
qoMaxSeqLength

*Input.* Largest sequence length expected in sequence data descriptors related to \( Q, O, dQ \) and \( dO \) inputs and outputs.

kvMaxSeqLength

*Input.* Largest sequence length expected in sequence data descriptors related to \( K, V, dK \) and \( dV \) inputs and outputs.

maxBatchSize

*Input.* Largest batch size expected in any `cudnnSeqDataDescriptor_t` container.

maxBeamSize

*Input.* Largest beam size expected in any `cudnnSeqDataDescriptor_t` container.

**Supported `attnMode` flags**

**CUDNN_ATTN_QUERYMAP_ALL_TO_ONE**

Forward declaration of mapping between \( Q \) and \( K, V \) vectors when the beam size is greater than one in the \( Q \) input. Multiple \( Q \) vectors from the same beam bundle map to the same \( K, V \) vectors. This means that beam sizes in the \( K, V \) sets are equal to one.

**CUDNN_ATTN_QUERYMAP_ONE_TO_ONE**

Forward declaration of mapping between \( Q \) and \( K, V \) vectors when the beam size is greater than one in the \( Q \) input. Multiple \( Q \) vectors from the same beam bundle map to different \( K, V \) vectors. This requires beam sizes in \( K, V \) sets to be the same as in the \( Q \) input.

**CUDNN_ATTN_DISABLE_PROJ_BIASES**

Use no biases in the attention input and output projections.

**CUDNN_ATTN_ENABLE_PROJ_BIASES**

Use extra biases in the attention input and output projections. In this case the projected \( \overline{K} \) vectors are computed as \( \overline{K}_i = W_{Kij}k+b[i\ldots1]_k \), where \( n \) is the number of columns in the \( K \) matrix. In other words, the same column vector \( b \) is added to all columns of \( K \) after the weight matrix multiplication.

**Supported combinations of `dataType`, `computePrec`, and `mathType`**

<table>
<thead>
<tr>
<th><code>dataType</code></th>
<th><code>computePrec</code></th>
<th><code>mathType</code></th>
</tr>
</thead>
<tbody>
<tr>
<td>CUDNN_DATA_DOUBLE</td>
<td>CUDNN_DATA_DOUBLE</td>
<td>CUDNN_DEFAULT_MATH</td>
</tr>
<tr>
<td>CUDNN_DATA_FLOAT</td>
<td>CUDNN_DATA_FLOAT</td>
<td>CUDNN_DEFAULT_MATH,</td>
</tr>
<tr>
<td></td>
<td></td>
<td>CUDNN_TENSOR_OP_MATH_ALLOW_CONVERSION</td>
</tr>
<tr>
<td>CUDNN_DATA_HALF</td>
<td>CUDNN_DATA_HALF,</td>
<td>CUDNN_DEFAULT_MATH,</td>
</tr>
<tr>
<td></td>
<td>CUDNN_DATA_FLOAT</td>
<td>CUDNN_TENSOR_OP_MATH,</td>
</tr>
<tr>
<td></td>
<td></td>
<td>CUDNN_TENSOR_OP_MATH_ALLOW_CONVERSION</td>
</tr>
</tbody>
</table>

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Unsupported features

1. The `paddingFill` argument in `cudnnSeqDataDescriptor_t` is currently ignored by all multi-head attention functions.

Returns

**CUDNN_STATUS_SUCCESS**

The attention descriptor was configured successfully.

**CUDNN_STATUS_BAD_PARAM**

An invalid input argument was encountered. Some examples include:

- post projection \( Q \) and \( K \) sizes were not equal
- `dataType`, `computePrec`, or `mathType` were invalid
- one or more of the following arguments were either negative or zero: \( \text{nHeads}, \text{qSize}, \text{kSize}, \text{vSize}, \text{qoMaxSeqLength}, \text{kvMaxSeqLength}, \text{maxBatchSize}, \text{maxBeamSize} \)
- one or more of the following arguments were negative: \( \text{qProjSize}, \text{kProjSize}, \text{vProjSize}, \text{smScaler} \)

**CUDNN_STATUS_NOT_SUPPORTED**

A requested option or a combination of input arguments is not supported.

7.2.44. `cudnnSetPersistentRNNPlan()`

This function has been deprecated in cuDNN 8.0.

This function sets the persistent RNN plan to be executed when using `rnnDesc` and `CUDNN_RNN_ALGO_PERSIST_DYNAMIC` `algo`.

```c
    cudnnStatus_t cudnnSetPersistentRNNPlan(
        cudnnRNNDescriptor_t        rnnDesc,
        cudnnPersistentRNNPlan_t    plan)
```

Returns

**CUDNN_STATUS_SUCCESS**

The plan was set successfully.

**CUDNN_STATUS_BAD_PARAM**

The algo selected in `rnnDesc` is not `CUDNN_RNN_ALGO_PERSIST_DYNAMIC`.

7.2.45. `cudnnSetRNNAlgorithmDescriptor()`

This function has been deprecated in cuDNN 8.0.
7.2.46. cudnnSetRNNBiasMode()

This function has been deprecated in cuDNN 8.0. Use cudnnSetRNNDescriptor_v8() instead of cudnnSetRNNBiasMode().

```c
#include <cudnn.h>

cudnnStatus_t cudnnSetRNNBiasMode(
    cudnnRNNDescriptor_t   rnnDesc,
    cudnnRNNBiasMode_t     biasMode);
```

The cudnnSetRNNBiasMode() function sets the number of bias vectors for a previously created and initialized RNN descriptor. This function should be called to enable the specified bias mode in an RNN. The default value of biasMode in rnnDesc after cudnnCreateRNNDescriptor() is CUDNN_RNN_DOUBLE_BIAS.

**Parameters**

- **rnnDesc**
  
  *Input/Output.* A previously created RNN descriptor.

- **biasMode**
  
  *Input.* Sets the number of bias vectors. For more information, refer to cudnnRNNBiasMode_t.

**Returns**

- **CUDNN_STATUS_BAD_PARAM**
  
  Either the rnnDesc is NULL or biasMode has an invalid enumerant value.

- **CUDNN_STATUS_SUCCESS**
  
  The biasMode was set successfully.

- **CUDNN_STATUS_NOT_SUPPORTED**
  
  Non-default bias mode (an enumerated type besides CUDNN_RNN_DOUBLE_BIAS) applied to an RNN algo other than CUDNN_RNN_ALGO_STANDARD.

7.2.47. cudnnSetRNNDataDescriptor()

This function initializes a previously created RNN data descriptor object. This data structure is intended to support the unpacked (padded) layout for input and output of extended RNN inference and training functions. A packed (unpadded) layout is also supported for backward compatibility.

```c
#include <cudnn.h>

cudnnStatus_t cudnnSetRNNDataDescriptor(
    cudnnRNNDataDescriptor_t       RNNDataDesc,
    cudnnDataType_t                dataType,
    cudnnRNNDataLayout_t           layout,
    int                            maxSeqLength,
    int                            batchSize,
    int                            vectorSize,
    const int                      seqLengthArray[],
    void                           *paddingFill);
```
Parameters

**RNNDataDesc**

*Input/Output*. A previously created RNN descriptor. For more information, refer to [cudnnRNNDataDescriptor_t](#).

**dataType**

*Input*. The datatype of the RNN data tensor. For more information, refer to [cudnnDataType_t](#).

**layout**

*Input*. The memory layout of the RNN data tensor.

**maxSeqLength**

*Input*. The maximum sequence length within this RNN data tensor. In the unpacked (padded) layout, this should include the padding vectors in each sequence. In the packed (unpadded) layout, this should be equal to the greatest element in `seqLengthArray`.

**batchSize**

*Input*. The number of sequences within the mini-batch.

**vectorSize**

*Input*. The vector length (embedding size) of the input or output tensor at each time-step.

**seqLengthArray**

*Input*. An integer array with `batchSize` number of elements. Describes the length (number of time-steps) of each sequence. Each element in `seqLengthArray` must be greater than or equal to 0 but less than or equal to `maxSeqLength`. In the packed layout, the elements should be sorted in descending order, similar to the layout required by the non-extended RNN compute functions.

**paddingFill**

*Input*. A user-defined symbol for filling the padding position in RNN output. This is only effective when the descriptor is describing the RNN output, and the unpacked layout is specified. The symbol should be in the host memory, and is interpreted as the same data type as that of the RNN data tensor. If a NULL pointer is passed in, then the padding position in the output will be undefined.

Returns

**CUDNN_STATUS_SUCCESS**

The object was set successfully.

**CUDNN_STATUS_NOT_SUPPORTED**

Any one of these have occurred:

- **dataType** is not one of **CUDNN_DATA_HALF**, **CUDNN_DATA_FLOAT**, **CUDNN_DATA_DOUBLE**.
- **maxSeqLength** is larger than 65535 (0xffff).
**CUDNN_STATUS_BAD_PARAM**

Any one of these have occurred:

- RNNDataDesc is NULL.
- Any one of maxSeqLength, batchSize or vectorSize is less than or equal to zero.
- An element of seqLengthArray is less than zero or greater than maxSeqLength.
- Layout is not one of CUDNN_RNN_DATA_LAYOUT_SEQ_MAJOR_UNPACKED, CUDNN_RNN_DATA_LAYOUT_SEQ_MAJOR_PACKED or CUDNN_RNN_DATA_LAYOUT_BATCH_MAJOR_UNPACKED.

**CUDNN_STATUS_ALLOC_FAILED**

The allocation of internal array storage has failed.

7.2.48. **cudnnSetRNNDescriptor_v6()**

This function has been deprecated in cuDNN 8.0. Use **cudnnSetRNNDescriptor_v8()** instead of **cudnnSetRNNDescriptor_v6()**.

```c
    cudnnStatus_t cudnnSetRNNDescriptor_v6(
        cudnnHandle_t                    handle,
        cudnnRNNDescriptor_t             rnnDesc,
        const int                        hiddenSize,
        const int                        numLayers,
        cudnnDropoutDescriptor_t         dropoutDesc,
        cudnnRNNInputMode_t              inputMode,
        cudnnDirectionMode_t             direction,
        cudnnRNNMode_t                   mode,
        cudnnRNNAlgo_t                   algo,
        cudnnDataType_t                  mathPrec)
```

This function initializes a previously created RNN descriptor object.

**Note:** Larger networks, for example, longer sequences or more layers, are expected to be more efficient than smaller networks.

**Parameters**

- **handle**
  
  *Input.* Handle to a previously created cuDNN library descriptor.

- **rnnDesc**
  
  *Input/Output.* A previously created RNN descriptor.

- **hiddenSize**
  
  *Input.* Size of the internal hidden state for each layer.

- **numLayers**
  
  *Input.* Number of stacked layers.

- **dropoutDesc**
  
  *Input.* Handle to a previously created and initialized dropout descriptor. Dropout will be applied between layers, for example, a single layer network will have no dropout applied.
**inputMode**

*Input.* Specifies the behavior at the input to the first layer.

**direction**

*Input.* Specifies the recurrence pattern, for example, bidirectional.

**mode**

*Input.* Specifies the type of RNN to compute.

**algo**

*Input.* Specifies which RNN algorithm should be used to compute the results.

**mathPrec**

*Input.* Math precision. This parameter is used for controlling the math precision in RNN. The following applies:

- For the input/output in FP16, the parameter `mathPrec` can be `CUDNN_DATA_HALF` or `CUDNN_DATA_FLOAT`.
- For the input/output in FP32, the parameter `mathPrec` can only be `CUDNN_DATA_FLOAT`.
- For the input/output in FP64, double type, the parameter `mathPrec` can only be `CUDNN_DATA_DOUBLE`.

**Returns**

**CUDNN_STATUS_SUCCESS**

The object was set successfully.

**CUDNN_STATUS_BAD_PARAM**

Either at least one of the parameters `hiddenSize` or `numLayers` was zero or negative, one of `inputMode`, `direction`, `mode`, `algo` or `dataType` has an invalid enumerant value, `dropoutDesc` is an invalid dropout descriptor or `rnnDesc` has not been created correctly.

### 7.2.49. cudnnSetRNNDescriptor_v8()

This function initializes a previously created RNN descriptor object. The RNN descriptor configured by `cudnnSetRNNDescriptor_v8()` was enhanced to store all information needed to compute the total number of adjustable weights/biases in the RNN model.

```c
void cudnnSetRNNDescriptor_v8(cudnnRNNDescriptor_t rnnDesc, 
   cudnnRNNAlgo_t algo, 
   cudnnRNNMode_t cellMode, 
   cudnnRNNBiasMode_t biasMode, 
   cudnnDirectionMode_t dirMode, 
   cudnnRNNInputMode_t inputMode, 
   cudnnDataType_t dataType, 
   cudnnDataType_t mathPrec, 
   cudnnMathType_t mathType, 
   int32_t inputSize, 
   int32_t hiddenSize, 
   int32_t projSize, 
   int32_t numLayers, 
   cudnnDropoutDescriptor_t dropoutDesc, 
   uint32_t auxFlags); 
```
Parameters

rnnDesc
  *Input*. A previously initialized RNN descriptor.

algo
  *Input*. RNN algo (CUDNN_RNN_ALGO_STANDARD, CUDNN_RNN_ALGO_PERSIST_STATIC, or CUDNN_RNN_ALGO_PERSIST_DYNAMIC).

cellMode
  *Input*. Specifies the RNN cell type in the entire model (CUDNN_RNN_RELU, CUDNN_RNN_TANH, CUDNN_RNN_LSTM, CUDNN_RNN_GRU).

biasMode
  *Input*. Sets the number of bias vectors (CUDNN_RNN_NO_BIAS, CUDNN_RNN_SINGLE_INP_BIAS, CUDNN_RNN_SINGLE_REC_BIAS, CUDNN_RNN_DOUBLE_BIAS). The two single bias settings are functionally the same for RELU, TANH and LSTM cell types. For differences in GRU cells, see the description of CUDNN_GRU in the cudnnRNNMode_t enumerated type.

dirMode
  *Input*. Specifies the recurrence pattern: CUDNN_UNIDIRECTIONAL or CUDNN_BIDIRECTIONAL. In bidirectional RNNs, the hidden states passed between physical layers are concatenations of forward and backward hidden states.

inputMode
  *Input*. Specifies how the input to the RNN model is processed by the first layer. When inputMode is CUDNN_LINEAR_INPUT, original input vectors of size inputSize are multiplied by the weight matrix to obtain vectors of hiddenSize. When inputMode is CUDNN_SKIP_INPUT, the original input vectors to the first layer are used as is without multiplying them by the weight matrix.

dataType
  *Input*. Specifies data type for RNN weights/biases and input and output data.

mathPrec
  *Input*. This parameter is used to control the compute math precision in the RNN model. The following applies:
  ```
  ▶ For the input/output in FP16, the parameter mathPrec can be CUDNN_DATA_HALF or CUDNN_DATA_FLOAT.
  ▶ For the input/output in FP32, the parameter mathPrec can only be CUDNN_DATA_FLOAT.
  ▶ For the input/output in FP64, double type, the parameter mathPrec can only be CUDNN_DATA_DOUBLE.
  ```

mathType
  *Input*. Sets the preferred option to use NVIDIA Tensor Cores accelerators on Volta (SM 7.0) or higher GPU-s.)
When `dataType` is `CUDNN_DATA_HALF`, the `mathType` parameter can be `CUDNN_DEFAULT_MATH` or `CUDNN_TENSOR_OP_MATH`. The `ALLOW_CONVERSION` setting is treated the same as `CUDNN_TENSOR_OP_MATH` for this data type.

When `dataType` is `CUDNN_DATA_FLOAT`, the `mathType` parameter can be `CUDNN_DEFAULT_MATH` or `CUDNN_TENSOR_OP_MATH_ALLOW_CONVERSION`. When the latter settings are used, original weights and intermediate results will be down-converted to `CUDNN_DATA_HALF` before they are used in another recursive iteration.

When `dataType` is `CUDNN_DATA_DOUBLE`, the `mathType` parameter can be `CUDNN_DEFAULT_MATH`.

This option has an advisory status meaning Tensor Cores may not be always utilized, for example, due to specific GEMM dimensions restrictions.

**inputSize**

*Input*. Size of the input vector in the RNN model. When the `inputMode=CUDNN_SKIP_INPUT`, the `inputSize` should match the `hiddenSize` value.

**hiddenSize**

*Input*. Size of the hidden state vector in the RNN model. The same hidden size is used in all RNN layers.

**projSize**

*Input*. The size of the LSTM cell output after the recurrent projection. This value should not be larger than `hiddenSize`. It is legal to set `projSize` equal to `hiddenSize`, however, in this case, the recurrent projection feature is disabled. The recurrent projection is an additional matrix multiplication in the LSTM cell to project hidden state vectors $h_t$ into smaller vectors $r_t = W_r h_t$, where $W_r$ is a rectangular matrix with `projSize` rows and `hiddenSize` columns. When the recurrent projection is enabled, the output of the LSTM cell (both to the next layer and unrolled in-time) is $r_t$ instead of $h_t$. The recurrent projection can be enabled for LSTM cells and `CUDNN_RNN_ALGO_STANDARD` only.

**numLayers**

*Input*. Number of stacked, physical layers in the deep RNN model. When `dirMode=CUDNN_BIDIRECTIONAL`, the physical layer consists of two pseudo-layers corresponding to forward and backward directions.

**dropoutDesc**

*Input*. Handle to a previously created and initialized dropout descriptor. Dropout operation will be applied between physical layers. A single layer network will have no dropout applied. Dropout is used in the training mode only.

**auxFlags**

*Input*. This argument is used to pass miscellaneous switches that do not require additional numerical values to configure the corresponding feature. In future cuDNN releases, this parameter will be used to extend the RNN functionality without adding new API functions (applicable options should be bitwise OR-ed). Currently, this parameter is used to enable or disable padded input/output (`CUDNN_RNN_PADDED_IO_DISABLED`, `CUDNN_RNN_PADDED_IO_ENABLED`). When the
padded I/O is enabled, layouts `CUDNN_RNN_DATA_LAYOUT_SEQ_MAJOR_UNPACKED` and `CUDNN_RNN_DATA_LAYOUT_BATCH_MAJOR_UNPACKED` are permitted in RNN data descriptors.

**Returns**

**CUDNN\_STATUS\_SUCCESS**

The RNN descriptor was configured successfully.

**CUDNN\_STATUS\_BAD\_PARAM**

An invalid input argument was detected.

**CUDNN\_STATUS\_NOT\_SUPPORTED**

The dimensions of the bias tensor refer to an amount of data that is incompatible with the output tensor dimensions or the `dataType` of the two tensor descriptors are different.

**CUDNN\_STATUS\_EXECUTION\_FAILED**

An incompatible or unsupported combination of input arguments was detected.

### 7.2.50. `cudnnSetRNNMatrixMathType()`

This function has been deprecated in cuDNN 8.0. Use `cudnnSetRNNDescriptor_v8()` instead of `cudnnSetRNNMatrixMathType()`.

```c
int cudnnStatus_t cudnnSetRNNMatrixMathType(
    cudnnRNNDescriptor_t rnnDesc,
    cudnnMathType_t mType)
```

This function sets the preferred option to use NVIDIA Tensor Cores accelerators on Volta GPUs (SM 7.0 or higher). When the `mType` parameter is `CUDNN\_TENSOR\_OP\_MATH`, inference and training RNN APIs will attempt use Tensor Cores when weights/biases are of type `CUDNN\_DATA\_HALF` or `CUDNN\_DATA\_FLOAT`. When RNN weights/biases are stored in the `CUDNN\_DATA\_FLOAT` format, the original weights and intermediate results will be down-converted to `CUDNN\_DATA\_HALF` before they are used in another recursive iteration.

**Parameters**

- **rnnDesc**
  
  *Input.* A previously created and initialized RNN descriptor.

- **mType**

  *Input.* A preferred compute option when performing RNN GEMMs (general matrix-matrix multiplications). This option has an advisory status meaning that Tensor Cores may not be utilized, for example, due to specific GEMM dimensions.

**Returns**

**CUDNN\_STATUS\_SUCCESS**

The preferred compute option for the RNN network was set successfully.

**CUDNN\_STATUS\_BAD\_PARAM**

An invalid input parameter was detected.
7.2.51. **cudnnSetRNNPaddingMode()**

This function has been deprecated in cuDNN 8.0. Use `cudnnSetRNNDescriptor_v8()` instead of `cudnnSetRNNPaddingMode()`.

```c
    cudnnStatus_t cudnnSetRNNPaddingMode(
        cudnnRNNDescriptor_t    _rnnDesc,
        cudnnRNNPaddingMode_t     paddingMode)
```

This function enables or disables the padded RNN input/output for a previously created and initialized RNN descriptor. This information is required before calling the `cudnnGetRNNWorkspaceSize()` and `cudnnGetRNNTrainingReserveSize()` functions, to determine whether additional workspace and training reserve space is needed. By default, the padded RNN input/output is not enabled.

**Parameters**

- **rnnDesc**: *Input/Output*. A previously created RNN descriptor.
- **paddingMode**: *Input*. Enables or disables the padded input/output. For more information, refer to `cudnnRNNPaddingMode_t`.

**Returns**

- **CUDNN_STATUS_SUCCESS**: The `paddingMode` was set successfully.
- **CUDNN_STATUS_BAD_PARAM**: Either the `rnnDesc` is NULL or `paddingMode` has an invalid enumerant value.

---

7.2.52. **cudnnSetRNNProjectionLayers()**

This function has been deprecated in cuDNN 8.0. Use `cudnnSetRNNDescriptor_v8()` instead of `cudnnSetRNNProjectionLayers()`.

```c
    cudnnStatus_t cudnnSetRNNProjectionLayers(
        cudnnHandle_t          handle,
        cudnnRNNDescriptor_t   rnnDesc,
        int                    recProjSize,
        int                    outProjSize)
```

The `cudnnSetRNNProjectionLayers()` function should be called to enable the recurrent and/or output projection in a recursive neural network. The recurrent projection is an additional matrix multiplication in the LSTM cell to project hidden state vectors $h_t$ into smaller vectors $r_t = W_r h_t$, where $W_r$ is a rectangular matrix with `recProjSize` rows and `hiddenSize` columns. When the recurrent projection is enabled, the output of the LSTM cell (both to the next layer and unrolled in-time) is $r_t$ instead of $h_t$. The dimensionality of $i_t$, $f_t$, $o_t$ and $c_t$ vectors used in conjunction with non-linear functions remains the same as in the canonical LSTM cell. To make this possible, the shapes of matrices in the LSTM formulas (refer to `cudnnRNNMode_t` type), such as $W_i$ in hidden RNN layers or $R_i$ in the entire network, become rectangular versus square in the canonical LSTM mode. Obviously, the result of $R_i^* W_r$ is a square matrix but it is rank deficient, reflecting
the compression of LSTM output. The recurrent projection is typically employed when the number of independent (adjustable) weights in the RNN network with projection is smaller in comparison to canonical LSTM for the same hiddenSize value.

The recurrent projection can be enabled for LSTM cells and CUDNN_RNN_ALGO_STANDARD only. The recProjSize parameter should be smaller than the hiddenSize value. It is legal to set recProjSize equal to hiddenSize but in that case the recurrent projection feature is disabled.

The output projection is currently not implemented.

For more information on the recurrent and output RNN projections, refer to the paper by Hasim Sak, et al.: Long Short-Term Memory Based Recurrent Neural Network Architectures For Large Vocabulary Speech Recognition.

Parameters

**handle**
- Input. Handle to a previously created cuDNN library descriptor.

**rnnDesc**
- Input. A previously created and initialized RNN descriptor.

**recProjSize**
- Input. The size of the LSTM cell output after the recurrent projection. This value should not be larger than hiddenSize.

**outProjSize**
- Input. This parameter should be zero.

Returns

**CUDNN_STATUS_SUCCESS**
- RNN projection parameters were set successfully.

**CUDNN_STATUS_BAD_PARAM**
- An invalid input argument was detected (for example, NULL handles, negative values for projection parameters).

**CUDNN_STATUS_NOT_SUPPORTED**
- Projection applied to RNN algo other than CUDNN_RNN_ALGO_STANDARD, cell type other than CUDNN_LSTM, recProjSize larger than hiddenSize.

### 7.2.53. cudnnSetSeqDataDescriptor()

This function initializes a previously created sequence data descriptor object. In the most simplified view, this descriptor defines dimensions (dimA) and the data layout (axes) of a four-dimensional tensor.

```c
void cudnnSetSeqDataDescriptor(
    cudnnSeqDataDescriptor_t seqDataDesc,
    cudnnDataType_t dataType,
    int nbDims,
    const int dimA[],
    const cudnnSeqDataAxis_t axes[],
    size_t seqLengthArraySize,
    const int seqLengthArray[],
)
```
All four dimensions of the sequence data descriptor have unique identifiers that can be used to index the `dimA[]` array:

<table>
<thead>
<tr>
<th>Identifier</th>
</tr>
</thead>
<tbody>
<tr>
<td>CUDNN_SEQDATA_TIME_DIM</td>
</tr>
<tr>
<td>CUDNN_SEQDATA_BATCH_DIM</td>
</tr>
<tr>
<td>CUDNN_SEQDATA_BEAM_DIM</td>
</tr>
<tr>
<td>CUDNN_SEQDATA_VECT_DIM</td>
</tr>
</tbody>
</table>

For example, to express information that vectors in our sequence data buffer are five elements long, we need to assign `dimA[CUDNN_SEQDATA_VECT_DIM]=5` in the `dimA[]` array.

The number of active dimensions in the `dimA[]` and `axes[]` arrays is defined by the `nbDims` argument. Currently, the value of this argument should be four. The actual size of the `dimA[]` and `axes[]` arrays should be declared using the `CUDNN_SEQDATA_DIM_COUNT` macro.

The `cudnnSeqDataDescriptor_t` container is treated as a collection of fixed length vectors that form sequences, similarly to words (vectors of characters) constructing sentences. The `TIME` dimension spans the sequence length. Different sequences are bundled together in a batch. A `BATCH` may be a group of individual sequences or beams. A `BEAM` is a cluster of alternative sequences or candidates. When thinking about the beam, consider a translation task from one language to another. You may want to keep around and experiment with several translated versions of the original sentence before selecting the best one. The number of candidates kept around is the `BEAM` size.

Every sequence can have a different length, even within the same beam, so vectors toward the end of the sequence can be just padding. The `paddingFill` argument specifies how the padding vectors should be written in output sequence data buffers. The `paddingFill` argument points to one value of type `dataType` that should be copied to all elements in padding vectors. Currently, the only supported value for `paddingFill` is `NULL` which means this option should be ignored. In this case, elements of the padding vectors in output buffers will have undefined values.

It is assumed that a non-empty sequence always starts from the time index zero. The `seqLengthArray[]` must specify all sequence lengths in the container so the total size of this array should be `dimA[CUDNN_SEQDATA_BATCH_DIM] * dimA[CUDNN_SEQDATA_BEAM_DIM]`. Each element of the `seqLengthArray[]` should have a non-negative value, less than or equal to `dimA[CUDNN_SEQDATA_TIME_DIM]` the maximum sequence length. Elements in `seqLengthArray[]` are always arranged in the same batch-major order, meaning, when considering `BEAM` and `BATCH` dimensions, `BATCH` is the outer or the slower changing index when we traverse the array in ascending order of the addresses. Using a simple example, the `seqLengthArray[]` array should hold sequence lengths in the following order:

```c
{batch_idx=0, beam_idx=0}
{batch_idx=0, beam_idx=1}
{batch_idx=1, beam_idx=0}
{batch_idx=1, beam_idx=1}
{batch_idx=2, beam_idx=0}
{batch_idx=2, beam_idx=1}
```


Data stored in the `cudnnSeqDataDescriptor_t` container must comply with the following constraints:
All data is fully packed. There are no unused spaces or gaps between individual vector elements or consecutive vectors.

The most inner dimension of the container is the vector. In other words, the first contiguous group of $\text{dimA}[\text{CUDNN\_SEQDATA\_VECT\_DIM}]$ elements belongs to the first vector, followed by elements of the second vector, and so on.

The axes argument in the `cudnnSetSeqDataDescriptor()` function is a bit more complicated. This array should have the same capacity as $\text{dimA}[]$. The axes[] array specifies the actual data layout in the GPU memory. In this function, the layout is described in the following way: as we move from one element of a vector to another in memory by incrementing the element pointer, what is the order of VECT, TIME, BATCH, and BEAM dimensions that we encounter. Let us assume that we want to define the following data layout:

**Figure 5. Data Layout Example for `cudnnSetSeqDataDescriptor()`**

That corresponds to tensor dimensions:

```c
int dimA[\text{CUDNN\_SEQDATA\_DIM\_COUNT}];
dimA[\text{CUDNN\_SEQDATA\_TIME\_DIM}] = 4;
dimA[\text{CUDNN\_SEQDATA\_BATCH\_DIM}] = 3;
dimA[\text{CUDNN\_SEQDATA\_BEAM\_DIM}] = 2;
dimA[\text{CUDNN\_SEQDATA\_VECT\_DIM}] = 5;
```

Now, let's initialize the axes[] array. Note that the most inner dimension is described by the last active element of axes[]. There is only one valid configuration here as we always traverse a full vector first. Thus, we need to write `\text{CUDNN\_SEQDATA\_VECT\_DIM}` in the last active element of axes[].

```c
cudnnSeqDataAxis_t axes[\text{CUDNN\_SEQDATA\_DIM\_COUNT}];
axes[3] = \text{CUDNN\_SEQDATA\_VECT\_DIM};  // 3 = \text{nbDims-1}
```

Now, let's work on the remaining three elements of axes[]. When we reach the end of the first vector, we jump to the next beam, therefore:

```c
axes[2] = \text{CUDNN\_SEQDATA\_BEAM\_DIM};
```

When we approach the end of the second vector, we move to the next batch, therefore:

```c
axes[1] = \text{CUDNN\_SEQDATA\_BATCH\_DIM};
```

The last (outermost) dimension is TIME:

```c
axes[0] = \text{CUDNN\_SEQDATA\_TIME\_DIM};
```

The four values of the axes[] array fully describe the data layout depicted in the figure.
The sequence data descriptor allows the user to select $3! = 6$ different data layouts or permutations of BEAM, BATCH and TIME dimensions. The multi-head attention API supports all six layouts.

**Parameters**

seqDataDesc
- Output. Pointer to a previously created sequence data descriptor.

dataType
- Input. Data type of the sequence data buffer (`CUDNN_DATA_HALF`, `CUDNN_DATA_FLOAT` or `CUDNN_DATA_DOUBLE`).

nbDims
- Input. Must be 4. The number of active dimensions in dimA[] and axes[] arrays. Both arrays should be declared to contain at least `CUDNN_SEQDATA_DIM_COUNT` elements.

dimA[]
- Input. Integer array specifying sequence data dimensions. Use the `cudnnSeqDataAxis_t` enumerated type to index all active dimA[] elements.

axes[]
- Input. Array of `cudnnSeqDataAxis_t` that defines the layout of sequence data in memory. The first nbDims elements of axes[] should be initialized with the outermost dimension in axes[0] and the innermost dimension in axes[nbDims-1].

seqLengthArraySize
- Input. Number of elements in the sequence length array, seqLengthArray[].

seqLengthArray[]
- Input. An integer array that defines all sequence lengths of the container.

paddingFill
- Input. Must be NULL. Pointer to a value of dataType that is used to fill up output vectors beyond the valid length of each sequence or NULL to ignore this setting.

**Returns**

CUDNN_STATUS_SUCCESS
All input arguments were validated and the sequence data descriptor was successfully updated.

CUDNN_STATUS_BAD_PARAM
An invalid input argument was found. Some examples include:
- seqDataDesc=NULL
- dataType was not a valid type of `cudnnDataType_t`
- nbDims was negative or zero
- seqLengthArraySize did not match the expected length
- some elements of seqLengthArray[] were invalid

CUDNN_STATUS_NOT_SUPPORTED
An unsupported input argument was encountered. Some examples include:
- nbDims is not equal to 4
- paddingFill is not NULL

**CUDNN_STATUS_ALLOC_FAILED**
Failed to allocate storage for the sequence data descriptor object.
Chapter 8.  cudnn_adv_train.so Library

This entity contains all the training counterparts of cudnn_adv_infer. The cudnn_adv_train library depends on cudnn_ops_infer, cudnn_ops_train, and cudnn_adv_infer.

8.1.  Data Type References
These are the data type references in the cudnn_adv_train.so library.

8.1.1.  Enumeration Types
These are the enumeration types in the cudnn_adv_train.so library.

8.1.1.1.  cudnnLossNormalizationMode_t

cudnnLossNormalizationMode_t is an enumerated type that controls the input normalization mode for a loss function. This type can be used with cudnnSetCTCLossDescriptorEx().

Values

**CUDA LOSS NORMALIZATION NONE**
The input probs of the cudnnCTCLoss() function is expected to be the normalized probability, and the output gradients is the gradient of loss with respect to the unnormalized probability.

**CUDA LOSS NORMALIZATION SOFTMAX**
The input probs of the cudnnCTCLoss() function is expected to be the unnormalized activation from the previous layer, and the output gradients is the gradient with respect to the activation. Internally the probability is computed by softmax normalization.
8.1.1.2. **cudnnWgradMode_t**

*cudnnWgradMode_t* is an enumerated type that selects how buffers holding gradients of the loss function, computed with respect to trainable parameters, are updated. Currently, this type is used by the `cudnnMultiHeadAttnBackwardWeights()` and `cudnnRNNBackwardWeights_v8()` functions only.

**Values**

**CUDNN_WGRAD_MODE_ADD**

A weight gradient component corresponding to a new batch of inputs is added to previously evaluated weight gradients. Before using this mode, the buffer holding weight gradients should be initialized to zero. Alternatively, the first API call outputting to an uninitialized buffer should use the `CUDNN_WGRAD_MODE_SET` option.

**CUDNN_WGRAD_MODE_SET**

A weight gradient component, corresponding to a new batch of inputs, overwrites previously stored weight gradients in the output buffer.

8.2. **API Functions**

These are the API functions in the *cudnn_adv_train.so* library.

8.2.1. **cudnnAdvTrainVersionCheck()**

This function checks whether the version of the *AdvTrain* subset of the library is consistent with the other sub-libraries.

```
cudnnStatus_t cudnnAdvTrainVersionCheck(void)
```

**Returns**

**CUDNN_STATUS_SUCCESS**

The version is consistent with other sub-libraries.

**CUDNN_STATUS_VERSION_MISMATCH**

The version of *AdvTrain* is not consistent with other sub-libraries. Users should check the installation and make sure all sub-component versions are consistent.

8.2.2. **cudnnCreateCTCLossDescriptor()**

This function creates a CTC loss function descriptor.

```
cudnnStatus_t cudnnCreateCTCLossDescriptor(
    cudnnCTCLossDescriptor_t* ctcLossDesc)
```
### Parameters

**ctcLossDesc**

*Output.* CTC loss descriptor to be set. For more information, refer to `cudnnCTCLossDescriptor_t`.

### Returns

**CUDNN_STATUS_SUCCESS**

The function returned successfully.

**CUDNN_STATUS_BAD_PARAM**

CTC loss descriptor passed to the function is invalid.

**CUDNN_STATUS_ALLOC_FAILED**

Memory allocation for this CTC loss descriptor failed.

### 8.2.3. `cudnnCTCLoss()`

This function returns the CTC costs and gradients, given the probabilities and labels.

```c
void cudnnCTCLoss(
    cudnnHandle_t handle,
    const cudnnTensorDescriptor_t probsDesc,
    const void *probs,
    const int hostLabels[],
    const int hostLabelLengths[],
    const int hostInputLengths[],
    void *costs,
    const cudnnTensorDescriptor_t gradientsDesc,
    const void *gradients,
    cudnnCTCLossAlgo_t algo,
    const cudnnCTCLossDescriptor_t ctcLossDesc,
    void *workspace,
    size_t *workSpaceSizeInBytes)
```

**Note:** This function can have an inconsistent interface depending on the `cudnnLossNormalizationMode_t` chosen (bound to the `cudnnCTCLossDescriptor_t` with `cudnnSetCTCLossDescriptorEx()`). For the **CUDNN LOSS NORMALIZATION NONE**, this function has an inconsistent interface, for example, the `probs` input is probability normalized by softmax, but the `gradients` output is with respect to the unnormalized activation. However, for **CUDNN LOSS NORMALIZATION SOFTMAX**, the function has a consistent interface; all values are normalized by softmax.

### Parameters

**handle**

*Input.* Handle to a previously created cuDNN context. For more information, refer to `cudnnHandle_t`.

**probsDesc**

*Input.* Handle to the previously initialized probabilities tensor descriptor. For more information, refer to `cudnnTensorDescriptor_t`. 

---

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probs
   Input. Pointer to a previously initialized probabilities tensor. These input probabilities are normalized by softmax.

hostLabels
   Input. Pointer to a previously initialized labels list, in CPU memory.

hostLabelLengths
   Input. Pointer to a previously initialized lengths list in CPU memory, to walk the above labels list.

hostInputLengths
   Input. Pointer to a previously initialized list of the lengths of the timing steps in each batch, in CPU memory.

costs
   Output. Pointer to the computed costs of CTC.

gradientsDesc
   Input. Handle to a previously initialized gradient tensor descriptor.

gradients
   Output. Pointer to the computed gradients of CTC. These computed gradient outputs are with respect to the unnormalized activation.

algo
   Input. Enumerant that specifies the chosen CTC loss algorithm. For more information, refer to cudnnCTCLossAlgo_t.

ctcLossDesc
   Input. Handle to the previously initialized CTC loss descriptor. For more information, refer to cudnnCTCLossDescriptor_t.

workspace
   Input. Pointer to GPU memory of a workspace needed to be able to execute the specified algorithm.

sizeInBytes
   Input. Amount of GPU memory needed as workspace to be able to execute the CTC loss computation with the specified algo.

Returns

CUDNN_STATUS_SUCCESS
   The query was successful.

CUDNN_STATUS_BAD_PARAM
   At least one of the following conditions are met:
   ▶ The dimensions of probsDesc do not match the dimensions of gradientsDesc.
   ▶ The inputLengths do not agree with the first dimension of probsDesc.
   ▶ The workSpaceSizeInBytes is not sufficient.
   ▶ The labelLengths is greater than 255.
CUDNN_STATUS_NOT_SUPPORTED
A compute or data type other than FLOAT was chosen, or an unknown algorithm type was chosen.

CUDNN_STATUS_EXECUTION_FAILED
The function failed to launch on the GPU.

8.2.4. cudnnCTCloss_v8()
This function returns the CTC costs and gradients, given the probabilities and labels. Many CTC API functions were updated in v8 with the _v8 suffix to support CUDA graphs. Label and input data is now passed in GPU memory, and cudnnCTClossDescriptor_t should be set using cudnnSetCTClossDescriptor_v8().

```c
void cudnnStatus_t cudnnCTCloss_v8(  
    cudnnHandle_t                        handle,  
    cudnnCTClossAlgo_t                   algo,  
    const cudnnCTClossDescriptor_t     ctcLossDesc,  
    const cudnnTensorDescriptor_t      probsDesc,  
    const void                        *probs,  
    const int                          labels[],  
    const int                          labelLengths[],  
    const int                          inputLengths[],  
    void                                *costs,  
    const cudnnTensorDescriptor_t      gradientsDesc,  
    const void                        *gradients,  
    size_t                              *workSpaceSizeInBytes,  
    void                                *workspace)
```

Note: This function can have an inconsistent interface depending on the cudnnLossNormalizationMode_t chosen (bound to the cudnnCTClossDescriptor_t with cudnnSetCTClossDescriptorEx()). For the CUDNN_LOSS_NORMALIZATION_NONE, this function has an inconsistent interface, for example, the probs input is probability normalized by softmax, but the gradients output is with respect to the unnormalized activation. However, for CUDNN_LOSS_NORMALIZATION_SOFTMAX, the function has a consistent interface; all values are normalized by softmax.

Parameters

**handle**
- *Input.* Handle to a previously created cuDNN context. For more information, refer to cudnnHandle_t.

**algo**
- *Input.* Enumerant that specifies the chosen CTC loss algorithm. For more information, refer to cudnnCTClossAlgo_t.

**ctcLossDesc**
- *Input.* Handle to the previously initialized CTC loss descriptor. To use this _v8 function, this descriptor must be set using cudnnSetCTClossDescriptor_v8(). For more information, refer to cudnnCTClossDescriptor_v8().

**probsDesc**
- *Input.* Handle to the previously initialized probabilities tensor descriptor. For more information, refer to cudnnTensorDescriptor_t.
probs
   Input. Pointer to a previously initialized probabilities tensor. These input probabilities are normalized by softmax.

labels
   Input. Pointer to a previously initialized labels list, in GPU memory.

labelLengths
   Input. Pointer to a previously initialized lengths list in GPU memory, to walk the above labels list.

inputLengths
   Input. Pointer to a previously initialized list of the lengths of the timing steps in each batch, in GPU memory.

costs
   Output. Pointer to the computed costs of CTC.

gradientsDesc
   Input. Handle to a previously initialized gradient tensor descriptor.

gradients
   Output. Pointer to the computed gradients of CTC. These computed gradient outputs are with respect to the unnormalized activation.

workspace
   Input. Pointer to GPU memory of a workspace needed to be able to execute the specified algorithm.

sizeInBytes
   Input. Amount of GPU memory needed as a workspace to be able to execute the CTC loss computation with the specified algo.

Returns

CUDNN_STATUS_SUCCESS
   The query was successful.

CUDNN_STATUS_BAD_PARAM
   At least one of the following conditions are met:
   ▶ The dimensions of probsDesc do not match the dimensions of gradientsDesc.
   ▶ The inputLengths do not agree with the first dimension of probsDesc.
   ▶ The workspaceSizeInBytes is not sufficient.
   ▶ The labelLengths is greater than 256.

CUDNN_STATUS_NOT_SUPPORTED
   A compute or data type other than FLOAT was chosen, or an unknown algorithm type was chosen.

CUDNN_STATUS_EXECUTION_FAILED
   The function failed to launch on the GPU.
8.2.5. **cudnnDestroyCTCLossDescriptor()**

This function destroys a CTC loss function descriptor object.

```
cudnnStatus_t cudnnDestroyCTCLossDescriptor(
    cudnnCTCLossDescriptor_t  ctcLossDesc)
```

**Parameters**

- `ctcLossDesc`
  - *Input*. CTC loss function descriptor to be destroyed.

**Returns**

- **CUDNN_STATUS_SUCCESS**
  - The function returned successfully.

8.2.6. **cudnnFindRNNBackwardDataAlgorithmEx()**

This function has been deprecated in cuDNN 8.0.

This function attempts all available cuDNN algorithms for `cudnnRNNBackwardData()`, using user-allocated GPU memory. It outputs the parameters that influence the performance of the algorithm to a user-allocated array of `cudnnAlgorithmPerformance_t`. These parameter metrics are written in sorted fashion where the first element has the lowest compute time.

```
cudnnStatus_t cudnnFindRNNBackwardDataAlgorithmEx(  
    cudnnHandle_t                    handle,  
    const cudnnRNNDescriptor_t       rnnDesc,  
    const int                        seqLength,  
    const cudnnTensorDescriptor_t    *yDesc,  
    const void                       *y,  
    const cudnnTensorDescriptor_t    *dyDesc,  
    const void                       *dy,  
    const cudnnTensorDescriptor_t    dhyDesc,  
    const void                       *dhy,  
    const cudnnTensorDescriptor_t    dcyDesc,  
    const void                       *dcy,  
    const cudnnFilterDescriptor_t    wDesc,  
    const void                       *w,  
    const cudnnTensorDescriptor_t    hxDesc,  
    const void                       *hx,  
    const cudnnTensorDescriptor_t    cxDesc,  
    const void                       *cx,  
    const cudnnTensorDescriptor_t    *dxDesc,  
    void                             *dx,  
    const cudnnTensorDescriptor_t    dhxDesc,  
    void                             *dhx,  
    const cudnnTensorDescriptor_t    dcxDesc,  
    void                             *dcx,  
    const float                      findIntensity,  
    const int                        requestedAlgoCount,  
    int                              *returnedAlgoCount,  
    cudnnAlgorithmPerformance_t      *perfResults,  
    void                             *workspace,  
    size_t                           workSpaceSizeInBytes,  
    const void                       *reserveSpace,  
    size_t                           reserveSpaceSizeInBytes)  
```
Parameters

**handle**
*Input.* Handle to a previously created cuDNN context.

**rnnDesc**
*Input.* A previously initialized RNN descriptor.

**seqLength**
*Input.* Number of iterations to unroll over. The value of this `seqLength` must not exceed the value that was used in the `cudnnGetRNNWorkspaceSize()` function for querying the workspace size required to execute the RNN.

**yDesc**
*Input.* An array of fully packed tensor descriptors describing the output from each recurrent iteration (one descriptor per iteration). The second dimension of the tensor depends on the `direction` argument used to initialize `rnnDesc`:

- If `direction` is `CUDNN_UNIDIRECTIONAL` the second dimension should match the `hiddenSize` argument.
- If `direction` is `CUDNN_BIDIRECTIONAL` the second dimension should match double the `hiddenSize` argument.

The first dimension of the tensor in `n` must match the first dimension of the tensor in `dyDesc`.

**y**
*Input.* Data pointer to GPU memory associated with the output tensor descriptor `yDesc`.

**dyDesc**
*Input.* An array of fully packed tensor descriptors describing the gradient at the output from each recurrent iteration (one descriptor per iteration). The second dimension of the tensor depends on the `direction` argument used to initialize `rnnDesc`:

- If `direction` is `CUDNN_UNIDIRECTIONAL` the second dimension should match the `hiddenSize` argument.
- If `direction` is `CUDNN_BIDIRECTIONAL` the second dimension should match double the `hiddenSize` argument.

The first dimension of the tensor in `n` must match the second dimension of the tensor in `dxDesc`.

**dy**
*Input.* Data pointer to GPU memory associated with the tensor descriptors in the array `dyDesc`. 
dhyDesc

*Input.* A fully packed tensor descriptor describing the gradients at the final hidden state of the RNN. The first dimension of the tensor depends on the `direction` argument used to initialize `rnnDesc`:

- If `direction` is `CUDNN_UNIDIRECTIONAL` the first dimension should match the `numLayers` argument.
- If `direction` is `CUDNN_BIDIRECTIONAL` the first dimension should match double the `numLayers` argument.

The second dimension must match the first dimension of the tensors described in `dxDesc`. The third dimension must match the `hiddenSize` argument used to initialize `rnnDesc`. The tensor must be fully packed.

dhy

*Input.* Data pointer to GPU memory associated with the tensor descriptor `dhyDesc`. If a `NULL` pointer is passed, the gradients at the final hidden state of the network will be initialized to zero.

dcyDesc

*Input.* A fully packed tensor descriptor describing the gradients at the final cell state of the RNN. The first dimension of the tensor depends on the `direction` argument used to initialize `rnnDesc`:

- If `direction` is `CUDNN_UNIDIRECTIONAL` the first dimension should match the `numLayers` argument.
- If `direction` is `CUDNN_BIDIRECTIONAL` the first dimension should match double the `numLayers` argument.

The second dimension must match the first dimension of the tensors described in `dxDesc`. The third dimension must match the `hiddenSize` argument used to initialize `rnnDesc`. The tensor must be fully packed.

dcy

*Input.* Data pointer to GPU memory associated with the tensor descriptor `dcyDesc`. If a `NULL` pointer is passed, the gradients at the final cell state of the network will be initialized to zero.

wDesc

*Input.* Handle to a previously initialized filter descriptor describing the weights for the RNN.

w

*Input.* Data pointer to GPU memory associated with the filter descriptor `wDesc`.

hxDesc

*Input.* A fully packed tensor descriptor describing the initial hidden state of the RNN. The first dimension of the tensor depends on the `direction` argument used to initialize `rnnDesc`. 
If `direction` is `CUDNN_UNIDIRECTIONAL` the first dimension should match the `numLayers` argument.

If `direction` is `CUDNN_BIDIRECTIONAL` the first dimension should match double the `numLayers` argument.

The second dimension must match the first dimension of the tensors described in `dxDesc`. The third dimension must match the `hiddenSize` argument used to initialize `rnnDesc`. The tensor must be fully packed.

**hx**

Input. Data pointer to GPU memory associated with the tensor descriptor `hxDesc`. If a NULL pointer is passed, the initial hidden state of the network will be initialized to zero.

**cxDesc**

Input. A fully packed tensor descriptor describing the initial cell state for LSTM networks. The first dimension of the tensor depends on the `direction` argument used to initialize `rnnDesc`:

- If `direction` is `CUDNN_UNIDIRECTIONAL` the first dimension should match the `numLayers` argument.
- If `direction` is `CUDNN_BIDIRECTIONAL` the first dimension should match double the `numLayers` argument.

The second dimension must match the first dimension of the tensors described in `dxDesc`. The third dimension must match the `hiddenSize` argument used to initialize `rnnDesc`. The tensor must be fully packed.

**cx**

Input. Data pointer to GPU memory associated with the tensor descriptor `cxDesc`. If a NULL pointer is passed, the initial cell state of the network will be initialized to zero.

**dxDesc**

Input. An array of fully packed tensor descriptors describing the gradient at the input of each recurrent iteration (one descriptor per iteration). The first dimension (batch size) of the tensors may decrease from element `n` to element `n+1` but may not increase. Each tensor descriptor must have the same second dimension (vector length).

**dx**

Output. Data pointer to GPU memory associated with the tensor descriptors in the array `dxDesc`.

**dhxDesc**

Input. A fully packed tensor descriptor describing the gradient at the initial hidden state of the RNN. The first dimension of the tensor depends on the `direction` argument used to initialize `rnnDesc`:

- If `direction` is `CUDNN_UNIDIRECTIONAL` the first dimension should match the `numLayers` argument.
- If `direction` is `CUDNN_BIDIRECTIONAL` the first dimension should match double the `numLayers` argument.
The second dimension must match the first dimension of the tensors described in dxDesc. The third dimension must match the hiddenSize argument used to initialize rnnDesc. The tensor must be fully packed.

**dx**

*Output.* Data pointer to GPU memory associated with the tensor descriptor dhxDesc. If a NULL pointer is passed, the gradient at the hidden input of the network will not be set.

**dcxDesc**

*Input.* A fully packed tensor descriptor describing the gradient at the initial cell state of the RNN. The first dimension of the tensor depends on the direction argument used to initialize rnnDesc:

- If `direction` is `CUDNN_UNIDIRECTIONAL` the first dimension should match the numLayers argument.
- If `direction` is `CUDNN_BIDIRECTIONAL` the first dimension should match double the numLayers argument.

The second dimension must match the first dimension of the tensors described in dxDesc. The third dimension must match the hiddenSize argument used to initialize rnnDesc. The tensor must be fully packed.

**dcx**

*Output.* Data pointer to GPU memory associated with the tensor descriptor dcxDesc. If a NULL pointer is passed, the gradient at the cell input of the network will not be set.

**findIntensity**

*Input.* This input was previously unused in versions prior to cuDNN 7.2.0. It is used in cuDNN 7.2.0 and later versions to control the overall runtime of the RNN find algorithms, by selecting the percentage of a large Cartesian product space to be searched.

- Setting `findIntensity` within the range \((0,1]\) will set a percentage of the entire RNN search space to search. When `findIntensity` is set to 1.0, a full search is performed over all RNN parameters.
- When `findIntensity` is set to 0.0f, a quick, minimal search is performed. This setting has the best runtime. However, in this case the parameters returned by this function will not correspond to the best performance of the algorithm; a longer search might discover better parameters. This option will execute up to three instances of the configured RNN problem. Runtime will vary proportionally to RNN problem size, as it will in the other cases, hence no guarantee of an explicit time bound can be given.
- Setting `findIntensity` within the range \([-1.0) sets a percentage of a reduced Cartesian product space to be searched. This reduced search space has been heuristically selected to have good performance. The setting of -1.0 represents a full search over this reduced search space.
Values outside the range [-1,1] are truncated to the range [-1,1], and then interpreted as per the above.

Setting findIntensity to 1.0 in cuDNN 7.2 and later versions is equivalent to the behavior of this function in versions prior to cuDNN 7.2.0.

This function times the single RNN executions over large parameter spaces - one execution per parameter combination. The times returned by this function are latencies.

requestedAlgoCount
   Input. The maximum number of elements to be stored in perfResults.

returnedAlgoCount
   Output. The number of output elements stored in perfResults.

perfResults
   Output. A user-allocated array to store performance metrics sorted ascending by compute time.

workspace
   Input. Data pointer to GPU memory to be used as a workspace for this call.

workSpaceSizeInBytes
   Input. Specifies the size in bytes of the provided workspace.

reserveSpace
   Input/Output. Data pointer to GPU memory to be used as a reserve space for this call.

reserveSpaceSizeInBytes
   Input. Specifies the size in bytes of the provided reserveSpace.

Returns

CUDNN_STATUS_SUCCESS
   The function launched successfully.

CUDNN_STATUS_NOT_SUPPORTED
   The function does not support the provided configuration.

CUDNN_STATUS_BAD_PARAM
   At least one of the following conditions are met:

   ▶ The descriptor rnnDesc is invalid.
   ▶ At least one of the descriptors dhxDesc, wDesc, hxDesc, cxDesc, dcxDesc, dhyDesc, or dcyDesc or one of the descriptors in yDesc, dxdesc, dydesc is invalid.
   ▶ The descriptors in one of yDesc, dxDesc, dyDesc, dhxDesc, wDesc, hxDesc, cxDesc, dcxDesc, dhyDesc, or dcyDesc has incorrect strides or dimensions.
   ▶ workSpaceSizeInBytes is too small.
   ▶ reserveSpaceSizeInBytes is too small.

CUDNN_STATUS_EXECUTION_FAILED
   The function failed to launch on the GPU.
The function was unable to allocate memory.

**8.2.7. **cudnnFindRNNBackwardWeightsAlgorithmEx()

This function has been deprecated in cuDNN 8.0.

This function attempts all available cuDNN algorithms for cudnnRNNBackwardWeights(), using user-allocated GPU memory. It outputs the parameters that influence the performance of the algorithm to a user-allocated array of cudnnAlgorithmPerformance_t. These parameter metrics are written in sorted fashion where the first element has the lowest compute time.

```c

cudnnStatus_t cudnnFindRNNBackwardWeightsAlgorithmEx(
    cudnnHandle_t                    handle,
    const cudnnRNNDescriptor_t       rnnDesc,
    const int                        seqLength,
    const cudnnTensorDescriptor_t    *xDesc,
    const void                       *x,
    const cudnnTensorDescriptor_t    hxDesc,
    const void                       *hx,
    const cudnnTensorDescriptor_t    *yDesc,
    const void                       *y,
    const float                      findIntensity,
    const int                        requestedAlgoCount,
    int                              *returnedAlgoCount,
    cudnnAlgorithmPerformance_t      *perfResults,
    const void                       *workspace,
    size_t                           workSpaceSizeInBytes,
    const cudnnFilterDescriptor_t    dwDesc,
    void                             *dw,
    const void                       *reserveSpace,
    size_t                           reserveSpaceSizeInBytes)
```

**Parameters**

**handle**

*Input*. Handle to a previously created cuDNN context.

**rnnDesc**

*Input*. A previously initialized RNN descriptor.

**seqLength**

*Input*. Number of iterations to unroll over. The value of this `seqLength` must not exceed the value that was used in the cudnnGetRNNWorkspaceSize() function for querying the workspace size required to execute the RNN.

**xDesc**

*Input*. An array of fully packed tensor descriptors describing the input to each recurrent iteration (one descriptor per iteration). The first dimension (batch size) of the tensors may decrease from element `n` to element `n+1` but may not increase. Each tensor descriptor must have the same second dimension (vector length).

**x**

*Input*. Data pointer to GPU memory associated with the tensor descriptors in the array xDesc.
hxDesc

*Input.* A fully packed tensor descriptor describing the initial hidden state of the RNN. The first dimension of the tensor depends on the `direction` argument used to initialize `rnnDesc`:

- If `direction` is `CUDNN_UNIDIRECTIONAL` the first dimension should match the `numLayers` argument.
- If `direction` is `CUDNN_BIDIRECTIONAL` the first dimension should match double the `numLayers` argument.

The second dimension must match the first dimension of the tensors described in `xDesc`. The third dimension must match the `hiddenSize` argument used to initialize `rnnDesc`. The tensor must be fully packed.

hx

*Input.* Data pointer to GPU memory associated with the tensor descriptor `hxDesc`. If a `NULL` pointer is passed, the initial hidden state of the network will be initialized to zero.

yDesc

*Input.* An array of fully packed tensor descriptors describing the output from each recurrent iteration (one descriptor per iteration). The second dimension of the tensor depends on the `direction` argument used to initialize `rnnDesc`:

- If `direction` is `CUDNN_UNIDIRECTIONAL` the second dimension should match the `hiddenSize` argument.
- If `direction` is `CUDNN_BIDIRECTIONAL` the second dimension should match double the `hiddenSize` argument.

The first dimension of the tensor `n` must match the first dimension of the tensor `n` in `dyDesc`.

y

*Input.* Data pointer to GPU memory associated with the output tensor descriptor `yDesc`.

findIntensity

*Input.* This input was previously unused in versions prior to cuDNN 7.2.0. It is used in cuDNN 7.2.0 and later versions to control the overall runtime of the RNN find algorithms, by selecting the percentage of a large Cartesian product space to be searched.

- Setting `findIntensity` within the range (0,1] will set a percentage of the entire RNN search space to search. When `findIntensity` is set to 1.0, a full search is performed over all RNN parameters.
- When `findIntensity` is set to 0.0f, a quick, minimal search is performed. This setting has the best runtime. However, in this case the parameters returned by this function will not correspond to the best performance of the algorithm; a longer search might discover better parameters. This option will execute up to three
instances of the configured RNN problem. Runtime will vary proportionally to RNN problem size, as it will in the other cases, hence no guarantee of an explicit time bound can be given.

- Setting `findIntensity` within the range [-1.0) sets a percentage of a reduced Cartesian product space to be searched. This reduced search space has been heuristically selected to have good performance. The setting of -1.0 represents a full search over this reduced search space.
- Values outside the range [-1,1] are truncated to the range [-1,1], and then interpreted as per the above.
- Setting `findIntensity` to 1.0 in cuDNN 7.2 and later versions is equivalent to the behavior of this function in versions prior to cuDNN 7.2.0.
- This function times the single RNN executions over large parameter spaces - one execution per parameter combination. The times returned by this function are latencies.

**requestedAlgoCount**

*Input*. The maximum number of elements to be stored in `perfResults`.

**returnedAlgoCount**

*Output*. The number of output elements stored in `perfResults`.

**perfResults**

*Output*. A user-allocated array to store performance metrics sorted ascending by compute time.

**workspace**

*Input*. Data pointer to GPU memory to be used as a workspace for this call.

**workSpaceSizeInBytes**

*Input*. Specifies the size in bytes of the provided `workspace`.

**dwDesc**

*Input*. Handle to a previously initialized filter descriptor describing the gradients of the weights for the RNN.

**dw**

*Input/Output*. Data pointer to GPU memory associated with the filter descriptor `dwDesc`.

**reserveSpace**

*Input*. Data pointer to GPU memory to be used as a reserve space for this call.

**reserveSpaceSizeInBytes**

*Input*. Specifies the size in bytes of the provided `reserveSpace`.

**Returns**

**CUDNN_STATUS_SUCCESS**

The function launched successfully.

**CUDNN_STATUS_NOT_SUPPORTED**

The function does not support the provided configuration.
CUDNN_STATUS_BAD_PARAM
At least one of the following conditions are met:

- The descriptor `rnnDesc` is invalid.
- At least one of the descriptors `hxDesc`, `dwDesc` or one of the descriptors in `xDesc`, `yDesc` is invalid.
- The descriptors in one of `xDesc`, `hxDesc`, `yDesc`, or `dwDesc` have incorrect strides or dimensions.
- `workSpaceSizeInBytes` is too small.
- `reserveSpaceSizeInBytes` is too small.

CUDNN_STATUS_EXECUTION_FAILED
The function failed to launch on the GPU.

CUDNN_STATUS_ALLOC_FAILED
The function was unable to allocate memory.

8.2.8. `cudnnFindRNNForwardTrainingAlgorithmEx()`
This function has been deprecated in cuDNN 8.0.

This function attempts all available cuDNN algorithms for `cudnnRNNForwardTraining()`, using user-allocated GPU memory. It outputs the parameters that influence the performance of the algorithm to a user-allocated array of `cudnnAlgorithmPerformance_t`. These parameter metrics are written in sorted fashion where the first element has the lowest compute time.

```c
void cudnnFindRNNForwardTrainingAlgorithmEx(
    cudnnHandle_t                 handle,
    const cudnnRNNDescriptor_t    rnnDesc,  
    const int                     seqLength,  
    const cudnnTensorDescriptor_t *xDesc,
    const void                    *x,  
    const cudnnTensorDescriptor_t *hxDesc,
    const void                    *hx,  
    const cudnnTensorDescriptor_t *cxDesc,
    const void                    *cx,  
    const cudnnFilterDescriptor_t *wDesc,  
    const void                    *w,  
    const cudnnTensorDescriptor_t *yDesc,
    void                           *y,  
    const cudnnTensorDescriptor_t *hyDesc,
    void                           *hy,  
    const cudnnTensorDescriptor_t *cyDesc,
    void                           *cy,
    const float                   findIntensity,
    const int                     requestedAlgoCount,
    int                            *returnedAlgoCount,
    cudnnAlgorithmPerformance_t   *perfResults,
    void                           *workspace,  
    size_t                         workSpaceSizeInBytes,
    void                           *reserveSpace,  
    size_t                         reserveSpaceSizeInBytes)
```
Parameters

**handle**
- *Input*: Handle to a previously created cuDNN context.

**rnnDesc**
- *Input*: A previously initialized RNN descriptor.

**xDesc**
- *Input*: An array of fully packed tensor descriptors describing the input to each recurrent iteration (one descriptor per iteration). The first dimension (batch size) of the tensors may decrease from element n to element n+1 but may not increase. Each tensor descriptor must have the same second dimension (vector length).

**seqLength**
- *Input*: Number of iterations to unroll over. The value of this seqLength must not exceed the value that was used in the `cudnnGetRNNWorkspaceSize()` function for querying the workspace size required to execute the RNN.

**x**
- *Input*: Data pointer to GPU memory associated with the tensor descriptors in the array xDesc.

**hxDesc**
- *Input*: A fully packed tensor descriptor describing the initial hidden state of the RNN. The first dimension of the tensor depends on the direction argument used to initialize `rnnDesc`:
  - If `direction` is `CUDNN_UNIDIRECTIONAL` the first dimension should match the `numLayers` argument.
  - If `direction` is `CUDNN_BIDIRECTIONAL` the first dimension should match double the `numLayers` argument.

  The second dimension must match the first dimension of the tensors described in xDesc. The third dimension must match the `hiddenSize` argument used to initialize `rnnDesc`. The tensor must be fully packed.

**hx**
- *Input*: Data pointer to GPU memory associated with the tensor descriptor hxDesc. If a NULL pointer is passed, the initial hidden state of the network will be initialized to zero.

**cxDesc**
- *Input*: A fully packed tensor descriptor describing the initial cell state for LSTM networks. The first dimension of the tensor depends on the direction argument used to initialize `rnnDesc`:
  - If `direction` is `CUDNN_UNIDIRECTIONAL` the first dimension should match the `numLayers` argument.
  - If `direction` is `CUDNN_BIDIRECTIONAL` the first dimension should match double the `numLayers` argument.
The second dimension must match the first dimension of the tensors described in xDesc. The third dimension must match the hiddenSize argument used to initialize rnnDesc. The tensor must be fully packed.

cx
Input. Data pointer to GPU memory associated with the tensor descriptor cxDesc. If a NULL pointer is passed, the initial cell state of the network will be initialized to zero.

wDesc
Input. Handle to a previously initialized filter descriptor describing the weights for the RNN.

w
Input. Data pointer to GPU memory associated with the filter descriptor wDesc.

yDesc
Input. An array of fully packed tensor descriptors describing the output from each recurrent iteration (one descriptor per iteration). The second dimension of the tensor depends on the direction argument used to initialize rnnDesc:

- If direction is CUDNN_UNIDIRECTIONAL the second dimension should match the hiddenSize argument.
- If direction is CUDNN_BIDIRECTIONAL the second dimension should match double the hiddenSize argument.

The first dimension of the tensor n must match the first dimension of the tensor n in xDesc.

y
Output. Data pointer to GPU memory associated with the output tensor descriptor yDesc.

hyDesc
Input. A fully packed tensor descriptor describing the final hidden state of the RNN. The first dimension of the tensor depends on the direction argument used to initialize rnnDesc:

- If direction is CUDNN_UNIDIRECTIONAL the first dimension should match the numLayers argument.
- If direction is CUDNN_BIDIRECTIONAL the first dimension should match double the numLayers argument.

The second dimension must match the first dimension of the tensors described in xDesc. The third dimension must match the hiddenSize argument used to initialize rnnDesc. The tensor must be fully packed.

hy
Output. Data pointer to GPU memory associated with the tensor descriptor hyDesc. If a NULL pointer is passed, the final hidden state of the network will not be saved.
**cyDesc**

*Input.* A fully packed tensor descriptor describing the final cell state for LSTM networks. The first dimension of the tensor depends on the `direction` argument used to initialize `rnnDesc`:

- If `direction` is `CUDNN_UNIDIRECTIONAL` the first dimension should match the `numLayers` argument.
- If `direction` is `CUDNN_BIDIRECTIONAL` the first dimension should match double the `numLayers` argument.

The second dimension must match the first dimension of the tensors described in `xDesc`. The third dimension must match the `hiddenSize` argument used to initialize `rnnDesc`. The tensor must be fully packed.

**cy**

*Output.* Data pointer to GPU memory associated with the tensor descriptor `cyDesc`. If a NULL pointer is passed, the final cell state of the network will not be saved.

**findIntensity**

*Input.* This input was previously unused in versions prior to cuDNN 7.2.0. It is used in cuDNN 7.2.0 and later versions to control the overall runtime of the RNN find algorithms, by selecting the percentage of a large Cartesian product space to be searched.

- Setting `findIntensity` within the range `[0, 1]` will set a percentage of the entire RNN search space to search. When `findIntensity` is set to 1.0, a full search is performed over all RNN parameters.
- When `findIntensity` is set to 0.0, a quick, minimal search is performed. This setting has the best runtime. However, in this case the parameters returned by this function will not correspond to the best performance of the algorithm; a longer search might discover better parameters. This option will execute up to three instances of the configured RNN problem. Runtime will vary proportionally to RNN problem size, as it will in the other cases, hence no guarantee of an explicit time bound can be given.
- Setting `findIntensity` within the range `[-1, 0)` sets a percentage of a reduced Cartesian product space to be searched. This reduced search space has been heuristically selected to have good performance. The setting of -1.0 represents a full search over this reduced search space.
- Values outside the range `[-1, 1]` are truncated to the range `[-1, 1]`, and then interpreted as per the above.
- Setting `findIntensity` to 1.0 in cuDNN 7.2 and later versions is equivalent to the behavior of this function in versions prior to cuDNN 7.2.0.
- This function times the single RNN executions over large parameter spaces - one execution per parameter combination. The times returned by this function are latencies.
requestedAlgoCount
   Input. The maximum number of elements to be stored in perfResults.

returnedAlgoCount
   Output. The number of output elements stored in perfResults.

perfResults
   Output. A user-allocated array to store performance metrics sorted ascending by compute time.

workspace
   Input. Data pointer to GPU memory to be used as a workspace for this call.

workSpaceSizeInBytes
   Input. Specifies the size in bytes of the provided workspace.

reserveSpace
   Input/Output. Data pointer to GPU memory to be used as a reserve space for this call.

reserveSpaceSizeInBytes
   Input. Specifies the size in bytes of the provided reserveSpace.

Returns

CUDNN_STATUS_SUCCESS
   The function launched successfully.

CUDNN_STATUS_BAD_PARAM
   At least one of the following conditions are met:
   ▶ The descriptor rnnDesc is invalid.
   ▶ At least one of the descriptors hxDesc, cxDesc, wDesc, hyDesc, or cyDesc or one of the descriptors in xDesc, yDesc is invalid.
   ▶ The descriptors in one of xDesc, hxDesc, cxDesc, wDesc, yDesc, hyDesc, or cyDesc have incorrect strides or dimensions.
   ▶ workSpaceSizeInBytes is too small.
   ▶ reserveSpaceSizeInBytes is too small.

CUDNN_STATUS_EXECUTION_FAILED
   The function failed to launch on the GPU.

CUDNN_STATUS_ALLOC_FAILED
   The function was unable to allocate memory.

8.2.9. **cudnnGetCTCLossDescriptor()**

This function returns the configuration of the passed CTC loss function descriptor.

cudnnStatus_t cudnnGetCTCLossDescriptor(
    cudnnCTCLossDescriptor_t ctcLossDesc,
    cudnnDataType_t* compType)
Parameters

ctcLossDesc
   *Input*. CTC loss function descriptor passed, from which to retrieve the configuration.

compType
   *Output*. Compute type associated with this CTC loss function descriptor.

Returns

CUDDNN_STATUS_SUCCESS
   The function returned successfully.

CUDDNN_STATUS_BAD_PARAM
   Input ctcLossDesc descriptor passed is invalid.

8.2.10. cudnnGetCTClossDescriptorEx()

This function returns the configuration of the passed CTC loss function descriptor.

cudnnStatus_t cudnnGetCTClossDescriptorEx(
    cudnnCTClossDescriptor_t         ctcLossDesc,
    cudnnDataType_t                 *compType,
    cudnnLossNormalizationMode_t    *normMode,
    cudnnNanPropagation_t           *gradMode)

Parameters

ctcLossDesc
   *Input*. CTC loss function descriptor passed, from which to retrieve the configuration.

compType
   *Output*. Compute type associated with this CTC loss function descriptor.

normMode
   *Output*. Input normalization type for this CTC loss function descriptor. For more information, see cudnnLossNormalizationMode_t.

gradMode
   *Output*. NaN propagation type for this CTC loss function descriptor.

Returns

CUDDNN_STATUS_SUCCESS
   The function returned successfully.

CUDDNN_STATUS_BAD_PARAM
   Input ctcLossDesc descriptor passed is invalid.

8.2.11. cudnnGetCTClossDescriptor_v8()

This function returns the configuration of the passed CTC loss function descriptor.

cudnnStatus_t cudnnGetCTClossDescriptor_v8(
    cudnnCTClossDescriptor_t         ctcLossDesc,
    cudnnDataType_t                 *compType,
    cudnnLossNormalizationMode_t    *normMode,
Parameters

ctcLossDesc
  Input. CTC loss function descriptor passed, from which to retrieve the configuration.

compType
  Output. Compute type associated with this CTC loss function descriptor.

normMode
  Output. Input normalization type for this CTC loss function descriptor. For more information, see cudnnLossNormalizationMode_t.

ggradMode
  Output. NaN propagation type for this CTC loss function descriptor.

maxLabelLength
  Output. The max label length for this CTC loss function descriptor.

Returns

CUDNN_STATUS_SUCCESS
  The function returned successfully.

CUDNN_STATUS_BAD_PARAM
  Input ctcLossDesc descriptor passed is invalid.

8.2.12. cudnnGetCTCLossWorkspaceSize()

This function returns the amount of GPU memory workspace the user needs to allocate to be able to call cudnnCTCLoss() with the specified algorithm. The workspace allocated will then be passed to the routine cudnnCTCLoss().

cudnnStatus_t cudnnGetCTCLossWorkspaceSize(
  cudnnHandle_t handle,
  const cudnnTensorDescriptor_t probsDesc,
  const cudnnTensorDescriptor_t gradientsDesc,
  const int *labels,
  const int *labelLengths,
  const int *inputLengths,
  cudnnCTCLossAlgo_t algo,
  const cudnnCTCLossDescriptor_t ctcLossDesc,
  size_t *sizeInBytes)

Parameters

handle
  Input. Handle to a previously created cuDNN context.

probsDesc
  Input. Handle to the previously initialized probabilities tensor descriptor.

gradientsDesc
  Input. Handle to a previously initialized gradient tensor descriptor.

labels
  Input. Pointer to a previously initialized labels list.
labelLengths
   Input. Pointer to a previously initialized lengths list, to walk the above labels list.

inputLengths
   Input. Pointer to a previously initialized list of the lengths of the timing steps in each batch.

algo
   Input. Enumerant that specifies the chosen CTC loss algorithm.

ctcLossDesc
   Input. Handle to the previously initialized CTC loss descriptor.

sizeInBytes
   Output. Amount of GPU memory needed as workspace to be able to execute the CTC loss computation with the specified algo.

Returns

CUDNN_STATUS_SUCCESS
   The query was successful.

CUDNN_STATUS_BAD_PARAM
   At least one of the following conditions are met:
   ▶ The dimensions of probsDesc do not match the dimensions of gradientsDesc.
   ▶ The inputLengths do not agree with the first dimension of probsDesc.
   ▶ The workSpaceSizeInBytes is not sufficient.
   ▶ The labelLengths is greater than 256.

CUDNN_STATUS_NOT_SUPPORTED
   A compute or data type other than FLOAT was chosen, or an unknown algorithm type was chosen.

8.2.13. cudnnGetCTCCLossWorkspaceSize_v8()

This function returns the amount of GPU memory workspace the user needs to allocate to be able to call cudnnCTCLoss_v8(), with the specified algorithm. The workspace allocated will then be passed to the routine cudnnCTCLoss_v8().

\[
\text{cudnnStatus_t cudnnGetCTCCLossWorkspaceSize_v8(}
\text{cudnnHandle_t handle,}
\text{cudnnCTCLossAlgo_t algo,}
\text{const cudnnCTCLossDescriptor_t ctcLossDesc,}
\text{const cudnnTensorDescriptor_t probsDesc,}
\text{const cudnnTensorDescriptor_t gradientsDesc,}
\text{size_t *} \text{sizeInBytes})}
\]

Parameters

handle
   Input. Handle to a previously created cuDNN context.

algo
   Input. Enumerant that specifies the chosen CTC loss algorithm.
ctcLossDesc
   Input. Handle to the previously initialized CTC loss descriptor.

probsDesc
   Input. Handle to the previously initialized probabilities tensor descriptor.

gradientsDesc
   Input. Handle to a previously initialized gradient tensor descriptor.

sizeInBytes
   Output. Amount of GPU memory needed as workspace to be able to execute the CTC loss computation with the specified algo.

Returns

CUDNN_STATUS_SUCCESS
   The query was successful.

CUDNN_STATUS_BAD_PARAM
   At least one of the following conditions are met:
   ▶ The dimensions of probsDesc do not match the dimensions of gradientsDesc.

CUDNN_STATUS_NOT_SUPPORTED
   A compute or data type other than FLOAT was chosen, or an unknown algorithm type was chosen.

8.2.14. cudnnGetRNNBackwardDataAlgorithmMaxCount()
This function has been deprecated in cuDNN 8.0.

8.2.15. cudnnGetRNNForwardTrainingAlgorithmMaxCount()
This function has been deprecated in cuDNN 8.0.

8.2.16. cudnnMultiHeadAttnBackwardData()
This function computes exact, first-order derivatives of the multi-head attention block with respect to its inputs: Q, K, V. If \( y = F(x) \) is a vector-valued function that represents the multi-head attention layer and it takes some vector \( w \in \mathbb{R}^n \) as an input (with all other parameters and inputs constant), and outputs vector \( y \in \mathbb{R}^m \), then
\[
\text{cudnnMultiHeadAttnBackwardData()} \text{ computes the result of } (\frac{\partial y_j}{\partial x_j})^T \delta_{\text{out}} \text{ where } \delta_{\text{out}} \text{ is the } m \times 1 \text{ gradient of the loss function with respect to multi-head attention outputs. The } \delta_{\text{out}} \text{ gradient is back propagated through prior layers of the deep learning model.} \frac{\partial y_j}{\partial x_j} \text{ is the } m \times n \text{ Jacobian matrix of } F(x). \text{ The input is supplied via the } \text{dout} \text{ argument and gradient results for Q, K, V are written to the } \text{dqueries}, \text{dkeys}, \text{and dvalues buffers.}
\]

```c
    cudnnStatus_t cudnnMultiHeadAttnBackwardData(
        cudnnHandle_t handle,
        const cudnnAttnDescriptor_t attnDesc,
        const int loWinIdx[],
        const int hiWinIdx[],
        const int devSeqLengthsDQDO[],
```

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```c
const int devSeqLengthsDKDV[],
const cudnnSeqDataDescriptor_t doDesc,
const void *dout,
const void *dqueries,
const void *dkeys,
const cudnnSeqDataDescriptor_t dqDesc,
void *dout,
const cudnnSeqDataDescriptor_t dkDesc,
void *dkeys,
const cudnnSeqDataDescriptor_t dvDesc,
void *dqueries,
void *dout,
const cudnnSeqDataDescriptor_t dkDesc,
void *dkeys,
const void *keys,
const cudnnSeqDataDescriptor_t dvDesc,
void *dvalues,
const void *values,
size_t weightSizeInBytes,
const void *weights,
size_t workSpaceSizeInBytes,
void *workSpace,
size_t reserveSpaceSizeInBytes,
void *reserveSpace);
```

The `cudnnMultiHeadAttnBackwardData()` function does not output partial derivatives for residual connections because this result is equal to $\delta_{\text{out}}$. If the multi-head attention model enables residual connections sourced directly from $Q$, then the $dout$ tensor needs to be added to $dqueries$ to obtain the correct result of the latter. This operation is demonstrated in the cuDNN multiHeadAttention sample code.

The `cudnnMultiHeadAttnBackwardData()` function must be invoked after `cudnnMultiHeadAttnForward()`. The `loWinIdx[]`, `hiWinIdx[]`, `queries`, `keys`, `values`, `weights`, and `reserveSpace` arguments should be the same as in the `cudnnMultiHeadAttnForward()` call. `devSeqLengthsDQDO[]` and `devSeqLengthsDKDV[]` device arrays should contain the same start and end attention window indices as `devSeqLengthsQO[]` and `devSeqLengthsKV[]` arrays in the forward function invocation.

**Note:** `cudnnMultiHeadAttnBackwardData()` does not verify that sequence lengths stored in `devSeqLengthsDQDO[]` and `devSeqLengthsDKDV[]` contain the same settings as `seqLengthArray[]` in the corresponding sequence data descriptor.

### Parameters

- **handle**
  - *Input*. The current cuDNN context handle.

- **attnDesc**
  - *Input*. A previously initialized attention descriptor.

- **loWinIdx[], hiWinIdx[]**
  - *Input*. Two host integer arrays specifying the start and end indices of the attention window for each $Q$ time-step. The start index in $K, V$ sets is inclusive, and the end index is exclusive.

- **devSeqLengthsDQDO[]**
  - *Input*. Device array containing a copy of the sequence length array from the $dqDesc$ or $doDesc$ sequence data descriptor.

- **devSeqLengthsDKDV[]**
  - *Input*. Device array containing a copy of the sequence length array from the $dkDesc$ or $dvDesc$ sequence data descriptor.
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doDesc
Input. Descriptor for the $\delta_{out}$ gradients (vectors of partial derivatives of the loss function with respect to the multi-head attention outputs).

dout
Pointer to $\delta_{out}$ gradient data in the device memory.

dqDesc
Input. Descriptor for queries and dqueries sequence data.

dqueries
Output. Device pointer to gradients of the loss function computed with respect to queries vectors.

queries
Input. Pointer to queries data in the device memory. This is the same input as in `cudnnMultiHeadAttnForward()`.

dkDesc
Input. Descriptor for keys and dkeys sequence data.

dkeys
Output. Device pointer to gradients of the loss function computed with respect to keys vectors.

keys
Input. Pointer to keys data in the device memory. This is the same input as in `cudnnMultiHeadAttnForward()`.

dvDesc
Input. Descriptor for values and dvalues sequence data.

dvalues
Output. Device pointer to gradients of the loss function computed with respect to values vectors.

values
Input. Pointer to values data in the device memory. This is the same input as in `cudnnMultiHeadAttnForward()`.

weightSizeInBytes
Input. Size of the weight buffer in bytes where all multi-head attention trainable parameters are stored.

weights
Input. Address of the weight buffer in the device memory.

workSpaceSizeInBytes
Input. Size of the work-space buffer in bytes used for temporary API storage.

workSpace
Input/Output. Address of the work-space buffer in the device memory.

reserveSpaceSizeInBytes
Input. Size of the reserve-space buffer in bytes used for data exchange between forward and backward (gradient) API calls.

reserveSpace
Input/Output. Address to the reserve-space buffer in the device memory.
Returns

**CUDNN_STATUS_SUCCESS**
No errors were detected while processing API input arguments and launching GPU kernels.

**CUDNN_STATUS_BAD_PARAM**
An invalid or incompatible input argument was encountered.

**CUDNN_STATUS_EXECUTION_FAILED**
The process of launching a GPU kernel returned an error, or an earlier kernel did not complete successfully.

**CUDNN_STATUS_INTERNAL_ERROR**
An inconsistent internal state was encountered.

**CUDNN_STATUS_NOT_SUPPORTED**
A requested option or a combination of input arguments is not supported.

**CUDNN_STATUS_ALLOC_FAILED**
Insufficient amount of shared memory to launch a GPU kernel.

### 8.2.17. cudnnMultiHeadAttnBackwardWeights()

This function computes exact, first-order derivatives of the multi-head attention block with respect to its trainable parameters: projection weights and projection biases. If \( y = F(w) \) is a vector-valued function that represents the multi-head attention layer and it takes some vector \( x \in \mathbb{R}^n \) of flatten weights or biases as an input (with all other parameters and inputs fixed), and outputs vector \( y \in \mathbb{R}^m \), then cudnnMultiHeadAttnBackwardWeights() computes the result of \( \nabla_y / \nabla x \) \( \delta_{out} \) where \( \delta_{out} \) is the \( m \times 1 \) gradient of the loss function with respect to multi-head attention outputs. The \( \delta_{out} \) gradient is back propagated through prior layers of the deep learning model. \( \nabla y / \nabla x \) is the \( m \times n \) Jacobian matrix of \( F(w) \). The \( \delta_{out} \) input is supplied via the \( dout \) argument.

```c

int cudnnStatus_t cudnnMultiHeadAttnBackwardWeights(
    cudnnHandle_t handle,
    const cudnnAttnDescriptor_t attnDesc,
    cudnnWgradMode_t addGrad,
    const cudnnSeqDataDescriptor_t qDesc,
    const void *queries,
    const cudnnSeqDataDescriptor_t kDesc,
    const void *keys,
    const cudnnSeqDataDescriptor_t vDesc,
    const void *values,
    const cudnnSeqDataDescriptor_t doDesc,
    const void *dout,
    size_t weightSizeInBytes,
    const void *weights,
    void *dweights,
    size_t workSpaceSizeInBytes,
    void *workSpace,
    size_t reserveSpaceSizeInBytes,
    void *reserveSpace);
```

All gradient results with respect to weights and biases are written to the \( dweights \) buffer. The size and the organization of the \( dweights \) buffer is the same as the \( weights \) buffer.
that holds multi-head attention weights and biases. The cuDNN multiHeadAttention sample code demonstrates how to access those weights.

Gradient of the loss function with respect to weights or biases is typically computed over multiple batches. In such a case, partial results computed for each batch should be summed together. The addGrad argument specifies if the gradients from the current batch should be added to previously computed results or the dweights buffer should be overwritten with the new results.

The cudnnMultiHeadAttnBackwardWeights() function should be invoked after cudnnMultiHeadAttnBackwardData(). The queries, keys, values, weights, and reserveSpace arguments should be the same as in cudnnMultiHeadAttnForward() and cudnnMultiHeadAttnBackwardData() calls. The dout argument should be the same as in cudnnMultiHeadAttnBackwardData().

Parameters

handle
   Input. The current cuDNN context handle.

attDesc
   Input. A previously initialized attention descriptor.

addGrad
   Input. Weight gradient output mode.

qDesc
   Input. Descriptor for the query sequence data.

queries
   Input. Pointer to queries sequence data in the device memory.

kDesc
   Input. Descriptor for the keys sequence data.

keys
   Input. Pointer to keys sequence data in the device memory.

vDesc
   Input. Descriptor for the values sequence data.

values
   Input. Pointer to values sequence data in the device memory.

doDesc
   Input. Descriptor for the \( \delta_{\text{out}} \) gradients (vectors of partial derivatives of the loss function with respect to the multi-head attention outputs).

do
   Input. Pointer to \( \delta_{\text{out}} \) gradient data in the device memory.

weightSizeInBytes
   Input. Size of the weights and dweights buffers in bytes.

weights
   Input. Address of the weight buffer in the device memory.

dweights
   Output. Address of the weight gradient buffer in the device memory.
workSpaceSizeInBytes
   Input. Size of the work-space buffer in bytes used for temporary API storage.

workSpace
   Input/Output. Address of the work-space buffer in the device memory.

reserveSpaceSizeInBytes
   Input. Size of the reserve-space buffer in bytes used for data exchange between
   forward and backward (gradient) API calls.

reserveSpace
   Input/Output. Address to the reserve-space buffer in the device memory.

Returns

CUDNN_STATUS_SUCCESS
   No errors were detected while processing API input arguments and launching GPU
   kernels.

CUDNN_STATUS_BAD_PARAM
   An invalid or incompatible input argument was encountered.

CUDNN_STATUS.ExecutionFailed
   The process of launching a GPU kernel returned an error, or an earlier kernel did not
   complete successfully.

CUDNN_STATUS_INCONSISTENT.INTERNAL_STATE
   An inconsistent internal state was encountered.

CUDNN_STATUS_NOT_SUPPORTED
   A requested option or a combination of input arguments is not supported.

8.2.18. cudnnRNNBackwardData()

This function has been deprecated in cuDNN 8.0. Use cudnnRNNBackwardData_v8() instead of cudnnRNNBackwardData().

cudnnStatus_t cudnnRNNBackwardData(
   cudnnHandle_t                   handle,
   const cudnnRNNDescriptor_t      rnnDesc,
   const int                       seqLength,
   const cudnnTensorDescriptor_t  *yDesc,
   const void                     *y,
   const cudnnTensorDescriptor_t  *dyDesc,
   const void                     *dy,
   const cudnnTensorDescriptor_t   dhyDesc,
   const void                     *dhy,
   const cudnnTensorDescriptor_t   dcyDesc,
   const void                     *dcy,
   const cudnnFilterDescriptor_t   wDesc,
   const void                     *w,
   const cudnnTensorDescriptor_t   hxDesc,
   const void                     *hx,
   const cudnnTensorDescriptor_t   cxDesc,
   const void                     *cx,
   const cudnnTensorDescriptor_t   dxdDesc,
   void                           *dx,
   const cudnnTensorDescriptor_t   dhxDesc,
   void                           *dhx,
   const cudnnTensorDescriptor_t   dcxDesc,
   void                           *dcx,
This routine executes the recurrent neural network described by `rnnDesc` with output gradients `dy`, `dhy`, and `dhc`, weights `w` and input gradients `dx`, `dhx`, and `dcx`. `workspace` is required for intermediate storage. The data in `reserveSpace` must have previously been generated by `cudnnRNNForwardTraining()`. The same `reserveSpace` data must be used for future calls to `cudnnRNNBackwardWeights()` if they execute on the same input data.

### Parameters

**handle**
- **Input.** Handle to a previously created cuDNN context. For more information, refer to `cudnnHandle_t`.

**rnnDesc**
- **Input.** A previously initialized RNN descriptor. For more information, refer to `cudnnRNNDescriptor_t`.

**seqLength**
- **Input.** Number of iterations to unroll over. The value of this `seqLength` must not exceed the value that was used in the `cudnnGetRNNWorkspaceSize()` function for querying the workspace size required to execute the RNN.

**yDesc**
- **Input.** An array of fully packed tensor descriptors describing the output from each recurrent iteration (one descriptor per iteration). For more information, refer to `cudnnTensorDescriptor_t`. The second dimension of the tensor depends on the `direction` argument used to initialize `rnnDesc`:
  - If `direction` is `CUDNN_UNIDIRECTIONAL` the second dimension should match the `hiddenSize` argument.
  - If `direction` is `CUDNN_BIDIRECTIONAL` the second dimension should match double the `hiddenSize` argument.

The first dimension of the tensor `n` must match the first dimension of the tensor `n` in `dyDesc`.

**y**
- **Input.** Data pointer to GPU memory associated with the output tensor descriptor `yDesc`.

**dyDesc**
- **Input.** An array of fully packed tensor descriptors describing the gradient at the output from each recurrent iteration (one descriptor per iteration). The second dimension of the tensor depends on the `direction` argument used to initialize `rnnDesc`:
  - If `direction` is `CUDNN_UNIDIRECTIONAL` the second dimension should match the `hiddenSize` argument.
- If `direction` is `CUDNN_BIDIRECTIONAL` the second dimension should match double the `hiddenSize` argument.

The first dimension of the tensor `n` must match the first dimension of the tensor `n` in `dxDesc`.

\( \text{dy} \)

*Input*. Data pointer to GPU memory associated with the tensor descriptors in the array `dyDesc`.

\( \text{dhyDesc} \)

*Input*. A fully packed tensor descriptor describing the gradients at the final hidden state of the RNN. The first dimension of the tensor depends on the `direction` argument used to initialize `rnnDesc`:

- If `direction` is `CUDNN_UNIDIRECTIONAL` the first dimension should match the `numLayers` argument.
- If `direction` is `CUDNN_BIDIRECTIONAL` the first dimension should match double the `numLayers` argument.

The second dimension must match the first dimension of the tensors described in `xDesc`. The third dimension must match the `hiddenSize` argument used to initialize `rnnDesc`. The tensor must be fully packed.

\( \text{dhy} \)

*Input*. Data pointer to GPU memory associated with the tensor descriptor `dhyDesc`. If a `NULL` pointer is passed, the gradients at the final hidden state of the network will be initialized to zero.

\( \text{dcyDesc} \)

*Input*. A fully packed tensor descriptor describing the gradients at the final cell state of the RNN. The first dimension of the tensor depends on the `direction` argument used to initialize `rnnDesc`:

- If `direction` is `CUDNN_UNIDIRECTIONAL` the first dimension should match the `numLayers` argument.
- If `direction` is `CUDNN_BIDIRECTIONAL` the first dimension should match double the `numLayers` argument.

The second dimension must match the first dimension of the tensors described in `xDesc`. The third dimension must match the `hiddenSize` argument used to initialize `rnnDesc`. The tensor must be fully packed.

\( \text{dcy} \)

*Input*. Data pointer to GPU memory associated with the tensor descriptor `dcyDesc`. If a `NULL` pointer is passed, the gradients at the final cell state of the network will be initialized to zero.
**wDesc**

*Input.* Handle to a previously initialized filter descriptor describing the weights for the RNN. For more information, refer to `cudnnFilterDescriptor_t`.

**w**

*Input.* Data pointer to GPU memory associated with the filter descriptor `wDesc`.

**hxDesc**

*Input.* A fully packed tensor descriptor describing the initial hidden state of the RNN. The first dimension of the tensor depends on the `direction` argument used to initialize `rnnDesc`:

- If `direction` is `CUDNN_UNIDIRECTIONAL` the first dimension should match the `numLayers` argument.
- If `direction` is `CUDNN_BIDIRECTIONAL` the first dimension should match double the `numLayers` argument.

The second dimension must match the second dimension of the tensors described in `xDesc`. The third dimension must match the `hiddenSize` argument used to initialize `rnnDesc`. The tensor must be fully packed.

**hx**

*Input.* Data pointer to GPU memory associated with the tensor descriptor `hxDesc`. If a `NULL` pointer is passed, the initial hidden state of the network will be initialized to zero.

**cxDesc**

*Input.* A fully packed tensor descriptor describing the initial cell state for LSTM networks. The first dimension of the tensor depends on the `direction` argument used to initialize `rnnDesc`:

- If `direction` is `CUDNN_UNIDIRECTIONAL` the first dimension should match the `numLayers` argument.
- If `direction` is `CUDNN_BIDIRECTIONAL` the first dimension should match double the `numLayers` argument.

The second dimension must match the second dimension of the tensors described in `xDesc`. The third dimension must match the `hiddenSize` argument used to initialize `rnnDesc`. The tensor must be fully packed.

**cx**

*Input.* Data pointer to GPU memory associated with the tensor descriptor `cxDesc`. If a `NULL` pointer is passed, the initial cell state of the network will be initialized to zero.

**dxDesc**

*Input.* An array of fully packed tensor descriptors describing the gradient at the input of each recurrent iteration (one descriptor per iteration). The first dimension (batch size) of the tensors may decrease from element \( n \) to element \( n+1 \) but may not increase. Each tensor descriptor must have the same second dimension (vector length).
dx

*Output.* Data pointer to GPU memory associated with the tensor descriptors in the array dxDesc.

dhxDesc

**Input.** A fully packed tensor descriptor describing the gradient at the initial hidden state of the RNN. The first dimension of the tensor depends on the `direction` argument used to initialize `rnnDesc`:

- If `direction` is `CUDNN_UNIDIRECTIONAL` the first dimension should match the `numLayers` argument.
- If `direction` is `CUDNN_BIDIRECTIONAL` the first dimension should match double the `numLayers` argument.

The second dimension must match the first dimension of the tensors described in xDesc. The third dimension must match the `hiddenSize` argument used to initialize `rnnDesc`. The tensor must be fully packed.

dhx

*Output.* Data pointer to GPU memory associated with the tensor descriptor dhxDesc. If a `NULL` pointer is passed, the gradient at the hidden input of the network will not be set.

dcxDesc

**Input.** A fully packed tensor descriptor describing the gradient at the initial cell state of the RNN. The first dimension of the tensor depends on the `direction` argument used to initialize `rnnDesc`:

- If `direction` is `CUDNN_UNIDIRECTIONAL` the first dimension should match the `numLayers` argument.
- If `direction` is `CUDNN_BIDIRECTIONAL` the first dimension should match double the `numLayers` argument.

The second dimension must match the first dimension of the tensors described in xDesc. The third dimension must match the `hiddenSize` argument used to initialize `rnnDesc`. The tensor must be fully packed.

dcx

*Output.* Data pointer to GPU memory associated with the tensor descriptor dcxDesc. If a `NULL` pointer is passed, the gradient at the cell input of the network will not be set.

workspace

**Input.** Data pointer to GPU memory to be used as a workspace for this call.

workspaceSizeInBytes

**Input.** Specifies the size in bytes of the provided `workspace`.

reserveSpace

**Input/Output.** Data pointer to GPU memory to be used as a reserve space for this call.

reserveSpaceSizeInBytes

**Input.** Specifies the size in bytes of the provided `reserveSpace`. 

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Returns

CUDNN_STATUS_SUCCESS
The function launched successfully.

CUDNN_STATUS_NOT_SUPPORTED
The function does not support the provided configuration.

CUDNN_STATUS_BAD_PARAM
At least one of the following conditions are met:

- The descriptor `rnnDesc` is invalid.
- At least one of the descriptors `dhxDesc, wDesc, hxDesc, cxDesc, dcxDesc, dhyDesc, or dcyDesc` or one of the descriptors in `yDesc, dxDesc, dyDesc` is invalid.
- The descriptors in one of `yDesc, dxDesc, dyDesc, dhxDesc, wDesc, hxDesc, cxDesc, dcxDesc, dhyDesc, or dcyDesc` has incorrect strides or dimensions.
- `workSpaceSizeInBytes` is too small.
- `reserveSpaceSizeInBytes` is too small.

CUDNN_STATUS_INVALID_VALUE
`cudnnSetPersistentRNNPlan()` was not called prior to the current function when `CUDNN_RNN_ALGO_PERSIST_DYNAMIC` was selected in the RNN descriptor.

CUDNN_STATUS_MAPPING_ERROR
A GPU/CUDA resource, such as a texture object, shared memory, or zero-copy memory is not available in the required size or there is a mismatch between the user resource and cuDNN internal resources. A resource mismatch may occur, for example, when calling `cudnnSetStream()`. There could be a mismatch between the user provided CUDA stream and the internal CUDA events instantiated in the cuDNN handle when `cudnnCreate()` was invoked.

This error status may not be correctable when it is related to texture dimensions, shared memory size, or zero-copy memory availability. If `CUDNN_STATUS_MAPPING_ERROR` is returned by `cudnnSetStream()`, then it is typically correctable, however, it means that the cuDNN handle was created on one GPU and the user stream passed to this function is associated with another GPU.

CUDNN_STATUS_EXECUTION_FAILED
The function failed to launch on the GPU.

CUDNN_STATUS_ALLOC_FAILED
The function was unable to allocate memory.

8.2.19. cudnnRNNDerivativeData_v8()

This function computes exact, first-order derivatives of the RNN model with respect to its inputs: `x, hx` and for the LSTM cell type also `cx`. If `o = [y, hy, cy] = F(x, hx, cx) = F(z)` is a vector-valued function that represents the entire RNN model and it takes vectors `x` (for all time-steps) and vectors `hx, cx` (for all layers) as inputs, concatenated into `z ∈ R^n`
(network weights and biases are assumed constant), and outputs vectors $y$, $hy$, $cy$ concatenated into a vector $o \in \mathbb{R}^m$, then `cudnnRNNBackwardData_v8()` computes the result of $(\partial o / \partial z) \delta_{out}$ where $\delta_{out}$ is the $m \times 1$ gradient of the loss function with respect to all RNN outputs. The $\delta_{out}$ gradient is back propagated through prior layers of the deep learning model, starting from the model output. $\partial o / \partial z$ is the $m \times n$ Jacobian matrix of $F(z)$. The $\delta_{out}$ input is supplied via the $dy$, $dhy$, and $dcy$ arguments and gradient results $(\partial o / \partial z) \delta_{out}$ are written to the $dx$, $dhx$, and $dcx$ buffers.

```c

cudnnStatus_t cudnnRNNBackwardData_v8(
    cudnnHandle_t handle,
    cudnnRNNDescriptor_t rnnDesc,
    const int32_t devSeqLengths[],
    cudnnRNNDataDescriptor_t yDesc,
    const void *y,
    const void *dy,
    cudnnRNNDataDescriptor_t xDesc,
    void *dx,
    cudnnTensorDescriptor_t hDesc,
    const void *hx,
    const void *dhy,
    void *dhx,
    cudnnTensorDescriptor_t cDesc,
    const void *cx,
    const void *dcy,
    void *dcx,
    size_t weightSpaceSize,
    const void *weightSpace,
    size_t workSpaceSize,
    void *workSpace,
    size_t reserveSpaceSize,
    void *reserveSpace);
```

Locations of $x$, $y$, $hx$, $cx$, $hy$, $dy$, $dhx$, $dcx$, $dhy$, and $dcy$ signals a multi-layer RNN model are shown in the following figure. Note that internal RNN signals (between timesteps and between layers) are not exposed by the `cudnnRNNBackwardData_v8()` function.
Figure 6. Locations of x, y, hx, cx, hy, cy, dx, dy, dhx, dcx, dhy, and dcy Signals a Multi-Layer RNN Model

Memory addresses to the primary RNN output y, the initial hidden state hx, and the initial cell state cx (for LSTM only) should point to the same data as in the preceding cudnnRNNForward() call. The dy and dx pointers cannot be NULL.

The cudnnRNNBackwardData_v8() function accepts any combination of dhy, dhx, dcy, dcx buffer addresses being NULL. When dhy or dcy are NULL, it is assumed that those inputs are zero. When dhx or dcx pointers are NULL then the corresponding results are not written by cudnnRNNBackwardData_v8().

When all hx, dhy, dhx pointers are NULL, then the corresponding tensor descriptor hDesc can be NULL too. The same rule applies to the cx, dcy, dcx pointers and the cDesc tensor descriptor.

The cudnnRNNBackwardData_v8() function allows the user to use padded layouts for inputs y, dy, and output dx. In padded or unpacked layouts (CUDNN_RNN_DATA_LAYOUT_SEQ_MAJOR_UNPACKED, CUDNN_RNN_DATA_LAYOUT_BATCH_MAJOR_UNPACKED) each sequence of vectors in a mini-batch has a fixed length defined by the maxSeqLength argument in the cudnnSetRNNDataDescriptor() function. The term "unpacked" refers here to the presence of padding vectors, and not unused address ranges between contiguous vectors.

Each padded, fixed-length sequence starts from a segment of valid vectors. The valid vector count is stored in seqLengthArray passed to cudnnSetRNNDataDescriptor(), such that 0 < seqLengthArray[i] <= maxSeqLength for all sequences in a mini-batch, that is, for i=0..batchSize-1. The remaining padding vectors make the combined sequence length equal to maxSeqLength. Both sequence-major and batch-major padded layouts are supported.
In addition, a packed sequence-major layout:
CUDNN_RNN_DATA_LAYOUT_SEQ_MAJOR_PACKED can be selected by the user. In the latter
layout, sequences of vectors in a mini-batch are sorted in the descending order according
to the sequence lengths. First, all vectors for time step zero are stored. They are followed
by vectors for time step one, and so on. This layout uses no padding vectors.

The same layout type must be specified in xDesc and yDesc descriptors.

Two host arrays named seqLengthArray in xDesc and yDesc RNN data descriptors must
be the same. In addition, a copy of seqLengthArray in the device memory must be passed
via the devSeqLengths argument. This array is supplied directly to GPU kernels. Starting in
cuDNN 8.9.1, the devSeqLengths parameter is no longer required and can be set to NULL.
The variable sequence length array is transferred automatically to GPU memory by the
cudnnRNNBackwardData_v8() function.

The cudnnRNNBackwardData_v8() function does not verify that sequence lengths stored
in devSeqLengths in GPU memory are the same as in xDesc and yDesc descriptors in
CPU memory. Sequence length arrays from xDesc and yDesc descriptors are checked for
consistency, however.

The cudnnRNNBackwardData_v8() function must be called after cudnnRNNForward().
The cudnnRNNForward() function should be invoked with the fwdMode argument of type
cudnnRNNForward() set to CUDNN_FWD_MODE_TRAINING.

Parameters

handle
    Input. The current cuDNN context handle.

rnnDesc
    Input. A previously initialized RNN descriptor.

devSeqLengths
    Input. A copy of seqLengthArray from xDesc or yDesc RNN data descriptors. The
devSeqLengths array must be stored in GPU memory as it is accessed asynchronously
by GPU kernels, possibly after the cudnnRNNBackwardData_v8() function exists. In
cuDNN 8.9.1 and later versions, devSeqLengths should be NULL.

yDesc
    Input. A previously initialized descriptor corresponding to the RNN model primary
output. The dataType, layout, maxSeqLength, batchSize, and seqLengthArray need to
match that of xDesc.

y, dy
    Input. Data pointers to GPU buffers holding the RNN model primary output and
gradient deltas (gradient of the loss function with respect to y). The y output should be
produced by the preceding cudnnRNNForward() call. The y and dy vectors are expected
to be laid out in memory according to the layout specified by yDesc. The elements in
the tensor (including elements in padding vectors) must be densely packed. The y and
dy arguments cannot be NULL.
**xDesc**

*Input.* A previously initialized RNN data descriptor corresponding to the gradient of the loss function with respect to the RNN primary model input. The `dataType`, `layout`, `maxSeqLength`, `batchSize`, and `seqLengthArray` must match that of `yDesc`. The parameter `vectorSize` must match the `inputSize` argument passed to the `cudnnSetRNNDescriptor_v8()` function.

**dx**

*Output.* Data pointer to GPU memory where back-propagated gradients of the loss function with respect to the RNN primary input `x` should be stored. The vectors are expected to be arranged in memory according to the layout specified by `xDesc`. The elements in the tensor (including padding vectors) must be densely packed. This argument cannot be `NULL`.

**hDesc**

*Input.* A tensor descriptor describing the initial RNN hidden state `hx` and gradients of the loss function with respect to the initial of the final hidden state. Hidden state data and the corresponding gradients are fully packed. The first dimension of the tensor depends on the `dirMode` argument passed to the `cudnnSetRNNDescriptor_v8()` function.

- If `dirMode` is `CUDNN_UNIDIRECTIONAL`, then the first dimension should match the `numLayers` argument passed to `cudnnSetRNNDescriptor_v8()`.
- If `dirMode` is `CUDNN_BIDIRECTIONAL`, then the first dimension should be double the `numLayers` argument passed to `cudnnSetRNNDescriptor_v8()`.

The second dimension must match the `batchSize` parameter described in `xDesc`. The third dimension depends on whether RNN mode is `CUDNN_LSTM` and whether the LSTM projection is enabled. Specifically:

- If RNN mode is `CUDNN_LSTM` and LSTM projection is enabled, the third dimension must match the `projSize` argument passed to the `cudnnSetRNNDescriptor_v8()` call.
- Otherwise, the third dimension must match the `hiddenSize` argument passed to the `cudnnSetRNNDescriptor_v8()` call used to initialize `rnnDesc`.

**hx, dhy**

*Input.* Addresses of GPU buffers with the RNN initial hidden state `hx` and gradient deltas `dhy`. Data dimensions are described by the `hDesc` tensor descriptor. If a `NULL` pointer is passed in `hx` or `dhy` arguments, the corresponding buffer is assumed to contain all zeros.

**dhx**

*Output.* Pointer to the GPU buffer where first-order derivatives corresponding to initial hidden state variables should be stored. Data dimensions are described by the `hDesc` tensor descriptor. If a `NULL` pointer is assigned to `dhx`, the back-propagated derivatives are not saved.
cDesc

*Input.* For LSTM networks only. A tensor descriptor describing the initial cell state $cx$ and gradients of the loss function with respect to the initial of the final cell state. Cell state data are fully packed. The first dimension of the tensor depends on the `dirMode` argument passed to the `cudnnSetRNNDescriptor_v8()` call.

– If `dirMode` is `CUDNN_UNIDIRECTIONAL`, then the first dimension should match the `numLayers` argument passed to `cudnnSetRNNDescriptor_v8()`.
– If `dirMode` is `CUDNN_BIDIRECTIONAL`, then the first dimension should be double the `numLayers` argument passed to `cudnnSetRNNDescriptor_v8()`.

The second tensor dimension must match the `batchSize` parameter in `xDesc`. The third dimension must match the `hiddenSize` argument passed to the `cudnnSetRNNDescriptor_v8()` call.

cx, dcy

*Input.* For LSTM networks only. Addresses of GPU buffers with the initial LSTM state data and gradient deltas $dcy$. Data dimensions are described by the `cDesc` tensor descriptor. If a `NULL` pointer is passed in `cx` or `dcy` arguments, the corresponding buffer is assumed to contain all zeros.

dcx

*Output.* For LSTM networks only. Pointer to the GPU buffer where first-order derivatives corresponding to initial LSTM state variables should be stored. Data dimensions are described by the `cDesc` tensor descriptor. If a `NULL` pointer is assigned to `dcx`, the back-propagated derivatives are not saved.

weightSpaceSize

*Input.* Specifies the size in bytes of the provided weight-space buffer.

weightSpace

*Input.* Address of the weight space buffer in GPU memory.

workSpaceSize

*Input.* Specifies the size in bytes of the provided workspace buffer.

workSpace

*Input/Output.* Address of the workspace buffer in GPU memory to store temporary data.

reserveSpaceSize

*Input.* Specifies the size in bytes of the reserve-space buffer.

reserveSpace

*Input/Output.* Address of the reserve-space buffer in GPU memory.

**Returns**

**CUDNN_STATUS_SUCCESS**

No errors were detected while processing API input arguments and launching GPU kernels.
**CUDNN_STATUS_NOT_SUPPORTED**

At least one of the following conditions are met:

- variable sequence length input is passed while CUDNN_RNN_ALGO_PERSIST_STATIC or CUDNN_RNN_ALGO_PERSIST_DYNAMIC is specified
- CUDNN_RNN_ALGO_PERSIST_STATIC or CUDNN_RNN_ALGO_PERSIST_DYNAMIC is requested on pre-Pascal devices
- the 'double' floating point type is used for input/output and the CUDNN_RNN_ALGO_PERSIST_STATIC algo

**CUDNN_STATUS_BAD_PARAM**

An invalid or incompatible input argument was encountered. For example:

- some input descriptors are NULL
- settings in rnnDesc, xDesc, yDesc, hDesc, or cDesc descriptors are invalid
- weightSpaceSize, workSpaceSize, or reserveSpaceSize is too small

**CUDNN_STATUS_MAPPING_ERROR**

A GPU/CUDA resource, such as a texture object, shared memory, or zero-copy memory is not available in the required size or there is a mismatch between the user resource and cuDNN internal resources. A resource mismatch may occur, for example, when calling cudnnSetStream(). There could be a mismatch between the user provided CUDA stream and the internal CUDA events instantiated in the cuDNN handle when cudnnCreate() was invoked.

This error status may not be correctable when it is related to texture dimensions, shared memory size, or zero-copy memory availability. If CUDNN_STATUS_MAPPING_ERROR is returned by cudnnSetStream(), then it is typically correctable, however, it means that the cuDNN handle was created on one GPU and the user stream passed to this function is associated with another GPU.

**CUDNN_STATUS_EXECUTION_FAILED**

The process of launching a GPU kernel returned an error, or an earlier kernel did not complete successfully.

**CUDNN_STATUS_ALLOC_FAILED**

The function was unable to allocate CPU memory.

8.2.20. **cudnnRNNBackwardDataEx()**

This function has been deprecated in cuDNN 8.0. Use cudnnRNNBackwardData_v8 instead of cudnnRNNBackwardDataEx().

```c
#include <cudnn.h>

__host__ cudnnStatus_t cudnnRNNBackwardDataEx(
    cudnnHandle_t                     handle,
    const cudnnRNNDescriptor_t        rnnDesc,
    const cudnnRNNDataDescriptor_t    yDesc,
    const void                        *y,
    const cudnnRNNDataDescriptor_t    dyDesc,
    const void                        *dy,
)
```
This routine is the extended version of the function `cudnnRNNBackwardData()`. This function `cudnnRNNBackwardDataEx()` allows the user to use an unpacked (padded) layout for input \( y \) and output \( dx \).

In the unpacked layout, each sequence in the mini-batch is considered to be of fixed length, specified by \( \text{maxSeqLength} \) in its corresponding RNNDataDescriptor. Each fixed-length sequence, for example, the \( n \)th sequence in the mini-batch, is composed of a valid segment specified by the \( \text{seqLengthArray}[n] \) in its corresponding RNNDataDescriptor; and a padding segment to make the combined sequence length equal to \( \text{maxSeqLength} \).

With the unpacked layout, both sequence major (meaning, time major) and batch major are supported. For backward compatibility, the packed sequence major layout is supported. However, similar to the non-extended function `cudnnRNNBackwardData()`, the sequences in the mini-batch need to be sorted in descending order according to length.

**Parameters**

**handle**

*Input*. Handle to a previously created This function is deprecated starting in cuDNN 8.0.0. context.

**rnnDesc**

*Input*. A previously initialized RNN descriptor.

**yDesc**

*Input*. A previously initialized RNN data descriptor. Must match or be the exact same descriptor previously passed into `cudnnRNNForwardTrainingEx()`.

**y**

*Input*. Data pointer to the GPU memory associated with the RNN data descriptor \( y\text{Desc} \). The vectors are expected to be laid out in memory according to the layout specified by \( y\text{Desc} \). The elements in the tensor (including elements in the padding vector) must be densely packed, and no strides are supported. Must contain the exact same data previously produced by `cudnnRNNForwardTrainingEx()`.
dyDesc

*Input.* A previously initialized RNN data descriptor. The `dataType`, `layout`, `maxSeqLength`, `batchSize`, `vectorSize`, and `seqLengthArray` need to match the `yDesc` previously passed to `cudnnRNNForwardTrainingEx()`.

dy

*Input.* Data pointer to the GPU memory associated with the RNN data descriptor `dyDesc`. The vectors are expected to be laid out in memory according to the layout specified by `dyDesc`. The elements in the tensor (including elements in the padding vector) must be densely packed, and no strides are supported.

dhyDesc

*Input.* A fully packed tensor descriptor describing the gradients at the final hidden state of the RNN. The first dimension of the tensor depends on the `direction` argument used to initialize `rnnDesc`. Additionally:

- If `direction` is `CUDNN_UNIDIRECTIONAL` the first dimension should match the `numLayers` argument.
- If `direction` is `CUDNN_BIDIRECTIONAL` the first dimension should match double the `numLayers` argument.

The second dimension must match the `batchSize` parameter in `xDesc`. The third dimension depends on whether the RNN mode is `CUDNN_LSTM` and whether LSTM projection is enabled. Additionally:

- If the RNN mode is `CUDNN_LSTM` and LSTM projection is enabled, the third dimension must match the `recProjSize` argument passed to `cudnnSetRNNProjectionLayers()` call used to set `rnnDesc`.
- Otherwise, the third dimension must match the `hiddenSize` argument used to initialize `rnnDesc`.

dhy

*Input.* Data pointer to GPU memory associated with the tensor descriptor `dhyDesc`. If a NULL pointer is passed, the gradients at the final hidden state of the network will be initialized to zero.

dcyDesc

*Input.* A fully packed tensor descriptor describing the gradients at the final cell state of the RNN. The first dimension of the tensor depends on the `direction` argument used to initialize `rnnDesc`. Additionally:

- If `direction` is `CUDNN_UNIDIRECTIONAL` the first dimension should match the `numLayers` argument.
- If `direction` is `CUDNN_BIDIRECTIONAL` the first dimension should match double the `numLayers` argument.
The second dimension must match the first dimension of the tensors described in xDesc. The third dimension must match the hiddenSize argument used to initialize rnnDesc. The tensor must be fully packed.

**dcy**

*Input.* Data pointer to GPU memory associated with the tensor descriptor dcyDesc. If a `NULL` pointer is passed, the gradients at the final cell state of the network will be initialized to zero.

**wDesc**

*Input.* Handle to a previously initialized filter descriptor describing the weights for the RNN.

**w**

*Input.* Data pointer to GPU memory associated with the filter descriptor wDesc.

**hxDesc**

*Input.* A fully packed tensor descriptor describing the initial hidden state of the RNN. Must match or be the exact same descriptor previously passed into cudnnRNNForwardTrainingEx().

**hx**

*Input.* Data pointer to GPU memory associated with the tensor descriptor hxDesc. If a `NULL` pointer is passed, the initial hidden state of the network will be initialized to zero. Must contain the exact same data previously passed into cudnnRNNForwardTrainingEx(), or be `NULL` if `NULL` was previously passed to cudnnRNNForwardTrainingEx().

**cxDesc**

*Input.* A fully packed tensor descriptor describing the initial cell state for LSTM networks. Must match or be the exact same descriptor previously passed into cudnnRNNForwardTrainingEx().

**cx**

*Input.* Data pointer to GPU memory associated with the tensor descriptor cxDesc. If a `NULL` pointer is passed, the initial cell state of the network will be initialized to zero. Must contain the exact same data previously passed into cudnnRNNForwardTrainingEx(), or be `NULL` if `NULL` was previously passed to cudnnRNNForwardTrainingEx().

**dxDesc**

*Input.* A previously initialized RNN data descriptor. The `dataType`, `layout`, `maxSeqLength`, `batchSize`, `vectorSize` and `seqLengthArray` need to match that of xDesc previously passed to cudnnRNNForwardTrainingEx().

**dx**

*Output.* Data pointer to the GPU memory associated with the RNN data descriptor dxDesc. The vectors are expected to be laid out in memory according to the layout specified by dxDesc. The elements in the tensor (including elements in the padding vector) must be densely packed, and no strides are supported.
dhxDesc
- *Input.* A fully packed tensor descriptor describing the gradient at the initial hidden state of the RNN. The descriptor must be set exactly the same way as dhyDesc.

dhx
- *Output.* Data pointer to GPU memory associated with the tensor descriptor dhxDesc. If a NULL pointer is passed, the gradient at the hidden input of the network will not be set.

dcxDesc
- *Input.* A fully packed tensor descriptor describing the gradient at the initial cell state of the RNN. The descriptor must be set exactly the same way as dcyDesc.

dcx
- *Output.* Data pointer to GPU memory associated with the tensor descriptor dcxDesc. If a NULL pointer is passed, the gradient at the cell input of the network will not be set.

dkDesc
- Reserved. Users may pass in NULL.

dkeys
- Reserved. Users may pass in NULL.

workspace
- *Input.* Data pointer to GPU memory to be used as a workspace for this call.

workSpaceSizeInBytes
- *Input.* Specifies the size in bytes of the provided workspace.

reserveSpace
- *Input/Output.* Data pointer to GPU memory to be used as a reserve space for this call.

reserveSpaceSizeInBytes
- *Input.* Specifies the size in bytes of the provided reserveSpace.

Returns

**CUDNN_STATUS_SUCCESS**
- The function launched successfully.

**CUDNN_STATUS_NOT_SUPPORTED**
- At least one of the following conditions are met:
  - Variable sequence length input is passed in while CUDNN_RNN_ALGO_PERSIST_STATIC or CUDNN_RNN_ALGO_PERSIST_DYNAMIC is used.
  - CUDNN_RNN_ALGO_PERSIST_STATIC or CUDNN_RNN_ALGO_PERSIST_DYNAMIC is used on pre-Pascal devices.
  - Double input/output is used for CUDNN_RNN_ALGO_PERSIST_STATIC.

**CUDNN_STATUS_BAD_PARAM**
- At least one of the following conditions are met:
  - The descriptor rnnDesc is invalid.
At least one of the descriptors \( y_{\text{Desc}}, \, dx_{\text{Desc}}, \, dy_{\text{Desc}}, \, dhx_{\text{Desc}}, \, w_{\text{Desc}}, \, hx_{\text{Desc}}, \) \( \), \( cx_{\text{Desc}}, \, dcx_{\text{Desc}}, \, dhy_{\text{Desc}}, \) or \( dcy_{\text{Desc}} \) is invalid or has incorrect strides or dimensions.

- \( \text{workSpaceSizeInBytes} \) is too small.
- \( \text{reserveSpaceSizeInBytes} \) is too small.

**CUDNN\_STATUS\_INVALID\_VALUE**

\texttt{cudnnSetPersistentRNNPlan()} was not called prior to the current function when \texttt{CUDNN\_RNN\_ALGO\_PERSIST\_DYNAMIC} was selected in the RNN descriptor.

**CUDNN\_STATUS\_MAPPING\_ERROR**

A GPU/CUDA resource, such as a texture object, shared memory, or zero-copy memory is not available in the required size or there is a mismatch between the user resource and cuDNN internal resources. A resource mismatch may occur, for example, when calling \texttt{cudnnSetStream()}. There could be a mismatch between the user provided CUDA stream and the internal CUDA events instantiated in the cuDNN handle when \texttt{cudnnCreate()} was invoked.

This error status may not be correctable when it is related to texture dimensions, shared memory size, or zero-copy memory availability. If \texttt{CUDNN\_STATUS\_MAPPING\_ERROR} is returned by \texttt{cudnnSetStream()}, then it is typically correctable, however, it means that the cuDNN handle was created on one GPU and the user stream passed to this function is associated with another GPU.

**CUDNN\_STATUS\_EXECUTION\_FAILED**

The function failed to launch on the GPU.

**CUDNN\_STATUS\_ALLOC\_FAILED**

The function was unable to allocate memory.

### 8.2.21. \texttt{cudnnRNNBackwardWeights()}  

This function has been deprecated in cuDNN 8.0. Use \texttt{cudnnRNNBackwardWeights\_v8()} instead of \texttt{cudnnRNNBackwardWeights()}.

```c

cudnnStatus_t cudnnRNNBackwardWeights(
    cudnnHandle_t                   handle,  
    const cudnnRNNDescriptor_t      rnnDesc,  
    const int                       seqLength,  
    const cudnnTensorDescriptor_t   *xDesc,  
    const void                      *x,  
    const cudnnTensorDescriptor_t   *hxDesc,  
    const void                      *hx,  
    const cudnnTensorDescriptor_t   *yDesc,  
    const void                      *y,  
    const void                      *workspace,  
    size_t                          workSpaceSizeInBytes,  
    const cudnnFilterDescriptor_t   *dwDesc,  
    void                            *dw,  
    const void                      *reserveSpace,  
    size_t                          reserveSpaceSizeInBytes)
```

This routine accumulates weight gradients \( dw \) from the recurrent neural network described by \( rnn_{\text{Desc}} \) with inputs \( x, \, h_{x} \) and outputs \( y \). The mode of operation in this case is additive, the weight gradients calculated will be added to those already existing in \( dw \).
workspace is required for intermediate storage. The data in reserveSpace must have
previously been generated by cudnnRNNBackwardData().

Parameters

**handle**
*Input*. Handle to a previously created cuDNN context.

**rnnDesc**
*Input*. A previously initialized RNN descriptor.

**seqLength**
*Input*. Number of iterations to unroll over. The value of this seqLength must not exceed
the value that was used in the cudnnGetRNNWorkspaceSize() function for querying
the workspace size required to execute the RNN.

**xDesc**
*Input*. An array of fully packed tensor descriptors describing the input to each
recurrent iteration (one descriptor per iteration). The first dimension (batch size) of
the tensors may decrease from element \( n \) to element \( n+1 \) but may not increase. Each
tensor descriptor must have the same second dimension (vector length).

**x**
*Input*. Data pointer to GPU memory associated with the tensor descriptors in the array
xDesc.

**hxDesc**
*Input*. A fully packed tensor descriptor describing the initial hidden state of the RNN.
The first dimension of the tensor depends on the direction argument used to
initialize rnnDesc:

- If direction is CUDNN_UNIDIRECTIONAL the first dimension should match the
  numLayers argument.
- If direction is CUDNN_BIDIRECTIONAL the first dimension should match double the
  numLayers argument.

The second dimension must match the first dimension of the tensors described in
xDesc. The third dimension must match the hiddenSize argument used to initialize
rnnDesc. The tensor must be fully packed.

**hx**
*Input*. Data pointer to GPU memory associated with the tensor descriptor hxDesc. If a
NULL pointer is passed, the initial hidden state of the network will be initialized to zero.

**yDesc**
*Input*. An array of fully packed tensor descriptors describing the output from each
recurrent iteration (one descriptor per iteration). The second dimension of the tensor
depends on the direction argument used to initialize rnnDesc:

- If direction is CUDNN_UNIDIRECTIONAL the second dimension should match the
  hiddenSize argument.
If direction is `CUDNN_BIDIRECTIONAL` the second dimension should match double the `hiddenSize` argument.

The first dimension of the tensor \( n \) must match the first dimension of the tensor \( n \) in `dyDesc`.

**y**

*Input*. Data pointer to GPU memory associated with the output tensor descriptor `yDesc`.

**workspace**

*Input*. Data pointer to GPU memory to be used as a workspace for this call.

**workSpaceSizeInBytes**

*Input*. Specifies the size in bytes of the provided `workspace`.

**dwDesc**

*Input*. Handle to a previously initialized filter descriptor describing the gradients of the weights for the RNN.

**dw**

*Input/Output*. Data pointer to GPU memory associated with the filter descriptor `dwDesc`.

**reserveSpace**

*Input*. Data pointer to GPU memory to be used as a reserve space for this call.

**reserveSpaceSizeInBytes**

*Input*. Specifies the size in bytes of the provided `reserveSpace`.

**Returns**

**CUDNN_STATUS_SUCCESS**

The function launched successfully.

**CUDNN_STATUS_NOT_SUPPORTED**

The function does not support the provided configuration.

**CUDNN_STATUS_BAD_PARAM**

At least one of the following conditions are met:

- The descriptor `rnnDesc` is invalid.
- At least one of the descriptors `hxDesc`, `dwDesc` or one of the descriptors in `xDesc`, `yDesc` is invalid.
- The descriptors in one of `xDesc`, `hxDesc`, `yDesc`, `dwDesc` have incorrect strides or dimensions.
- `workSpaceSizeInBytes` is too small.
- `reserveSpaceSizeInBytes` is too small.

**CUDNN_STATUS_EXECUTION_FAILED**

The function failed to launch on the GPU.

**CUDNN_STATUS_ALLOC_FAILED**

The function was unable to allocate memory.
8.2.22. **cudnnRNNBackwardWeights_v8()**

This function computes exact, first-order derivatives of the RNN model with respect to all trainable parameters: weights and biases. If \( \mathbf{o} = [\mathbf{y}, \mathbf{h}, \mathbf{c}] = F(\mathbf{w}) \) is a vector-valued function that represents the multi-layer RNN model and it takes some vector \( \mathbf{w} \in \mathbb{R}^n \) of "flatten" weights or biases as input (with all other data inputs constant), and outputs vector \( \mathbf{o} \in \mathbb{R}^m \), then `cudnnRNNBackwardWeights_v8()` computes the result of \( \left( \frac{\partial \mathbf{o}}{\partial \mathbf{w}} \right)^T \mathbf{\delta}_{\text{out}} \) where \( \mathbf{\delta}_{\text{out}} \) is the \( m \times 1 \) gradient of the loss function with respect to all RNN outputs. The \( \mathbf{\delta}_{\text{out}} \) gradient is back propagated through prior layers of the deep learning model, starting from the model output. \( \frac{\partial \mathbf{o}}{\partial \mathbf{w}} \) is the \( m \times n \) Jacobian matrix of \( F(\mathbf{w}) \). The \( \mathbf{\delta}_{\text{out}} \) input is supplied via the \( dy, dh, \) and \( dc \) arguments in the `cudnnRNNBackwardData_v8()` function.

```c

cudnnStatus_t cudnnRNNBackwardWeights_v8(
    cudnnHandle_t handle,
    cudnnRNNDescriptor_t rnnDesc,
    cudnnWgradMode_t addGrad,
    const int32_t devSeqLengths[],
    cudnnRNNDataDescriptor_t xDesc,
    const void *x,
    cudnnTensorDescriptor_t hDesc,
    const void *hx,
    cudnnRNNDataDescriptor_t yDesc,
    const void *y,
    size_t weightSpaceSize,
    void *dweightSpace,
    size_t workSpaceSize,
    void *workSpace,
    size_t reserveSpaceSize,
    void *reserveSpace);
```

All gradient results \( \left( \frac{\partial \mathbf{o}}{\partial \mathbf{w}} \right)^T \mathbf{\delta}_{\text{out}} \) with respect to weights and biases are written to the \( dweightSpace \) buffer. The size and the organization of the \( dweightSpace \) buffer is the same as the \( weightSpace \) buffer that holds RNN weights and biases.

Gradient of the loss function with respect to weights and biases is typically computed over multiple mini-batches. In such a case, partial results computed for each mini-batch should be aggregated. The \( addGrad \) argument specifies if gradients from the current mini-batch should be added to previously computed results (\( \text{CUDNN_WGRAD_MODE_ADD} \)) or the \( dweightSpace \) buffer should be overwritten with the new results (\( \text{CUDNN_WGRAD_MODE_SET} \)). Currently, the `cudnnRNNBackwardWeights_v8()` function supports the \( \text{CUDNN_WGRAD_MODE_ADD} \) mode only so the \( dweightSpace \) buffer should be zeroed by the user before invoking the routine for the first time.

The same sequence lengths must be specified in the \( xDesc \) descriptor and in the device array \( devSeqLengths \). Starting in cuDNN 8.9.1, the \( devSeqLengths \) parameter is no longer required and can be set to \( \text{NULL} \). The variable sequence length array is transferred automatically to GPU memory by the `cudnnRNNBackwardWeights_v8()` function.

The `cudnnRNNBackwardWeights_v8()` function should be invoked after `cudnnRNNBackwardData()`.
Parameters

handle
  *Input*. The current cuDNN context handle.

rnnDesc
  *Input*. A previously initialized RNN descriptor.

addGrad
  *Input*. Weight gradient output mode. For more details, see the description of the cudnnWgradMode_t enumerated type. Currently, only the CUDNN_WGRAD_MODE_ADD mode is supported by the cudnnRNNBackwardWeights_v8() function.

devSeqLengths
  *Input*. A copy of seqLengthArray from the xDesc RNN data descriptor. The devSeqLengths array must be stored in GPU memory as it is accessed asynchronously by GPU kernels, possibly after the cudnnRNNBackwardWeights_v8() function exists. In cuDNN 8.9.1 and later versions, devSeqLengths should be NULL.

xDesc
  *Input*. A previously initialized descriptor corresponding to the RNN model input data. This is the same RNN data descriptor as used in the preceding cudnnRNNForward() and cudnnRNNBackwardData_v8() calls.

x
  *Input*. Pointer to the GPU buffer with the primary RNN input. The same buffer address x should be provided in prior cudnnRNNForward() and cudnnRNNBackwardData_v8() calls.

hDesc
  *Input*. A tensor descriptor describing the initial RNN hidden state. Hidden state data are fully packed. This is the same tensor descriptor as used in prior cudnnRNNForward() and cudnnRNNBackwardData_v8() calls.

hx
  *Input*. Pointer to the GPU buffer with the RNN initial hidden state. The same buffer address hx should be provided in prior cudnnRNNForward() and cudnnRNNBackwardData_v8() calls.

yDesc
  *Input*. A previously initialized descriptor corresponding to the RNN model output data. This is the same RNN data descriptor as used in prior cudnnRNNForward() and cudnnRNNBackwardData_v8() calls.

y
  *Output*. Pointer to the GPU buffer with the primary RNN output as generated by the prior cudnnRNNForward() call. Data in the y buffer are described by the yDesc descriptor. Elements in the y tensor (including elements in padding vectors) must be densely packed.

weightSpaceSize
  *Input*. Specifies the size in bytes of the provided weight-space buffer.
dweightSpace
   Output. Address of the weight space buffer in GPU memory.

workSpaceSize
   Input. Specifies the size in bytes of the provided workspace buffer.

workSpace
   Input/Output. Address of the workspace buffer in GPU memory to store temporary data.

reserveSpaceSize
   Input. Specifies the size in bytes of the reserve-space buffer.

reserveSpace
   Input/Output. Address of the reserve-space buffer in GPU memory.

Returns

CUDNN_STATUS_SUCCESS
   No errors were detected while processing API input arguments and launching GPU kernels.

CUDNN_STATUS_NOT_SUPPORTED
   The function does not support the provided configuration.

CUDNN_STATUS_BAD_PARAM
   An invalid or incompatible input argument was encountered. For example:
   ▶ some input descriptors are NULL
   ▶ settings in rnnDesc, xDesc, yDesc, or hDesc descriptors are invalid
   ▶ weightSpaceSize, workSpaceSize, or reserveSpaceSize values are too small
   ▶ the addGrad argument is not equal to CUDNN_WGRAD_MODE_ADD

CUDNN_STATUS_EXECUTION_FAILED
   The process of launching a GPU kernel returned an error, or an earlier kernel did not complete successfully.

CUDNN_STATUS_ALLOC_FAILED
   The function was unable to allocate CPU memory.

8.2.23. cudnnRNNBackwardWeightsEx()

This function has been deprecated in cuDNN 8.0. Use cudnnRNNBackwardWeights_v8() instead of cudnnRNNBackwardWeightsEx().

cudnnStatus_t cudnnRNNBackwardWeightsEx(
   cudnnHandle_t handle,                      
   const cudnnRNNDescriptor_t      rnnDesc,    
   const cudnnRNNDataDescriptor_t   xDesc,      
   const void                      *x,          
   const cudnnTensorDescriptor_t    hxDesc,     
   const void                      *hx,         
   const cudnnRNNDataDescriptor_t   yDesc,      
   const void                      *y,          
   void                            *workSpace,   
   size_t                          workSpaceSizeInBytes, 
   const cudnnFilterDescriptor_t   dwDesc,     
);
This routine is the extended version of the function `cudnnRNNBackwardWeights()`. This function `cudnnRNNBackwardWeightsEx()` allows the user to use an unpacked (padded) layout for input `x` and output `dw`.

In the unpacked layout, each sequence in the mini-batch is considered to be of fixed length, specified by `maxSeqLength` in its corresponding RNNDataDescriptor. Each fixed-length sequence, for example, the `nth` sequence in the mini-batch, is composed of a valid segment specified by the `seqLengthArray[n]` in its corresponding RNNDataDescriptor; and a padding segment to make the combined sequence length equal to `maxSeqLength`.

With the unpacked layout, both sequence major (meaning, time major) and batch major are supported. For backward compatibility, the packed sequence major layout is supported. However, similar to the non-extended function `cudnnRNNBackwardWeights()`, the sequences in the mini-batch need to be sorted in descending order according to length.

**Parameters**

- **handle**
  - *Input*. Handle to a previously created cuDNN context.

- **rnnDesc**
  - *Input*. A previously initialized RNN descriptor.

- **xDesc**
  - *Input*. A previously initialized RNN data descriptor. Must match or be the exact same descriptor previously passed into `cudnnRNNForwardTrainingEx()`.

- **x**
  - *Input*. Data pointer to GPU memory associated with the tensor descriptors in the array `xDesc`. Must contain the exact same data previously passed into `cudnnRNNForwardTrainingEx()`.

- **hxDesc**
  - *Input*. A fully packed tensor descriptor describing the initial hidden state of the RNN. Must match or be the exact same descriptor previously passed into `cudnnRNNForwardTrainingEx()`.

- **hx**
  - *Input*. Data pointer to GPU memory associated with the tensor descriptor `hxDesc`. If a NULL pointer is passed, the initial hidden state of the network will be initialized to zero. Must contain the exact same data previously passed into `cudnnRNNForwardTrainingEx()`, or be NULL if NULL was previously passed to `cudnnRNNForwardTrainingEx()`.

- **yDesc**
  - *Input*. A previously initialized RNN data descriptor. Must match or be the exact same descriptor previously passed into `cudnnRNNForwardTrainingEx()`.
y

*Input*. Data pointer to GPU memory associated with the output tensor descriptor `yDesc`. Must contain the exact same data previously produced by `cudnnRNNForwardTrainingEx()`.

`workspace`

*Input*. Data pointer to GPU memory to be used as a workspace for this call.

`workspaceSizeInBytes`

*Input*. Specifies the size in bytes of the provided `workspace`.

`dwDesc`

*Input*. Handle to a previously initialized filter descriptor describing the gradients of the weights for the RNN.

`dw`

*Input/Output*. Data pointer to GPU memory associated with the filter descriptor `dwDesc`.

`reserveSpace`

*Input*. Data pointer to GPU memory to be used as a reserve space for this call.

`reserveSpaceSizeInBytes`

*Input*. Specifies the size in bytes of the provided `reserveSpace`.

**Returns**

**CUDNN_STATUS_SUCCESS**

The function launched successfully.

**CUDNN_STATUS_NOT_SUPPORTED**

The function does not support the provided configuration.

**CUDNN_STATUS_BAD_PARAM**

At least one of the following conditions are met:

- The descriptor `rnnDesc` is invalid.
- At least one of the descriptors `xDesc`, `yDesc`, `hxDesc`, `dwDesc` is invalid, or has incorrect strides or dimensions.
- `workspaceSizeInBytes` is too small.
- `reserveSpaceSizeInBytes` is too small.

**CUDNN_STATUS_EXECUTION_FAILED**

The function failed to launch on the GPU.

**CUDNN_STATUS_ALLOC_FAILED**

The function was unable to allocate memory.

### 8.2.24. cudnnRNNForwardTraining()

This function is deprecated starting in cuDNN 8.0.0. Use `cudnnRNNForward()` instead of `cudnnRNNForwardTraining()`.

```c
#include <cudnn.h>

__GlobalFunctions__
cudnnStatus_t cudnnRNNForwardTraining(
    cudnnHandle_t       handle,
    const cudnnRNNDescriptor_t    rnnDesc,

```
This routine executes the recurrent neural network described by **rnnDesc** with inputs \(x\), \(hx\), and \(cx\), weights \(w\) and outputs \(y\), \(hy\), and \(cy\). \(workspace\) is required for intermediate storage. \(reserveSpace\) stores data required for training. The same \(reserveSpace\) data must be used for future calls to **cudnnRNNBackwardData()** and **cudnnRNNBackwardWeights()** if these execute on the same input data.

### Parameters

**handle**

*Input*. Handle to a previously created cuDNN context.

**rnnDesc**

*Input*. A previously initialized RNN descriptor.

**seqLength**

*Input*. Number of iterations to unroll over. The value of this **seqLength** must not exceed the value that was used in the **cudnnGetRNNWorkspaceSize()** function for querying the workspace size required to execute the RNN.

**xDesc**

*Input*. An array of **seqLength** fully packed tensor descriptors. Each descriptor in the array should have three dimensions that describe the input data format to one recurrent iteration (one descriptor per RNN time-step). The first dimension (batch size) of the tensors may decrease from iteration element \(n\) to iteration element \(n+1\) but may not increase. Each tensor descriptor must have the same second dimension (RNN input vector length, \(inputSize\)). The third dimension of each tensor should be 1. Input vectors are expected to be arranged in the column-major order so strides in \(xDesc\) should be set as follows:


**x**

*Input*. Data pointer to GPU memory associated with the array of tensor descriptors \(xDesc\). The input vectors are expected to be packed contiguous with the first vector of iterations (time-step) \(n+1\) following directly the last vector of iteration \(n\). In other words, input vectors for all RNN time-steps should be packed in the contiguous block of GPU memory with no gaps between the vectors.
hxDesc

*Input.* A fully packed tensor descriptor describing the initial hidden state of the RNN. The first dimension of the tensor depends on the `direction` argument used to initialize `rnnDesc`:

- If `direction` is `CUDNN_UNIDIRECTIONAL` the first dimension should match the `numLayers` argument.
- If `direction` is `CUDNN_BIDIRECTIONAL` the first dimension should match double the `numLayers` argument.

The second dimension must match the first dimension of the tensors described in `xDesc`. The third dimension must match the `hiddenSize` argument used to initialize `rnnDesc`. The tensor must be fully packed.

hx

*Input.* Data pointer to GPU memory associated with the tensor descriptor `hxDesc`. If a `NULL` pointer is passed, the initial hidden state of the network will be initialized to zero.

cxDesc

*Input.* A fully packed tensor descriptor describing the initial cell state for LSTM networks. The first dimension of the tensor depends on the `direction` argument used to initialize `rnnDesc`:

- If `direction` is `CUDNN_UNIDIRECTIONAL` the first dimension should match the `numLayers` argument.
- If `direction` is `CUDNN_BIDIRECTIONAL` the first dimension should match double the `numLayers` argument.

The second dimension must match the first dimension of the tensors described in `xDesc`. The third dimension must match the `hiddenSize` argument used to initialize `rnnDesc`. The tensor must be fully packed.

cx

*Input.* Data pointer to GPU memory associated with the tensor descriptor `cxDesc`. If a `NULL` pointer is passed, the initial cell state of the network will be initialized to zero.

wDesc

*Input.* Handle to a previously initialized filter descriptor describing the weights for the RNN.

w

*Input.* Data pointer to GPU memory associated with the filter descriptor `wDesc`.

yDesc

*Input.* An array of fully packed tensor descriptors describing the output from each recurrent iteration (one descriptor per iteration). The second dimension of the tensor depends on the `direction` argument used to initialize `rnnDesc`:

- If `direction` is `CUDNN_UNIDIRECTIONAL` the second dimension should match the `hiddenSize` argument.
If `direction` is `CUDNN_BIDIRECTIONAL` the second dimension should match double the `hiddenSize` argument.

The first dimension of the tensor `n` must match the first dimension of the tensor `n` in `xDesc`.

`y`  
*Output.* Data pointer to GPU memory associated with the output tensor descriptor `yDesc`.

`hyDesc`  
*Input.* A fully packed tensor descriptor describing the final hidden state of the RNN. The first dimension of the tensor depends on the `direction` argument used to initialize `rnnDesc`:

- If `direction` is `CUDNN_UNIDIRECTIONAL` the first dimension should match the `numLayers` argument.
- If `direction` is `CUDNN_BIDIRECTIONAL` the first dimension should match double the `numLayers` argument.

The second dimension must match the first dimension of the tensors described in `xDesc`. The third dimension must match the `hiddenSize` argument used to initialize `rnnDesc`. The tensor must be fully packed.

`hy`  
*Output.* Data pointer to GPU memory associated with the tensor descriptor `hyDesc`. If a `NULL` pointer is passed, the final hidden state of the network will not be saved.

`cyDesc`  
*Input.* A fully packed tensor descriptor describing the final cell state for LSTM networks. The first dimension of the tensor depends on the `direction` argument used to initialize `rnnDesc`:

- If `direction` is `CUDNN_UNIDIRECTIONAL` the first dimension should match the `numLayers` argument.
- If `direction` is `CUDNN_BIDIRECTIONAL` the first dimension should match double the `numLayers` argument.

The second dimension must match the first dimension of the tensors described in `xDesc`. The third dimension must match the `hiddenSize` argument used to initialize `rnnDesc`. The tensor must be fully packed.

`cy`  
*Output.* Data pointer to GPU memory associated with the tensor descriptor `cyDesc`. If a `NULL` pointer is passed, the final cell state of the network will not be saved.

`workspace`  
*Input.* Data pointer to GPU memory to be used as a workspace for this call.

`workSpaceSizeInBytes`  
*Input.* Specifies the size in bytes of the provided `workspace`. 
reserveSpace
   Input/Output. Data pointer to GPU memory to be used as a reserve space for this call.

reserveSpaceSizeInBytes
   Input. Specifies the size in bytes of the provided reserveSpace.

Returns

CUDNN_STATUS_SUCCESS
   The function launched successfully.

CUDNN_STATUS_BAD_PARAM
   At least one of the following conditions are met:
   ▶ The descriptor rnnDesc is invalid.
   ▶ At least one of the descriptors hxDesc, cxDesc, wDesc, hyDesc, cyDesc or one of the descriptors in xDesc, yDesc is invalid.
   ▶ The descriptors in one of xDesc, hxDesc, cxDesc, wDesc, yDesc, hyDesc, cyDesc have incorrect strides or dimensions.
   ▶ workSpaceSizeInBytes is too small.
   ▶ reserveSpaceSizeInBytes is too small.

CUDNN_STATUS_INVALID_VALUE
   cudnnSetPersistentRNNPlan() was not called prior to the current function when CUDNN_RNN_ALGO_PERSIST_DYNAMIC was selected in the RNN descriptor.

CUDNN_STATUS_EXECUTION_FAILED
   The function failed to launch on the GPU.

CUDNN_STATUS_ALLOC_FAILED
   The function was unable to allocate memory.

8.2.25. cudnnRNNForwardTrainingEx()

This function has been deprecated starting in cuDNN 8.0. Use cudnnRNNForward() instead of cudnnRNNForwardTrainingEx().

```c
void cudnnRNNForwardTrainingEx(
    cudnnHandle_t      handle,
    const cudnnRNNDescriptor_t  rnnDesc,
    const cudnnRNNDataDescriptor_t  xDesc,
    const void *       x,
    const cudnnTensorDescriptor_t   hxDesc,
    const void *       hx,
    const cudnnTensorDescriptor_t   cxDesc,
    const void *       cx,
    const cudnnFilterDescriptor_t   wDesc,
    const void *       w,
    const cudnnRNNDataDescriptor_t  yDesc,
    const void *       y,
    void *              y,
    const cudnnTensorDescriptor_t   hyDesc,
    void *              hy,
    const cudnnTensorDescriptor_t   cyDesc,
    void *              cy,
)
```
This routine is the extended version of the cudnnRNNForwardTraining() function. The cudnnRNNForwardTrainingEx() allows the user to use unpacked (padded) layout for input x and output y.

In the unpacked layout, each sequence in the mini-batch is considered to be of fixed length, specified by maxSeqLength in its corresponding RNNDataDescriptor. Each fixed-length sequence, for example, the nth sequence in the mini-batch, is composed of a valid segment specified by the seqLengthArray[n] in its corresponding RNNDataDescriptor; and a padding segment to make the combined sequence length equal to maxSeqLength.

With the unpacked layout, both sequence major (meaning, time major) and batch major are supported. For backward compatibility, the packed sequence major layout is supported. However, similar to the non-extended function cudnnRNNForwardTraining(), the sequences in the mini-batch need to be sorted in descending order according to length.

**Parameters**

**handle**

*Input*. Handle to a previously created cuDNN context.

**rnnDesc**

*Input*. A previously initialized RNN descriptor.

**xDesc**

*Input*. A previously initialized RNN Data descriptor. The dataType, layout, maxSeqLength, batchSize, and seqLengthArray need to match that of yDesc.

**x**

*Input*. Data pointer to the GPU memory associated with the RNN data descriptor xDesc. The input vectors are expected to be laid out in memory according to the layout specified by xDesc. The elements in the tensor (including elements in the padding vector) must be densely packed, and no strides are supported.

**hxDesc**

*Input*. A fully packed tensor descriptor describing the initial hidden state of the RNN.

The first dimension of the tensor depends on the direction argument used to initialize rnnDesc. Moreover:

- If direction is CUDNN_UNIDIRECTIONAL then the first dimension should match the numLayers argument.
- If `direction` is `CUDNN_BIDIRECTIONAL` then the first dimension should match double the `numLayers` argument.

The second dimension must match the `batchSize` parameter in `xDesc`. The third dimension depends on whether RNN mode is `CUDNN_LSTM` and whether LSTM projection is enabled. Additionally:

- If RNN mode is `CUDNN_LSTM` and LSTM projection is enabled, the third dimension must match the `recProjSize` argument passed to `cudnnSetRNNProjectionLayers()` call used to set `rnnDesc`.
- Otherwise, the third dimension must match the `hiddenSize` argument used to initialize `rnnDesc`.

**hx**

*Input.* Data pointer to GPU memory associated with the tensor descriptor `hxDesc`. If a NULL pointer is passed, the initial hidden state of the network will be initialized to zero.

**cxDesc**

*Input.* A fully packed tensor descriptor describing the initial cell state for LSTM networks.

The first dimension of the tensor depends on the `direction` argument used to initialize `rnnDesc`. Additionally:

- If `direction` is `CUDNN_UNIDIRECTIONAL` the first dimension should match the `numLayers` argument.
- If `direction` is `CUDNN_BIDIRECTIONAL` the first dimension should match double the `numLayers` argument.

The second dimension must match the first dimension of the tensors described in `xDesc`. The third dimension must match the `hiddenSize` argument used to initialize `rnnDesc`. The tensor must be fully packed.

**cx**

*Input.* Data pointer to GPU memory associated with the tensor descriptor `cxDesc`. If a NULL pointer is passed, the initial cell state of the network will be initialized to zero.

**wDesc**

*Input.* Handle to a previously initialized filter descriptor describing the weights for the RNN.

**w**

*Input.* Data pointer to GPU memory associated with the filter descriptor `wDesc`.

**yDesc**

*Input.* A previously initialized RNN data descriptor. The `dataType`, `layout`, `maxSeqLength`, `batchSize`, and `seqLengthArray` need to match that of `dyDesc` and `dxDesc`. The parameter `vectorSize` depends on whether the RNN mode is `CUDNN_LSTM` and whether LSTM projection is enabled and whether the network is bidirectional. Specifically:
For a unidirectional network, if the RNN mode is `CUDNN_LSTM` and LSTM projection is enabled, the parameter `vectorSize` must match the `recProjSize` argument passed to `cudnnSetRNNProjectionLayers()` call used to set `rnnDesc`. If the network is bidirectional, then multiply the value by 2.

Otherwise, for unidirectional network, the parameter `vectorSize` must match the `hiddenSize` argument used to initialize `rnnDesc`. If the network is bidirectional, then multiply the value by 2.

\( y \)

**Output.** Data pointer to GPU memory associated with the RNN data descriptor `yDesc`. The input vectors are expected to be laid out in memory according to the layout specified by `yDesc`. The elements in the tensor (including elements in the padding vector) must be densely packed, and no strides are supported.

\( hyDesc \)

**Input.** A fully packed tensor descriptor describing the final hidden state of the RNN. The descriptor must be set exactly the same as `hxDesc`.

\( hy \)

**Output.** Data pointer to GPU memory associated with the tensor descriptor `hyDesc`. If a NULL pointer is passed, the final hidden state of the network will not be saved.

\( cyDesc \)

**Input.** A fully packed tensor descriptor describing the final cell state for LSTM networks. The descriptor must be set exactly the same as `cxDesc`.

\( cy \)

**Output.** Data pointer to GPU memory associated with the tensor descriptor `cyDesc`. If a NULL pointer is passed, the final cell state of the network will not be saved.

\( kDesc \)

Reserved. Users may pass in NULL.

\( keys \)

Reserved. Users may pass in NULL.

\( cDesc \)

Reserved. Users may pass in NULL.

\( cAttn \)

Reserved. Users may pass in NULL.

\( iDesc \)

Reserved. Users may pass in NULL.

\( iAttn \)

Reserved. Users may pass in NULL.

\( qDesc \)

Reserved. Users may pass in NULL.

\( queries \)

Reserved. Users may pass in NULL.

\( workspace \)

**Input.** Data pointer to GPU memory to be used as a workspace for this call.
workSpaceSizeInBytes
   Input. Specifies the size in bytes of the provided workspace.

reserveSpace
   Input/Output. Data pointer to GPU memory to be used as a reserve space for this call.

reserveSpaceSizeInBytes
   Input. Specifies the size in bytes of the provided reserveSpace.

Returns

CUDNN_STATUS_SUCCESS
   The function launched successfully.

CUDNN_STATUS_NOT_SUPPORTED
   At least one of the following conditions are met:
   ▶ Variable sequence length input is passed in while
     CUDNN_RNN_ALGO_PERSIST_STATIC or CUDNN_RNN_ALGO_PERSIST_DYNAMIC is used.
   ▶ CUDNN_RNN_ALGO_PERSIST_STATIC or CUDNN_RNN_ALGO_PERSIST_DYNAMIC is used on
     pre-Pascal devices.
   ▶ Double input/output is used for CUDNN_RNN_ALGO_PERSIST_STATIC.

CUDNN_STATUS_BAD_PARAM
   At least one of the following conditions are met:
   ▶ The descriptor rnnDesc is invalid.
   ▶ At least one of the descriptors xDesc, yDesc, hxDesc, cxDesc, wDesc, hyDesc, and
     cyDesc is invalid, or have incorrect strides or dimensions.
   ▶ workSpaceSizeInBytes is too small.
   ▶ reserveSpaceSizeInBytes is too small.

CUDNN_STATUS_INVALID_VALUE
   cudnnSetPersistentRNNPlan() was not called prior to the current function when
   CUDNN_RNN_ALGO_PERSIST_DYNAMIC was selected in the RNN descriptor.

CUDNN_STATUS_EXECUTION_FAILED
   The function failed to launch on the GPU.

CUDNN_STATUS_ALLOC_FAILED
   The function was unable to allocate memory.

8.2.26. cudnnSetCTCLossDescriptor()

This function sets a CTC loss function descriptor. See also the extended version
   cudnnSetCTCLossDescriptorEx() to set the input normalization mode.
When the extended version \texttt{cudnnSetCTCLossDescriptorEx()} is used with \texttt{normMode} set to \texttt{CUDNN\_LOSS\_NORMALIZATION\_NONE} and the \texttt{gradMode} set to \texttt{CUDNN\_NOT\_PROPAGATE\_NAN}, then it is the same as the current function \texttt{cudnnSetCTCLossDescriptor()}, meaning:
\begin{verbatim}
cudnnSetCtcLossDescriptor(*) = cudnnSetCtcLossDescriptorEx(*, 
normMode=CUDNN\_LOSS\_NORMALIZATION\_NONE, gradMode=CUDNN\_NOT\_PROPAGATE\_NAN)
\end{verbatim}

\section*{Parameters}

\begin{itemize}
\item \texttt{ctcLossDesc}
  \textit{Output}. CTC loss descriptor to be set.
\item \texttt{compType}
  \textit{Input}. Compute type for this CTC loss function.
\end{itemize}

\section*{Returns}

\begin{itemize}
\item \texttt{CUDNN\_STATUS\_SUCCESS}
  The function returned successfully.
\item \texttt{CUDNN\_STATUS\_BAD\_PARAM}
  At least one of the input parameters passed is invalid.
\end{itemize}

\subsection*{8.2.27. \texttt{cudnnSetCTCLossDescriptorEx}()}

This function is an extension of \texttt{cudnnSetCTCLossDescriptor()}. This function provides an additional interface \texttt{normMode} to set the input normalization mode for the CTC loss function, and \texttt{gradMode} to control the \texttt{NaN} propagation type.
\begin{verbatim}
cudnnStatus_t cudnnSetCTCLossDescriptorEx(
    cudnnCTCLossDescriptor_t        ctcLossDesc,
    cudnnDataType_t                 compType,
    cudnnLossNormalizationMode_t    normMode,
    cudnnNanPropagation_t           gradMode)
\end{verbatim}

When this function \texttt{cudnnSetCTCLossDescriptorEx()} is used with \texttt{normMode} set to \texttt{CUDNN\_LOSS\_NORMALIZATION\_NONE} and the \texttt{gradMode} set to \texttt{CUDNN\_NOT\_PROPAGATE\_NAN}, then it is the same as \texttt{cudnnSetCTCLossDescriptor()}, meaning:
\begin{verbatim}
cudnnSetCtcLossDescriptor(*) = cudnnSetCtcLossDescriptorEx(*, 
normMode=CUDNN\_LOSS\_NORMALIZATION\_NONE, gradMode=CUDNN\_NOT\_PROPAGATE\_NAN)
\end{verbatim}

\section*{Parameters}

\begin{itemize}
\item \texttt{ctcLossDesc}
  \textit{Output}. CTC loss descriptor to be set.
\item \texttt{compType}
  \textit{Input}. Compute type for this CTC loss function.
\item \texttt{normMode}
  \textit{Input}. Input normalization type for this CTC loss function. For more information, refer to \texttt{cudnnLossNormalizationMode_t}.
\item \texttt{gradMode}
  \textit{Input}. NaN propagation type for this CTC loss function. For $L$ the sequence length, $R$ the number of repeated letters in the sequence, and $T$ the length of sequential data, the following applies: when a sample with $L+R > T$ is encountered during
the gradient calculation, if `gradMode` is set to `CUDNN_PROPAGATE_NAN` (refer to `cudnnNanPropagation_t`), then the CTC loss function does not write to the gradient buffer for that sample. Instead, the current values, even not finite, are retained. If `gradMode` is set to `CUDNN_NOT_PROPAGATE_NAN`, then the gradient for that sample is set to zero. This guarantees a finite gradient.

**Returns**

- **CUDNN_STATUS_SUCCESS**
  The function returned successfully.
- **CUDNN_STATUS_BAD_PARAM**
  At least one of the input parameters passed is invalid.

### 8.2.28. `cudnnSetCTCLossDescriptor_v8()`

Many CTC API functions are updated in cuDNN version 8.0.0 to support CUDA graphs. In order to do so, a new parameter is needed, `maxLabelLength`. Now that label and input data are assumed to be in GPU memory, this information is not otherwise readily available.

```c
void cudnnStatus_t cudnnSetCTCLossDescriptorEx(
    cudnnCTCLossDescriptor_t ctcLossDesc, 
    cudnnDataType_t compType, 
    cudnnLossNormalizationMode_t normMode, 
    cudnnNanPropagation_t gradMode, 
    int maxLabelLength)
```

**Parameters**

- **ctcLossDesc**
  *Output*. CTC loss descriptor to be set.

- **compType**
  *Input*. Compute type for this CTC loss function.

- **normMode**
  *Input*. Input normalization type for this CTC loss function. For more information, refer to `cudnnLossNormalizationMode_t`.

- **gradMode**
  *Input*. NaN propagation type for this CTC loss function. For a sequence length, `L` the number of repeated letters in the sequence, and `T` the length of sequential data, the following applies: when a sample with `L+R > T` is encountered during the gradient calculation, if `gradMode` is set to `CUDNN_PROPAGATE_NAN` (refer to `cudnnNanPropagation_t`), then the CTC loss function does not write to the gradient buffer for that sample. Instead, the current values, even not finite, are retained. If `gradMode` is set to `CUDNN_NOT_PROPAGATE_NAN`, then the gradient for that sample is set to zero. This guarantees a finite gradient.

- **maxLabelLength**
  *Input*. The maximum label length from the labels data.
Returns

**CUDNN_STATUS_SUCCESS**

The function returned successfully.

**CUDNN_STATUS_BAD_PARAM**

At least one of input parameters passed is invalid.
Chapter 9. cuDNN Backend API

This chapter documents the current implemented behavior of the cudnnBackend* API introduced in cuDNN version 8.x. Users specify the computational case, set up an execution plan for it, and execute the computation via numerous descriptors. The typical use pattern for a descriptor with attributes consists of the following sequence of API calls:

1. `cudnnBackendCreateDescriptor()` creates a descriptor of a specified type.
2. `cudnnBackendSetAttribute()` sets the values of a settable attribute for the descriptor. All required attributes must be set before the next step.
3. `cudnnBackendFinalize()` finalizes the descriptor.
4. `cudnnBackendGetAttribute()` gets the values of an attribute from a finalized descriptor.

The enumeration type `cudnnBackendDescriptorType_t` enumerates the list of valid cuDNN backend descriptor types. The enumeration type `cudnnBackendAttributeName_t` enumerates the list of valid attributes. Each descriptor type in `cudnnBackendDescriptorType_t` has a disjoint subset of valid attribute values of `cudnnBackendAttributeName_t`. The full description of each descriptor type and their attributes are specified in the Backend Descriptor Types section.

9.1. Data Type References

These are the data type references for the cuDNN Backend API.

9.1.1. Enumeration Types

These are the enumeration types for the cuDNN Backend API.

9.1.1.1. `cudnnBackendAttributeName_t`

cudnnBackendAttributeName_t is an enumerated type that indicates the backend descriptor attributes that can be set or get using `cudnnBackendSetAttribute()` and `cudnnBackendGetAttribute()` functions. The backend descriptor to which an attribute belongs is identified by the prefix of the attribute name.

```c
typedef enum {
    CUDNN_ATTR_POINTWISE_MODE = 0,
    CUDNN_ATTR_POINTWISE_MATH_PREC = 1,
} cudnnBackendAttributeName_t;
```
<table>
<thead>
<tr>
<th>Attribute Name</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>CUDNN_ATTR_POINTWISE_NAN_PROPAGATION</td>
<td>2</td>
</tr>
<tr>
<td>CUDNN_ATTR_POINTWISE_RELU_LOWER_CLIP</td>
<td>3</td>
</tr>
<tr>
<td>CUDNN_ATTR_POINTWISE_RELU_UPPER_CLIP</td>
<td>4</td>
</tr>
<tr>
<td>CUDNN_ATTR_POINTWISE_RELU_LOWER_CLIP_SLOPE</td>
<td>5</td>
</tr>
<tr>
<td>CUDNN_ATTR_POINTWISE_ELU_ALPHA</td>
<td>6</td>
</tr>
<tr>
<td>CUDNN_ATTR_POINTWISE_SOFTPLUS_BETA</td>
<td>7</td>
</tr>
<tr>
<td>CUDNN_ATTR_POINTWISE_SWISH_BETA</td>
<td>8</td>
</tr>
<tr>
<td>CUDNN_ATTR_POINTWISE_AXIS</td>
<td>9</td>
</tr>
<tr>
<td>CUDNN_ATTR_CONVOLUTION_COMP_TYPE</td>
<td>100</td>
</tr>
<tr>
<td>CUDNN_ATTR_CONVOLUTION_CONV_MODE</td>
<td>101</td>
</tr>
<tr>
<td>CUDNN_ATTR_CONVOLUTION_DILATIONS</td>
<td>102</td>
</tr>
<tr>
<td>CUDNN_ATTR_CONVOLUTION_FILTER_STRIDES</td>
<td>103</td>
</tr>
<tr>
<td>CUDNN_ATTR_CONVOLUTION_POST_PADDINGS</td>
<td>104</td>
</tr>
<tr>
<td>CUDNN_ATTR_CONVOLUTION_PRE_PADDINGS</td>
<td>105</td>
</tr>
<tr>
<td>CUDNN_ATTR_CONVOLUTION_SPATIAL_DIMS</td>
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</tr>
<tr>
<td>CUDNN_ATTR_ENGINEHEUR_MODE</td>
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<td>CUDNN_ATTR_ENGINEHEUR_OPERATION_GRAPH</td>
<td>201</td>
</tr>
<tr>
<td>CUDNN_ATTR_ENGINEHEUR_RESULTS</td>
<td>202</td>
</tr>
<tr>
<td>CUDNN_ATTR_ENGINEHEUR_SM_COUNT_TARGET</td>
<td>203</td>
</tr>
<tr>
<td>CUDNN_ATTR_ENGINECFG_ENGINE</td>
<td>300</td>
</tr>
<tr>
<td>CUDNN_ATTR_ENGINECFG_INTERMEDIATE_INFO</td>
<td>301</td>
</tr>
<tr>
<td>CUDNN_ATTR_ENGINECFG_KNOB_CHOICES</td>
<td>302</td>
</tr>
<tr>
<td>CUDNN_ATTR_EXECUTION_PLAN_HANDLE</td>
<td>400</td>
</tr>
<tr>
<td>CUDNN_ATTR_EXECUTION_PLAN_ENGINE_CONFIG</td>
<td>401</td>
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<tr>
<td>CUDNN_ATTR_EXECUTION_PLAN_WORKSPACE_SIZE</td>
<td>402</td>
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<tr>
<td>CUDNN_ATTR_EXECUTION_PLAN_COMPUTED_INTERMEDIATE_UIDS</td>
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</tr>
<tr>
<td>CUDNN_ATTR_EXECUTION_PLAN_RUN_ONLY_INTERMEDIATE_UIDS</td>
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</tr>
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<td>CUDNN_ATTR_INTERMEDIATE_INFO_UNIQUE_ID</td>
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<tr>
<td>CUDNN_ATTR_INTERMEDIATE_INFO_SIZE</td>
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</tr>
<tr>
<td>CUDNN_ATTR_INTERMEDIATE_INFO_DEPENDENT_DATA_UIDS</td>
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<tr>
<td>CUDNN_ATTR_INTERMEDIATE_INFO_DEPENDENT_ATTRIBUTES</td>
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</tr>
<tr>
<td>CUDNN_ATTR_KNOB_CHOICE_KNOB_TYPE</td>
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<tr>
<td>CUDNN_ATTR_KNOB_CHOICE_KNOB_VALUE</td>
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<tr>
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<td>CUDNN_ATTR_OPERATION_CONVOLUTION_FORWARD_W</td>
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<tr>
<td>CUDNN_ATTR_OPERATION_CONVOLUTION_FORWARD_X</td>
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<tr>
<td>CUDNN_ATTR_OPERATION_CONVOLUTION_FORWARD_Y</td>
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<tr>
<td>CUDNN_ATTR_OPERATION_CONVOLUTION_BWD_DATA_W</td>
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</tr>
<tr>
<td>CUDNN_ATTR_OPERATION_CONVOLUTION_BWD_DATA_DX</td>
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</tr>
<tr>
<td>CUDNN_ATTR_OPERATION_CONVOLUTION_BWD_DATA_DY</td>
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<tr>
<td>CUDNN_ATTR_OPERATION_CONVOLUTION_BWD_FILTER_ALPHA</td>
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<tr>
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<tr>
<td>CUDNN_ATTR_OPERATION_CONVOLUTION_BWD_FILTER_CONV_DESC</td>
<td>714</td>
</tr>
<tr>
<td>CUDNN_ATTR_OPERATION_CONVOLUTION_BWD_FILTER_DW</td>
<td>715</td>
</tr>
<tr>
<td>CUDNN_ATTR_OPERATION_CONVOLUTION_BWD_FILTER_X</td>
<td>716</td>
</tr>
<tr>
<td>CUDNN_ATTR_OPERATION_CONVOLUTION_BWD_FILTER_DY</td>
<td>717</td>
</tr>
<tr>
<td>CUDNN_ATTR_OPERATION_POINTWISE_PW_DESCRIPTOR</td>
<td>750</td>
</tr>
<tr>
<td>CUDNN_ATTR_OPERATION_POINTWISE_XDESC</td>
<td>751</td>
</tr>
<tr>
<td>CUDNN_ATTR_OPERATION_POINTWISE_BDESC</td>
<td>752</td>
</tr>
<tr>
<td>CUDNN_ATTR_OPERATION_POINTWISE_YDESC</td>
<td>753</td>
</tr>
<tr>
<td>CUDNN_ATTR_OPERATION_POINTWISE_ALPHA1</td>
<td>754</td>
</tr>
<tr>
<td>CUDNN_ATTR_OPERATION_POINTWISE_ALPHA2</td>
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<tr>
<td>CUDNN_ATTR_OPERATION_POINTWISE_DXDESC</td>
<td>756</td>
</tr>
<tr>
<td>CUDNN_ATTR_OPERATION_POINTWISE_DYDESC</td>
<td>757</td>
</tr>
<tr>
<td>CUDNN_ATTR_OPERATION_POINTWISE_TDDESC</td>
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</tbody>
</table>
CUDNN_ATTR_OPERATION GENSTATS_MODE = 770,
CUDNN_ATTR_OPERATION GENSTATS_MATH_PREC = 771,
CUDNN_ATTR_OPERATION GENSTATS_XDESC = 772,
CUDNN_ATTR_OPERATION GENSTATS_SUMDESC = 773,
CUDNN_ATTR_OPERATION GENSTATS_SQSUMDESC = 774,
CUDNN_ATTR_OPERATION BN_FINALIZE_STATS_MODE = 780,
CUDNN_ATTR_OPERATION BN_FINALIZE_MATH_PREC = 781,
CUDNN_ATTR_OPERATION BN_FINALIZE_Y_SUM_DESC = 782,
CUDNN_ATTR_OPERATION BN_FINALIZE_Y_SQ_SUM_DESC = 783,
CUDNN_ATTR_OPERATION BN_FINALIZE_SCALE_DESC = 784,
CUDNN_ATTR_OPERATION BN_FINALIZE_BIAS_DESC = 785,
CUDNN_ATTR_OPERATION BN_FINALIZE_PREV_RUNNING_MEAN_DESC = 786,
CUDNN_ATTR_OPERATION BN_FINALIZE_PREV_RUNNING_VAR_DESC = 787,
CUDNN_ATTR_OPERATION BN_FINALIZE_UPDATED_RUNNING_MEAN_DESC = 788,
CUDNN_ATTR_OPERATION BN_FINALIZE_UPDATED_RUNNING_VAR_DESC = 789,
CUDNN_ATTR_OPERATION BN_FINALIZE_SAVED_MEAN_DESC = 790,
CUDNN_ATTR_OPERATION BN_FINALIZE_SAVED_INV_STD_DESC = 791,
CUDNN_ATTR_OPERATION BN_FINALIZE_EQ_SCALE_DESC = 792,
CUDNN_ATTR_OPERATION BN_FINALIZE_EQ_BIAS_DESC = 793,
CUDNN_ATTR_OPERATION BN_FINALIZE_ACCUM_COUNT_DESC = 794,
CUDNN_ATTR_OPERATION BN_FINALIZE_EPSILON_DESC = 795,
CUDNN_ATTR_OPERATION BN_FINALIZE_EQ_AVERAGE_FACTOR_DESC = 796,
CUDNN_ATTR_OPERATIONGRAPH_HANDLE = 800,
CUDNN_ATTR_OPERATIONGRAPH_OPS = 801,
CUDNN_ATTR_OPERATIONGRAPH_ENGINE_GLOBAL_COUNT = 802,
CUDNN_ATTR_TENSOR_BYTE_ALIGNMENT = 900,
CUDNN_ATTR_TENSOR_DATA_TYPE = 901,
CUDNN_ATTR_TENSOR_DIMENSIONS = 902,
CUDNN_ATTR_TENSOR_STRIDES = 903,
CUDNN_ATTR_TENSOR_VECTOR_COUNT = 904,
CUDNN_ATTR_TENSOR_VECTORIZED_DIMENSION = 905,
CUDNN_ATTR_TENSOR_UNIQUE_ID = 906,
CUDNN_ATTR_TENSOR_IS_VIRTUAL = 907,
CUDNN_ATTR_TENSOR_IS_BY_VALUE = 908,
CUDNN_ATTR_TENSOR_REORDERING_MODE = 909,
CUDNN_ATTR_TENSOR_RAGGED_OFFSET_DESC = 910,
CUDNN_ATTR_VARIANT_PACK_UNIQUE_IDS = 1000,
CUDNN_ATTR_VARIANT_PACK_DATA_POINTERS = 1001,
CUDNN_ATTR_VARIANT_PACK_INTERMEDIATES = 1002,
CUDNN_ATTR_VARIANT_PACK_WORKSPACE = 1003,
CUDNN_ATTR_LAYOUT_INFO_TENSOR_UID = 1100,
CUDNN_ATTR_LAYOUT_INFO_TYPES = 1101,
CUDNN_ATTR_KNOB_INFO_TYPE = 1200,
CUDNN_ATTR_KNOB_INFO_MAXIMUM_VALUE = 1201,
CUDNN_ATTR_KNOB_INFO_MINIMUM_VALUE = 1202,
CUDNN_ATTR_KNOB_INFO_STRIDE = 1203,
CUDNN_ATTR_ENGINE_OPERATION_GRAPH = 1300,
CUDNN_ATTR_ENGINE_GLOBAL_INDEX = 1301,
CUDNN_ATTR_ENGINE_KNOB_INFO = 1302,
CUDNN_ATTR_ENGINE_NUMERICAL_NOTE = 1303,
CUDNN_ATTR_ENGINE_LAYOUT_INFO = 1304,
CUDNN_ATTR_ENGINE_BEHAVIOR_NOTE = 1305,
CUDNN_ATTR_ENGINE_SM_COUNT_TARGET = 1306,
CUDNN_ATTR_MATMUL_COMP_TYPE = 1500,
CUDNN_ATTR_MATMUL_PADDING_VALUE = 1501,
CUDNN_ATTR_OPERATION_MATMUL_CDESC = 1522,
CUDNN_ATTR_OPERATION_MATMUL_DESC = 1523,
CUDNN_ATTR_OPERATION_MATMUL_IRREGULARLY_STRIDED_BATCH_COUNT = 1524,
CUDNN_ATTR_OPERATION_MATMUL_GEMM_M_OVERRIDE_DESC = 1525,
CUDNN_ATTR_OPERATION_MATMUL_GEMM_N_OVERRIDE_DESC = 1526,
CUDNN_ATTR_OPERATION_MATMUL_GEMM_K_OVERRIDE_DESC = 1527,

CUDNN_ATTR_REDUCTION_OPERATOR = 1600,
CUDNN_ATTR_REDUCTION_COMP_TYPE = 1601,

CUDNN_ATTR_OPERATION_REDUCTION_XDESC = 1610,
CUDNN_ATTR_OPERATION_REDUCTION_YDESC = 1611,
CUDNN_ATTR_OPERATION_REDUCTION_DESC = 1612,

CUDNN_ATTR_OPERATION_BN_BWD_WEIGHTS_MATH_PREC = 1620,
CUDNN_ATTR_OPERATION_BN_BWD_WEIGHTS_MEAN_DESC = 1621,
CUDNN_ATTR_OPERATION_BN_BWD_WEIGHTS_INVSTD_DESC = 1622,
CUDNN_ATTR_OPERATION_BN_BWD_WEIGHTS_BN_SCALE_DESC = 1623,
CUDNN_ATTR_OPERATION_BN_BWD_WEIGHTS_X_DESC = 1624,
CUDNN_ATTR_OPERATION_BN_BWD_WEIGHTS_DY_DESC = 1625,
CUDNN_ATTR_OPERATION_BN_BWD_WEIGHTS_DBN_SCALE_DESC = 1626,
CUDNN_ATTR_OPERATION_BN_BWD_WEIGHTS_DBN_BIAS_DESC = 1627,
CUDNN_ATTR_OPERATION_BN_BWD_WEIGHTS_EQ_DY_SCALE_DESC = 1628,
CUDNN_ATTR_OPERATION_BN_BWD_WEIGHTS_EQ_X_SCALE_DESC = 1629,
CUDNN_ATTR_OPERATION_BN_BWD_WEIGHTS_EQ_BIAS = 1630,

CUDNN_ATTR_RESAMPLE_MODE = 1700,
CUDNN_ATTR_RESAMPLE_COMP_TYPE = 1701,
CUDNN_ATTR_RESAMPLE_SPATIAL_DIMS = 1702,
CUDNN_ATTR_RESAMPLE_POST_PADDINGS = 1703,
CUDNN_ATTR_RESAMPLE_PRE_PADDINGS = 1704,
CUDNN_ATTR_RESAMPLE_STRIDES = 1705,
CUDNN_ATTR_RESAMPLE_WINDOW_DIMS = 1706,
CUDNN_ATTR_RESAMPLE_NAN_PROPAGATION = 1707,
CUDNN_ATTR_RESAMPLE_PADDING_MODE = 1708,

CUDNN_ATTR_OPERATION_RESAMPLE_FWD_XDESC = 1710,
CUDNN_ATTR_OPERATION_RESAMPLE_FWD_YDESC = 1711,
CUDNN_ATTR_OPERATION_RESAMPLE_FWD_IDXDESC = 1712,
CUDNN_ATTR_OPERATION_RESAMPLE_FWD_ALPHA = 1713,
CUDNN_ATTR_OPERATION_RESAMPLE_FWD_BETA = 1714,
CUDNN_ATTR_OPERATION_RESAMPLE_FWD_DESC = 1716,

CUDNN_ATTR_OPERATION_RESAMPLE_BWD_DXDESC = 1720,
CUDNN_ATTR_OPERATION_RESAMPLE_BWD_DXDESC = 1721,
CUDNN_ATTR_OPERATION_RESAMPLE_BWD_DYDESC = 1722,
CUDNN_ATTR_OPERATION_RESAMPLE_BWD_IDXDESC = 1723,
CUDNN_ATTR_OPERATION_RESAMPLE_BWD_ALPHA = 1724,
CUDNN_ATTR_OPERATION_RESAMPLE_BWD_BETA = 1725,
CUDNN_ATTR_OPERATION_RESAMPLE_BWD_DESC = 1726,
CUDNN_ATTR_OPERATION_RESAMPLE_BWD_YDESC = 1727,

CUDNN_ATTR_OPERATIONConcatAxis = 1800,
CUDNN_ATTR_OPERATIONConcatInputDescs = 1801,
CUDNN_ATTR_OPERATIONConcatInplaceIndex = 1802,
CUDNN_ATTR_OPERATIONConcatOutputDesc = 1803,

CUDNN_ATTR_OPERATION_SIGNAL_MODE = 1900,
CUDNN_ATTR_OPERATION_SIGNAL_FLAGDESC = 1901,
CUDNN_ATTR_OPERATION_SIGNAL_VALUE = 1902,
CUDNN_ATTR_OPERATION_SIGNAL_XDESC = 1903,
CUDNN_ATTR_OPERATION_SIGNAL_YDESC = 1904,

CUDNN_ATTR_OPERATIONNormFWDMode = 2000,
CUDNN_ATTR_OPERATIONNormFWDPhase = 2001,
CUDNN_ATTR_OPERATIONNormFWDXDESC = 2002,


9.1.1.2. `cudnnBackendAttributeType_t`

The enumeration type `cudnnBackendAttributeType_t` specifies the data type of an attribute of a cuDNN backend descriptor. It is used to specify the type of data pointed to by the `void *arrayOfElements` argument of `cudnnBackendSetAttribute()` and `cudnnBackendGetAttribute()`.
Table 51. Attribute Types for `cudnnBackendAttributeType_t`

<table>
<thead>
<tr>
<th>cudnnBackendAttributeType_t</th>
<th>Attribute type</th>
</tr>
</thead>
<tbody>
<tr>
<td>CUDNN_TYPE_HANDLE</td>
<td><code>cudnnHandle_t</code></td>
</tr>
<tr>
<td>CUDNN_TYPE_DATA_TYPE</td>
<td><code>cudnnDataType_t</code></td>
</tr>
<tr>
<td>CUDNN_TYPE_BOOLEAN</td>
<td><code>bool</code></td>
</tr>
<tr>
<td>CUDNN_TYPE_INT64</td>
<td><code>int64_t</code></td>
</tr>
<tr>
<td>CUDNN_TYPE_FLOAT</td>
<td><code>float</code></td>
</tr>
<tr>
<td>CUDNN_TYPE_DOUBLE</td>
<td><code>double</code></td>
</tr>
<tr>
<td>CUDNN_TYPE_VOID_PTR</td>
<td><code>void *</code></td>
</tr>
<tr>
<td>CUDNN_TYPE_CONVOLUTION_MODE</td>
<td><code>cudnnConvolutionMode_t</code></td>
</tr>
<tr>
<td>CUDNN_TYPE_HEUR_MODE</td>
<td><code>cudnnBackendHeurMode_t</code></td>
</tr>
<tr>
<td>CUDNN_TYPE_KNOB_TYPE</td>
<td><code>cudnnBackendKnobType_t</code></td>
</tr>
<tr>
<td>CUDNN_TYPE_NAN_PROPOGATION</td>
<td><code>cudnnNanPropagation_t</code></td>
</tr>
<tr>
<td>CUDNN_TYPE_NUMERICAL_NOTE</td>
<td><code>cudnnBackendNumericalNote_t</code></td>
</tr>
<tr>
<td>CUDNN_TYPE_LAYOUT_TYPE</td>
<td><code>cudnnBackendLayoutType_t</code></td>
</tr>
<tr>
<td>CUDNN_TYPE_ATTRIB_NAME</td>
<td><code>cudnnBackendAttributeName_t</code></td>
</tr>
<tr>
<td>CUDNN_TYPE_POINTWISE_MODE</td>
<td><code>cudnnPointwiseMode_t</code></td>
</tr>
<tr>
<td>CUDNN_TYPE_BACKEND_DESCRIPTOR</td>
<td><code>cudnnBackendDescriptor_t</code></td>
</tr>
<tr>
<td>CUDNN_TYPE_GENSTATS_MODE</td>
<td><code>cudnnGenStatsMode_t</code></td>
</tr>
<tr>
<td>CUDNN_TYPE_BN_FINALIZE_STATS_MODE</td>
<td><code>cudnnBnFinalizeStatsMode_t</code></td>
</tr>
<tr>
<td>CUDNN_TYPE_REDUCTION_OPERATOR_TYPE</td>
<td><code>cudnnReduceTensorOp_t</code></td>
</tr>
<tr>
<td>CUDNN_TYPE_BEHAVIOR_NOTE</td>
<td><code>cudnnBackendBehaviorNote_t</code></td>
</tr>
<tr>
<td>CUDNN_TYPE_TENSOR_REORDERING_MODE</td>
<td><code>cudnnBackendTensorReordering_t</code></td>
</tr>
<tr>
<td>CUDNN_TYPE_RESAMPLE_MODE</td>
<td><code>cudnnResampleMode_t</code></td>
</tr>
<tr>
<td>CUDNN_TYPE_PADDING_MODE</td>
<td><code>cudnnPaddingMode_t</code></td>
</tr>
<tr>
<td>CUDNN_TYPE_INT32</td>
<td><code>int32_t</code></td>
</tr>
<tr>
<td>CUDNN_TYPE_CHAR</td>
<td><code>char</code></td>
</tr>
<tr>
<td>CUDNN_TYPE_SIGNAL_MODE</td>
<td><code>cudnnSignalMode_t</code></td>
</tr>
</tbody>
</table>
9.1.1.3. **cudnnBackendBehaviorNote_t**

cudnnBackendBehaviorNote_t is an enumerated type that indicates queryable behavior notes of an engine. Users can query for an array of behavior notes from an CUDNN_BACKEND_ENGINE_DESC using the cudnnBackendGetAttribute() function.

```c
typedef enum {
    CUDNN_BEHAVIOR_NOTE_RUNTIME_COMPILATION             = 0,
    CUDNN_BEHAVIOR_NOTE_REQUIRES_FILTER_INT8x32_REORDER = 1,
    CUDNN_BEHAVIOR_NOTE_REQUIRES_BIAS_INT8x32_REORDER   = 2,
    CUDNN_BEHAVIOR_NOTE_TYPE_COUNT,
} cudnnBackendBehaviorNote_t;
```

9.1.1.4. **cudnnBackendDescriptorType_t**

cudnnBackendDescriptor_t is an enumerated type that indicates the type of backend descriptors. Users create a backend descriptor of a particular type by passing a value from this enumerate to the cudnnBackendCreateDescriptor() function.

```c
typedef enum {
    CUDNN_BACKEND_POINTWISE_DESCRIPTOR = 0,
    CUDNN_BACKEND_CONVOLUTION_DESCRIPTOR,
    CUDNN_BACKEND_ENGINE_DESCRIPTOR,
    CUDNN_BACKEND_ENGINECFG_DESCRIPTOR,
    CUDNN_BACKEND_ENGINEHEUR_DESCRIPTOR,
    CUDNN_BACKEND_EXECUTION_PLAN_DESCRIPTOR,
    CUDNN_BACKEND_INTERMEDIATE_INFO_DESCRIPTOR,
    CUDNN_BACKEND_KNOB_CHOICE_DESCRIPTOR,
    CUDNN_BACKEND_KNOB_INFO_DESCRIPTOR,
    CUDNN_BACKEND_LAYOUT_INFO_DESCRIPTOR,
    CUDNN_BACKEND_OPERATION_CONVOLUTION_FORWARD_DESCRIPTOR,
    CUDNN_BACKEND_OPERATION_CONVOLUTION_BACKWARD_FILTER_DESCRIPTOR,
    CUDNN_BACKEND_OPERATION_CONVOLUTION_BACKWARD_DATA_DESCRIPTOR,
    CUDNN_BACKEND_OPERATION_POINTWISE_DESCRIPTOR,
    CUDNN_BACKEND_OPERATION_GEN_STATS_DESCRIPTOR,
    CUDNN_BACKEND_OPERATIONGRAPH_DESCRIPTOR,
    CUDNN_BACKEND_VARIANT_PACK_DESCRIPTOR,
    CUDNN_BACKEND_TENSOR_DESCRIPTOR,
    CUDNN_BACKEND_MATMUL_DESCRIPTOR,
    CUDNN_BACKEND_OPERATION_BN_FINALIZE_STATISTICS_DESCRIPTOR,
    CUDNN_BACKEND_REDUCTION_DESCRIPTOR,
    CUDNN_BACKEND_OPERATION_BN_BWD_WEIGHTS_DESCRIPTOR,
    CUDNN_BACKEND_RESAMPLE_DESCRIPTOR,
    CUDNN_BACKEND_OPERATION_RESAMPLE_FWD_DESCRIPTOR,
    CUDNN_BACKEND_OPERATION_RESAMPLE_BWD_DESCRIPTOR,
    CUDNN_BACKEND_OPERATION_CONCAT_DESCRIPTOR,
    CUDNN_BACKEND_OPERATION_SIGNAL_DESCRIPTOR,
    CUDNN_BACKEND_OPERATION_NORM_FORWARD_DESCRIPTOR,
    CUDNN_BACKEND_OPERATION_NORM_BACKWARD_DESCRIPTOR,
} cudnnBackendDescriptorType_t;
```
9.1.1.5. **cudnnBackendHeurMode_t**

*cudnnBackendHeurMode_t* is an enumerated type that indicates the operation mode of a `CUDNN_BACKEND_ENGINEHEUR_DESCRIPTOR`.

```c
typedef enum {
    CUDNN_HEUR_MODE_INSTANT = 0,
    CUDNN_HEUR_MODE_B = 1,
    CUDNN_HEUR_MODE_FALLBACK = 2,
    CUDNN_HEUR_MODE_A = 3
} Values
```

**Values**

**CUDNN_HEUR_MODE_A** & **CUDNN_HEUR_MODE_INSTANT**

*CUDNN_HEUR_MODE_A* provides the exact same functionality as *CUDNN_HEUR_MODE_INSTANT*. The purpose of this renaming is to better match the naming of *CUDNN_HEUR_MODE_B*. Consider the use of *CUDNN_HEUR_MODE_INSTANT* as deprecated; instead, use *CUDNN_HEUR_MODE_A*.

*CUDNN_HEUR_MODE_A* utilizes a decision tree heuristic which provides optimal inference time on the CPU in comparison to *CUDNN_HEUR_MODE_B*.

*CUDNN_HEUR_MODE_A* and *CUDNN_HEUR_MODE_INSTANT* support the following operation node or operation graph:

- **ConvolutionFwd**
- **ConvolutionBwFilter**
- **ConvolutionBwData**
- **ConvBNfprop**
- **ConvBNwgrad**
- **ConvBiasAct**
- **ConvScaleBiasAct**
- **DgradDreluBNBwdWeight**
- **patterns supported by the runtime fusion engine**

All other operation graphs are not supported.

**CUDNN_HEUR_MODE_B**

Can utilize the neural net based heuristics to improve generalization performance compared to *CUDNN_HEUR_MODE_INSTANT*. In cases where the neural net is utilized, inference time on the CPU will be increased by 10-100x compared to *CUDNN_HEUR_MODE_INSTANT*. These neural net heuristics are not supported for any of the following cases:

- 3-D convolutions
- Grouped convolutions (groupCount larger than 1)
Dilated convolutions (any dilation for any spatial dimension larger than 1)

Further, the neural net is only enabled on x86 platforms when cuDNN is run on an A100 GPU. In cases where the neural net is not supported, 
**CUDNN_HEUR_MODE_B** will also fall back to **CUDNN_HEUR_MODE_INSTANT**. 
**CUDNN_HEUR_MODE_B** will fall back to **CUDNN_HEUR_MODE_INSTANT** in cases where the overhead of **CUDNN_HEUR_MODE_B** is projected to reduce overall network performance.

**CUDNN_HEUR_MODE_FALLBACK**

This heuristic mode is intended to be used for finding fallback options which provide functional support (without any expectation of providing optimal GPU performance).

### 9.1.1.6. cudnnBackendKnobType_t

**cudnnBackendKnobType_t** is an enumerated type that indicates the type of performance knobs. Performance knobs are runtime settings to an engine that will affect its performance. Users can query for an array of performance knobs and their valid value range from a **CUDNN_BACKEND_ENGINE_DESCRIPTOR** using the **cudnnBackendGetAttribute()** function. Users can set the choice for each knob using the **cudnnBackendSetAttribute()** function with a **CUDNN_BACKEND_KNOB_CHOICE_DESCRIPTOR** descriptor.

```c
typedef enum {
    CUDNN_KNOB_TYPE_SPLIT_K          = 0,
    CUDNN_KNOB_TYPE_SWIZZLE          = 1,
    CUDNN_KNOB_TYPE_TILE_SIZE        = 2,
    CUDNN_KNOB_TYPE_USE_TEX          = 3,
    CUDNN_KNOB_TYPE_EDGE             = 4,
    CUDNN_KNOB_TYPE_KBLOCK           = 5,
    CUDNN_KNOB_TYPE_LDGA             = 6,
    CUDNN_KNOB_TYPE_LDGB             = 7,
    CUDNN_KNOB_TYPE_CHUNK_K          = 8,
    CUDNN_KNOB_TYPE_SPLIT_H          = 9,
    CUDNN_KNOB_TYPE_WINO_TILE        = 10,
    CUDNN_KNOB_TYPE_MULTIPLY         = 11,
    CUDNN_KNOB_TYPE_SPLIT_K_BUF      = 12,
    CUDNN_KNOB_TYPE_TILEK            = 13,
    CUDNN_KNOB_TYPE_STAGES           = 14,
    CUDNN_KNOB_TYPE_REDUCTION_MODE   = 15,
    CUDNN_KNOB_TYPE_CTA_SPLIT_K_MODE = 16,
    CUDNN_KNOB_TYPE_SPLIT_K_SLC      = 17,
    CUDNN_KNOB_TYPE_IDX_MODE         = 18,
    CUDNN_KNOB_TYPE_SLICED           = 19,
    CUDNN_KNOB_TYPE_SPLIT_RS         = 20,
    CUDNN_KNOB_TYPE_SINGLÉBUFFER     = 21,
    CUDNN_KNOB_TYPE_LDGC             = 22,
    CUDNN_KNOB_TYPE_SPECFILT         = 23,
    CUDNN_KNOB_TYPE_KERNEL_CFG       = 24,
    CUDNN_KNOB_TYPE_WORKSPACE        = 25,
    CUDNN_KNOB_TYPE_COUNTS = 26,
} cudnnBackendKnobType_t;
```

### 9.1.1.7. cudnnBackendLayoutType_t

**cudnnBackendLayoutType_t** is an enumerated type that indicates queryable layout requirements of an engine. Users can query for layout requirements from a
CUDNN_BACKEND_ENGINE_DESC descriptor using the cudnnBackendGetAttribute() function.

typedef enum {
    CUDNN_LAYOUT_TYPE_PREFERRED_NCHW   = 0,
    CUDNN_LAYOUT_TYPE_PREFERRED_NHWC   = 1,
    CUDNN_LAYOUT_TYPE_PREFERRED_PAD4CK = 2,
    CUDNN_LAYOUT_TYPE_PREFERRED_PAD8CK = 3,
    CUDNN_LAYOUT_TYPE_COUNT            = 4,
} cudnnBackendLayoutType_t;

9.1.1.8. cudnnBackendNormFwdPhase_t

cudnnBackendNormFwdPhase_t is an enumerated type used to distinguish the inference
and training phase of the normalization forward operation.

typedef enum {
    CUDNN_NORM_FWD_INFERENCE = 0,
    CUDNN_NORM_FWD_TRAINING  = 1,
} cudnnBackendNormFwdPhase_t;

9.1.1.9. cudnnBackendNormMode_t

cudnnBackendNormMode_t is an enumerated type to indicate the normalization mode in
the backend normalization forward and normalization backward operations.

For reference:
- The definition of layer normalization can be found in the Layer Normalization paper.
- The definition of instance normalization can be found in the Instance Normalization:
  The Missing Ingredient for Fast Stylization paper.
- The definition of batch normalization can be found in the Batch Normalization:
  Accelerating Deep Network Training by Reducing Internal Covariate Shift paper.

CUDNN_GROUP_NORM is not yet supported. If you try to use it, cuDNN returns a
CUDNN_STATUS_INTERNAL_ERROR error.

typedef enum {
    CUDNN_LAYER_NORM    = 0,
    CUDNN_INSTANCE_NORM = 1,
    CUDNN_BATCH_NORM    = 2,
    CUDNN_GROUP_NORM    = 3,
} cudnnBackendNormMode_t;

9.1.1.10. cudnnBackendNumericalNote_t

cudnnBackendNumericalNote_t is an enumerated type that indicates queryable numerical
properties of an engine. Users can query for an array of numerical notes from an
CUDNN_BACKEND_ENGINE_DESC using the cudnnBackendGetAttribute() function.

typedef enum {
    CUDNN_NUMERICAL_NOTE_TENSOR_CORE = 0,
    CUDNN_NUMERICAL_NOTE_DOWN_CONVERT_INPUTS,
    CUDNN_NUMERICAL_NOTE_REDUCED_PRECISION_REDUCTION,
    CUDNN_NUMERICAL_NOTE_FFT,
    CUDNN_NUMERICAL_NOTE_NONDETERMINISTIC,
    CUDNN_NUMERICAL_NOTE_WINOGRAD,
    CUDNN_NUMERICAL_NOTE_WINOGRAD TILE_4x4,
    CUDNN_NUMERICAL_NOTE_WINOGRAD TILE_6x6,
    CUDNN_NUMERICAL_NOTE_WINOGRAD TILE_13x13,
    CUDNN_NUMERICAL_NOTE_TYPE_COUNT,
}
9.1.1.11. cudnnBackendTensorReordering_t

cudnnBackendTensorReordering_t is an enumerated type that indicates tensor reordering as a property of the tensor descriptor. Users can get and set this property in a CUDNN_BACKEND_TENSOR_DESCRIPTOR via cudnnBackendSetAttribute() and cudnnBackendGetAttribute() functions.

typedef enum {
    CUDNN_TENSOR_REORDERING_NONE    = 0,
    CUDNN_TENSOR_REORDERING_INT8x32 = 1,
    CUDNN_TENSOR_REORDERING_F16x16  = 2,
} cudnnBackendTensorReordering_t;

9.1.1.12. cudnnBnFinalizeStatsMode_t

cudnnBnFinalizeStatsMode_t is an enumerated type that exposes the different mathematical operation modes that converts batchnorm statistics and the trained scale and bias to the equivalent scale and bias to be applied in the next normalization stage for inference and training use cases.

typedef enum {
    CUDNN_BN_FINALIZE_STATISTICS_TRAINING  = 0,
    CUDNN_BN_FINALIZE_STATISTICS_INFERENCE = 1,
} cudnnBnFinalizeStatsMode_t;

Table 52. BN Statistics for cudnnBnFinalizeStatsMode_t

<table>
<thead>
<tr>
<th>BN Statistics Mode</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>CUDNN_BN_FINALIZE_STATISTICS_TRAINING</td>
<td>Computes the equivalent scale and bias from ySum, ySqSum and learned scale, bias. Optionally, update running statistics and generate saved stats for interoperability with cudnnBatchNormalizationBackward(), cudnnBatchNormalizationBackwardEx(), or cudnnNormalizationBackward().</td>
</tr>
<tr>
<td>CUDNN_BN_FINALIZE_STATISTICS_INFERENCE</td>
<td>Computes the equivalent scale and bias from the learned running statistics and the learned scale, bias.</td>
</tr>
</tbody>
</table>

9.1.1.13. cudnnFraction_t

cudnnFraction_t is a structure that allows a user to define int64_t fractions.

typedef struct cudnnFractionStruct {
    int64_t numerator;
    int64_t denominator;
} cudnnFraction_t;

9.1.1.14. cudnnGenStatsMode_t

cudnnGenStatsMode_t is an enumerated type to indicate the statistics mode in the backend statistics generation operation.
Values

CUDNN_GENSTATS_SUM_SQSUM
In this mode, the sum and sum of squares of the input tensor along the specified dimensions are computed and written out. The reduction dimensions currently supported are limited per channel, however additional support may be added upon request.

9.1.1.15. cudnnPaddingMode_t

cudnnPaddingMode_t is an enumerated type to indicate the padding mode in the backend resample operations.

typedef enum {
    CUDNN_ZERO_PAD     = 0,
    CUDNN_NEG_INF_PAD  = 1,
    CUDNN_EDGE_VAL_PAD = 2,
} cudnnPaddingMode_t;

9.1.1.16. cudnnPointwiseMode_t

cudnnPointwiseMode_t is an enumerated type to indicate the intended pointwise math operation in the backend pointwise operation descriptor.

Values

CUDNN_POINTWISE_ADD
In this mode, a pointwise addition between two tensors is computed.

CUDNN_POINTWISE_ADD_SQUARE
In this mode, a pointwise addition between the first tensor and the square of the second tensor is computed.

CUDNN_POINTWISE_DIV
In this mode, a pointwise true division of the first tensor by second tensor is computed.

CUDNN_POINTWISE_MAX
In this mode, a pointwise maximum is taken between two tensors.

CUDNN_POINTWISE_MIN
In this mode, a pointwise minimum is taken between two tensors.

CUDNN_POINTWISE_MOD
In this mode, a pointwise floating-point remainder of the first tensor’s division by the second tensor is computed.

CUDNN_POINTWISE_MUL
In this mode, a pointwise multiplication between two tensors is computed.

CUDNN_POINTWISE_POW
In this mode, a pointwise value from the first tensor to the power of the second tensor is computed.

CUDNN_POINTWISE_SUB
In this mode, a pointwise subtraction between two tensors is computed.
CUDNN_POINTWISE_ABS
In this mode, a pointwise absolute value of the input tensor is computed.

CUDNN_POINTWISE_CEIL
In this mode, a pointwise ceiling of the input tensor is computed.

CUDNN_POINTWISE_COS
In this mode, a pointwise trigonometric cosine of the input tensor is computed.

CUDNN_POINTWISE_EXP
In this mode, a pointwise exponential of the input tensor is computed.

CUDNN_POINTWISE_FLOOR
In this mode, a pointwise floor of the input tensor is computed.

CUDNN_POINTWISE_LOG
In this mode, a pointwise natural logarithm of the input tensor is computed.

CUDNN_POINTWISE_NEG
In this mode, a pointwise numerical negative of the input tensor is computed.

CUDNN_POINTWISE_RSQRT
In this mode, a pointwise reciprocal of the square root of the input tensor is computed.

CUDNN_POINTWISE_SIN
In this mode, a pointwise trigonometric sine of the input tensor is computed.

CUDNN_POINTWISE_SQRT
In this mode, a pointwise square root of the input tensor is computed.

CUDNN_POINTWISE_TAN
In this mode, a pointwise trigonometric tangent of the input tensor is computed.

CUDNN_POINTWISE_ERF
In this mode, a pointwise Error Function is computed.

CUDNN_POINTWISE_IDENTITY
In this mode, no computation is performed. As with other pointwise modes, this mode provides implicit conversions by specifying the data type of the input tensor as one type, and the data type of the output tensor as another.

CUDNN_POINTWISE_RELU_FWD
In this mode, a pointwise rectified linear activation function of the input tensor is computed.

CUDNN_POINTWISE_TANH_FWD
In this mode, a pointwise tanh activation function of the input tensor is computed.

CUDNN_POINTWISE_SIGMOID_FWD
In this mode, a pointwise sigmoid activation function of the input tensor is computed.

CUDNN_POINTWISE_ELU_FWD
In this mode, a pointwise Exponential Linear Unit activation function of the input tensor is computed.

CUDNN_POINTWISE_GELU_FWD
In this mode, a pointwise Gaussian Error Linear Unit activation function of the input tensor is computed.

CUDNN_POINTWISE_SOFTPLUS_FWD
In this mode, a pointwise softplus activation function of the input tensor is computed.
CUDNN_POINTWISE_SWISH_FWD
In this mode, a pointwise swish activation function of the input tensor is computed.

CUDNN_POINTWISE_GELU_APPROX_TANH_FWD
In this mode, a pointwise tanh approximation of the Gaussian Error Linear Unit activation function of the input tensor is computed. The tanh GELU approximation is computed as

\[ 0.5x \left( 1 + \tanh \left( \sqrt{\frac{2}{\pi}} \left( x + 0.044715x^3 \right) \right) \right) \]

For more information, refer to the GAUSSIAN ERROR LINEAR UNIT (GELU) paper.

CUDNN_POINTWISE_RELU_BWD
In this mode, a pointwise first derivative of rectified linear activation of the input tensor is computed.

CUDNN_POINTWISE_TANH_BWD
In this mode, a pointwise first derivative of tanh activation of the input tensor is computed.

CUDNN_POINTWISE_SIGMOID_BWD
In this mode, a pointwise first derivative of sigmoid activation of the input tensor is computed.

CUDNN_POINTWISE_ELU_BWD
In this mode, a pointwise first derivative of Exponential Linear Unit activation of the input tensor is computed.

CUDNN_POINTWISE_GELU_BWD
In this mode, a pointwise first derivative of Gaussian Error Linear Unit activation of the input tensor is computed.

CUDNN_POINTWISE_SOFTPLUS_BWD
In this mode, a pointwise first derivative of softplus activation of the input tensor is computed.

CUDNN_POINTWISE_SWISH_BWD
In this mode, a pointwise first derivative of swish activation of the input tensor is computed.

CUDNN_POINTWISE_GELU_APPROX_TANH_BWD
In this mode, a pointwise first derivative of the tanh approximation of the Gaussian Error Linear Unit activation of the input tensor is computed. This is computed as

\[ 0.5 \left( 1 + \tanh \left( b \left( x + cx^3 \right) \right) + bx \sec \left( \sqrt{\pi} \left( b \left( c x^3 + x \right) \left( 3c x^2 + 1 \right) \right) \right) \right) \]

where \( b = \sqrt{\pi} \) and \( c = 0.044715 \).

CUDNN_POINTWISE_CMP_EQ
In this mode, a pointwise truth value of the first tensor equal to the second tensor is computed.

CUDNN_POINTWISE_CMP_NEQ
In this mode, a pointwise truth value of the first tensor not equal to the second tensor is computed.

CUDNN_POINTWISE_CMP_GT
In this mode, a pointwise truth value of the first tensor greater than the second tensor is computed.
**CUDNN_POINTWISE_CMP_GE**
In this mode, a pointwise truth value of the first tensor greater than equal to the second tensor is computed.

**CUDNN_POINTWISE_CMP_LT**
In this mode, a pointwise truth value of the first tensor less than the second tensor is computed.

**CUDNN_POINTWISE_CMP_LE**
In this mode, a pointwise truth value of the first tensor less than equal to the second tensor is computed.

**CUDNN_POINTWISE_LOGICAL_AND**
In this mode, a pointwise truth value of the first tensor logical AND second tensor is computed.

**CUDNN_POINTWISE_LOGICAL_OR**
In this mode, a pointwise truth value of the first tensor logical OR second tensor is computed.

**CUDNN_POINTWISE_LOGICAL_NOT**
In this mode, a pointwise truth value of input tensor’s logical NOT is computed.

**CUDNN_POINTWISE_GEN_INDEX**
In this mode, a pointwise index value of the input tensor is generated along a given axis.

**CUDNN_POINTWISE_BINARY_SELECT**
In this mode, a pointwise value is selected amongst two input tensors based on a given predicate tensor.

**CUDNN_POINTWISE_RECIPROCAL**
In this mode, a pointwise reciprocal of the input tensor is computed. In other words, for every element x in the input tensor, 1/x is computed.

### 9.1.1.17. cudnnResampleMode_t

cudnnResampleMode_t is an enumerated type to indicate the resample mode in the backend resample operations.

```c
typedef enum {
    CUDNN_RESAMPLE_NEAREST = 0,
    CUDNN_RESAMPLE_BILINEAR = 1,
    CUDNN_RESAMPLE_AVGPOOL = 2,
    CUDNN_RESAMPLE_AVGPOOL_INCLUDE_PADDING = 2,
    CUDNN_RESAMPLE_AVGPOOL_EXCLUDE_PADDING = 4,
    CUDNN_RESAMPLE_MAXPOOL = 3,
} cudnnResampleMode_t;
```

### 9.1.1.18. cudnnRngDistribution_t

cudnnRngDistribution_t is an enumerated type to indicate the distribution to be used in the backend Rng (random number generator) operation.

```c
typedef enum {
    CUDNN_RNG_DISTRIBUTION_BERNOULLI,
    CUDNN_RNG_DISTRIBUTION_UNIFORM,
    CUDNN_RNG_DISTRIBUTION_NORMAL,
} cudnnRngDistribution_t;
```
Values

CUDNN_RNG_DISTRIBUTION_BERNOULLI
In this mode, the bernoulli distribution is used for the random number generation. The attribute CUDNN_ATTR_RNG_BERNOULLI_DIST_PROBABILITY can be used to specify the probability of generating 1’s.

CUDNN_RNG_DISTRIBUTION_UNIFORM
In this mode, the normal distribution is used for the random number generation. The attribute CUDNN_ATTR_RNG_NORMAL_DIST_MEAN and CUDNN_ATTR_RNG_NORMAL_DIST_STANDARD_DEVIATION can be used to specify the mean and standard deviation of the random number generator.

9.1.1.19. cudnnSignalMode_t

cudnnSignalMode_t is an enumerated type to indicate the signaling mode in the backend signal operation.

typedef enum {
    CUDNN_SIGNAL_SET  = 0,
    CUDNN_SIGNAL_WAIT = 1,
} cudnnSignalMode_t;

Values

CUDNN_SIGNAL_SET
In this mode, the flag variable is updated with the provided signal value atomically.

CUDNN_SIGNAL_WAIT
In this mode, the operation blocks until the flag variable keeps comparing equal to the provided signal value.

9.1.2. Data Types Found In cudnn_backend.h

These are the data types found in cudnn_backend.h.

9.1.2.1. cudnnBackendDescriptor_t

cudnnBackendDescriptor_t is a typedef void pointer to one of many opaque descriptor structures. The type of structure that it points to is determined by the argument when allocating the memory for the opaque structure using cudnnBackendCreateDescriptor().

Attributes of a descriptor can be set using cudnnBackendSetAttribute(). After all required attributes of a descriptor are set, the descriptor can be finalized by cudnnBackendFinalize(). From a finalized descriptor, one can query its queryable attributes using cudnnBackendGetAttribute(). Finally, the memory allocated for a descriptor can be freed using cudnnBackendDestroyDescriptor().
9.2. API Functions

These are the API functions in the cuDNN Backend API.

9.2.1. cudnnBackendCreateDescriptor()

This function allocates memory in the descriptor for a given descriptor type and at the location pointed by the descriptor.

\[
\text{cudnnStatus_t cudnnBackendCreateDescriptor(cudnnBackendDescriptorType_t descriptorType, cudnnBackendDescriptor_t *descriptor)}
\]

Note: The cudnnBackendDescriptor_t is a pointer to void *.

Parameters

descriptorType

Input. One among the enumerated cudnnBackendDescriptorType_t.

descriptor

Input. Pointer to an instance of cudnnBackendDescriptor_t to be created.

Returns

CUDNN_STATUS_SUCCESS

The creation was successful.

CUDNN_STATUS_NOT_SUPPORTED

Creating a descriptor of a given type is not supported.

CUDNN_STATUS_ALLOC_FAILED

The memory allocation failed.

Additional return values depend on the arguments used as explained in the cuDNN Backend API.

9.2.2. cudnnBackendDestroyDescriptor()

This function destroys instances of cudnnBackendDescriptor_t that were previously created using cudnnBackendCreateDescriptor().

\[
\text{cudnnStatus_t cudnnBackendDestroyDescriptor(cudnnBackendDescriptor_t descriptor)}
\]

Parameters

descriptor

Input. Instance of cudnnBackendDescriptor_t previously created by cudnnBackendCreateDescriptor().
Returns

**CUDNN_STATUS_SUCCESS**

The memory was destroyed successfully.

**CUDNN_STATUS_ALLOC_FAILED**

The destruction of memory failed.

**Undefined Behavior**

The descriptor was altered between the Create and Destroy Descriptor.

**Undefined**

The value pointed by the descriptor will be Undefined after the memory is free and done.

Additional return values depend on the arguments used as explained in the cuDNN Backend API.

### 9.2.3. `cudnnBackendExecute()`

This function executes the given Engine Configuration Plan on the VariantPack and the finalized ExecutionPlan on the data. The data and the working space are encapsulated in the VariantPack.

```c

cudnnStatus_ cudnnBackendExecute(cudnnHandle_t handle, cudnnBackendDescriptor_t executionPlan, cudnnBackendDescriptor_t varianPack)
```

**Parameters**

- **executionPlan**
  
  *Input*. Pointer to the cuDNN handle to be destroyed.

- **variantPack**
  
  *Input*. Pointer to the finalized VariantPack consisting of:

  - Data pointer for each non-virtual pointer of the operation set in the execution plan.
  - Pointer to user-allocated workspace in global memory at least as large as the size queried from CUDNN_BACKEND_.

**Returns**

- **CUDNN_STATUS_SUCCESS**
  
  The ExecutionPlan was executed successfully.

- **CUDNN_STATUS_BAD_PARAM**
  
  An incorrect or inconsistent value is encountered. Some examples:

  - A required data pointer is invalid.

- **CUDNN_STATUS_INTERNAL_ERROR**
  
  Some internal errors were encountered.

- **CUDNN_STATUS_EXECUTION_FAILED**
  
  An error was encountered executing the plan with the variant pack.
cuDNN Backend API

9.2.4. **cudnnBackendFinalize()**

This function finalizes the memory pointed to by the descriptor. The type of finalization is done depending on the descriptorType argument with which the descriptor was created using `cudnnBackendCreateDescriptor()` or initialized using `cudnnBackendInitialize()`.

```c
void cudnnBackendFinalize(const cudnnBackendDescriptor descriptor);
```

cudnnBackendFinalize() also checks all the attributes set between the create/initialization and finalize phase. If successful, cudnnBackendFinalize() returns CUDNN_STATUS_SUCCESS and the finalized state of the descriptor is set to true. In this state, setting attributes using `cudnnBackendSetAttribute()` is not allowed. Getting attributes using `cudnnBackendGetAttribute()` is only allowed when the finalized state of the descriptor is true.

**Parameters**

- **descriptor**
  - *Input*. Instance of `cudnnBackendDescriptor_t` to finalize.

**Returns**

- **CUDNN_STATUS_SUCCESS**
  - The descriptor was finalized successfully.

- **CUDNN_STATUS_BAD_PARAM**
  - Invalid descriptor attribute values or combination thereof is encountered.

- **CUDNN_STATUS_NOT_SUPPORTED**
  - Descriptor attribute values or combinations therefore not supported by the current version of cuDNN are encountered.

- **CUDNN_STATUS_INTERNAL_ERROR**
  - Some internal errors are encountered.

Additional return values depend on the arguments used as explained in the cuDNN Backend API.

9.2.5. **cudnnBackendGetAttribute()**

This function retrieves the value(s) of an attribute of a descriptor. `attributeName` is the name of the attribute whose value is requested. The `attributeType` is the type of attribute. `requestedElementCount` is the number of elements to be potentially retrieved. The number of elements for the requested attribute is stored in `elementCount`. The retrieved values are stored in `arrayOfElements`. When the attribute is expected to have a single value, `arrayOfElements` can be pointer to the output value. This function will return CUDNN_STATUS_NOT_INITIALIZED if the descriptor has not been successfully finalized using `cudnnBackendFinalize()`.

```c
void cudnnBackendGetAttribute(const cudnnBackendDescriptor descriptor, const char attributeName, cudnnAttributeType attributeType, const size_t requestedElementCount, cudnnSize_t *elementCount, const cudnnPointer attributeValue);
```

Additional return values depend on the arguments used as explained in the cuDNN Backend API.
cudnnBackendDescriptor_t descriptor,
cudnnBackendAttributeName_t attributeName,
cudnnBackendAttributeType_t attributeType,
int64_t requestedElementCount,
int64_t *elementCount,
void *arrayOfElements);

Parameters

descriptor
  Input. Instance of cudnnBackendDescriptor_t whose attribute the user wants to retrieve.

attributeName
  Input. The name of the attribute being get from the on the descriptor.

attributeType
  Input. The type of attribute.

requestedElementCount
  Input. Number of elements to output to arrayOfElements.

elementCount
  Input. Output pointer for the number of elements the descriptor attribute has. Note that cudnnBackendGetAttribute() will only write the least of this and requestedElementCount elements to arrayOfElements.

arrayOfElements
  Input. Array of elements of the datatype of the attributeType. The datatype of the attributeType is listed in the mapping table of cudnnBackendAttributeType_t.

Returns

CUDNN_STATUS_SUCCESS
  The attributeName was given to the descriptor successfully.

CUDNN_STATUS_BAD_PARAM
  One or more invalid or inconsistent argument values were encountered. Some examples:
  ▶ attributeName is not a valid attribute for the descriptor.
  ▶ attributeType is not one of the valid types for the attribute.

CUDNN_STATUS_NOT_INITIALIZED
  The descriptor has not been successfully finalized using cudnnBackendFinalize().

Additional return values depend on the arguments used as explained in the cuDNN Backend API.
9.2.6. **cudnnBackendInitialize()**

This function repurposes a pre-allocated memory pointed to by a descriptor of size `sizeInBytes` to a backend descriptor of type `descriptorType`. The finalized state of the descriptor is set to false.

```c
void *cudnnBackendInitialize(cudnnBackendDescriptor_t descriptor, cudnnBackendDescriptorType_t descriptorType, size_t sizeInBytes)
```

**Parameters**

- **descriptor**
  - `Input`. Instance of `cudnnBackendDescriptor_t` to be initialized.
- **descriptorType**
  - `Input`. Enumerated value for the type of cuDNN backend descriptor.
- **sizeInBytes**
  - `Input`. Size of memory pointed to by `descriptor`.

**Returns**

- **CUDNN_STATUS_SUCCESS**
  - The memory was initialized successfully.
- **CUDNN_STATUS_BAD_PARAM**
  - An invalid or inconsistent argument value is encountered. For example:
    - `descriptor` is a `nullptr`
    - `sizeInBytes` is less than the size required by the descriptor type

Additional return values depend on the arguments used as explained in the cuDNN Backend API.

9.2.7. **cudnnBackendSetAttribute()**

This function sets an attribute of a descriptor to value(s) provided as a pointer.

```c
void *cudnnBackendSetAttribute(  cudnnBackendDescriptor_t descriptor,  cudnnBackendAttributeName_t attributeName,  cudnnBackendAttributeType_t attributeType,  int64_t elementCount,  void *arrayOfElements)
```

**Parameters**

- **descriptor**
  - `Input`. Instance of `cudnnBackendDescriptor_t` whose attribute is being set.
attributeName

   Input. The name of the attribute being set on the descriptor.

attributeType

   Input. The type of attribute.

elementCount

   Input. Number of elements being set.

arrayOfElements

   Input. The starting location for an array from where to read the values from. The elements of the array are expected to be of the datatype of the attributeType. The datatype of the attributeType is listed in the mapping table of cudnnBackendAttributeType_t.

Returns

CUDNN_STATUS_SUCCESS

   The attributeName was set to the descriptor.

CUDNN_STATUS_NOT_INITIALIZED

   The backend descriptor pointed to by the descriptor is already in the finalized state.

CUDNN_STATUS_BAD_PARAM

   The function is called with arguments that correspond to invalid values. Some possible causes are:
   
   ▶ attributeName is not a settable attribute of descriptor
   ▶ attributeType is incorrect for this attributeName.
   ▶ elemCount value is unexpected.
   ▶ arrayOfElements contains values invalid for the attributeType.

CUDNN_STATUS_NOT_SUPPORTED

   The value(s) to which the attributes are being set is not supported by the current version of cuDNN.

Additional return values depend on the arguments used as explained in the cuDNN Backend API.

9.3. Backend Descriptor Types

This section enumerates all valid attributes of various descriptors.

9.3.1. cudnn_BACKEND_CONVOLUTION_DESCRIPTOR

Created with cudnnBackendCreateDescriptor(CUDNN_B Backend_CONVOLUTION_DESCRIPTOR, &desc); the cuDNN backend convolution descriptor specifies the parameters for a convolution operator for both forward and backward propagation: compute data type, convolution mode, filter dilation and stride, and padding on both sides.
Attributes

Attributes of a cuDNN backend convolution descriptor are values of enumeration type `cudnnBackendAttributeName_t` with prefix `CUDNN_ATTR_CONVOLUTION_`:

**CUDNN_ATTR_CONVOLUTION_COMP_TYPE**
The compute type of the convolution operator.
- `CUDNN_TYPE_DATA_TYPE`; one element.
- Required attribute.

**CUDNN_ATTR_CONVOLUTION_CONV_MODE**
Convolution or cross-correlation mode.
- `CUDNN_TYPE_CONVOLUTION_MODE`; one element.
- Required attribute.

**CUDNN_ATTR_CONVOLUTION_DILATIONS**
Filter dilation.
- `CUDNN_TYPE_INT64`; one or more, but at most `CUDNN_MAX_DIMS` elements.
- Required attribute.

**CUDNN_ATTR_CONVOLUTION_FILTER_STRIDES**
Filter stride.
- `CUDNN_TYPE_INT64`; one or more, but at most `CUDNN_MAX_DIMS` elements.
- Required attribute.

**CUDNN_ATTR_CONVOLUTION_PRE_PADDINGS**
Padding at the beginning of each spatial dimension.
- `CUDNN_TYPE_INT64`; one or more, but at most `CUDNN_MAX_DIMS` elements.
- Required attribute.

**CUDNN_ATTR_CONVOLUTION_POST_PADDINGS**
Padding at the end of each spatial dimension.
- `CUDNN_TYPE_INT64`; one or more, but at most `CUDNN_MAX_DIMS` elements.
- Required attribute.

**CUDNN_ATTR_CONVOLUTION_SPATIAL_DIMS**
The number of spatial dimensions in the convolution.
- `CUDNN_TYPE_INT64`; one element.
- Required attribute.
Finalization

`cudnnBackendFinalize()` with a `CUDNN_BACKEND_CONVOLUTION_DESCRIPTOR` can have the following return values:

**CUDNN_STATUS_BAD_PARAM**
An `elemCount` argument for setting `CUDNN_ATTR_CONVOLUTION_DILATIONS`, `CUDNN_ATTR_CONVOLUTION_FILTER_STRIDES`, `CUDNN_ATTR_CONVOLUTION_PRE_PADDINGS`, and `CUDNN_ATTR_CONVOLUTION_POST_PADDINGS` is not equal to the value set for `CUDNN_ATTR_CONVOLUTION_SPATIAL_DIMS`.

**CUDNN_STATUS_SUCCESS**
The descriptor was finalized successfully.

9.3.2. **CUDNN_BACKEND_ENGINE_DESCRIPTOR**

Created with descriptor type value `CUDNN_BACKEND_ENGINE_DESCRIPTOR`, cuDNN backend engine descriptor describes an engine to compute an operation graph. An engine is a grouping of kernels with similar compute and numerical attributes.

Attributes

Attributes of a cuDNN backend convolution descriptor are values of enumeration type `cudnnBackendAttributeName_t` with prefix `CUDNN_ATTR_ENGINE_`:

**CUDNN_ATTR_ENGINE_OPERATION_GRAPH**
The operation graph to compute.

- `CUDNN_TYPE_BACKEND_DESCRIPTOR`; one element of descriptor type `CUDNN_BACKEND_OPERATIONGRAPH_DESCRIPTOR`.
- Required attribute.

**CUDNN_ATTR_ENGINE_GLOBAL_INDEX**
The index for the engine.

- `CUDNN_TYPE_INT64`; one element.
- Valid values are between 0 and `CUDNN_ATTR_OPERATIONGRAPH_ENGINE_GLOBAL_COUNT-1`.
- Required attribute.

**CUDNN_ATTR_ENGINE_KNOB_INFO**
The descriptors of performance knobs of the engine.

- `CUDNN_TYPE_BACKEND_DESCRIPTOR`; one element of descriptor type `CUDNN_BACKEND_KNOB_INFO_DESCRIPTOR`.
- Read-only attribute.

**CUDNN_ATTR_ENGINE_NUMERICAL_NOTE**
The numerical attributes of the engine.
- CUDNN_TYPE_NUMERICAL_NOTE; zero or more elements.
- Read-only attribute.

CUDNN_ATTR_ENGINE_LAYOUT_INFO
The preferred tensor layouts of the engine.
- CUDNN_TYPE_BACKEND_DESCRIPTOR; one element of descriptor type
  CUDNN_BACKEND_LAYOUT_INFO_DESCRIPTOR.
- Read-only attribute.

CUDNN_ATTR_ENGINE_BEHAVIOR_NOTE
The behavior attributes of the engine.
- CUDNN_TYPE_BEHAVIOR_NOTE; zero or more elements.
- Read-only attribute.

CUDNN_ATTR_ENGINE_SM_COUNT_TARGET
The number of SMs to target.
- CUDNN_TYPE_INT32; one element.
- Valid values are between 0 and the number of SMs on the device, where 0 is default
  meaning all the SMs will be used.
- Optional attribute.

Finalization

CUDNN_STATUS_SUCCESS
The descriptor was finalized successfully.

CUDNN_STATUS_NOT_SUPPORTED
The descriptor attribute set is not supported by the current version of cuDNN. Some
examples include:
- The value of CUDNN_ATTR_ENGINE_GLOBAL_INDEX is not in a valid range.

CUDNN_STATUS_BAD_PARAM
The descriptor attribute set is inconsistent or in an unexpected state. Some examples
include:
- The operation graph descriptor set is not already finalized.

9.3.3. CUDNN_BACKENDENGINECFG_DESCRIPTOR
Created with cudnnBackendCreateDescriptor(CUDNN_BACKENDENGINECFG_DESCRIPTOR,
&desc); the cuDNN backend engine configuration descriptor consists of an engine
descriptor and an array of knob choice descriptors. Users can query from engine config
information about intermediates: computational intermediate results that can be reused
between executions.
Attributes

**CUDNN_ATTR_ENGINECFG_ENGINE**
The backend engine.
- **CUDNN_TYPE_BACKEND_DESCRIPTOR**: one element, a backend descriptor of type CUDNN_BACKEND_ENGINE_DESCRIPTOR.
- Required attribute.

**CUDNN_ATTR_ENGINECFG_KNob_CHOICES**
The engine tuning knobs and choices.
- **CUDNN_TYPE_BACKEND_DESCRIPTOR**: zero or more elements, backend descriptors of type CUDNN_BACKEND_KNOB_CHOICE_DESCRIPTOR.

**CUDNN_ATTR_ENGINECFG_INTERMEDIATE_INFO**
Information of the computational intermediate of this engine config.
- **CUDNN_TYPE_BACKEND_DESCRIPTOR**: one element, a backend descriptor of type CUDNN_BACKEND_INTERMEDIATE_INFO_DESCRIPTOR.
- Read-only attribute.
- Currently unsupported. Placeholder for future implementation.

Finalization

**CUDNN_STATUS_SUCCESS**
The descriptor was finalized successfully.

**CUDNN_STATUS_NOT_SUPPORTED**
The descriptor attribute set is not supported by the current version of cuDNN. Some examples include:
- The value knob.

### 9.3.4. CUDNN_BACKEND_ENGINEHEUR_DESCRIPTOR

Created with `cudnnBackendCreateDescriptor(CUDNN_BACKEND_ENGINEHEUR_DESCRIPTOR, &desc);` the cuDNN backend engine heuristics descriptor allows users to obtain for an operation graph engine configuration descriptors ranked by performance according to cuDNN’s heuristics.

Attributes

**CUDNN_ATTR_ENGINEHEUR_OPERATION_GRAPH**
The operation graph for which heuristics result in a query.

**CUDNN_TYPE_BACKEND_DESCRIPTOR**
One element.
 cuDNN Backend API

- Required attribute.

CUDNN_ATTRENGINEHEUR_MODE
The heuristic mode to query the result.

- CUDNN_TYPEHEUR_MODE; one element.

CUDNN_ATTRENGINEHEUR_RESULTS
The result of the heuristics query.

- CUDNN_TYPE_BACKEND_DESCRIPTOR; zero or more elements of descriptor type CUDNN_BACKEND_ENGINECFG_DESCRIPTOR.

- Get-only attribute.

CUDNN_ATTRENGINEHEUR_SM_COUNT_TARGET
The number of SMs to target.

- CUDNN_TYPE_INT32; one element.

- Valid values are between 0 and the number of SMs on the device, where 0 is default meaning all the SMs will be used.

- Optional attribute.

Finalization
Return values of cudnnBackendFinalize(desc) where desc is a cuDNN backend engine heuristics descriptor:

CUDNN_STATUS_SUCCESS
The descriptor was finalized successfully.

9.3.5. CUDNN_BACKEND_EXECUTION_PLAN_DESCRIPTOR
Created with cudnnBackendCreateDescriptor(CUDNN_BACKEND_EXECUTION_PLAN_DESCRIPTOR, &desc); the cuDNN backend execution plan descriptor allows the user to specify an execution plan, consists of a cuDNN handle, an engine configuration, and optionally an array of intermediates to compute.

Attributes

CUDNN_ATTR_EXECUTION_PLAN_HANDLE
A cuDNN handle.

- CUDNN_TYPE_HANDLE; one element.

- Required attribute.

CUDNN_ATTR_EXECUTION_PLAN_ENGINE_CONFIG
An engine configuration to execute.
• CUDNN_BACKEND_ENGINECFG_DESCRIPTOR; one element.
  • Required attribute.

CUDNN_ATTR_EXECUTION_PLAN_RUN_ONLY_INTERMEDIATE_UIDS
Unique identifiers of intermediates to compute.

• CUDNN_TYPE_INT64; zero or more elements.
  • Optional attribute. If set, the execution plan will only compute the specified
    intermediate and not any of the output tensors on the operation graph in the
    engine configuration.

CUDNN_ATTR_EXECUTION_PLAN_COMPUTED_INTERMEDIATE_UIDS
Unique identifiers of precomputed intermediates.

• CUDNN_TYPE_INT64; zero or more elements.
  • Optional attribute. If set, the plan will expect and use pointers for each
    intermediate in the variant pack descriptor during execution.
  • Not supported currently: placeholder for future implementation.

CUDNN_ATTR_EXECUTION_PLAN_WORKSPACE_SIZE
The size of the workspace buffer required to execute this plan.

• CUDNN_TYPE_INT64; one element.
  • Read-only attribute.

CUDNN_ATTR_EXECUTION_PLAN_JSON_REPRESENTATION
The JSON representation of the serialized execution plan. Serialization and
deserialization can be done by getting and setting this attribute, respectively.

• CUDNN_TYPE_CHAR; many elements, the same amount as the size of a null-
terminated string of the json representation of the execution plan.

Finalization

Return values of cudnnBackendFinalize(desc) where desc is a cuDNN backend
execution plan descriptor:

CUDNN_STATUS_SUCCESS
The descriptor was finalized successfully.

9.3.6. CUDNN_BACKEND_INTERMEDIATE_INFO_DESCRIPTOR

Created with
cudnnBackendCreateDescriptor(CUDNN_BACKEND_INTERMEDIATE_INFO_DESCRIPTOR,
&desc); the cuDNN backend intermediate descriptor is a read-only descriptor that
contains information about an execution intermediate. An execution intermediate is some
intermediate computation for an engine config in device memory that can be reused
between plan execution to amortize the kernel. Each intermediate is identified by a unique
ID. Users can query for the device memory size of the intermediate. An intermediate can
depend on the data of one or more tensors identified by the tensor UIDs or one more attribute of the operation graph.

This is a read-only descriptor. Users cannot set the descriptor attributes or finalize the descriptor. User query for a finalized descriptor from an engine config descriptor.

Attributes

- **CUDNN_ATTR_INTERMEDIATE_INFO_UNIQUE_ID**
  A unique identifier of the intermediate.
  - **CUDNN_TYPE_INT64**; one element.
  - Read-only attribute.

- **CUDNN_ATTR_INTERMEDIATE_INFO_SIZE**
  The required device memory size for the intermediate.
  - **CUDNN_TYPE_INT64**; one element.
  - Read-only attribute.

- **CUDNN_ATTR_INTERMEDIATE_INFO_DEPENDENT_DATA_UIDS**
  UID of tensors on which the intermediate depends.
  - **CUDNN_TYPE_INT64**; zero or more elements.
  - Read-only attribute.

- **CUDNN_ATTR_INTERMEDIATE_INFO_DEPENDENT_ATTRIBUTES**
  Placeholder for future implementation.

Finalization

User does not finalize this descriptor. `cudnnBackendFinalize(desc)` with a backend intermediate descriptor returns `CUDNN_STATUS_NOT_SUPPORTED`.

9.3.7. **CUDNN_BACKEND_KNOB_CHOICE_DESCRIPTOR**

Created with `cudnnBackendCreateDescriptor(CUDNN_BACKEND_KNOB_CHOICE_DESCRIPTOR, &desc);` the cuDNN backend knob choice descriptor consists of the type of knobs to be set and the value to which the knob is set.

Attributes

- **CUDNN_ATTR_KNOB_CHOICE_KNOB_TYPE**
  The type of knobs to be set.
  - **CUDNN_TYPE_KNOB_TYPE**: one element.
  - Required attribute.
CUDNN_ATTR_Knob_CHOICE_Knob_VALUE

- CUDNN_TYPE_INT64: one element.
- Required attribute.

**Finalization**

Return values of cudnnBackendFinalize(desc) where desc is a cuDNN backend knob choice descriptor:

CUDNN_STATUS_SUCCESS

The knob choice descriptor was finalized successfully.

**9.3.8. CUDNN_BACKEND_Knob_INFO_DESCRIPTOR**

Created with cudnnBackendCreateDescriptor(CUDNN_BACKEND_INFO_DESCRIPTOR, &desc); the cuDNN backend knob info descriptor consists of the type and valid value range of an engine performance knob. Valid value range is given in terms of minimum, maximum, and stride of valid values. This is a purely informative descriptor type. Setting descriptor attributes is not supported. User obtains an array of finalized descriptors, one for each knob type, from a finalized backend descriptor.

**Attributes**

CUDNN_ATTR_Knob_INFO_TYPE

The type of the performance knob.

- CUDNN_TYPE_Knob_TYPE: one element.
- Read-only attribute.

CUDNN_ATTR_Knob_INFO_MAXIMUM_VALUE

The smallest valid value choice value for this knob.

- CUDNN_TYPE_INT64: one element.
- Read-only attribute.

CUDNN_ATTR_Knob_INFO_MINIMUM_VALUE

The largest valid choice value for this knob.

- CUDNN_TYPE_INT64: one element.
- Read-only attribute.

CUDNN_ATTR_Knob_INFO_STRIDE

The stride of valid choice values for this knob.

- CUDNN_TYPE_INT64: one element.
- Read-only attribute.
Finalization
This descriptor is read-only; it is retrieved and finalized from a cuDNN backend engine configuration descriptor. Users cannot set or finalize.

9.3.9. **CUDNN_BACKEND_LAYOUT_INFO_DESCRIPTOR**
Created with descriptor type value CUDNN_BACKEND_LAYOUT_INFO_DESCRIPTOR, cuDNN backend layout info descriptor provides information on the preferred layout for a tensor.

Attributes

CUDNN_ATTR_LAYOUT_INFO_TENSOR_UID
The UID of the tensor.

- CUDNN_TYPE_INT64; one element.
- Read-only attribute.

CUDNN_ATTR_LAYOUT_INFO_TYPES
The preferred layout of the tensor.

- CUDNN_TYPE_LAYOUT_TYPE: zero or more element cudnnBackendLayoutType_t.
- Read-only attribute.

Finalization
This descriptor is read-only; it is retrieved and finalized from a cuDNN backend engine configuration descriptor. Users cannot set its attribute or finalize it.

9.3.10. **CUDNN_BACKEND_MATMUL_DESCRIPTOR**
Created with cudnnBackendCreateDescriptor(CUDNN_BACKEND_MATMUL_DESCRIPTOR, &desc); the cuDNN backend matmul descriptor specifies any metadata needed for the matmul operation.

Attributes

CUDNN_ATTR_MATMUL_COMP_TYPE
The compute precision used for the matmul operation.

- CUDNN_TYPE_DATA_TYPE; one element.
- Required attribute.

Finalization
Return values of cudnnBackendFinalize(desc) where desc is a cuDNN backend matmul descriptor:
**CUDNN_STATUS_SUCCESS**

The descriptor was finalized successfully.

### 9.3.11. **CUDNN_BACKEND_OPERATION_CONCAT_DESCRIPTOR**

Created with `cudnnBackendCreateDescriptor(CUDNN_BACKEND_OPERATION_CONCAT_DESCRIPTOR, &desc);` the cuDNN backend concatenation operation descriptor specifies an operation node for concatenating a given vector of tensors along a given concatenation axis.

This operation also supports an in-place mode, where one of the input tensors is already assumed to be at the correct location in the output tensor, that is, they share the same device buffer.

**Attributes**

Attributes of a cuDNN backend concat operation descriptor are values of enumeration type `cudnnBackendAttributeName_t` with prefix `CUDNN_ATTR_OPERATION_CONCAT_`.

**CUDNN_ATTR_OPERATION_CONCAT_AXIS**

The dimension which tensors are being concatenated over.

- **Type:** `CUDNN_TYPE_INT64`
- **Required attribute.**

**CUDNN_ATTR_OPERATION_CONCAT_INPUT_DESCS**

A vector of input tensor descriptors, which are concatenated in the same order as provided in this vector.

- `CUDNN_TYPE_BACKEND_DESCRIPTOR`; one or more elements of descriptor type `CUDNN_BACKEND_TENSOR_DESCRIPTOR`.
- **Required attribute.**

**CUDNN_ATTR_OPERATION_CONCAT_INPLACE_INDEX**

The index of input tensor in the vector of input tensor descriptors that is already present in-place in the output tensor.

- **Type:** `CUDNN_TYPE_INT64`
- **Optional attribute.**

**CUDNN_ATTR_OPERATION_CONCAT_OUTPUT_DESC**

The output tensor descriptor for the result from concatenation of input tensors.

- `CUDNN_TYPE_BACKEND_DESCRIPTOR`; one element of descriptor type `CUDNN_BACKEND_TENSOR_DESCRIPTOR`.
- **Required attribute.**
Finalization

cudnnBackendFinalize() with a CUDNN_BACKEND_OPERATION_CONCAT_DESCRIPTOR() can have the following return values:

**CUDNN_STATUS_BAD_PARAM**
Invalid or inconsistent attribute values are encountered. Some possible causes:

- The tensors involved in the operation should have the same shape in all dimensions except the dimension that they are being concatenated over.
- The output tensor shape in the concatenating dimension should equal the sum of tensor shape of all input tensors in that same dimension.
- Concatenation axis should be a valid tensor dimension.
- If provided, the in-place input tensor index should be a valid index in the vector of input tensor descriptors.

**CUDNN_STATUS_SUCCESS**
The descriptor was finalized successfully.

9.3.12. **CUDNN_BACKEND_OPERATION_CONVOLUTION_BACKWARD_DATA_DESCRIPTOR**

Created with cudnnBackendCreateDescriptor(CUDNN_BACKEND_OPERATION_CONVOLUTION_BACKWARD_DATA_DESCRIPTOR, &desc); the cuDNN backend convolution backward data operation descriptor specifies an operation node for convolution backward data to compute the gradient of input data $dx$ with filter tensor $w$ and gradient of response $dy$ with output $\#$ scaling and residue add with $\#$ scaling. That is, the equation $dx = \alpha (w \ast dy) + \beta dx$, where $\ast$ denotes the convolution backward data operator.

Attributes

Attributes of a cuDNN backend convolution descriptor are values of enumeration type cudnnBackendAttributeName_t with prefix CUDNN_ATTR_OPERATION_CONVOLUTION_BWD_DATA:

**CUDNN_ATTR_OPERATION_CONVOLUTION_BWD_DATA_ALPHA**
The alpha value.

- CUDNN_TYPE_FLOAT or CUDNN_TYPE_DOUBLE; one or more elements.
- Required attribute.

**CUDNN_ATTR_OPERATION_CONVOLUTION_BWD_DATA_BETA**
The beta value.

- CUDNN_TYPE_FLOAT or CUDNN_TYPE_DOUBLE; one or more elements.
- Required attribute.

**CUDNN_ATTR_OPERATION_CONVOLUTION_BWD_DATA_CONV_DESC**
The convolution operator descriptor.
CUDNN_BACKEND_DESCRIPTOR; one element of descriptor type
CUDNN_BACKEND_CONVOLUTION_DESCRIPTOR.
Required attribute.

CUDNN_ATTR_OPERATION_CONVOLUTION_BWD_DATA_W
The convolution filter tensor descriptor.
CUDNN_TYPE_BACKEND_DESCRIPTOR; one element of descriptor type
CUDNN_BACKEND_TENSOR_DESCRIPTOR.
Required attribute.

CUDNN_ATTR_OPERATION_CONVOLUTION_BWD_DATA_DX
The image gradient tensor descriptor.
CUDNN_TYPE_BACKEND_DESCRIPTOR; one element of descriptor type
CUDNN_BACKEND_TENSOR_DESCRIPTOR.
Required attribute.

CUDNN_ATTR_OPERATION_CONVOLUTION_BWD_DATA_DY
The response gradient tensor descriptor.
CUDNN_TYPE_BACKEND_DESCRIPTOR; one element of descriptor type
CUDNN_BACKEND_TENSOR_DESCRIPTOR.
Required attribute.

Finalization
In finalizing the convolution operation, the tensor dimensions of the tensor DX, W, and DY are bound based on the same interpretations as the X, W, and Y tensor dimensions described in the CUDNN_BACKEND_OPERATION_CONVOLUTION_FORWARD_DESCRIPTOR section.

cudnnBackendFinalize() with a
CUDNN_BACKEND_OPERATION_CONVOLUTION_BACKWARD_DATA_DESCRIPTOR() can have the following return values:

CUDNN_STATUS_BAD_PARAM
Invalid or inconsistent attribute values are encountered. Some possible cause:
The DX, W, and DY tensors do not constitute a valid convolution operation under the convolution operator.

CUDNN_STATUS_SUCCESS
The descriptor was finalized successfully.

9.3.13. CUDNN_BACKEND_OPERATION_CONVOLUTION_BACKWARD

Created with
cudnnBackendCreateDescriptor(CUDNN_BACKEND_OPERATION_CONVOLUTION_BACKWARD_FILTER_DESCRIPTOR,
&desc); the cuDNN backend convolution backward filter operation descriptor specifies an operation node for convolution backward filter to compute the gradient of filter dw with
image tensor $x$ and gradient of response $dy$ with output $# scaling and residue add with $# scaling. That is, the equation: $dw = \alpha (x^*dy) + \beta dw$, where $^*$ denotes the convolution backward filter operator.

**Attributes**

Attributes of a cuDNN backend convolution descriptor are values of enumeration type `cudnnBackendAttributeName_t` with prefix `CUDNN_ATTR_OPERATION_CONVOLUTION_BWD_FILTER_`

- **CUDNN_ATTR_OPERATION_CONVOLUTION_BWD_FILTER_ALPHA**
  - The alpha value.
  - `CUDNN_TYPE_FLOAT` or `CUDNN_TYPE_DOUBLE`; one or more elements.
  - Required attribute. Required to be set before finalization.

- **CUDNN_ATTR_OPERATION_CONVOLUTION_BWD_FILTER_BETA**
  - The beta value.
  - `CUDNN_TYPE_FLOAT` or `CUDNN_TYPE_DOUBLE`; one or more elements.
  - Required attribute. Required to be set before finalization.

- **CUDNN_ATTR_OPERATION_CONVOLUTION_BWD_FILTER_CONV_DESC**
  - The convolution operator descriptor.
  - `CUDNN_TYPE_BACKEND_DESCRIPTOR`; one element of descriptor type `CUDNN_BACKEND_CONVOLUTION_DESCRIPTOR`.
  - Required attribute. Required to be set before finalization.

- **CUDNN_ATTR_OPERATION_CONVOLUTION_BWD_FILTER_DW**
  - The convolution filter tensor descriptor.
  - `CUDNN_TYPE_BACKEND_DESCRIPTOR`; one element of descriptor type `CUDNN_BACKEND_TENSOR_DESCRIPTOR`.
  - Required attribute. Required to be set before finalization.

- **CUDNN_ATTR_OPERATION_CONVOLUTION_BWD_FILTER_X**
  - The image gradient tensor descriptor.
  - `CUDNN_TYPE_BACKEND_DESCRIPTOR`; one element of descriptor type `CUDNN_BACKEND_TENSOR_DESCRIPTOR`.
  - Required attribute. Required to be set before finalization.

- **CUDNN_ATTR_OPERATION_CONVOLUTION_BWD_FILTER_DY**
  - The response gradient tensor descriptor.
  - `CUDNN_TYPE_BACKEND_DESCRIPTOR`; one element of descriptor type `CUDNN_BACKEND_TENSOR_DESCRIPTOR`.
  - Required attribute. Required to be set before finalization.
Finalization

In finalizing the convolution operation, the tensor dimensions of the tensor $X$, $DW$, and $DY$ are bound based on the same interpretations as the $X$, $W$, and $Y$ tensor dimensions described in the CUDNN_BACKEND_OPERATION_CONVOLUTION_FORWARD_DESCRIPTOR section.

`cudnnBackendFinalize()` with a CUDNN_BACKEND_OPERATION_CONVOLUTION_BACKWARD_FILTER_DESCRIPTOR() can have the following return values:

**CUDNN_STATUS_BAD_PARAM**
Invalid or inconsistent attribute values are encountered. Some possible cause:
- The $X$, $DW$, and $DY$ tensors do not constitute a valid convolution operation under the convolution operator.

**CUDNN_STATUS_SUCCESS**
The descriptor was finalized successfully.

9.3.14. **CUDNN_BACKEND_OPERATION_CONVOLUTION_FORWARD_DESCRIPTOR**

Created with `cudnnBackendCreateDescriptor(CUDNN_BACKEND_OPERATION_CONVOLUTION_FORWARD_DESCRIPTOR, &desc)`; the cuDNN backend convolution forward operation descriptor specifies an operation node for forward convolution to compute the response tensor $Y$ of image tensor $X$ convoluted with filter tensor $W$ with output scaling $\alpha$ and residual add with $\beta$ scaling. That is, the equation $Y = \alpha (W \ast X) + \beta Y$, where $\ast$ is the convolution operator in the forward direction.

Attributes

Attributes of a cuDNN backend convolution descriptor are values of enumeration type `cudnnBackendAttributeName_t` with prefix CUDNN_ATTR_OPERATION_CONVOLUTION_FORWARD:

**CUDNN_ATTR_OPERATION_CONVOLUTION_FORWARD_ALPHA**
The alpha value.
- **CUDNN_TYPE_FLOAT** or **CUDNN_TYPE_DOUBLE**; one or more elements.
- Required to be set before finalization.

**CUDNN_ATTR_OPERATION_CONVOLUTION_FORWARD_BETA**
The beta value.
- **CUDNN_TYPE_FLOAT** or **CUDNN_TYPE_DOUBLE**; one or more elements.
- Required attribute.

**CUDNN_ATTR_OPERATION_CONVOLUTION_FORWARD_CONV_DESC**
The convolution operator descriptor.
- CUDNN_TYPE_BACKEND_DESCRIPTOR; one element of descriptor type CUDNN_BACKEND_CONVOLUTION_DESCRIPTOR.
  - Required attribute.

**CUDNN_ATTR_OPERATION_CONVOLUTION_FORWARD_W**

The convolution filter tensor descriptor.

- CUDNN_TYPE_BACKEND_DESCRIPTOR; one element of descriptor type CUDNN_BACKEND_TENSOR_DESCRIPTOR.
  - Required attribute.

**CUDNN_ATTR_OPERATION_CONVOLUTION_FORWARD_X**

The image tensor descriptor.

- CUDNN_TYPE_BACKEND_DESCRIPTOR; one element of descriptor type CUDNN_BACKEND_TENSOR_DESCRIPTOR.
  - Required attribute.

**CUDNN_ATTR_OPERATION_CONVOLUTION_FORWARD_Y**

The response tensor descriptor.

- CUDNN_TYPE_BACKEND_DESCRIPTOR; one element of descriptor type CUDNN_BACKEND_TENSOR_DESCRIPTOR.
  - Required attribute.

**CUDNN_ATTR_CONVOLUTION_SPATIAL_DIMS**

The number of spatial dimensions in the convolution.

- CUDNN_TYPE_INT64, one element.
  - Required attribute.

**Finalization**

In finalizing the convolution operation, the tensor dimensions of the tensor x, w, and y are bound based on the following interpretations:

The CUDNN_ATTR_CONVOLUTION_SPATIAL_DIMS attribute of CUDNN_ATTR_OPERATION_CONVOLUTION_FORWARD_CONV_DESC is the number of spatial dimension of the convolution. The number of dimensions for tensor x, w, and y must be larger than the number of spatial dimensions by 2 or 3 depending on how users choose to specify the convolution tensors.

If the number of tensor dimension is the number of spatial dimensions plus 2:

- x tensor dimension and stride arrays are \([N, GC, \ldots]\)
- w tensor dimension and stride arrays are \([KG, C, \ldots]\)
- y tensor dimension and stride arrays are \([N, GK, \ldots]\)
where the ellipsis \( \ldots \) are shorthand for spatial dimensions of each tensor, \( G \) is the number of convolution groups, and \( C \) and \( K \) are the number of input and output feature maps per group. In this interpretation, it is assumed that the memory layout for each group is packed. \texttt{cudnnBackendFinalize()} asserts the tensors dimensions and strides are consistent with this interpretation or it returns \texttt{CUDNN\_STATUS\_BAD\_PARAM}.

If the number of tensor dimension is the number of spatial dimensions plus 3:

\[\begin{align*}
\text{X tensor dimension and stride arrays are} & \quad [N, G, C, \ldots] \\
\text{W tensor dimension and stride arrays are} & \quad [G, K, C, \ldots] \\
\text{Y tensor dimension and stride arrays are} & \quad [N, G, K, \ldots]
\end{align*}\]

where the ellipsis \( \ldots \) are shorthand for spatial dimensions of each tensor, \( G \) is the number of convolution groups, and \( C \) and \( K \) are the number of input and output feature maps per group. In this interpretation, users can specify an unpacked group stride. \texttt{cudnnBackendFinalize()} asserts the tensors dimensions and strides are consistent with this interpretation or it returns \texttt{CUDNN\_STATUS\_BAD\_PARAM}.

\texttt{cudnnBackendFinalize()} with a \texttt{CUDNN\_BACKEND\_OPERATION\_CONVOLUTION\_FORWARD\_DESCRIPTOR} can have the following return values:

\texttt{CUDNN\_STATUS\_BAD\_PARAM}

Invalid or inconsistent attribute values are encountered. Some possible cause:

\[\begin{align*}
\text{The X, W, and Y tensors do not constitute a valid convolution operation under the convolution operator.}
\end{align*}\]

\texttt{CUDNN\_STATUS\_SUCCESS}

The descriptor was finalized successfully.

9.3.15. \texttt{CUDNN\_BACKEND\_OPERATION\_GEN\_STATS\_DESCRIPTOR}

Represents an operation that will generate per-channel statistics. The specific statistics that will be generated depends on the \texttt{CUDNN\_ATTR\_OPERATION\_GENSTATS\_MODE} attribute in the descriptor. Currently, only \texttt{CUDNN\_GENSTATS\_SUM\_SQSUM} is supported for the \texttt{CUDNN\_ATTR\_OPERATION\_GENSTATS\_MODE}. It will generate the sum and quadratic sum of per-channel elements of the input tensor \( x \). The output dimension should be all 1 except the \( C \) dimension. Also, the \( C \) dimension of outputs should equal the \( C \) dimension of the input. This opaque struct can be created with \texttt{cudnnBackendCreateDescriptor()} (\texttt{CUDNN\_BACKEND\_OPERATION\_GEN\_STATS\_DESCRIPTOR}).

Attributes

\texttt{CUDNN\_ATTR\_OPERATION\_GENSTATS\_MODE}

Sets the \texttt{CUDNN\_TYPE\_GENSTATS\_MODE} of the operation. This attribute is required.

\texttt{CUDNN\_ATTR\_OPERATION\_GENSTATS\_MATH\_PREC}

The math precision of the computation. This attribute is required.
CUDNN_ATTR_OPERATION_GENSTATS_XDESC
Sets the descriptor for the input tensor \( x \). This attribute is required.

CUDNN_ATTR_OPERATION_GENSTATS_SUMDESC
Sets the descriptor for the output tensor \( \text{sum} \). This attribute is required.

CUDNN_ATTR_OPERATION_GENSTATS_SQSUMDESC
Sets the descriptor for the output tensor \( \text{quadraticsum} \). This attribute is required.

**Finalization**

In the finalization stage, the attributes are cross checked to make sure there are no conflicts. The status below may be returned:

CUDNN_STATUS_BAD_PARAM
Invalid or inconsistent attribute values are encountered. Some possible causes are:

- The number of dimensions do not match between the input and output tensors.
- The input/output tensor dimensions do not agree with the above description.

CUDNN_STATUS_SUCCESS
The descriptor was finalized successfully.

### 9.3.16. CUDNN_BACKEND_OPERATION_MATMUL_DESCRIPTOR

Created with

```c
cudaBackendCreateDescriptor(CUDNN_BACKEND_OPERATION_MATMUL_DESCRIPTOR, &desc);
```

the cuDNN backend matmul operation descriptor specifies an operation node for matmul to compute the matrix product \( C \) by multiplying matrix \( A \) and matrix \( B \), as shown in the following equation:

\[
C = AB
\]

When using the matmul operation, the matrices are expected to be at least rank-2 tensors. The last two dimensions are expected to correspond to either \( M, K \) or \( N \). All the preceding dimensions are interpreted as batch dimensions. If there are zero batch dimensions then the requirements are as follows:

<table>
<thead>
<tr>
<th>Case</th>
<th>Matrix A</th>
<th>Matrix B</th>
<th>Matrix C</th>
</tr>
</thead>
<tbody>
<tr>
<td>Single matmul</td>
<td>( M \times K )</td>
<td>( K \times N )</td>
<td>( M \times N )</td>
</tr>
</tbody>
</table>

For a single batch dimension we have the following requirements:

<table>
<thead>
<tr>
<th>Case</th>
<th>Matrix A</th>
<th>Matrix B</th>
<th>Matrix C</th>
</tr>
</thead>
<tbody>
<tr>
<td>Single matmul</td>
<td>( 1 \times M \times K )</td>
<td>( 1 \times K \times N )</td>
<td>( 1 \times M \times N )</td>
</tr>
</tbody>
</table>
where:

- B indicates the batch size
- M is the number of rows of the matrix A
- K is the number or columns of the input matrix A (which is the same as the number of rows as the input matrix B)
- N is the number of columns of the input matrix B

If either the batch size of matrix A or B is set to 1, this indicates that the matrix will be broadcasted in the batch matmul. The resulting output matrix C will be a tensor of B x M x N.

The above broadcasting convention is extended to all the batch dimensions. Concretely, for tensors with three batch dimensions:

**Table 55. CUDNN_BACKEND_OPERATION_MATMUL_DESCRIPTOR for a Three Batch Dimension**

<table>
<thead>
<tr>
<th>Case</th>
<th>Matrix A</th>
<th>Matrix B</th>
<th>Matrix C</th>
</tr>
</thead>
<tbody>
<tr>
<td>Batch matmul</td>
<td>B x M x K</td>
<td>B x K x N</td>
<td>B x M x N</td>
</tr>
<tr>
<td>Broadcast A</td>
<td>1 x M x K</td>
<td>B x K x N</td>
<td></td>
</tr>
<tr>
<td>Broadcast B</td>
<td>B x M x K</td>
<td>1 x K x N</td>
<td></td>
</tr>
<tr>
<td>Multiple batched matmul</td>
<td>B1 x 1 x B3 x M x K</td>
<td>1 x B2 x B3 x K x N</td>
<td>B1 x B2 x B3 x M x N</td>
</tr>
</tbody>
</table>

The functionality of having multiple batch dimensions allows you to have layouts where the batch is not packed at a single stride. This case is especially seen in multi-head attention.

The addressing of the matrix elements from a given tensor can be specified using strides in the tensor descriptor. The strides represent the spacing between elements for each tensor dimension. Considering a matrix tensor A (B x M x N) with strides [BS, MS, NS], it indicates that the actual matrix element A[x, y, z] is found at (A_base_address + x * BS + y * MS + z * NS) from the linear memory space allocated for tensor A. With our current support, the innermost dimension must be packed, which requires either MS=1 or NS=1. Otherwise, there are no other technical constraints with regard to how the strides can be specified in a tensor descriptor as it should follow the aforementioned addressing formula and the strides as specified by the user.

This representation provides support for some common usages, such as leading dimension and matrix transpose as we will explain through the following examples.

1. The most basic case is a fully packed row-major batch matrix, without any consideration of leading dimension or transpose. In this case, BS = M*N, MS = N and NS = 1.
2. Matrix transpose can be achieved by exchanging the inner and outer dimensions using strides. Namely:
   a). To specify a non-transposed matrix: BS = M*N, MS = N and NS = 1.
   b). To specify matrix transpose: BS = M*N, MS = 1 and NS = M.
3. Leading dimension, a widely used concept in BLAS-like APIs, describes the inner dimension of the 2D array memory allocation (as opposed to the conceptual matrix dimension). It resembles the stride in a way that it defines the spacing between elements in the outer dimension. The most typical use cases where it shows difference from the matrix inner dimension is when the matrix is only part of the data in the allocated memory, addressing submatrices, or addressing matrices from an aligned memory allocation. Therefore, the leading dimension LDA in a column-major matrix A must satisfy LDA >= M, whereas in a row-major matrix A, it must satisfy LDA >= N. To transition from the leading dimension concept to using strides, this entails MS >= N and NS = 1 or MS = 1 and NS >= M. Keep in mind that, while these are some practical use cases, these inequalities do not impose technical constraints with respect to an acceptable specification of the strides.

Other commonly used GEMM features, such as alpha/beta output blending, can also be achieved using this matmul operation along with other pointwise operations.

Attributes

The commonly used GEMM operation can also be achieved using this matmul operation along with other pointwise operations for output blending.

Attributes of a cuDNN backend matmul descriptor are values of enumeration type cudnnBackendAttributeName_t with prefix CUDNN_ATTR_OPERATION_MATMUL:

**CUDNN_ATTR_OPERATION_MATMUL_ADESC**

The matrix A descriptor.

- CUDNN_TYPE_BACKEND_DESCRIPTOR; one element of descriptor type CUDNN_BACKEND_TENSOR_DESCRIPTOR.
- Required attribute.

**CUDNN_ATTR_OPERATION_MATMUL_BDESC**

The matrix B descriptor.

- CUDNN_TYPE_BACKEND_DESCRIPTOR; one element of descriptor type CUDNN_BACKEND_TENSOR_DESCRIPTOR.
- Required attribute.

**CUDNN_ATTR_OPERATION_MATMUL_CDESC**

The matrix C descriptor.

- CUDNN_TYPE_BACKEND_DESCRIPTOR; one element of descriptor type CUDNN_BACKEND_TENSOR_DESCRIPTOR.
- Required attribute.
**CUDNN_ATTR_OPERATION_MATMUL_IRREGULARLY_STRIDED_BATCH_COUNT**
Number of \textit{matmul} operations to perform in the batch on matrix. Default = 1.

- CUDNN\_TYPE\_INT64; one element.
- Default value is 1.

**CUDNN_ATTR_OPERATION_MATMUL\_GEMM\_M\_OVERRIDE\_DESC**
The tensor \texttt{gemm\_m\_override} descriptor. Allows you to override the M dimension of a batch matrix multiplication through this tensor. It is only supported as documented in the Fused Attention \texttt{fprop}, Fused Attention \texttt{bprop}, Fused Flash Attention \texttt{fprop}, and Fused Flash Attention \texttt{bprop} sections.

- CUDNN\_TYPE\_BACKEND\_DESCRIPTOR; one element of descriptor type CUDNN\_BACKEND\_TENSOR\_DECRIPTOR.
- Optional attribute.

**CUDNN_ATTR_OPERATION_MATMUL\_GEMM\_N\_OVERRIDE\_DESC**
The tensor \texttt{gemm\_n\_override} descriptor. Allows you to override the N dimension of a batch matrix multiplication through this tensor. It is only supported as documented in the Fused Attention \texttt{fprop}, Fused Attention \texttt{bprop}, Fused Flash Attention \texttt{fprop}, and Fused Flash Attention \texttt{bprop} sections.

- CUDNN\_TYPE\_BACKEND\_DESCRIPTOR; one element of descriptor type CUDNN\_BACKEND\_TENSOR\_DESCRIPTOR.
- Optional attribute.

**CUDNN_ATTR_OPERATION_MATMUL\_GEMM\_K\_OVERRIDE\_DESC**
The tensor \texttt{gemm\_k\_override} descriptor. Allows you to override the K dimension of a batch matrix multiplication through this tensor. It is only supported as documented in the Fused Attention \texttt{fprop}, Fused Attention \texttt{bprop}, Fused Flash Attention \texttt{fprop}, and Fused Flash Attention \texttt{bprop} sections.

- CUDNN\_TYPE\_BACKEND\_DESCRIPTOR; one element of descriptor type CUDNN\_BACKEND\_TENSOR\_DESCRIPTOR.
- Optional attribute.

**CUDNN_ATTR_OPERATION_MATMUL\_DESC**
The \textit{matmul} operation descriptor.

- CUDNN\_TYPE\_BACKEND\_DESCRIPTOR; one element of descriptor type CUDNN\_BACKEND\_MATMUL\_DESCRIPTOR.
- Required attribute.

**Finalization**
In the finalization of the \textit{matmul} operation, the tensor dimensions of the matrices A, B and C will be checked to ensure that they satisfy the requirements of matrix multiplication:
`cudnnBackendFinalize()` with a `CUDNN_BACKEND_OPERATION_MATMUL_DESCRIPTOR` can have the following return values:

**CUDNN_STATUS_NOT_SUPPORTED**
An unsupported attribute value was encountered. Some possible cause:
- If not all of the matrices A, B and C are at least rank-2 tensors.

**CUDNN_STATUS_BAD_PARAM**
Invalid or inconsistent attribute values are encountered. Some possible causes:
- The `CUDNN_ATTR_OPERATION_MATMUL_IRREGULARLY_STRIDED_BATCH_COUNT` specified is a negative value.
- The `CUDNN_ATTR_OPERATION_MATMUL_IRREGULARLY_STRIDED_BATCH_COUNT` and one or more of the batch sizes of the matrices A, B and C are not equal to one. That is to say there is a conflict where both irregularly and regularly strided batched matrix multiplication are specified, which is not a valid use case.
- The dimensions of the matrices A, B and C do not satisfy the requirements of matrix multiplication.

**CUDNN_STATUS_SUCCESS**
The descriptor was finalized successfully.

### 9.3.17. `CUDNN_BACKEND_OPERATION_NORM_BACKWARD_DESCRIPTOR`

Created with `cudnnBackendCreateDescriptor(CUDNN_BACKEND_OPERATION_NORM_BACKWARD_DESCRIPTOR, &desc)`, the cuDNN backend normalization backward operation specifies a node for a backward normalization that takes as input the gradient tensor `dY` and outputs the gradient tensor `dX` and weight gradients `dScale` and `dBias`. The normalization mode is set using the `CUDNN_ATTR_OPERATION_NORM_BWD_MODE` attribute.

**Limitations**
- Does not support `CUDNN_GROUP_NORM` mode.

**Table 56. Supported Configurations for `CUDNN_BACKEND_OPERATION_NORM_BACKWARD_DESCRIPTOR`**

<table>
<thead>
<tr>
<th><code>CUDNN_ATTR_OPERATION_NORM_BWD_MODE</code></th>
<th><code>CUDNN_LAYER_NORM</code></th>
<th><code>CUDNN_INSTANCE_NORM</code></th>
<th><code>CUDNN_BATCH_NORM</code></th>
<th><code>CUDNN_GROUP_NORM</code></th>
</tr>
</thead>
<tbody>
<tr>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>No</td>
</tr>
</tbody>
</table>

**Note:** In addition to single GPU, `CUDNN_BATCH_NORM` also supports single node multi-GPU batch norm, while other normalization modes only support running on a single GPU. For more information, refer to the DReluForkDBn pattern.
Attributes

**CUDNN_ATTR_OPERATION_NORM_BWD_MODE**
Chooses the normalization mode for the norm backward operation.

- CUDNN_TYPE_NORM_MODE; one element.
- Required attribute.

**CUDNN_ATTR_OPERATION_NORM_BWD_XDESC**
Input tensor descriptor.

- CUDNN_TYPE_BACKEND_DESCRIPTOR; one element of descriptor type
  CUDNN_BACKEND_TENSOR_DESCRIPTOR.
- Required attribute.

**CUDNN_ATTR_OPERATION_NORM_BWD_MEAN_DESC**
Saved mean input tensor descriptor for reusing the mean computed during the forward computation of the training phase.

- CUDNN_TYPE_BACKEND_DESCRIPTOR; one element of descriptor type
  CUDNN_BACKEND_TENSOR_DESCRIPTOR.
- Optional attribute.

**CUDNN_ATTR_OPERATION_NORM_BWD_INV_VARIANCE_DESC**
Saved inverse variance input tensor descriptor for reusing the mean computed during the forward computation of the training phase.

- CUDNN_TYPE_BACKEND_DESCRIPTOR; one element of descriptor type
  CUDNN_BACKEND_TENSOR_DESCRIPTOR.
- Optional attribute.

**CUDNN_ATTR_OPERATION_NORM_BWD_DYDESC**
Gradient tensor descriptor.

- CUDNN_TYPE_BACKEND_DESCRIPTOR; one element of descriptor type
  CUDNN_BACKEND_TENSOR_DESCRIPTOR.
- Optional attribute.

**CUDNN_ATTR_OPERATION_NORM_BWD_SCALE_DESC**
Normalization scale descriptor. Note that the bias descriptor is not necessary for the backward pass.
CUDNN_BACKEND_TENSOR_DESCRIPTOR

- **CUDNN_ATTR_OPERATION_NORM_BWD_EPSILON_DESC**
  
  Scalar input tensor descriptor for the epsilon value. The epsilon values are needed only if the saved mean and variances are not passed as inputs to the operation.

- **CUDNN_ATTR_OPERATION_NORM_BWD_DSCALE_DESC**
  
  Scale gradient tensor descriptor.

- **CUDNN_ATTR_OPERATION_NORM_BWD_DBIAS_DESC**
  
  Bias gradient tensor descriptor.

- **CUDNN_ATTR_OPERATION_NORM_BWD_DXDESC**
  
  Input gradient tensor descriptor.

- **CUDNN_ATTR_OPERATION_NORM_BWD_PEER_STAT_DESCS**
  
  Vector of tensor descriptors for the communication buffers used in multi-GPU normalization. Typically, one buffer is provided for every GPU in the node. This is an optional attribute only used for multi-GPU tensor stats reduction.

Finalization

In the finalization stage, the attributes are checked to ensure there are no conflicts.

**CUDNN_STATUS_BAD_PARAM**

Invalid or inconsistent attribute values are encountered. Some possible causes are:
The tensor dimensions of the gradient tensors $dY$, $dX$, and input tensor $X$, do not match.

The channel count $C$ for the `mean`, `scale`, and `inv_variance` tensors do not match.

**CUDNN_STATUS_SUCCESS**

The descriptor was finalized successfully.

### 9.3.18. **CUDNN_BACKEND_OPERATION_NORM_FORWARD_DESCRIPTOR**

Created with

```
cudnnBackendCreateDescriptor(CUDNN_BACKEND_OPERATION_NORM_FORWARD_DESCRIPTOR, &desc)
```

the cuDNN backend normalization forward operation specifies a node for a forward normalization that takes as input a tensor $X$ and produces a normalized output $Y$ with the normalization mode set by the `CUDNN_ATTR_OPERATION_NORM_FWD_MODE` attribute. The operation supports optional running stats computation and allows for storing the computed means and variances for reuse in the backwards calculation depending on the setting of the `CUDNN_ATTR_OPERATION_NORM_FWD_PHASE` attribute.

**Limitations**

- Does not support `CUDNN_GROUP_NORM` mode.
- Batch norm only supports forward training and not forward inference.

**Table 57. Supported Configurations for CUDNN_BACKEND_OPERATION_NORM_FORWARD_DESCRIPTOR**

<table>
<thead>
<tr>
<th>CUDNN_ATTR_OPE</th>
<th>CUDNN_ATTR_OPERATION_NORM_FWD_MODE</th>
<th>CUDNN_LAYER_NOI</th>
<th>CUDNN_INSTANCE</th>
<th>CUDNN_BATCH_NOI</th>
<th>CUDNN_GROUP_NORM</th>
</tr>
</thead>
<tbody>
<tr>
<td>CUDNN_NORM_FWD_TRAINING</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>No</td>
<td></td>
</tr>
<tr>
<td>CUDNN_NORM_FWD_INFERENCE</td>
<td>Yes</td>
<td>Yes</td>
<td>No</td>
<td>No</td>
<td></td>
</tr>
</tbody>
</table>

**Note:** In addition to single-GPU, batch normalization supports running on single node multi-GPUs, while other normalization modes only support running on a single GPU. For more information, refer to the [BNAddRelu](#) pattern.

**Attributes**

**CUDNN_ATTR_OPERATION_NORM_FWD_MODE**

Chooses the normalization mode for the norm forward operation.

- `CUDNN_TYPE_NORM_MODE`; one element.
- Required attribute.

**CUDNN_ATTR_OPERATION_NORM_FWD_PHASE**

Selects the training or inference phase for the norm forward operation.
- **CUDNN_TYPE_NORM_FWD_PHASE**: one element.
  - Required attribute.

**CUDNN_ATTR_OPERATION_NORM_FWD_XDESC**
Input tensor descriptor.

- **CUDNN_TYPE_BACKEND_DESCRIPTOR**: one element of descriptor type
  CUDNN_BACKEND_TENSOR_DESCRIPTOR.
  - Required attribute.

**CUDNN_ATTR_OPERATION_NORM_FWD_MEAN_DESC**
Estimated mean input tensor descriptor for the inference phase and the computed mean output tensor descriptor for the training phase.

- **CUDNN_TYPE_BACKEND_DESCRIPTOR**: one element of descriptor type
  CUDNN_BACKEND_TENSOR_DESCRIPTOR.
  - Optional attribute.

**CUDNN_ATTR_OPERATION_NORM_FWD_INV_VARIANCE_DESC**
Estimated inverse variance input tensor descriptor for the inference phase and the computed inverse variance output tensor descriptor for the training phase.

- **CUDNN_TYPE_BACKEND_DESCRIPTOR**: one element of descriptor type
  CUDNN_BACKEND_TENSOR_DESCRIPTOR.
  - Optional attribute.

**CUDNN_ATTR_OPERATION_NORM_FWD_SCALE_DESC**
Normalization scale input tensor descriptor.

- **CUDNN_TYPE_BACKEND_DESCRIPTOR**: one element of descriptor type
  CUDNN_BACKEND_TENSOR_DESCRIPTOR.
  - Required attribute.

**CUDNN_ATTR_OPERATION_NORM_FWD_BIAS_DESC**
Normalization bias input tensor descriptor.

- **CUDNN_TYPE_BACKEND_DESCRIPTOR**: one element of descriptor type
  CUDNN_BACKEND_TENSOR_DESCRIPTOR.
  - Required attribute.

**CUDNN_ATTR_OPERATION_NORM_FWD_EPSILON_DESC**
Scalar input tensor descriptor for the epsilon value used in normalization calculation.

- **CUDNN_TYPE_BACKEND_DESCRIPTOR**: one element of descriptor type
  CUDNN_BACKEND_TENSOR_DESCRIPTOR.
  - Required attribute.
CUDNN_ATTR_OPERATION_NORM_FWD_EXP_AVG_FACTOR_DESC
Scalar input tensor descriptor for the exponential average factor value used in running stats computation.

- CUDNN_TYPE_BACKEND_DESCRIPTOR; one element of descriptor type CUDNN_BACKEND_TENSOR_DESCRIPTOR.
- Optional attribute.

CUDNN_ATTR_OPERATION_NORM_FWD_INPUT_RUNNING_MEAN_DESC
Input running mean tensor descriptor for the running stats computation in the training phase.

- CUDNN_TYPE_BACKEND_DESCRIPTOR; one element of descriptor type CUDNN_BACKEND_TENSOR_DESCRIPTOR.
- Optional attribute.

CUDNN_ATTR_OPERATION_NORM_FWD_INPUT_RUNNING_VAR_DESC
Input running variance tensor descriptor for the running stats computation in the training phase.

- CUDNN_TYPE_BACKEND_DESCRIPTOR; one element of descriptor type CUDNN_BACKEND_TENSOR_DESCRIPTOR.
- Optional attribute.

CUDNN_ATTR_OPERATION_NORM_FWD_OUTPUT_RUNNING_MEAN_DESC
Output running mean tensor descriptor for the running stats computation in the training phase.

- CUDNN_TYPE_BACKEND_DESCRIPTOR; one element of descriptor type CUDNN_BACKEND_TENSOR_DESCRIPTOR.
- Optional attribute.

CUDNN_ATTR_OPERATION_NORM_FWD_OUTPUT_RUNNING_VAR_DESC
Output running variance tensor descriptor for the running stats computation in the training phase.

- CUDNN_TYPE_BACKEND_DESCRIPTOR; one element of descriptor type CUDNN_BACKEND_TENSOR_DESCRIPTOR.
- Optional attribute.

CUDNN_ATTR_OPERATION_NORM_FWD_YDESC
Tensor descriptor for the output of the normalization operation.

- CUDNN_TYPE_BACKEND_DESCRIPTOR; one element of descriptor type CUDNN_BACKEND_TENSOR_DESCRIPTOR.
- Required attribute.
**CUDNN_ATTR_OPERATION_NORM_FWD_PEER_STAT_DESCS**

Vector of tensor descriptors for the communication buffers used in multi-GPU normalization. Typically, one buffer is provided for every GPU in the node. This is an optional attribute only used for multi-GPU tensor stats reduction.

- **CUDNN_TYPE_BACKEND_DESCRIPTOR;** one or more elements of descriptor type **CUDNN_BACKEND_TENSOR_DESCRIPTOR.**
- **Optional attribute.**

**Finalization**

In the finalization stage, the attributes are checked to ensure there are no conflicts.

**CUDNN_STATUS_BAD_PARAM**

Invalid or inconsistent attribute values are encountered. Some possible causes are:

- The output tensor dimensions do not match the input tensor dimensions.
- The channel count $C$ for the `mean`, `scale`, `bias`, and `inv_variance` tensors do not match.

**CUDNN_STATUS_SUCCESS**

The descriptor was finalized successfully.

### 9.3.19. **CUDNN_BACKEND_OPERATION_POINTWISE_DESCRIPTOR**

Represents a pointwise operation that implements the equation

$Y = \text{op}(\alpha_1 \cdot X) \text{ or } Y = \text{op}(\alpha_1 \cdot X, \alpha_2 \cdot B)$

depending on the operation type. The actual type of operation represented by $\text{op}()$ above depends on the **CUDNN_ATTR_OPERATION_POINTWISE_PW_DESCRIPTOR** attribute in the descriptor. This operation descriptor supports operations with single-input single-output.

For a list of supported operations, refer to the **cudnnPointwiseMode_t** section.

For dual-input pointwise operations, broadcasting is assumed when a tensor dimension in one of the tensors is 1 while the other tensors corresponding dimension is not 1.

For three-input single-output pointwise operations, we do not support broadcasting in any tensor.

This opaque struct can be created with **cudnnBackendCreateDescriptor()** (CUDNN_BACKEND_OPERATION_POINTWISE_DESCRIPTOR).

**Attributes**

**CUDNN_ATTR_OPERATION_POINTWISE_PW_DESCRIPTOR**

Sets the descriptor containing the mathematical settings of the pointwise operation. This attribute is required.

**CUDNN_ATTR_OPERATION_POINTWISE_XDESC**

Sets the descriptor for the input tensor $X$. This attribute is required for pointwise mathematical functions or activation forward propagation computations.
CUDDL_ATTR_OPERATION_POINTWISE_BDESC
   If the operation requires 2 inputs, such as add or multiply, this attribute sets the
   second input tensor #. If the operation requires only 1 input, this field is not used and
   should not be set.

CUDDL_ATTR_OPERATION_POINTWISE_YDESC
   Sets the descriptor for the output tensor Y. This attribute is required for pointwise
   mathematical functions or activation forward propagation computations.

CUDDL_ATTR_OPERATION_POINTWISE_TDESC
   Sets the descriptor for the tensor T. This attribute is required for
   CUDNN_ATTR_POINTWISE_MODE set to CUDNN_POINTWISE_BINARY_SELECT and acts as the
   mask based on which the selection is done.

CUDDL_ATTR_OPERATION_POINTWISE_ALPHA1
   Sets the scalar alpha1 value in the equation. Can be in float or half. This attribute is
   optional, if not set, the default value is 1.0.

CUDDL_ATTR_OPERATION_POINTWISE_ALPHA2
   If the operation requires two inputs, such as add or multiply, this attribute sets the
   scalar alpha2 value in the equation. Can be in float or half. This attribute is optional, if
   not set, the default value is 1.0. If the operation requires only 1 input, this field is not
   used and should not be set.

CUDDL_ATTR_OPERATION_POINTWISE_DXDESC
   Sets the descriptor for the output tensor dX. This attribute is required for pointwise
   activation back propagation computations.

CUDDL_ATTR_OPERATION_POINTWISE_DYDESC
   Sets the descriptor for the input tensor dY. This attribute is required for pointwise
   activation back propagation computations.

Finalization

In the finalization stage, the attributes are cross checked to make sure there are no
conflicts. The status below may be returned:

CUDDL_STATUS_BAD_PARAM
   Invalid or inconsistent attribute values are encountered. Some possible causes are:
     ▶ The number of dimensions do not match between the input and output tensors.
     ▶ The input/output tensor dimensions do not agree with the above described
       automatic broadcasting rules.

CUDDL_STATUS_SUCCESS
   The descriptor was finalized successfully.

9.3.20. CUDNN_BACKEND_OPERATION_REDUCTION_DESCRIPTOR

The cuDNN backend reduction operation descriptor represents an operation node that
implements reducing values of an input tensor x in one or more dimensions to get an
output tensor y. The math operation and compute data type used for reducing tensor
values is specified via CUDNN_ATTR_OPERATION_REDUCTION_DESC.
This operation descriptor can be created with
\texttt{cudnnBackendCreateDescriptor(CUDNN_BACKEND_OPERATION_REDUCTION_DESCRIPTOR,}
&\texttt{desc);)

The output tensor $Y$ should be the size as that of input tensor $X$, except dimension(s) where its size is 1.

\section*{Attributes}

Attributes of a cuDNN backend reduction descriptor are values of enumeration type \texttt{cudnnBackendAttributeName_t} with prefix CUDNN_ATTR_OPERATION_REDUCTION_:

\begin{description}
  \item[\texttt{CUDNN_ATTR_OPERATION_REDUCTION_XDESC}] The matrix $X$ descriptor.
    \begin{itemize}
      \item \texttt{CUDNN_TYPE_BACKEND_DESCRIPTOR} one element of descriptor type \texttt{CUDNN_BACKEND_TENSOR_DESCRIPTOR}.
      \item Required attribute.
    \end{itemize}
  \item[\texttt{CUDNN_ATTR_OPERATION_REDUCTION_YDESC}] The matrix $Y$ descriptor.
    \begin{itemize}
      \item \texttt{CUDNN_TYPE_BACKEND_DESCRIPTOR} one element of descriptor type \texttt{CUDNN_BACKEND_TENSOR_DESCRIPTOR}.
      \item Required attribute.
    \end{itemize}
  \item[\texttt{CUDNN_ATTR_OPERATION_REDUCTION_DESC}] The reduction operation descriptor.
    \begin{itemize}
      \item \texttt{CUDNN_TYPE_BACKEND_DESCRIPTOR} one element of descriptor type \texttt{CUDNN_BACKEND_REDUCTION_DESCRIPTOR}.
      \item Required attribute.
    \end{itemize}
\end{description}

\section*{Finalization}

In the finalization of the reduction operation, the dimensions of tensors $X$ and $Y$ are checked to ensure that they satisfy the requirements of the reduction operation.

\texttt{cudnnBackendFinalize()} with a \texttt{CUDNN_BACKEND_OPERATION_REDUCTION_DESCRIPTOR} can have the following return values:

\begin{description}
  \item[\texttt{CUDNN_STATUS_BAD_PARAM}] Invalid or inconsistent attribute values are encountered. Some possible causes:
    \begin{itemize}
      \item The dimensions of the tensors $X$ and $Y$ do not satisfy the requirements of the reduction operation.
    \end{itemize}
  \item[\texttt{CUDNN_STATUS_SUCCESS}] The descriptor was finalized successfully.
\end{description}
9.3.21. **CUDNN_BACKEND_OPERATION_RESAMPLE_BWD_DESCRIPTOR**

Created with

```
cudnnBackendCreateDescriptor(CUDNN_BACKEND_OPERATION_RESAMPLE_BWD_DESCRIPTOR, &desc);
```

the cuDNN backend resample backward operation descriptor specifies an operation node for backward resampling. It computes the input tensor gradient \( dx \) from output tensor gradient \( dy \) with backward resampling done according to \( \text{CUDNN_ATTR_RESAMPLE_MODE} \) with output scaling \# and residual add with \# scaling.

**Attributes**

**CUDNN_ATTR_OPERATION_RESAMPLE_BWD_DESC**

Resample operation descriptor (CUDNN_BACKEND_OPERATION_RESAMPLE_DESCRIPTOR) instance containing metadata about the operation.

- **CUDNN_TYPE_BACKEND_DESCRIPTOR;** one element of descriptor type CUDNN_BACKEND_RESAMPLE_DESCRIPTOR.
- Required attribute.

**CUDNN_ATTR_OPERATION_RESAMPLE_BWD_DXDESC**

Input tensor gradient descriptor.

- **CUDNN_TYPE_BACKEND_DESCRIPTOR;** one element of descriptor type CUDNN_BACKEND_TENSOR_DESCRIPTOR.
- Required attribute.

**CUDNN_ATTR_OPERATION_RESAMPLE_BWD_DYDESC**

Output tensor gradient descriptor.

- **CUDNN_TYPE_BACKEND_DESCRIPTOR;** one element of descriptor type CUDNN_BACKEND_TENSOR_DESCRIPTOR.
- Required attribute.

**CUDNN_ATTR_OPERATION_RESAMPLE_BWD_IDXDESC**

Tensor containing maxpool or nearest neighbor resampling indices to be used in backprop.

- **CUDNN_TYPE_BACKEND_DESCRIPTOR;** one element of descriptor type CUDNN_BACKEND_TENSOR_DESCRIPTOR.
- Optional attribute.

**CUDNN_ATTR_OPERATION_RESAMPLE_BWD_ALPHA**

Sets the alpha parameter used in blending.

- **CUDNN_TYPE_DOUBLE or CUDNN_TYPE_FLOAT;** one element.
- Optional attribute.
- Default value is \( 1.0 \).
**CUDNN_ATTR_OPERATION_RESAMPLE_BWD_BETA**
Sets the beta parameter used in blending.

- CUDNN_TYPE_DOUBLE or CUDNN_TYPE_FLOAT; one element.
- Optional attribute.
- Default value is 0.0.

**CUDNN_ATTR_OPERATION_RESAMPLE_BWD_XDESC**
Input tensor X descriptor.

- CUDNN_TYPE_BACKEND_DESCRIPTOR; one element of descriptor type CUDNN_BACKEND_TENSOR_DESCRIPTOR.
- Optional attribute.
- Required for NCHW layout.

**CUDNN_ATTR_OPERATION_RESAMPLE_BWD_YDESC**
Input tensor Y descriptor.

- CUDNN_TYPE_BACKEND_DESCRIPTOR; one element of descriptor type CUDNN_BACKEND_TENSOR_DESCRIPTOR.
- Optional attribute.
- Required for NCHW layout

**Finalization**

In the finalization stage, the attributes are cross checked to make sure there are no conflicts. The status below may be returned:

**CUDNN_STATUS_BAD_PARAM**
Invalid or inconsistent attribute values are encountered. Possible causes are:

- The output shape calculated based on the padding and strides does not match the given output tensor dimensions.
- The shape of YDESC and IDXDESC (if given) do not match.

**CUDNN_STATUS_SUCCESS**

The descriptor was finalized successfully.

**9.3.22. CUDNN_BACKEND_OPERATION_RESAMPLE_FWD_DESCRIPTOR**

Created with

cudnnBackendCreateDescriptor(CUDNN_BACKEND_OPERATION_RESAMPLE_FWD_DESCRIPTOR, &desc);

the cuDNN backend resample forward operation descriptor specifies an operation node for forward resampling. It computes the output tensor y of image tensor x resampled according to CUDNN_ATTR_RESAMPLE_MODE, with output scaling # and residual add with # scaling.

The resampling mode acts independently on each spatial dimension. For spatial dimension i, the output spatial dimension size y_i can be calculated by combining input
image's spatial dimension size \( x_i \), post padding \( post_i \), pre padding \( pre_i \), stride \( s_i \),
window size \( w_i \) as:
\[
y_i = l + (x_i + post_i + pre_i - w_i) / s_i
\]

Attributes

**CUDNN_ATTR_OPERATION_RESAMPLE_FWD_DESC**
Resample operation descriptor (CUDNN_BACKEND_RESAMPLE_DESCRIPTOR) instance containing metadata about the operation.

- CUDNN_TYPE_BACKEND_DESCRIPTOR; one element of descriptor type CUDNN_BACKEND_RESAMPLE_DESCRIPTOR.
- Required attribute.

**CUDNN_ATTR_OPERATION_RESAMPLE_FWD_XDESC**
Input tensor descriptor.

- CUDNN_TYPE_BACKEND_DESCRIPTOR; one element of descriptor type CUDNN_BACKEND_TENSOR_DESCRIPTOR.
- Required attribute.

**CUDNN_ATTR_OPERATION_RESAMPLE_FWD_YDESC**
Output tensor descriptor.

- CUDNN_TYPE_BACKEND_DESCRIPTOR; one element of descriptor type CUDNN_BACKEND_TENSOR_DESCRIPTOR.
- Required attribute.

**CUDNN_ATTR_OPERATION_RESAMPLE_FWD_IDXDESC**
Tensor containing maxpool or nearest neighbor resampling indices to be used in backprop.

- CUDNN_TYPE_BACKEND_DESCRIPTOR; one element of descriptor type CUDNN_BACKEND_TENSOR_DESCRIPTOR.
- Optional attribute (primarily used for use cases involving training).

**CUDNN_ATTR_OPERATION_RESAMPLE_FWD_ALPHA**
Sets the alpha parameter used in blending.

- CUDNN_TYPE_DOUBLE or CUDNN_TYPE_FLOAT; one element.
- Optional attribute.
- Default value is \( 1.0 \).

**CUDNN_ATTR_OPERATION_RESAMPLE_FWD_BETA**
Sets the beta parameter used in blending.

- CUDNN_TYPE_DOUBLE or CUDNN_TYPE_FLOAT; one element.
- Optional attribute.
- Default value is \( 0.0 \).
Finalization

In the finalization stage, the attributes are cross checked to make sure there are no conflicts. The status below may be returned:

**CUDNN_STATUS_BAD_PARAM**

Invalid or inconsistent attribute values are encountered. Possible causes are:

- The output shape calculated based on the padding and strides does not match the given output tensor dimensions.
- The shape of the \texttt{YDESC} and \texttt{IDXDESC} (if given) do not match.

**CUDNN_STATUS_SUCCESS**

The descriptor was finalized successfully.

9.3.23. **CUDNN_BACKEND_OPERATION_RNG_DESCRIPTOR**

Created with \texttt{cudnnBackendCreateDescriptor(CUDNN_BACKEND_OPERATION_RNG_DESCRIPTOR, \&desc)}; the cuDNN backend Rng operation descriptor specifies an operation node for generating a tensor with random numbers based on the probability distribution specified in the Rng descriptor.

The random numbers are generated using a Philox random number generator (RNG) as described in Pytorch. The Philox object takes a seed value, a subsequence for starting the generation, and an offset for the subsequence. Seed and offset can be set by using the attributes. The subsequence is internally set, to ensure independent random numbers.

Attributes

**CUDNN_ATTR_OPERATION_RNG_DESC**

Rng descriptor (CUDNN_BACKEND_RNG_DESCRIPTOR) instance containing metadata about the operation.

- \texttt{CUDNN_TYPE_BACKEND_DESCRIPTOR}; one element of descriptor type \texttt{CUDNN_BACKEND_RNG_DESCRIPTOR}.
- Required attribute.

**CUDNN_ATTR_OPERATION_RNG_YDESC**

Output tensor descriptor.

- \texttt{CUDNN_TYPE_BACKEND_DESCRIPTOR}; one element of descriptor type \texttt{CUDNN_BACKEND_TENSOR_DESCRIPTOR}.
- Required attribute.

**CUDNN_ATTR_OPERATION_RNG_SEED**

Sets the seed for the random number generator which creates the \(Y\) tensor. It can be a host INT64 value or a backend descriptor binded to a value on the device. Only supports a tensor with all dimensions set to 1 and all strides set to 1.
- CUDNN_TYPE_INT64; one element or CUDNN_TYPE_BACKEND_DESCRIPTOR; one element of descriptor type CUDNN_BACKEND_TENSOR_DESCRIPTOR.
- Optional attribute.
- Default value is 0.

**CUDNN_ATTR_OPERATION_RNG_OFFSET_DESC**
Tensor descriptor for the offset used in the RNG Philox object. Only supports a tensor with all dimensions set to 1 and all strides set to 1.
- CUDNN_TYPE_BACKEND_DESCRIPTOR; one element of descriptor type CUDNN_BACKEND_TENSOR_DESCRIPTOR.
- Required attribute.

**Finalization**
In the finalization stage, the attributes are cross checked to make sure there are no conflicts. The status below may be returned:

**CUDNN_STATUS_BAD_PARAM**
- CUDNN_ATTR_OPERATION_RNG_OFFSET_DESC or CUDNN_ATTR_OPERATION_RNG_SEED do not have all dimensions and strides set to 1.

**CUDNN_STATUS_SUCCESS**
The descriptor was finalized successfully.

### 9.3.24. CUDNN_BACKEND_OPERATION_SIGNAL_DESCRIPTOR

Created with `cudnnBackendCreateDescriptor(CUDNN_BACKEND_OPERATION_SIGNAL_DESCRIPTOR, &desc)`; the cuDNN backend signal operation descriptor specifies an operation node for updating or waiting on a flag variable. Signaling operations can be used to communicate between cuDNN operation graphs, even with operation graphs in another GPU.

This operation, to connect to other nodes in the graph, also has a pass-through input tensor, which is not operated on and is just passed along to the output tensor. This mandatory pass-through input tensor helps in determining the predecessor node after which the signal operation should be executed. The optional output tensor helps in determining the successor node before which the signal execution should have completed. It is also guaranteed that for a non-virtual tensor as the output tensor, all writes for the tensor will have taken place before the signal value is updated by the operation.

**Attributes**

**CUDNN_ATTR_OPERATION_SIGNAL_MODE**
The signaling mode to use.

- CUDNN_TYPE_SIGNAL_MODE;
- Required attribute.
**CUDNN_ATTR_OPERATION_SIGNAL_FLAGDESC**
Flag tensor descriptor.

**CUDNN_ATTR_OPERATION_RESAMPLE_FWD_YDESC**
Output tensor descriptor.

- CUDNN_TYPE_BACKEND_DESCRIPTOR; one element of descriptor type
  CUDNN_BACKEND_TENSOR_DESCRIPTOR.
- Required attribute.

**CUDNN_ATTR_OPERATION_SIGNAL_VALUE**
The scalar value to compare or update the flag variable with.

- CUDNN_TYPE_INT64
- Required attribute.

**CUDNN_ATTR_OPERATION_SIGNAL_XDESC**
A pass-through input tensor to enable connecting this signal operation to other nodes in the graph.

- CUDNN_TYPE_BACKEND_DESCRIPTOR; one element of descriptor type
  CUDNN_BACKEND_TENSOR_DESCRIPTOR.
- Required attribute.

**CUDNN_ATTR_OPERATION_SIGNAL_YDESC**
The output tensor for the pass-through input tensor.

- CUDNN_TYPE_BACKEND_DESCRIPTOR; one element of descriptor type
  CUDNN_BACKEND_TENSOR_DESCRIPTOR.
- Optional attribute.

**Finalization**

In the finalization stage, the attributes are cross checked to make sure there are no conflicts. The status below may be returned:

**CUDNN_STATUS_BAD_PARAM**
Invalid or inconsistent attribute values are encountered.

**CUDNN_STATUS_SUCCESS**
The descriptor was finalized successfully.

**9.3.25. CUDNN_BACKEND_OPERATIONGRAPH_DESCRIPTOR**

Created with descriptor type value CUDNN_BACKEND_OPERATIONGRAPH_DESCRIPTOR, cuDNN backend operation graph descriptor describes an operation graph, a small network of one or more operations connected by virtual tensors. Operation graph defines users’ computation case or mathematical expression that they wish to compute.
Attributes

Attributes of a cuDNN backend convolution descriptor are values of enumeration type cudnnBackendAttributeName_t with prefix CUDNN_ATTR_OPERATIONGRAPH_:

**CUDNN_ATTR_OPERATIONGRAPH_HANDLE**
A cuDNN handle.
- CUDNN_TYPE_HANDLE; one element.
- Required attribute.

**CUDNN_ATTR_OPERATIONGRAPH_OPS**
Operation nodes to form the operation graph.
- CUDNN_TYPE_BACKEND_DESCRIPTOR; one or more elements of descriptor type CUDNN_BACKEND_OPERATION_*_DESCRIPTOR().
- Required attribute.

**CUDNN_ATTR_OPERATIONGRAPH_ENGINE_GLOBAL_COUNT**
The number of engines to support the operation graph.
- CUDNN_TYPE_INT64; one element.
- Read-only attribute.

**CUDNN_ATTR_OPERATIONGRAPH_ENGINE_SUPPORTED_COUNT**
The number of engines that support the operation graph.
- CUDNN_TYPE_INT64; one element.
- Read-only attribute; placeholder only: currently not supported.

Finalization

**CUDNN_STATUS_BAD_PARAM**
An invalid attribute value was encountered. For example:

- One of the backend descriptors in CUDNN_ATTR_OPERATIONGRAPH_OPS is not finalized.
- The value CUDNN_ATTR_OPERATIONGRAPH_HANDLE is not a valid cuDNN handle.

**CUDNN_STATUS_NOT_SUPPORTED**
An unsupported attribute value was encountered. For example:

- The combination of operations of attribute CUDNN_ATTR_OPERATIONGRAPH_OPS is not supported.

**CUDNN_STATUS_SUCCESS**
The descriptor was finalized successfully.
9.3.26. **CUDNN_BACKEND_POINTWISE_DESCRIPTOR**

Created with `cudnnBackendCreateDescriptor(CUDNN_BACKEND_POINTWISE_DESCRIPTOR, &desc);` the cuDNN backend pointwise descriptor specifies the parameters for a pointwise operator like mode, math precision, nan propagation and so on.

### Attributes

Attributes of a cuDNN backend convolution descriptor are values of enumeration type `cudnnBackendAttributeName_t` with prefix `CUDNN_ATTR_POINTWISE_`:

**CUDNN_ATTR_POINTWISE_MODE**

Mode of the pointwise operation.

- `CUDNN_TYPE_POINTWISE_MODE`; one element.
- Required attribute.

**CUDNN_ATTR_POINTWISE_MATH_PREC**

The math precision of the computation.

- `CUDNN_TYPE_DATA_TYPE`; one element.
- Required attribute.

**CUDNN_ATTR_POINTWISE_NAN_PROPAGATION**

Specifies a method by which to propagate NaNs.

- `CUDNN_TYPE_NAN_PROPOGATION`; one element.
- Required only for comparison based pointwise modes, like ReLU.
- Current support only includes enum value `CUDNN_PROPAGATE_NAN`.
- Default value: `CUDNN_NOT_PROPAGATE_NAN`.

**CUDNN_ATTR_POINTWISE_RELU_LOWER_CLIP**

Sets the lower clip value for ReLU. If $(value < lower\_clip) value = lower\_clip + lower\_clip\_slope * (value - lower\_clip)$;

- `CUDNN_TYPE_DOUBLE` / `CUDNN_TYPE_FLOAT`; one element.
- Default value: $0.0f$.

**CUDNN_ATTR_POINTWISE_RELU_UPPER_CLIP**

Sets the upper clip value for ReLU. If $(value > upper\_clip) value = upper\_clip$;

- `CUDNN_TYPE_DOUBLE` / `CUDNN_TYPE_FLOAT`; one element.
- Default value: Numeric limit max.

**CUDNN_ATTR_POINTWISE_RELU_LOWER_CLIP_SLOPE**

Sets the lower clip slope value for ReLU. If $(value < lower\_clip) value = lower\_clip + lower\_clip\_slope * (value - lower\_clip)$;

- `CUDNN_TYPE_DOUBLE` / `CUDNN_TYPE_FLOAT`; one element.
- Default value: 0.0f.

**CUDNN_ATTR_POINTWISE_ELU_ALPHA**
Sets the alpha value for ELU. If (value < 0.0) value = alpha * (e^value - 1.0);
- CUDNN_TYPE_DOUBLE / CUDNN_TYPE_FLOAT; one element.
- Default value: 1.0f.

**CUDNN_ATTR_POINTWISE_SOFTPLUS_BETA**
Sets the beta value for softplus; value = log (1 + e^(beta * value)) / beta
- CUDNN_TYPE_DOUBLE / CUDNN_TYPE_FLOAT; one element.
- Default value: 1.0f

**CUDNN_ATTR_POINTWISE_SWISH_BETA**
Sets the beta value for swish; value = value / (1 + e^(-beta * value))
- CUDNN_TYPE_DOUBLE / CUDNN_TYPE_FLOAT; one element.
- Default value: 1.0f.

**CUDNN_ATTR_POINTWISE_AXIS**
Sets the axis value for **GEN_INDEX**. The index will be generated for this axis.
- CUDNN_TYPE_INT64; one element.
- Default value: -1.
- Needs to lie between [0,input_dim_size-1]. For example, if your input has dimensions [N,C,H,W], the axis can be set to anything in [0,3].

**Finalization**

\texttt{cudnnBackendFinalize()} with a **CUDNN_BACKEND_POINTWISE_DESCRIPTOR** can have the following return values:

**CUDNN_STATUS_SUCCESS**
The descriptor was finalized successfully.

### 9.3.27. **CUDNN_BACKEND_REDUCTION_DESCRIPTOR**

Created with \texttt{cudnnBackendCreateDescriptor(CUDNN_BACKEND_REDUCTION_DESCRIPTOR, &desc)}; the cuDNN backend reduction descriptor specifies any metadata, including the math operation and compute data type, needed for the reduction operation.

**Attributes**

**CUDNN_ATTR_REDUCTION_OPERATOR**
The math operation used for the reduction operation.
- CUDNN_TYPE_REDUCTION_OPERATOR_TYPE; one element.
- Required attribute.
CUDDN_ATTRIB_REDUCTION_COMP_TYPE
The compute precision used for the reduction operation.

- CUDNN_TYPE_DATA_TYPE; one element.
- Required attribute.

Finalization
Return values of cudnnBackendFinalize(desc) where desc is
CUDNN_BACKEND_REDUCTION_DESCRIPTOR are:

CUDDN_STATUS_NOT_SUPPORTED
An unsupported attribute value was encountered. Some possible causes are:

- CUDNN_ATTRIB_REDUCTION_OPERATOR is not set to either of
  CUDNN_REDUCE_TENSOR_ADD, CUDNN_REDUCE_TENSOR_MUL,
  CUDNN_REDUCE_TENSOR_MIN, or CUDNN_REDUCE_TENSOR_MAX.

CUDDN_STATUS_SUCCESS
The descriptor was finalized successfully.

9.3.28. CUDDN_BACKEND_RESAMPLE_DESCRIPTOR
Created with cudnnBackendCreateDescriptor(CUDNN_BACKEND_RESAMPLE_DESCRIPTOR,
&desc); the cuDNN backend resample descriptor specifies the parameters for a resample
operation (upsampling or downsampling) in both forward and backward propagation.

Attributes

CUDDN_ATTRIB_RESAMPLE_MODE
Specifies mode of resampling, for example, average pool, nearest-neighbor, etc.

- CUDNN_TYPE_RESAMPLE_MODE; one element.
- Default value is CUDNN_RESAMPLE_NEAREST.

CUDDN_ATTRIB_RESAMPLE_COMP_TYPE
Compute data type for the resampling operator.

- CUDNN_TYPE_DATA_TYPE; one element.
- Default value is CUDNN_DATA_FLOAT.

CUDDN_ATTRIB_RESAMPLE_NAN_PROPAGATION
Specifies a method by which to propagate NaNs.

- CUDNN_TYPE_NAN_PROPAGATION; one element.
- Default value is CUDNN_NOT_PROPAGATE_NAN.

CUDDN_ATTRIB_RESAMPLE_SPATIAL_DIMS
Specifies the number of spatial dimensions to perform the resampling over.

- CUDNN_TYPE_INT64; one element.
- Required attribute.

**CUDNN_ATTR_RESAMPLE_PADDING_MODE**
Specifies which values to use for padding.
- CUDNN_TYPE_PADDING_MODE; one element.
- Default value is CUDNN_ZERO_PAD.

**CUDNN_ATTR_RESAMPLE_STRIDES**
Stride in each dimension for the kernel/filter.
- CUDNN_TYPE_INT64 or CUDNN_TYPE_FRACTION; at most CUDNN_MAX_DIMS - 2.
- Required attribute.

**CUDNN_ATTR_RESAMPLE_PRE_PADDINGS**
Padding added to the beginning of the input tensor in each dimension.
- CUDNN_TYPE_INT64 or CUDNN_TYPE_FRACTION; at most CUDNN_MAX_DIMS - 2.
- Required attribute.

**CUDNN_ATTR_RESAMPLE_POST_PADDINGS**
Padding added to the end of the input tensor in each dimension.
- CUDNN_TYPE_INT64 or CUDNN_TYPE_FRACTION; at most CUDNN_MAX_DIMS - 2.
- Required attribute.

**CUDNN_ATTR_RESAMPLE_WINDOW_DIMS**
Spatial dimensions of filter.
- CUDNN_TYPE_INT64 or CUDNN_TYPE_FRACTION; at most CUDNN_MAX_DIMS - 2.
- Required attribute.

**Finalization**
The return values for `cudnnBackendFinalize()` when called with a
CUDNN_BACKEND_RESAMPLE_DESCRIPTOR is:

**CUDNN_STATUS_NOT_SUPPORTED**
An unsupported attribute value was encountered. Some possible causes are:
- An elemCount argument for setting CUDNN_ATTR_RESAMPLE_WINDOW_DIMS,
  CUDNN_ATTR_RESAMPLE_STRIDES, CUDNN_ATTR_RESAMPLE_PRE_PADDINGS,
  and CUDNN_ATTR_RESAMPLE_POST_PADDINGS is not equal to the value set for
  CUDNN_ATTR_RESAMPLE_SPATIAL_DIMS.
- CUDNN_ATTR_RESAMPLE_MODE is set to CUDNN_RESAMPLE_BILINEAR and any of the
  CUDNN_ATTR_RESAMPLE_WINDOW_DIMS are not set to 2.

**CUDNN_STATUS_SUCCESS**
The descriptor was finalized successfully.
9.3.29. **CUDNN_BACKEND_RNG_DESCRIPTOR**

Created with `cudnnBackendCreateDescriptor(CUDNN_BACKEND_RNG_DESCRIPTOR, &desc);` the cuDNN backend `Rng` descriptor specifies any metadata, including the probability distribution that will be used to generate the tensor and the distribution’s corresponding parameters.

### Attributes

- **CUDNN_ATTR_RNG_DISTRIBUTION**
  The probability distribution used for the `rng` operation.
  - `CUDNN_TYPE_RNG_DISTRIBUTION`; one element.
  - Default value is `CUDNN_RNG_DISTRIBUTION_BERNOULLI`.

- **CUDNN_ATTR_RNG_NORMAL_DIST_MEAN**
  The mean value for the normal distribution, used if `CUDNN_ATTR_RNG_DISTRIBUTION = CUDNN_RNG_DISTRIBUTION_NORMAL`.
  - `CUDNN_TYPE_DOUBLE`; one element.
  - Default value is `-1`.

- **CUDNN_ATTR_RNG_NORMAL_DIST_STANDARD_DEVIATION**
  The standard deviation value for the normal distribution, used if `CUDNN_ATTR_RNG_DISTRIBUTION = CUDNN_RNG_DISTRIBUTION_NORMAL`.
  - `CUDNN_TYPE_DOUBLE`; one element.
  - Default value is `-1`.

- **CUDNN_ATTR_RNG_UNIFORM_DIST_MAXIMUM**
  The maximum value for the range used in uniform distribution, used if `CUDNN_ATTR_RNG_DISTRIBUTION = CUDNN_RNG_DISTRIBUTION_UNIFORM`.
  - `CUDNN_TYPE_DOUBLE`; one element.
  - Default value is `-1`.

- **CUDNN_ATTR_RNG_UNIFORM_DIST_MINIMUM**
  The minimum value for the range used in uniform distribution, used if `CUDNN_ATTR_RNG_DISTRIBUTION = CUDNN_RNG_DISTRIBUTION_UNIFORM`.
  - `CUDNN_TYPE_DOUBLE`; one element.
  - Default value is `-1`.

- **CUDNN_ATTR_RNG_BERNOULLI_DIST_PROBABILITY**
  The probability of generating 1’s in the tensor, used if `CUDNN_ATTR_RNG_DISTRIBUTION = CUDNN_RNG_DISTRIBUTION_BERNOULLI`.
  - `CUDNN_TYPE_DOUBLE`; one element.
Default value is -1.

Finalization

Return values of `cudnnBackendFinalize(desc)` where `desc` is `CUDNN_BACKEND_RNG_DESCRIPTOR` are:

- **CUDNN_STATUS_BAD_PARAM**
  An invalid attribute value was encountered. For example:
  - If `CUDNN_ATTR_RNG_DISTRIBUTION = CUDNN_RNG_DISTRIBUTION_NORMAL` and the standard deviation supplied is negative.
  - If `CUDNN_ATTR_RNG_DISTRIBUTION = CUDNN_RNG_DISTRIBUTION_UNIFORM` and the maximum value of the range is lower than minimum value.
  - If `CUDNN_ATTR_RNG_DISTRIBUTION = CUDNN_RNG_DISTRIBUTION_BERNOULLI` and the probability supplied is negative.

- **CUDNN_STATUS_SUCCESS**
  The descriptor was finalized successfully.

9.3.30. **CUDNN_BACKEND_TENSOR_DESCRIPTOR**

Created with `cudnnBackendCreateDescriptor(CUDNN_BACKEND_TENSOR_DESCRIPTOR, &desc)`; the cuDNN backend tensor allows users to specify the memory storage of a generic tensor. A tensor is identified by a unique identifier and described by its data type, its data byte-alignment requirements, and the extents and strides of its dimensions. Optionally, a tensor element can be vector in one of its dimensions. A tensor can also be set to be virtual when it is an intermediate variable in a computation graph and not mapped to physical global memory storage.

Attributes

Attributes of a cuDNN backend tensor descriptors are values of enumeration type `cudnnBackendAttributeName_t` with prefix `CUDNN_ATTR_TENSOR_`:

- **CUDNN_ATTR_TENSOR_UNIQUE_ID**
  An integer that uniquely identifies the tensor.
  - `CUDNN_TYPE_INT64`; one element.
  - Required attribute.

- **CUDNN_ATTR_TENSOR_DATA_TYPE**
  Data type of tensor.
  - `CUDNN_TYPE_DATA_TYPE`; one element.
  - Required attribute.

- **CUDNN_ATTR_TENSOR_BYTE_ALIGNMENT**
  Byte alignment of pointers for this tensor.
  - `CUDNN_TYPE_INT64`; one element.
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- Required attribute.

**CUDNN_ATTR_TENSOR_DIMENSIONS**

Tensor dimensions.

- CUDNN_TYPE_INT64; at most CUDNN_MAX_DIMS elements.
- Required attribute.

**CUDNN_ATTR_TENSOR_STRIDES**

Tensor strides.

- CUDNN_TYPE_INT64; at most CUDNN_MAX_DIMS elements.
- Required attribute.

**CUDNN_ATTR_TENSOR_VECTOR_COUNT**

Size of vectorization.

- CUDNN_TYPE_INT64; one element.
- Default value: 1

**CUDNN_ATTR_TENSOR_VECTORIZED_DIMENSION**

Index of the vectorized dimension.

- CUDNN_TYPE_INT64; one element.
- Required to be set before finalization if CUDNN_ATTR_TENSOR_VECTOR_COUNT is set to a value different than its default; otherwise it’s ignored.

**CUDNN_ATTR_TENSOR_IS_VIRTUAL**

Indicates whether the tensor is virtual. A virtual tensor is an intermediate tensor in the operation graph that exists in transient and not read from or written to in global device memory.

- CUDNN_TYPE_BOOL; one element.
- Default value: false

**CUDNN_ATTR_TENSOR_RAGGED_OFFSET_DESC**

A ragged tensor, that is, a tensor with nested variable length lists as inner dimensions, will have another tensor called the ragged offset descriptor that contains offsets in memory to the next variable length list.

- CUDNN_TYPE_BACKEND_DESCRIPTOR; one element.
- Default value: None

**Finalization**

cudnnBackendFinalize() with a CUDNN_BACKEND_CONVOLUTION_DESCRIPTOR can have the following return values:

**CUDNN_STATUS_BAD_PARAM**

An invalid attribute value was encountered. For example:
Any of the tensor dimensions or strides is not positive.
The value of the tensor alignment attribute is not divisible by the size of the data type.

**CUDNN_STATUS_NOT_SUPPORTED**
An unsupported attribute value was encountered. For example:
- The data type attribute is `CUDNN_DATA_INT8x4`, `CUDNN_DATA_UINT8x4`, or `CUDNN_DATA_INT8x32`.
- The data type attribute is `CUDNN_DATA_INT8` and `CUDNN_ATTR_TENSOR_VECTOR_COUNT` value is not 1, 4, or 32.

**CUDNN_STATUS_SUCCESS**
The descriptor was finalized successfully.

### 9.3.31. **CUDNN_BACKEND_VARIANT_PACK_DESCRIPTOR**

Created with `cudnnBackendCreateDescriptor(CUDNN_BACKEND_VARIANT_PACK_DESCRIPTOR, &desc)`; the cuDNN backend variant pack plan allows users to set up pointers to device buffers to various non-virtual tensors, identified by unique identifiers, of the operation graph, workspace, and computation intermediates.

**Attributes**

**CUDNN_ATTR_VARIANT_PACK_UNIQUE_IDS**
A unique identifier of tensor for each data pointer.
- `CUDNN_TYPE_INT64`; zero of more elements.
- Required attribute.

**CUDNN_ATTR_VARIANT_PACK_DATA_POINTERS**
Tensor data device pointers.
- `CUDNN_TYPE_VOID_PTR`; zero or more elements.
- Required attribute.

**CUDNN_ATTR_VARIANT_PACK_INTERMEDIATES**
Intermediate device pointers.
- `CUDNN_TYPE_VOID_PTR`; zero or more elements.
- Setting attribute unsupported. Placeholder for support to be added in a future version.

**CUDNN_ATTR_VARIANT_PACK_WORKSPACE**
Workspace to device pointer.
- `CUDNN_TYPE_VOID_PTR`; one element.
- Required attribute.
Finalization

The return values for `cudnnBackendFinalize()` when called with a cuDNN backend variant pack descriptor is:

**CUDNN_STATUS_SUCCESS**

The descriptor was finalized successfully.

9.4. Use Cases

This section describes some typical use cases of the cuDNN backend API; for example, setting up a simple operation graph, setting up an engine config for that operation graph, and finally setting up an execution plan and executing it with data pointers set in a variant pack descriptor.

9.4.1. Setting Up An Operation Graph For A Grouped Convolution

This use case creates an operation graph with a single grouped 3D convolution forward operation. It starts by setting up the input and output tensors, binding them to a convolution forward operation, and finally setting up an operation graph with a single node.

1. Create tensor descriptors.

   ```
   cudnnBackendDescriptor_t xDesc;
   cudnnBackendCreateDescriptor(CUDNN_BACKEND_TENSOR_DESCRIPTOR, &xDesc);
   
   cudnnDataType_t dtype = CUDNN_DATA_FLOAT;
   cudnnBackendSetAttribute(xDesc, CUDNN_ATTR_TENSOR_DATA_TYPE,
                            CUDNN_TYPE_DATA_TYPE, 1, &dtype);
   
   int64_t xDim[] = {n, g, c, d, h, w};
   int64_t xStr[] = {g * c * d * h * w, c * d * h * w, d * h * w, h * w, w, 1};
   int64_t xUi = 'x';
   int64_t alignment = 4;
   cudnnBackendSetAttribute(xDesc, CUDNN_ATTR_TENSOR_DIMENSIONS,
                            CUDNN_TYPE_INT64, 6, xDim);
   cudnnBackendSetAttribute(xDesc, CUDNN_ATTR_TENSOR_STRIDES,
                            CUDNN_TYPE_INT64, 6, xStr);
   cudnnBackendSetAttribute(xDesc, CUDNN_ATTR_TENSOR_UNIQUE_ID,
                            CUDNN_TYPE_INT64, 1, &xUi);
   cudnnBackendSetAttribute(xDesc, CUDNN_ATTR_TENSOR_BYTE_ALIGNMENT,
                            CUDNN_TYPE_INT64, 1, &alignment);
   cudnnBackendFinalize(xDesc);
   ```

2. Repeat the above step for the convolution filter and output tensor descriptor. The six filter tensor dimensions are \([g, k, c, t, r, s]\) and the six output tensor dimensions are \([n, g, k, o, p, q]\), respectively. Below, when finalizing a convolution operator to which the tensors are bound, dimension consistency is
checked, meaning all \(n, g, c, k\) values shared among the three tensors are required to be the same. Otherwise, \texttt{CUDNN\_STATUS\_BAD\_PARAM} status is returned.

For backward compatibility with how tensors are specified in \texttt{cudnnTensorDescriptor\_t} and used in convolution API, it is also possible to specify a 5D tensor with the following dimension:

- image: \([n, g*c, d, h, w]\)
- filter: \([g*k, c, t, r, s]\)
- response: \([n, g*k, o, p, q]\)

In this format, a similar consistency check is performed when finalizing a convolution operator descriptor to which the tensors are bound.

3. Create, set, and finalize a convolution operator descriptor.

```c
// Create descriptor.

int64_t nbDims = 3;

// Set attributes.

cudnnBackendCreateDescriptor(CUDNN_BACKEND_CONVOLUTION_DESCRIPTOR, &cDesc);
cudnnBackendSetAttribute(cDesc, CUDNN_ATTR_CONVOLUTION_SPATIAL_DIMS, CUDNN_TYPE_INT64, 1, &nbDims);
cudnnBackendSetAttribute(cDesc, CUDNN_ATTR_CONVOLUTION_COMP_TYPE, CUDNN_TYPE_DATA_TYPE, 1, &compType);
cudnnBackendSetAttribute(cDesc, CUDNN_ATTR_CONVOLUTION_CONV_MODE, CUDNN_TYPE_CONVOLUTION_MODE, 1, &mode);
cudnnBackendSetAttribute(cDesc, CUDNN_ATTR_CONVOLUTION_PRE_PADDINGS, CUDNN_TYPE_INT64, nbDims, pad);
cudnnBackendSetAttribute(cDesc, CUDNN_ATTR_CONVOLUTION_POST_PADDINGS, CUDNN_TYPE_INT64, nbDims, pad);
cudnnBackendSetAttribute(cDesc, CUDNN_ATTR_CONVOLUTION_DILATIONS, CUDNN_TYPE_INT64, nbDims, dilation);
cudnnBackendSetAttribute(cDesc, CUDNN_ATTR_CONVOLUTION_FILTER_STRIDES, CUDNN_TYPE_INT64, nbDims, filterStr);
cudnnBackendFinalize(cDesc);
```

4. Create, set, and finalize a convolution forward operation descriptor.

```c
// Create descriptor.

float alpha = 1.0;
float beta = 0.5;

cudnnBackendCreateDescriptor(CUDNN_BACKEND_OPERATION_CONVOLUTION_FORWARD_DESCRIPTOR, fprop);
cudnnBackendSetAttribute(fprop, CUDNN_ATTR_OPERATION_CONVOLUTION_FORWARD_X, CUDNN_TYPE_BACKEND_DESCRIPTOR, 1, &xDesc);
cudnnBackendSetAttribute(fprop, CUDNN_ATTR_OPERATION_CONVOLUTION_FORWARD_W, CUDNN_TYPE_BACKEND_DESCRIPTOR, 1, &wDesc);
cudnnBackendSetAttribute(fprop, CUDNN_ATTR_OPERATION_CONVOLUTION_FORWARD_Y, CUDNN_TYPE_BACKEND_DESCRIPTOR, 1, &yDesc);
cudnnBackendSetAttribute(fprop, CUDNN_ATTR_OPERATION_CONVOLUTION_FORWARD_CONV_DESC, CUDNN_TYPE_BACKEND_DESCRIPTOR, 1, &cDesc);
```
5. Create, set, and finalize an operation graph descriptor.

```c
5. Create, set, and finalize an operation graph descriptor.
cudnnBackendDescriptor_t op_graph;
cudnnBackendCreateDescriptor(CUDNN_BACKEND_OPERATIONGRAPH_DESCRIPTOR, &op_graph);
cudnnBackendSetAttribute(op_graph, CUDNN_ATTR_OPERATIONGRAPH_OPS, CUDNN_TYPE_BACKEND_DESCRIPTOR, 1, &fprop);
cudnnBackendSetAttribute(op_graph, CUDNN_ATTR_OPERATIONGRAPH_HANDLE, CUDNN_TYPE_HANDLE, 1, &handle);
cudnnBackendFinalize(op_graph);
```

9.4.2. Setting Up An Engine Configuration

This use case describes the steps with which users can set up an engine config from a previously finalized operation graph. This is an example in which users would like to use the engine with `CUDNN_ATTR_ENGINE_GLOBAL_INDEX 0` for this operation graph and does not set any performance knobs.

1. Create, set, and finalize an engine descriptor.

```c
1. Create, set, and finalize an engine descriptor.
cudnnBackendDescriptor_t engine;
cudnnBackendCreateDescriptor(CUDNN_BACKEND_ENGINE_DESCRIPTOR, &engine);
cudnnBackendSetAttribute(engine, CUDNN_ATTR_ENGINE_OPERATION_GRAPH, CUDNN_TYPE_BACKEND_DESCRIPTOR, 1, &op_graph);
int64_t gidx = 0;
cudnnBackendSetAttribute(engine, CUDNN_ATTR_ENGINE_GLOBAL_INDEX, CUDNN_TYPE_INT64, 1, &gidx);
cudnnBackendFinalize(engine);
```

The user can query a finalized engine descriptor with `cudnnBackendGetAttribute()` API call for its attributes, including the performance knobs that it has. For simplicity, this use case skips this step and assumes the user is setting up an engine config descriptor below without making any changes to performance knobs.

2. Create, set, and finalize an engine config descriptor.

```c
2. Create, set, and finalize an engine config descriptor.
cudnnBackendDescriptor_t engcfg;
cudnnBackendCreateDescriptor(CUDNN_BACKEND_ENGINECFG_DESCRIPTOR, &engcfg);
cudnnBackendSetAttribute(engcfg, CUDNN_ATTR_ENGINECFG_ENGINE, CUDNN_TYPE_BACKEND_DESCRIPTOR, 1, &engine);
cudnnBackendFinalize(engcfg);
```

9.4.3. Setting Up And Executing A Plan

This use case describes the steps with which users set up an execution plan with a previously finalized engine config descriptor, set up the data pointer variant pack, and finally execute the plan.

1. Create, set, and finalize an execution plan descriptor. Obtain workspace size to allocate.

```c
1. Create, set, and finalize an execution plan descriptor. Obtain workspace size to allocate.
cudnnBackendDescriptor_t plan;
cudnnBackendCreateDescriptor(CUDNN_BACKEND_EXECUTION_PLAN_DESCRIPTOR, &plan);
cudnnBackendSetAttribute(plan, CUDNN_ATTR_EXECUTION_PLAN_HANDLE, CUDNN_TYPE_HANDLE, 1, &handle);
cudnnBackendSetAttribute(plan, CUDNN_ATTR_EXECUTION_PLAN_ENGINE_CONFIG,
CUDNN_TYPE_BACKEND_DESCRIPTOR, 1, &engcfg);
cudnnBackendFinalize(plan);

int64_t workspaceSize;
cudnnBackendGetAttribute(plan, CUDNN_ATTR_EXECUTION_PLAN_WORKSPACE_SIZE,
   CUDNN_TYPE_INT64, 1, NULL, &workspaceSize);

2. Create, set and finalize a variant pack descriptor.

    void *dev_ptrs[3] = {xData, wData, yData}; // device pointer
    int64_t uids[3] = {'x', 'w', 'y'};
    void *workspace;

    cudnnBackendDescriptor_t varpack;
cudnnBackendCreateDescriptor(CUDNN_BACKEND_VARIANT_PACK_DESCRIPTOR, &varpack);
cudnnBackendSetAttribute(varpack, CUDNN_ATTR_VARIANT_PACK_DATA_POINTERS,
       CUDNN_TYPE_VOID_PTR, 3, dev_ptrs);
cudnnBackendSetAttribute(varpack, CUDNN_ATTR_VARIANT_PACK_UNIQUE_IDS,
       CUDNN_TYPE_INT64, 3, uids);
cudnnBackendSetAttribute(varpack, CUDNN_ATTR_VARIANT_PACK_WORKSPACE,
       CUDNN_TYPE_VOID_PTR, 1, &workspace);
cudnnBackendFinalize(varpack);

3. Execute the plan with a variant pack.

    cudnnBackendExecute(handle, plan, varpack);
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