CUDNN 7.5.1

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Developer Guide

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Chapter 1. OVERVIEW

NVIDIA® cuDNN is a GPU-accelerated library of primitives for deep neural networks. It provides highly tuned implementations of routines arising frequently in DNN applications:

- Convolution forward and backward, including cross-correlation
- Pooling forward and backward
- Softmax forward and backward
- Neuron activations forward and backward:
  - Rectified linear (ReLU)
  - Sigmoid
  - Hyperbolic tangent (TANH)
- Tensor transformation functions
- LRN, LCN and batch normalization forward and backward

cuDNN's convolution routines aim for a performance that is competitive with the fastest GEMM (matrix multiply)-based implementations of such routines, while using significantly less memory.

cuDNN features include customizable data layouts, supporting flexible dimension ordering, striding, and subregions for the 4D tensors used as inputs and outputs to all of its routines. This flexibility allows easy integration into any neural network implementation, and avoids the input/output transposition steps sometimes necessary with GEMM-based convolutions.

cuDNN offers a context-based API that allows for easy multithreading and (optional) interoperability with CUDA streams.

Chapter 2. GENERAL DESCRIPTION

Basic concepts are described in this section.

2.1. Programming Model

The cuDNN Library exposes a Host API but assumes that for operations using the GPU, the necessary data is directly accessible from the device.

An application using cuDNN must initialize a handle to the library context by calling `cudnnCreate()`. This handle is explicitly passed to every subsequent library function that operates on GPU data. Once the application finishes using cuDNN, it can release the resources associated with the library handle using `cudnnDestroy()`. This approach allows the user to explicitly control the library's functioning when using multiple host threads, GPUs and CUDA Streams.

For example, an application can use `cudaSetDevice()` to associate different devices with different host threads, and in each of those host threads, use a unique cuDNN handle that directs the library calls to the device associated with it. Thus the cuDNN library calls made with different handles will automatically run on different devices.

The device associated with a particular cuDNN context is assumed to remain unchanged between the corresponding **`cudnnCreate()`** and **`cudnnDestroy()`** calls. In order for the cuDNN library to use a different device within the same host thread, the application must set the new device to be used by calling **`cudaSetDevice()`** and then create another cuDNN context, which will be associated with the new device, by calling **`cudnnCreate()`**.

cuDNN API Compatibility

Beginning in cuDNN 7, the binary compatibility of patch and minor releases is maintained as follows:

- Any patch release x.y.z is forward- or backward-compatible with applications built against another cuDNN patch release x.y.w (i.e., of the same major and minor version number, but having w!=z)

- cuDNN minor releases beginning with cuDNN 7 are binary backward-compatible with applications built against the same or earlier patch release (i.e., an app built against cuDNN 7.x is binary compatible with cuDNN library 7.y, where y>=x)
- Applications compiled with a cuDNN version 7.y are not guaranteed to work with 7.x release when y > x.

2.2. Convolution Formulas

This section describes the various convolution formulas implemented in cuDNN convolution functions.

The convolution terms described in the table below apply to all the convolution formulas that follow.

TABLE OF CONVOLUTION TERMS

Term	Description
x	Input (image) Tensor
w	Weight Tensor
y	Output Tensor
n	Current Batch Size
c	Current Input Channel
C	Total Input Channels
H	Input Image Height
W	Input Image Width
k	Current Output Channel
K	Total Output Channels
p	Current Output Height Position
q	Current Output Width Position
G	Group Count
pad	Padding Value
u	Vertical Subsample Stride (along Height)
v	Horizontal Subsample Stride (along Width)
dil_h	Vertical Dilation (along Height)
dil_w	Horizontal Dilation (along Width)
r	Current Filter Height
R	Total Filter Height
s	Current Filter Width
S	Total Filter Width

Term	Description
C_g	$\frac{C}{G}$
K_g	$\frac{K}{G}$

Normal Convolution (using cross-correlation mode)

$$y_{n,k,p,q} = \sum_{c}^{C} \sum_{r}^{R} \sum_{s}^{S} x_{n,c,p+r,q+s} \times w_{k,c,r,s}$$

Convolution with Padding

$$x_{<0,<0} = 0$$

$$x_{>H,>W} = 0$$

$$y_{n,k,p,q} = \sum_{c}^{C} \sum_{r}^{R} \sum_{s}^{S} x_{n,c,p+r-pad,q+s-pad} \times w_{k,c,r,s}$$

Convolution with Subsample-Striding

$$y_{n,k,p,q} = \sum_{c}^{C} \sum_{r}^{R} \sum_{s}^{S} x_{n,c,(p*u)+r,(q*v)+s} \times w_{k,c,r,s}$$

Convolution with Dilation

$$y_{n,k,p,q} = \sum_{c}^{C} \sum_{r}^{R} \sum_{s}^{S} x_{n,c,p+(r*dilh),q+(s*dilw)} \times w_{k,c,r,s}$$

Convolution using Convolution Mode

$$y_{n,k,p,q} = \sum_{c}^{C} \sum_{r}^{R} \sum_{s}^{S} x_{n,c,p+r,q+s} \times w_{k,c,R-r-1,S-s-1}$$

Convolution using Grouped Convolution

$$C_g = \frac{C}{G}$$

$$K_g = \frac{K}{G}$$

$$y_{n,k,p,q} = \sum_{c}^{Cg} \sum_{r}^{R} \sum_{s}^{S} x_{n,Cg*floor(k/Kg)+c,p+r,q+s} \times w_{k,c,r,s}$$

2.3. Notation

As of CUDNN v4 we have adopted a mathematicaly-inspired notation for layer inputs and outputs using **`x,y,dx,dy,b,w`** for common layer parameters. This was done to improve the readability and ease of understanding of the meaning of the parameters. All layers now follow a uniform convention as below:

During Inference:

`y = layerFunction(x, otherParams)`.

During backpropagation:

`(dx, dOtherParams) = layerFunctionGradient(x,y,dy,otherParams)`

For **convolution** the notation is

`y = x*w+b`

where **`w`** is the matrix of filter weights, **`x`** is the previous layer's data (during inference), **`y`** is the next layer's data, **`b`** is the bias and **`*`** is the convolution operator.

In backpropagation routines the parameters keep their meanings.

The parameters **`dx,dy,dw,db`** always refer to the gradient of the final network error function with respect to a given parameter. So **`dy`** in all backpropagation routines always refers to error gradient backpropagated through the network computation graph so far. Similarly other parameters in more specialized layers, such as, for instance, **`dMeans`** or **`dBnBias`** refer to gradients of the loss function wrt those parameters.

`w` is used in the API for both the width of the **`x`** tensor and convolution filter matrix. To resolve this ambiguity we use **`w`** and **`filter`** notation interchangeably for convolution filter weight matrix. The meaning is clear from the context since the layer width is always referenced near its height.

2.4. Tensor Descriptor

The cuDNN Library describes data holding images, videos and any other data with contents with a generic n-D tensor defined with the following parameters :

- a dimension **`nbDims`** from 3 to 8
- a data type (32-bit floating point, 64 bit-floating point, 16 bit floating point...)
- **`dimA`** integer array defining the size of each dimension
- **`strideA`** integer array defining the stride of each dimension (e.g the number of elements to add to reach the next element from the same dimension)

The first dimension of the tensor defines the batch size **`n`**, and the second dimension defines the number of features maps **`c`**. This tensor definition allows for example to have some dimensions overlapping each others within the same tensor by having the stride of one dimension smaller than the product of the dimension and the stride of the next dimension. In cuDNN, unless specified otherwise, all routines will support tensors with overlapping dimensions for forward pass input tensors, however, dimensions of the output tensors cannot overlap. Even though this tensor format supports negative strides (which can be useful for data mirroring), cuDNN routines do not support tensors with negative strides unless specified otherwise.

2.4.1. WXYZ Tensor Descriptor

Tensor descriptor formats are identified using acronyms, with each letter referencing a corresponding dimension. In this document, the usage of this terminology implies :

- all the strides are strictly positive
- the dimensions referenced by the letters are sorted in decreasing order of their respective strides

2.4.2. 4-D Tensor Descriptor

A 4-D Tensor descriptor is used to define the format for batches of 2D images with 4 letters : N,C,H,W for respectively the batch size, the number of feature maps, the height and the width. The letters are sorted in decreasing order of the strides. The commonly used 4-D tensor formats are :

- NCHW
- NHWC
- CHWN

2.4.3. 5-D Tensor Description

A 5-D Tensor descriptor is used to define the format of batch of 3D images with 5 letters : N,C,D,H,W for respectively the batch size, the number of feature maps, the depth, the height and the width. The letters are sorted in descreasing order of the strides. The commonly used 5-D tensor formats are called :

- NCDHW
- NDHWC
- CDHWN

2.4.4. Fully-packed tensors

A tensor is defined as **`XYZ-fully-packed`** if and only if :

- the number of tensor dimensions is equal to the number of letters preceding the **`fully-packed`** suffix.
- the stride of the i-th dimension is equal to the product of the (i+1)-th dimension by the (i+1)-th stride.
- the stride of the last dimension is 1.

2.4.5. Partially-packed tensors

The partially 'XYZ-packed' terminology only applies in a context of a tensor format described with a superset of the letters used to define a partially-packed tensor. A WXYZ tensor is defined as **`XYZ-packed`** if and only if :

- the strides of all dimensions NOT referenced in the -packed suffix are greater or equal to the product of the next dimension by the next stride.
- the stride of each dimension referenced in the -packed suffix in position i is equal to the product of the (i+1)-st dimension by the (i+1)-st stride.
- if last tensor's dimension is present in the -packed suffix, its stride is 1.

For example a NHWC tensor WC-packed means that the c_stride is equal to 1 and w_stride is equal to c_dim x c_stride. In practice, the -packed suffix is usually with slowest changing dimensions of a tensor but it is also possible to refer to a NCHW tensor that is only N-packed.

2.4.6. Spatially packed tensors

Spatially-packed tensors are defined as partially-packed in spatial dimensions.

For example a spatially-packed 4D tensor would mean that the tensor is either NCHW HW-packed or CNHW HW-packed.

2.4.7. Overlapping tensors

A tensor is defined to be overlapping if a iterating over a full range of dimensions produces the same address more than once.

In practice an overlapped tensor will have stride[i-1] < stride[i]*dim[i] for some of the i from [1,nbDims] interval.

2.5. Data Layout Formats

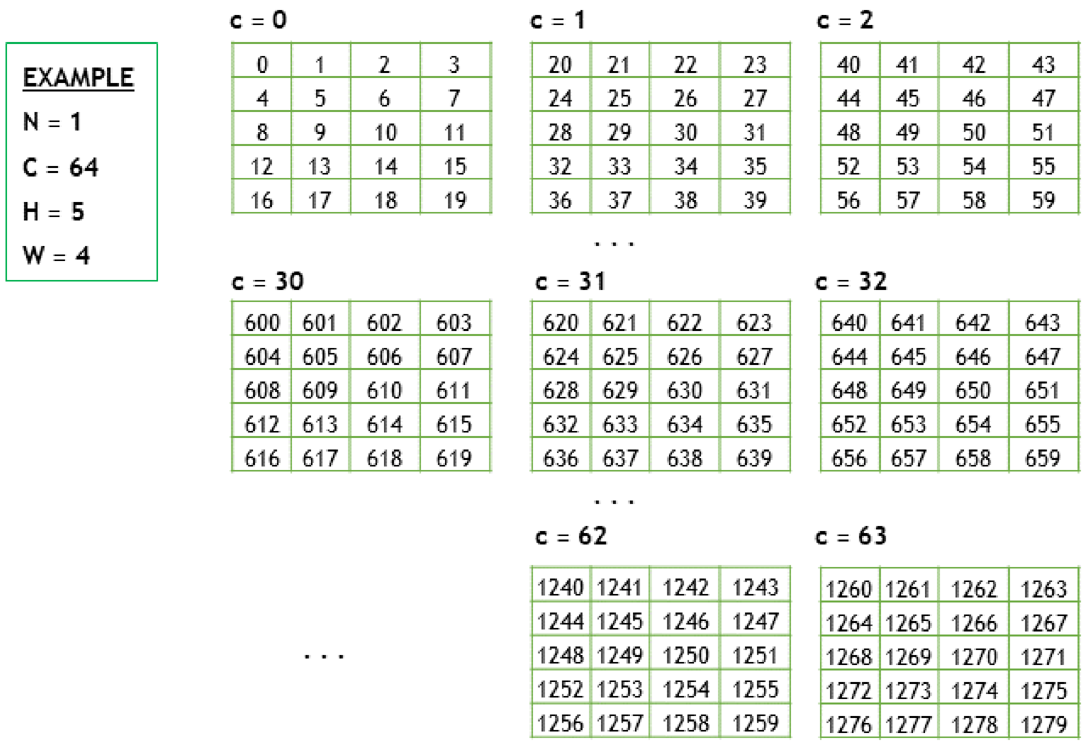
This section describes how cuDNN Tensors are arranged in memory. See cudnnTensorFormat_t for enumerated Tensor format types.

2.5.1. Example

Consider a batch of images in 4D with the following dimensions:

- **N**, the batch size, is 1
- **C**, the number of feature maps (i.e., number of channels), is 64
- **H**, the image height, is 5, and
- **W**, the image width, is 4

To keep the example simple, the image pixel elements are expressed as a sequence of integers, 0, 1, 2, 3, and so on. See Figure 1.



EXAMPLE
N = 1
C = 64
H = 5
W = 4

c = 0

0	1	2	3
4	5	6	7
8	9	10	11
12	13	14	15
16	17	18	19

c = 1

20	21	22	23
24	25	26	27
28	29	30	31
32	33	34	35
36	37	38	39

c = 2

40	41	42	43
44	45	46	47
48	49	50	51
52	53	54	55
56	57	58	59

. . .

c = 30

600	601	602	603
604	605	606	607
608	609	610	611
612	613	614	615
616	617	618	619

c = 31

620	621	622	623
624	625	626	627
628	629	630	631
632	633	634	635
636	637	638	639

c = 32

640	641	642	643
644	645	646	647
648	649	650	651
652	653	654	655
656	657	658	659

. . .

. . .

c = 62

1240	1241	1242	1243
1244	1245	1246	1247
1248	1249	1250	1251
1252	1253	1254	1255
1256	1257	1258	1259

c = 63

1260	1261	1262	1263
1264	1265	1266	1267
1268	1269	1270	1271
1272	1273	1274	1275
1276	1277	1278	1279

Figure 1 Example with N=1, C=64, H=5, W=4.

2.5.2. NCHW Memory Layout

The above 4D Tensor is laid out in the memory in the NCHW format as below:

1. Beginning with the first channel (c=0), the elements are arranged contiguously in row-major order.
2. Continue with second and subsequent channels until the elements of all the channels are laid out.

   See Figure 2.
3. Proceed to the next batch (if **N** is > 1).

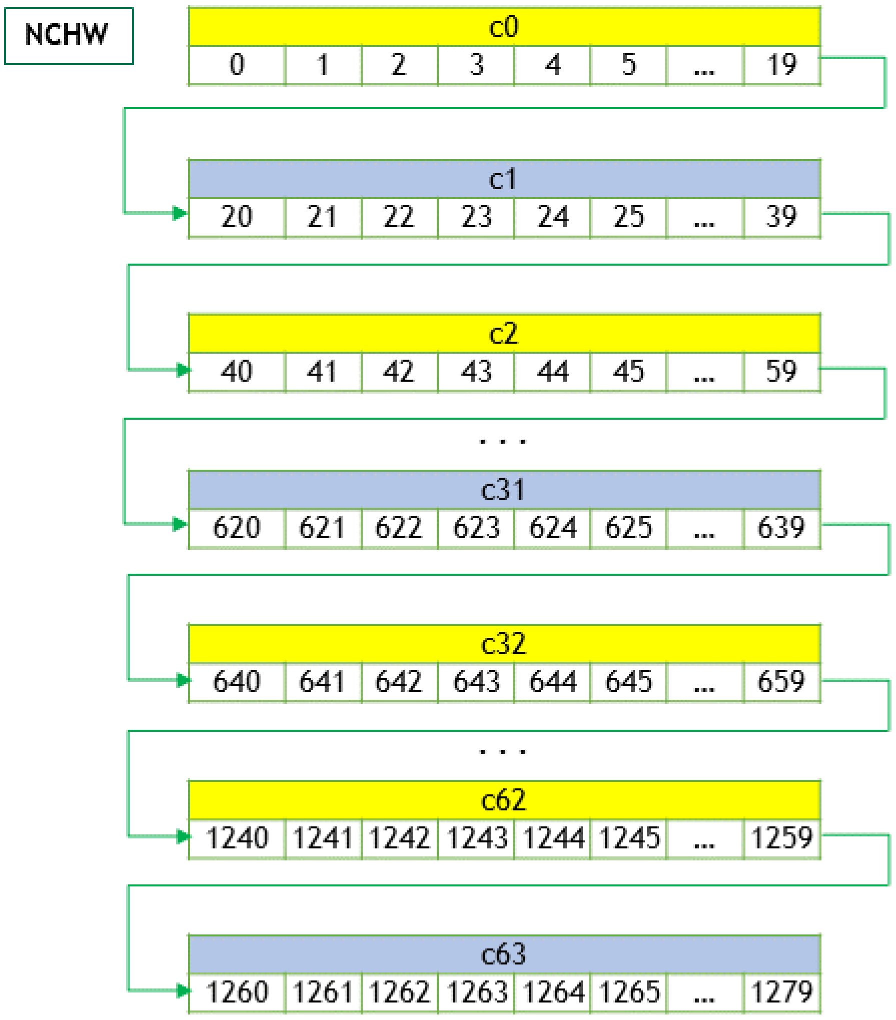


Figure 2 NCHW Memory Layout

2.5.3. NHWC Memory Layout

For the NHWC memory layout, the corresponding elements in all the **C** channels are laid out first, as below:

1. Begin with the first element of channel 0, then proceed to the first element of channel 1, and so on, until the first elements of all the **C** channels are laid out.
2. Next, select the second element of channel 0, then proceed to the second element of channel 1, and so on, until the second element of all the channels are laid out.
3. Follow the row-major order in channel 0 and complete all the elements. See Figure 3.
4. Proceed to the next batch (if **N** is > 1).

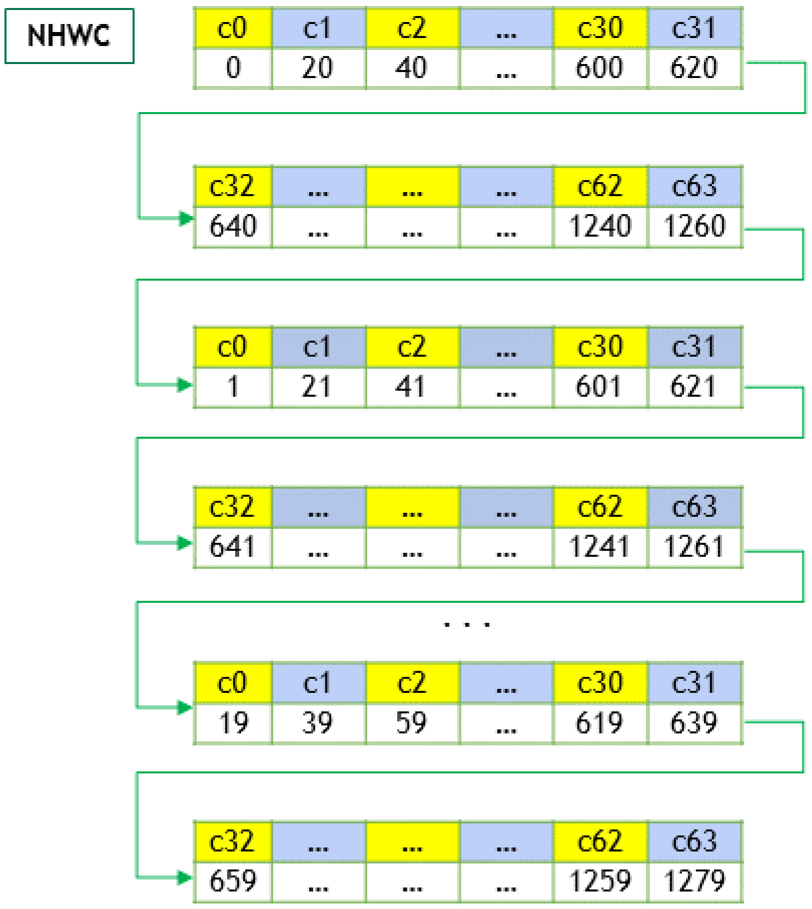


Figure 3 NHWC Memory Layout

2.5.4. NC/32HW32 Memory Layout

The NC/32HW32 is similar to NHWC, with a key difference. For the NC/32HW32 memory layout, the 64 channels are grouped into two groups of 32 channels each—first group consisting of channels c0 through c31, and the second group consisting of channels c32 through c63. Then each group is laid out using the NHWC format. See Figure 4.

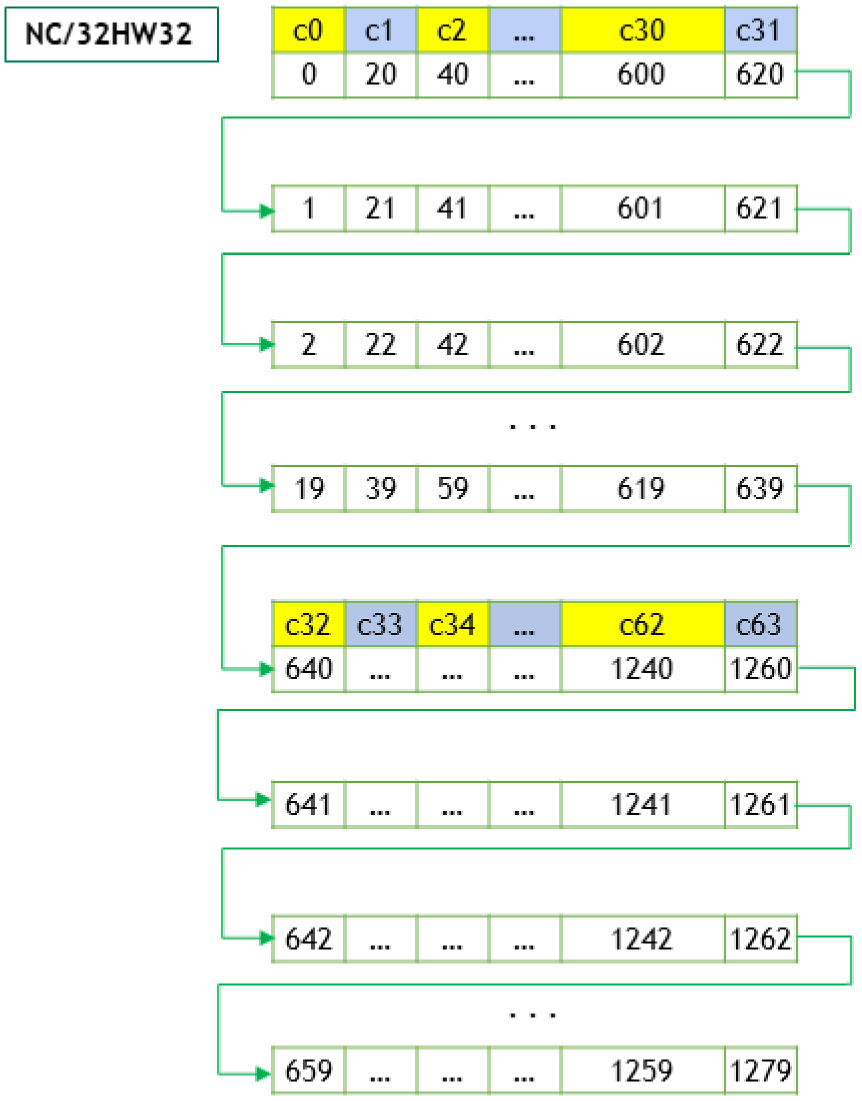


Figure 4   NC/32HW32 Memory Layout

For the generalized NC/xHWx layout format, the following observations apply:

- Only the channel dimension, **C**, is grouped into x channels each.
- When x = 1, each group has only one channel. Hence, the elements of one channel (i.e, one group) are arranged contiguously (in the row-major order), before proceeding to the next group (i.e., next channel). This is the same as NCHW format.
- When x = C, then NC/xHWx is identical to NHWC, i.e., the entire channel depth C is considered as a single group. The case x = C can be thought of as vectorizing entire C dimension as one big vector, laying out all the Cs, followed by the remaining dimensions, just like NHWC.
- The tensor format 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.

2.6. Thread Safety

The library is thread safe and its functions can be called from multiple host threads, as long as threads to do not share the same cuDNN handle simultaneously.

2.7. Reproducibility (determinism)

By design, most of cuDNN's routines from a given version generate the same bit-wise results across runs when executed on GPUs with the same architecture and the same number of SMs. However, bit-wise reproducibility is not guaranteed across versions, as the implementation of a given routine may change. With the current release, the following routines do not guarantee reproducibility because they use atomic operations:

- **`cudnnConvolutionBackwardFilter`** when **`CUDNN_CONVOLUTION_BWD_FILTER_ALGO_0`** or **`CUDNN_CONVOLUTION_BWD_FILTER_ALGO_3`** is used
- **`cudnnConvolutionBackwardData`** when **`CUDNN_CONVOLUTION_BWD_DATA_ALGO_0`** is used
- **`cudnnPoolingBackward`** when **`CUDNN_POOLING_MAX`** is used
- **`cudnnSpatialTfSamplerBackward`**

2.8. Scaling Parameters

Many cuDNN routines like cudnnConvolutionForward accept pointers in host memory to scaling factors **`alpha`** and **`beta`**. These scaling factors are used to blend the computed values with the prior values in the destination tensor as follows (see Figure 5):

```
dstValue = alpha*computedValue + beta*priorDstValue.
```

The **`dstValue`** is written to after being read.

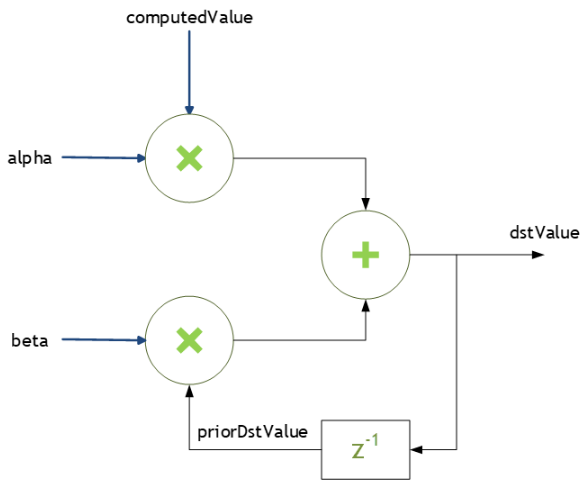


Figure 5 Scaling Parameters for Convolution

When **beta** is zero, the output is not read and may contain uninitialized data (including NaN).

These parameters are passed using a host memory pointer. The storage data types for **alpha** and **beta** are:

- **float** for HALF and FLOAT tensors, and
- **double** for DOUBLE tensors.

For improved performance use **beta** = 0.0. Use a non-zero value for beta only when you need to blend the current output tensor values with the prior values of the output tensor.

Type Conversion

When the data input **x**, the filter input **w** and the output **y** are all in INT8 data type, the function **cudnnConvolutionBiasActivationForward()** will perform the type conversion as shown in Figure 6:

Accumulators are 32-bit integers which wrap on overflow.

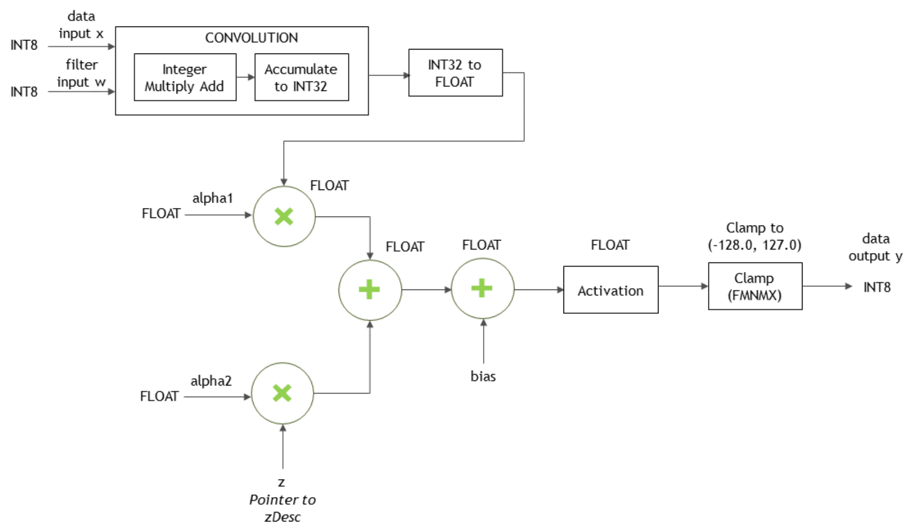


Figure 6 INT8 for cudnnConvolutionBiasActivationForward

2.9. Tensor Core Operations

The cuDNN v7 library introduced the acceleration of compute-intensive routines using Tensor Core hardware on supported GPU SM versions. Tensor core operations are supported on the Volta and Turing GPU families.

2.9.1. Basics

Tensor core operations perform parallel floating point accumulation of multiple floating point product terms. Setting the math mode to CUDNN_TENSOR_OP_MATH via the cudnnMathType_t enumerator indicates that the library will use Tensor Core operations. This enumerator specifies the available options to enable the Tensor Core, and should be applied on a per-routine basis.

The default math mode is CUDNN_DEFAULT_MATH, which indicates that the Tensor Core operations will be avoided by the library. Because the CUDNN_TENSOR_OP_MATH mode uses the Tensor Cores, it is possible that these two modes generate slightly different numerical results due to different sequencing of the floating point operations.

For example, the result of multiplying two matrices using Tensor Core operations is very close to, but not always identical, the result achieved using a sequence of scalar floating point operations. For this reason, the cuDNN library requires an explicit user opt-in before enabling the use of Tensor Core operations.

However, experiments with training common deep learning models show negligible differences between using Tensor Core operations and scalar floating point paths, as measured by both the final network accuracy and the iteration count to convergence. Consequently, the cuDNN library treats both modes of operation as functionally indistinguishable, and allows for the scalar paths to serve as legitimate fallbacks for cases in which the use of Tensor Core operations is unsuitable.

Kernels using Tensor Core operations are available for both convolutions and RNNs.

See also Training with Mixed Precision.

2.9.2. Convolution Functions

2.9.2.1. Prerequisite

For the supported GPUs, the Tensor Core operations will be triggered for convolution functions only when cudnnSetConvolutionMathType is called on the appropriate convolution descriptor by setting the **`mathType`** to CUDNN_TENSOR_OP_MATH or CUDNN_TENSOR_OP_MATH_ALLOW_CONVERSION.

2.9.2.2. Supported Algorithms

When the prerequisite is met, the below convolution functions can be run as Tensor Core operations:

- cudnnConvolutionForward
- cudnnConvolutionBackwardData
- cudnnConvolutionBackwardFilter

See the table below for supported algorithms:

Supported Convolution Function	Supported Algos
cudnnConvolutionForward	-CUDNN_CONVOLUTION_FWD_ALGO_IMPLICIT_PRECOMP_GEMM, -CUDNN_CONVOLUTION_FWD_ALGO_WINOGRAD_NONFUSED
cudnnConvolutionBackwardData	-CUDNN_CONVOLUTION_BWD_DATA_ALGO_1, -CUDNN_CONVOLUTION_BWD_DATA_ALGO_WINOGRAD_NONFUSED
cudnnConvolutionBackwardFilter	-CUDNN_CONVOLUTION_BWD_FILTER_ALGO_1, -CUDNN_CONVOLUTION_BWD_FILTER_ALGO_WINOGRAD_NONFUSED

2.9.2.3. Data and Filter Formats

The cuDNN library may use padding, folding, and NCHW-to-NHWC transformations to call the Tensor Core operations. See Tensor Transformations.

For algorithms other than *_ALGO_WINOGRAD_NONFUSED, when the following requirements are met, the cuDNN library will trigger the Tensor Core operations:

- Input, filter, and output descriptors (**`xDesc`**, **`yDesc`**, **`wDesc`**, **`dxDesc`**, **`dyDesc`** and **`dwDesc`** as applicable) are of the **`dataType`** = CUDNN_DATA_HALF (i.e., FP16). For FP32 **`dataType`** see FP32-to-FP16 Conversion.

- The number of input and output feature maps (i.e., channel dimension **`C`**) is a multiple of 8. When the channel dimension is not a multiple of 8, see Padding.
- The filter is of type CUDNN_TENSOR_NCHW or CUDNN_TENSOR_NHWC.
- If using a filter of type CUDNN_TENSOR_NHWC, then: the input, filter, and output data pointers (**`X`**, **`Y`**, **`W`**, **`dX`**, **`dY`**, and **`dW`** as applicable) are aligned to 128-bit boundaries.

2.9.3. RNN Functions

2.9.3.1. Prerequisite

Tensor core operations will be triggered for these RNN functions only when cudnnSetRNNMatrixMathType is called on the appropriate RNN descriptor setting **`mathType`** to CUDNN_TENSOR_OP_MATH or CUDNN_TENSOR_OP_MATH_ALLOW_CONVERSION.

2.9.3.2. Supported Algorithms

When the above prerequisite is met, the RNN functions below can be run as Tensor Core operations:

- cudnnRNNForwardInference
- cudnnRNNForwardTraining
- cudnnRNNBackwardData
- cudnnRNNBackwardWeights
- cudnnRNNForwardInferenceEx
- cudnnRNNForwardTrainingEx
- cudnnRNNBackwardDataEx
- cudnnRNNBackwardWeightsEx

See the table below for the supported algorithms:

RNN Function	**Support Algos**
All RNN functions that support Tensor Core operations	-CUDNN_RNN_ALGO_STANDARD -CUDNN_RNN_ALGO_PERSIST_STATIC (new for cuDNN 7.1)

2.9.3.3. Data and Filter Formats

When the following requirements are met, then the cuDNN library will trigger the Tensor Core operations:

- For algo = CUDNN_RNN_ALGO_STANDARD:
  - The hidden state size, input size and the batch size is a multiple of 8.
  - All user-provided tensors, workspace, and reserve space are aligned to 128 bit boundaries.
  - For FP16 input/output, the CUDNN_TENSOR_OP_MATH or CUDNN_TENSOR_OP_MATH_ALLOW_CONVERSION is selected.
  - For FP32 input/output, CUDNN_TENSOR_OP_MATH_ALLOW_CONVERSION is selected.

- For algo = CUDNN_RNN_ALGO_PERSIST_STATIC:
    - The hidden state size and the input size is a multiple of 32.
    - The batch size is a multiple of 8.
    - If the batch size exceeds 96 (for forward training or inference) or 32 (for backward data), then the batch sizes constraints may be stricter, and large power-of-two batch sizes may be needed. (new for 7.1).
    - All user-provided tensors, workspace, and reserve space are aligned to 128 bit boundaries.
    - For FP16 input/output, CUDNN_TENSOR_OP_MATH or CUDNN_TENSOR_OP_MATH_ALLOW_CONVERSION is selected.
    - For FP32 input/output, CUDNN_TENSOR_OP_MATH_ALLOW_CONVERSION is selected.

See also Features of RNN Functions.

2.9.4. Tensor Transformations

A few functions in the cuDNN library will perform transformations such as folding, padding, and NCHW-to-NHWC conversion while performing the actual function operation. See below.

2.9.4.1. FP16 Data

Tensor Cores operate on FP16 input data with FP32 accumulation. The FP16 multiply leads to a full-precision result that is accumulated in FP32 operations with the other products in a given dot product for a matrix with `m x n x k` dimensions. See Figure 7.

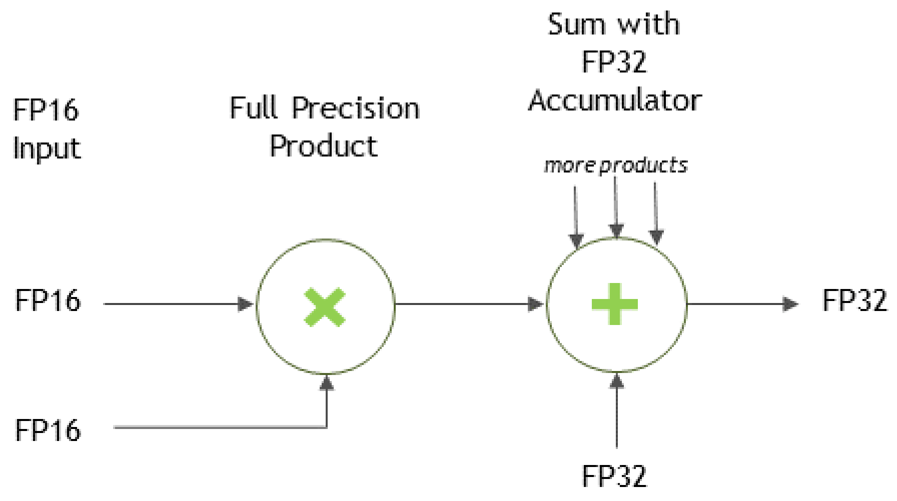


Figure 7 Tensor Operation with FP16 Inputs

2.9.4.2. FP32-to-FP16 Conversion

The cuDNN API for allows the user to specify that FP32 input data may be copied and converted to FP16 data internally to use Tensor Core Operations for potentially improved performance. This can be achieved by selecting CUDNN_TENSOR_OP_MATH_ALLOW_CONVERSION enum for cudnnMathType_t. In this mode, the FP32 Tensors are internally down-converted to FP16, the Tensor Op math is performed, and finally up-converted to FP32 as outputs. See Figure 8.

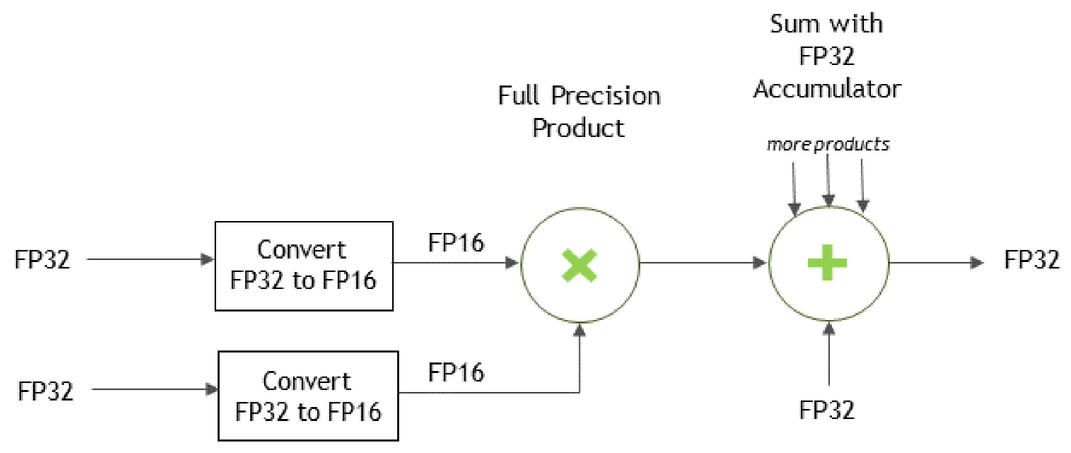


Figure 8 Tensor Operation with FP32 Inputs

For Convolutions:

For convolutions, the FP32-to-FP16 conversion can be achieved by passing the CUDNN_TENSOR_OP_MATH_ALLOW_CONVERSION enum value to the cudnnSetConvolutionMathType() call. See the below code snippet:

```
// Set the math type to allow cuDNN to use Tensor Cores:
checkCudnnErr(cudnnSetConvolutionMathType(cudnnConvDesc,
 CUDNN_TENSOR_OP_MATH_ALLOW_CONVERSION));
```

For RNNs:

For RNNs, the FP32-to-FP16 conversion can be achieved by passing the CUDNN_TENSOR_OP_MATH_ALLOW_CONVERSION enum value to the cudnnSetRNNMatrixMathType() call to allow FP32 data to be converted for use in RNNs. See the below code snippet example:

```
// Set the math type to allow cuDNN to use Tensor Cores:
checkCudnnErr(cudnnSetRNNMatrixMathType(cudnnRnnDesc,
 CUDNN_TENSOR_OP_MATH_ALLOW_CONVERSION));
```

2.9.4.3. Padding

For packed NCHW data, when the channel dimension is not a multiple of 8, then the cuDNN library will pad the tensors as needed to enable Tensor Core operations. This padding is automatic for packed NCHW data in both the CUDNN_TENSOR_OP_MATH and the CUDNN_TENSOR_OP_MATH_ALLOW_CONVERSION cases.

The padding occurs with a negligible loss of performance. Hence, the NCHW Tensor dimensions such as below are allowed:

```
// Set NCHW Tensor dimensions, not necessarily as multiples of eight (only the
 input tensor is shown here):
int dimA[] = {1, 7, 32, 32};
int strideA[] = {7168, 1024, 32, 1};
```

2.9.4.4. Folding

In the folding operation the cuDNN library implicitly performs the formatting of input tensors and saves the input tensors in an internal workspace. This can lead to an acceleration of the call to Tensor Cores.

Folding enables the input Tensors to be transformed to a format that the Tensor Cores support (i.e., no strides).

2.9.4.5. Conversion Between NCHW and NHWC

Tensor Cores require that the Tensors be in NHWC data layout. Conversion between NCHW and NHWC is performed when the user requests Tensor Op math. However, as stated in Basics, a request to use Tensor Cores is just that, a request, and Tensor Cores may not be used in some cases. The cuDNN library converts between NCHW and NHWC if and only if Tensor Cores are requested and are actually used.

If your input (and output) are NCHW, then expect a layout change. See also for packed NCHW data.

Non-Tensor Op convolutions will not perform conversions between NCHW and NHWC.

In very rare, and difficult-to-qualify, cases that are a complex function of padding and filter sizes, it is possible that Tensor Ops are not enabled. In such cases, users should pre-pad.

2.9.5. Guidelines for a Deep Learning Compiler

For a deep learning compiler, the following are the key guidelines:

- Make sure that the convolution operation is eligible for Tensor Cores by avoiding any combinations of large padding and large filters.
- Transform the inputs and filters to NHWC, pre-pad channel and batch size to be a multiple of 8.
- Make sure that all user-provided tensors, workspace and reserve space are aligned to 128 bit boundaries.

2.10. GPU and driver requirements

cuDNN v7.0 supports NVIDIA GPUs of compute capability 3.0 and higher. For x86_64 platform, cuDNN v7.0 comes with two deliverables: one requires a NVIDIA Driver compatible with CUDA Toolkit 8.0, the other requires a NVIDIA Driver compatible with CUDA Toolkit 9.0.

If you are using cuDNN with a Volta GPU, version 7 or later is required.

2.11. Backward compatibility and deprecation policy

When changing the API of an existing cuDNN function "foo" (usually to support some new functionality), first, a new routine "foo_v**`<n>`**" is created where **`n`** represents the cuDNN version where the new API is first introduced, leaving "foo" untouched. This ensures backward compatibility with the version **`n-1`** of cuDNN. At this point, "foo" is considered deprecated, and should be treated as such by users of cuDNN. We gradually eliminate deprecated and suffixed API entries over the course of a few releases of the library per the following policy:

- In release **`n+1`**, the legacy API entry "foo" is remapped to a new API "foo_v**`<f>`**" where **`f`** is some cuDNN version anterior to **`n`**.
- Also in release **`n+1`**, the unsuffixed API entry "foo" is modified to have the same signature as "foo_**`<n>`**". "foo_**`<n>`**" is retained as-is.
- The deprecated former API entry with an anterior suffix _v**`<f>`** and new API entry with suffix _v**`<n>`** are maintained in this release.
- In release **`n+2`**, both suffixed entries of a given entry are removed.

As a rule of thumb, when a routine appears in two forms, one with a suffix and one with no suffix, the non-suffixed entry is to be treated as deprecated. In this case, it is strongly advised that users migrate to the new suffixed API entry to guarantee backwards compatibility in the following cuDNN release. When a routine appears with multiple suffixes, the unsuffixed API entry is mapped to the higher numbered suffix. In that case it is strongly advised to use the non-suffixed API entry to guarantee backward compatibiliy with the following cuDNN release.

2.12. Grouped Convolutions

cuDNN supports grouped convolutions by setting groupCount > 1 for the convolution descriptor **`convDesc`**, using **`cudnnSetConvolutionGroupCount()`**.

By default the convolution descriptor **`convDesc`** is set to groupCount of 1.

Basic Idea

Conceptually, in grouped convolutions the input channels and the filter channels are split into groupCount number of independent groups, with each group having a reduced number of channels. Convolution operation is then performed separately on these input and filter groups.

For example, consider the following: if the number of input channels is 4, and the number of filter channels of 12. For a normal, ungrouped convolution, the number of computation operations performed are 12*4.

If the groupCount is set to 2, then there are now two input channel groups of two input channels each, and two filter channel groups of six filter channels each.

As a result, each grouped convolution will now perform 2*6 computation operations, and two such grouped convolutions are performed. Hence the computation savings are 2x: (12*4)/(2*(2*6))

cuDNN Grouped Convolution

- When using **`groupCount`** for grouped convolutions, you must still define all tensor descriptors so that they describe the size of the entire convolution, instead of specifying the sizes per group.
- Grouped convolutions are supported for all formats that are currently supported by the functions **`cuDNNConvolutionForward()`**, **`cudnnConvolutionBackwardData()`** and **`cudnnConvolutionBackwardFilter()`**.
- The tensor stridings that are set for **`groupCount`** of 1 are also valid for any group count.
- By default the convolution descriptor **`convDesc`** is set to **`groupCount`** of 1.

See Convolution Formulas for the math behind the cuDNN Grouped Convolution.

Example

Below is an example showing the dimensions and strides for grouped convolutions for NCHW format, for 2D convolution.

Note that the symbols "*" and "/" are used to indicate multiplication and division.

`xDesc or dxDesc:`

- **Dimensions**: **`[batch_size, input_channel, x_height, x_width]`**
- **Strides**: **`[input_channels*x_height*x_width, x_height*x_width, x_width, 1]`**

`wDesc or dwDesc:`

- **Dimensions**: **`[output_channels, input_channels/groupCount, w_height, w_width]`**
- **Format**: **`NCHW`**

`convDesc:`

- **Group Count**: **`groupCount`**

`yDesc or dyDesc:`

- **Dimensions**: **`[batch_size, output_channels, y_height, y_width]`**
- **`Strides: [output_channels*y_height*y_width, y_height*y_width, y_width, 1]`**

2.13. API Logging

cuDNN API logging is a tool that records all input parameters passed into every cuDNN API function call. This functionality is disabled by default, and can be enabled through methods described in this section.

The log output contains variable names, data types, parameter values, device pointers, process ID, thread ID, cuDNN handle, cuda stream ID, and metadata such as time of the function call in microseconds.

When logging is enabled, the log output will be handled by the built-in default callback function. The user may also write their own callback function, and use the **`cudnnSetCallback`** to pass in the function pointer of their own callback function. The following is a sample output of the API log.

```
Function cudnnSetActivationDescriptor() called:
mode: type=cudnnActivationMode_t; val=CUDNN_ACTIVATION_RELU (1);
reluNanOpt: type=cudnnNanPropagation_t; val=CUDNN_NOT_PROPAGATE_NAN (0);
coef: type=double; val=1000.000000;
Time: 2017-11-21T14:14:21.366171 (0d+0h+1m+5s since start)
Process: 21264, Thread: 21264, cudnn_handle: NULL, cudnn_stream: NULL.
```

There are two methods to enable API logging.

Method 1: Using Environment Variables

To enable API logging using environment variables, follow these steps:

- Set the environment variable **`CUDNN_LOGINFO_DBG`** to “1”, and
- Set the environment varialbe **`CUDNN_LOGDEST_DBG`** to one of the following:
  - **`stdout`**, **`stderr`**, or a user-desired file path, for example, **`/home/userName1/log.txt`**.
- Include the conversion specifiers in the file name. For example:
  - To include date and time in the file name, use the date and time conversion specificers: **`log_%Y_%m_%d_%H_%M_%S.txt`**. The conversion specifiers will be automatically replaced with the date and time when the program is initiated, resulting in **`log_2017_11_21_09_41_00.txt`**.
  - To include the process id in the file name, use the **`%i`** conversion specifier: **`log_%Y_%m_%d_%H_%M_%S_%i.txt`** for the result: **`log_2017_11_21_09_41_00_21264.txt`** when the process id is **`21264`**. When

you have several processes running, using the process id conversion specifier will prevent these processes writing to the same file at the same time.

The supported conversion specifiers are similar to the `strftime` function.

If the file already exists, the log will overwrite the existing file.

These environmental variables are only checked once at the initialization. Any subsequent changes in these environmental variables will not be effective in the current run. Also note that these environment settings can be overridden by the Method 2 below.

See also Table 1 for the impact on performance of API logging using environment variables.

Table 1 API Logging Using Environment Variables

Environment variables	CUDNN_LOGINFO_DBG=0	CUDNN_LOGINFO_DBG=1
CUDNN_LOGDEST_DBG not set	- No logging output - No performance loss	- No logging output - No performance loss
CUDNN_LOGDEST_DBG=`NULL`	- No logging output - No performance loss	- No logging output - No performance loss
CUDNN_LOGDEST_DBG=`stdout` or `stderr`	- No logging output - No performance loss	- Logging to `stdout` or `stderr` - Some performance loss
CUDNN_LOGDEST_DBG= `filename.txt`	- No logging output - No performance loss	- Logging to `filename.txt` - Some performance loss

Method 2

Method 2: To use API function calls to enable API logging, refer to the API description of `cudnnSetCallback()` and `cudnnGetCallback()`.

2.14. Features of RNN Functions

The **RNN** functions are:

- cudnnRNNForwardInference
- cudnnRNNForwardTraining
- cudnnRNNBackwardData

- cudnnRNNBackwardWeights
- cudnnRNNForwardInferenceEx
- cudnnRNNForwardTrainingEx
- cudnnRNNBackwardDataEx
- cudnnRNNBackwardWeightsEx

See the table below for a list of features supported by each RNN function:

For each of these terms, the short-form versions shown in the paranthesis are used in the tables below for brevity: **`CUDNN_RNN_ALGO_STANDARD`** (_ALGO_STANDARD), **`CUDNN_RNN_ALGO_PERSIST_STATIC`** (_ALGO_PERSIST_STATIC), **`CUDNN_RNN_ALGO_PERSIST_DYNAMIC`** (_ALGO_PERSIST_DYNAMIC), and **`CUDNN_TENSOR_OP_MATH_ALLOW_CONVERSION`** (_ALLOW_CONVERSION).

Functions	Input output layout supported	Supports variable sequence length in batch	Commonly supported
`cudnnRNNForwardInference`	Only Sequence major, packed (non-padded)	Only with **`_ALGO_STANDARD`** Require input sequences descending sorted according to length	Mode (cell type) supported: **`CUDNN_RNN_RELU`**, **`CUDNN_RNN_TANH`**, **`CUDNN_LSTM`**, **`CUDNN_GRU`** Algo supported* (see the table below for an elaboration on these algorithms): **`_ALGO_STANDARD`**, **`_ALGO_PERSIST_STATIC`**, **`_ALGO_PERSIST_DYNAMIC`** Math mode supported: **`CUDNN_DEFAULT_MATH`**, **`CUDNN_TENSOR_OP_MATH`** (will automatically fall back if run on pre-Volta or if algo doesn't support Tensor Cores) **`_ALLOW_CONVERSION`** (may do down conversion to utilize Tensor Cores) Direction mode supported: **`CUDNN_UNIDIRECTIONAL`**, **`CUDNN_BIDIRECTIONAL`** RNN input mode: **`CUDNN_LINEAR_INPUT`**, **`CUDNN_SKIP_INPUT`**
`cudnnRNNForwardTraining`			
`cudnnRNNBackwardData`			
`cudnnRNNBackwardWeights`			
`cudnnRNNForwardInferenceEx`	Sequence major unpacked, Batch major unpacked**, Sequence major packed**	Only with **`_ALGO_STANDARD`** For unpacked layout**, no input sorting required. For packed layout, require input sequences descending sorted according to length	
`cudnnRNNForwardTrainingEx`			
`cudnnRNNBackwardDataEx`			
`cudnnRNNBackwardWeightsEx`			

* Do not mix different algos for different steps of training. It's also not recommended to mix non-extended and extended API for different steps of training.

** To use unpacked layout, user need to set CUDNN_RNN_PADDED_IO_ENABLED through **`cudnnSetRNNPaddingMode`**.

The following table provides the features supported by the algorithms referred in the above table: **`CUDNN_RNN_ALGO_STANDARD`**, **`CUDNN_RNN_ALGO_PERSIST_STATIC`**, and **`CUDNN_RNN_ALGO_PERSIST_DYNAMIC`**.

Features	`_ALGO_STANDARD`	`_ALGO_PERSIST_STATIC`	`_ALGO_PERSIST_DYNAMIC`
Half input **Single accumulation** **Half output**	Supported Half intermediate storage Single accumulation		
Single input **Single accumulation** **Single output**	Supported If running on Volta, with `CUDNN_TENSOR_OP_MATH_ALLOW_CONVERSION`[1], will down-convert and use half intermediate storage. Otherwise: Single intermediate storage Single accumulation		
Double input **Double accumulation** **Double output**	Supported Double intermediate storage Double accumulation	Not Supported	Supported Double intermediate storage Double accumulation
LSTM recurrent projection	Supported	Not Supported	Not Supported
LSTM cell clipping	Supported		
Variable sequence length in batch	Supported	Not Supported	Not Supported
Tensor Cores on Volta/ Xavier	Supported For half input/output, acceleration requires setting `CUDNN_TENSOR_OP_MATH`[1] or `CUDNN_TENSOR_OP_MATH_ALLOW_CONVERSION`[1] Acceleration requires `inputSize` and `hiddenSize` to be multiple of 8 For single input/output, acceleration requires setting `CUDNN_TENSOR_OP_MATH_ALLOW_CONVERSION`[1] Acceleration requires `inputSize` and `hiddenSize` to be multiple of 8		Not Supported, will execute normally ignoring `CUDNN_TENSOR_OP_MATH`[1] or `_ALLOW_CONVERSION`[1]

Other limitations		Max problem size is limited by GPU specifications.	Requires real time compilation through NVRTC

!**`CUDNN_TENSOR_OP_MATH`** or **`CUDNN_TENSOR_OP_MATH_ALLOW_CONVERSION`** can be set through **`cudnnSetRNNMatrixMathType`**.

2.15. Mixed Precision Numerical Accuracy

When the computation precision and the output precision are not the same, it is possible that the numerical accuracy will vary from one algorithm to the other.

For example, when the computation is performed in FP32 and the output is in FP16, the CUDNN_CONVOLUTION_BWD_FILTER_ALGO_0 ("ALGO_0") has lower accuracy compared to the CUDNN_CONVOLUTION_BWD_FILTER_ALGO_1 ("ALGO_1"). This is because ALGO_0 does not use extra workspace, and is forced to accumulate the intermediate results in FP16, i.e., half precision float, and this reduces the accuracy. The ALGO_1, on the other hand, uses additonal workspace to accumulate the intermediate values in FP32, i.e., full precision float.

Chapter 3. CUDNN DATATYPES REFERENCE

This chapter describes all the types and enums of the cuDNN library API.

3.1. cudnnAttnDescriptor_t

cudnnAttnDescriptor_t is a pointer to an opaque structure holding the description of attention. Use the function cudnnCreateAttnDescriptor to create one instance, and cudnnDestroyAttnDescriptor to destroy a previously created descriptor.

3.2. cudnnAttnQueryMap_t

cudnnAttnQueryMap_t is an enumerated type to select the query mapping type.

Member	Description
CUDNN_ATTN_QUERYMAP_ALL_TO_ONE = 0	When beam width > 1, multiple query sequences are mapped to the same key and value sequences.
CUDNN_ATTN_QUERYMAP_ONE_TO_ONE = 1	When beam width > 1, multiple query sequences are mapped to corresponding key and value sequences.

3.3. cudnnActivationDescriptor_t

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

3.4. 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 (new for 7.1)`

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()`**.

3.5. 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 non-convolutional network layers. In this mode the tensor dimensions of **`bnBias`** and **`bnScale`**, 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`**, **`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 for 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_BATCHNORM_SPATIAL will produce finite results. The user can invoke **cudnnQueryRuntimeError()** to check if a numerical overflow occurred in this mode.

3.6. 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.

3.7. 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

3.8. 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 be used to initialize this instance, **cudnnDestroyCTCLossDescriptor()** is be used to destroy this instance.

3.9. 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 run 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 occured during workspace allocation or if provided workspace is insufficient.
- **CUDNN_STATUS_INTERNAL_ERROR** if any error occured 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.

3.10. 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 product without actually explicitly form the matrix that holds the input tensor data. The sum is done using atomic adds 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 form 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. Significant workspace may be needed to store intermediate results. The results are deterministic.

3.11. cudnnConvolutionBwdDataPreference_t

`cudnnConvolutionBwdDataPreference_t` is an enumerated type used by **`cudnnGetConvolutionBackwardDataAlgorithm()`** to help the choice of the algorithm used for the backward data convolution.

Values

`CUDNN_CONVOLUTION_BWD_DATA_NO_WORKSPACE`

In this configuration, the routine **`cudnnGetConvolutionBackwardDataAlgorithm()`** is guaranteed to return an algorithm that does not require any extra workspace to be provided by the user.

`CUDNN_CONVOLUTION_BWD_DATA_PREFER_FASTEST`

In this configuration, the routine **`cudnnGetConvolutionBackwardDataAlgorithm()`** will return the fastest algorithm regardless how much workspace is needed to execute it.

`CUDNN_CONVOLUTION_BWD_DATA_SPECIFY_WORKSPACE_LIMIT`

In this configuration, the routine **`cudnnGetConvolutionBackwardDataAlgorithm()`** will return the fastest algorithm that fits within the memory limit that the user provided.

3.12. 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 run 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 occured during workspace allocation or if provided workspace is insufficient.
- **`CUDNN_STATUS_INTERNAL_ERROR`** if any error occured 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.

3.13. 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 product without actually explicitly form the matrix that holds the input tensor data. The sum is done using atomic adds 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 form 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. 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 precomputes 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. 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. Significant workspace may be needed to store intermediate results. The results are deterministic.

3.14. cudnnConvolutionBwdFilterPreference_t

`cudnnConvolutionBwdFilterPreference_t` is an enumerated type used by **`cudnnGetConvolutionBackwardFilterAlgorithm()`** to help the choice of the algorithm used for the backward filter convolution.

Values

`CUDNN_CONVOLUTION_BWD_FILTER_NO_WORKSPACE`

In this configuration, the routine **`cudnnGetConvolutionBackwardFilterAlgorithm()`** is guaranteed to return an algorithm that does not require any extra workspace to be provided by the user.

`CUDNN_CONVOLUTION_BWD_FILTER_PREFER_FASTEST`

In this configuration, the routine **`cudnnGetConvolutionBackwardFilterAlgorithm()`** will return the fastest algorithm regardless how much workspace is needed to execute it.

`CUDNN_CONVOLUTION_BWD_FILTER_SPECIFY_WORKSPACE_LIMIT`

In this configuration, the routine **`cudnnGetConvolutionBackwardFilterAlgorithm()`** will return the fastest algorithm that fits within the memory limit that the user provided.

3.15. 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.

3.16. 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 run 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 occured during workspace allocation or if provided workspace is insufficient.
- **`CUDNN_STATUS_INTERNAL_ERROR`** if any error occured 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.

3.17. 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 form the matrix that holds the input tensor data.

`CUDNN_CONVOLUTION_FWD_ALGO_IMPLICIT_PRECOMP_GEMM`

This algorithm expresses the convolution as a matrix product without actually explicitly form 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 (e.g 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. Significant workspace may be needed to store intermediate results.

3.18. cudnnConvolutionFwdPreference_t

`cudnnConvolutionFwdPreference_t` is an enumerated type used by **`cudnnGetConvolutionForwardAlgorithm()`** to help the choice of the algorithm used for the forward convolution.

Values

`CUDNN_CONVOLUTION_FWD_NO_WORKSPACE`

In this configuration, the routine **`cudnnGetConvolutionForwardAlgorithm()`** is guaranteed to return an algorithm that does not require any extra workspace to be provided by the user.

`CUDNN_CONVOLUTION_FWD_PREFER_FASTEST`

In this configuration, the routine **`cudnnGetConvolutionForwardAlgorithm()`** will return the fastest algorithm regardless how much workspace is needed to execute it.

`CUDNN_CONVOLUTION_FWD_SPECIFY_WORKSPACE_LIMIT`

In this configuration, the routine **`cudnnGetConvolutionForwardAlgorithm()`** will return the fastest algorithm that fits within the memory limit that the user provided.

3.19. cudnnConvolutionMode_t

`cudnnConvolutionMode_t` is an enumerated type used by **`cudnnSetConvolutionDescriptor()`** 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.

3.20. 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 32-bit single-precision floating point (**`float`**).

`CUDNN_DATA_DOUBLE`

The data is 64-bit double-precision floating point (**`double`**).

`CUDNN_DATA_HALF`

The data is 16-bit floating point.

`CUDNN_DATA_INT8`

The data is 8-bit signed integer.

`CUDNN_DATA_UINT8 (new for 7.1)`

The data is 8-bit unsigned integer.

`CUDNN_DATA_INT32`

The data is 32-bit signed integer.

`CUDNN_DATA_INT8x4`

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

`CUDNN_DATA_INT8x32`

The data is 32-element vectors, each element being 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,” i.e., CUDNN_CONVOLUTION_FWD_ALGO_IMPLICIT_PRECOMP_GEMM. See cudnnConvolutionFwdAlgo_t.

`CUDNN_DATA_UINT8x4 (new for 7.1)`

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

3.21. cudnnDeterminism_t

`cudnnDeterminism_t` is an enumerated type used to indicate if the computed results are deterministic (reproducible). See section 2.5 (Reproducibility) for more details on determinism.

Values

`CUDNN_NON_DETERMINISTIC`

Results are not guaranteed to be reproducible

`CUDNN_DETERMINISTIC`

Results are guaranteed to be reproducible

3.22. 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 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.

3.23. 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 that 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 impelemented using average pooling) and added to the destDiffData tensor produced by cudnnDivisiveNormalizationBackward.

3.24. 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.

3.25. 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.

3.26. 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.

3.27. cudnnFoldingDirection_t

cudnnFoldingDirection_t is an enumerated type used to select the folding direction. See also cudnnTensorTransformDescriptor_t.

Member	Description
CUDNN_TRANSFORM_FOLD = 0U	Selects folding.
CUDNN_TRANSFORM_UNFOLD = 1U	Selects unfolding.

3.28. 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.

3.29. 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 long indices

`CUDNN_16BIT_INDICES`

Compute unsigned short indices

`CUDNN_8BIT_INDICES`

Compute unsigned char indices

3.30. 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 tensor's dimension dimA[1].

3.31. cudnnMathType_t

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

Values

`CUDNN_DEFAULT_MATH`

Tensor Core Operations are not used.

`CUDNN_TENSOR_OP_MATH`

The use of Tensor Core Operations is permitted.

`CUDNN_TENSOR_OP_MATH_ALLOW_CONVERSION`

Enables the use of FP32 tensors for both input and output.

3.32. cudnnMultiHeadAttnWeightKind_t

cudnnMultiHeadAttnWeightKind_t is an enumerated type to specify the multi-head weight group.

Member	Description
CUDNN_ATTN_Q_WEIGHTS = 0	Selects the multi-head query weight group.
CUDNN_ATTN_K_WEIGHTS = 1	Selects the multi-head key weight group.
CUDNN_ATTN_V_WEIGHTS = 2	Selects the multi-head value weight group.
CUDNN_ATTN_O_WEIGHTS = 3	Selects the multi-head output weight group.

3.33. 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

3.34. cudnnOpTensorDescriptor_t

`cudnnOpTensorDescriptor_t` is a pointer to an opaque structure holding the description of a Tensor Ccore Operation, used as a parameter to **`cudnnOpTensor()`**. **`cudnnCreateOpTensorDescriptor()`** is used to create one instance, and **`cudnnSetOpTensorDescriptor()`** must be used to initialize this instance.

3.35. 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

3.36. cudnnPersistentRNNPlan_t

`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.

3.37. 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.

3.38. cudnnPoolingMode_t

`cudnnPoolingMode_t` is an enumerated type passed to **`cudnnSetPoolingDescriptor()`** 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.

3.39. 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 (ie. 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 (ie. a small minibatch). When using **`CUDNN_RNN_ALGO_PERSIST_DYNAMIC`** persistent kernels are prepared at runtime and are able to optimized 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.

3.40. cudnnRNNBiasMode_t

cudnnRNNBiasMode_t is an enumerated type used to specify the number of bias vectors for RNN functions. See 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.

3.41. 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.

3.42. 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, and **cudnnSetRNNDescriptor()** must be used to initialize this instance.

3.43. cudnnRNNDataDescriptor_t

`cudnnRNNDataDescriptor_t` is a pointer to an opaque structure holding the description of a RNN data set. The function **`cudnnCreateRNNDataDescriptor()`** is used to create one instance, and **`cudnnSetRNNDataDescriptor()`** must be used to initialize this instance.

3.44. 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.

3.45. 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 **`ReLU(x) = max(x, 0)`**.

If **`cudnnRNNBiasMode_t biasMode`** in **`rnnDesc`** is **`CUDNN_RNN_DOUBLE_BIAS`** (default mode), then the following equation with biasesb_W and b_R applies:

$h_t = \text{ReLU}(W_i x_t + R_i h_{t-1} + b_{Wi} + b_{Ri})$

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:

$h_t = \text{ReLU}(W_i x_t + R_i h_{t-1} + b_i)$

If **cudnnRNNBiasMode_t biasMode** in **rnnDesc** is **CUDNN_RNN_NO_BIAS**, then the following equation applies:

$h_t = \mathrm{ReLU}(W_i x_t + R_i h_{t-1})$

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:

$$h_t = \tanh(W_i x_t + R_i h_{t-1} + b_{Wi} + b_{Ri})$$

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:

$$h_t = \tanh(W_i x_t + R_i h_{t-1} + b_i)$$

If **cudnnRNNBiasMode_t biasMode** in **rnnDesc** is **CUDNN_RNN_NO_BIAS**, then the following equation applies:

$$h_t = \tanh(W_i x_t + R_i h_{t-1})$$

CUDNN_LSTM

A four-gate Long Short-Term Memory 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:

- σ is the sigmoid operator such that: $\sigma(x) = 1 / (1 + e^{-x})$,
- $\circ$ 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:

$$\begin{aligned}
i_t &= \sigma(W_i x_t + R_i h_{t-1} + b_{Wi} + b_{Ri}) \\
f_t &= \sigma(W_f x_t + R_f h_{t-1} + b_{Wf} + b_{Rf}) \\
o_t &= \sigma(W_o x_t + R_o h_{t-1} + b_{Wo} + b_{Ro}) \\
c'_t &= \tanh(W_c x_t + R_c h_{t-1} + b_{Wc} + b_{Rc}) \\
c_t &= f_t \circ c_{t-1} + i_t \circ c'_t \\
h_t &= o_t \circ \tanh(c_t)
\end{aligned}$$

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:

$$\begin{aligned}
i_t &= \sigma(W_i x_t + R_i h_{t-1} + b_i) \\
f_t &= \sigma(W_f x_t + R_f h_{t-1} + b_f) \\
o_t &= \sigma(W_o x_t + R_o h_{t-1} + b_o) \\
c'_t &= \tanh(W_c x_t + R_c h_{t-1} + b_c) \\
c_t &= f_t \circ c_{t-1} + i_t \circ c'_t
\end{aligned}$$

$$h_t = o_t \circ \tanh(c_t)$$

If **cudnnRNNBiasMode_t biasMode** in **rnnDesc** is **CUDNN_RNN_NO_BIAS,** then the following equations apply:

$$\begin{aligned}
i_t &= \sigma(W_i x_t + R_i h_{t-1}) \\
f_t &= \sigma(W_f x_t + R_f h_{t-1}) \\
o_t &= \sigma(W_o x_t + R_o h_{t-1}) \\
c'_t &= \tanh(W_c x_t + R_c h_{t-1}) \\
c_t &= f_t \circ c_{t-1} + i_t \circ c'_t \\
h_t &= o_t \circ \tanh(c_t)
\end{aligned}$$

CUDNN_GRU

A three-gate network consisting of Gated Recurrent Units.

In the forward pass, the output $\mathbf{h_t}$ for a given iteration can be computed from the recurrent input $\mathbf{h_{t-1}}$ and the previous layer input $\mathbf{x_t}$ given matrices **W, R** and the bias vectors.

In addition, σ is the sigmoid operator: $\sigma(x) = 1 / (1 + e^{-x})$, $\circ$ represents a point-wise multiplication and **tanh** is the hyperbolic tangent function. $\mathbf{i_t}$, $\mathbf{r_t}$, $\mathbf{h'_t}$ represent the input, reset, new gates respectively.

If **cudnnRNNBiasMode_t biasMode** in **rnnDesc** is **CUDNN_RNN_DOUBLE_BIAS** (default mode), then the following equations with biases$\mathbf{b_W}$ and $\mathbf{b_R}$ apply:

$$\begin{aligned}
i_t &= \sigma(W_i x_t + R_i h_{t-1} + b_{Wi} + b_{Ru}) \\
r_t &= \sigma(W_r x_t + R_r h_{t-1} + b_{Wr} + b_{Rr}) \\
h'_t &= \tanh(W_h x_t + r_t \circ (R_h h_{t-1} + b_{Rh}) + b_{Wh}) \\
h_t &= (1 - i_t) \circ h'_t + i_t \circ h_{t-1}
\end{aligned}$$

If **cudnnRNNBiasMode_t biasMode** in **rnnDesc** is **CUDNN_RNN_SINGLE_INP_BIAS,** then the following equations with bias **b** apply:

$$\begin{aligned}
i_t &= \sigma(W_i x_t + R_i h_{t-1} + b_i) \\
r_t &= \sigma(W_r x_t + R_r h_{t-1} + b_r) \\
h'_t &= \tanh(W_h x_t + r_t \circ (R_h h_{t-1}) + b_{Wh}) \\
h_t &= (1 - i_t) \circ h'_t + i_t \circ h_{t-1}
\end{aligned}$$

If **cudnnRNNBiasMode_t biasMode** in **rnnDesc** is **CUDNN_RNN_SINGLE_REC_BIAS,** then the following equations with bias **b** apply:

$$\begin{aligned}
i_t &= \sigma(W_i x_t + R_i h_{t-1} + b_i) \\
r_t &= \sigma(W_r x_t + R_r h_{t-1} + b_r) \\
h'_t &= \tanh(W_h x_t + r_t \circ (R_h h_{t-1} + b_{Rh})) \\
h_t &= (1 - i_t) \circ h'_t + i_t \circ h_{t-1}
\end{aligned}$$

If **cudnnRNNBiasMode_t biasMode** in **rnnDesc** is **CUDNN_RNN_NO_BIAS,** then the following equations apply:

$$\begin{aligned}
i_t &= \sigma(W_i x_t + R_i h_{t-1}) \\
r_t &= \sigma(W_r x_t + R_r h_{t-1}) \\
h'_t &= \tanh(W_h x_t + r_t \circ (R_h h_{t-1})) \\
h_t &= (1 - i_t) \circ h'_t + i_t \circ h_{t-1}
\end{aligned}$$

3.46. 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.

3.47. 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.

3.48. 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.

3.49. 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 sum of squares

`CUDNN_REDUCE_TENSOR_MUL_NO_ZEROS`

The operation to be performed is multiplication, not including elements of value zero

3.50. 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.

3.51. cudnnSeqDataAxis_t

cudnnSeqDataAxis_t is an enumerated type to specify each supported sequence data axis.

For continued API compatibility, the user is recommended to use these enumerated labels when fetching and storing axes-arrays such as **`dimA`**, and **`axes`**.

User should:

1. Specify the dimension of sequence data buffer as follows:

   ```
   int dimA[CUDNN_SEQDATA_DIM_COUNT];
   dimA[CUDNN_SEQDATA_TIME_DIM] = n_timesteps;
   dimA[CUDNN_SEQDATA_BATCH_DIM] = n_batch;
   dimA[CUDNN_SEQDATA_BEAM_DIM]] = beam_size;
   dimA[CUDNN_SEQDATA_VECT_DIM]] = hidden_size;
   ```
2. Specify the axes order as follows:

   ```
   cudnnSeqDataAxis_t axes[CUDNN_SEQDATA_DIM_COUNT] =
    {CUDNN_SEQDATA_TIME_DIM,
     CUDNN_SEQDATA_BATCH_DIM,
     CUDNN_SEQDATA_BEAM_DIM,
     CUDNN_SEQDATA_VECT_DIM};
   ```

The CUDNN_SEQDATA_DIM_COUNT defines the number of supported dimensions or axes for sequential data. This value is currently set to 4.

The user is advised against using the equivalent integer values for the enumerated labels.

Member	Description
CUDNN_SEQDATA_TIME_DIM = 0	Time step index.
CUDNN_SEQDATA_BATCH_DIM = 1	Batch index.
CUDNN_SEQDATA_BEAM_DIM = 2	Beam index.
CUDNN_SEQDATA_VECT_DIM = 3	Hidden vector index.

3.52. cudnnSeqDataDescriptor_t

cudnnSeqDataDescriptor_t is a pointer to an opaque structure holding the description of sequence data. Use the function cudnnCreateSeqDataDescriptor to create one instance, and cudnnDestroySeqDataDescriptor to destroy a previously created descriptor.

3.53. 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`**

3.54. 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 the dimension C.

3.55. 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, **`cudnnDestroySpatialTransformerDescriptor()`** is used to destroy this instance.

3.56. 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 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 a 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

Runtime library required by RNN calls (libcuda.so or nvcuda.dll) cannot be found in predefined search paths.

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.

3.57. cudnnTensorDescriptor_t

cudnnCreateTensorDescriptor_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 routrines **cudnnSetTensorNdDescriptor()**, **cudnnSetTensor4dDescriptor()** or **cudnnSetTensor4dDescriptorEx()** must be used to initialize this instance.

3.58. 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, see 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.

3.59. 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.

3.60. cudnnWgradMode_t

cudnnWgradMode_t is an enumerated type to select how the weight gradient output buffers should be updated with the partial gradients.

Member	Description
CUDNN_WGRAD_MODE_ADD = 0	Adds the partial gradients to the weight gradient output buffers (i.e., weight gradient output buffers = weight gradient output buffers + partial gradients).
CUDNN_WGRAD_MODE_ADD = 1	Replaces the weight gradient output buffer values with the partial gradients (i.e., weight gradient output buffers = partial gradients).

Chapter 4. CUDNN API REFERENCE

This chapter describes the API of all the routines of the cuDNN library.

4.1. cudnnActivationBackward

```
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)
```

This routine computes the gradient of a neuron activation function.

In-place operation is allowed for this routine; i.e. **`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 in-place operation to be allowed).

All tensor formats are supported for 4 and 5 dimensions, however 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. See cudnnHandle_t.

activationDesc

Input. Activation descriptor. See 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]*result + beta[0]*priorDstValue. Refer to this section for additional details.

yDesc

Input. Handle to the previously initialized input tensor descriptor. See cudnnTensorDescriptor_t.

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 **`dyDesc`**.

xDesc

Input. Handle to the previously initialized output tensor descriptor.

x

Input. Data pointer to GPU memory associated with the output 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`**.

The possible error values returned by this function and their meanings are listed below.

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, wStride`** of the input differential tensor and output differential tensors differ and in-place operation is used.

`CUDNN_STATUS_NOT_SUPPORTED`

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

- The dimensions **`n,c,h,w`** of the input tensor and output tensors differ.
- The **`datatype`** of the input tensor and output tensors differs.

- The strides **nStride, cStride, hStride, wStride** of the input tensor and the input differential tensor differ.
- The strides **nStride, cStride, hStride, wStride** of the output tensor and the output differential tensor differ.

CUDNN_STATUS_EXECUTION_FAILED

The function failed to launch on the GPU.

4.2. cudnnActivationForward

```
cudnnStatus_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)
```

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

In-place operation is allowed for this routine; i.e., **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 in-place operation to be allowed).

All tensor formats are supported for 4 and 5 dimensions, however 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. See cudnnHandle_t.

activationDesc

Input. Activation descriptor. See 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]*result + beta[0]*priorDstValue. Please refer to this section for additional details.

xDesc

Input. Handle to the previously initialized input tensor descriptor. See 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`**.

The possible error values returned by this function and their meanings are listed below.

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,w`** of the input tensor and output tensors differ.
- The **`datatype`** of the input tensor and output tensors differs.
- The strides **`nStride,cStride,hStride,wStride`** of the input tensor and output tensors differ and in-place operation is used (i.e., **`x`** and **`y`** pointers are equal).

`CUDNN_STATUS_EXECUTION_FAILED`

The function failed to launch on the GPU.

4.3. cudnnAddTensor

```
cudnnStatus_t cudnnAddTensor(
    cudnnHandle_t                     handle,
    const void                       *alpha,
    const cudnnTensorDescriptor_t     aDesc,
    const void                       *A,
    const void                       *beta,
    const cudnnTensorDescriptor_t     cDesc,
    void                             *C)
```

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.

Up to dimension 5, all tensor formats are supported. Beyond those dimensions, this routine is not supported

Parameters

handle

Input. Handle to a previously created cuDNN context. See cudnnHandle_t.

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]*srcValue + beta[0]*priorDstValue. Refer to this section for additional details.

aDesc

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

The possible error values returned by this function and their meanings are listed below.

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 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.

4.4. cudnnBatchNormalizationBackward

```
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)
```

This function performs the backward batch normalization layer computation. This layer is based on the paper *Batch Normalization: Accelerating Deep Network Training by Reducing Internal Covariate Shift*, S. Ioffe, C. Szegedy, 2015.

See **cudnnDeriveBNTensorDescriptor** for the secondary tensor descriptor generation for the parameters using in this function.

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**, **dx**.

Parameters

handle

Input. Handle to a previously created cuDNN library descriptor. See cudnnHandle_t.

mode

Input. Mode of operation (spatial or per-activation). See 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 = alphaDataDiff[0]*resultValue + betaDataDiff[0]*priorDstValue. Refer to this section for additional details.

***alphaParamDiff, *betaParamDiff**

Inputs. Pointers to scaling factors (in host memory) used to blend the gradient outputs **resultBnScaleDiff** and **resultBnBiasDiff** with prior values in the destination tensor as follows:

dstValue = alphaParamDiff[0]*resultValue + betaParamDiff[0]*priorDstValue. Refer to this section for additional details.

xDesc, dxDesc, dyDesc

Inputs. 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** data.

***dy**

Inputs. Data pointer to GPU memory associated with the tensor descriptor **`dyDesc`**, for the backpropagated differential **`dy`** input.

***dx**

Inputs. Data pointer to GPU memory associated with the tensor descriptor **`dxDesc`**, for the resulting differential output with respect to **`x`**.

bnScaleBiasDiffDesc

Input. Shared tensor descriptor for the following five tensors: **`bnScale, resultBnScaleDiff, resultBnBiasDiff, savedMean, savedInvVariance`**. The dimensions for this tensor descriptor are dependent on normalization mode. See cudnnDeriveBNTensorDescriptor.

> The data type of this tensor descriptor must be 'float' for FP16 and FP32 input tensors, and 'double' for FP64 input tensors.

***bnScale**

Input. Pointer in the device memory for the batch normalization **`scale`** parameter (in original paper the quantity **`scale`** is referred to as gamma).

> The **`bnBias`** parameter is not needed for this layer's computation.

resultBnScaleDiff, 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. 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 has to remain unchanged until this backward function is called.

> 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.

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, resultBnBiasDiff** is NULL.
- Number of **xDesc** or **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.
- 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, dxDesc.**

4.5. cudnnBatchNormalizationBackwardEx

```
cudnnStatus_t 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,
    const void                       *bnScaleData,
    const void                       *bnBiasData,
    void                             *dBnScaleData,
    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 function is an extension of the **cudnnBatchNormalizationBackward()** for performing the backward batch normalization layer computation with a fast NHWC semi-persistent kernel. This API will trigger the new semi-persistent NHWC kernel when the below conditions are true:

- All tensors, namely, **x, y, dz, dy, 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_BATCHNORM_SPATIAL_PERSISTENT.
- **`workspace`** is not NULL.
- **`workSpaceSizeInBytes`** is equal or larger than the amount required by cudnnGetBatchNormalizationBackwardExWorkspaceSize().
- **`reserveSpaceSizeInBytes`** is equal 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, dx`**.

Parameters

handle

Input. Handle to a previously created cuDNN library descriptor. See cudnnHandle_t.

mode

Input. Mode of operation (spatial or per-activation). See cudnnBatchNormMode_t.

bnOps

Input. Mode of operation for the fast NHWC kernel. See 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:

`dstValue = alpha[0]*resultValue + beta[0]*priorDstValue.` Refer to this section for additional details.

***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:

`dstValue = alpha[0]*resultValue + beta[0]*priorDstValue.` Refer to this section for additional details.

xDesc, *x,yDesc, *yData, dyDesc, *dyData, dzDesc, *dzData, dxDesc, *dx/dt

Inputs. 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.`** See cudnnTensorDescriptor_t.

dBnScaleBiasDesc

Input. Shared tensor descriptor for the following six tensors: **`bnScaleData, bnBiasData, dBnScaleData, dBnBiasData, savedMean, and savedInvVariance.`** See cudnnDeriveBNTensorDescriptor.

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.

See cudnnTensorDescriptor_t.

***bnScaleData**

Input. Pointer in the device memory for the batch normalization scale parameter (in the original paper the quantity scale is referred to as gamma).

***bnBiasData**

Input. Pointers in the device memory for the batch normalization bias parameter (in the original paper bias is referred to as beta). This parameter is used only when activation should be performed.

***dBnScaleData, dBnBiasData**

Inputs. Pointers in the device memory for the gradients of **`bnScaleData`** and **`bnBiasData`**, respectively.

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. 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. Tensor descriptor for the activation operation.

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. 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`**. Must be equal or larger than the amount required by **`cudnnGetBatchNormalizationTrainingExReserveSpaceSize()`**.

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, resultBnBiasDiff`** is NULL.
- Number of **`xDesc`** or **`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`**, **`dxDesc`**.

4.6. cudnnBatchNormalizationForwardInference

```
cudnnStatus_t cudnnBatchNormalizationForwardInference(
     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,
     const void                      *estimatedMean,
     const void                      *estimatedVariance,
     double                           epsilon)
```

This function performs the forward batch normalization layer computation for the inference phase. This layer is based on the paper *Batch Normalization: Accelerating Deep Network Training by Reducing Internal Covariate Shift*, S. Ioffe, C. Szegedy, 2015.

See `cudnnDeriveBNTensorDescriptor` for the secondary tensor descriptor generation for the parameters using in this function.

Only 4D and 5D tensors are supported.

The input transformation performed by this function is defined as:

```
y = beta*y + alpha *[bnBias + (bnScale * (x-estimatedMean)/
sqrt(epsilon + estimatedVariance)]
```

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

For training phase use `cudnnBatchNormalizationForwardTraining`.

Higher performance can be obtained when HW-packed tensors are used for all of **`x`** and **`dx`**.

Parameters

handle

Input. Handle to a previously created cuDNN library descriptor. See cudnnHandle_t.

mode

Input. Mode of operation (spatial or per-activation). See 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]*resultValue + beta[0]*priorDstValue.` Refer to this section for additional details.

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**

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

bnScaleBiasMeanVarDesc, bnScale, bnBias

Inputs. Tensor descriptor and pointers in device memory for the batch normalization scale and bias parameters (in the original 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.

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, estimatedInvVariance`** is NULL.
- 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 CUDNN_BN_MIN_EPSILON.
- Dimensions or data types mismatch for **`xDesc`**, **`yDesc.`**

4.7. cudnnBatchNormalizationForwardTraining

```
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)
```

This function performs the forward batch normalization layer computation for the training phase. This layer is based on the paper *Batch Normalization: Accelerating Deep Network Training by Reducing Internal Covariate Shift*, S. Ioffe, C. Szegedy, 2015.

See **`cudnnDeriveBNTensorDescriptor`** for the secondary tensor descriptor generation for the parameters using in this function.

Only 4D and 5D tensors are supported.

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

For inference phase use `cudnnBatchNormalizationForwardInference`.

Higher performance can be obtained when HW-packed tensors are used for both `x` and `y`.

Parameters

handle

Handle to a previously created cuDNN library descriptor. See cudnnHandle_t.

mode

Mode of operation (spatial or per-activation). See 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]*resultValue + beta[0]*priorDstValue.` Refer to this section for additional details.

xDesc, yDesc

Tensor descriptors and pointers in device memory for the layer's **`x`** and **`y`** data. See 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 original 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:

```
runningMean = runningMean*(1-factor) + newMean*factor
```

Use a **`factor=1/(1+n)`** at **`N`**-th call to the function to get Cumulative Moving Average (CMA) behavior such that:

`CMA[n] = (x[1]+...+x[n])/n`. This is proved below:

Writing **`CMA[n+1] = (n*CMA[n]+x[n+1])/(n+1)`**

`= ((n+1)*CMA[n]-CMA[n])/(n+1) + x[n+1]/(n+1)`

`= CMA[n]*(1-1/(n+1))+x[n+1]*1/(n+1)`

`= CMA[n]*(1-factor) + x(n+1)*factor.`

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 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. 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.

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** is NULL.
- 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 is NULL.
- Exactly one of **resultRunningMean**, **resultRunningInvVariance** pointers is NULL.
- **epsilon** value is less than CUDNN_BN_MIN_EPSILON.
- Dimensions or data types mismatch for **xDesc**, **yDesc**

4.8. cudnnBatchNormalizationForwardTrainingEx

```
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
   void                                *reserveSpace
   size_t                              reserveSpaceSizeInBytes);
```

This function is an extension of the **cudnnBatchNormalizationForwardTraining()** for performing the forward batch normalization layer computation.

This API will trigger the new semi-persistent NHWC kernel when the below conditions are true:

- All tensors, namely, **x, y, dz, dy, 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_BATCHNORM_SPATIAL_PERSISTENT.
- **workspace** is not NULL.
- **workSpaceSizeInBytes** is equal or larger than the amount required by **cudnnGetBatchNormalizationForwardTrainingExWorkspaceSize**().
- **reserveSpaceSizeInBytes** is equal 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, dx**.

Parameters

handle

Input. Handle to a previously created cuDNN library descriptor. See cudnnHandle_t.

mode

Input. Mode of operation (spatial or per-activation). See cudnnBatchNormMode_t.

bnOps

Input. Mode of operation for the fast NHWC kernel. See 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.` Refer to this section for additional details.

xDesc, *xData, zDesc, *zData, yDesc, *yData

Tensor descriptors and pointers in device memory for the layer's **`x`** and **`y`** data, and for the optional **`z`** tensor input for residual addition to the result of the batch normalization operation, prior to the activation. The optional tensor input **`z`** should be exact the same size as **`x`** and the final output **`y`**. This **`z`** input is element-wise added to the output of batch normalization. This addition optionally happens after batch normalization and before the activation. See 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 the device memory for the for the batch normalization scale and bias data. In the original paper bias is referred to as beta and scale as gamma. Note that **`bnBiasData`** parameter can replace the previous operation's bias parameter for improved efficiency.

exponentialAverageFactor

Input. Factor used in the moving average computation as follows:

`runningMean = runningMean*(1-factor) + newMean*factor`

Use a **`factor=1/(1+n)`** at **`N`**-th call to the function to get Cumulative Moving Average (CMA) behavior such that:

`CMA[n] = (x[1]+...+x[n])/n`. This is proved below:

Writing **`CMA[n+1] = (n*CMA[n]+x[n+1])/(n+1)`**

`= ((n+1)*CMA[n]-CMA[n])/(n+1) + x[n+1]/(n+1)`

`= CMA[n]*(1-1/(n+1))+x[n+1]*1/(n+1)`

`= CMA[n]*(1-factor) + x(n+1)*factor.`

***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 **`resultRunningVarianceData`** (or passed as an input in inference mode) is the sample variance, and is the moving average of variance[x] where 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. 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. 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.

***workspace, workSpaceSizeInBytes**

Inputs. **`*workspace`** is a pointer to the GPU workspace, and **`workSpaceSizeInBytes`** is the size of the workspace. When the **`*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()`**.

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, bnBiasData`** is NULL.

- 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 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 **saveMean**, **saveInvVariance** pointers is NULL.
- Exactly one of **resultRunningMeanData**, **resultRunningInvVarianceData** pointers is NULL.
- **epsilon** value is less than CUDNN_BN_MIN_EPSILON.
- Dimensions or data types mismatch for **xDesc**, **yDesc**

4.9. cudnnCTCLoss

```
cudnnStatus_t cudnnCTCLoss(
    cudnnHandle_t                        handle,
    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,
    cudnnCTCLossAlgo_t                   algo,
    const   cudnnCTCLossDescriptor_t     ctcLossDesc,
    void                                *workspace,
    size_t                              *workSpaceSizeInBytes)
```

This function returns the ctc costs and gradients, given the probabilities and labels.

This function has an inconsistent interface, i.e., the **probs** input is probability normalized by softmax, but the **gradients** output is with respect to the unnormalized activation.

Parameters

handle

Input. Handle to a previously created cuDNN context. See cudnnHandle_t.

probsDesc

Input. Handle to the previously initialized probabilities tensor descriptor. See 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.

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.

costs

Output. Pointer to the computed costs of CTC.

gradientsDesc

Input. Handle to a previously initialized gradients 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. See cudnnCTCLossAlgo_t.

ctcLossDesc

Input. Handle to the previously initialized CTC loss descriptor. See cudnnCTCLossDescriptor_t.

workspace

Input. Pointer to GPU memory of a workspace needed to 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`**.

The possible error values returned by this function and their meanings are listed below.

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

4.10. cudnnConvolutionBackwardBias

```
cudnnStatus_t cudnnConvolutionBackwardBias(
    cudnnHandle_t                     handle,
    const void                       *alpha,
    const cudnnTensorDescriptor_t     dyDesc,
    const void                       *dy,
    const void                       *beta,
    const cudnnTensorDescriptor_t     dbDesc,
    void                             *db)
```

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.

Parameters

handle

Input. Handle to a previously created cuDNN context. See 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: dstValue = alpha[0]*result + beta[0]*priorDstValue. Refer to this section for additional details.

dyDesc

Input. Handle to the previously initialized input tensor descriptor. See 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`**.

The possible error values returned by this function and their meanings are listed below.

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,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 are different.

4.11. cudnnConvolutionBackwardData

```
cudnnStatus_t 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)
```

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`**.

Parameters

handle

Input. Handle to a previously created cuDNN context. See 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: dstValue = alpha[0]*result + beta[0]*priorDstValue. Refer to this section for additional details.

wDesc

Input. Handle to a previously initialized filter descriptor. See 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. See cudnnTensorDescriptor_t.

dy

Input. Data pointer to GPU memory associated with the input differential tensor descriptor **`dyDesc`**.

convDesc

Input. Previously initialized convolution descriptor. See cudnnConvolutionDescriptor_t.

algo

Input. Enumerant that specifies which backward data convolution algorithm shoud be used to compute the results. See cudnnConvolutionBwdDataAlgo_t.

workSpace

Input. Data pointer to GPU memory to a workspace needed to 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.

TABLE OF THE SUPPORTED CONFIGURATIONS

This function supports the following combinations of data types for **`wDesc`**, **`dyDesc`**, **`convDesc`**, and **`dxDesc`**. See the following table for a list of the supported configurations.

Data Type Configurations	`wDesc`'s, `dyDesc`'s and `dxDesc`'s Data Type	`convDesc`'s Data Type
TRUE_HALF_CONFIG (only supported on architectures with true fp16 support, i.e., compute capability 5.3 and later).	CUDNN_DATA_HALF	CUDNN_DATA_HALF
PSEUDO_HALF_CONFIG	CUDNN_DATA_HALF	CUDNN_DATA_FLOAT
FLOAT_CONFIG	CUDNN_DATA_FLOAT	CUDNN_DATA_FLOAT
DOUBLE_CONFIG	CUDNN_DATA_DOUBLE	CUDNN_DATA_DOUBLE

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.

TABLE OF THE SUPPORTED ALGORITHMS

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 paranthesis are used in the table below, for brevity:

- CUDNN_CONVOLUTION_BWD_DATA_ALGO_0 (**_ALGO_0)**
- CUDNN_CONVOLUTION_BWD_DATA_ALGO_1 (**_ALGO_1)**
- CUDNN_CONVOLUTION_BWD_DATA_ALGO_FFT (**_FFT)**

- CUDNN_CONVOLUTION_BWD_DATA_ALGO_FFT_TILING **(_FFT_TILING)**
- CUDNN_CONVOLUTION_BWD_DATA_ALGO_WINOGRAD **(_WINOGRAD)**
- CUDNN_CONVOLUTION_BWD_DATA_ALGO_WINOGRAD_NONFUSED **(_WINOGRAD_NONFUSED)**
- CUDNN_TENSOR_NCHW **(_NCHW)**
- CUDNN_TENSOR_NHWC **(_NHWC)**
- CUDNN_TENSOR_NCHW_VECT_C **(_NCHW_VECT_C)**

FOR 2D CONVOLUTIONS.

Filter descriptor `wDesc`: `_NHWC`. See cudnnTensorFormat_t.					
Algo Name (see below for 3D Convolutions)	**Deterministic (Yes or No)**	**Tensor Formats Supported for `dyDesc`**	**Tensor Formats Supported for `dxDesc`**	**Data Type Configurations Supported**	**Important**
_ALGO_1		NHWC HWC-packed	NHWC HWC-packed	- TRUE_HALF_CONFIG, - PSEUDO_HALF_CONFIG, and - FLOAT_CONFIG	
Filter descriptor `wDesc`: `_NCHW`.					
Algo Name	**Deterministic (Yes or No)**	**Tensor Formats Supported for `dyDesc`**	**Tensor Formats Supported for `dxDesc`**	**Data Type Configurations Supported**	**Important**
_ALGO_0	No	NCHW CHW-packed	All except `_NCHW_VECT_C`	- PSEUDO_HALF_CONFIG, - FLOAT_CONFIG, and - DOUBLE_CONFIG	- **Dilation:** greater than 0 for all dimensions - `convDesc` Group Count Support: Greater than 0.
_ALGO_1	Yes	NCHW CHW-packed	_All except `_NCHW_VECT_C`	- TRUE_HALF_CONFIG, - PSEUDO_HALF_CONFIG, - FLOAT_CONFIG, and - DOUBLE_CONFIG	- **Dilation:** 1 for all dimensions - `convDesc` Group Count Support: Greater than 0.
_FFT	Yes	NCHW CHW-packed	NCHW HW-packed	- PSEUDO_HALF_CONFIG, and - FLOAT_CONFIG	- **Dilation:** 1 for all dimensions - `convDesc` Group Count Support: Greater than 0. - `dxDesc`'s feature map height + 2 * `convDesc`'s zero-padding height

					must equal 256 or less - **dxDesc**'s feature map width + 2 * **convDesc**'s zero-padding width must equal 256 or less - **convDesc**'s vertical and horizontal filter stride must equal 1 - **wDesc**'s filter height must be greater than **convDesc**'s zero-padding height - **wDesc**'s filter width must be greater than **convDesc**'s zero-padding width
_FFT_TILING	Yes	NCHW CHW-packed	NCHW HW-packed	- PSEUDO_HALF_CONFIG and - FLOAT_CONFIG - DOUBLE_CONFIG is also supported when the task can be handled by 1D FFT, ie, one of the filter dimension, width or height is 1.	- **Dilation:** 1 for all dimensions - **convDesc** Group Count Support: Greater than 0. - When neither of **wDesc**'s filter dimension is 1, the filter width and height must not be larger than 32 - When either of **wDesc**'s filter dimension is 1, the largest filter dimension should not exceed 256 - **convDesc**'s vertical and horizontal filter stride must equal 1 when either the filter width or filter height is 1, otherwise the stride can be 1 or 2 - **wDesc**'s filter height must be greater than **convDesc**'s zero-padding height - **wDesc**'s filter width must be

					greater than **convDesc**'s zero-padding width
_WINOGRAD	Yes	NCHW CHW-packed	All except **_NCHW_VECT_C**	- PSEUDO_HALF_CONFIG, and - FLOAT_CONFIG	- **Dilation**: 1 for all dimensions - **convDesc** Group Count Support: Greater than 0. - **convDesc**'s vertical and horizontal filter stride must equal 1 - **wDesc**'s filter height must be 3 - **wDesc**'s filter width must be 3
_WINOGRAD_NONFUSED	Yes	NCHW CHW-packed	All except **_NCHW_VECT_C**	- TRUE_HALF_CONFIG, - PSEUDO_HALF_CONFIG, and - FLOAT_CONFIG	- **Dilation**: 1 for all dimensions - **convDesc** Group Count Support: Greater than 0. - **convDesc**'s vertical and horizontal filter stride must equal 1 - **wDesc**'s filter (height, width) must be (3,3) or (5,5) - If **wDesc**'s filter (height, width) is (5,5) then the data type config TRUE_HALF_CONFIG is not supported

FOR 3D CONVOLUTIONS.

Filter descriptor **wDesc: _NCHW**					
Algo Name (3D Convolutions)	**Deterministic (Yes or No)**	**Tensor Formats Supported for dyDesc**	**Tensor Formats Supported for dxDesc**	**Data Type Configurations Support**	**Important**
_ALGO_0	Yes	NCDHW CDHW-packed	All except **_NCDHW_VECT_C**	- PSEUDO_HALF_CONFIG, - FLOAT_CONFIG, and - DOUBLE_CONFIG.	- **Dilation**: greater than 0 for all dimensions - **convDesc** Group Count Support: Greater than 0.

_ALGO_1	Yes	NCDHW-fully-packed	NCDHW-fully-packed	- TRUE_HALF_CONFIG, - PSEUDO_HALF_CONFIG, - FLOAT_CONFIG, and - DOUBLE_CONFIG.	- **Dilation**: 1 for all dimensions - **`convDesc`** Group Count Support: Greater than 0.
_FFT_TILING	Yes	NCDHW CDHW-packed	NCDHW DHW-packed	- PSEUDO_HALF_CONFIG, - FLOAT_CONFIG, and - DOUBLE_CONFIG.	- **Dilation**: 1 for all dimensions - **`convDesc`** Group Count Support: Greater than 0. - **`wDesc`**'s filter height must equal 16 or less - **`wDesc`**'s filter width must equal 16 or less - **`wDesc`**'s filter depth must equal 16 or less - **`convDesc`**'s must have all filter strides equal to 1 - **`wDesc`**'s filter height must be greater than **`convDesc`**'s zero-padding height - **`wDesc`**'s filter width must be greater than **`convDesc`**'s zero-padding width - **`wDesc`**'s filter depth must be greater than **`convDesc`**'s zero-padding width

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`**, **`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).
- **dyDescs's** 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 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 exhaustive list of parameter support for 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 the filter data or the input differential tensor data

CUDNN_STATUS_EXECUTION_FAILED

The function failed to launch on the GPU.

4.12. cudnnConvolutionBackwardFilter

```
cudnnStatus_t 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)
```

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**.

Parameters

handle

Input. Handle to a previously created cuDNN context. See 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: dstValue = alpha[0]*result + beta[0]*priorDstValue. Refer to this section for additional details.

xDesc

Input. Handle to a previously initialized tensor descriptor. See 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. See cudnnConvolutionDescriptor_t.

algo

Input. Enumerant that specifies which convolution algorithm shoud be used to compute the results. See cudnnConvolutionBwdFilterAlgo_t.

workSpace

Input. Data pointer to GPU memory to a workspace needed to 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. See cudnnFilterDescriptor_t.

dw

Input/Output. Data pointer to GPU memory associated with the filter gradient descriptor **`dwDesc`** that carries the result.

TABLE OF THE SUPPORTED CONFIGURATIONS

This function supports the following combinations of data types for **`xDesc`**, **`dyDesc`**, **`convDesc`**, and **`dwDesc`**. See the following table for a list of the supported configurations.

Data Type Configurations	`xDesc`'s, `dyDesc`'s and `dwDesc`'s Data Type	`convDesc`'s Data Type
TRUE_HALF_CONFIG (only supported on architectures with true fp16 support, i.e., compute capability 5.3 and later).	CUDNN_DATA_HALF	CUDNN_DATA_HALF
PSEUDO_HALF_CONFIG	CUDNN_DATA_HALF	CUDNN_DATA_FLOAT
FLOAT_CONFIG	CUDNN_DATA_FLOAT	CUDNN_DATA_FLOAT
DOUBLE_CONFIG	CUDNN_DATA_DOUBLE	CUDNN_DATA_DOUBLE

Specifying a separate algorithm can cause changes in performance, support and computation determinism. See the following for an exhaustive list of algorithm options and their respective supported parameters and deterministic behavior.

TABLE OF THE SUPPORTED ALGORITHMS

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 paranthesis 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)**

FOR 2D CONVOLUTIONS.

Filter descriptor `dwDesc: _NHWC`. See cudnnTensorFormat_t.					
Algo Name (see below for 3D Convolutions)	**Deterministic (Yes or No)**	**Tensor Formats Supported for `xDesc`**	**Tensor Formats Supported for `dyDesc`**	**Data Type Configurations Supported**	**Important**
_ALGO_0, and **_ALGO_1**		NHWC HWC-packed	NHWC HWC-packed	- PSEUDO_HALF_CONFIG, and - FLOAT_CONFIG	
Filter descriptor `wDesc: _NCHW`.					

Algo Name	Deterministic (Yes or No)	Tensor Formats Supported for `xDesc`	Tensor Formats Supported for `dyDesc`	Data Type Configurations Supported	Important
_ALGO_0	No	All except `_NCHW_VECT_C`	NCHW CHW-packed	- PSEUDO_HALF_CONFIG, - FLOAT_CONFIG, and - DOUBLE_CONFIG	- **Dilation:** greater than 0 for all dimensions - `convDesc` Group Count Support: Greater than 0. - This algo is not supported if output is of type `CUDNN_DATA_HALF` and the number of elements in `dw` is odd.
_ALGO_1	Yes	_NCHW or _NHWC	NCHW CHW-packed	- TRUE_HALF_CONFIG, - PSEUDO_HALF_CONFIG, - FLOAT_CONFIG, and - DOUBLE_CONFIG	- **Dilation:** 1 for all dimensions - `convDesc` Group Count Support: Greater than 0.
_FFT	Yes	NCHW CHW-packed	NCHW CHW-packed	- PSEUDO_HALF_CONFIG, and - FLOAT_CONFIG	- **Dilation:** 1 for all dimensions - `convDesc` Group Count Support: Greater than 0. - `xDesc`'s feature map height + 2 * `convDesc`'s zero-padding height must equal 256 or less - `xDesc`'s feature map width + 2 * `convDesc`'s zero-padding width must equal 256 or less - `convDesc`'s vertical and horizontal filter stride must equal 1 - `dwDesc`'s filter height must be greater than `convDesc`'s zero-padding height

					- **dwDesc**'s filter width must be greater than **convDesc**'s zero-padding width
_ALGO_3	Yes	All except **_NCHW_VECT_C**	NCHW CHW-packed	- PSEUDO_HALF_CONFIG, - FLOAT_CONFIG, and - DOUBLE_CONFIG	- **Dilation:** 1 for all dimensions - **convDesc** Group Count Support: Greater than 0.
_WINOGRAD_NONFUSED	Yes	All except **_NCHW_VECT_C**	NCHW CHW-packed	- TRUE_HALF_CONFIG, - PSEUDO_HALF_CONFIG, and - FLOAT_CONFIG	- **Dilation:** 1 for all dimensions - **convDesc** Group Count Support: Greater than 0. - **convDesc**'s vertical and horizontal filter stride must equal 1 - **wDesc**'s filter (height, width) must be (3,3) or (5,5) - If **wDesc**'s filter (height, width) is (5,5), then the data type config TRUE_HALF_CONFIG is not supported.
_FFT_TILING	Yes	NCHW CHW-packed	NCHW CHW-packed	- PSEUDO_HALF_CONFIG, - FLOAT_CONFIG, and - DOUBLE_CONFIG	- **Dilation:** 1 for all dimensions - **convDesc** Group Count Support: Greater than 0. - **xDesc**'s width or height must equal 1 - **dyDesc**'s width or height must equal 1 (the same dimension as in **xDesc**.) The other dimension must be less than or equal to 256, i.e., the largest 1D tile size currently supported. - **convDesc**'s vertical and

					horizontal filter stride must equal 1 - **`dwDesc`**'s filter height must be greater than **`convDesc`**'s zero-padding height. - **`dwDesc`**'s filter width must be greater than **`convDesc`**'s zero-padding width.

FOR 3D CONVOLUTIONS.

Filter descriptor `wDesc`: `_NCHW`					
Algo Name	**Deterministic (Yes or No)**	**Tensor Formats Supported for `xDesc`**	**Tensor Formats Supported for `dyDesc`**	**Data Type Configurations Support**	**Important**
_ALGO_0	No	All except **`_NCDHW_VECT_C.`**	NCDHW CDHW-packed	- PSEUDO_HALF_CONFIG, - FLOAT_CONFIG, and - DOUBLE_CONFIG.	- **Dilation:** greater than 0 for all dimensions - **`convDesc`** Group Count Support: Greater than 0.
_ALGO_3	No	NCDHW-fully-packed	NCDHW-fully-packed	- PSEUDO_HALF_CONFIG, - FLOAT_CONFIG, and - DOUBLE_CONFIG.	- **Dilation:** 1 for all dimensions - **`convDesc`** Group Count Support: Greater than 0.

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`**, **`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 **wDesc** 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 binding of the filter data.

CUDNN_STATUS_EXECUTION_FAILED

The function failed to launch on the GPU.

4.13. cudnnConvolutionBiasActivationForward

```
cudnnStatus_t 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)
```

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 = act ( alpha1 * conv(x) + alpha2 * z + bias )`**.

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. See also the documentation for the function **`cudnnSetActivationDescriptor()`**.

Parameters

handle

Input. Handle to a previously created cuDNN context. See cudnnHandle_t.

alpha1, alpha2

Input. Pointers to scaling factors (in host memory) used to blend the computation result with prior value in the output layer as described by the above equation. Please refer to this section for additional details.

xDesc

Input. Handle to a previously initialized tensor descriptor. See cudnnTensorDescriptor_t.

x

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

wDesc

Input. Handle to a previously initialized filter descriptor. See cudnnFilterDescriptor_t.

w

Input. Data pointer to GPU memory associated with the filter descriptor **`wDesc`**.

convDesc

Input. Previously initialized convolution descriptor. See cudnnConvolutionDescriptor_t.

algo

Input. Enumerant that specifies which convolution algorithm should be used to compute the results. See cudnnConvolutionFwdAlgo_t.

workSpace

Input. Data pointer to GPU memory to a workspace needed to 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. See 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 Key: X = CUDNN_DATA

x	w	y and z	bias	alpha1/alpha2
X_DOUBLE	X_DOUBLE	X_DOUBLE	X_DOUBLE	X_DOUBLE
X_FLOAT	X_FLOAT	X_FLOAT	X_FLOAT	X_FLOAT
X_HALF	X_HALF	X_HALF	X_HALF	X_FLOAT
X_INT8	X_INT8	X_INT8	X_FLOAT	X_FLOAT
X_INT8	X_INT8	X_FLOAT	X_FLOAT	X_FLOAT
X_INT8x4	X_INT8x4	X_INT8x4	X_FLOAT	X_FLOAT
X_INT8x4	X_INT8x4	X_FLOAT	X_FLOAT	X_FLOAT
X_UINT8	X_INT8	X_INT8	X_FLOAT	X_FLOAT
X_UINT8	X_INT8	X_FLOAT	X_FLOAT	X_FLOAT
X_UINT8x4	X_INT8x4	X_INT8x4	X_FLOAT	X_FLOAT
X_UINT8x4	X_INT8x4	X_FLOAT	X_FLOAT	X_FLOAT

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.

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: **`zDesc`**, **`zData`**, **`biasDesc`**, **`bias`**, **`activationDesc`**.

- The second dimension of **biasDesc** and the first dimension of **filterDesc** are not equal.
- **zDesc** and **destDesc** do not match.

CUDNN_STATUS_NOT_SUPPORTED

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

- The **mode** of **activationDesc** is neither **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 data type of **biasDesc** does not correspond to the data type of **yDesc** as listed in the above data types table.

CUDNN_STATUS_EXECUTION_FAILED

The function failed to launch on the GPU.

4.14. cudnnConvolutionForward

```
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)
```

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.

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. See 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: dstValue = alpha[0]*result + beta[0]*priorDstValue. Refer to this section for additional details.

xDesc

Input. Handle to a previously initialized tensor descriptor. See cudnnTensorDescriptor_t.

x

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

wDesc

Input. Handle to a previously initialized filter descriptor. See cudnnFilterDescriptor_t.

w

Input. Data pointer to GPU memory associated with the filter descriptor **`wDesc`**.

convDesc

Input. Previously initialized convolution descriptor. See cudnnConvolutionDescriptor_t.

algo

Input. Enumerant that specifies which convolution algorithm shoud be used to compute the results. See cudnnConvolutionFwdAlgo_t.

workSpace

Input. Data pointer to GPU memory to a workspace needed to 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.

TABLE OF THE SUPPORTED CONFIGURATIONS

This function supports the following combinations of data types for **`xDesc`**, **`wDesc`**, **`convDesc`**, and **`yDesc`**. See the following table for a list of the supported configurations.

Data Type Configurations	`xDesc` and `wDesc`	`convDesc`	`yDesc`
TRUE_HALF_CONFIG (only supported on architectures with true fp16 support, i.e., compute capability 5.3 and later).	CUDNN_DATA_HALF	CUDNN_DATA_HALF	CUDNN_DATA_HALF
PSEUDO_HALF_CONFIG	CUDNN_DATA_HALF	CUDNN_DATA_FLOAT	CUDNN_DATA_HALF
FLOAT_CONFIG	CUDNN_DATA_FLOAT	CUDNN_DATA_FLOAT	CUDNN_DATA_FLOAT

Data Type Configurations	`xDesc` and `wDesc`	`convDesc`	`yDesc`
DOUBLE_CONFIG	CUDNN_DATA_DOUBLE	CUDNN_DATA_DOUBLE	CUDNN_DATA_DOUBLE
INT8_CONFIG (only supported on architectures with DP4A support, i.e., compute capability 6.1 and later).	CUDNN_DATA_INT8	CUDNN_DATA_INT32	CUDNN_DATA_INT8
INT8_EXT_CONFIG (only supported on architectures with DP4A support, i.e., compute capability 6.1 and later).	CUDNN_DATA_INT8	CUDNN_DATA_INT32	CUDNN_DATA_FLOAT
INT8x4_CONFIG (only supported on architectures with DP4A support, i.e., compute capability 6.1 and later).	CUDNN_DATA_INT8x4	CUDNN_DATA_INT32	CUDNN_DATA_INT8x4
INT8x4_EXT_CONFIG (only supported on architectures with DP4A support, i.e., compute capability 6.1 and later).	CUDNN_DATA_INT8x4	CUDNN_DATA_INT32	CUDNN_DATA_FLOAT
UINT8x4_CONFIG (new for 7.1) (only supported on architectures with DP4A support, i.e., compute capability 6.1 and later).	CUDNN_DATA_UINT8x4	CUDNN_DATA_INT32	CUDNN_DATA_UINT8x4
UINT8x4_EXT_CONFIG (new for 7.1) (only supported on architectures with DP4A support, i.e., compute capability 6.1 and later).	CUDNN_DATA_UINT8x4	CUDNN_DATA_INT32	CUDNN_DATA_FLOAT

For this function, all algorithms perform deterministic computations. Specifying a separate algorithm can cause changes in performance and support.

TABLE OF THE SUPPORTED ALGORITHMS

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 paranthesis 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)**

FOR 2D CONVOLUTIONS.

Filter descriptor `wDesc`: `_NCHW`. See cudnnTensorFormat_t.

`convDesc` Group count support: Greater than 0, for all algos.

Algo Name (see below for 3D Convolutions)	**Tensor Formats Supported for `xDesc`**	**Tensor Formats Supported for `yDesc`**	**Data Type Configurations Supported**	**Important**
_IMPLICIT_GEMM	All except `_NCHW_VECT_C`.	All except `_NCHW_VECT_C`.	- PSEUDO_HALF_CONFIG, - FLOAT_CONFIG, and - DOUBLE_CONFIG	**Dilation:** Greater than 0 for all dimensions.
_IMPLICIT_PRECOMP_GEMM			- TRUE_HALF_CONFIG, - PSEUDO_HALF_CONFIG, - FLOAT_CONFIG, and - DOUBLE_CONFIG.	**Dilation:** 1 for all dimensions.
_GEMM			- PSEUDO_HALF_CONFIG, - FLOAT_CONFIG, and - DOUBLE_CONFIG	**Dilation:** 1 for all dimensions.
_FFT	NCHW HW-packed	NCHW HW-packed	- PSEUDO_HALF_CONFIG, and - FLOAT_CONFIG	**Dilation:** 1 for all dimensions. - xDesc's feature map **height** + 2 * convDesc's zero-padding height must equal 256 or less

				- xDesc's feature map **width** + 2 * convDesc's zero-padding width must equal 256 or less - convDesc's vertical and horizontal filter stride must equal 1 - wDesc's filter height must be greater than convDesc's zero-padding **height** - wDesc's filter width must be greater than convDesc's zero-padding **width**
_FFT_TILING			- PSEUDO_HALF_CONFIG, and - FLOAT_CONFIG DOUBLE_CONFIG is also supported when the task can be handled by 1D FFT, i.e., one of the filter dimension, width or height is 1.	**Dilation:** 1 for all dimensions. - When **neither** of wDesc's filter dimension is 1, the filter width and height must not be larger than 32 - When **either** of wDesc's filter dimension is 1, the largest filter dimension should not exceed 256 - convDesc's vertical and horizontal filter stride must equal 1 when either the filter width or filter height is 1, otherwise the stride can be 1 or 2 - wDesc's filter height must be greater than convDesc's zero-padding height - wDesc's filter width must be greater than convDesc's zero-padding width
_WINOGRAD	All **except:** _NCHW_VECT_C	All **except:** _NCHW_VECT_C	- PSEUDO_HALF_CONFIG, and - FLOAT_CONFIG	**Dilation:** 1 for all dimensions. - convDesc's vertical and horizontal filter stride must equal 1 - wDesc's filter **height** must be 3

				- wDesc's filter **width** must be 3
_WINOGRAD_NONFUSED			- TRUE_HALF_CONFIG, - PSEUDO_HALF_CONFIG, and - FLOAT_CONFIG	**Dilation:** 1 for all dimensions. - convDesc's vertical and horizontal filter stride must equal 1 - wDesc's filter (height, width) must be (3,3) or (5,5) - If wDesc's filter (height, width) is (5,5), then data type config TRUE_HALF_CONFIG is not supported
_DIRECT	Currently not implemented in cuDNN.			

Filter descriptor `wDesc`: `_NHWC` `convDesc` Group count support: Greater than 0.				
Algo Name	**`xDesc`**	**`yDesc`**	**Data Type Configurations Support**	**Important**
_IMPLICIT_GEMM	NCHWC HWC-packed	NCHWC HWC-packed	- PSEUDO_HALF_CONFIG, and - FLOAT_CONFIG	**Dilation:** Greater than 0 for all dimensions.

Filter descriptor `wDesc`: `_NHWC` `convDesc` Group count support: Greater than 0.				
Algo Name	**`xDesc`**	**`yDesc`**	**Data Type Configurations Support**	**Important**
_IMPLICIT_PRECOMP_GEMM	NHWC	NHWC	- INT8_CONFIG, - INT8_EXT_CONFIG, - INT8x4_CONFIG, - INT8x4_EXT_CONFIG, - UINT8x4_CONFIG, and - UINT8x4_EXT_CONFIG	**Dilation:** 1 for all dimensions. Input and output features maps must be multiple of 4.

FOR 3D CONVOLUTIONS.

Filter descriptor `wDesc`: `_NCHW`

`convDesc` Group count support: Greater than 0, for all algos.				
Algo Name	**`xDesc`**	**`yDesc`**	**Data Type Configurations Support**	**Important**
_IMPLICIT_GEMM	All except `_NCHW_VECT_C`.	All except `_NCHW_VECT_C`.	- PSEUDO_HALF_CONFIG, - FLOAT_CONFIG, and - DOUBLE_CONFIG.	**Dilation:** Greater than 0 for all dimensions.
_IMPLICIT_PRECOMP_GEMM				**Dilation:** 1 for all dimensions.
_FFT_TILING	NCDHW DHW-packed	NCDHW DHW-packed	- PSEUDO_HALF_CONFIG, - FLOAT_CONFIG, and - DOUBLE_CONFIG.	**Dilation:** 1 for all dimensions. -**`wDesc`**'s filter height must equal 16 or less - **`wDesc`**'s filter width must equal 16 or less -**`wDesc`**'s filter depth must equal 16 or less - **`convDesc`**'s must have all filter strides equal to 1 - **`wDesc`**'s filter height must be greater than **`convDesc`**'s zero-padding height - **`wDesc`**'s filter width must be greater than **`convDesc`**'s zero-padding width - **`wDesc`**'s filter depth must be greater than **`convDesc`**'s zero-padding width

Tensors can be converted to, and from, CUDNN_TENSOR_NCHW_VECT_C with **`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`**, **`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 **convDesc**'s 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
- **yDescs's** 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 exhaustive list of parameter support for each algo

CUDNN_STATUS_MAPPING_ERROR

An error occured during the texture binding of the filter data.

CUDNN_STATUS_EXECUTION_FAILED

The function failed to launch on the GPU.

4.15. cudnnCreate

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

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.

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 (e.g., different current CUDA streams) may be created. 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.

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

handle

Output. Pointer to pointer where to store the address to the allocated cuDNN handle. See cudnnHandle_t.

Returns

`CUDNN_STATUS_BAD_PARAM`

Invalid (NULL) input pointer supplied.

`CUDNN_STATUS_NOT_INITIALIZED`

No compatible GPU found, CUDA driver not installed or disabled, CUDA runtime API initialization failed.

`CUDNN_STATUS_ARCH_MISMATCH`

NVIDIA GPU architecture is too old.

`CUDNN_STATUS_ALLOC_FAILED`

Host memory allocation failed.

`CUDNN_STATUS_INTERNAL_ERROR`

CUDA resource allocation failed.

`CUDNN_STATUS_LICENSE_ERROR`

cuDNN license validation failed (only when the feature is enabled).

`CUDNN_STATUS_SUCCESS`

cuDNN handle was created successfully.

4.16. cudnnCreateActivationDescriptor

```
cudnnStatus_t cudnnCreateActivationDescriptor(
        cudnnActivationDescriptor_t   *activationDesc)
```

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

Returns

`CUDNN_STATUS_SUCCESS`

The object was created successfully.

`CUDNN_STATUS_ALLOC_FAILED`

The resources could not be allocated.

4.17. cudnnCreateAlgorithmDescriptor

```
cudnnStatus_t cudnnCreateAlgorithmDescriptor(
    cudnnAlgorithmDescriptor_t *algoDesc)
```

(New for 7.1)

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

Returns

CUDNN_STATUS_SUCCESS

The object was created successfully.

CUDNN_STATUS_ALLOC_FAILED

The resources could not be allocated.

4.18. cudnnCreateAlgorithmPerformance

```
cudnnStatus_t cudnnCreateAlgorithmPerformance(
    cudnnAlgorithmPerformance_t *algoPerf,
    int                          numberToCreate)
```

(New for 7.1)

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

Returns

CUDNN_STATUS_SUCCESS

The object was created successfully.

CUDNN_STATUS_ALLOC_FAILED

The resources could not be allocated.

4.19. cudnnCreateAttnDescriptor

```
cudnnStatus_t cudnnCreateAttnDescriptor(cudnnAttnDescriptor_t *attnDesc);
```

This function creates an attention descriptor object by allocating the memory needed to hold its structure. Use the cudnnSetAttnDescriptor function to initialize the descriptor, and the cudnnDestroyAttnDescriptor function to destroy the descriptor.

Parameters:

Parameter	Input / Output	Description
attnDesc	Output	An uninitialized attention descriptor.

Returns:

Return Value	Description
CUDNN_STATUS_SUCCESS	The descriptor object is created successfully.
CUDNN_STATUS_BAD_PARAM	The **attnDesc** is NULL.
CUDNN_STATUS_ALLOC_FAILED	The memory allocation failed.

4.20. cudnnCreateCTCLossDescriptor

```
cudnnStatus_t cudnnCreateCTCLossDescriptor(
    cudnnCTCLossDescriptor_t* ctcLossDesc)
```

This function creates a CTC loss function descriptor. .

Parameters

ctcLossDesc

Output. CTC loss descriptor to be set. See 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.

4.21. cudnnCreateConvolutionDescriptor

```
cudnnStatus_t cudnnCreateConvolutionDescriptor(
    cudnnConvolutionDescriptor_t *convDesc)
```

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

Returns

`CUDNN_STATUS_SUCCESS`

The object was created successfully.

`CUDNN_STATUS_ALLOC_FAILED`

The resources could not be allocated.

4.22. cudnnCreateDropoutDescriptor

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

This function creates a generic dropout descriptor object by allocating the memory needed to hold its opaque structure. See cudnnDropoutDescriptor_t.

Returns

`CUDNN_STATUS_SUCCESS`

The object was created successfully.

`CUDNN_STATUS_ALLOC_FAILED`

The resources could not be allocated.

4.23. cudnnCreateFilterDescriptor

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

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

Returns

CUDNN_STATUS_SUCCESS

The object was created successfully.

CUDNN_STATUS_ALLOC_FAILED

The resources could not be allocated.

4.24. cudnnCreateLRNDescriptor

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

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.

Returns

CUDNN_STATUS_SUCCESS

The object was created successfully.

CUDNN_STATUS_ALLOC_FAILED

The resources could not be allocated.

4.25. cudnnCreateOpTensorDescriptor

```
cudnnStatus_t cudnnCreateOpTensorDescriptor(
    cudnnOpTensorDescriptor_t*  opTensorDesc)
```

This function creates a Tensor Pointwise math descriptor. See cudnnOpTensorDescriptor_t.

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.

4.26. cudnnCreatePersistentRNNPlan

```
cudnnStatus_t cudnnCreatePersistentRNNPlan(
    cudnnRNNDescriptor_t        rnnDesc,
    const int                   minibatch,
    const cudnnDataType_t       dataType,
    cudnnPersistentRNNPlan_t   *plan)
```

This function creates a plan to execute persistent RNNs when using the **CUDNN_RNN_ALGO_PERSIST_DYNAMIC** algo. This plan is tailored to the current GPU and problem hyperparemeters. This function call is expected to be expensive in terms of runtime, and should be used infrequently. See cudnnRNNDescriptor_t, cudnnDataType_t, and cudnnPersistentRNNPlan_t.

Returns

CUDNN_STATUS_SUCCESS

The object was created successfully.

CUDNN_STATUS_ALLOC_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.

4.27. cudnnCreatePoolingDescriptor

```
cudnnStatus_t cudnnCreatePoolingDescriptor(
    cudnnPoolingDescriptor_t    *poolingDesc)
```

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

Returns

CUDNN_STATUS_SUCCESS

The object was created successfully.

CUDNN_STATUS_ALLOC_FAILED

The resources could not be allocated.

4.28. cudnnCreateRNNDescriptor

```
cudnnStatus_t cudnnCreateRNNDescriptor(
    cudnnRNNDescriptor_t    *rnnDesc)
```

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

Returns

CUDNN_STATUS_SUCCESS

The object was created successfully.

CUDNN_STATUS_ALLOC_FAILED

The resources could not be allocated.

4.29. cudnnCreateRNNDataDescriptor

```
cudnnStatus_t cudnnCreateRNNDataDescriptor(
    cudnnRNNDataDescriptor_t *RNNDataDesc)
```

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

Returns

CUDNN_STATUS_SUCCESS

The RNN data descriptor object was created successfully.

CUDNN_STATUS_BAD_PARAM

RNNDataDesc is NULL.

CUDNN_STATUS_ALLOC_FAILED

The resources could not be allocated.

4.30. cudnnCreateReduceTensorDescriptor

```
cudnnStatus_t cudnnCreateReduceTensorDescriptor(
 cudnnReduceTensorDescriptor_t* reduceTensorDesc)
```

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

Parameters

None.

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.

4.31. cudnnCreateSeqDataDescriptor

```
cudnnStatus_t cudnnCreateSeqDataDescriptor(cudnnSeqDataDescriptor_t
 *seqDataDesc);
```

This function creates a sequence data descriptor object by allocating the memory needed to hold its opaque structure. The sequence data is initialized to be all zero. Use the cudnnSetSeqDataDescriptor function to initialize the descriptor created by this function.

Parameters:

Parameter	Input / Output	Description
seqDataDesc	Output	A sequence data descriptor whose sequence data is initialized to be all zero.

Returns:

Return Value	Description
CUDNN_STATUS_SUCCESS	The descriptor object was created successfully.
CUDNN_STATUS_BAD_PARAM	The **seqDataDesc** is NULL.
CUDNN_STATUS_ALLOC_FAILED	The memory allocation failed.

4.32. cudnnCreateSpatialTransformerDescriptor

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

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

Returns

CUDNN_STATUS_SUCCESS

The object was created successfully.

CUDNN_STATUS_ALLOC_FAILED

The resources could not be allocated.

4.33. cudnnCreateTensorDescriptor

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

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

Parameters

tensorDesc

Input. 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.

4.34. cudnnCreateTensorTransformDescriptor

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

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

Parameters:

Parameter	Input / Output	Description
transformDesc	Output	A pointer to an uninitialized Tensor transform descriptor.

Returns:

Return Value	Description
CUDNN_STATUS_SUCCESS	The descriptor object was created successfully.
CUDNN_STATUS_BAD_PARAM	The **`transformDesc`** is NULL.
CUDNN_STATUS_ALLOC_FAILED	The memory allocation failed.

4.35. cudnnDeriveBNTensorDescriptor

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

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

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, and 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.

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 setup 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.

4.36. cudnnDestroy

```
cudnnStatus_t cudnnDestroy(cudnnHandle_t handle)
```

This function releases resources used by the cuDNN handle. This function is usually the last call with a particular handle to 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.

Parameters

handle

Input. Pointer to the cuDNN handle to be destroyed.

Returns

`CUDNN_STATUS_SUCCESS`

The cuDNN context destruction was successful.

`CUDNN_STATUS_BAD_PARAM`

Invalid (NULL) pointer supplied.

4.37. cudnnDestroyActivationDescriptor

```
cudnnStatus_t cudnnDestroyActivationDescriptor(
        cudnnActivationDescriptor_t activationDesc)
```

This function destroys a previously created activation descriptor object.

Returns

`CUDNN_STATUS_SUCCESS`

The object was destroyed successfully.

4.38. cudnnDestroyAlgorithmDescriptor

```
cudnnStatus_t cudnnDestroyAlgorithmDescriptor(
        cudnnActivationDescriptor_t algorithmDesc)
```

(New for 7.1)

This function destroys a previously created algorithm descriptor object.

Returns

`CUDNN_STATUS_SUCCESS`

The object was destroyed successfully.

4.39. cudnnDestroyAlgorithmPerformance

```
cudnnStatus_t cudnnDestroyAlgorithmPerformance(
        cudnnAlgorithmPerformance_t     algoPerf)
```

(New for 7.1)

This function destroys a previously created algorithm descriptor object.

Returns

`CUDNN_STATUS_SUCCESS`

The object was destroyed successfully.

4.40. cudnnDestroyAttnDescriptor

```
cudnnStatus_t cudnnDestroyAttnDescriptor(
 cudnnAttnDescriptor_t attnDesc);
```

This function destroys a previously created attention descriptor.

Parameters:

Parameter	Input / Output	Description
`attnDesc`	Input	The attention descriptor to be destroyed.

Returns:

Return Value	Description
CUDNN_STATUS_SUCCESS	The descriptor was destroyed successfully.

4.41. cudnnDestroyCTCLossDescriptor

```
cudnnStatus_t cudnnDestroyCTCLossDescriptor(
    cudnnCTCLossDescriptor_t  ctcLossDesc)
```

This function destroys a CTC loss function descriptor object.

Parameters

ctcLossDesc

Input. CTC loss function descriptor to be destroyed.

Returns

`CUDNN_STATUS_SUCCESS`

The function returned successfully.

4.42. cudnnDestroyConvolutionDescriptor

```
cudnnStatus_t cudnnDestroyConvolutionDescriptor(
    cudnnConvolutionDescriptor_t convDesc)
```

This function destroys a previously created convolution descriptor object.

Returns

CUDNN_STATUS_SUCCESS

The object was destroyed successfully.

4.43. cudnnDestroyDropoutDescriptor

```
cudnnStatus_t cudnnDestroyDropoutDescriptor(
    cudnnDropoutDescriptor_t dropoutDesc)
```

This function destroys a previously created dropout descriptor object.

Returns

CUDNN_STATUS_SUCCESS

The object was destroyed successfully.

4.44. cudnnDestroyFilterDescriptor

```
cudnnStatus_t cudnnDestroyFilterDescriptor(
    cudnnFilterDescriptor_t filterDesc)
```

This function destroys a previously created Tensor4D descriptor object.

Returns

CUDNN_STATUS_SUCCESS

The object was destroyed successfully.

4.45. cudnnDestroyLRNDescriptor

```
cudnnStatus_t cudnnDestroyLRNDescriptor(
    cudnnLRNDescriptor_t lrnDesc)
```

This function destroys a previously created LRN descriptor object.

Returns

CUDNN_STATUS_SUCCESS

The object was destroyed successfully.

4.46. cudnnDestroyOpTensorDescriptor

```
cudnnStatus_t cudnnDestroyOpTensorDescriptor(
    cudnnOpTensorDescriptor_t   opTensorDesc)
```

This function deletes a Tensor Pointwise math descriptor object.

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.

4.47. cudnnDestroyPersistentRNNPlan

```
cudnnStatus_t cudnnDestroyPersistentRNNPlan(
    cudnnPersistentRNNPlan_t plan)
```

This function destroys a previously created persistent RNN plan object.

Returns

`CUDNN_STATUS_SUCCESS`

The object was destroyed successfully.

4.48. cudnnDestroyPoolingDescriptor

```
cudnnStatus_t cudnnDestroyPoolingDescriptor(
    cudnnPoolingDescriptor_t poolingDesc)
```

This function destroys a previously created pooling descriptor object.

Returns

`CUDNN_STATUS_SUCCESS`

The object was destroyed successfully.

4.49. cudnnDestroyRNNDescriptor

```
cudnnStatus_t cudnnDestroyRNNDescriptor(
    cudnnRNNDescriptor_t rnnDesc)
```

This function destroys a previously created RNN descriptor object.

Returns

`CUDNN_STATUS_SUCCESS`

The object was destroyed successfully.

4.50. cudnnDestroyRNNDataDescriptor

```
cudnnStatus_t cudnnDestroyRNNDataDescriptor(
    cudnnRNNDataDescriptor_t RNNDataDesc)
```

This function destroys a previously created RNN data descriptor object.

Returns

`CUDNN_STATUS_SUCCESS`

The RNN data descriptor object was destroyed successfully.

4.51. cudnnDestroyReduceTensorDescriptor

```
cudnnStatus_t cudnnDestroyReduceTensorDescriptor(
    cudnnReduceTensorDescriptor_t   tensorDesc)
```

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

Parameters

tensorDesc

Input. Pointer to the reduce tensor descriptor object to be destroyed.

Returns

`CUDNN_STATUS_SUCCESS`

The object was destroyed successfully.

4.52. cudnnDestroySeqDataDescriptor

```
cudnnStatus_t cudnnDestroySeqDataDescriptor(cudnnSeqDataDescriptor_t
 seqDataDesc);
```

Destroys a previously created sequence data descriptor.

Parameters:

Parameter	Input / Output	Description
seqDataDesc	Input	The sequence data descriptor to be destroyed.

Returns:

Return Value	Description
CUDNN_STATUS_SUCCESS	The descriptor was destroyed successfully.

4.53. cudnnDestroySpatialTransformerDescriptor

```
cudnnStatus_t cudnnDestroySpatialTransformerDescriptor(
    cudnnSpatialTransformerDescriptor_t stDesc)
```

This function destroys a previously created spatial transformer descriptor object.

Returns

`CUDNN_STATUS_SUCCESS`

The object was destroyed successfully.

4.54. cudnnDestroyTensorDescriptor

```
cudnnStatus_t cudnnDestroyTensorDescriptor(cudnnTensorDescriptor_t tensorDesc)
```

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

Parameters

tensorDesc

Input. Pointer to the tensor descriptor object to be destroyed.

Returns

`CUDNN_STATUS_SUCCESS`

The object was destroyed successfully.

4.55. cudnnDestroyTensorTransformDescriptor

```
cudnnStatus_t cudnnDestroyTensorTransformDescriptor(
 cudnnTensorTransformDescriptor_t transformDesc);
```

Destroys a previously created Tensor transform descriptor.

Parameters:

Parameter	Input / Output	Description
transformDesc	Input	The Tensor transform descriptor to be destroyed.

Returns:

Return Value	Description
CUDNN_STATUS_SUCCESS	The descriptor was destroyed successfully.

4.56. cudnnDivisiveNormalizationBackward

```
cudnnStatus_t 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)
```

This function performs the backward DivisiveNormalization layer computation.

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 intialized 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. Please refer to this section for additional details.

xDesc, x, means

Input. Tensor descriptor and pointers in device memory for the layer's x and means data. Note: 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 layer's resulting cumulative gradients dx and dMeans (dLoss/dx and dLoss/dMeans). Both share the same descriptor.

Possible error values returned by this function and their meanings are listed below.

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, tmep2, 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. See the following for some examples of non-supported configurations:

- Any of the input and output tensor strides mismatch (for the same dimension).

4.57. cudnnDivisiveNormalizationForward

```
cudnnStatus_t cudnnDivisiveNormalizationForward(
    cudnnHandle_t                    handle,
    cudnnLRNDescriptor_t             normDesc,
    cudnnDivNormMode_t               mode,
    const void                      *alpha,
    const cudnnTensorDescriptor_t    xDesc,
    const void                      *x,
    const void                      *means,
    void                               *temp,
    void                               *temp2,
    const void                         *beta,
    const cudnnTensorDescriptor_t       yDesc,
    void                               *y)
```

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 *"What is the Best Multi-Stage Architecture for Object Recognition"*, Jarrett 2009, Local Contrast Normalization Layer section. Note that Divisive Normalization only implements the x/max(c, sigma_x) portion of the computation, where sigma_x is the variance over the spatial neighborhood of x. The full LCN (Local Contrastive Normalization) computation can be implemented as a two-step process:

x_m = x-mean(x);

y = x_m/max(c, sigma(x_m));

The "x-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 addTensor.

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 intialized LRN parameter descriptor. This descriptor is used for both LRN and DivisiveNormalization layers.

divNormMode

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. Please refer to this section for additional details.

xDesc, yDesc

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

x

Input. Input tensor data pointer in device memory.

means

Input. Input means tensor data pointer in device memory. Note that this tensor can be NULL (in that case its values are assumed to be zero during the computation). This tensor also doesn't have to contain 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.

Possible error values returned by this function and their meanings are listed below.

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, 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. See the following for some examples of non-supported configurations:

- Any of the input and output tensor strides mismatch (for the same dimension).

4.58. cudnnDropoutBackward

```
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)
```

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**.

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 size in bytes of the provided memory for the reserve space

The possible error values returned by this function and their meanings are listed below.

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 then 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.

4.59. cudnnDropoutForward

```
cudnnStatus_t 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)
```

This function performs forward dropout operation over **`x`** returning results in **`y`**. If **`dropout`** was used as a parameter to **`cudnnSetDropoutDescriptor`**, the approximately **`dropout`** fraction of **`x`** values will be replaces by `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`**.

Better performance is obtained for fully packed tensors

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 contents of **`reserveSpace`** doe not change between **`cudnnDropoutForward`** and **`cudnnDropoutBackward`** calls.

reserveSpaceSizeInBytes

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

The possible error values returned by this function and their meanings are listed below.

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 then 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.

4.60. cudnnDropoutGetReserveSpaceSize

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

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.

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.

The possible error values returned by this function and their meanings are listed below.

Returns

`CUDNN_STATUS_SUCCESS`

The query was successful.

4.61. cudnnDropoutGetStatesSize

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

This function is used to query the amount of space required to store the states of the random number generators used by **`cudnnDropoutForward`** function.

Parameters

handle

Input. Handle to a previously created cuDNN context.

sizeInBytes

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

The possible error values returned by this function and their meanings are listed below.

Returns

`CUDNN_STATUS_SUCCESS`

The query was successful.

4.62. cudnnFindConvolutionBackwardDataAlgorithm

```
cudnnStatus_t cudnnFindConvolutionBackwardDataAlgorithm(
    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)
```

This function attempts all cuDNN algorithms (including CUDNN_TENSOR_OP_MATH and CUDNN_DEFAULT_MATH versions of algorithms where CUDNN_TENSOR_OP_MATH may be available) for **`cudnnConvolutionBackwardData()`**, using memory allocated via **`cudaMalloc()`** and outputs performance metrics to a user-allocated array of **`cudnnConvolutionBwdDataAlgoPerf_t`**. These metrics are written in sorted fashion where the first element has the lowest compute time. The total number of resulting algorithms can be queried through the API **`cudnnGetConvolutionBackwardMaxCount()`**.

This function is host blocking.

It is recommend 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.

The possible error values returned by this function and their meanings are listed below.

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 neccesary timing objects.
- The function was unable to deallocate neccesary timing objects.
- The function was unable to deallocate sample input, filters and output.

4.63. cudnnFindConvolutionBackwardDataAlgorithmEx

```
cudnnStatus_t cudnnFindConvolutionBackwardDataAlgorithmEx(
    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)
```

This function attempts all cuDNN algorithms (including CUDNN_TENSOR_OP_MATH and CUDNN_DEFAULT_MATH versions of algorithms where CUDNN_TENSOR_OP_MATH may be available) for **cudnnConvolutionBackwardData**, using user-allocated GPU memory, and outputs performance metrics to a user-allocated array of **cudnnConvolutionBwdDataAlgoPerf_t**. These metrics are written in sorted fashion where the first element has the lowest compute time. The total number of resulting algorithms can be queried through the API **cudnnGetConvolutionBackwardMaxCount()**.

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 arbitary 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 that is a necessary workspace for some algorithms. The size of this workspace will determine the availabilty of algorithms. A nil pointer is considered a workSpace of 0 bytes.

workSpaceSizeInBytes

Input. Specifies the size in bytes of the provided **`workSpace`**

The possible error values returned by this function and their meanings are listed below.

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 neccesary timing objects.
- The function was unable to deallocate neccesary timing objects.
- The function was unable to deallocate sample input, filters and output.

4.64. cudnnFindConvolutionBackwardFilterAlgorithm

```
cudnnStatus_t cudnnFindConvolutionBackwardFilterAlgorithm(
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)
```

This function attempts all cuDNN algorithms (including CUDNN_TENSOR_OP_MATH and CUDNN_DEFAULT_MATH versions of algorithms where CUDNN_TENSOR_OP_MATH may be available) for **`cudnnConvolutionBackwardFilter()`**, using GPU memory allocated via **`cudaMalloc()`**, and outputs performance metrics to a user-allocated array of **`cudnnConvolutionBwdFilterAlgoPerf_t`**. These metrics are written in sorted fashion where the first element has the lowest compute time. The total number of resulting algorithms can be queried through the API **`cudnnGetConvolutionBackwardMaxCount()`**.

This function is host blocking.

It is recommend 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.

The possible error values returned by this function and their meanings are listed below.

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`** is 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 neccesary timing objects.
- The function was unable to deallocate neccesary timing objects.
- The function was unable to deallocate sample input, filters and output.

4.65. cudnnFindConvolutionBackwardFilterAlgorithmEx

```
cudnnStatus_t 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)
```

This function attempts all cuDNN algorithms (including CUDNN_TENSOR_OP_MATH and CUDNN_DEFAULT_MATH versions of algorithms where CUDNN_TENSOR_OP_MATH may be available) for **`cudnnConvolutionBackwardFilter`**, using user-allocated GPU memory, and outputs performance metrics to a user-allocated array of **`cudnnConvolutionBwdFilterAlgoPerf_t`**. These metrics are written in sorted fashion where the first element has the lowest compute time. The total number of resulting algorithms can be queried through the API **`cudnnGetConvolutionBackwardMaxCount()`**.

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 arbitary 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 that is a necessary workspace for some algorithms. The size of this workspace will determine the availabilty of algorithms. A nil pointer is considered a workSpace of 0 bytes.

workSpaceSizeInBytes

Input. Specifies the size in bytes of the provided **`workSpace`**

The possible error values returned by this function and their meanings are listed below.

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`** is 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 neccesary timing objects.
- The function was unable to deallocate neccesary timing objects.
- The function was unable to deallocate sample input, filters and output.

4.66. cudnnFindConvolutionForwardAlgorithm

```
cudnnStatus_t 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)
```

This function attempts all cuDNN algorithms (including CUDNN_TENSOR_OP_MATH and CUDNN_DEFAULT_MATH versions of algorithms where CUDNN_TENSOR_OP_MATH may be available) for **`cudnnConvolutionForward()`**, using memory allocated via **`cudaMalloc()`**, and outputs performance metrics to a user-allocated array of **`cudnnConvolutionFwdAlgoPerf_t`**. These metrics are written in sorted fashion where the first element has the lowest compute time. The total number of resulting algorithms can be queried through the API **`cudnnGetConvolutionForwardMaxCount()`**.

This function is host blocking.

It is recommend 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.

The possible error values returned by this function and their meanings are listed below.

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`** is 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 neccesary timing objects.
- The function was unable to deallocate neccesary timing objects.
- The function was unable to deallocate sample input, filters and output.

4.67. cudnnFindConvolutionForwardAlgorithmEx

```
cudnnStatus_t 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)
```

This function attempts all available cuDNN algorithms (including CUDNN_TENSOR_OP_MATH and CUDNN_DEFAULT_MATH versions of algorithms where CUDNN_TENSOR_OP_MATH may be available) for **cudnnConvolutionForward**, using user-allocated GPU memory, and outputs performance metrics to a user-allocated array of **cudnnConvolutionFwdAlgoPerf_t**. These metrics are written in sorted fashion where the first element has the lowest compute time. The total number of resulting algorithms can be queried through the API **cudnnGetConvolutionForwardMaxCount()**.

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 arbitary 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 that 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`**.

The possible error values returned by this function and their meanings are listed below.

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`** is 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 neccesary timing objects.

- The function was unable to deallocate neccesary timing objects.
- The function was unable to deallocate sample input, filters and output.

4.68. cudnnFindRNNBackwardDataAlgorithmEx

```
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)
```

(New for 7.1)

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.

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 **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 passed to the **`cudnnSetRNNDescriptor`** call used to initialize **`rnnDesc`**:

- If **`direction`** is **`CUDNN_UNIDIRECTIONAL`** the second dimension should match the **`hiddenSize`** argument passed to **`cudnnSetRNNDescriptor`**.
- If **`direction`** is **`CUDNN_BIDIRECTIONAL`** the second dimension should match double the **`hiddenSize`** argument passed to **`cudnnSetRNNDescriptor`**.

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 passed to the **`cudnnSetRNNDescriptor`** call used to initialize **`rnnDesc`**:

- If **`direction`** is **`CUDNN_UNIDIRECTIONAL`** the second dimension should match the **`hiddenSize`** argument passed to **`cudnnSetRNNDescriptor`**.
- If **`direction`** is **`CUDNN_BIDIRECTIONAL`** the second dimension should match double the **`hiddenSize`** argument passed to **`cudnnSetRNNDescriptor`**.

The first dimension of the tensor **`n`** must match the second dimension of the tensor **`n`** 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 passed to the **`cudnnSetRNNDescriptor`** call used to initialize **`rnnDesc`**:

- If **`direction`** is **`CUDNN_UNIDIRECTIONAL`** the first dimension should match the **`numLayers`** argument passed to **`cudnnSetRNNDescriptor`**.
- If **`direction`** is **`CUDNN_BIDIRECTIONAL`** the first dimension should match double the **`numLayers`** argument passed to **`cudnnSetRNNDescriptor`**.

The second dimension must match the first dimension of the tensors described in **`dxDesc`**. The third dimension must match the **`hiddenSize`** argument passed to the **`cudnnSetRNNDescriptor`** call 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 passed to the **`cudnnSetRNNDescriptor`** call used to initialize **`rnnDesc`**:

- If **`direction`** is **`CUDNN_UNIDIRECTIONAL`** the first dimension should match the **`numLayers`** argument passed to **`cudnnSetRNNDescriptor`**.
- If **`direction`** is **`CUDNN_BIDIRECTIONAL`** the first dimension should match double the **`numLayers`** argument passed to **`cudnnSetRNNDescriptor`**.

The second dimension must match the first dimension of the tensors described in **`dxDesc`**. The third dimension must match the **`hiddenSize`** argument passed to the **`cudnnSetRNNDescriptor`** call 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 passed to the **`cudnnSetRNNDescriptor`** call used to initialize **`rnnDesc`**:

- If **`direction`** is **`CUDNN_UNIDIRECTIONAL`** the first dimension should match the **`numLayers`** argument passed to **`cudnnSetRNNDescriptor`**.
- If **`direction`** is **`CUDNN_BIDIRECTIONAL`** the first dimension should match double the **`numLayers`** argument passed to **`cudnnSetRNNDescriptor`**.

The second dimension must match the first dimension of the tensors described in **`dxDesc`**. The third dimension must match the **`hiddenSize`** argument passed to the **`cudnnSetRNNDescriptor`** call 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 passed to the **`cudnnSetRNNDescriptor`** call used to initialize **`rnnDesc`**:

- If **`direction`** is **`CUDNN_UNIDIRECTIONAL`** the first dimension should match the **`numLayers`** argument passed to **`cudnnSetRNNDescriptor`**.
- If **`direction`** is **`CUDNN_BIDIRECTIONAL`** the first dimension should match double the **`numLayers`** argument passed to **`cudnnSetRNNDescriptor`**.

The second dimension must match the first dimension of the tensors described in **`dxDesc`**. The third dimension must match the **`hiddenSize`** argument passed to the **`cudnnSetRNNDescriptor`** call 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 passed to the **`cudnnSetRNNDescriptor`** call used to initialize **`rnnDesc`**:

- If **`direction`** is **`CUDNN_UNIDIRECTIONAL`** the first dimension should match the **`numLayers`** argument passed to **`cudnnSetRNNDescriptor`**.
- If **`direction`** is **`CUDNN_BIDIRECTIONAL`** the first dimension should match double the **`numLayers`** argument passed to **`cudnnSetRNNDescriptor`**.

The second dimension must match the first dimension of the tensors described in **`dxDesc`**. The third dimension must match the **`hiddenSize`** argument passed to the **`cudnnSetRNNDescriptor`** call 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 passed to the **`cudnnSetRNNDescriptor`** call used to initialize **`rnnDesc`**:

- If **`direction`** is **`CUDNN_UNIDIRECTIONAL`** the first dimension should match the **`numLayers`** argument passed to **`cudnnSetRNNDescriptor`**.
- If **`direction`** is **`CUDNN_BIDIRECTIONAL`** the first dimension should match double the **`numLayers`** argument passed to **`cudnnSetRNNDescriptor`**.

The second dimension must match the first dimension of the tensors described in **`dxDesc`**. The third dimension must match the **`hiddenSize`** argument passed to the **`cudnnSetRNNDescriptor`** call 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 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 searched 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`**.

The possible error values returned by this function and their meanings are listed below.

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, 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, 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.

`CUDNN_STATUS_ALLOC_FAILED`

The function was unable to allocate memory.

4.69. cudnnFindRNNBackwardWeightsAlgorithmEx

```
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)
```

(New for 7.1)

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.

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 **`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 passed to the **`cudnnSetRNNDescriptor`** call used to initialize **`rnnDesc`**:

- If **`direction`** is **`CUDNN_UNIDIRECTIONAL`** the first dimension should match the **`numLayers`** argument passed to **`cudnnSetRNNDescriptor`**.
- If **`direction`** is **`CUDNN_BIDIRECTIONAL`** the first dimension should match double the **`numLayers`** argument passed to **`cudnnSetRNNDescriptor`**.

The second dimension must match the first dimension of the tensors described in **`xDesc`**. The third dimension must match the **`hiddenSize`** argument passed to the **`cudnnSetRNNDescriptor`** call 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 passed to the **`cudnnSetRNNDescriptor`** call used to initialize **`rnnDesc`**:

- If **`direction`** is **`CUDNN_UNIDIRECTIONAL`** the second dimension should match the **`hiddenSize`** argument passed to **`cudnnSetRNNDescriptor`**.
- If **`direction`** is **`CUDNN_BIDIRECTIONAL`** the second dimension should match double the **`hiddenSize`** argument passed to **`cudnnSetRNNDescriptor`**.

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 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 searched 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`**

The possible error values returned by this function and their meanings are listed below.

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`** 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.

4.70. cudnnFindRNNForwardInferenceAlgorithmEx

```
cudnnStatus_t 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,
    void                             *hy,
    const cudnnTensorDescriptor_t     cyDesc,
    void                             *cy,
    const float                      findIntensity,
    const int                        requestedAlgoCount,
    int                              *returnedAlgoCount,
    cudnnAlgorithmPerformance_t      *perfResults,
    void                             *workspace,
    size_t                            workSpaceSizeInBytes)
```

(New for 7.1)

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.

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 **`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 passed to the **`cudnnSetRNNDescriptor`** call used to initialize **`rnnDesc`**:

- If **`direction`** is **`CUDNN_UNIDIRECTIONAL`** the first dimension should match the **`numLayers`** argument passed to **`cudnnSetRNNDescriptor`**.
- If **`direction`** is **`CUDNN_BIDIRECTIONAL`** the first dimension should match double the **`numLayers`** argument passed to **`cudnnSetRNNDescriptor`**.

The second dimension must match the first dimension of the tensors described in **`xDesc`**. The third dimension must match the **`hiddenSize`** argument passed to the **`cudnnSetRNNDescriptor`** call 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 passed to the **`cudnnSetRNNDescriptor`** call used to initialize **`rnnDesc`**:

- If **`direction`** is **`CUDNN_UNIDIRECTIONAL`** the first dimension should match the **`numLayers`** argument passed to **`cudnnSetRNNDescriptor`**.
- If **`direction`** is **`CUDNN_BIDIRECTIONAL`** the first dimension should match double the **`numLayers`** argument passed to **`cudnnSetRNNDescriptor`**.

The second dimension must match the first dimension of the tensors described in **`xDesc`**. The third dimension must match the **`hiddenSize`** argument passed to the

cudnnSetRNNDescriptor call 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 passed to the **cudnnSetRNNDescriptor** call used to initialize **rnnDesc**:

- If **direction** is **CUDNN_UNIDIRECTIONAL** the second dimension should match the **hiddenSize** argument passed to **cudnnSetRNNDescriptor**.
- If **direction** is **CUDNN_BIDIRECTIONAL** the second dimension should match double the **hiddenSize** argument passed to **cudnnSetRNNDescriptor**.

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 passed to the **cudnnSetRNNDescriptor** call used to initialize **rnnDesc**:

- If **direction** is **CUDNN_UNIDIRECTIONAL** the first dimension should match the **numLayers** argument passed to **cudnnSetRNNDescriptor**.
- If **direction** is **CUDNN_BIDIRECTIONAL** the first dimension should match double the **numLayers** argument passed to **cudnnSetRNNDescriptor**.

The second dimension must match the first dimension of the tensors described in **xDesc**. The third dimension must match the **hiddenSize** argument passed to the **cudnnSetRNNDescriptor** call 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 passed to the **`cudnnSetRNNDescriptor`** call used to initialize **`rnnDesc`**:

- If **`direction`** is **`CUDNN_UNIDIRECTIONAL`** the first dimension should match the **`numLayers`** argument passed to **`cudnnSetRNNDescriptor`**.
- If **`direction`** is **`CUDNN_BIDIRECTIONAL`** the first dimension should match double the **`numLayers`** argument passed to **`cudnnSetRNNDescriptor`**.

The second dimension must match the first dimension of the tensors described in **`xDesc`**. The third dimension must match the **`hiddenSize`** argument passed to the **`cudnnSetRNNDescriptor`** call 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 be 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 0.0f, 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 searched 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, 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.

`CUDNN_STATUS_EXECUTION_FAILED`

The function failed to launch on the GPU.

`CUDNN_STATUS_ALLOC_FAILED`

The function was unable to allocate memory.

4.71. cudnnFindRNNForwardTrainingAlgorithmEx

```
cudnnStatus_t 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)
```

(New for 7.1)

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.

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 **`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 passed to the **`cudnnSetRNNDescriptor`** call used to initialize **`rnnDesc`**:

- If **`direction`** is **`CUDNN_UNIDIRECTIONAL`** the first dimension should match the **`numLayers`** argument passed to **`cudnnSetRNNDescriptor`**.
- If **`direction`** is **`CUDNN_BIDIRECTIONAL`** the first dimension should match double the **`numLayers`** argument passed to **`cudnnSetRNNDescriptor`**.

The second dimension must match the first dimension of the tensors described in **`xDesc`**. The third dimension must match the **`hiddenSize`** argument passed to the

cudnnSetRNNDescriptor call 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 passed to the **cudnnSetRNNDescriptor** call used to initialize **rnnDesc**:

- If **direction** is **CUDNN_UNIDIRECTIONAL** the first dimension should match the **numLayers** argument passed to **cudnnSetRNNDescriptor**.
- If **direction** is **CUDNN_BIDIRECTIONAL** the first dimension should match double the **numLayers** argument passed to **cudnnSetRNNDescriptor**.

The second dimension must match the first dimension of the tensors described in **xDesc**. The third dimension must match the **hiddenSize** argument passed to the **cudnnSetRNNDescriptor** call 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 passed to the **cudnnSetRNNDescriptor** call used to initialize **rnnDesc**:

- If **direction** is **CUDNN_UNIDIRECTIONAL** the second dimension should match the **hiddenSize** argument passed to **cudnnSetRNNDescriptor**.
- If **direction** is **CUDNN_BIDIRECTIONAL** the second dimension should match double the **hiddenSize** argument passed to **cudnnSetRNNDescriptor**.

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 passed to the **`cudnnSetRNNDescriptor`** call used to initialize **`rnnDesc`**:

- If **`direction`** is **`CUDNN_UNIDIRECTIONAL`** the first dimension should match the **`numLayers`** argument passed to **`cudnnSetRNNDescriptor`**.
- If **`direction`** is **`CUDNN_BIDIRECTIONAL`** the first dimension should match double the **`numLayers`** argument passed to **`cudnnSetRNNDescriptor`**.

The second dimension must match the first dimension of the tensors described in **`xDesc`**. The third dimension must match the **`hiddenSize`** argument passed to the **`cudnnSetRNNDescriptor`** call 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 passed to the **`cudnnSetRNNDescriptor`** call used to initialize **`rnnDesc`**:

- If **`direction`** is **`CUDNN_UNIDIRECTIONAL`** the first dimension should match the **`numLayers`** argument passed to **`cudnnSetRNNDescriptor`**.
- If **`direction`** is **`CUDNN_BIDIRECTIONAL`** the first dimension should match double the **`numLayers`** argument passed to **`cudnnSetRNNDescriptor`**.

The second dimension must match the first dimension of the tensors described in **`xDesc`**. The third dimension must match the **`hiddenSize`** argument passed to the **`cudnnSetRNNDescriptor`** call 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 be 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 0.0f, 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 searched 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`**

The possible error values returned by this function and their meanings are listed below.

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_EXECUTION_FAILED

The function failed to launch on the GPU.

CUDNN_STATUS_ALLOC_FAILED

The function was unable to allocate memory.

4.72. cudnnGetActivationDescriptor

```
cudnnStatus_t cudnnGetActivationDescriptor(
        const cudnnActivationDescriptor_t   activationDesc,
        cudnnActivationMode_t              *mode,
        cudnnNanPropagation_t              *reluNanOpt,
        double                             *coef)
```

This function queries a previously initialized generic activation descriptor object.

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 threashod 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**.

The possible error values returned by this function and their meanings are listed below.

Returns

CUDNN_STATUS_SUCCESS

The object was queried successfully.

4.73. cudnnGetAlgorithmDescriptor

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

(New for 7.1)

This function queries a previously initialized generic algorithm descriptor object.

Parameters

algorithmDesc

Input. Handle to a previously created algorithm descriptor.

algorithm

Input. Struct to specify the algorithm.

Returns

`CUDNN_STATUS_SUCCESS`

The object was queried successfully.

4.74. cudnnGetAlgorithmPerformance

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

(New for 7.1)

This function queries a previously initialized generic algorithm performance object.

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.

timecoef

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.

4.75. cudnnGetAlgorithmSpaceSize

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

(New for 7.1)

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

Parameters

handle

Input. Handle to a previously created cuDNN context.

algoDesc

Input. A previously created algorithm descriptor.

algoSpaceSizeInBytes

Ouptut. Amount of host memory needed as 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.

4.76. cudnnGetAttnDescriptor

```
cudnnStatus_t cudnnGetAttnDescriptor(
 cudnnAttnDescriptor_t attnDesc,
 cudnnAttnQueryMap_t *queryMap,
 int *nHeads,
 double *smScaler,
 cudnnDataType_t *dataType,
 cudnnDataType_t *computePrec,
 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);
```

This function retrieves the values from a previously initialized attention descriptor.

Parameters:

Parameter	Input / Output	Description
attnDesc	Input	Attention descriptor whose values are to be retrieved.
queryMap	Output	Query mapping mode.

nHeads	Output	Number of attention heads.
smScaler	Output	Softmax smoothing, or sharpening, coefficient.
dataType	Output	Data type for Q,K,V inputs, weights, and the output.
computePrec	Output	Compute data type (precision).
mathType	Output	The Tensor Core Operations settings.
attnDropoutDesc	Output	Dropout descriptor for the dropout at the attention layer.
postDropoutDesc	Output	Dropout descriptor for the dropout at the output.
qSize, kSize, vSize	Output	Hidden size of Q, K, and V input sequence data.
qProjSize, kProjSize, vProjSize	Output	Hidden size of projected Q, K and V sequence data; 0 if no projection.
oProjSize	Output	Output projection size.
qoMaxSeqLength	Output	Largest sequence length allowed in sequence data Q and O.
kvMaxSeqLength	Output	Largest sequence length allowed in sequence data K and V.
maxBatchSize	Output	Largest batch size allowed in sequence data.
maxBeamSize	Output	Largest beam size allowed in sequence data.

Returns:

Return Value	Description
CUDNN_STATUS_BAD_PARAM	`attDesc` is a NULL pointer.
CUDNN_STATUS_SUCCESS	The attention descriptor structure values are retrieved successfully.

4.77. cudnnBatchNormalizationBackwardExWorkspaceSize

```
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);
```

This function returns the amount of GPU memory workspace the user should allocate to be able to call cudnnGetBatchNormalizationBackwardEx() function for the specified **bnOps** input setting. The workspace allocated will then be passed to the function **cudnnGetBatchNormalizationBackwardEx()**.

Parameters

handle

Input. Handle to a previously created cuDNN library descriptor. See cudnnHandle_t.

mode

Input. Mode of operation (spatial or per-activation). See cudnnBatchNormMode_t.

bnOps

Input. Mode of operation for the fast NHWC kernel. See 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**. See 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: The data type of this tensor descriptor must be 'float' for FP16 and FP32 input tensors, and 'double' for FP64 input tensors.

activationDesc

Input. Tensor descriptor for the activation operation.

***sizeInBytes**

Output. Amount of GPU memory required for the workspace, as determined by this function, to be able to execute the **cudnnGetBatchNormalizationBackwardEx()** function with the specified **bnOps** input setting.

Possible error values returned by this function and their meanings are listed below.

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`** or **`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, dxDesc

4.78. cudnnBatchNormalizationForwardTrainingExWorkspac

```
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);
```

This function returns the amount of GPU memory workspace the user should allocate to be able to call **`cudnnGetBatchNormalizationForwardTrainingEx()`** function for the specified **`bnOps`** input setting. The workspace allocated should then be passed by the user to the function **`cudnnGetBatchNormalizationForwardTrainingEx()`**.

Parameters

handle

Input. Handle to a previously created cuDNN library descriptor. See cudnnHandle_t.

mode

Input. Mode of operation (spatial or per-activation). See cudnnBatchNormMode_t.

bnOps

Input. Mode of operation for the fast NHWC kernel. See 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. See 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: The data type of this tensor descriptor must be 'float' for FP16 and FP32 input tensors, and 'double' for FP64 input tensors.

activationDesc

Input. 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.

***sizeInBytes**

Output. Amount of GPU memory required for the workspace, as determined by this function, to be able to execute the **`cudnnGetBatchNormalizationForwardTrainingEx()`** 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`** or **`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, yDesc`**.

4.79. cudnnGetBatchNormalizationTrainingExReserveSpace

```
cudnnStatus_t cudnnGetBatchNormalizationTrainingExReserveSpaceSize(
    cudnnHandle_t                      handle,
    cudnnBatchNormMode_t               mode,
    cudnnBatchNormOps_t                bnOps,
    const cudnnActivationDescriptor_t  activationDesc,
    const cudnnTensorDescriptor_t      xDesc,
    size_t                             *sizeInBytes);
```

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.

Parameters

handle

Input. Handle to a previously created cuDNN library descriptor. See cudnnHandle_t.

mode

Input. Mode of operation (spatial or per-activation). See cudnnBatchNormMode_t.

bnOps

Input. Mode of operation for the fast NHWC kernel. See 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. See cudnnTensorDescriptor_t.

activationDesc

Input. Tensor descriptor for the activation operation.

***sizeInBytes**

Output. Amount of GPU memory reserved.

Possible error values returned by this function and their meanings are listed below.

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.)

4.80. cudnnGetCTCLossDescriptor

```
cudnnStatus_t cudnnGetCTCLossDescriptor(
    cudnnCTCLossDescriptor_t         ctcLossDesc,
    cudnnDataType_t*                 compType)
```

This function returns configuration of the passed CTC loss function descriptor.

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

`CUDNN_STATUS_SUCCESS`

The function returned successfully.

`CUDNN_STATUS_BAD_PARAM`

Input OpTensor descriptor passed is invalid.

4.81. cudnnGetCTCLossWorkspaceSize

```
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)
```

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`**.

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 gradients 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`**.

The possible error values returned by this function and their meanings are listed below.

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.

4.82. cudnnGetCallback

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

(New for 7.1)

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

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.

4.83. cudnnGetConvolution2dDescriptor

```
cudnnStatus_t cudnnGetConvolution2dDescriptor(
    const 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)
```

This function queries a previously initialized 2D convolution descriptor object.

Parameters

convDesc

Input/Output. 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.

The possible error values returned by this function and their meanings are listed below.

Returns

`CUDNN_STATUS_SUCCESS`

The operation was successful.

`CUDNN_STATUS_BAD_PARAM`

The parameter **`convDesc`** is nil.

4.84. cudnnGetConvolution2dForwardOutputDim

```
cudnnStatus_t cudnnGetConvolution2dForwardOutputDim(
    const cudnnConvolutionDescriptor_t  convDesc,
    const cudnnTensorDescriptor_t        inputTensorDesc,
    const cudnnFilterDescriptor_t        filterDesc,
    int                                 *n,
    int                                 *c,
    int                                 *h,
    int                                 *w)
```

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.

Each dimension **`h and w`** of the output images is computed as followed:

```
    outputDim = 1 + ( inputDim + 2*pad - (((filterDim-1)*dilation)+1) )/
convolutionStride;
```

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.

The possible error values returned by this function and their meanings are listed below.

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.

4.85. cudnnGetConvolutionBackwardDataAlgorithm

```
cudnnStatus_t cudnnGetConvolutionBackwardDataAlgorithm(
    cudnnHandle_t                          handle,
    const cudnnFilterDescriptor_t          wDesc,
    const cudnnTensorDescriptor_t          dyDesc,
    const cudnnConvolutionDescriptor_t     convDesc,
    const cudnnTensorDescriptor_t          dxDesc,
    cudnnConvolutionBwdDataPreference_t    preference,
    size_t                                 memoryLimitInBytes,
    cudnnConvolutionBwdDataAlgo_t         *algo)
```

This function serves as a heuristic for obtaining the best suited algorithm for **cudnnConvolutionBackwardData** for the given layer specifications. Based on the input preference, this function will either return the fastest algorithm or the fastest algorithm within a given memory limit. For an exhaustive search for the fastest algorithm, please use **cudnnFindConvolutionBackwardDataAlgorithm**.

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.

preference

Input. Enumerant to express the preference criteria in terms of memory requirement and speed.

memoryLimitInBytes

Input. It is to specify the maximum amount of GPU memory the user is willing to use as a workspace. This is currently a placeholder and is not used.

algo

Output. Enumerant that specifies which convolution algorithm should be used to compute the results according to the specified preference

The possible error values returned by this function and their meanings are listed below.

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.

4.86. cudnnGetConvolutionBackwardDataAlgorithmMaxCou

```
cudnnStatus_t cudnnGetConvolutionBackwardDataAlgorithmMaxCount(
    cudnnHandle_t       handle,
    int                 *count)
```

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.

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.

4.87. cudnnGetConvolutionBackwardDataAlgorithm_v7

```
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)
```

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 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, please use **`cudnnFindConvolutionBackwardDataAlgorithm`**. The total number of resulting algorithms can be queried through the API **`cudnnGetConvolutionBackwardMaxCount()`**.

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.

The possible error values returned by this function and their meanings are listed below.

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, 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.

4.88. cudnnGetConvolutionBackwardDataWorkspaceSize

```
cudnnStatus_t 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)
```

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`** 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.

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`**

The possible error values returned by this function and their meanings are listed below.

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.

4.89. cudnnGetConvolutionBackwardFilterAlgorithm

```
cudnnStatus_t cudnnGetConvolutionBackwardFilterAlgorithm(
    cudnnHandle_t                          handle,
    const cudnnTensorDescriptor_t          xDesc,
    const cudnnTensorDescriptor_t          dyDesc,
    const cudnnConvolutionDescriptor_t     convDesc,
    const cudnnFilterDescriptor_t          dwDesc,
    cudnnConvolutionBwdFilterPreference_t  preference,
    size_t                                 memoryLimitInBytes,
    cudnnConvolutionBwdFilterAlgo_t       *algo)
```

This function serves as a heuristic for obtaining the best suited algorithm for **`cudnnConvolutionBackwardFilter`** for the given layer specifications. Based on the input preference, this function will either return the fastest algorithm or the fastest algorithm within a given memory limit. For an exhaustive search for the fastest algorithm, please use **`cudnnFindConvolutionBackwardFilterAlgorithm`**.

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.

preference

Input. Enumerant to express the preference criteria in terms of memory requirement and speed.

memoryLimitInBytes

Input. It is to specify the maximum amount of GPU memory the user is willing to use as a workspace. This is currently a placeholder and is not used.

algo

Output. Enumerant that specifies which convolution algorithm should be used to compute the results according to the specified preference.

The possible error values returned by this function and their meanings are listed below.

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.

4.90. cudnnGetConvolutionBackwardFilterAlgorithmMaxCou

```
cudnnStatus_t cudnnGetConvolutionBackwardFilterAlgorithmMaxCount(
    cudnnHandle_t       handle,
    int                 *count)
```

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.

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.

CUDNN_STATUS_BAD_PARAM

The provided handle is not allocated properly.

4.91. cudnnGetConvolutionBackwardFilterAlgorithm_v7

```
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)
```

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, please use **`cudnnFindConvolutionBackwardFilterAlgorithm`**. The total number of resulting algorithms can be queried through the API **`cudnnGetConvolutionBackwardMaxCount()`**.

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.

The possible error values returned by this function and their meanings are listed below.

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, 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.

4.92. cudnnGetConvolutionBackwardFilterWorkspaceSize

```
cudnnStatus_t 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)
```

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`** 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.

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`**.

The possible error values returned by this function and their meanings are listed below.

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.

4.93. cudnnGetConvolutionForwardAlgorithm

```
cudnnStatus_t cudnnGetConvolutionForwardAlgorithm(
    cudnnHandle_t                      handle,
    const cudnnTensorDescriptor_t      xDesc,
    const cudnnFilterDescriptor_t      wDesc,
    const cudnnConvolutionDescriptor_t convDesc,
    const cudnnTensorDescriptor_t      yDesc,
    cudnnConvolutionFwdPreference_t    preference,
    size_t                             memoryLimitInBytes,
    cudnnConvolutionFwdAlgo_t         *algo)
```

This function serves as a heuristic for obtaining the best suited algorithm for **`cudnnConvolutionForward`** for the given layer specifications. Based on the input preference, this function will either return the fastest algorithm or the fastest algorithm within a given memory limit. For an exhaustive search for the fastest algorithm, please use **`cudnnFindConvolutionForwardAlgorithm`**.

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.

preference

Input. Enumerant to express the preference criteria in terms of memory requirement and speed.

memoryLimitInBytes

Input. It is used when enumerant **`preference`** is set to **`CUDNN_CONVOLUTION_FWD_SPECIFY_WORKSPACE_LIMIT`** to specify the maximum amount of GPU memory the user is willing to use as a workspace

algo

Output. Enumerant that specifies which convolution algorithm should be used to compute the results according to the specified preference

The possible error values returned by this function and their meanings are listed below.

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 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.

4.94. cudnnGetConvolutionForwardAlgorithmMaxCount

```
cudnnStatus_t cudnnGetConvolutionForwardAlgorithmMaxCount(
    cudnnHandle_t   handle,
    int             *count)
```

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.

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.

4.95. cudnnGetConvolutionForwardAlgorithm_v7

```
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)
```

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 fastest being index 0 of perfResults. For an exhaustive search for the fastest algorithm, please use **`cudnnFindConvolutionForwardAlgorithm`**. The total number of resulting algorithms can be queried through the API **`cudnnGetConvolutionForwardMaxCount()`**.

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.

The possible error values returned by this function and their meanings are listed below.

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, 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.

4.96. cudnnGetConvolutionForwardWorkspaceSize

```
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)
```

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`** 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.

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`**

The possible error values returned by this function and their meanings are listed below.

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 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.

4.97. cudnnGetConvolutionGroupCount

```
cudnnStatus_t cudnnGetConvolutionGroupCount(
    cudnnConvolutionDescriptor_t    convDesc,
    int                            *groupCount)
```

This function returns the group count specified in the given convolution descriptor.

Returns

CUDNN_STATUS_SUCCESS

The group count was returned successfully.

CUDNN_STATUS_BAD_PARAM

An invalid convolution descriptor was provided.

4.98. cudnnGetConvolutionMathType

```
cudnnStatus_t cudnnGetConvolutionMathType(
    cudnnConvolutionDescriptor_t    convDesc,
    cudnnMathType_t                *mathType)
```

This function returns the math type specified in a given convolution descriptor.

Returns

CUDNN_STATUS_SUCCESS

The math type was returned successfully.

CUDNN_STATUS_BAD_PARAM

An invalid convolution descriptor was provided.

4.99. cudnnGetConvolutionNdDescriptor

```
cudnnStatus_t cudnnGetConvolutionNdDescriptor(
    const cudnnConvolutionDescriptor_t  convDesc,
    int                                 arrayLengthRequested,
    int                                *arrayLength,
    int                                 padA[],
    int                                 filterStrideA[],
    int                                 dilationA[],
    cudnnConvolutionMode_t              *mode,
    cudnnDataType_t                     *dataType)
```

This function queries a previously initialized convolution descriptor object.

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

`CUDNN_STATUS_SUCCESS`

The query was successfully.

`CUDNN_STATUS_BAD_PARAM`

At least one of the following conditions are met:

- The descriptor **`convDesc`** is nil.
- The **`arrayLengthRequest`** is negative.

`CUDNN_STATUS_NOT_SUPPORTED`

The **`arrayLengthRequested`** is greater than CUDNN_DIM_MAX-2.

4.100. cudnnGetConvolutionNdForwardOutputDim

```
cudnnStatus_t cudnnGetConvolutionNdForwardOutputDim(
    const cudnnConvolutionDescriptor_t  convDesc,
    const cudnnTensorDescriptor_t       inputTensorDesc,
    const cudnnFilterDescriptor_t       filterDesc,
    int                                 nbDims,
    int                                 tensorOuputDimA[])
```

This function returns the dimensions of the resulting n-D 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.

Each dimension of the **`(nbDims-2)-D`** images of the output tensor is computed as followed:

```
    outputDim = 1 + ( inputDim + 2*pad - (((filterDim-1)*dilation)+1) )/
convolutionStride;
```

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

The possible error values returned by this function and their meanings are listed below.

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 exits successfully.

4.101. cudnnGetCudartVersion

```
size_t 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.

4.102. cudnnGetDropoutDescriptor

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

This function queries the fields of a previously initialized dropout descriptor.

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.

The possible error values returned by this function and their meanings are listed below.

Returns

`CUDNN_STATUS_SUCCESS`

The call was successful.

CUDNN_STATUS_BAD_PARAM

One or more of the arguments was an invalid pointer.

4.103. cudnnGetErrorString

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

This function converts the cuDNN status code to a NUL 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".

Parameters

status

Input. cuDNN enumerated status code.

Returns

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

4.104. cudnnGetFilter4dDescriptor

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

This function queries the parameters of the previouly initialized filter descriptor object.

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.

The possible error values returned by this function and their meanings are listed below.

Returns

`CUDNN_STATUS_SUCCESS`

The object was set successfully.

4.105. cudnnGetFilterNdDescriptor

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

This function queries a previously initialized filter descriptor object.

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 dimension of at least **`nbDimsRequested`** that will be filled with the filter parameters from the provided filter descriptor.

The possible error values returned by this function and their meanings are listed below.

Returns

`CUDNN_STATUS_SUCCESS`

The object was set successfully.

`CUDNN_STATUS_BAD_PARAM`

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

4.106. cudnnGetLRNDescriptor

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

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

Parameters

normDesc

Output. Handle to a previously created LRN descriptor.

lrnN, lrnAlpha, lrnBeta, lrnK

Output. Pointers to receive values of parameters stored in the descriptor object. See cudnnSetLRNDescriptor for more details. Any of these pointers can be NULL (no value is returned for the corresponding parameter).

Possible error values returned by this function and their meanings are listed below.

Returns

CUDNN_STATUS_SUCCESS

Function completed successfully.

4.107. cudnnGetMultiHeadAttnBuffers

```
cudnnStatus_t cudnnGetMultiHeadAttnBuffers(
 cudnnHandle_t handle,
 const cudnnAttnDescriptor_t attnDesc,
 size_t *weightSizeInBytes,
 size_t *workSpaceSizeInBytes,
 size_t *reserveSpaceSizeInBytes);
```

This function obtains workspace and reserve space sizes for the multihead attention. When only the workspace size is requested with NULL value for **reserveSpaceSizeInBytes**, it is assumed that the user intention is to invoke cudnnMultiHeadAttnForward in the "inference" mode.

Parameters:

Parameter	Input / Output	Description
handle	Input	cuDNN handle.
attnDesc	Input	Pointer to a previously initialized multi-head attention descriptor.
weightSizeInBytes	Output	Size required to store various projection weights.
workSpaceSizeInBytes	Output	Size required for workspace.

reserveSpaceSizeInBytes	Output	Size required for the reserve space in training mode.

Returns:

Return Value	Description
CUDNN_STATUS_SUCCESS	The requested spaces values are evaluated successfully.
CUDNN_STATUS_BAD_PARAM	Either invalid values in **`attnDesc`** or **`workSpaceSizeInBytes`** is NULL.

4.108. cudnnGetMultiHeadAttnWeights

```
cudnnStatus_t cudnnGetMultiHeadAttnWeights(
 cudnnHandle_t handle,
 const cudnnAttnDescriptor_t attnDesc,
 cudnnMultiHeadAttnWeightKind_t wKind,
 size_t weightSizeInBytes,
 const void *w,
 cudnnTensorDescriptor_t wDesc,
 void **wAddr);
```

This function obtains the tensor descriptors and pointers to project weight of a particular kind in the weight buffer w of size **`weightSizeInBytes`**. There are four kinds of weights, enumerated in the type cudnnMultiHeadAttnWeightKind_t.

Parameters:

Parameter	Input / Output	Description
handle	Input	A cuDNN context handle.
attnDesc	Input	A previously initialized multi-head attention descriptor.
wKind	Input	The specific weight group (Q, K, V, or O) whose attention weights should be retrieved.
weightSizeInBytes	Input	Pointer to a location, in host memory, where the attention weight sizes (in bytes) are stored.
w	Input	Pointer to weight buffer in device memory.
wDesc	Output	Tensor descriptor for the attention weights. - **`wDesc.dimA`** are all [nHeads, projected size, input size] - **`wDesc.strideA`** describe how the buffer is packed, depending on the projection weight kind.
wAddr	Output	Pointer to a location, in device memory, of the requested weight tensor. Weight tensor is three dimensional whose

		dimensions and layout are also returned in tensor descriptor **`wDesc`**. If any of queries, keys, values, or output projection size is zero in the attention descriptor, then **`wAddr`** is set to NULL. Check for this before applying the weights.

Returns:

Return Value	Description
CUDNN_STATUS_SUCCESS	When weight tensor descriptor and address in the device memory are successfully determined.
CUDNN_STATUS_BAD_PARAM	Invalid or inconsistent value is found. For example when **`wKind`** does not have a valid value or when **`weightSizeInBytes`** is not equal to the weight buffer size as computed by cudnnGetMultiHeadAttnBuffers.

4.109. cudnnGetOpTensorDescriptor

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

This function returns configuration of the passed Tensor Pointwise math descriptor.

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.

4.110. cudnnGetPooling2dDescriptor

```
cudnnStatus_t cudnnGetPooling2dDescriptor(
    const cudnnPoolingDescriptor_t      poolingDesc,
    cudnnPoolingMode_t                 *mode,
    cudnnNanPropagation_t              *maxpoolingNanOpt,
    int                                *windowHeight,
    int                                *windowWidth,
    int                                *verticalPadding,
    int                                *horizontalPadding,
    int                                *verticalStride,
    int                                *horizontalStride)
```

This function queries a previously created 2D pooling descriptor object.

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.

The possible error values returned by this function and their meanings are listed below.

Returns

CUDNN_STATUS_SUCCESS

The object was set successfully.

4.111. cudnnGetPooling2dForwardOutputDim

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

This function provides the output dimensions of a tensor after 2d pooling has been applied

Each dimension **`h and w`** of the output images is computed as followed:

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

Parameters

poolingDesc

Input. Handle to a previously inititalized 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.

The possible error values returned by this function and their meanings are listed below.

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).

4.112. cudnnGetPoolingNdDescriptor

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

This function queries a previously initialized generic pooling descriptor object.

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

Input. 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.

The possible error values returned by this function and their meanings are listed below.

Returns

`CUDNN_STATUS_SUCCESS`

The object was queried successfully.

`CUDNN_STATUS_NOT_SUPPORTED`

The parameter **`nbDimsRequested`** is greater than CUDNN_DIM_MAX.

4.113. cudnnGetPoolingNdForwardOutputDim

```
cudnnStatus_t cudnnGetPoolingNdForwardOutputDim(
    const cudnnPoolingDescriptor_t  poolingDesc,
    const cudnnTensorDescriptor_t   inputDesc,
    int                             nbDims,
    int                             outDimA[])
```

This function provides the output dimensions of a tensor after Nd pooling has been applied

Each dimension of the **(nbDims-2)-D** images of the output tensor is computed as followed:

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

Parameters

poolingDesc

Input. Handle to a previously inititalized 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 nbDims output dimensions.

The possible error values returned by this function and their meanings are listed below.

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**.

4.114. cudnnGetProperty

```
cudnnStatus_t cudnnGetProperty(
    libraryPropertyType     type,
    int                    *value)
```

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

Parameters

type

Input. Enumerated type that instructs the function to report the numerical value of the cuDNN major version, minor version, or the 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.

4.115. 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**

Input. Pointer 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 set successfully.

4.116. cudnnGetRNNDataDescriptor

```
cudnnStatus_t cudnnGetRNNDataDescriptor(
    cudnnRNNDataDescriptor_t       RNNDataDesc,
    cudnnDataType_t                *dataType,
    cudnnRNNDataLayout_t           *layout,
    int                            *maxSeqLength,
    int                            *batchSize,
    int                            *vectorSize,
    int                                arrayLengthRequested,
    int                                seqLengthArray[],
    void                               *paddingFill);
```

This function retrieves a previously created RNN data descriptor object.

Parameters

RNNDataDesc

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.

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 (i.e. embedding size) of the input or output tensor at each timestep.

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 (i.e. number of timesteps) of each sequence. This is allowed to be a NULL pointer if **`arrayLengthRequested`** is zero.

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`**, **`paddingFill`** is NULL.
- **`seqLengthArray`** is NULL while **`arrayLengthRequested`** is greater than zero.
- **`arrayLengthRequested`** is less than zero.

4.117. cudnnGetRNNDescriptor

```
cudnnStatus_t cudnnGetRNNDescriptor(
    cudnnHandle_t                 handle,
    cudnnRNNDescriptor_t          rnnDesc,
    int *                         hiddenSize,
    int *                         numLayers,
    cudnnDropoutDescriptor_t *    dropoutDesc,
    cudnnRNNInputMode_t *         inputMode,
    cudnnDirectionMode_t *        direction,
    cudnnRNNMode_t *              mode,
    cudnnRNNAlgo_t *              algo,
    cudnnDataType_t *             dataType)
```

This function retrieves RNN network parameters that were configured by cudnnSetRNNDescriptor(). 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 network parameters. The parameters are verified when they are written to the RNN descriptor.

Parameters

handle

Input. Handle to a previously created cuDNN library descriptor.

rnnDesc

Input. A previously created and initialized RNN descriptor.

hiddenSize

Output. Pointer where the size of the hidden state should be stored (the same value is used in every layer).

numLayers

Output. Pointer where the number of RNN layers should be stored.

dropoutDesc

Output. Pointer where the handle to a previously configured dropout descriptor should be stored.

inputMode

Output. Pointer where the mode of the first RNN layer should be saved.

direction

Output. Pointer where RNN uni-directional/bi-directional mode should be saved.

mode

Output. Pointer where RNN cell type should be saved.

algo

Output. Pointer where RNN algorithm type should be stored.

dataType

Output. Pointer where the data type of RNN weights/biases 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 cudnnGetRNNDescriptor() function is NULL.

4.118. cudnnGetRNNLinLayerBiasParams

```
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`**.

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 returned the total number of vector elements in **`linLayerBiasDesc`** as follows:

```
filterDimA[0]=total_size,
filterDimA[1]=1,
filterDimA[2]=1
```

(see the description of the cudnnGetFilterNdDescriptor() function).

In v7.1.1, the format was changed to:

```
filterDimA[0]=1,
filterDimA[1]=rows,
filterDimA[2]=1 (number of columns).
```

In both cases, the "format" field of the filter descriptor should be ignored when retrieved by **`cudnnGetFilterNdDescriptor()`**.

Note that the RNN implementation in cuDNN uses two bias vectors before the cell non-linear function (see equations in Chapter 3 describing the **`cudnnRNNMode_t`** enumerated type).

Note that the RNN implementation in cuDNN depends on the number of bias vectors before the cell non-linear function. See the equations in the cudnnRNNMode_t description, for the enumerated type based on the value of

cudnnRNNBiasMode_tbiasMode 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
filterDimA[2]=2
```

and sets **linLayerBias** to NULL. See the details for 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 uni-directional RNN-s, 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 bi-directional RNN-s there are twice as many pseudo-layers in comparison to "physical" layers (pseudoLayer=0 and pseudoLayer=1 are both input layers; pseudoLayer=0 refers to the forward part and 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_INP_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_INP_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 **`biasMode`** in **`rnnDesc`** is **`CUDNN_RNN_SINGLE_INP_BIAS`** or **`CUDNN_RNN_DOUBLE_BIAS`**).
    - Values of 3, 4 and 5 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 3 reference the reset gate.
        - Values 1 and 4 reference the update gate.
        - Values 2 and 5 reference the new memory gate.

Also refer to cudnnRNNMode_t for additional details on modes and bias modes.

linLayerBiasDesc

Output. Handle to a previously created filter descriptor.

linLayerBias

Output. Data pointer to GPU memory associated with the filter descriptor **`linLayerBiasDesc`**.

The possible error values returned by this function and their meanings are listed below.

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`**, **`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 be outside the 'w' buffer boundaries as specified by the **wDesc** descriptor.

4.119. cudnnGetRNNLinLayerMatrixParams

```
cudnnStatus_t 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**.

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, e.g 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 v7.1.1, 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 uni-directional RNN-s, 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 bi-directional RNN-s there are twice as many pseudo-layers in comparison to "physical" layers (pseudoLayer=0 and pseudoLayer=1 are both input layers; pseudoLayer=0 refers to the forward part and 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`** a value of 0 references the matrix multiplication applied to the input from the previous layer, a value of 1 references the matrix multiplication applied to the recurrent input.
- If **`mode`** in **`rnnDesc`** was set to **`CUDNN_LSTM`** values of 0-3 reference matrix multiplications applied to the input from the previous layer, value of 4-7 reference matrix multiplications applied to the recurrent input.
  - 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.
  - Value 8 references the "recurrent" projection matrix when enabled by the cudnnSetRNNProjectionLayers() function.
- If **`mode`** in **`rnnDesc`** was set to **`CUDNN_GRU`** values of 0-2 reference matrix multiplications applied to the input from the previous layer, value of 3-5 reference matrix multiplications applied to the recurrent input.
  - 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.

Please refer to Chapter 3 for additional details on modes.

linLayerMatDesc

Output. Handle to a previously created filter descriptor. When the weight matrix does not exist, the returned filer descriptor has all fields set to zero.

linLayerMat

Output. Data pointer to GPU memory associated with the filter descriptor **linLayerMatDesc**. When the weight matrix does not exist, the returned pointer is NULL.

The possible error values returned by this function and their meanings are listed below.

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**, **linLayerMatDesc**, **linLayerMat**.
- 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 **linLayerMat** vector are be outside the **'w'** buffer boundaries as specified by the **wDesc** descriptor.

4.120. 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 inputs 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.

The possible error values returned by this function and their meanings are listed below.

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.

4.121. 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.

4.122. cudnnGetRNNProjectionLayers

```
cudnnStatus_t cudnnGetRNNProjectionLayers(
    cudnnHandle_t           handle,
    cudnnRNNDescriptor_t    rnnDesc,
    int                     *recProjSize,
    int                     *outProjSize)
```

(New for 7.1)

This function retrieves the current RNN "projection" parameters. By default the projection feature is disabled so invoking this function immediately after cudnnSetRNNDescriptor() 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.

4.123. 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 inputs 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 **`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.

The possible error values returned by this function and their meanings are listed below.

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`** is not fully packed.

`CUDNN_STATUS_NOT_SUPPORTED`

The the data types in tensors described by xDesc is not supported.

4.124. cudnnGetRNNWorkspaceSize

```
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 inputs 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 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 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.

The possible error values returned by this function and their meanings are listed below.

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`** is not fully packed.

`CUDNN_STATUS_NOT_SUPPORTED`

The data types in tensors described by xDesc is not supported.

4.125. cudnnGetReduceTensorDescriptor

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

This function queries a previously initialized reduce tensor descriptor object.

Parameters

reduceTensorDesc

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

reduceTensorOp

Output. Enumerant to specify the reduce tensor operation.

reduceTensorCompType

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

reduceTensorNanOpt

Input. Enumerant to specify the Nan propagation mode.

reduceTensorIndices

Output. Enumerant to specify the reduce tensor indices.

reduceTensorIndicesType

Output. Enumerant to specify the reduce tensor indices type.

Returns

CUDNN_STATUS_SUCCESS

The object was queried successfully.

CUDNN_STATUS_BAD_PARAM

reduceTensorDesc is NULL.

4.126. cudnnGetReductionIndicesSize

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

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.

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.

4.127. cudnnGetReductionWorkspaceSize

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

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.

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.

4.128. cudnnGetSeqDataDescriptor

```
cudnnStatus_t cudnnGetSeqDataDescriptor(
 const cudnnSeqDataDescriptor_t seqDataDesc,
 cudnnDataType_t *dataType,
 int *nbDims,
 int nbDimsRequested,
 int dimA[],
 cudnnSeqDataAxis_t axes[],
 size_t *seqLengthArraySize,
 size_t seqLengthSizeRequsted,
 int seqLengthArray[],
 void *paddingFill);
```

This function returns the current values stored in a previously initialized sequence data descriptor.

Parameters:

Parameter	Input / Output	Description
seqDataDesc	Input	A sequence data descriptor whose present value is requested.
dataType	Output	The data type of the sequence data.
nbDims	Output	Number of dimensions.
nbDimsRequested	Input	Number of elements of **dimA** (the axes array) requested. Only the first **nbDimsRequested** elements or **nbDims** elements, whichever is smaller, is reported.
dimA[]	Output	Size of the axes dimensions.
axes[]	Output	Axes, in the order of outermost to innermost dimension.
seqLengthArraySize	Output	Length of **seqLengthArray**.
seqLengthSizeRequested	Input	Number of elements of **seqLengthArray** requested. Only the first **seqLengthArraySize** elements, or **seqLengthSizeRequsted** elements, whichever is smaller, is reported.
seqLengthArray[]	Output	Length of each sequence.
paddingFill	Output	Value used for filling the padding elements in the buffer.

Returns:

Return Value	Description
CUDNN_STATUS_SUCCESS	The requested values were obtained successfully.
CUDNN_STATUS_BAD_PARAM	Any of the below is true for the input arguments: -**seqDataDesc** is NULL. -**nbDimsRequested** is not positive. -**seqLengthSizeRequsted** is larger than **seqLengthArraySize** **dimA[CUDNN_SEQDATA_BATCH_DIM] * dimA[CUDNN_SEQDATA_BEAM_DIM]**
CUDNN_STATUS_NOT_SUPPORTED	A value not supported is encountered. For example, the **nbDimsRequested** is larger

	than CUDNN_SEQDATA_DIM_COUNT. See **`cudnnSeqDataAxis_t`**.
CUDNN_STATUS_INTERNAL_ERROR	Encountered an invalid field value in **`seqDataDesc`**.

4.129. cudnnGetStream

```
cudnnStatus_t cudnnGetStream(
    cudnnHandle_t    handle,
    cudaStream_t    *streamId)
```

This function retrieves the user CUDA stream programmed in the cuDNN handle. When the user's CUDA stream was not set in the cuDNN handle, this function reports the null-stream.

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.

4.130. cudnnGetTensor4dDescriptor

```
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)
```

This function queries the parameters of the previouly initialized Tensor4D descriptor object.

Parameters

tensorDesc

Input. Handle to a previously insitialized 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.

The possible error values returned by this function and their meanings are listed below.

Returns

`CUDNN_STATUS_SUCCESS`

The operation succeeded.

4.131. cudnnGetTensorNdDescriptor

```
cudnnStatus_t cudnnGetTensorNdDescriptor(
    const cudnnTensorDescriptor_t   tensorDesc,
    int                             nbDimsRequested,
    cudnnDataType_t                *dataType,
    int                            *nbDims,
    int                             dimA[],
    int                             strideA[])
```

This function retrieves values stored in a previously initialized Tensor descriptor object.

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 dimension of at least **`nbDimsRequested`** that will be filled with the dimensions from the provided tensor descriptor.

strideA

Input. Array of dimension of at least **`nbDimsRequested`** that will be filled with the strides from the provided tensor descriptor.

The possible error values returned by this function and their meanings are listed below.

Returns

`CUDNN_STATUS_SUCCESS`

The results were returned successfully.

`CUDNN_STATUS_BAD_PARAM`

Either **`tensorDesc`** or **`nbDims`** pointer is NULL.

4.132. cudnnGetTensorSizeInBytes

```
cudnnStatus_t cudnnGetTensorSizeInBytes(
    const cudnnTensorDescriptor_t   tensorDesc,
    size_t                         *size)
```

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.

Parameters

tensorDesc

Input. Handle to a previously initialized tensor descriptor.

size

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

The possible error values returned by this function and their meanings are listed below.

Returns

`CUDNN_STATUS_SUCCESS`

The results were returned successfully.

4.133. cudnnGetTensorTransformDescriptor

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

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

Parameters:

Parameter	Input / Output	Description
transformDesc	Input	A previously initialized Tensor transform descriptor.
nbDimsRequested	Input	The number of dimensions to consider. See also https://docs.nvidia.com/deeplearning/sdk/cudnn-developer-guide/index.html#tensor-descriptor
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 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. See cudnnFoldingDirection_t.

Returns:

Return Value	Description
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.

4.134. cudnnGetVersion

```
size_t cudnnGetVersion()
```

This function returns the version number of the cuDNN Library. It returns the **`CUDNN_VERSION`** define 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 define **`CUDNN_VERSION`** can be used to have the same application linked against different cuDNN versions using conditional compilation statements.

4.135. cudnnIm2Col

```
cudnnStatus_t cudnnIm2Col(
    cudnnHandle_t                    handle,
    cudnnTensorDescriptor_t          srcDesc,
    const void                       *srcData,
    cudnnFilterDescriptor_t          filterDesc,
    cudnnConvolutionDescriptor_t     convDesc,
    void                             *colBuffer)
```

This function constructs the A matrix necessary to perform a forward pass of GEMM convolution. 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 xDesc's first dimension, y_height/y_width are computed from **`cudnnGetConvolutionNdForwardOutputDim()`**, input_channels is xDesc's second dimension, filter_height/filter_width are wDesc's 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.

4.136. cudnnInitTransformDest

```
cudnnStatus_t cudnnInitTransformDest(
 const cudnnTransformDescriptor_t transformDesc,
 const cudnnTensorDescriptor_t srcDesc,
 cudnnTensorDescriptor_t destDesc,
 size_t *destSizeInBytes);
```

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.

The returned Tensor descriptor will be packed.

Parameters:

Parameter	Input / Output	Description
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:

Return Value	Description
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.
CUDNN_STATUS_NOT_SUPPORTED	If the provided configuration is not 4D.
CUDNN_STATUS_EXECUTION_FAILED	Function failed to launch on the GPU.

4.137. cudnnLRNCrossChannelBackward

```
cudnnStatus_t 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)
```

This function performs the backward LRN layer computation.

Supported formats are: positive-strided, NCHW 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.

Parameters

handle

Input. Handle to a previously created cuDNN library descriptor.

normDesc

Input. Handle to a previously intialized 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: dstValue = alpha[0]*resultValue + beta[0]*priorDstValue. Please refer to this section for additional details.

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).

Possible error values returned by this function and their meanings are listed below.

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 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,dy.
- Any tensor parameters strides are negative.

4.138. cudnnLRNCrossChannelForward

```
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)
```

This function performs the forward LRN layer computation.

Supported formats are: positive-strided, NCHW 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.

Parameters

handle

Input. Handle to a previously created cuDNN library descriptor.

normDesc

Input. Handle to a previously intialized 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: dstValue = alpha[0]*resultValue + beta[0]*priorDstValue. Please refer to this section for additional details.

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.

Possible error values returned by this function and their meanings are listed below.

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 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.
- x and y tensor dimensions mismatch.
- Any tensor parameters strides are negative.

4.139. cudnnMultiHeadAttnBackwardData

```
cudnnStatus_t cudnnMultiHeadAttnBackwardData(
 cudnnHandle_t handle,
 const cudnnAttnDescriptor_t attnDesc,
 const int *loWinIdx,
 const int *hiWinIdx,
 const int *seqLengthArrayDQDO,
 const int *seqLengthArrayDKDV,
 const cudnnSeqDataDescriptor_t doDesc,
 const void *dout,
 const cudnnSeqDataDescriptor_t dqDesc,
 void *dqueries,
 const void *queries,
 const cudnnSeqDataDescriptor_t dkDesc,
 void *dkeys,
 const void *keys,
 const cudnnSeqDataDescriptor_t dvDesc,
 void *dvalues,
 const void *values,
 size_t weightSizeInBytes,
 const void *w,
 size_t workSpaceSizeInBytes,
 void *workSpace,
 size_t reserveSpaceSizeInBytes,
 void *reserveSpace);
```

This function computes the data gradients with backpropagation.

Parameters:

Parameter	Input / Output	Description
handle	Input	A cuDNN context handle.
attnDesc	Input	A previously initialized multi-head attention descriptor.
loWinIdx, hiWinIdx	Input	An array of lower (inclusive) and upper (exclusive) key and value time steps windows.
seqLengthArrayDQDO	Input	Sequence lengths of queries and output sequences data.
seqLengthArrayDKDV	Input	Sequence lengths of keys and values sequences data.
doDesc	Input	Descriptor for output gradient sequence data.
dout	Input	Output gradient data in device memory.
dqDesc	Input	Descriptor for queries sequence data.
dqueries	Output	Queries gradient data in device memory.
queries	Input	Queries data in device memory.
dkDesc	Input	Descriptor for the keys vectors.
dkeys	Output	Keys gradient data in device memory.
keys	Input	Keys data in device memory.
dvDesc	Input	Descriptor for the values vectors.
dvalues	Output	Values gradient data in device memory.
values	Input	Values data in device memory.

weightSizeInBytes	Input	Pointer to a location, in host memory, where the attention weight sizes (in bytes) are stored.
w	Input	Weight data in device memory.
workSpaceSizeInBytes	Input	Pointer to a location, in host memory, of the workspace size (in bytes). For inference and training.
workSpace	Input	Workspace data in device memory.
reserveSpaceSizeInBytes	Input	Pointer to a location, in host memory, of the reserve space size (in bytes). For training.
reserveSpace	Input/Output	Reserve space data in device memory.

Returns:

Return Value	Description
CUDNN_STATUS_SUCCESS	The forward calculation is successful.
CUDNN_STATUS_EXECUTION_FAILED	Failed to launch the kernel, or other kernel errors.

4.140. cudnnMultiHeadAttnBackwardWeights

```
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 *w,
 void *dw,
 size_t workSpaceSizeInBytes,
 void *workSpace,
 size_t reserveSpaceSizeInBytes,
 void *reserveSpace);
```

This function computes the weight gradients with backpropagation.

Parameters:

Parameter	Input / Output	Description
handle	Input	A cuDNN context handle.
attnDesc	Input	A previously initialized multi-head attention descriptor.
addGrad	Input	Weight gradient output mode. See cudnnWgradMode_t <link>.
qDesc	Input	Descriptor of the query sequence data.

queries	Input	Query data in device memory.
kDesc	Input	Descriptor for the keys sequence data.
keys	Input	Keys data in device memory.
vDesc	Input	Descriptor for the values sequence data.
values	Input	Values data in device memory.
doDesc	Input	Descriptor for the output gradient sequence data.
dout	Input	Output gradient data in device memory.
weightSizeInBytes	Input	Pointer to a location, in host memory, where the attention weight sizes (in bytes) are stored.
w	Input	Pointer to the weight buffer address.
dw	Output	Weight gradient data in device memory.
workSpaceSizeInBytes	Input	Pointer to a location, in host memory, of the workspace size (in bytes). For inference and training.
workSpace	Input	Workspace data in device memory.
reserveSpaceSizeInBytes	Input	Pointer to a location, in host memory, of the reserve space size (in bytes). For training.
reserveSpace	Input	Reserve space data in device memory.

Returns:

Return Value	Description
CUDNN_STATUS_SUCCESS	The forward calculation is successful.
CUDNN_STATUS_EXECUTION_FAILED	Failed to launch the kernel, or other kernel errors.

4.141. cudnnMultiHeadAttnForward

```
cudnnStatus_t cudnnMultiHeadAttnForward(
 cudnnHandle_t handle,
 const cudnnAttnDescriptor_t attnDesc,
 int currIdx,
 const int *loWinIdx,
 const int *hiWinIdx,
 const int *seqLengthArrayQRO,
 const int *seqLengthArrayKV,
 const cudnnSeqDataDescriptor_t qDesc,
 const void *queries,
 const void *residuals,
 const cudnnSeqDataDescriptor_t kDesc,
 const void *keys,
 const cudnnSeqDataDescriptor_t vDesc,
 const void *values,
 const cudnnSeqDataDescriptor_t oDesc,
 void *out,
 size_t weightSizeInBytes,
 const void *w,
 size_t workSpaceSizeInBytes,
 void *workSpace,
 size_t reserveSpaceSizeInBytes,
 void *reserveSpace);
```

The function cudnnMultiHeadAttnForward() performs the multi-head attention response computation, as described in the paper Attention Is All You Need.

Parameters:

Parameter	Input / Output	Description
handle	Input	A cuDNN context handle.
attnDesc	Input	A previously initialized multi-head attention descriptor.
currIdx	Input	Output timestep(s) to compute. < 0 for the training mode, and >=0 for the inference mode.
loWinIdx, hiWinIdx	Input	An array of lower (inclusive) and upper (exclusive) key and value time steps windows.
seqLengthArrayQRO	Input	Length of each sequence of the query, residual, and output data.
seqLengthArrayKV	Input	Length of each sequence of the key and value data.
qDesc	Input	Descriptor for the queries and residual sequence data.
queries	Input	Queries data in device memory.
residuals	Input	Residual data in device memory. NULL if no residual connection.
kDesc	Input	Descriptor for the keys sequence data.
keys	Input	Keys data in device memory.
vDesc	Input	Descriptor for the values sequence data.
values	Input	Values data in device memory.
oDesc	Input	Descriptor for the multi-head attention output sequence data.
out	Output	Output data in device memory.
weightSizeInBytes	Input	Pointer to a location, in host memory, where the attention weight sizes (in bytes) are stored.
w	Input	Weight data in device memory.
workSpaceSizeInBytes	Input	Pointer to a location, in host memory, of the workspace size (in bytes). For inference and training.
workSpace	Input	Workspace data in device memory.
reserveSpaceSizeInBytes	Input	Pointer to a location, in host memory, of the reserve space size (in bytes). For training.

reserveSpace	Input/Output	Reserve space data in device memory. If this is NULL it is inference mode, otherwise it is training.

Returns:

Return Value	Description
CUDNN_STATUS_SUCCESS	The forward calculation is successful.
CUDNN_STATUS_EXECUTION_FAILED	Failed to launch the kernel, or other kernel errors.
CUDNN_STATUS_INTERNAL_ERROR	Inconsistent internal state(s) encountered.
CUDNN_STATUS_BAD_PARAM	An invalid or incompatible parameter value is encountered. For example: - Any required input pointers are NULL - currIdx is out of bound or is negative in inference mode (indicated by reserveSpace == NULL) - The descriptor value for attention, query, key, value, and output are incompatible with one another. - Dropout is enabled but with dropout rate >= 1.
CUDNN_STATUS_NOT_SUPPORTED	An unsupported parameter value is encountered. For example: - A combination of **`dataType`** and **`mathPrec`** that is not supported.
CUDNN_STATUS_ALLOC_FAILED	Not enough device share memory to launch kernel.

4.142. cudnnOpTensor

```
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)
```

This function implements the equation C = op (alpha1[0] * A, alpha2[0] * B) + beta[0] * C, given tensors A, B, and C and scaling factors alpha1, alpha2, and beta. The op to use is indicated by the descriptor **`opTensorDesc`**. Currently-supported ops are listed by the **`cudnnOpTensorOp_t`** enum.

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`** must match. If the data type of the destination tensor **`C`** is double, then the data type of the input tensors also must be double.

If the data type of the destination tensor **`C`** is double, then **`opTensorCompType`** in **`opTensorDesc`** must be double. Else **`opTensorCompType`** must be float.

If the input tensor **`B`** is the same tensor as the destination tensor **`C`**, then the input tensor **`A`** also must be the same tensor as the destination tensor **`C`**.

Up to dimension 5, all tensor formats are supported. Beyond those dimensions, this routine is not supported

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 indicated by the above op equation. Please refer to this section for additional details.

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.

The possible error values returned by this function and their meanings are listed below.

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 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 conditions in the above paragraphs are unmet.

CUDNN_STATUS_EXECUTION_FAILED

The function failed to launch on the GPU.

4.143. cudnnPoolingBackward

```
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)
```

This function computes the gradient of a pooling operation.

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 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.

All tensor formats are supported, best performance is expected when using **`HW-packed`** tensors. Only 2 and 3 spatial dimensions are allowed

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]*result + beta[0]*priorDstValue. Please refer to this section for additional details.

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`**.

xDesc

Input. Handle to the previously initialized output tensor descriptor.

x

Input. Data pointer to GPU memory associated with the output 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`**.

The possible error values returned by this function and their meanings are listed below.

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.

4.144. cudnnPoolingForward

```
cudnnStatus_t cudnnPoolingForward(
    cudnnHandle_t                    handle,
    const cudnnPoolingDescriptor_t   poolingDesc,
    const void                      *alpha,
    const cudnnTensorDescriptor_t    xDesc,
    const void                      *x,
    const void                      *beta,
    const cudnnTensorDescriptor_t    yDesc,
    void                            *y)
```

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

All tensor formats are supported, best performance is expected when using **`HW-packed`** tensors. Only 2 and 3 spatial dimensions are allowed.

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

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]*result + beta[0]*priorDstValue. Refer to this section for additional details.

xDesc

Input. Handle to the previously initialized input tensor descriptor. Must be of type FLOAT, or DOUBLE, or HALF, or INT8. See 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, or DOUBLE, or HALF, or INT8. See cudnnDataType_t.

y

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

The possible error values returned by this function and their meanings are listed below.

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. 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.

4.145. cudnnQueryRuntimeError

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

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.

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, 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 started 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 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, i.e., 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.

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

Input. Remote error query mode.

tag

Input/Output. Currently, this argument should be NULL.

The possible error values returned by this function and their meanings are listed below.

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`

Device cannot access zero-copy memory to report kernel errors.

4.146. 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  *dxDesc,
    void                           *dx,
    const cudnnTensorDescriptor_t   dhxDesc,
    void                           *dhx,
    const cudnnTensorDescriptor_t   dcxDesc,
    void                           *dcx,
    void                           *workspace,
    size_t                          workSpaceSizeInBytes,
    const void                     *reserveSpace,
    size_t                          reserveSpaceSizeInBytes)
```

This routine executes the recurrent neural network described by **`rnnDesc`** with output gradients **`dy, dhy, dhc`**, weights **`w`** and input gradients **`dx, dhx, 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. See cudnnHandle_t.

rnnDesc

Input. A previously initialized RNN descriptor. See cudnnRNNDescriptor_t.

seqLength

Input. Number of iterations to unroll over. The value of this **`seqLength`** must not exceed the value that was used in **`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). See cudnnTensorDescriptor_t. The second dimension of the tensor depends on the **`direction`** argument passed to the **`cudnnSetRNNDescriptor`** call used to initialize **`rnnDesc`**:

- If **`direction`** is **`CUDNN_UNIDIRECTIONAL`** the second dimension should match the **`hiddenSize`** argument passed to **`cudnnSetRNNDescriptor`**.
- If **`direction`** is **`CUDNN_BIDIRECTIONAL`** the second dimension should match double the **`hiddenSize`** argument passed to **`cudnnSetRNNDescriptor`**.

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 passed to the **`cudnnSetRNNDescriptor`** call used to initialize **`rnnDesc`**:

- If **`direction`** is **`CUDNN_UNIDIRECTIONAL`** the second dimension should match the **`hiddenSize`** argument passed to **`cudnnSetRNNDescriptor`**.
- If **`direction`** is **`CUDNN_BIDIRECTIONAL`** the second dimension should match double the **`hiddenSize`** argument passed to **`cudnnSetRNNDescriptor`**.

The first dimension of the tensor **`n`** must match the first dimension of the tensor **`n`** 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 passed to the **`cudnnSetRNNDescriptor`** call used to initialize **`rnnDesc`**:

- If **`direction`** is **`CUDNN_UNIDIRECTIONAL`** the first dimension should match the **`numLayers`** argument passed to **`cudnnSetRNNDescriptor`**.
- If **`direction`** is **`CUDNN_BIDIRECTIONAL`** the first dimension should match double the **`numLayers`** argument passed to **`cudnnSetRNNDescriptor`**.

The second dimension must match the first dimension of the tensors described in **`xDesc`**. The third dimension must match the **`hiddenSize`** argument passed to the **`cudnnSetRNNDescriptor`** call 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 passed to the **`cudnnSetRNNDescriptor`** call used to initialize **`rnnDesc`**:

- If **`direction`** is **`CUDNN_UNIDIRECTIONAL`** the first dimension should match the **`numLayers`** argument passed to **`cudnnSetRNNDescriptor`**.
- If **`direction`** is **`CUDNN_BIDIRECTIONAL`** the first dimension should match double the **`numLayers`** argument passed to **`cudnnSetRNNDescriptor`**.

The second dimension must match the first dimension of the tensors described in **`xDesc`**. The third dimension must match the **`hiddenSize`** argument passed to the **`cudnnSetRNNDescriptor`** call 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. See 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 passed to the **`cudnnSetRNNDescriptor`** call used to initialize **`rnnDesc`**:

- If **`direction`** is **`CUDNN_UNIDIRECTIONAL`** the first dimension should match the **`numLayers`** argument passed to **`cudnnSetRNNDescriptor`**.
- If **`direction`** is **`CUDNN_BIDIRECTIONAL`** the first dimension should match double the **`numLayers`** argument passed to **`cudnnSetRNNDescriptor`**.

The second dimension must match the second dimension of the tensors described in **`xDesc`**. The third dimension must match the **`hiddenSize`** argument passed to the **`cudnnSetRNNDescriptor`** call 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 passed to the **`cudnnSetRNNDescriptor`** call used to initialize **`rnnDesc`**:

- If **`direction`** is **`CUDNN_UNIDIRECTIONAL`** the first dimension should match the **`numLayers`** argument passed to **`cudnnSetRNNDescriptor`**.
- If **`direction`** is **`CUDNN_BIDIRECTIONAL`** the first dimension should match double the **`numLayers`** argument passed to **`cudnnSetRNNDescriptor`**.

The second dimension must match the second dimension of the tensors described in **`xDesc`**. The third dimension must match the **`hiddenSize`** argument passed to the **`cudnnSetRNNDescriptor`** call 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 passed to the **`cudnnSetRNNDescriptor`** call used to initialize **`rnnDesc`**:

- If **`direction`** is **`CUDNN_UNIDIRECTIONAL`** the first dimension should match the **`numLayers`** argument passed to **`cudnnSetRNNDescriptor`**.
- If **`direction`** is **`CUDNN_BIDIRECTIONAL`** the first dimension should match double the **`numLayers`** argument passed to **`cudnnSetRNNDescriptor`**.

The second dimension must match the first dimension of the tensors described in **`xDesc`**. The third dimension must match the **`hiddenSize`** argument passed to the **`cudnnSetRNNDescriptor`** call 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 passed to the **`cudnnSetRNNDescriptor`** call used to initialize **`rnnDesc`**:

- If **`direction`** is **`CUDNN_UNIDIRECTIONAL`** the first dimension should match the **`numLayers`** argument passed to **`cudnnSetRNNDescriptor`**.
- If **`direction`** is **`CUDNN_BIDIRECTIONAL`** the first dimension should match double the **`numLayers`** argument passed to **`cudnnSetRNNDescriptor`**.

The second dimension must match the first dimension of the tensors described in **`xDesc`**. The third dimension must match the **`hiddenSize`** argument passed to the **`cudnnSetRNNDescriptor`** call 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`**.

The possible error values returned by this function and their meanings are listed below.

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, 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, 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.

`CUDNN_STATUS_ALLOC_FAILED`

The function was unable to allocate memory.

4.147. cudnnRNNBackwardDataEx

```
cudnnStatus_t cudnnRNNBackwardDataEx(
    cudnnHandle_t                         handle,
    const cudnnRNNDescriptor_t        rnnDesc,
    const cudnnRNNDataDescriptor_t    yDesc,
    const void                        *y,
    const cudnnRNNDataDescriptor_t    dyDesc,
    const void                        *dy,
    const cudnnRNNDataDescriptor_t    dcDesc,
    const void                        *dcAttn,
    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 cudnnRNNDataDescriptor_t    dxDesc,
    void                              *dx,
    const cudnnTensorDescriptor_t     dhxDesc,
    void                              *dhx,
    const cudnnTensorDescriptor_t     dcxDesc,
    void                              *dcx,
    const cudnnRNNDataDescriptor_t    dkDesc,
    void                              *dkeys,
    void                              *workSpace,
    size_t                            workSpaceSizeInBytes,
    void                              *reserveSpace,
    size_t                            reserveSpaceSizeInBytes)
```

This routine is the extended version of the function **`cudnnRNNBackwardData`**. This function **`cudnnRNNBackwardDataEx`** allows the user to use 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 **`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 (i.e. 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 cuDNN 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 **`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. 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 passed to the **`cudnnSetRNNDescriptor`** call used to initialize **`rnnDesc`**. Moreover:

- If **`direction`** is **`CUDNN_UNIDIRECTIONAL`** the first dimension should match the **`numLayers`** argument passed to **`cudnnSetRNNDescriptor`**.
- If **`direction`** is **`CUDNN_BIDIRECTIONAL`** the first dimension should match double the **`numLayers`** argument passed to **`cudnnSetRNNDescriptor`**.

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. Moreover:

- 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 passed to the **`cudnnSetRNNDescriptor`** call 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 passed to the **`cudnnSetRNNDescriptor`** call used to initialize **`rnnDesc`**. Moreover:

- If **`direction`** is **`CUDNN_UNIDIRECTIONAL`** the first dimension should match the **`numLayers`** argument passed to **`cudnnSetRNNDescriptor`**.
- If **`direction`** is **`CUDNN_BIDIRECTIONAL`** the first dimension should match double the **`numLayers`** argument passed to **`cudnnSetRNNDescriptor`**.

The second dimension must match the first dimension of the tensors described in **`xDesc`**.

The third dimension must match the **`hiddenSize`** argument passed to the **`cudnnSetRNNDescriptor`** call 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. User may pass in NULL.

dkeys

Reserved. User 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 **yDesc**, **dxdesc**, **dydesc**, **dhxDesc**, **wDesc**, **hxDesc**, **cxDesc**, **dcxDesc**, **dhyDesc**, **dcyDesc** 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.

4.148. cudnnRNNBackwardWeights

```
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 **rnnDesc** with inputs **x, hx**, 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 `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 passed to the `cudnnSetRNNDescriptor` call used to initialize `rnnDesc`:

- If `direction` is `CUDNN_UNIDIRECTIONAL` the first dimension should match the `numLayers` argument passed to `cudnnSetRNNDescriptor`.
- If `direction` is `CUDNN_BIDIRECTIONAL` the first dimension should match double the `numLayers` argument passed to `cudnnSetRNNDescriptor`.

The second dimension must match the first dimension of the tensors described in `xDesc`. The third dimension must match the `hiddenSize` argument passed to the `cudnnSetRNNDescriptor` call 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 passed to the `cudnnSetRNNDescriptor` call used to initialize `rnnDesc`:

- If `direction` is `CUDNN_UNIDIRECTIONAL` the second dimension should match the `hiddenSize` argument passed to `cudnnSetRNNDescriptor`.
- If `direction` is `CUDNN_BIDIRECTIONAL` the second dimension should match double the `hiddenSize` argument passed to `cudnnSetRNNDescriptor`.

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`**

The possible error values returned by this function and their meanings are listed below.

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`** 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.

4.149. 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,
    void                              *dw,
    void                              *reserveSpace,
    size_t                            reserveSpaceSizeInBytes)
```

This routine is the extended version of the function **`cudnnRNNBackwardWeights`**. This function **`cudnnRNNBackwardWeightsEx`** allows the user to use 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 (i.e. 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 invalud, 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.

4.150. cudnnRNNForwardInference

```
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, cx**, weights **w** and outputs **y, hy, 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 **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: strideA[0]=inputSize, strideA[1]=1, strideA[2]=1.

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 passed to the **`cudnnSetRNNDescriptor`** call used to initialize **`rnnDesc`**:

- If **`direction`** is **`CUDNN_UNIDIRECTIONAL`** the first dimension should match the **`numLayers`** argument passed to **`cudnnSetRNNDescriptor`**.
- If **`direction`** is **`CUDNN_BIDIRECTIONAL`** the first dimension should match double the **`numLayers`** argument passed to **`cudnnSetRNNDescriptor`**.

The second dimension must match the first dimension of the tensors described in **`xDesc`**. The third dimension must match the **`hiddenSize`** argument passed to the **`cudnnSetRNNDescriptor`** call 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 passed to the **`cudnnSetRNNDescriptor`** call used to initialize **`rnnDesc`**:

- If **`direction`** is **`CUDNN_UNIDIRECTIONAL`** the first dimension should match the **`numLayers`** argument passed to **`cudnnSetRNNDescriptor`**.
- If **`direction`** is **`CUDNN_BIDIRECTIONAL`** the first dimension should match double the **`numLayers`** argument passed to **`cudnnSetRNNDescriptor`**.

The second dimension must match the first dimension of the tensors described in **`xDesc`**. The third dimension must match the **`hiddenSize`** argument passed to the **`cudnnSetRNNDescriptor`** call 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 passed to the **`cudnnSetRNNDescriptor`** call used to initialize **`rnnDesc`**:

- If **`direction`** is **`CUDNN_UNIDIRECTIONAL`** the second dimension should match the **`hiddenSize`** argument passed to **`cudnnSetRNNDescriptor`**.
- If **`direction`** is **`CUDNN_BIDIRECTIONAL`** the second dimension should match double the **`hiddenSize`** argument passed to **`cudnnSetRNNDescriptor`**.

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 passed to the **`cudnnSetRNNDescriptor`** call used to initialize **`rnnDesc`**:

- If **`direction`** is **`CUDNN_UNIDIRECTIONAL`** the first dimension should match the **`numLayers`** argument passed to **`cudnnSetRNNDescriptor`**.
- If **`direction`** is **`CUDNN_BIDIRECTIONAL`** the first dimension should match double the **`numLayers`** argument passed to **`cudnnSetRNNDescriptor`**.

The second dimension must match the first dimension of the tensors described in **`xDesc`**. The third dimension must match the **`hiddenSize`** argument passed to the **`cudnnSetRNNDescriptor`** call 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 passed to the **`cudnnSetRNNDescriptor`** call used to initialize **`rnnDesc`**:

- If **`direction`** is **`CUDNN_UNIDIRECTIONAL`** the first dimension should match the **`numLayers`** argument passed to **`cudnnSetRNNDescriptor`**.
- If **`direction`** is **`CUDNN_BIDIRECTIONAL`** the first dimension should match double the **`numLayers`** argument passed to **`cudnnSetRNNDescriptor`**.

The second dimension must match the first dimension of the tensors described in **`xDesc`**. The third dimension must match the **`hiddenSize`** argument passed to the **`cudnnSetRNNDescriptor`** call 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 be 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`**.

The possible error values returned by this function and their meanings are listed below.

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, 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.

`CUDNN_STATUS_EXECUTION_FAILED`

The function failed to launch on the GPU.

`CUDNN_STATUS_ALLOC_FAILED`

The function was unable to allocate memory.

4.151. cudnnRNNForwardInferenceEx

```
cudnnStatus_t cudnnRNNForwardInferenceEx(
    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,
    void                               *y,
    const cudnnTensorDescriptor_t      hyDesc,
    void                               *hy,
    const cudnnTensorDescriptor_t      cyDesc,
    void                               *cy,
    const cudnnRNNDataDescriptor_t     kDesc,
    const void                         *keys,
    const cudnnRNNDataDescriptor_t     cDesc,
    void                               *cAttn,
    const cudnnRNNDataDescriptor_t     iDesc,
    void                               *iAttn,
    const cudnnRNNDataDescriptor_t     qDesc,
    void                               *queries,
    void                               *workSpace,
    size_t                             workSpaceSizeInBytes)
```

This routine is the extended version of the **`cudnnRNNForwardInference`** 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 unpacked layout, both sequence major (i.e. 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 passed to the **`cudnnSetRNNDescriptor`** call used to initialize **`rnnDesc`**:

- If **`direction`** is **`CUDNN_UNIDIRECTIONAL`** the first dimension should match the **`numLayers`** argument passed to **`cudnnSetRNNDescriptor`**.
- If **`direction`** is **`CUDNN_BIDIRECTIONAL`** the first dimension should match double the **`numLayers`** argument passed to **`cudnnSetRNNDescriptor`**.

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. In specific:

- 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 passed to the **`cudnnSetRNNDescriptor`** call 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 passed to the **`cudnnSetRNNDescriptor`** call used to initialize **`rnnDesc`**:

- If **`direction`** is **`CUDNN_UNIDIRECTIONAL`** the first dimension should match the **`numLayers`** argument passed to **`cudnnSetRNNDescriptor`**.
- If **`direction`** is **`CUDNN_BIDIRECTIONAL`** the first dimension should match double the **`numLayers`** argument passed to **`cudnnSetRNNDescriptor`**.

The second dimension must match the **`batchSize`** parameter in **`xDesc`**. The third dimension must match the **`hiddenSize`** argument passed to the **`cudnnSetRNNDescriptor`** call 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. In specific:

- For uni-directional network, if 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 uni-directional network, the parameter **`vectorSize`** must match the **`hiddenSize`** argument passed to the **`cudnnSetRNNDescriptor`** call used to initialize **`rnnDesc`**. If the network is bidirectional, then multiply the value by 2.

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.

hyDesc

Input. A fully packed tensor descriptor describing the final hidden state of the RNN. The descriptor must be set exactly the same way 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 way 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 be not be saved.

kDesc

Reserved. User may pass in NULL.

Keys

Reserved. User may pass in NULL.

cDesc

Reserved. User may pass in NULL.

cAttn

Reserved. User may pass in NULL.

iDesc

Reserved. User may pass in NULL.

iAttn

Reserved. User may pass in NULL.

qDesc

Reserved. User may pass in NULL.

Queries

Reserved. User 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`**.

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`**, **`cyDesc`** is invalid, or have incorrect strides or dimensions.
- **`reserveSpaceSizeInBytes`** is too small.
- **`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.

4.152. cudnnRNNForwardTraining

```
cudnnStatus_t cudnnRNNForwardTraining(
    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,
    void                            *reserveSpace,
    size_t                           reserveSpaceSizeInBytes)
```

This routine executes the recurrent neural network described by **`rnnDesc`** with inputs **`x, hx, cx`**, weights **`w`** and outputs **`y, hy, 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 **`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: strideA[0]=inputSize, strideA[1]=1, strideA[2]=1.

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 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 passed to the **`cudnnSetRNNDescriptor`** call used to initialize **`rnnDesc`**:

- If **`direction`** is **`CUDNN_UNIDIRECTIONAL`** the first dimension should match the **`numLayers`** argument passed to **`cudnnSetRNNDescriptor`**.
- If **`direction`** is **`CUDNN_BIDIRECTIONAL`** the first dimension should match double the **`numLayers`** argument passed to **`cudnnSetRNNDescriptor`**.

The second dimension must match the first dimension of the tensors described in **`xDesc`**. The third dimension must match the **`hiddenSize`** argument passed to the **`cudnnSetRNNDescriptor`** call 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 passed to the **`cudnnSetRNNDescriptor`** call used to initialize **`rnnDesc`**:

- If **`direction`** is **`CUDNN_UNIDIRECTIONAL`** the first dimension should match the **`numLayers`** argument passed to **`cudnnSetRNNDescriptor`**.
- If **`direction`** is **`CUDNN_BIDIRECTIONAL`** the first dimension should match double the **`numLayers`** argument passed to **`cudnnSetRNNDescriptor`**.

The second dimension must match the first dimension of the tensors described in **`xDesc`**. The third dimension must match the **`hiddenSize`** argument passed to the **`cudnnSetRNNDescriptor`** call 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 passed to the **`cudnnSetRNNDescriptor`** call used to initialize **`rnnDesc`**:

- If **`direction`** is **`CUDNN_UNIDIRECTIONAL`** the second dimension should match the **`hiddenSize`** argument passed to **`cudnnSetRNNDescriptor`**.
- If **`direction`** is **`CUDNN_BIDIRECTIONAL`** the second dimension should match double the **`hiddenSize`** argument passed to **`cudnnSetRNNDescriptor`**.

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 passed to the **`cudnnSetRNNDescriptor`** call used to initialize **`rnnDesc`**:

- If **`direction`** is **`CUDNN_UNIDIRECTIONAL`** the first dimension should match the **`numLayers`** argument passed to **`cudnnSetRNNDescriptor`**.
- If **`direction`** is **`CUDNN_BIDIRECTIONAL`** the first dimension should match double the **`numLayers`** argument passed to **`cudnnSetRNNDescriptor`**.

The second dimension must match the first dimension of the tensors described in **`xDesc`**. The third dimension must match the **`hiddenSize`** argument passed to the **`cudnnSetRNNDescriptor`** call 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 passed to the **`cudnnSetRNNDescriptor`** call used to initialize **`rnnDesc`**:

- If **`direction`** is **`CUDNN_UNIDIRECTIONAL`** the first dimension should match the **`numLayers`** argument passed to **`cudnnSetRNNDescriptor`**.
- If **`direction`** is **`CUDNN_BIDIRECTIONAL`** the first dimension should match double the **`numLayers`** argument passed to **`cudnnSetRNNDescriptor`**.

The second dimension must match the first dimension of the tensors described in **`xDesc`**. The third dimension must match the **`hiddenSize`** argument passed to the

cudnnSetRNNDescriptor call 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 be 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**

The possible error values returned by this function and their meanings are listed below.

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_EXECUTION_FAILED

The function failed to launch on the GPU.

CUDNN_STATUS_ALLOC_FAILED

The function was unable to allocate memory.

4.153. cudnnRNNForwardTrainingEx

```
cudnnStatus_t 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,
    void                                  *y,
    const cudnnTensorDescriptor_t         hyDesc,
    void                                  *hy,
    const cudnnTensorDescriptor_t         cyDesc,
    void                                  *cy,
    const cudnnRNNDataDescriptor_t        kDesc,
    const void                            *keys,
    const cudnnRNNDataDescriptor_t        cDesc,
    void                                  *cAttn,
    const cudnnRNNDataDescriptor_t        iDesc,
    void                                  *iAttn,
    const cudnnRNNDataDescriptor_t        qDesc,
    void                                  *queries,
    void                                  *workSpace,
    size_t                                workSpaceSizeInBytes,
    void                                  *reserveSpace,
    size_t                                reserveSpaceSizeInBytes);
```

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 **`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 the unpacked layout, both sequence major (i.e. 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 passed to the **cudnnSetRNNDescriptor** call used to initialize **rnnDesc**. Moreover:

- If **direction** is **CUDNN_UNIDIRECTIONAL** then the first dimension should match the **numLayers** argument passed to **cudnnSetRNNDescriptor**.
- If **direction** is **CUDNN_BIDIRECTIONAL** then the first dimension should match double the **numLayers** argument passed to **cudnnSetRNNDescriptor**.

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. Moreover:

- 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 passed to the **cudnnSetRNNDescriptor** call 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 passed to the **cudnnSetRNNDescriptor** call used to initialize **rnnDesc**. Moreover:

- If **direction** is **CUDNN_UNIDIRECTIONAL** the first dimension should match the **numLayers** argument passed to **cudnnSetRNNDescriptor**.
- If **direction** is **CUDNN_BIDIRECTIONAL** the first dimension should match double the **numLayers** argument passed to **cudnnSetRNNDescriptor**.

The second dimension must match the first dimension of the tensors described in **xDesc**.

The third dimension must match the **hiddenSize** argument passed to the **cudnnSetRNNDescriptor** call 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 RNN mode is **`CUDNN_LSTM`** and whether LSTM projection is enabled and whether the network is bidirectional. In specific:

- For uni-directional network, if 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 uni-directional network, the parameter **`vectorSize`** must match the **`hiddenSize`** argument passed to the **`cudnnSetRNNDescriptor`** call 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 be not be saved.

kDesc

Reserved. User may pass in NULL.

Keys

Reserved. User may pass in NULL.

cDesc

Reserved. User may pass in NULL.

cAttn

Reserved. User may pass in NULL.

iDesc

Reserved. User may pass in NULL.

iAttn

Reserved. User may pass in NULL.

qDesc

Reserved. User may pass in NULL.

Queries

Reserved. User 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, cyDesc`** is invalid, or 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.

4.154. cudnnRNNGetClip

```
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.

4.155. cudnnRNNSetClip

```
cudnnStatus_t 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 are 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.

4.156. cudnnReduceTensor

```
cudnnStatus_t 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)
```

This function reduces tensor A by implementing the equation C = alpha * reduce op (A) + beta * 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.

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, i.e. 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.

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 indicated by the above op equation. Please refer to this section for additional details.

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.

The possible error values returned by this function and their meanings are listed below.

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.

4.157. cudnnRestoreAlgorithm

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

(New for 7.1)

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.

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 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.

4.158. cudnnRestoreDropoutDescriptor

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

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

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.

seed

Input. Seed used in prior call 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**.

The possible error values returned by this function and their meanings are listed below.

Returns

CUDNN_STATUS_SUCCESS

The call was successful.

CUDNN_STATUS_INVALID_VALUE

States buffer size (as indicated in stateSizeInBytes) is too small.

4.159. cudnnSaveAlgorithm

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

(New for 7.1)

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.

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 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.

4.160. cudnnScaleTensor

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

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

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.

alpha

Input. Pointer in Host memory to a single value that all elements of the tensor will be scaled with. Please refer to this section for additional details.

The possible error values returned by this function and their meanings are listed below.

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.

4.161. cudnnSetActivationDescriptor

```
cudnnStatus_t cudnnSetActivationDescriptor(
    cudnnActivationDescriptor_t         activationDesc,
    cudnnActivationMode_t               mode,
    cudnnNanPropagation_t               reluNanOpt,
    double                              coef)
```

This function initializes a previously created generic activation descriptor object.

Parameters

activationDesc

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

mode

Input. Enumerant to specify the activation mode.

reluNanOpt

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

coef

Input. floating point number to specify the clipping threashold 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`**.

The possible error values returned by this function and their meanings are listed below.

Returns

`CUDNN_STATUS_SUCCESS`

The object was set successfully.

`CUDNN_STATUS_BAD_PARAM`

`mode` or **`reluNanOpt`** has an invalid enumerant value.

4.162. cudnnSetAlgorithmDescriptor

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

(New for 7.1)

This function initializes a previously created generic algorithm descriptor object.

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.

4.163. cudnnSetAlgorithmPerformance

```
cudnnStatus_t cudnnSetAlgorithmPerformance(
    cudnnAlgorithmPerformance_t     algoPerf,
    cudnnAlgorithmDescriptor_t      algoDesc,
    cudnnStatus_t                   status,
    float                           time,
    size_t                          memory)
```

(New for 7.1)

This function initializes a previously created generic algorithm performance object.

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.

Returns

`CUDNN_STATUS_SUCCESS`

The object was set successfully.

`CUDNN_STATUS_BAD_PARAM`

`mode` or **`reluNanOpt`** has an invalid enumerant value.

4.164. cudnnSetAttnDescriptor

```
cudnnStatus_t cudnnSetAttnDescriptor(
cudnnAttnDescriptor_t attnDesc,
 cudnnAttnQueryMap_t queryMap,
 int nHeads,
 double smScaler,
 cudnnDataType_t dataType,
 cudnnDataType_t computePrec,
 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);
```

This function initializes a multi-head attention descriptor that was previously created using the cudnnCreateAttnDescriptor function.

For query, key, and value input data, the effective projection size is equal to the respective **`[qkv]ProjSize`** when the value is positive, and is equal to **`[qkv]Size`** otherwise.

The output projection size decides the hidden vector size of the forward output sequence data. It is equal to **`oProjSize`** when the value is positive, otherwise is equal to **`nHeads`** times effective value-projection size.

Parameters:

Parameter	Input / Output	Description
attnDesc	Output	Attention descriptor whose values are to be initialized.
queryMap	Input	Query mapping mode.
nHeads	Input	Number of attention heads.
smScaler	Input	Softmax smoothing, or sharpening, coefficient.
dataType	Input	Data type for Q,K,V inputs, weights, and the output.
computePrec	Input	Compute data type (precision).
mathType	Input	The Tensor Core Operations settings.
attnDropoutDesc	Input	Dropout descriptor for the dropout at the attention layer.
postDropoutDesc	Input	Dropout descriptor for the dropout at the output.
qSize, kSize, vSize	Input	Hidden size of Q, K, and V input sequence data.
qProjSize, kProjSize, vProjSize	Input	Hidden size of projected Q, K and V sequence data; 0 if no projection.
oProjSize	Input	Output projection size.
qoMaxSeqLength	Input	Largest sequence length allowed in sequence data Q and O.
kvMaxSeqLength	Input	Largest sequence length allowed in sequence data K and V.
maxBatchSize	Input	Largest batch size allowed in sequence data.
maxBeamSize	Input	Largest beam size allowed in sequence data.

Returns:

Return Value	Description
CUDNN_STATUS_SUCCESS	The **`attnDesc`** field values are updated successfully.
CUDNN_STATUS_BAD_PARAM	An invalid input value is encountered. For example: - **`attnDesc`** is NULL - **`queryMap`** is not one of enumerated labels of **`cudnnAttnQueryMap_t`**

	- Effective Q, K projection size are not equal (see remark below) - **dataType**, **computePrec**, **mathType** are invalid Any of the following valid ranges are violated: - **nHeads, qSize, kSize, vSize, qoMaxSeqLength, kvMaxSeqLength, maxBatchSize, maxBeamSize** >= 1 - **qProjSize, kProjSize, vProjSize** >= 0 - **smScaler** >= 0.0
CUDNN_STATUS_NOT_SUPPORTED	An unsupported value is encountered.

4.165. cudnnSetCTCLossDescriptor

```
cudnnStatus_t cudnnSetCTCLossDescriptor(
    cudnnCTCLossDescriptor_t        ctcLossDesc,
    cudnnDataType_t                 compType)
```

This function sets a CTC loss function descriptor.

Parameters

ctcLossDesc

Output. CTC loss descriptor to be set.

compType

Input. Compute type for this CTC loss function.

Returns

CUDNN_STATUS_SUCCESS

The function returned successfully.

CUDNN_STATUS_BAD_PARAM

At least one of input parameters passed is invalid.

4.166. cudnnSetCallback

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

(New for 7.1)

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

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 (see Section 2.11).

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):

```
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 message is terminated by "**\0\0**". User may select what is necessary to show in the log, and may reformat the string.

Returns

CUDNN_STATUS_SUCCESS

The function launched successfully.

4.167. cudnnSetConvolution2dDescriptor

```
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)
```

This function initializes a previously created convolution descriptor object into a 2D correlation. This function assumes that the tensor and filter descriptors corresponds to the formard 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.

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.

The possible error values returned by this function and their meanings are listed below.

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.

4.168. cudnnSetConvolutionGroupCount

```
cudnnStatus_t cudnnSetConvolutionGroupCount(
    cudnnConvolutionDescriptor_t    convDesc,
    int                             groupCount)
```

This function allows the user to specify the number of groups to be used in the associated convolution.

Returns

CUDNN_STATUS_SUCCESS

The group count was set successfully.

CUDNN_STATUS_BAD_PARAM

An invalid convolution descriptor was provided

4.169. cudnnSetConvolutionMathType

```
cudnnStatus_t cudnnSetConvolutionMathType(
    cudnnConvolutionDescriptor_t    convDesc,
    cudnnMathType_t                 mathType)
```

This function allows the user to specify whether or not the use of tensor op is permitted in library routines associated with a given convolution descriptor.

Returns

CUDNN_STATUS_SUCCESS

The math type was was set successfully.

CUDNN_STATUS_BAD_PARAM

Either an invalid convolution descriptor was provided or an invalid math type was specified.

4.170. cudnnSetConvolutionNdDescriptor

```
cudnnStatus_t cudnnSetConvolutionNdDescriptor(
    cudnnConvolutionDescriptor_t    convDesc,
    int                             arrayLength,
    const int                       padA[],
    const int                       filterStrideA[],
    const int                       dilationA[],
    cudnnConvolutionMode_t          mode,
    cudnnDataType_t                 dataType)
```

This function initializes a previously created generic convolution descriptor object into a n-D correlation. That same convolution descriptor can be reused in the backward path provided it corresponds to the same layer. The convolution computation will done in the specified **`dataType`**, which can be potentially different from the input/output tensors.

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 fitler 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 datatype in which the computation will be done.

The possible error values returned by this function and their meanings are listed below.

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.

4.171. cudnnSetDropoutDescriptor

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

This function initializes a previously created dropout descriptor object. If **`states`** argument is equal to NULL, random number generator states won't be initialized, and only **`dropout`** value will be set. No other function should be writing to the memory pointed at by **`states`** argument while this function is running. The user is expected not to change memory pointed at by **`states`** for the duration of the computation.

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 size in bytes of the provided memory for the states

seed

Input. Seed used to initialize random number generator states.

The possible error values returned by this function and their meanings are listed below.

Returns

CUDNN_STATUS_SUCCESS

The call was successful.

CUDNN_STATUS_INVALID_VALUE

sizeInBytes is less than the value returned by **cudnnDropoutGetStatesSize**.

CUDNN_STATUS_EXECUTION_FAILED

The function failed to launch on the GPU

4.172. cudnnSetFilter4dDescriptor

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

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

Tensor format CUDNN_TENSOR_NHWC has limited support in **cudnnConvolutionForward**, **cudnnConvolutionBackwardData** and **cudnnConvolutionBackwardFilter**; please refer to the documentation for each function for more information.

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 enumerated values allowed by **cudnnTensorFormat_t** descriptor, then the layout of the filter is in the form of KCRS (K represents the number of output feature maps, C the number of input feature maps, R the number of rows per filter, and S 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. See also the description for **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.

The possible error values returned by this function and their meanings are listed below.

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.

4.173. cudnnSetFilterNdDescriptor

```
cudnnStatus_t cudnnSetFilterNdDescriptor(
    cudnnFilterDescriptor_t filterDesc,
    cudnnDataType_t         dataType,
    cudnnTensorFormat_t     format,
    int                     nbDims,
    const int               filterDimA[])
```

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

The tensor format CUDNN_TENSOR_NHWC has limited support in **`cudnnConvolutionForward`**, **`cudnnConvolutionBackwardData`** and **`cudnnConvolutionBackwardFilter`**; please refer to the documentation for each function for more information.

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 enumerated values allowed by **`cudnnTensorFormat_t`** descriptor, then the layout of the filter is as follows:

- For N=4, i.e., for a 4D filter descriptor, the filter layout is in the form of KCRS (K represents the number of output feature maps, C the number of input feature maps, R the number of rows per filter, and S the number of columns per filter.)
- For N=3, i.e., for 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 follow 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, i.e., for a 4D filter descriptor, the filter layout is in the form of KRSC.
- For N=3, i.e., for 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. See also the description for **`cudnnTensorFormat_t`**.

nbDims

Input. Dimension of the filter.

filterDimA

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

The possible error values returned by this function and their meanings are listed below.

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.

4.174. cudnnSetLRNDescriptor

```
cudnnStatus_t cudnnSetLRNDescriptor(
    cudnnLRNDescriptor_t   normDesc,
    unsigned               lrnN,
    double                 lrnAlpha,
    double                 lrnBeta,
    double                 lrnK)
```

This function initializes a previously created LRN descriptor object.

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. 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 DivisiveNormalization layer the window has the same extents 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 normalization formula. By default this value is set to 2.0.

Possible error values returned by this function and their meanings are listed below.

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.

4.175. cudnnSetOpTensorDescriptor

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

This function initializes a Tensor Pointwise math descriptor.

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 input parameters passed is invalid.

4.176. cudnnSetPersistentRNNPlan

```
cudnnStatus_t cudnnSetPersistentRNNPlan(
    cudnnRNNDescriptor_t        rnnDesc,
    cudnnPersistentRNNPlan_t    plan)
```

This function sets the persistent RNN plan to be executed when using **rnnDesc** and **CUDNN_RNN_ALGO_PERSIST_DYNAMIC** algo.

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**.

4.177. cudnnSetPooling2dDescriptor

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

This function initializes a previously created generic pooling descriptor object into a 2D description.

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.

The possible error values returned by this function and their meanings are listed below.

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 enumerant value.

4.178. cudnnSetPoolingNdDescriptor

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

This function initializes a previously created generic pooling descriptor object.

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 (i.e., 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 enumerant value.

4.179. cudnnSetRNNBiasMode

```
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 after **cudnnSetRNNDescriptor()** 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. See 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 RNN algo other than **CUDNN_RNN_ALGO_STANDARD**.

4.180. cudnnSetRNNDataDescriptor

```
cudnnStatus_t cudnnSetRNNDataDescriptor(
    cudnnRNNDataDescriptor_t       RNNDataDesc,
    cudnnDataType_t                dataType,
    cudnnRNNDataLayout_t           layout,
    int                            maxSeqLength,
    int                            batchSize,
    int                            vectorSize,
    const int                      seqLengthArray[],
    void                           *paddingFill);
```

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.

Parameters

RNNDataDesc

Input/Output. A previously created RNN descriptor. See cudnnRNNDataDescriptor_t.

dataType

Input. The datatype of the RNN data tensor. See 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 (i.e. embedding size) of the input or output tensor at each timestep.

seqLengthArray

Input. An integer array with **`batchSize`** number of elements. Describes the length (i.e. number of timesteps) of each sequence. Each element in **`seqLengthArray`** must be greater than 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 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`

`dataType` is not one of **`CUDNN_DATA_HALF`**, **`CUDNN_DATA_FLOAT`**, **`CUDNN_DATA_DOUBLE`**.

`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 or equal to 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.

4.181. cudnnSetRNNDescriptor

```
cudnnStatus_t cudnnSetRNNDescriptor(
    cudnnHandle_t                handle,
    cudnnRNNDescriptor_t         rnnDesc,
    int                          hiddenSize,
    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.

> Larger networks (e.g., longer sequences, more layers) are expected to be more efficient than smaller networks.

Parameters

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; 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. (e.g., bidirectional).

mode

Input. Specifies the type of RNN to compute.

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, and
- 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, numLayers`** was zero or negative, one of **`inputMode, direction, mode, dataType`** has an invalid enumerant value, **`dropoutDesc`** is an invalid dropout descriptor or **`rnnDesc`** has not been created correctly.

4.182. cudnnSetRNNDescriptor_v5

```
cudnnStatus_t cudnnSetRNNDescriptor_v5(
    cudnnRNNDescriptor_t     rnnDesc,
    int                      hiddenSize,
    int                      numLayers,
    cudnnDropoutDescriptor_t dropoutDesc,
    cudnnRNNInputMode_t      inputMode,
    cudnnDirectionMode_t     direction,
    cudnnRNNMode_t           mode,
    cudnnDataType_t          mathPrec)
```

This function initializes a previously created RNN descriptor object.

Larger networks (e.g., longer sequences, more layers) are expected to be more efficient than smaller networks.

Parameters

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 (e.g., 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. (e.g., bidirectional)

mode

Input. Specifies the type of RNN to compute.

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, and
- For the input/output in FP64, double type, the parameter **`mathPrec`** can only be CUDNN_DATA_DOUBLE.

The possible error values returned by this function and their meanings are listed below.

Returns

`CUDNN_STATUS_SUCCESS`

The object was set successfully.

`CUDNN_STATUS_BAD_PARAM`

Either at least one of the parameters **`hiddenSize, numLayers`** was zero or negative, one of **`inputMode, direction, mode, algo, dataType`** has an invalid enumerant value, **`dropoutDesc`** is an invalid dropout descriptor or **`rnnDesc`** has not been created correctly.

4.183. cudnnSetRNNDescriptor_v6

```
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.

Larger networks (e.g., longer sequences, 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 (e.g., 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. (e.g., 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, and
- For the input/output in FP64, double type, the parameter **`mathPrec`** can only be CUDNN_DATA_DOUBLE.

The possible error values returned by this function and their meanings are listed below.

Returns

`CUDNN_STATUS_SUCCESS`

The object was set successfully.

`CUDNN_STATUS_BAD_PARAM`

Either at least one of the parameters **`hiddenSize, numLayers`** was zero or negative, one of **`inputMode, direction, mode, algo, dataType`** has an invalid enumerant value, **`dropoutDesc`** is an invalid dropout descriptor or **`rnnDesc`** has not been created correctly.

4.184. cudnnSetRNNMatrixMathType

```
cudnnStatus_t cudnnSetRNNMatrixMathType(
    cudnnRNNDescriptor_t    rnnDesc,
    cudnnMathType_t         mType)
```

This function sets the preferred option to use NVIDIA Tensor Cores accelerators on Volta GPU-s (SM 7.0 or higher). When the mType parameter is CUDNN_TENSOR_OP_MATH, inference and training RNN API-s 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 GEMM-s (general matrix-matrix multiplications). This option has an “advisory” status meaning that Tensor Cores may not be utilized, e.g., 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.

4.185. cudnnSetRNNPaddingMode

```
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. See the description for **`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.

4.186. cudnnSetRNNProjectionLayers

```
cudnnStatus_t cudnnSetRNNProjectionLayers(
    cudnnHandle_t           handle,
    cudnnRNNDescriptor_t    rnnDesc,
    int                     recProjSize,
    int                     outProjSize)
```

(New for 7.1)

The **`cudnnSetRNNProjectionLayers()`** function should be called after **`cudnnSetRNNDescriptor()`** 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 (see the chapter describing the **`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 programmed in the **`cudnnSetRNNDescriptor()`** call. 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 see 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 programmed via cudnnSetRNNDescriptor().

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 (e.g., 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.

4.187. cudnnSetReduceTensorDescriptor

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

This function initializes a previously created reduce tensor descriptor object.

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 datatype of the reduction.

reduceTensorNanOpt

Input. Enumerant to specify the Nan propagation mode.

reduceTensorIndices

Input. Enumerant to specify the reduce 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).

4.188. cudnnSetSeqDataDescriptor

```
cudnnStatus_t cudnnSetSeqDataDescriptor(
 cudnnSeqDataDescriptor_t seqDataDesc,
 cudnnDataType_t dataType,
 int nbDims,
 const int dimA[],
 const cudnnSeqDataAxis_t axes[],
 size_t seqLengthArraySize,
 const int seqLengthArray[],
 void *paddingFill);
```

This function initializes a previously created sequence data descriptor object. This descriptor points to a buffer that holds a batch of sequence samples. Each sample consists of a fixed beam size number of sequences.

Sequence data are regularly strided in memory with the order of time, batch, beam, and vector axes specified by the array **`axes[]`**.

Each sequence has different sequence length and is specified in **`seqLengthArray`**, an array of size **`seqLengthArraySize`**.

The value of **`seqLengthArraySize`** is < **`dimA[CUDNN_SEQDATA_TIME_DIM]`**.

Parameters:

Parameter	Input / Output	Description
seqDataDesc	Output	Pointer to a previously created **`cudnnSeqDataDescriptor`** structure to initialize.
dataType	Input	Data type of the sequence data.
nbDims	Input	Number of sequence data dimensions.
dimA[]	Input	Size of each axes dimension. Array that contains the dimensions of the buffer that holds a batch of sequence samples. This **`dimA`** is an array of 4 positive integers, where: - **`dimA[CUDNN_SEQDATA_TIME_DIM]`** is the maximum allowed sequence length - **`dimA[CUDNN_SEQDATA_BATCH_DIM]`** is the maximum allowed batch size - **`dimA[CUDNN_SEQDATA_BEAM_DIM]`** is the number of beam in each sample - **`dimA[CUDNN_SEQDATA_VECT_DIM]`** is the vector length.
axes[]	Input	Array of axes, sorted from outermost to innermost dimension. The array size is CUDNN_SEQDATA_DIM_COUNT. The elements of **`axes[]`** array is a valid permutation of enumerated labels of cudnnSeqDataAxis_t (in the order from the outermost to the innermost axes in memory.)
seqLengthArraySize	Input	Number of elements in, i.e., the length of, the **`seqLengthArray`**. The value of this **`seqLengthArraySize`** is < **`dimA[CUDNN_SEQDATA_TIME_DIM]`**.
seqLengthArray[]	Input	Array that holds the sequence lengths of each sequence.

paddingFill	Input	Points to a value, of **`dataType`**, that is used to fill up the buffer beyond the sequence length of each sequence. The only supported value for `paddingFill` is 0.

Returns:

Return Value	Description
CUDNN_STATUS_SUCCESS	All input values are validated and the descriptor value updated successfully.
CUDNN_STATUS_BAD_PARAM	Any of the below invalid inputs has occurred: - **`seqDataDesc == NULL`** - **`dateType`** is not a valid data type - **`nbDims`** is not positive. - Any element of dimA is not positive - **`seqLengthArraySize`** is not equal to **`dimA[CUDNN_SEQDATA_BATCH_DIM] * dimA[CUDNN_SEQDATA_BEAM_DIM]`** - Any element of **`seqLengthArray`** is not positive - Any element of **`seqLengthArray`** is larger than **`dimA[CUDNN_SEQDATA_TIME_DIM]`**
CUDNN_STATUS_NOT_SUPPORTED	Encountered any of the below unsupported values: - **`nbDims`** is not equal to CUDNN_SEQDATA_DIM_COUNT (4) - **`paddingFill`** is not a NULL pointer, and the value pointed to is not of the **`dataType`**.
CUDNN_STATUS_ALLOC_FAILED	Failed to allocate storage for some field of the descriptor structure.

4.189. cudnnSetSpatialTransformerNdDescriptor

```
cudnnStatus_t cudnnSetSpatialTransformerNdDescriptor(
    cudnnSpatialTransformerDescriptor_t     stDesc,
    cudnnSamplerType_t                      samplerType,
    cudnnDataType_t                         dataType,
    const int                               nbDims,
    const int                               dimA[])
```

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

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.

The possible error values returned by this function and their meanings are listed below.

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

4.190. cudnnSetStream

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

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.

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.

4.191. cudnnSetTensor

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

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

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**.

The possible error values returned by this function and their meanings are listed below.

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.

4.192. cudnnSetTensor4dDescriptor

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

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.

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.

The possible error values returned by this function and their meanings are listed below.

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 **`format`** has an invalid enumerant value or **`dataType`** has an invalid enumerant value.

`CUDNN_STATUS_NOT_SUPPORTED`

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

4.193. cudnnSetTensor4dDescriptorEx

```
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)
```

This function initializes a previously created generic Tensor descriptor object into a 4D tensor, similarly to **`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.

At present, some cuDNN routines have limited support for strides; Those routines will return CUDNN_STATUS_NOT_SUPPORTED if a Tensor4D 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 **`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.

The possible error values returned by this function and their meanings are listed below.

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 maximim limit of 2 Giga-elements.

4.194. cudnnSetTensorNdDescriptor

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

This function initializes a previously created generic Tensor descriptor object.

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.

Do not use 2 dimensions. Due to historical reasons, the minimum number of dimensions in the filter descriptor is three. See also the cudnnGetRNNLinLayerBiasParams().

dimA

Input. Array of dimension **`nbDims`** that contain the size of the tensor for every dimension. Size along unused dimensions should be set to 1.

strideA

Input. Array of dimension **`nbDims`** that contain the stride of the tensor for every dimension.

The possible error values returned by this function and their meanings are listed below.

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 enumerant value.

`CUDNN_STATUS_NOT_SUPPORTED`

The parameter **`nbDims`** is outside the range [4, CUDNN_DIM_MAX], or the total size of the tensor descriptor exceeds the maximim limit of 2 Giga-elements.

4.195. cudnnSetTensorNdDescriptorEx

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

This function initializes an n-D tensor descriptor.

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.

Do not use 2 dimensions. Due to historical reasons, the minimum number of dimensions in the filter descriptor is three. See also the cudnnGetRNNLinLayerBiasParams().

dimA

Input. Array containing 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.

4.196. cudnnSetTensorTransformDescriptor

```
cudnnStatus_t 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);
```

This function initializes a Tensor transform descriptor that was previously created using the cudnnCreateTensorTransformDescriptor function.

Parameters:

Parameter	Input / Output	Description
transformDesc	Output	The Tensor transform descriptor to be initialized.
nbDims	Input	The dimensionality of the transform operands. Must be greater than 2. See also https://docs.nvidia.com/deeplearning/sdk/cudnn-developer-guide/index.html#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. See cudnnFoldingDirection_t.

Returns:

Return Value	Description
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 (i.e., one of the **`nbDims`** is larger than CUDNN_DIM_MAX), or if **`destFromat`** is something other than NCHW or NHWC.

4.197. cudnnSoftmaxBackward

```
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)
```

This routine computes the gradient of the softmax function.

In-place operation is allowed for this routine; i.e., **`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

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]*result + beta[0]*priorDstValue. Please refer to this section for additional details.

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`**.

The possible error values returned by this function and their meanings are listed below.

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.

4.198. cudnnSoftmaxForward

```
cudnnStatus_t 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)
```

This routine computes the softmax function.

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

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]*result + beta[0]*priorDstValue. Please refer to this section for additional details.

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`**.

The possible error values returned by this function and their meanings are listed below.

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.

4.199. cudnnSpatialTfGridGeneratorBackward

```
cudnnStatus_t cudnnSpatialTfGridGeneratorBackward(
    cudnnHandle_t                              handle,
    const cudnnSpatialTransformerDescriptor_t   stDesc,
    const void                                *dgrid,
    void                                      *dtheta)
```

This function computes the gradient of a grid generation operation.

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.

The possible error values returned by this function and their meanings are listed below.

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, 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 transformed tensor specified in **stDesc** > 4.

CUDNN_STATUS_EXECUTION_FAILED

The function failed to launch on the GPU.

4.200. cudnnSpatialTfGridGeneratorForward

```
cudnnStatus_t cudnnSpatialTfGridGeneratorForward(
    cudnnHandle_t                              handle,
    const cudnnSpatialTransformerDescriptor_t   stDesc,
    const void                                *theta,
    void                                      *grid)
```

This function generates a grid of coordinates in the input tensor corresponding to each pixel from the output tensor.

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*2*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*h*w*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.

The possible error values returned by this function and their meanings are listed below.

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, theta`** 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 transformed tensor specified in **`stDesc`** > 4.

`CUDNN_STATUS_EXECUTION_FAILED`

The function failed to launch on the GPU.

4.201. cudnnSpatialTfSamplerBackward

```
cudnnStatus_t 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)
```

This function computes the gradient of a sampling operation.

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]*srcValue + beta[0]*priorDstValue. Please refer to this section for additional details.

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: dstValue =

alpha[0]*srcValue + beta[0]*priorDstValue. Please refer to this section for additional details.

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.

The possible error values returned by this function and their meanings are listed below.

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.

4.202. cudnnSpatialTfSamplerForward

```
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)
```

This function performs a sampler operation and generates the output tensor using the grid given by the grid generator.

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]*srcValue + beta[0]*priorDstValue. Please refer to this section for additional details.

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`**.

The possible error values returned by this function and their meanings are listed below.

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, grid`** 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 transformed tensor > 4.

CUDNN_STATUS_EXECUTION_FAILED

The function failed to launch on the GPU.

4.203. cudnnTransformTensor

```
cudnnStatus_t cudnnTransformTensor(
    cudnnHandle_t                  handle,
    const void                    *alpha,
    const cudnnTensorDescriptor_t  xDesc,
    const void                    *x,
    const void                    *beta,
    const cudnnTensorDescriptor_t  yDesc,
    void                          *y)
```

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 (i.e., tensors cannot be transformed in place). This function can be used to convert a tensor with an unsupported format to a supported one.

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: dstValue = alpha[0]*srcValue + beta[0]*priorDstValue. Please refer to this section for additional details.

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.

The possible error values returned by this function and their meanings are listed below.

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.

4.204. cudnnTransformTensorEx

```
cudnnStatus_t cudnnTransformTensorEx(
 cudnnHandle_t handle,
 const cudnnTransformDescriptor_t transDesc,
 const void *alpha,
 const cudnnTensorDescriptor_t srcDesc,
 const void *srcData,
 const void *beta,
 const cudnnTensorDescriptor_t destDesc,
 void *destData);
```

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.

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 (i.e., Tensors cannot be transformed in place).

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:

Parameter	Input / Output	Description
handle	Input	Handle to a previously created cuDNN context.
transDesc	Input	A descriptor containing the details of the requested Tensor transformation.
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. 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 initialed Tensor descriptors. **`srcDesc`** and **`destDesc`** must not overlap.
srcData, destData	Input	Pointers, in the host memory, to the data of the Tensor described by **`srcDesc`** and **`destData`** respectively.

Returns:

Return Value	**Description**
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.

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