



# CUDNN 7.1.4

DU-06702-001\_v07 | May 2018

## Developer Guide



# TABLE OF CONTENTS

|   |           |
|---|-----------|
| <b>Chapter 1. Overview</b> .....                        | <b>1</b>  |
| <b>Chapter 2. General Description</b> .....             | <b>2</b>  |
| 2.1. Programming Model.....                             | 2         |
| 2.2. Notation.....                                      | 3         |
| 2.3. Tensor Descriptor.....                             | 3         |
| 2.3.1. WXYZ Tensor Descriptor.....                      | 4         |
| 2.3.2. 4-D Tensor Descriptor.....                       | 4         |
| 2.3.3. 5-D Tensor Description.....                      | 4         |
| 2.3.4. Fully-packed tensors.....                        | 4         |
| 2.3.5. Partially-packed tensors.....                    | 5         |
| 2.3.6. Spatially packed tensors.....                    | 5         |
| 2.3.7. Overlapping tensors.....                         | 5         |
| 2.4. Thread Safety.....                                 | 5         |
| 2.5. Reproducibility (determinism).....                 | 5         |
| 2.6. Scaling parameters alpha and beta.....             | 6         |
| 2.7. Tensor Core Operations.....                        | 6         |
| 2.7.1. Tensor Core Operations Notes.....                | 7         |
| 2.8. GPU and driver requirements.....                   | 8         |
| 2.9. Backward compatibility and deprecation policy..... | 8         |
| 2.10. Grouped Convolutions.....                         | 9         |
| 2.11. API Logging (new for 7.1).....                    | 9         |
| <b>Chapter 3. cuDNN Datatypes Reference</b> .....       | <b>11</b> |
| 3.1. cudnnActivationDescriptor_t.....                   | 11        |
| 3.2. cudnnActivationMode_t.....                         | 11        |
| 3.3. cudnnBatchNormMode_t.....                          | 12        |
| 3.4. cudnnCTCLossAlgo_t.....                            | 12        |
| 3.5. cudnnCTCLossDescriptor_t.....                      | 13        |
| 3.6. cudnnConvolutionBwdDataAlgoPerf_t.....             | 13        |
| 3.7. cudnnConvolutionBwdDataAlgo_t.....                 | 14        |
| 3.8. cudnnConvolutionBwdDataPreference_t.....           | 14        |
| 3.9. cudnnConvolutionBwdFilterAlgoPerf_t.....           | 15        |
| 3.10. cudnnConvolutionBwdFilterAlgo_t.....              | 16        |
| 3.11. cudnnConvolutionBwdFilterPreference_t.....        | 16        |
| 3.12. cudnnConvolutionDescriptor_t.....                 | 17        |
| 3.13. cudnnConvolutionFwdAlgoPerf_t.....                | 17        |
| 3.14. cudnnConvolutionFwdAlgo_t.....                    | 18        |
| 3.15. cudnnConvolutionFwdPreference_t.....              | 19        |
| 3.16. cudnnConvolutionMode_t.....                       | 19        |
| 3.17. cudnnDataType_t.....                              | 19        |
| 3.18. cudnnDeterminism_t.....                           | 20        |

|   |           |
|---|-----------|
| 3.19. cudnnDirectionMode_t.....                   | 20        |
| 3.20. cudnnDivNormMode_t.....                     | 21        |
| 3.21. cudnnDropoutDescriptor_t.....               | 21        |
| 3.22. cudnnErrQueryMode_t.....                    | 21        |
| 3.23. cudnnFilterDescriptor_t.....                | 22        |
| 3.24. cudnnHandle_t.....                          | 22        |
| 3.25. cudnnIndicesType_t.....                     | 22        |
| 3.26. cudnnLRNMode_t.....                         | 23        |
| 3.27. cudnnMathType_t.....                        | 23        |
| 3.28. cudnnNanPropagation_t.....                  | 23        |
| 3.29. cudnnOpTensorDescriptor_t.....              | 23        |
| 3.30. cudnnOpTensorOp_t.....                      | 24        |
| 3.31. cudnnPersistentRNNPlan_t.....               | 24        |
| 3.32. cudnnPoolingDescriptor_t.....               | 24        |
| 3.33. cudnnPoolingMode_t.....                     | 24        |
| 3.34. cudnnRNNAlgo_t.....                         | 25        |
| 3.35. cudnnRNNDescriptor_t.....                   | 26        |
| 3.36. cudnnRNNInputMode_t.....                    | 26        |
| 3.37. cudnnRNNMode_t.....                         | 26        |
| 3.38. cudnnReduceTensorDescriptor_t.....          | 27        |
| 3.39. cudnnReduceTensorIndices_t.....             | 27        |
| 3.40. cudnnReduceTensorOp_t.....                  | 28        |
| 3.41. cudnnSamplerType_t.....                     | 28        |
| 3.42. cudnnSoftmaxAlgorithm_t.....                | 29        |
| 3.43. cudnnSoftmaxMode_t.....                     | 29        |
| 3.44. cudnnSpatialTransformerDescriptor_t.....    | 29        |
| 3.45. cudnnStatus_t.....                          | 30        |
| 3.46. cudnnTensorDescriptor_t.....                | 31        |
| 3.47. cudnnTensorFormat_t.....                    | 31        |
| <b>Chapter 4. cuDNN API Reference.....</b>        | <b>33</b> |
| 4.1. cudnnActivationBackward.....                 | 33        |
| 4.2. cudnnActivationForward.....                  | 35        |
| 4.3. cudnnAddTensor.....                          | 36        |
| 4.4. cudnnBatchNormalizationBackward.....         | 37        |
| 4.5. cudnnBatchNormalizationForwardInference..... | 39        |
| 4.6. cudnnBatchNormalizationForwardTraining.....  | 41        |
| 4.7. cudnnCTCLoss.....                            | 43        |
| 4.8. cudnnConvolutionBackwardBias.....            | 45        |
| 4.9. cudnnConvolutionBackwardData.....            | 46        |
| 4.10. cudnnConvolutionBackwardFilter.....         | 51        |
| 4.11. cudnnConvolutionBiasActivationForward.....  | 55        |
| 4.12. cudnnConvolutionForward.....                | 58        |
| 4.13. cudnnCreate.....                            | 64        |

|  |    |
|--|----|
| 4.14. cudnnCreateActivationDescriptor.....               | 65 |
| 4.15. cudnnCreateAlgorithmDescriptor.....                | 65 |
| 4.16. cudnnCreateAlgorithmPerformance.....               | 66 |
| 4.17. cudnnCreateCTCLossDescriptor.....                  | 66 |
| 4.18. cudnnCreateConvolutionDescriptor.....              | 67 |
| 4.19. cudnnCreateDropoutDescriptor.....                  | 67 |
| 4.20. cudnnCreateFilterDescriptor.....                   | 67 |
| 4.21. cudnnCreateLRNDescriptor.....                      | 68 |
| 4.22. cudnnCreateOpTensorDescriptor.....                 | 68 |
| 4.23. cudnnCreatePersistentRNNPlan.....                  | 68 |
| 4.24. cudnnCreatePoolingDescriptor.....                  | 69 |
| 4.25. cudnnCreateRNNDescriptor.....                      | 69 |
| 4.26. cudnnCreateReduceTensorDescriptor.....             | 70 |
| 4.27. cudnnCreateSpatialTransformerDescriptor.....       | 70 |
| 4.28. cudnnCreateTensorDescriptor.....                   | 70 |
| 4.29. cudnnDeriveBNTensorDescriptor.....                 | 71 |
| 4.30. cudnnDestroy.....                                  | 72 |
| 4.31. cudnnDestroyActivationDescriptor.....              | 72 |
| 4.32. cudnnDestroyAlgorithmDescriptor.....               | 72 |
| 4.33. cudnnDestroyAlgorithmPerformance.....              | 73 |
| 4.34. cudnnDestroyCTCLossDescriptor.....                 | 73 |
| 4.35. cudnnDestroyConvolutionDescriptor.....             | 73 |
| 4.36. cudnnDestroyDropoutDescriptor.....                 | 74 |
| 4.37. cudnnDestroyFilterDescriptor.....                  | 74 |
| 4.38. cudnnDestroyLRNDescriptor.....                     | 74 |
| 4.39. cudnnDestroyOpTensorDescriptor.....                | 74 |
| 4.40. cudnnDestroyPersistentRNNPlan.....                 | 75 |
| 4.41. cudnnDestroyPoolingDescriptor.....                 | 75 |
| 4.42. cudnnDestroyRNNDescriptor.....                     | 75 |
| 4.43. cudnnDestroyReduceTensorDescriptor.....            | 75 |
| 4.44. cudnnDestroySpatialTransformerDescriptor.....      | 76 |
| 4.45. cudnnDestroyTensorDescriptor.....                  | 76 |
| 4.46. cudnnDivisiveNormalizationBackward.....            | 76 |
| 4.47. cudnnDivisiveNormalizationForward.....             | 78 |
| 4.48. cudnnDropoutBackward.....                          | 80 |
| 4.49. cudnnDropoutForward.....                           | 81 |
| 4.50. cudnnDropoutGetReserveSpaceSize.....               | 83 |
| 4.51. cudnnDropoutGetStatesSize.....                     | 83 |
| 4.52. cudnnFindConvolutionBackwardDataAlgorithm.....     | 84 |
| 4.53. cudnnFindConvolutionBackwardDataAlgorithmEx.....   | 85 |
| 4.54. cudnnFindConvolutionBackwardFilterAlgorithm.....   | 87 |
| 4.55. cudnnFindConvolutionBackwardFilterAlgorithmEx..... | 89 |
| 4.56. cudnnFindConvolutionForwardAlgorithm.....          | 91 |

|   |     |
|---|-----|
| 4.57. cudnnFindConvolutionForwardAlgorithmEx.....             | 92  |
| 4.58. cudnnFindRNNBackwardDataAlgorithmEx.....                | 94  |
| 4.59. cudnnFindRNNBackwardWeightsAlgorithmEx.....             | 100 |
| 4.60. cudnnFindRNNForwardInferenceAlgorithmEx.....            | 102 |
| 4.61. cudnnFindRNNForwardTrainingAlgorithmEx.....             | 106 |
| 4.62. cudnnGetActivationDescriptor.....                       | 110 |
| 4.63. cudnnGetAlgorithmDescriptor.....                        | 111 |
| 4.64. cudnnGetAlgorithmPerformance.....                       | 111 |
| 4.65. cudnnGetAlgorithmSpaceSize.....                         | 112 |
| 4.66. cudnnGetCTCLossDescriptor.....                          | 113 |
| 4.67. cudnnGetCTCLossWorkspaceSize.....                       | 113 |
| 4.68. cudnnGetCallback.....                                   | 114 |
| 4.69. cudnnGetConvolution2dDescriptor.....                    | 115 |
| 4.70. cudnnGetConvolution2dForwardOutputDim.....              | 116 |
| 4.71. cudnnGetConvolutionBackwardDataAlgorithm.....           | 117 |
| 4.72. cudnnGetConvolutionBackwardDataAlgorithmMaxCount.....   | 118 |
| 4.73. cudnnGetConvolutionBackwardDataAlgorithm_v7.....        | 119 |
| 4.74. cudnnGetConvolutionBackwardDataWorkspaceSize.....       | 120 |
| 4.75. cudnnGetConvolutionBackwardFilterAlgorithm.....         | 121 |
| 4.76. cudnnGetConvolutionBackwardFilterAlgorithmMaxCount..... | 122 |
| 4.77. cudnnGetConvolutionBackwardFilterAlgorithm_v7.....      | 123 |
| 4.78. cudnnGetConvolutionBackwardFilterWorkspaceSize.....     | 124 |
| 4.79. cudnnGetConvolutionForwardAlgorithm.....                | 125 |
| 4.80. cudnnGetConvolutionForwardAlgorithmMaxCount.....        | 126 |
| 4.81. cudnnGetConvolutionForwardAlgorithm_v7.....             | 127 |
| 4.82. cudnnGetConvolutionForwardWorkspaceSize.....            | 128 |
| 4.83. cudnnGetConvolutionGroupCount.....                      | 129 |
| 4.84. cudnnGetConvolutionMathType.....                        | 130 |
| 4.85. cudnnGetConvolutionNdDescriptor.....                    | 130 |
| 4.86. cudnnGetConvolutionNdForwardOutputDim.....              | 131 |
| 4.87. cudnnGetCudartVersion.....                              | 132 |
| 4.88. cudnnGetDropoutDescriptor.....                          | 132 |
| 4.89. cudnnGetErrorString.....                                | 133 |
| 4.90. cudnnGetFilter4dDescriptor.....                         | 134 |
| 4.91. cudnnGetFilterNdDescriptor.....                         | 134 |
| 4.92. cudnnGetLRNDescriptor.....                              | 135 |
| 4.93. cudnnGetOpTensorDescriptor.....                         | 136 |
| 4.94. cudnnGetPooling2dDescriptor.....                        | 136 |
| 4.95. cudnnGetPooling2dForwardOutputDim.....                  | 137 |
| 4.96. cudnnGetPoolingNdDescriptor.....                        | 138 |
| 4.97. cudnnGetPoolingNdForwardOutputDim.....                  | 139 |
| 4.98. cudnnGetProperty.....                                   | 140 |
| 4.99. cudnnGetRNNDescriptor.....                              | 141 |

|        |                                     |     |
|--------|-------------------------------------|-----|
| 4.100. | cudaGetRNNLinLayerBiasParams.....   | 142 |
| 4.101. | cudaGetRNNLinLayerMatrixParams..... | 144 |
| 4.102. | cudaGetRNNParamsSize.....           | 146 |
| 4.103. | cudaGetRNNProjectionLayers.....     | 147 |
| 4.104. | cudaGetRNNTrainingReserveSize.....  | 148 |
| 4.105. | cudaGetRNNWorkspaceSize.....        | 149 |
| 4.106. | cudaGetReduceTensorDescriptor.....  | 150 |
| 4.107. | cudaGetReductionIndicesSize.....    | 151 |
| 4.108. | cudaGetReductionWorkspaceSize.....  | 151 |
| 4.109. | cudaGetStream.....                  | 152 |
| 4.110. | cudaGetTensor4dDescriptor.....      | 152 |
| 4.111. | cudaGetTensorNdDescriptor.....      | 153 |
| 4.112. | cudaGetTensorSizeInBytes.....       | 154 |
| 4.113. | cudaGetVersion.....                 | 155 |
| 4.114. | cudaIm2Col.....                     | 155 |
| 4.115. | cudaLRNCrossChannelBackward.....    | 156 |
| 4.116. | cudaLRNCrossChannelForward.....     | 158 |
| 4.117. | cudaOpTensor.....                   | 159 |
| 4.118. | cudaPoolingBackward.....            | 161 |
| 4.119. | cudaPoolingForward.....             | 162 |
| 4.120. | cudaQueryRuntimeError.....          | 164 |
| 4.121. | cudaRNNBackwardData.....            | 165 |
| 4.122. | cudaRNNBackwardWeights.....         | 170 |
| 4.123. | cudaRNNForwardInference.....        | 173 |
| 4.124. | cudaRNNForwardTraining.....         | 176 |
| 4.125. | cudaReduceTensor.....               | 180 |
| 4.126. | cudaRestoreAlgorithm.....           | 182 |
| 4.127. | cudaRestoreDropoutDescriptor.....   | 183 |
| 4.128. | cudaSaveAlgorithm.....              | 184 |
| 4.129. | cudaScaleTensor.....                | 184 |
| 4.130. | cudaSetActivationDescriptor.....    | 185 |
| 4.131. | cudaSetAlgorithmDescriptor.....     | 186 |
| 4.133. | cudaSetCTCLossDescriptor.....       | 186 |
| 4.134. | cudaSetCallback.....                | 187 |
| 4.135. | cudaSetConvolution2dDescriptor..... | 188 |
| 4.136. | cudaSetConvolutionGroupCount.....   | 189 |
| 4.137. | cudaSetConvolutionMathType.....     | 189 |
| 4.138. | cudaSetConvolutionNdDescriptor..... | 189 |
| 4.139. | cudaSetDropoutDescriptor.....       | 191 |
| 4.140. | cudaSetFilter4dDescriptor.....      | 192 |
| 4.141. | cudaSetFilterNdDescriptor.....      | 193 |
| 4.142. | cudaSetLRNDescriptor.....           | 194 |
| 4.143. | cudaSetOpTensorDescriptor.....      | 195 |

|  |            |
|--|------------|
| 4.144. cudnnSetPersistentRNNPlan.....              | 195        |
| 4.145. cudnnSetPooling2dDescriptor.....            | 196        |
| 4.146. cudnnSetPoolingNdDescriptor.....            | 197        |
| 4.147. cudnnSetRNNDescriptor.....                  | 198        |
| 4.148. cudnnSetRNNDescriptor_v5.....               | 199        |
| 4.149. cudnnSetRNNDescriptor_v6.....               | 200        |
| 4.150. cudnnSetRNNMatrixMathType.....              | 201        |
| 4.151. cudnnSetRNNProjectionLayers.....            | 202        |
| 4.152. cudnnSetReduceTensorDescriptor.....         | 203        |
| 4.153. cudnnSetSpatialTransformerNdDescriptor..... | 204        |
| 4.154. cudnnSetStream.....                         | 204        |
| 4.155. cudnnSetTensor.....                         | 205        |
| 4.156. cudnnSetTensor4dDescriptor.....             | 206        |
| 4.157. cudnnSetTensor4dDescriptorEx.....           | 207        |
| 4.158. cudnnSetTensorNdDescriptor.....             | 208        |
| 4.159. cudnnSetTensorNdDescriptorEx.....           | 209        |
| 4.160. cudnnSoftmaxBackward.....                   | 210        |
| 4.161. cudnnSoftmaxForward.....                    | 212        |
| 4.162. cudnnSpatialTfGridGeneratorBackward.....    | 213        |
| 4.163. cudnnSpatialTfGridGeneratorForward.....     | 214        |
| 4.164. cudnnSpatialTfSamplerBackward.....          | 215        |
| 4.165. cudnnSpatialTfSamplerForward.....           | 217        |
| 4.166. cudnnTransformTensor.....                   | 218        |
| <b>Chapter 5. Acknowledgments.....</b>             | <b>220</b> |
| 5.1. University of Tennessee.....                  | 220        |
| 5.2. University of California, Berkeley.....       | 220        |
| 5.3. Facebook AI Research, New York.....           | 221        |





# 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 performance competitive with the fastest GEMM (matrix multiply) based implementations of such routines while using significantly less memory.

cuDNN features 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 chapter.

### 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 **cudaDnnCreate()**. 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 **cudaDnnDestroy()**. 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 which directs library calls to the device associated with it. cuDNN library calls made with different handles will thus automatically run on different devices. The device associated with a particular cuDNN context is assumed to remain unchanged between the corresponding **cudaDnnCreate()** and **cudaDnnDestroy()** 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 **cudaDnnCreate()**.

#### cuDNN API Compatibility

Beginning in cuDNN 7, 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  $w \neq z$ )
- ▶ 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  $y \geq x$ )

- ▶ Applications compiled with a cuDNN version 7.y are not guaranteed to work with 7.x release when  $y > x$ .

## 2.2. Notation

As of CUDNN v4 we have adopted a mathematically-inspired notation for layer inputs and outputs using  $\mathbf{x}, \mathbf{y}, \mathbf{dx}, \mathbf{dy}, \mathbf{b}, \mathbf{w}$  for common layer parameters. This was done to improve readability and ease of understanding of parameters meaning. All layers now follow a uniform convention that during inference

$\mathbf{y} = \text{layerFunction}(\mathbf{x}, \text{otherParams})$ .

And during backpropagation

$(\mathbf{dx}, \mathbf{dOtherParams}) = \text{layerFunctionGradient}(\mathbf{x}, \mathbf{y}, \mathbf{dy}, \text{otherParams})$

For convolution the notation is

$\mathbf{y} = \mathbf{x} * \mathbf{w} + \mathbf{b}$

where  $\mathbf{w}$  is the matrix of filter weights,  $\mathbf{x}$  is the previous layer's data (during inference),  $\mathbf{y}$  is the next layer's data,  $\mathbf{b}$  is the bias and  $*$  is the convolution operator. In backpropagation routines the parameters keep their meanings.  $\mathbf{dx}, \mathbf{dy}, \mathbf{dw}, \mathbf{db}$  always refer to the gradient of the final network error function with respect to a given parameter. So  $\mathbf{dy}$  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,  $\mathbf{dMeans}$  or  $\mathbf{dBnBias}$  refer to gradients of the loss function wrt those parameters.



$\mathbf{w}$  is used in the API for both the width of the  $\mathbf{x}$  tensor and convolution filter matrix. To resolve this ambiguity we use  $\mathbf{w}$  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.

## 2.3. 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 `dim` from 3 to 8
- ▶ a data type (32-bit floating point, 64 bit-floating point, 16 bit floating point...)
- ▶ `dim` integers defining the size of each dimension
- ▶ `dim` integers 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 two dimensions define respectively the batch size `n` and 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.

### 2.3.1. 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

### 2.3.2. 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

### 2.3.3. 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 decreasing order of the strides. The commonly used 5-D tensor formats are called :

- ▶ NCDHW
- ▶ NDHWC
- ▶ CDHWN

### 2.3.4. 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.

### 2.3.5. 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, it's 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.

### 2.3.6. 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.

### 2.3.7. 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  $\text{stride}[i-1] < \text{stride}[i] * \text{dim}[i]$  for some of the  $i$  from  $[1, \text{nbDims}]$  interval.

## 2.4. 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.

## 2.5. 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:

- ▶ `cudaConvolutionBackwardFilter` when `CUDNN_CONVOLUTION_BWD_FILTER_ALGO_0` or `CUDNN_CONVOLUTION_BWD_FILTER_ALGO_3` is used
- ▶ `cudaConvolutionBackwardData` when `CUDNN_CONVOLUTION_BWD_DATA_ALGO_0` is used
- ▶ `cudaPoolingBackward` when `CUDNN_POOLING_MAX` is used
- ▶ `cudaSpatialTfSamplerBackward`

## 2.6. Scaling parameters `alpha` and `beta`

Many cuDNN routines like `cudaConvolutionForward` take pointers to scaling factors (in host memory), that are used to blend computed values with initial values in the destination tensor as follows:  $dstValue = alpha[0]*computedValue + beta[0]*priorDstValue$ . When `beta[0]` is zero, the output is not read and may contain any uninitialized data (including NaN). The storage data type for `alpha[0]`, `beta[0]` is float for HALF and FLOAT tensors, and double for DOUBLE tensors. These parameters are passed using a host memory pointer.



For improved performance it is advised to use `beta[0] = 0.0`. Use a non-zero value for `beta[0]` only when blending with prior values stored in the output tensor is needed.

## 2.7. Tensor Core Operations

cuDNN v7 introduces acceleration of compute intensive routines using Tensor Core hardware on supported GPU SM versions. Tensor Core acceleration (using Tensor Core Operations) can be exploited by the library user via the `cudaMathType_t` enumerator. This enumerator specifies the available options for Tensor Core enablement and is expected to be applied on a per-routine basis.

Kernels using Tensor Core Operations for are available for both Convolutions and RNNs.

The Convolution functions are:

- ▶ `cudaConvolutionForward`
- ▶ `cudaConvolutionBackwardData`
- ▶ `cudaConvolutionBackwardFilter`

Tensor Core Operations kernels will be triggered in these paths only when:

- ▶ `cudaSetConvolutionMathType` is called on the appropriate convolution descriptor setting `mathType` to `CUDNN_TENSOR_OP_MATH`.
- ▶ `cudaConvolutionForward` is called using `algo = CUDNN_CONVOLUTION_FWD_ALGO_IMPLICIT_PRECOMP_GEMM` or `CUDNN_CONVOLUTION_FWD_ALGO_WINOGRAD_NONFUSED`; `cudaConvolutionBackwardData` using `algo = CUDNN_CONVOLUTION_BWD_DATA_ALGO_1` or

CUDNN\_CONVOLUTION\_BWD\_DATA\_ALGO\_WINOGRAD\_NONFUSED;  
 and cudnnConvolutionBackwardFilter using algo =  
 CUDNN\_CONVOLUTION\_BWD\_FILTER\_ALGO\_1 or  
 CUDNN\_CONVOLUTION\_BWD\_FILTER\_ALGO\_WINOGRAD\_NONFUSED.

For algorithms other than \*\_ALGO\_WINOGRAD\_NONFUSED, the following are some of the requirements to run Tensor Core operations:

- ▶ Input, Filter and Output descriptors (xDesc, yDesc, wDesc, dxDesc, dyDesc and dwDesc as applicable) have dataType = CUDNN\_DATA\_HALF.
- ▶ The number of Input and Output feature maps is a multiple of 8.
- ▶ The Filter is of type CUDNN\_TENSOR\_NCHW or CUDNN\_TENSOR\_NHWC. When using a filter of type CUDNN\_TENSOR\_NHWC, Input, Filter and Output data pointers (X, Y, W, dX, dY, and dW as applicable) need to be aligned to 128 bit boundaries.

The RNN functions are:

- ▶ cudnnRNNForwardInference
- ▶ cudnnRNNForwardTraining
- ▶ cudnnRNNBackwardData
- ▶ cudnnRNNBackwardWeights

Tensor Core Operations kernels will be triggered in these paths only when:

- ▶ cudnnSetRNNMatrixMathType is called on the appropriate RNN descriptor setting mathType to CUDNN\_TENSOR\_OP\_MATH.
- ▶ All routines are called using algo = CUDNN\_RNN\_ALGO\_STANDARD or CUDNN\_RNN\_ALGO\_PERSIST\_STATIC. (new for 7.1)
- ▶ For algo = CUDNN\_RNN\_ALGO\_STANDARD, Hidden State size, Input size and Batch size are all multiples of 8. (new for 7.1)
- ▶ For algo = CUDNN\_RNN\_ALGO\_PERSIST\_STATIC, Hidden State size and Input size are multiples of 32, Batch size is a multiple of 8. If Batch size exceeds 96 (forward training or inference) or 32 (backward data), Batch sizes constraints may be stricter and large power-of-two Batch sizes may be needed. (new for 7.1)

For all cases, the CUDNN\_TENSOR\_OP\_MATH enumerator is an indicator that the use of Tensor Cores is permissible, but not required. cuDNN may prefer not to use Tensor Core Operations (for instance, when the problem size is not suited to Tensor Core acceleration), and instead use an alternative implementation based on regular floating point operations.

## 2.7.1. Tensor Core Operations Notes

Some notes on Tensor Core Operations use in cuDNN v7 on sm\_70:

Tensor Core operations are supported on the Volta GPU family, those operations perform parallel floating point accumulation of multiple floating point products. Setting the math mode to CUDNN\_TENSOR\_OP\_MATH indicates that the library will use Tensor Core operations as mentioned previously. The default is CUDNN\_DEFAULT\_MATH, this default indicates that the Tensor Core operations

will be avoided by the library. The default mode is a serialized operation, the Tensor Core operations are parallelized operation, thus the two might result in slight different numerical results due to the different sequencing of operations. Note: The library falls back to the default math mode when Tensor Core operations are not supported or not permitted.

The result of multiplying two matrices using Tensor Core Operations is very close, but not always identical, to the product achieved using some sequence of legacy scalar floating point operations. So cuDNN requires explicit user opt-in before enabling the use of Tensor Core Operations. However, experiments training common Deep Learning models show negligible difference between using Tensor Core Operations and legacy floating point paths as measured by both final network accuracy and iteration count to convergence. Consequently, the library treats both modes of operation as functionally indistinguishable, and allows for the legacy paths to serve as legitimate fallbacks for cases in which the use of Tensor Core Operations is unsuitable.

## 2.8. 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.

## 2.9. 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\_v<n>". "foo\_v<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 compatibility with the following cuDNN release.

## 2.10. Grouped Convolutions

cuDNN supports Grouped Convolutions by setting `GroupCount > 1` using `cudaSetConvolutionGroupCount()`. In memory, all input/output tensors store all independent groups. In this way, all tensor descriptors must describe the size of the entire convolution (as opposed to specifying the sizes per group). See following dimensions/strides explaining how to run Grouped Convolutions for NCHW format for 2-D convolutions. Note that other formats and 3-D convolutions are supported (see associated Convolution API for info on support); the tensor stridings for group count of 1 should still work for any group count.

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

| xDesc or dxDesc   | wDesc or dwDesc  | convDesc                | yDesc or dyDesc   |
|---|--|-------------------------|---|
| Dimensions: [batch_size, input_channels, x_height, x_width]<br>Strides: [input_channels*x_height*x_width, x_height*x_width, x_width, 1] | Dimensions: [output_channels, input_channels/group_count, w_height, w_width]<br>Format: NCHW | GroupCount: group_count | Dimensions: [batch_size, output_channels, y_height, y_width]<br>Strides: [output_channels*y_height*y_width, y_height*y_width, y_width, 1] |

## 2.11. API Logging (new for 7.1)

cuDNN API logging is a tool that records all input parameters passed into every cuDNN API function call. This functionality is by default disabled, and can be enabled through methods described in the next paragraph. The log output contains variable names, data types, parameter values, device pointers, and metadata such as time of the function call in microseconds, process ID, thread ID, cuDNN handle and cuda stream ID. When logging is enabled, the log output will be handled by the built-in default callback function. However, the user may also write their own callback function, and use the `cudaSetCallback` to pass in the function pointer of their own callback function. Following is a sample output of the API log.

```
Function cudaSetActivationDescriptor() called:
mode: type=cudaActivationMode_t; val=CUDA_ACTIVATION_RELU (1);
reluNanOpt: type=cudaNanPropagation_t; val=CUDA_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, cuda_handle: NULL, cuda_stream: NULL.
```

There are two methods to enable API logging.

Method 1: To enable it through environment variables, set “`CUDNN_LOGINFO_DBG`” to “1”, and set “`CUDNN_LOGDEST_DBG`” to one of the following: “`stdout`”, “`stderr`”, or user desired file path, e.g. “`/home/userName1/log.txt`”. You may include date and time conversion specifiers in the file name like “`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, like “`log_2017_11_21_09_41_00.txt`”. The supported conversion specifiers are similar to the “`strftime`” function. If the file already exists, the log will overwrite the existing file. Note that these environmental variables are only checked once at the initialization, and any later changes in these environmental variables will not be effective in the current run. Also note that settings through environment can be overridden by method 2 below.

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

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

# Chapter 3.

## CUDNN DATATYPES REFERENCE

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

### 3.1. 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.

### 3.2. 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 `cudaDnnConvolutionBiasActivationForward()` (need to use `CUDNN_CONVOLUTION_FWD_ALGO_IMPLICIT_GEMM`). Does not work with `cudaDnnActivationForward()` or `cudaDnnActivationBackward()`.

### 3.3. `cudaDnnBatchNormMode_t`

`cudaDnnBatchNormMode_t` is an enumerated type used to specify the mode of operation in `cudaDnnBatchNormalizationForwardInference()`, `cudaDnnBatchNormalizationForwardTraining()`, `cudaDnnBatchNormalizationBackward()` and `cudaDnnDeriveBNTensorDescriptor()` 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 `bnBias` and `bnScale` tensor dimensions 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 `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` data types, compute capability 6.0 or higher, and the following two batch normalization API calls: `cudaDnnBatchNormalizationForwardTraining`, and `cudaDnnBatchNormalizationBackward`. In the latter case `savedMean` and `savedInvVariance` arguments should not be `NULL`. The `CUDNN_BATCHNORM_SPATIAL_PERSISTENT` mode may use scaled atomic integer reduction that is deterministic but imposes some restrictions on the input data range. When a numerical overflow occurs, a NaN (not-a-number) floating point value is written to the output buffer. The user can invoke `cudaDnnQueryRuntimeError` to check if a numerical overflow occurred in this mode.

### 3.4. `cudaDnnCTCLossAlgo_t`

`cudaDnnCTCLossAlgo_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

## 3.5. cudnnCTCLossDescriptor\_t

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

## 3.6. 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 occurred during workspace allocation or if provided workspace is insufficient.
- ▶ **CUDNN\_STATUS\_INTERNAL\_ERROR** if any error occurred during timing calculations or workspace deallocation.
- ▶ Otherwise, this will be the return status of **cudnnConvolutionBackwardData()**.

**float time**

The execution time of **cudnnConvolutionBackwardData()** (in milliseconds).

**size\_t memory**

The workspace size (in bytes).

**cudnnDeterminism\_t determinism**

The determinism of the algorithm.

**cudnnMathType\_t mathType**

The math type provided to the algorithm.

```
int reserved[3]
```

Reserved space for future properties.

## 3.7. 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.

## 3.8. 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

`cudaGetConvolutionBackwardDataAlgorithm()` 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

`cudaGetConvolutionBackwardDataAlgorithm()` 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

`cudaGetConvolutionBackwardDataAlgorithm()` will return the fastest algorithm that fits within the memory limit that the user provided.

## 3.9. `cudaConvolutionBwdFilterAlgoPerf_t`

`cudaConvolutionBwdFilterAlgoPerf_t` is a structure containing performance results returned by `cudaFindConvolutionBackwardFilterAlgorithm()` or heuristic results returned by `cudaGetConvolutionBackwardFilterAlgorithm_v7()`.

### Data Members

`cudaConvolutionBwdFilterAlgo_t` algo

The algorithm run to obtain the associated performance metrics.

`cudaStatus_t` status

If any error occurs during the workspace allocation or timing of `cudaConvolutionBackwardFilter()`, this status will represent that error. Otherwise, this status will be the return status of `cudaConvolutionBackwardFilter()`.

- ▶ `CUDNN_STATUS_ALLOC_FAILED` if any error occurred during workspace allocation or if provided workspace is insufficient.
- ▶ `CUDNN_STATUS_INTERNAL_ERROR` if any error occurred during timing calculations or workspace deallocation.
- ▶ Otherwise, this will be the return status of `cudaConvolutionBackwardFilter()`.

`float` time

The execution time of `cudaConvolutionBackwardFilter()` (in milliseconds).

`size_t` memory

The workspace size (in bytes).

`cudaDeterminism_t` determinism

The determinism of the algorithm.

**cudaMathType\_t mathType**

The math type provided to the algorithm.

**int reserved[3]**

Reserved space for future properties.

## 3.10. 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.

## 3.11. 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

**cudaDnnGetConvolutionBackwardFilterAlgorithm()** 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

**cudaDnnGetConvolutionBackwardFilterAlgorithm()** 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

**cudaDnnGetConvolutionBackwardFilterAlgorithm()** will return the fastest algorithm that fits within the memory limit that the user provided.

## 3.12. **cudaDnnConvolutionDescriptor\_t**

**cudaDnnConvolutionDescriptor\_t** is a pointer to an opaque structure holding the description of a convolution operation. **cudaDnnCreateConvolutionDescriptor()** is used to create one instance, and **cudaDnnSetConvolutionNdDescriptor()** or **cudaDnnSetConvolution2dDescriptor()** must be used to initialize this instance.

## 3.13. **cudaDnnConvolutionFwdAlgoPerf\_t**

**cudaDnnConvolutionFwdAlgoPerf\_t** is a structure containing performance results returned by **cudaDnnFindConvolutionForwardAlgorithm()** or heuristic results returned by **cudaDnnGetConvolutionForwardAlgorithm\_v7()**.

### Data Members

**cudaDnnConvolutionFwdAlgo\_t algo**

The algorithm run to obtain the associated performance metrics.

**cudaDnnStatus\_t status**

If any error occurs during the workspace allocation or timing of **cudaDnnConvolutionForward()**, this status will represent that error. Otherwise, this status will be the return status of **cudaDnnConvolutionForward()**.

- ▶ **CUDNN\_STATUS\_ALLOC\_FAILED** if any error occurred during workspace allocation or if provided workspace is insufficient.
- ▶ **CUDNN\_STATUS\_INTERNAL\_ERROR** if any error occurred during timing calculations or workspace deallocation.
- ▶ Otherwise, this will be the return status of **cudaDnnConvolutionForward()**.

**float time**

The execution time of **cudaDnnConvolutionForward()** (in milliseconds).

**size\_t memory**

The workspace size (in bytes).

**cudaDnnDeterminism\_t determinism**

The determinism of the algorithm.

**cudaDnnMathType\_t mathType**

The math type provided to the algorithm.

**int reserved[3]**

Reserved space for future properties.

## 3.14. cudaDnnConvolutionFwdAlgo\_t

**cudaDnnConvolutionFwdAlgo\_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.

## 3.15. 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.

## 3.16. 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.

## 3.17. cudnnDataType\_t

**cudaDataType\_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\_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.

## 3.18. cudnnDeterminism\_t

**cudaDeterminism\_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

## 3.19. cudnnDirectionMode\_t

`cudaDnnDirectionMode_t` is an enumerated type used to specify the recurrence pattern in the `cudaDnnRNNForwardInference()`, `cudaDnnRNNForwardTraining()`, `cudaDnnRNNBackwardData()` and `cudaDnnRNNBackwardWeights()` routines.

### Values

#### `CUDA_DNN_UNIDIRECTIONAL`

The network iterates recurrently from the first input to the last.

#### `CUDA_DNN_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.

## 3.20. `cudaDnnDivNormMode_t`

`cudaDnnDivNormMode_t` is an enumerated type used to specify the mode of operation in `cudaDnnDivisiveNormalizationForward()` and `cudaDnnDivisiveNormalizationBackward()`.

### Values

#### `CUDA_DNN_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 implemented using average pooling) and added to the `destDiffData` tensor produced by `cudaDnnDivisiveNormalizationBackward`.

## 3.21. `cudaDnnDropoutDescriptor_t`

`cudaDnnDropoutDescriptor_t` is a pointer to an opaque structure holding the description of a dropout operation. `cudaDnnCreateDropoutDescriptor()` is used to create one instance, `cudaDnnSetDropoutDescriptor()` is used to initialize this instance, `cudaDnnDestroyDropoutDescriptor()` is used to destroy this instance, `cudaDnnGetDropoutDescriptor()` is used to query fields of a previously initialized instance, `cudaDnnRestoreDropoutDescriptor()` is used to restore an instance to a previously saved off state.

## 3.22. `cudaDnnErrQueryMode_t`

`cudaDnnErrQueryMode_t` is an enumerated type passed to `cudaDnnQueryRuntimeError()` 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.

## 3.23. 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.

## 3.24. 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.

## 3.25. 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

## 3.26. 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].

## 3.27. 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.

## 3.28. 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

## 3.29. 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.

### 3.30. 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

### 3.31. 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.

### 3.32. 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.

### 3.33. 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.

## 3.34. 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  $\geq 6.0$ .

### **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  $\geq 6.0$  on Linux machines.

### 3.35. 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.

### 3.36. 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.

### 3.37. 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  $\mathbf{h}_t$  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  $\mathbf{W}$ ,  $\mathbf{R}$  and biases  $\mathbf{b}_W$ ,  $\mathbf{b}_R$  from the following equation:

$$\mathbf{h}_t = \text{ReLU}(\mathbf{W}_i \mathbf{x}_t + \mathbf{R}_i \mathbf{h}_{t-1} + \mathbf{b}_{W_i} + \mathbf{b}_{R_i})$$

Where  $\text{ReLU}(\mathbf{x}) = \max(\mathbf{x}, 0)$ .

##### **CUDNN\_RNN\_TANH**

A single-gate recurrent neural network with a tanh activation function.

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  $\mathbf{W}$ ,  $\mathbf{R}$  and biases  $\mathbf{b}_W$ ,  $\mathbf{b}_R$  from the following equation:

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

Where  $\tanh$  is the hyperbolic tangent function.

#### CUDNN\_LSTM

A four-gate Long Short-Term Memory network with no peephole connections.

In the forward pass the output  $\mathbf{h}_t$  and cell output  $\mathbf{c}_t$  for a given iteration can be computed from the recurrent input  $\mathbf{h}_{t-1}$ , the cell input  $\mathbf{c}_{t-1}$  and the previous layer input  $\mathbf{x}_t$  given matrices  $\mathbf{W}$ ,  $\mathbf{R}$  and biases  $\mathbf{b}_W$ ,  $\mathbf{b}_R$  from the following equations:

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

Where  $\sigma$  is the sigmoid operator:  $\sigma(\mathbf{x}) = 1 / (1 + e^{-\mathbf{x}})$ ,  $\circ$  represents a point-wise multiplication and  $\tanh$  is the hyperbolic tangent function.  $i_t$ ,  $f_t$ ,  $o_t$ ,  $c'_t$  represent the input, forget, output and new gates respectively.

#### 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  $\mathbf{W}$ ,  $\mathbf{R}$  and biases  $\mathbf{b}_W$ ,  $\mathbf{b}_R$  from the following equations:

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

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

## 3.38. 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.

## 3.39. cudnnReduceTensorIndices\_t

**cudaReduceTensorIndices\_t** is an enumerated type used to indicate whether indices are to be computed by the **cudaReduceTensor()** routine. This enumerated type is used as a field for the **cudaReduceTensorDescriptor\_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.

## 3.40. cudaReduceTensorOp\_t

**cudaReduceTensorOp\_t** is an enumerated type used to indicate the Tensor Core Operation to be used by the **cudaReduceTensor()** routine. This enumerated type is used as a field for the **cudaReduceTensorDescriptor\_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

## 3.41. cudaSamplerType\_t

`cudaSamplerType_t` is an enumerated type passed to `cudaSetSpatialTransformerNdDescriptor()` to select the sampler type to be used by `cudaSpatialTfSamplerForward()` and `cudaSpatialTfSamplerBackward()`.

#### Values

`CUDNN_SAMPLER_BILINEAR`

Selects the bilinear sampler.

## 3.42. `cudaSoftmaxAlgorithm_t`

`cudaSoftmaxAlgorithm_t` is used to select an implementation of the softmax function used in `cudaSoftmaxForward()` and `cudaSoftmaxBackward()`.

#### 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`

## 3.43. `cudaSoftmaxMode_t`

`cudaSoftmaxMode_t` is used to select over which data the `cudaSoftmaxForward()` and `cudaSoftmaxBackward()` 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.

## 3.44. `cudaSpatialTransformerDescriptor_t`

`cudaSpatialTransformerDescriptor_t` is a pointer to an opaque structure holding the description of a spatial transformation operation.

`cudaCreateSpatialTransformerDescriptor()` is used to create one instance,

`cudaSetSpatialTransformerNdDescriptor()` is used to initialize this instance,

`cudaDestroySpatialTransformerDescriptor()` is used to destroy this instance.

## 3.45. 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 an internal error/bug in the library.

**CUDNN\_STATUS\_INTERNAL\_ERROR**

An internal cuDNN operation failed.

**CUDNN\_STATUS\_NOT\_SUPPORTED**

The functionality requested is not presently supported by cuDNN.

**CUDNN\_STATUS\_LICENSE\_ERROR**

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

**CUDNN\_STATUS\_RUNTIME\_PREREQUISITE\_MISSING**

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.

## 3.46. `cudaTensorDescriptor_t`

`cudaCreateTensorDescriptor_t` is a pointer to an opaque structure holding the description of a generic n-D dataset. `cudaCreateTensorDescriptor()` is used to create one instance, and one of the routines `cudaSetTensorNdDescriptor()`, `cudaSetTensor4dDescriptor()` or `cudaSetTensor4dDescriptorEx()` must be used to initialize this instance.

## 3.47. `cudaTensorFormat_t`

`cudaTensorFormat_t` is an enumerated type used by `cudaSetTensor4dDescriptor()` to create a tensor with a pre-defined layout.

### 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 and CUDNN\_DATA\_UINT8x4.



# Chapter 4.

## CUDNN API REFERENCE

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

### 4.1. cudnnActivationBackward

```
cudaStatus_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.

##### **activationDesc,**

*Input.* Activation 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:  $\text{dstValue} = \text{alpha}[0] * \text{result} + \text{beta}[0] * \text{priorDstValue}$ . [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 **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.

#### activationDesc

*Input.* Activation 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:  $\text{dstValue} = \text{alpha}[0] * \text{result} + \text{beta}[0] * \text{priorDstValue}$ . [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 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.

**alpha, beta**

*Input.* Pointers to scaling factors (in host memory) used to blend the source value with prior value in the destination tensor as follows:  $\text{dstValue} = \text{alpha}[0] * \text{srcValue} + \text{beta}[0] * \text{priorDstValue}$ . [Please refer to this section for additional details.](#)

**aDesc**

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

**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 BatchNormalization layer computation.



Only 4D and 5D tensors are supported.



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



Much higher performance when HW-packed tensors are used for all of  $x$ ,  $dy$ ,  $dx$ .

## Parameters

### **handle**

Handle to a previously created cuDNN library descriptor.

### **mode**

Mode of operation (spatial or per-activation). [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:  $dstValue = alpha[0]*resultValue + beta[0]*priorDstValue$ . [Please refer to this section for additional details.](#)

### **alphaParamDiff, betaParamDiff**

*Inputs.* Pointers to scaling factors (in host memory) used to blend the gradient outputs  $dBnScaleResult$  and  $dBnBiasResult$  with prior values in the destination tensor as follows:  $dstValue = alpha[0]*resultValue + beta[0]*priorDstValue$ . [Please refer to this section for additional details.](#)

### **xDesc, x, dyDesc, dy, dxDesc, dx**

Tensor descriptors and pointers in device memory for the layer's  $x$  data, backpropagated differential  $dy$  (inputs) and resulting differential with respect to  $x$ ,  $dx$  (output).

### **bnScaleBiasDiffDesc**

Shared tensor descriptor for all the 5 tensors below in the argument list ( $bnScale$ ,  $resultBnScaleDiff$ ,  $resultBnBiasDiff$ ,  $savedMean$ ,  $savedInvVariance$ ). The dimensions for this tensor descriptor are dependent on normalization mode. Note: The data type of this tensor descriptor must be 'float' for FP16 and FP32 input tensors, and 'double' for FP64 input tensors.

### **bnScale**

*Input.* Pointers in device memory for the batch normalization scale parameter (in original paper bias is referred to as  $\gamma$ ). Note that  $bnBias$  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 scale and bias gradients are not backpropagated below this layer (since they are dead-end computation DAG nodes).

## epsilon

Epsilon value used in batch normalization formula. Minimum allowed value is CUDNN\_BN\_MIN\_EPSILON defined 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 bnScale, bnBias data has to remain unchanged until the backward function is called. Note that both of 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.

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:

- ▶ 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 [4,5] range.
- ▶ bnScaleBiasMeanVarDesc dimensions are not 1xC(x1)x1x1 for spatial or 1xC(xD)xHxW for per-activation mode (parentheses for 5D).
- ▶ 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. 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 BatchNormalization layer computation for 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.



Only 4D and 5D tensors are supported.



The input transformation performed by this function is defined as:  $y := \alpha * y + \beta * (\text{bnScale} * (x - \text{estimatedMean}) / \sqrt{\text{epsilon} + \text{estimatedVariance}} + \text{bnBias})$



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



For training phase use `cudaBatchNormalizationForwardTraining`.



Much higher performance when HW-packed tensors are used for all of `x`, `dy`, `dx`.

## Parameters

### **handle**

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

### **mode**

*Input.* Mode of operation (spatial or per-activation). `cudaBatchNormMode_t`

### **alpha, beta**

*Inputs.* Pointers to scaling factors (in host memory) used to blend the layer output value with prior value in the destination tensor as follows:  $\text{dstValue} = \alpha[0] * \text{resultValue} + \beta[0] * \text{priorDstValue}$ . [Please refer to this section for additional details.](#)

### **xDesc, yDesc, x, y**

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

### **bnScaleBiasMeanVarDesc, bnScaleData, bnBiasData**

*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). It is suggested that `resultRunningMean`, `resultRunningVariance` from the `cudaBatchNormalizationForwardTraining` call accumulated during the training phase are passed as inputs here.



## epsilon

*Input.* Epsilon value used in the batch normalization formula. Minimum allowed value is CUDNN\_BN\_MIN\_EPSILON defined in cudnn.h.

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:

- ▶ One of the pointers **alpha**, **beta**, **x**, **y**, **bnScaleData**, **bnBiasData**, **estimatedMean**, **estimatedInvVariance** is NULL.
- ▶ Number of xDesc or yDesc tensor descriptor dimensions is not within the [4,5] range.
- ▶ bnScaleBiasMeanVarDesc dimensions are not 1xC(x1)x1x1 for spatial or 1xC(xD)xHxW for per-activation mode (parenthesis for 5D).
- ▶ epsilon value is less than CUDNN\_BN\_MIN\_EPSILON
- ▶ Dimensions or data types mismatch for xDesc, yDesc

## 4.6. 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 BatchNormalization layer computation for training phase.



Only 4D and 5D tensors are supported.



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



For inference phase use `cudaDnnBatchNormalizationForwardInference`.



Much higher performance for HW-packed tensors for both x and y.

## Parameters

### **handle**

Handle to a previously created cuDNN library descriptor.

### **mode**

Mode of operation (spatial or per-activation). [cudaDnnBatchNormMode\\_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:  $dstValue = alpha[0]*resultValue + beta[0]*priorDstValue$ . [Please refer to this section for additional details.](#)

### **xDesc, yDesc, x, y**

Tensor descriptors and pointers in device memory for the layer's x and y data.

### **bnScaleBiasMeanVarDesc**

Shared tensor descriptor desc for all the 6 tensors below in the argument list. 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 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  $runningMean = newMean*factor + runningMean*(1-factor)$ . Use a  $factor=1/(1+n)$  at N-th call to the function to get Cumulative Moving Average (CMA) behavior  $CMA[n] = (x[1]+...+x[n])/n$ . Since  $CMA[n+1] = (n*CMA[n]+x[n+1])/(n+1) = ((n+1)*CMA[n]-CMA[n])/(n+1) + x[n+1]/(n+1) = CMA[n]*(1-1/(n+1))+x[n+1]*1/(n+1)$

### **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 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

Epsilon value used in the batch normalization formula. Minimum allowed value is `CUDNN_BN_MIN_EPSILON` defined in `cuda.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 can then be reused to speed up the backward pass. For this to work correctly, the bottom layer data has to remain unchanged until the backward function is called. Note that both of these parameters can be `NULL` but only at the same time. It is recommended to use this cache since memory overhead is relatively small because these tensors have a much lower product of dimensions than the data tensors.

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:

- ▶ 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.
- ▶ `bnScaleBiasMeanVarDesc` dimensions are not `1xC(x1)x1x1` for spatial or `1xC(xD)xHxW` for per-activation mode (parens for 5D).
- ▶ 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`

## 4.7. 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.

## Parameters

### handle

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

### probsDesc

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

### probs

*Input.* Pointer to a previously initialized probabilities tensor.

### 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.

### algo

*Input.* Enumerant that specifies the chosen CTC loss algorithm.

### ctcLossDesc

*Input.* Handle to the previously initialized CTC loss descriptor.

### 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

## 4.8. 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.

**alpha, beta**

*Input.* Pointers to scaling factors (in host memory) used to blend the computation result with prior value in the output layer as follows:  $\text{dstValue} = \alpha[0] * \text{result} + \beta[0] * \text{priorDstValue}$ . [Please refer to this section for additional details.](#)

**dyDesc**

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

**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.

## 4.9. 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 gradient with respect to the output tensor using the specified **algo**, returning results in **gradDesc**. Scaling factors **alpha** and **beta** can be used to scale the input tensor and the output tensor respectively.

**Parameters****handle**

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

**alpha, beta**

*Input.* Pointers to scaling factors (in host memory) used to blend the computation result with prior value in the output layer as follows:  $\text{dstValue} = \text{alpha}[0] * \text{result} + \text{beta}[0] * \text{priorDstValue}$ . [Please refer to this section for additional details.](#)

**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 input differential tensor descriptor **dyDesc**.

**convDesc**

*Input.* Previously initialized convolution descriptor.

**algo**

*Input.* Enumerant that specifies which backward data convolution algorithm should be used to compute the results.

**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.

This function supports only three specific combinations of data types for **wDesc**, **dyDesc**, **convDesc** and **dxDesc**. See the following for an exhaustive list of these configurations.

| Data Type Configurations | wDesc's, dyDesc's and dxDesc's Data Type | convDesc's Data Type |
|--------------------------|--|----------------------|
| TRUE_HALF_CONFIG         | 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.

**wDesc** may only have format CUDNN\_TENSOR\_NHWC when all of the following are true:

- ▶ **algo** is CUDNN\_CONVOLUTION\_BWD\_DATA\_ALGO\_1
- ▶ **dyDesc** and **dxDesc** is NHWC HWC-packed
- ▶ Data type configuration is PSEUDO\_HALF\_CONFIG or FLOAT\_CONFIG
- ▶ The convolution is 2-dimensional

When the filter descriptor **wDesc** is in CUDNN\_TENSOR\_NCHW format, the following is an exhaustive list of algo support for 2-d convolutions.

- ▶ **CUDNN\_CONVOLUTION\_BWD\_DATA\_ALGO\_0**
  - ▶ Deterministic: No
  - ▶ **dyDesc** Format Support: NCHW CHW-packed
  - ▶ **dxDesc** Format Support: All except NCHW\_VECT\_C
  - ▶ Data Type Config Support: All except TRUE\_HALF\_CONFIG
  - ▶ Dilation: greater than 0 for all dimensions
  - ▶ **convDesc** Group Count Support: Greater than 0.
- ▶ **CUDNN\_CONVOLUTION\_BWD\_DATA\_ALGO\_1**
  - ▶ Deterministic: Yes
  - ▶ **dyDesc** Format Support: NCHW CHW-packed
  - ▶ **dxDesc** Format Support: All except NCHW\_VECT\_C
  - ▶ Data Type Config Support: All
  - ▶ Dilation: 1 for all dimensions
  - ▶ **convDesc** Group Count Support: Greater than 0.
- ▶ **CUDNN\_CONVOLUTION\_BWD\_DATA\_ALGO\_FFT**
  - ▶ Deterministic: Yes
  - ▶ **dyDesc** Format Support: NCHW CHW-packed
  - ▶ **dxDesc** Format Support: NCHW HW-packed
  - ▶ Data Type Config Support: PSEUDO\_HALF\_CONFIG, FLOAT\_CONFIG
  - ▶ Dilation: 1 for all dimensions
  - ▶ **convDesc** Group Count Support: Greater than 0.
  - ▶ Notes:
    - ▶ **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
- ▶ **CUDNN\_CONVOLUTION\_BWD\_DATA\_ALGO\_FFT\_TILING**
  - ▶ Deterministic: Yes
  - ▶ **dyDesc** Format Support: NCHW CHW-packed
  - ▶ **dxDesc** Format Support: NCHW HW-packed



- ▶ Data Type Config Support: PSEUDO\_HALF\_CONFIG, 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.
- ▶ Notes:
  - ▶ 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
  - ▶ **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
- ▶ **CUDNN\_CONVOLUTION\_BWD\_DATA\_ALGO\_WINOGRAD**
  - ▶ Deterministic: Yes
  - ▶ **xDesc** Format Support: NCHW CHW-packed
  - ▶ **yDesc** Format Support: All except NCHW\_VECT\_C
  - ▶ Data Type Config Support: PSEUDO\_HALF\_CONFIG, FLOAT\_CONFIG
  - ▶ Dilation: 1 for all dimensions
  - ▶ **convDesc** Group Count Support: Greater than 0.
  - ▶ Notes:
    - ▶ **convDesc**'s vertical and horizontal filter stride must equal 1
    - ▶ **wDesc**'s filter height must be 3
    - ▶ **wDesc**'s filter width must be 3
- ▶ **CUDNN\_CONVOLUTION\_BWD\_DATA\_ALGO\_WINOGRAD\_NONFUSED**
  - ▶ Deterministic: Yes
  - ▶ **xDesc** Format Support: NCHW CHW-packed
  - ▶ **yDesc** Format Support: All except NCHW\_VECT\_C
  - ▶ Data Type Config Support: All except DOUBLE\_CONFIG
  - ▶ Dilation: 1 for all dimensions
  - ▶ **convDesc** Group Count Support: Greater than 0.
  - ▶ Notes:
    - ▶ **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), data type config TRUE\_HALF\_CONFIG is not supported

The following is an exhaustive list of algo support for 3-d convolutions.

- ▶ **CUDNN\_CONVOLUTION\_BWD\_DATA\_ALGO\_0**
  - ▶ Deterministic: No
  - ▶ **dyDesc** Format Support: NCDHW CDHW-packed
  - ▶ **dxDesc** Format Support: All except NCHW\_VECT\_C

- ▶ Data Type Config Support: All except TRUE\_HALF\_CONFIG
- ▶ Dilation: greater than 0 for all dimensions
- ▶ **convDesc** Group Count Support: Greater than 0.
- ▶ **CUDNN\_CONVOLUTION\_BWD\_DATA\_ALGO\_1**
  - ▶ Deterministic: Yes
  - ▶ **dyDesc** Format Support: NCDHW-fully-packed
  - ▶ **dxDesc** Format Support: NCDHW-fully-packed
  - ▶ Data Type Config Support: All
  - ▶ Dilation: 1 for all dimensions
  - ▶ **convDesc** Group Count Support: Greater than 0.
- ▶ **CUDNN\_CONVOLUTION\_BWD\_DATA\_ALGO\_FFT\_TILING**
  - ▶ Deterministic: Yes
  - ▶ **dyDesc** Format Support: NCDHW CDHW-packed
  - ▶ **dxDesc** Format Support: NCDHW DHW-packed
  - ▶ Data Type Config Support: All except TRUE\_HALF\_CONFIG
  - ▶ Dilation: 1 for all dimensions
  - ▶ **convDesc** Group Count Support: Greater than 0.
  - ▶ Notes:
    - ▶ **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

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: **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.

## 4.10. 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 gradient with respect to filter coefficients using the specified **algo**, returning results in **gradDesc**. Scaling factors **alpha** and **beta** can be used to scale the input tensor and the output tensor respectively.

### Parameters

#### handle

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

#### alpha, beta

*Input.* Pointers to scaling factors (in host memory) used to blend the computation result with prior value in the output layer as follows:  $\text{dstValue} = \text{alpha}[0] * \text{result} + \text{beta}[0] * \text{priorDstValue}$ . [Please refer to this section for additional details.](#)

#### xDesc

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

#### 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.

**algo**

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

**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.

**dw**

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

This function supports only three specific combinations of data types for **xDesc**, **dyDesc**, **convDesc** and **dwDesc**. See the following for an exhaustive list of these configurations.

| Data Type Configurations | <b>xDesc</b> 's, <b>dyDesc</b> 's and <b>dwDesc</b> 's Data Type | <b>convDesc</b> 's Data Type |
|--------------------------|--|------------------------------|
| TRUE_HALF_CONFIG         | 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.

**dwDesc** may only have format CUDNN\_TENSOR\_NHWC when all of the following are true:

- ▶ **algo** is CUDNN\_CONVOLUTION\_BWD\_FILTER\_ALGO\_0 or CUDNN\_CONVOLUTION\_BWD\_FILTER\_ALGO\_1
- ▶ **xDesc** and **dyDesc** is NHWC HWC-packed

- ▶ Data type configuration is PSEUDO\_HALF\_CONFIG or FLOAT\_CONFIG
- ▶ The convolution is 2-dimensional

The following is an exhaustive list of algo support for 2-d convolutions.

- ▶ **CUDNN\_CONVOLUTION\_BWD\_FILTER\_ALGO\_0**
  - ▶ Deterministic: No
  - ▶ **xDesc** Format Support: All except NCHW\_VECT\_C
  - ▶ **dyDesc** Format Support: NCHW CHW-packed
  - ▶ Data Type Config Support: All except TRUE\_HALF\_CONFIG
  - ▶ Dilation: greater than 0 for all dimensions
  - ▶ **convDesc** Group Count Support: Greater than 0.
  - ▶ Not supported if output is of type CUDNN\_DATA\_HALF and the number of elements in dw is odd.
- ▶ **CUDNN\_CONVOLUTION\_BWD\_FILTER\_ALGO\_1**
  - ▶ Deterministic: Yes
  - ▶ **xDesc** Format Support: All
  - ▶ **dyDesc** Format Support: NCHW CHW-packed
  - ▶ Data Type Config Support: All
  - ▶ Dilation: 1 for all dimensions
  - ▶ **convDesc** Group Count Support: Greater than 0.
- ▶ **CUDNN\_CONVOLUTION\_BWD\_FILTER\_ALGO\_FFT**
  - ▶ Deterministic: Yes
  - ▶ **xDesc** Format Support: NCHW CHW-packed
  - ▶ **dyDesc** Format Support: NCHW CHW-packed
  - ▶ Data Type Config Support: PSEUDO\_HALF\_CONFIG, FLOAT\_CONFIG
  - ▶ **convDesc** Group Count Support: Greater than 0.
  - ▶ Dilation: 1 for all dimensions
  - ▶ Notes:
    - ▶ **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
- ▶ **CUDNN\_CONVOLUTION\_BWD\_FILTER\_ALGO\_3**
  - ▶ Deterministic: No
  - ▶ **xDesc** Format Support: All except NCHW\_VECT\_C
  - ▶ **dyDesc** Format Support: NCHW CHW-packed
  - ▶ Data Type Config Support: All except TRUE\_HALF\_CONFIG
  - ▶ **convDesc** Group Count Support: Greater than 0.
  - ▶ Dilation: 1 for all dimensions

- ▶ **CUDNN\_CONVOLUTION\_BWD\_FILTER\_ALGO\_WINOGRAD\_NONFUSED**
  - ▶ Deterministic: Yes
  - ▶ **xDesc** Format Support: All except CUDNN\_TENSOR\_NCHW\_VECT\_C
  - ▶ **yDesc** Format Support: NCHW CHW-packed
  - ▶ Data Type Config Support: All except DOUBLE\_CONFIG
  - ▶ Dilation: 1 for all dimensions
  - ▶ **convDesc** Group Count Support: Greater than 0.
  - ▶ Notes:
    - ▶ **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), data type config TRUE\_HALF\_CONFIG is not supported
- ▶ **CUDNN\_CONVOLUTION\_BWD\_FILTER\_ALGO\_FFT\_TILING**
  - ▶ Deterministic: Yes
  - ▶ **xDesc** Format Support: NCHW CHW-packed
  - ▶ **dyDesc** Format Support: NCHW CHW-packed
  - ▶ Data Type Config Support: PSEUDO\_HALF\_CONFIG, FLOAT\_CONFIG, DOUBLE\_CONFIG
  - ▶ Dilation: 1 for all dimensions
  - ▶ **convDesc** Group Count Support: Greater than 0.
  - ▶ Notes:
    - ▶ **xDesc**'s width or height must be equal to 1
    - ▶ **dyDesc**'s width or height must be equal to 1 (the same dimension as in **xDesc**). The other dimension must be less than or equal to 256, ie, 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

The following is an exhaustive list of algo support for 3-d convolutions.

- ▶ **CUDNN\_CONVOLUTION\_BWD\_FILTER\_ALGO\_0**
  - ▶ Deterministic: No
  - ▶ **xDesc** Format Support: All except NCHW\_VECT\_C
  - ▶ **dyDesc** Format Support: NCDHW CDHW-packed
  - ▶ Data Type Config Support: All except TRUE\_HALF\_CONFIG
  - ▶ Dilation: greater than 0 for all dimensions
  - ▶ **convDesc** Group Count Support: Greater than 0.
- ▶ **CUDNN\_CONVOLUTION\_BWD\_FILTER\_ALGO\_3**
  - ▶ Deterministic: No
  - ▶ **xDesc** Format Support: NCDHW-fully-packed
  - ▶ **dyDesc** Format Support: NCDHW-fully-packed
  - ▶ Data Type Config Support: All except TRUE\_HALF\_CONFIG

- ▶ Dilation: 1 for all dimensions
- ▶ **convDesc** Group Count Support: Greater than 0.

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: **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.

## 4.11. cudnnConvolutionBiasActivationForward

```

cudnnStatus_t cudnnConvolutionBiasActivationForward(
    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             *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  $y = \text{act} ( \text{alpha1} * \text{conv}(x) + \text{alpha2} * z + \text{bias} )$ .



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`.

## Parameters

### **handle**

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

### **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.

### **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.

### **algo**

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

### **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.

**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 `cudaConvolutionForward()`. The following table specifies the supported combinations of data types for **x**, **y**, **z**, **bias**, and **alpha1/alpha2**.

Table Key: X = CUDNN\_DATA

| <b>x</b>  | <b>w</b> | <b>y and z</b> | <b>bias</b> | <b>alpha1/alpha2</b> |
|-----------|----------|----------------|-------------|----------------------|
| 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 `cudaConvolutionForward()`, 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.

## 4.12. 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.

**alpha, beta**

*Input.* Pointers to scaling factors (in host memory) used to blend the computation result with prior value in the output layer as follows:  $\text{dstValue} = \text{alpha}[0] * \text{result} + \text{beta}[0] * \text{priorDstValue}$ . [Please refer to this section for additional details.](#)

**xDesc**

*Input.* Handle to a previously initialized 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.

**algo**

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

**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.


This function supports only eight specific combinations of data types for **xDesc**, **wDesc**, **convDesc** and **yDesc**. See the following table for an exhaustive list of these configurations.

| Data Type Configurations | <b>xDesc</b> and <b>wDesc</b> | <b>convDesc</b>  | <b>yDesc</b>     |
|--------------------------|-------------------------------|------------------|------------------|
| TRUE_HALF_CONFIG         | 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 | <b>xDesc</b> and <b>wDesc</b> | <b>convDesc</b>   | <b>yDesc</b>       |
|--------------------------|-------------------------------|-------------------|--------------------|
| DOUBLE_CONFIG            | CUDNN_DATA_DOUBLE             | CUDNN_DATA_DOUBLE | CUDNN_DATA_DOUBLE  |
| INT8_CONFIG              | CUDNN_DATA_INT8               | CUDNN_DATA_INT32  | CUDNN_DATA_INT8    |
| INT8_EXT_CONFIG          | CUDNN_DATA_INT8               | CUDNN_DATA_INT32  | CUDNN_DATA_FLOAT   |
| INT8x4_CONFIG            | CUDNN_DATA_INT8x4             | CUDNN_DATA_INT32  | CUDNN_DATA_INT8x4  |
| INT8x4_EXT_CONFIG        | CUDNN_DATA_INT8x4             | CUDNN_DATA_INT32  | CUDNN_DATA_FLOAT   |
| UINT8x4_CONFIG           | CUDNN_DATA_UINT8x4            | CUDNN_DATA_INT32  | CUDNN_DATA_UINT8x4 |
| UINT8x4_EXT_CONFIG       | CUDNN_DATA_UINT8x4            | CUDNN_DATA_INT32  | CUDNN_DATA_FLOAT   |

**Table Note: UINT8x4\_CONFIG and UINT8x4\_EXT\_CONFIG are new for 7.1**

 TRUE\_HALF\_CONFIG is only supported on architectures with true fp16 support (compute capability 5.3 and 6.0).

 INT8\_CONFIG, INT8\_EXT\_CONFIG, INT8x4\_CONFIG, INT8x4\_EXT\_CONFIG, UINT8x4\_CONFIG, and UINT8x4\_EXT\_CONFIG are only supported on architectures with DP4A support (compute capability 6.1 and later).

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

For the datatype configurations TRUE\_HALF\_CONFIG, PSEUDO\_HALF\_CONFIG, FLOAT\_CONFIG and DOUBLE\_CONFIG, when the filter descriptor **wDesc** is in CUDNN\_TENSOR\_NCHW format the following is the exhaustive list of algo supported for 2-d convolutions.

- ▶ **CUDNN\_CONVOLUTION\_FWD\_ALGO\_IMPLICIT\_GEMM**
  - ▶ **xDesc** Format Support: All except CUDNN\_TENSOR\_NCHW\_VECT\_C
  - ▶ **yDesc** Format Support: All except CUDNN\_TENSOR\_NCHW\_VECT\_C
  - ▶ Data Type Config Support: All except TRUE\_HALF\_CONFIG
  - ▶ Dilation: greater than 0 for all dimensions
  - ▶ **convDesc** Group Count Support: Greater than 0.
- ▶ **CUDNN\_CONVOLUTION\_FWD\_ALGO\_IMPLICIT\_PRECOMP\_GEMM**
  - ▶ **xDesc** Format Support: All except CUDNN\_TENSOR\_NCHW\_VECT\_C
  - ▶ **yDesc** Format Support: All except CUDNN\_TENSOR\_NCHW\_VECT\_C
  - ▶ Data Type Config Support: All
  - ▶ Dilation: 1 for all dimensions
  - ▶ **convDesc** Group Count Support: Greater than 0.
- ▶ **CUDNN\_CONVOLUTION\_FWD\_ALGO\_GEMM**
  - ▶ **xDesc** Format Support: All except CUDNN\_TENSOR\_NCHW\_VECT\_C
  - ▶ **yDesc** Format Support: All except CUDNN\_TENSOR\_NCHW\_VECT\_C
  - ▶ Data Type Config Support: All except TRUE\_HALF\_CONFIG

- ▶ Dilation: 1 for all dimensions
- ▶ **convDesc** Group Count Support: Greater than 0.
- ▶ **CUDNN\_CONVOLUTION\_FWD\_ALGO\_DIRECT**
  - ▶ This algorithm has no current implementation in cuDNN.
- ▶ **CUDNN\_CONVOLUTION\_FWD\_ALGO\_FFT**
  - ▶ **xDesc** Format Support: NCHW HW-packed
  - ▶ **yDesc** Format Support: NCHW HW-packed
  - ▶ Data Type Config Support: PSEUDO\_HALF\_CONFIG, FLOAT\_CONFIG
  - ▶ Dilation: 1 for all dimensions
  - ▶ **convDesc** Group Count Support: Greater than 0.
  - ▶ Notes:
    - ▶ **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
- ▶ **CUDNN\_CONVOLUTION\_FWD\_ALGO\_FFT\_TILING**
  - ▶ **xDesc** Format Support: NCHW HW-packed
  - ▶ **yDesc** Format Support: NCHW HW-packed
  - ▶ Data Type Config Support: PSEUDO\_HALF\_CONFIG, 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.
  - ▶ Notes:
    - ▶ 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
    - ▶ **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
- ▶ **CUDNN\_CONVOLUTION\_FWD\_ALGO\_WINOGRAD**
  - ▶ **xDesc** Format Support: All except CUDNN\_TENSOR\_NCHW\_VECT\_C
  - ▶ **yDesc** Format Support: All except CUDNN\_TENSOR\_NCHW\_VECT\_C
  - ▶ Data Type Config Support: PSEUDO\_HALF\_CONFIG, FLOAT\_CONFIG
  - ▶ Dilation: 1 for all dimensions
  - ▶ **convDesc** Group Count Support: Greater than 0.
  - ▶ Notes:
    - ▶ **convDesc**'s vertical and horizontal filter stride must equal 1

- ▶ **wDesc**'s filter height must be 3
- ▶ **wDesc**'s filter width must be 3
- ▶ **CUDNN\_CONVOLUTION\_FWD\_ALGO\_WINOGRAD\_NONFUSED**
  - ▶ **xDesc** Format Support: All except CUDNN\_TENSOR\_NCHW\_VECT\_C
  - ▶ **yDesc** Format Support: All except CUDNN\_TENSOR\_NCHW\_VECT\_C
  - ▶ Data Type Config Support: All except DOUBLE\_CONFIG
  - ▶ Dilation: 1 for all dimensions
  - ▶ **convDesc** Group Count Support: Greater than 0.
  - ▶ Notes:
    - ▶ **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), data type config TRUE\_HALF\_CONFIG is not supported

For the datatype configurations TRUE\_HALF\_CONFIG, PSEUDO\_HALF\_CONFIG, FLOAT\_CONFIG and DOUBLE\_CONFIG, when the filter descriptor **wDesc** is in CUDNN\_TENSOR\_NHWC format the only algo supported is CUDNN\_CONVOLUTION\_FWD\_ALGO\_IMPLICIT\_GEMM with the following conditions :

- ▶ **xDesc** and **yDesc** is NHWC HWC-packed
- ▶ Data type configuration is PSEUDO\_HALF\_CONFIG or FLOAT\_CONFIG
- ▶ The convolution is 2-dimensional
- ▶ Dilation is 1 for all dimensions
- ▶ **convDesc** Group Count Support: Greater than 0.

For the datatype configurations TRUE\_HALF\_CONFIG, PSEUDO\_HALF\_CONFIG, FLOAT\_CONFIG and DOUBLE\_CONFIG, when the filter descriptor **wDesc** is in CUDNN\_TENSOR\_NCHW format the following is the exhaustive list of algo supported for 3-d convolutions.

- ▶ **CUDNN\_CONVOLUTION\_FWD\_ALGO\_IMPLICIT\_GEMM**
  - ▶ **xDesc** Format Support: All except CUDNN\_TENSOR\_NCHW\_VECT\_C
  - ▶ **yDesc** Format Support: All except CUDNN\_TENSOR\_NCHW\_VECT\_C
  - ▶ Data Type Config Support: All except TRUE\_HALF\_CONFIG
  - ▶ Dilation: greater than 0 for all dimensions
  - ▶ **convDesc** Group Count Support: Greater than 0.
- ▶ **CUDNN\_CONVOLUTION\_FWD\_ALGO\_IMPLICIT\_PRECOMP\_GEMM**
  - ▶ **xDesc** Format Support: All except CUDNN\_TENSOR\_NCHW\_VECT\_C
  - ▶ **yDesc** Format Support: All except CUDNN\_TENSOR\_NCHW\_VECT\_C
  - ▶ Data Type Config Support: All except TRUE\_HALF\_CONFIG
  - ▶ Dilation: 1 for all dimensions
  - ▶ **convDesc** Group Count Support: Greater than 0.
- ▶ **CUDNN\_CONVOLUTION\_FWD\_ALGO\_FFT\_TILING**
  - ▶ **xDesc** Format Support: NCDHW DHW-packed

- ▶ **yDesc** Format Support: NCDHW DHW-packed
- ▶ Data Type Config Support: All except TRUE\_HALF\_CONFIG
- ▶ Dilation: 1 for all dimensions
- ▶ **convDesc** Group Count Support: Greater than 0.
- ▶ Notes:
  - ▶ **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

For the datatype configurations INT8\_CONFIG, INT8\_EXT\_CONFIG, UINT8x4\_CONFIG, and UINT8x4\_EXT\_CONFIG, the only algo supported is CUDNN\_CONVOLUTION\_FWD\_ALGO\_IMPLICIT\_PRECOMP\_GEMM with the following conditions:

- ▶ **xDesc** Format Support: CUDNN\_TENSOR\_NHWC
- ▶ **yDesc** Format Support: CUDNN\_TENSOR\_NHWC
- ▶ Input and output features maps must be multiple of 4
- ▶ **wDesc** Format Support: CUDNN\_TENSOR\_NHWC
- ▶ Dilation: 1 for all dimensions
- ▶ **convDesc** Group Count Support: Greater than 0.

For the datatype configurations INT8x4\_CONFIG and INT8x4\_EXT\_CONFIG, the only algo supported is CUDNN\_CONVOLUTION\_FWD\_ALGO\_IMPLICIT\_PRECOMP\_GEMM with the following conditions :

- ▶ **xDesc** Format Support: CUDNN\_TENSOR\_NCHW\_VECT\_C
- ▶ **yDesc** Format Support: CUDNN\_TENSOR\_NCHW when datatype is CUDNN\_DATA\_FLOAT, CUDNN\_TENSOR\_NCHW\_VECT\_C when datatype is CUDNN\_DATA\_INT8x4 or CUDNN\_DATA\_UINT8x4
- ▶ Input and output features maps must be multiple of 4
- ▶ **wDesc** Format Support: CUDNN\_TENSOR\_NCHW\_VECT\_C
- ▶ Dilation: 1 for all dimensions
- ▶ **convDesc** Group Count Support: Greater than 0.



Tensors can be converted to/from CUDNN\_TENSOR\_NCHW\_VECT\_C with `cudaTransformTensor()`.

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: `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
- ▶ `yDesc`'s spatial sizes do not match with the expected size as determined by `cudaGetConvolutionNdForwardOutputDim`
- ▶ 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 occurred during the texture binding of the filter data.

**CUDNN\_STATUS\_EXECUTION\_FAILED**

The function failed to launch on the GPU.

## 4.13. cudnnCreate

```
cudaStatus_t cudnnCreate(cudaHandle_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.

### 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.

## 4.14. cudnnCreateActivationDescriptor

```

cudnnStatus_t cudnnCreateActivationDescriptor(
    cudnnActivationDescriptor_t *activationDesc)

```

This function creates a activation 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.

## 4.15. 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.

## 4.16. 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.

## 4.17. cudnnCreateCTCLossDescriptor

```

cudnnStatus_t cudnnCreateCTCLossDescriptor(
    cudnnCTCLossDescriptor_t* ctcLossDesc)

```

This function creates a CTC loss function descriptor. .

**Parameters**

**ctcLossDesc**

*Output.* CTC loss descriptor to be set.

**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.

## 4.18. cudnnCreateConvolutionDescriptor

```

cudnnStatus_t cudnnCreateConvolutionDescriptor(
    cudnnConvolutionDescriptor_t *convDesc)

```

This function creates a convolution 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.

## 4.19. 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.

### Returns

**CUDNN\_STATUS\_SUCCESS**

The object was created successfully.

**CUDNN\_STATUS\_ALLOC\_FAILED**

The resources could not be allocated.

## 4.20. cudnnCreateFilterDescriptor

```

cudnnStatus_t cudnnCreateFilterDescriptor(
    cudnnFilterDescriptor_t *filterDesc)

```

This function creates a filter 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.

## 4.21. 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.

## 4.22. cudnnCreateOpTensorDescriptor

```

cudnnStatus_t cudnnCreateOpTensorDescriptor(
    cudnnOpTensorDescriptor_t* opTensorDesc)

```

This function creates a Tensor Pointwise math descriptor.

### 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.

## 4.23. 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 hyperparameters. This function call is expected to be expensive in terms of runtime, and should be used infrequently.

### 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.

## 4.24. 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.

## 4.25. 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.

## 4.26. 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.

## 4.27. 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.

## 4.28. 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.

## 4.29. cudnnDeriveBNTensorDescriptor

```

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

```

Derives a secondary tensor descriptor for BatchNormalization scale, invVariance, bnBias, bnScale subtensors from the layer's x data descriptor. Use the tensor descriptor produced by this function as the bnScaleBiasMeanVarDesc and bnScaleBiasDiffDesc parameters in Spatial and Per-Activation Batch Normalization forward and backward functions. Resulting dimensions will be **1xC(x1)x1x1** for BATCHNORM\_MODE\_SPATIAL and **1xC(xD)xHxW** for BATCHNORM\_MODE\_PER\_ACTIVATION (parentheses for 5D). 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.



derivedBnDesc has to 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.

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**

Invalid Batch Normalization mode.

## 4.30. cudnnDestroy

```
cudaError_t cudnnDestroy(cudaDnnHandle_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.

## 4.31. cudnnDestroyActivationDescriptor

```
cudaError_t cudnnDestroyActivationDescriptor(
    cudnnActivationDescriptor_t activationDesc)
```

This function destroys a previously created activation descriptor object.

### Returns

#### **CUDNN\_STATUS\_SUCCESS**

The object was destroyed successfully.

## 4.32. cudnnDestroyAlgorithmDescriptor

```
cudaError_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.

## 4.33. 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.

## 4.34. 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.

## 4.35. 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.

## 4.36. 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.

## 4.37. 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.

## 4.38. 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.

## 4.39. 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.

## 4.40. 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.

## 4.41. 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.

## 4.42. 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.

## 4.43. 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.

## 4.44. 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.

## 4.45. 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.

## 4.46. 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 initialized LRN parameter descriptor (this descriptor is used for both LRN and DivisiveNormalization layers).

### mode

*Input.* DivisiveNormalization layer mode of operation. Currently only CUDNN\_DIVNORM\_PRECOMPUTED\_MEANS is implemented. Normalization is performed using the means input tensor that is expected to be precomputed by the user.

### alpha, beta

*Input.* Pointers to scaling factors (in host memory) used to blend the layer output value with prior value in the destination tensor as follows:  $\text{dstValue} = \alpha[0] * \text{resultValue} + \beta[0] * \text{priorDstValue}$ . [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**, **temp2**, **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).

## 4.47. 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 it's 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:

$$x\_m = x - \text{mean}(x);$$

$$y = x\_m / \max(c, \text{sigma}(x\_m));$$

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 initialized 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:  $\text{dstValue} = \text{alpha}[0] * \text{resultValue} + \text{beta}[0] * \text{priorDstValue}$ . [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 it's 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).

## 4.48. 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 **cudaDnnDropoutForward** 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 than the value returned by **cudaDnnDropoutGetReserveSpaceSize**
- ▶ **cudaDnnSetDropoutDescriptor** has not been called on **dropoutDesc** with the non-NULL **states** argument

**CUDNN\_STATUS\_EXECUTION\_FAILED**

The function failed to launch on the GPU.

## 4.49. cudaDnnDropoutForward

```

cudaDnnStatus_t cudaDnnDropoutForward(
    cudaDnnHandle_t          handle,
    const cudaDnnDropoutDescriptor_t dropoutDesc,
    const cudaDnnTensorDescriptor_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 **cudaDnnSetDropoutDescriptor**, the approximately **dropout** fraction of **x** values will be replaced by 0, and the rest will be scaled by **1 / (1 - dropout)**. This function should not be running concurrently with another **cudaDnnDropoutForward** 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** do not change between **cudaDnnDropoutForward** and **cudaDnnDropoutBackward** 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 than the value returned by **cudaDnnDropoutGetReserveSpaceSize**.
- ▶ **cudaDnnSetDropoutDescriptor** has not been called on **dropoutDesc** with the non-NULL **states** argument.

**CUDNN\_STATUS\_EXECUTION\_FAILED**

The function failed to launch on the GPU.

## 4.50. cudaDnnDropoutGetReserveSpaceSize

```
cudaDnnStatus_t cudaDnnDropoutGetReserveSpaceSize(
    cudaDnnTensorDescriptor_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 **cudaDnnDropoutForward** and **cudaDnnDropoutBackward**, and its contents is expected to remain unchanged between **cudaDnnDropoutForward** and **cudaDnnDropoutBackward** 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.

## 4.51. cudaDnnDropoutGetStatesSize

```
cudaDnnStatus_t cudaDnnDropoutGetStatesSize(
```

```

    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 `cudaDnnDropoutForward` 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.

## 4.52. 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 `cudaDnnConvolutionBackwardData()`, 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 `cudaDnnGetConvolutionBackwardMaxCount()`.



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

## 4.53. cudnnFindConvolutionBackwardDataAlgorithmEx

```
cudaStatus_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 arbitrary values.

**requestedAlgoCount**

*Input.* The maximum number of elements to be stored in perfResults.

**returnedAlgoCount**

*Output.* The number of output elements stored in perfResults.

**perfResults**

*Output.* A user-allocated array to store performance metrics sorted ascending by compute time.

**workSpace**

*Input.* Data pointer to GPU memory 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.
- ▶ **wDesc**, **dyDesc** or **dxDesc** is not allocated properly.
- ▶ **wDesc**, **dyDesc** or **dxDesc** has fewer than 1 dimension.
- ▶ **w**, **dy** or **dx** is nil.
- ▶ Either **returnedCount** or **perfResults** is nil.
- ▶ **requestedCount** is less than 1.

**CUDNN\_STATUS\_INTERNAL\_ERROR**

At least one of the following conditions are met:

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

## 4.54. 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 necessary timing objects.
- ▶ The function was unable to deallocate necessary timing objects.
- ▶ The function was unable to deallocate sample input, filters and output.

## 4.55. 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 arbitrary values.

**requestedAlgoCount**

*Input.* The maximum number of elements to be stored in perfResults.

**returnedAlgoCount**

*Output.* The number of output elements stored in perfResults.

**perfResults**

*Output.* A user-allocated array to store performance metrics sorted ascending by compute time.

**workSpace**

*Input.* Data pointer to GPU memory 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**, **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 necessary timing objects.
- ▶ The function was unable to deallocate necessary timing objects.
- ▶ The function was unable to deallocate sample input, filters and output.

## 4.56. 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 necessary timing objects.
- ▶ The function was unable to deallocate necessary timing objects.
- ▶ The function was unable to deallocate sample input, filters and output.

## 4.57. 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 arbitrary values.

### requestedAlgoCount

*Input.* The maximum number of elements to be stored in perfResults.

### returnedAlgoCount

*Output.* The number of output elements stored in perfResults.

**perfResults**

*Output.* A user-allocated array to store performance metrics sorted ascending by compute time.

**workSpace**

*Input.* Data pointer to GPU memory 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 necessary timing objects.
- ▶ The function was unable to deallocate necessary timing objects.
- ▶ The function was unable to deallocate sample input, filters and output.

## 4.58. 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 **cudaRNNBackwardData**, using user-allocated GPU memory, and outputs performance metrics to a user-allocated array of **cudnnAlgorithmPerformance\_t**. These 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.

**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 **cudaSetRNNDescriptor** call used to initialize **rnnDesc**:

- ▶ If **direction** is **CUDNN\_UNIDIRECTIONAL** the second dimension should match the **hiddenSize** argument passed to **cudaSetRNNDescriptor**.
- ▶ If **direction** is **CUDNN\_BIDIRECTIONAL** the second dimension should match double the **hiddenSize** argument passed to **cudaSetRNNDescriptor**.

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 **cudaSetRNNDescriptor** call used to initialize **rnnDesc**:

- ▶ If **direction** is **CUDNN\_UNIDIRECTIONAL** the second dimension should match the **hiddenSize** argument passed to **cudaSetRNNDescriptor**.
- ▶ If **direction** is **CUDNN\_BIDIRECTIONAL** the second dimension should match double the **hiddenSize** argument passed to **cudaSetRNNDescriptor**.

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 **cudaSetRNNDescriptor** call used to initialize **rnnDesc**:

- ▶ If **direction** is **CUDNN\_UNIDIRECTIONAL** the first dimension should match the **numLayers** argument passed to **cudaSetRNNDescriptor**.
- ▶ If **direction** is **CUDNN\_BIDIRECTIONAL** the first dimension should match double the **numLayers** argument passed to **cudaSetRNNDescriptor**.

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 **cudaSetRNNDescriptor** 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 **cudaSetRNNDescriptor** call used to initialize **rnnDesc**:

- ▶ If **direction** is **CUDNN\_UNIDIRECTIONAL** the first dimension should match the **numLayers** argument passed to **cudaSetRNNDescriptor**.
- ▶ If **direction** is **CUDNN\_BIDIRECTIONAL** the first dimension should match double the **numLayers** argument passed to **cudaSetRNNDescriptor**.

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 **cudaSetRNNDescriptor** 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 **cudaSetRNNDescriptor** call used to initialize **rnnDesc**:

- ▶ If **direction** is **CUDNN\_UNIDIRECTIONAL** the first dimension should match the **numLayers** argument passed to **cudaSetRNNDescriptor**.
- ▶ If **direction** is **CUDNN\_BIDIRECTIONAL** the first dimension should match double the **numLayers** argument passed to **cudaSetRNNDescriptor**.

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 **cudaSetRNNDescriptor** 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 **cudaSetRNNDescriptor** call used to initialize **rnnDesc**:

- ▶ If **direction** is **CUDNN\_UNIDIRECTIONAL** the first dimension should match the **numLayers** argument passed to **cudaSetRNNDescriptor**.
- ▶ If **direction** is **CUDNN\_BIDIRECTIONAL** the first dimension should match double the **numLayers** argument passed to **cudaSetRNNDescriptor**.

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 **cudaSetRNNDescriptor** 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 **cudaSetRNNDescriptor** call used to initialize **rnnDesc**:

- ▶ If **direction** is **CUDNN\_UNIDIRECTIONAL** the first dimension should match the **numLayers** argument passed to **cudaSetRNNDescriptor**.
- ▶ If **direction** is **CUDNN\_BIDIRECTIONAL** the first dimension should match double the **numLayers** argument passed to **cudaSetRNNDescriptor**.

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 **cudaSetRNNDescriptor** 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 **cudaSetRNNDescriptor** call used to initialize **rnnDesc**:

- ▶ If **direction** is **CUDNN\_UNIDIRECTIONAL** the first dimension should match the **numLayers** argument passed to **cudaSetRNNDescriptor**.
- ▶ If **direction** is **CUDNN\_BIDIRECTIONAL** the first dimension should match double the **numLayers** argument passed to **cudaSetRNNDescriptor**.

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 **cudaSetRNNDescriptor** 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.* Currently unused; for future use.

**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.

## 4.59. 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, and outputs performance metrics to a user-allocated array of **cudnnAlgorithmPerformance\_t**. These 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.

**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 **cudaSetRNNDescriptor** call used to initialize **rnnDesc**:

- ▶ If **direction** is **CUDNN\_UNIDIRECTIONAL** the first dimension should match the **numLayers** argument passed to **cudaSetRNNDescriptor**.
- ▶ If **direction** is **CUDNN\_BIDIRECTIONAL** the first dimension should match double the **numLayers** argument passed to **cudaSetRNNDescriptor**.

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 **cudaSetRNNDescriptor** 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 **cudaSetRNNDescriptor** call used to initialize **rnnDesc**:

- ▶ If **direction** is **CUDNN\_UNIDIRECTIONAL** the second dimension should match the **hiddenSize** argument passed to **cudaSetRNNDescriptor**.
- ▶ If **direction** is **CUDNN\_BIDIRECTIONAL** the second dimension should match double the **hiddenSize** argument passed to **cudaSetRNNDescriptor**.

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.* Currently unused; for future use.

**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.

## 4.60. 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 **cudaDNNForwardInference**, using user-allocated GPU memory, and outputs performance metrics to a user-allocated array of **cudnnAlgorithmPerformance\_t**. These 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.

**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 **cudaDNNSetRNNDescriptor** call used to initialize **rnnDesc**:

- ▶ If **direction** is **CUDNN\_UNIDIRECTIONAL** the first dimension should match the **numLayers** argument passed to **cudaSetRNNDescriptor**.
- ▶ If **direction** is **CUDNN\_BIDIRECTIONAL** the first dimension should match double the **numLayers** argument passed to **cudaSetRNNDescriptor**.

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 **cudaSetRNNDescriptor** 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 **cudaSetRNNDescriptor** call used to initialize **rnnDesc**:

- ▶ If **direction** is **CUDNN\_UNIDIRECTIONAL** the first dimension should match the **numLayers** argument passed to **cudaSetRNNDescriptor**.
- ▶ If **direction** is **CUDNN\_BIDIRECTIONAL** the first dimension should match double the **numLayers** argument passed to **cudaSetRNNDescriptor**.

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 **cudaSetRNNDescriptor** 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 **cudaSetRNNDescriptor** call used to initialize **rnnDesc**:

- ▶ If **direction** is **CUDNN\_UNIDIRECTIONAL** the second dimension should match the **hiddenSize** argument passed to **cudaSetRNNDescriptor**.
- ▶ If **direction** is **CUDNN\_BIDIRECTIONAL** the second dimension should match double the **hiddenSize** argument passed to **cudaSetRNNDescriptor**.



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 **cudaSetRNNDescriptor** call used to initialize **rnnDesc**:

- ▶ If **direction** is **CUDNN\_UNIDIRECTIONAL** the first dimension should match the **numLayers** argument passed to **cudaSetRNNDescriptor**.
- ▶ If **direction** is **CUDNN\_BIDIRECTIONAL** the first dimension should match double the **numLayers** argument passed to **cudaSetRNNDescriptor**.

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 **cudaSetRNNDescriptor** 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 **cudaSetRNNDescriptor** call used to initialize **rnnDesc**:

- ▶ If **direction** is **CUDNN\_UNIDIRECTIONAL** the first dimension should match the **numLayers** argument passed to **cudaSetRNNDescriptor**.
- ▶ If **direction** is **CUDNN\_BIDIRECTIONAL** the first dimension should match double the **numLayers** argument passed to **cudaSetRNNDescriptor**.

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 **cudaSetRNNDescriptor** 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.* Currently unused; for future use..

**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.

## 4.61. 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 **cudaNNRNNForwardTraining**, using user-allocated GPU memory, and outputs performance metrics to a user-allocated array of **cudnnAlgorithmPerformance\_t**. These 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.

**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 **cudaNNSetRNNDescriptor** call used to initialize **rnnDesc**:

- ▶ If **direction** is **CUDNN\_UNIDIRECTIONAL** the first dimension should match the **numLayers** argument passed to **cudaNNSetRNNDescriptor**.
- ▶ If **direction** is **CUDNN\_BIDIRECTIONAL** the first dimension should match double the **numLayers** argument passed to **cudaNNSetRNNDescriptor**.

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 **cudaNNSetRNNDescriptor** 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 **cudaSetRNNDescriptor** call used to initialize **rnnDesc**:

- ▶ If **direction** is **CUDNN\_UNIDIRECTIONAL** the first dimension should match the **numLayers** argument passed to **cudaSetRNNDescriptor**.
- ▶ If **direction** is **CUDNN\_BIDIRECTIONAL** the first dimension should match double the **numLayers** argument passed to **cudaSetRNNDescriptor**.

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 **cudaSetRNNDescriptor** 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 **cudaSetRNNDescriptor** call used to initialize **rnnDesc**:

- ▶ If **direction** is **CUDNN\_UNIDIRECTIONAL** the second dimension should match the **hiddenSize** argument passed to **cudaSetRNNDescriptor**.
- ▶ If **direction** is **CUDNN\_BIDIRECTIONAL** the second dimension should match double the **hiddenSize** argument passed to **cudaSetRNNDescriptor**.

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 **cudaSetRNNDescriptor** call used to initialize **rnnDesc**:

- ▶ If **direction** is **CUDNN\_UNIDIRECTIONAL** the first dimension should match the **numLayers** argument passed to **cudaSetRNNDescriptor**.
- ▶ If **direction** is **CUDNN\_BIDIRECTIONAL** the first dimension should match double the **numLayers** argument passed to **cudaSetRNNDescriptor**.

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 **cudaSetRNNDescriptor** 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 **cudaSetRNNDescriptor** call used to initialize **rnnDesc**:

- ▶ If **direction** is **CUDNN\_UNIDIRECTIONAL** the first dimension should match the **numLayers** argument passed to **cudaSetRNNDescriptor**.
- ▶ If **direction** is **CUDNN\_BIDIRECTIONAL** the first dimension should match double the **numLayers** argument passed to **cudaSetRNNDescriptor**.

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 **cudaSetRNNDescriptor** 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.* Currently unused; for future use..

**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.

## 4.62. 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 threshold when the activation mode is set to **CUDNN\_ACTIVATION\_CLIPPED\_RELU** or to specify the alpha coefficient when the activation mode is set to **CUDNN\_ACTIVATION\_ELU**.

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

**Returns****CUDNN\_STATUS\_SUCCESS**

The object was queried successfully.

## 4.63. 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.

## 4.64. 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.

## 4.65. 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**

*Output.* 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.



## 4.66. 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.

## 4.67. 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.

## 4.68. 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.

## 4.69. 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.

## 4.70. 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.

## 4.71. 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.

## 4.72. cudnnGetConvolutionBackwardDataAlgorithmMaxCount

```

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.

## 4.73. 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.

## 4.74. 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.

## 4.75. 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.

## 4.76. cudnnGetConvolutionBackwardFilterAlgorithmMaxCount

```

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.

## 4.77. 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.

## 4.78. `cudaGetConvolutionBackwardFilterWorkspaceSize`

```

cudaStatus_t cudaGetConvolutionBackwardFilterWorkspaceSize(
    cudaHandle_t          handle,
    const cudaTensorDescriptor_t  xDesc,
    const cudaTensorDescriptor_t  dyDesc,
    const cudaConvolutionDescriptor_t  convDesc,
    const cudaFilterDescriptor_t   dwDesc,
    cudaConvolutionBwdFilterAlgo_t  algo,
    size_t                *sizeInBytes)

```

This function returns the amount of GPU memory workspace the user needs to allocate to be able to call `cudaConvolutionBackwardFilter` with the specified algorithm. The workspace allocated will then be passed to the routine `cudaConvolutionBackwardFilter`. The specified algorithm can be the result of the call to `cudaGetConvolutionBackwardFilterAlgorithm` 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.

## 4.79. 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.

## 4.80. `cudaGetConvolutionForwardAlgorithmMaxCount`

```
cudaStatus_t cudaGetConvolutionForwardAlgorithmMaxCount(
    cudaHandle_t  handle,
    int          *count)
```

This function returns the maximum number of algorithms which can be returned from `cudaFindConvolutionForwardAlgorithm()` and `cudaGetConvolutionForwardAlgorithm_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.

## 4.81. 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.

## 4.82. 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.

## 4.83. 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.

## 4.84. 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.

## 4.85. 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**.

## 4.86. cudnnGetConvolutionNdForwardOutputDim

```

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

```

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

**tensorOutputDimA**

*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.

## 4.87. 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.

## 4.88. 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.

## 4.89. 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.

## 4.90. 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 previously 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.

## 4.91. 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.

## 4.92. 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.

## 4.93. 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.

## 4.94. 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.

## 4.95. 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 initialized pooling descriptor.

**inputDesc**

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

**N**

*Output.* Number of images in the output.

**C**

*Output.* Number of channels in the output.

**H**

*Output.* Height of images in the output.

**W**

*Output.* Width of images in the output.

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).

## 4.96. 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.

## 4.97. 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 initialized pooling descriptor.

**inputDesc**

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

**nbDims**

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

**outDimA**

*Output.* Array of 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**.

## 4.98. 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.

## 4.99. cudnnGetRNNDescrptor

```

cudnnStatus_t cudnnGetRNNDescrptor(
    cudnnHandle_t          handle,
    cudnnRNNDescrptor_t   rnnDesc,
    int *                  hiddenSize,
    int *                  numLayers,
    cudnnDropoutDescrptor_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 `cudnnSetRNNDescrptor()`. 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 `cudaGetRNNDescriptor()` function is NULL.

## 4.100. `cudaGetRNNLinLayerBiasParams`

```

cudaStatus_t cudaGetRNNLinLayerBiasParams (
    cudaHandle_t          handle,
    const cudaRNNDescriptor_t  rnnDesc,
    const int             pseudoLayer,
    const cudaTensorDescriptor_t  xDesc,
    const cudaFilterDescriptor_t  wDesc,
    const void           *w,
    const int            linLayerID,
    cudaFilterDescriptor_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 `cudaGetRNNLinLayerBiasParams()` function was changed in cuDNN version 7.1.1 to match the behavior of `cudaGetRNNLinLayerMatrixParams()`.

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

**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 bias applied to the input from the previous layer, a value of 1 references the bias applied to the recurrent input.
- ▶ 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, value of 4, 5, 6 and 7 reference bias 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.
- ▶ 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, value of 3, 4 and 5 reference bias 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.

### **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.

## 4.101. 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,
const 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 `cudaSetRNNProjectionLayers()` 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 filter 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 outside the '**w**' buffer boundaries as specified by the **wDesc** descriptor.

## 4.102. 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.

## 4.103. 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.

## 4.104. 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.

**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.

## 4.105. 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.

**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 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.

## 4.106. 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.

## 4.107. 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.

## 4.108. 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.

## 4.109. 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.

## 4.110. 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 previously initialized Tensor4D descriptor object.

### Parameters

#### tensorDesc

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

#### datatype

*Output.* Data type.

#### n

*Output.* Number of images.

#### c

*Output.* Number of feature maps per image.

#### h

*Output.* Height of each feature map.

#### w

*Output.* Width of each feature map.

#### nStride

*Output.* Stride between two consecutive images.

#### cStride

*Output.* Stride between two consecutive feature maps.

#### hStride

*Output.* Stride between two consecutive rows.

#### wStride

*Output.* Stride between two consecutive columns.

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

### Returns

#### CUDNN\_STATUS\_SUCCESS

The operation succeeded.

## 4.111. 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.

## 4.112. cudnnGetTensorSizeInBytes

```
cudaStatus_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.

## 4.113. 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.

## 4.114. 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.

## 4.115. 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 initialized LRN parameter descriptor.

**lrnMode**

*Input.* LRN layer mode of operation. Currently only CUDNN\_LRN\_CROSS\_CHANNEL\_DIM1 is implemented. Normalization is performed along the tensor's dimA[1].

**alpha, beta**

*Input.* Pointers to scaling factors (in host memory) used to blend the layer output value with prior value in the destination tensor as follows:  $\text{dstValue} = \text{alpha}[0] * \text{resultValue} + \text{beta}[0] * \text{priorDstValue}$ . [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.

## 4.116. 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 initialized LRN parameter descriptor.

#### lrnMode

*Input.* LRN layer mode of operation. Currently only CUDNN\_LRN\_CROSS\_CHANNEL\_DIM1 is implemented. Normalization is performed along the tensor's dimA[1].

#### alpha, beta

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

## 4.117. 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  $C = \text{op}(\alpha_1[0] * A, \alpha_2[0] * B) + \beta[0] * C$ , 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.



## 4.118. 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            *xDData,
    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:  $\text{dstValue} = \alpha[0] * \text{result} + \beta[0] * \text{priorDstValue}$ . [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.

## 4.119. 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 `cudaDnnGetPooling2dForwardOutputDim` or `cudaDnnGetPoolingNdForwardOutputDim`.

## 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:  $\text{dstValue} = \alpha[0] * \text{result} + \beta[0] * \text{priorDstValue}$ . [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\_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.

## 4.120. 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 `cudaQueryRuntimeError`.



The `cudaQueryRuntimeError` function should be used in conjunction with `cudaBatchNormalizationForwardTraining` and `cudaBatchNormalizationBackward` when the `cudaBatchNormMode_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.

## 4.121. cudaRNNBackwardData

```

cudaStatus_t cudaRNNBackwardData(
    cudaHandle_t          handle,
    const cudaRNNDescriptor_t  rnnDesc,
    const int             seqLength,
    const cudaTensorDescriptor_t *yDesc,
    const void            *y,
    const cudaTensorDescriptor_t *dyDesc,
    const void            *dy,
    const cudaTensorDescriptor_t *dhyDesc,
    const void            *dhy,
    const cudaTensorDescriptor_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 **cudaRNNForwardTraining**. The same **reserveSpace** data must be used for future calls to **cudaRNNBackwardWeights** if they 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.

### 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 **cudaSetRNNDesc** call used to initialize **rnnDesc**:

- ▶ If **direction** is **CUDNN\_UNIDIRECTIONAL** the second dimension should match the **hiddenSize** argument passed to **cudaSetRNNDesc**.
- ▶ If **direction** is **CUDNN\_BIDIRECTIONAL** the second dimension should match double the **hiddenSize** argument passed to **cudaSetRNNDesc**.

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 **cudaSetRNNDescriptor** call used to initialize **rnnDesc**:

- ▶ If **direction** is **CUDNN\_UNIDIRECTIONAL** the second dimension should match the **hiddenSize** argument passed to **cudaSetRNNDescriptor**.
- ▶ If **direction** is **CUDNN\_BIDIRECTIONAL** the second dimension should match double the **hiddenSize** argument passed to **cudaSetRNNDescriptor**.

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 **cudaSetRNNDescriptor** call used to initialize **rnnDesc**:

- ▶ If **direction** is **CUDNN\_UNIDIRECTIONAL** the first dimension should match the **numLayers** argument passed to **cudaSetRNNDescriptor**.
- ▶ If **direction** is **CUDNN\_BIDIRECTIONAL** the first dimension should match double the **numLayers** argument passed to **cudaSetRNNDescriptor**.

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 **cudaSetRNNDescriptor** 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 **cudaSetRNNDescriptor** call used to initialize **rnnDesc**:

- ▶ If **direction** is **CUDNN\_UNIDIRECTIONAL** the first dimension should match the **numLayers** argument passed to **cudaSetRNNDescriptor**.
- ▶ If **direction** is **CUDNN\_BIDIRECTIONAL** the first dimension should match double the **numLayers** argument passed to **cudaSetRNNDescriptor**.

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 **cudaSetRNNDescriptor** 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 **cudaSetRNNDescriptor** call used to initialize **rnnDesc**:

- ▶ If **direction** is **CUDNN\_UNIDIRECTIONAL** the first dimension should match the **numLayers** argument passed to **cudaSetRNNDescriptor**.
- ▶ If **direction** is **CUDNN\_BIDIRECTIONAL** the first dimension should match double the **numLayers** argument passed to **cudaSetRNNDescriptor**.

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 **cudaSetRNNDescriptor** 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 **cudaSetRNNDescriptor** call used to initialize **rnnDesc**:

- ▶ If **direction** is **CUDNN\_UNIDIRECTIONAL** the first dimension should match the **numLayers** argument passed to **cudaSetRNNDescriptor**.
- ▶ If **direction** is **CUDNN\_BIDIRECTIONAL** the first dimension should match double the **numLayers** argument passed to **cudaSetRNNDescriptor**.

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 **cudaSetRNNDescriptor** 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 **cudaSetRNNDescriptor** call used to initialize **rnnDesc**:

- ▶ If **direction** is **CUDNN\_UNIDIRECTIONAL** the first dimension should match the **numLayers** argument passed to **cudaSetRNNDescriptor**.
- ▶ If **direction** is **CUDNN\_BIDIRECTIONAL** the first dimension should match double the **numLayers** argument passed to **cudaSetRNNDescriptor**.

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 **cudaSetRNNDescriptor** 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 **cudaSetRNNDescriptor** call used to initialize **rnnDesc**:

- ▶ If **direction** is **CUDNN\_UNIDIRECTIONAL** the first dimension should match the **numLayers** argument passed to **cudaSetRNNDescriptor**.
- ▶ If **direction** is **CUDNN\_BIDIRECTIONAL** the first dimension should match double the **numLayers** argument passed to **cudaSetRNNDescriptor**.

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 **cudaSetRNNDescriptor** 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.

## 4.122. 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
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.

### 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 **cudaSetRNNDescriptor** call used to initialize **rnnDesc**:

- ▶ If **direction** is **CUDNN\_UNIDIRECTIONAL** the second dimension should match the **hiddenSize** argument passed to **cudaSetRNNDescriptor**.
- ▶ If **direction** is **CUDNN\_BIDIRECTIONAL** the second dimension should match double the **hiddenSize** argument passed to **cudaSetRNNDescriptor**.

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.

## 4.123. 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.

#### 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 `cudaSetRNNDescriptor` call used to initialize `rnnDesc`:

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

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 `cudaSetRNNDescriptor` 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 `cudaSetRNNDescriptor` call used to initialize `rnnDesc`:

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

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 `cudaSetRNNDescriptor` 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 **cudaSetRNNDescriptor** call used to initialize **rnnDesc**:

- ▶ If **direction** is **CUDNN\_UNIDIRECTIONAL** the second dimension should match the **hiddenSize** argument passed to **cudaSetRNNDescriptor**.
- ▶ If **direction** is **CUDNN\_BIDIRECTIONAL** the second dimension should match double the **hiddenSize** argument passed to **cudaSetRNNDescriptor**.

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 **cudaSetRNNDescriptor** call used to initialize **rnnDesc**:

- ▶ If **direction** is **CUDNN\_UNIDIRECTIONAL** the first dimension should match the **numLayers** argument passed to **cudaSetRNNDescriptor**.
- ▶ If **direction** is **CUDNN\_BIDIRECTIONAL** the first dimension should match double the **numLayers** argument passed to **cudaSetRNNDescriptor**.

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 **cudaSetRNNDescriptor** 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 **cudaSetRNNDescriptor** call used to initialize **rnnDesc**:

- ▶ If **direction** is **CUDNN\_UNIDIRECTIONAL** the first dimension should match the **numLayers** argument passed to **cudaSetRNNDescriptor**.

- ▶ If **direction** is **CUDNN\_BIDIRECTIONAL** the first dimension should match double the **numLayers** argument passed to **cudaSetRNNDescriptor**.

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 **cudaSetRNNDescriptor** 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 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.

## 4.124. 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 **cudaRNNBackwardData** and **cudaRNNBackwardWeights** 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 (RNN time steps).

### 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 **cudaSetRNNDescriptor** call used to initialize **rnnDesc**:

- ▶ If **direction** is **CUDNN\_UNIDIRECTIONAL** the first dimension should match the **numLayers** argument passed to **cudaSetRNNDescriptor**.
- ▶ If **direction** is **CUDNN\_BIDIRECTIONAL** the first dimension should match double the **numLayers** argument passed to **cudaSetRNNDescriptor**.

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 **cudaSetRNNDescriptor** 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 **cudaSetRNNDescriptor** call used to initialize **rnnDesc**:

- ▶ If **direction** is **CUDNN\_UNIDIRECTIONAL** the first dimension should match the **numLayers** argument passed to **cudaSetRNNDescriptor**.
- ▶ If **direction** is **CUDNN\_BIDIRECTIONAL** the first dimension should match double the **numLayers** argument passed to **cudaSetRNNDescriptor**.

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 **cudaSetRNNDescriptor** 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 **cudaSetRNNDescriptor** call used to initialize **rnnDesc**:

- ▶ If **direction** is **CUDNN\_UNIDIRECTIONAL** the second dimension should match the **hiddenSize** argument passed to **cudaSetRNNDescriptor**.
- ▶ If **direction** is **CUDNN\_BIDIRECTIONAL** the second dimension should match double the **hiddenSize** argument passed to **cudaSetRNNDescriptor**.

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 **cudaSetRNNDescriptor** call used to initialize **rnnDesc**:

- ▶ If **direction** is **CUDNN\_UNIDIRECTIONAL** the first dimension should match the **numLayers** argument passed to **cudaSetRNNDescriptor**.
- ▶ If **direction** is **CUDNN\_BIDIRECTIONAL** the first dimension should match double the **numLayers** argument passed to **cudaSetRNNDescriptor**.

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 **cudaSetRNNDescriptor** 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 **cudaSetRNNDescriptor** call used to initialize **rnnDesc**:

- ▶ If **direction** is **CUDNN\_UNIDIRECTIONAL** the first dimension should match the **numLayers** argument passed to **cudaSetRNNDescriptor**.
- ▶ If **direction** is **CUDNN\_BIDIRECTIONAL** the first dimension should match double the **numLayers** argument passed to **cudaSetRNNDescriptor**.

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 **cudaSetRNNDescriptor** 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.

## 4.125. 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  $C = \alpha * \text{reduce op} (A) + \beta * C$ , 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 `cudaReduceTensorIndices_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 `cudaIndicesType_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.

## 4.126. 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.

## 4.127. 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.

## 4.128. 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.

## 4.129. 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.

## 4.130. 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 threshold when the activation mode is set to `CUDNN_ACTIVATION_CLIPPED_RELU` or to specify the alpha coefficient when the activation mode is set to `CUDNN_ACTIVATION_ELU`.

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.

## 4.131. 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.

## 4.133. 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.

## 4.134. 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 whose 4 least significant bits are used for switching on/off different levels of error reporting messages, the bit position is in correspondence with the enum of `cudnnSeverity_t`. The user may use predefined macros `CUDNN_SEV_ERROR_EN`, `CUDNN_SEV_WARNING_EN`, `CUDNN_SEV_INFO_EN` to form the bit mask. Output of level `CUDNN_SEV_FATAL` is always enabled and cannot be disabled. When a bit is set to 1, the corresponding message is enabled. For example, when bit 3 is set to 1, API logging is enabled. Currently only log output of level `CUDNN_SEV_INFO` is functional; the others are not yet implemented.

`CUDNN_SEV_ERROR_EN` = 0b0010 (not yet functional)

`CUDNN_SEV_WARNING_EN` = 0b0100 (not yet functional)

`CUDNN_SEV_INFO_EN` = 0b1000

**udata**

*Input.* Pointer to a mutex lock that the user may pass in. It will be used when the default callback function is writing into the output stream. When NULL is passed in, cuDNN will not use mutex when writing to output streams.

**fptr**

*Input.* Pointer to any callback function that the user writes. When this parameter is NULL, cuDNN uses the built-in default callback function.

**Returns****CUDNN\_STATUS\_SUCCESS**

The function launched successfully.

## 4.135. 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 forward convolution path and checks if their settings are valid. That same convolution descriptor can be reused in the backward path provided it corresponds to the same layer.

### 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.

## 4.136. 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

## 4.137. 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.

## 4.138. 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 be 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 filter stride represents the number of elements to slide to reach the next start of the filtering window of the next point.

### **dilationA**

*Input.* Array of dimension **arrayLength** containing the dilation factor for each dimension.

### **mode**

*Input.* Selects between **CUDNN\_CONVOLUTION** and **CUDNN\_CROSS\_CORRELATION**.

### **datatype**

*Input.* Selects the 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.

## 4.139. 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 **cudaDnnDropoutGetStatesSize**.

**CUDNN\_STATUS\_EXECUTION\_FAILED**

The function failed to launch on the GPU

## 4.140. **cudaDnnSetFilter4dDescriptor**

```

cudaDnnStatus_t cudaDnnSetFilter4dDescriptor(
    cudaDnnFilterDescriptor_t  filterDesc,
    cudaDnnDataType_t         dataType,
    cudaDnnTensorFormat_t     format,
    int                        k,
    int                        c,
    int                        h,
    int                        w)

```

This function initializes a previously created filter descriptor object into a 4D filter. Filters layout must be contiguous in memory.

Tensor format **CUDNN\_TENSOR\_NHWC** has limited support in **cudaDnnConvolutionForward**, **cudaDnnConvolutionBackwardData** and **cudaDnnConvolutionBackwardFilter**; please refer to each function's documentation for more information.

### Parameters

#### **filterDesc**

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

#### **datatype**

*Input.* Data type.

#### **format**

*Input.* Type of format.

#### **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.

## 4.141. 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. Filters layout must be contiguous in memory.

Tensor format CUDNN\_TENSOR\_NHWC has limited support in **cudnnConvolutionForward**, **cudnnConvolutionBackwardData** and **cudnnConvolutionBackwardFilter**; please refer to each function's documentation for more information.

### Parameters

#### **filterDesc**

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

#### **dataType**

*Input.* Data type.

#### **format**

*Input.* Type of format.

#### **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`.

## 4.142. 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  $(\text{window width})^{\#\text{spatialDimensions}}$  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.

## 4.143. 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.

## 4.144. 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`.

## 4.145. 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.

## 4.146. cudnnSetPoolingNdDescriptor

```

cudnnStatus_t cudnnSetPoolingNdDescriptor(
    cudnnPoolingDescriptor_t poolingDesc,
    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.

**windowDimA**

*Output.* Array of dimension **nbDims** containing the window size for each dimension.

**paddingA**

*Output.* Array of dimension **nbDims** containing the padding size for each dimension.

**strideA**

*Output.* Array of dimension **nbDims** containing the striding size 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 arrays **windowDimA**, **paddingA** or **strideA** is negative or **mode** or **maxpoolingNanOpt** has an invalid enumerant value.

## 4.147. 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      dataType)

```

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.

#### dataType

*Input.* Math 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**

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.

## 4.148. 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        dataType)

```

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.

#### **dataType**

*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**

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.

## 4.149. cudnnSetRNNDescriptor\_v6

```

cudnnStatus_t cudnnSetRNNDescriptor_v6(
    cudnnHandle_t      handle,
    cudnnRNNDescriptor_t  rnnDesc,
    cudnnDropoutDescriptor_t dropoutDesc,
    cudnnRNNInputMode_t  inputMode,
    cudnnDirectionMode_t direction,
    cudnnRNNMode_t       mode,
    cudnnRNNAlgo_t       algo,
    cudnnDataType_t      dataType)

```

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.

**dataType**

*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**

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.

## 4.150. 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.

## 4.151. 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.

## 4.152. 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).

## 4.153. 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

## 4.154. 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.

## 4.155. 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.

## 4.156. 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 maximum limit of 2 Giga-elements.

## 4.157. 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.

## 4.158. 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 `cuda.h`). When working with lower dimensional data, it is recommended that the user create a 4D tensor, and set the size along unused dimensions to 1.

### Parameters

#### **tensorDesc**

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

#### **datatype**

*Input.* Data type.

#### **nbDims**

*Input.* Dimension of the tensor. Note: Do not use 2 dimensions.

#### **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 maximum limit of 2 Giga-elements.

## 4.159. 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.* Tensor dimension size.

**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.

## 4.160. 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:  $\text{dstValue} = \text{alpha}[0] * \text{result} + \text{beta}[0] * \text{priorDstValue}$ . [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.

## 4.161. 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:  $\text{dstValue} = \alpha[0] * \text{result} + \beta[0] * \text{priorDstValue}$ . [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.

## 4.162. 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.

## 4.163. 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.

## 4.164. 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:  $\text{dstValue} = \text{alpha}[0] * \text{srcValue} + \text{beta}[0] * \text{priorDstValue}$ . [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 **cudaSpatialTfGridGeneratorForward**.

**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.



## 4.165. 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:  $\text{dstValue} = \text{alpha}[0] * \text{srcValue} + \text{beta}[0] * \text{priorDstValue}$ . [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.

## 4.166. 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:  $\text{dstValue} = \text{alpha}[0] * \text{srcValue} + \text{beta}[0] * \text{priorDstValue}$ . [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.

# Chapter 5.

## ACKNOWLEDGMENTS

Some of the cuDNN library routines were derived from code developed by others and are subject to the following:

### 5.1. University of Tennessee

```
Copyright (c) 2010 The University of Tennessee.
```

```
All rights reserved.
```

```
Redistribution and use in source and binary forms, with or without  
modification, are permitted provided that the following conditions are  
met:
```

- \* Redistributions of source code must retain the above copyright notice, this list of conditions and the following disclaimer.
- \* Redistributions in binary form must reproduce the above copyright notice, this list of conditions and the following disclaimer listed in this license in the documentation and/or other materials provided with the distribution.
- \* Neither the name of the copyright holders nor the names of its contributors may be used to endorse or promote products derived from this software without specific prior written permission.

```
THIS SOFTWARE IS PROVIDED BY THE COPYRIGHT HOLDERS AND CONTRIBUTORS  
"AS IS" AND ANY EXPRESS OR IMPLIED WARRANTIES, INCLUDING, BUT NOT  
LIMITED TO, THE IMPLIED WARRANTIES OF MERCHANTABILITY AND FITNESS FOR  
A PARTICULAR PURPOSE ARE DISCLAIMED. IN NO EVENT SHALL THE COPYRIGHT  
OWNER OR CONTRIBUTORS BE LIABLE FOR ANY DIRECT, INDIRECT, INCIDENTAL,  
SPECIAL, EXEMPLARY, OR CONSEQUENTIAL DAMAGES (INCLUDING, BUT NOT  
LIMITED TO, PROCUREMENT OF SUBSTITUTE GOODS OR SERVICES; LOSS OF USE,  
DATA, OR PROFITS; OR BUSINESS INTERRUPTION) HOWEVER CAUSED AND ON ANY  
THEORY OF LIABILITY, WHETHER IN CONTRACT, STRICT LIABILITY, OR TORT  
(INCLUDING NEGLIGENCE OR OTHERWISE) ARISING IN ANY WAY OUT OF THE USE  
OF THIS SOFTWARE, EVEN IF ADVISED OF THE POSSIBILITY OF SUCH DAMAGE.
```

### 5.2. University of California, Berkeley

```
COPYRIGHT
```

```
All contributions by the University of California:  
Copyright (c) 2014, The Regents of the University of California (Regents)
```

All rights reserved.

All other contributions:  
 Copyright (c) 2014, the respective contributors  
 All rights reserved.

Caffe uses a shared copyright model: each contributor holds copyright over their contributions to Caffe. The project versioning records all such contribution and copyright details. If a contributor wants to further mark their specific copyright on a particular contribution, they should indicate their copyright solely in the commit message of the change when it is committed.

#### LICENSE

Redistribution and use in source and binary forms, with or without modification, are permitted provided that the following conditions are met:

1. Redistributions of source code must retain the above copyright notice, this list of conditions and the following disclaimer.
2. Redistributions in binary form must reproduce the above copyright notice, this list of conditions and the following disclaimer in the documentation and/or other materials provided with the distribution.

THIS SOFTWARE IS PROVIDED BY THE COPYRIGHT HOLDERS AND CONTRIBUTORS "AS IS" AND ANY EXPRESS OR IMPLIED WARRANTIES, INCLUDING, BUT NOT LIMITED TO, THE IMPLIED WARRANTIES OF MERCHANTABILITY AND FITNESS FOR A PARTICULAR PURPOSE ARE DISCLAIMED. IN NO EVENT SHALL THE COPYRIGHT OWNER OR CONTRIBUTORS BE LIABLE FOR ANY DIRECT, INDIRECT, INCIDENTAL, SPECIAL, EXEMPLARY, OR CONSEQUENTIAL DAMAGES (INCLUDING, BUT NOT LIMITED TO, PROCUREMENT OF SUBSTITUTE GOODS OR SERVICES; LOSS OF USE, DATA, OR PROFITS; OR BUSINESS INTERRUPTION) HOWEVER CAUSED AND ON ANY THEORY OF LIABILITY, WHETHER IN CONTRACT, STRICT LIABILITY, OR TORT (INCLUDING NEGLIGENCE OR OTHERWISE) ARISING IN ANY WAY OUT OF THE USE OF THIS SOFTWARE, EVEN IF ADVISED OF THE POSSIBILITY OF SUCH DAMAGE.

#### CONTRIBUTION AGREEMENT

By contributing to the BVLC/caffe repository through pull-request, comment, or otherwise, the contributor releases their content to the license and copyright terms herein.

## 5.3. Facebook AI Research, New York

Copyright (c) 2014, Facebook, Inc. All rights reserved.

Redistribution and use in source and binary forms, with or without modification, are permitted provided that the following conditions are met:

- \* Redistributions of source code must retain the above copyright notice, this list of conditions and the following disclaimer.
- \* Redistributions in binary form must reproduce the above copyright notice, this list of conditions and the following disclaimer in the documentation and/or other materials provided with the distribution.
- \* Neither the name Facebook nor the names of its contributors may be used to endorse or promote products derived from this software without specific prior written permission.

THIS SOFTWARE IS PROVIDED BY THE COPYRIGHT HOLDERS AND CONTRIBUTORS "AS IS" AND ANY EXPRESS OR IMPLIED WARRANTIES, INCLUDING, BUT NOT LIMITED TO, THE IMPLIED WARRANTIES OF MERCHANTABILITY AND FITNESS FOR A PARTICULAR PURPOSE ARE DISCLAIMED. IN NO EVENT SHALL THE COPYRIGHT HOLDER OR CONTRIBUTORS BE LIABLE FOR ANY DIRECT, INDIRECT, INCIDENTAL, SPECIAL, EXEMPLARY, OR CONSEQUENTIAL DAMAGES

(INCLUDING, BUT NOT LIMITED TO, PROCUREMENT OF SUBSTITUTE GOODS OR SERVICES; LOSS OF USE, DATA, OR PROFITS; OR BUSINESS INTERRUPTION) HOWEVER CAUSED AND ON ANY THEORY OF LIABILITY, WHETHER IN CONTRACT, STRICT LIABILITY, OR TORT (INCLUDING NEGLIGENCE OR OTHERWISE) ARISING IN ANY WAY OUT OF THE USE OF THIS SOFTWARE, EVEN IF ADVISED OF THE POSSIBILITY OF SUCH DAMAGE.

### Additional Grant of Patent Rights

"Software" means fbcunn software distributed by Facebook, Inc.

Facebook hereby grants you a perpetual, worldwide, royalty-free, non-exclusive, irrevocable (subject to the termination provision below) license under any rights in any patent claims owned by Facebook, to make, have made, use, sell, offer to sell, import, and otherwise transfer the Software. For avoidance of doubt, no license is granted under Facebook's rights in any patent claims that are infringed by (i) modifications to the Software made by you or a third party, or (ii) the Software in combination with any software or other technology provided by you or a third party.

The license granted hereunder will terminate, automatically and without notice, for anyone that makes any claim (including by filing any lawsuit, assertion or other action) alleging (a) direct, indirect, or contributory infringement or inducement to infringe any patent: (i) by Facebook or any of its subsidiaries or affiliates, whether or not such claim is related to the Software, (ii) by any party if such claim arises in whole or in part from any software, product or service of Facebook or any of its subsidiaries or affiliates, whether or not such claim is related to the Software, or (iii) by any party relating to the Software; or (b) that any right in any patent claim of Facebook is invalid or unenforceable.

## Notice

THE INFORMATION IN THIS GUIDE AND ALL OTHER INFORMATION CONTAINED IN NVIDIA DOCUMENTATION REFERENCED IN THIS GUIDE IS PROVIDED “AS IS.” NVIDIA MAKES NO WARRANTIES, EXPRESSED, IMPLIED, STATUTORY, OR OTHERWISE WITH RESPECT TO THE INFORMATION FOR THE PRODUCT, AND EXPRESSLY DISCLAIMS ALL IMPLIED WARRANTIES OF NONINFRINGEMENT, MERCHANTABILITY, AND FITNESS FOR A PARTICULAR PURPOSE. Notwithstanding any damages that customer might incur for any reason whatsoever, NVIDIA’s aggregate and cumulative liability towards customer for the product described in this guide shall be limited in accordance with the NVIDIA terms and conditions of sale for the product.

THE NVIDIA PRODUCT DESCRIBED IN THIS GUIDE IS NOT FAULT TOLERANT AND IS NOT DESIGNED, MANUFACTURED OR INTENDED FOR USE IN CONNECTION WITH THE DESIGN, CONSTRUCTION, MAINTENANCE, AND/OR OPERATION OF ANY SYSTEM WHERE THE USE OR A FAILURE OF SUCH SYSTEM COULD RESULT IN A SITUATION THAT THREATENS THE SAFETY OF HUMAN LIFE OR SEVERE PHYSICAL HARM OR PROPERTY DAMAGE (INCLUDING, FOR EXAMPLE, USE IN CONNECTION WITH ANY NUCLEAR, AVIONICS, LIFE SUPPORT OR OTHER LIFE CRITICAL APPLICATION). NVIDIA EXPRESSLY DISCLAIMS ANY EXPRESS OR IMPLIED WARRANTY OF FITNESS FOR SUCH HIGH RISK USES. NVIDIA SHALL NOT BE LIABLE TO CUSTOMER OR ANY THIRD PARTY, IN WHOLE OR IN PART, FOR ANY CLAIMS OR DAMAGES ARISING FROM SUCH HIGH RISK USES.

NVIDIA makes no representation or warranty that the product described in this guide will be suitable for any specified use without further testing or modification. Testing of all parameters of each product is not necessarily performed by NVIDIA. It is customer’s sole responsibility to ensure the product is suitable and fit for the application planned by customer and to do the necessary testing for the application in order to avoid a default of the application or the product. Weaknesses in customer’s product designs may affect the quality and reliability of the NVIDIA product and may result in additional or different conditions and/or requirements beyond those contained in this guide. NVIDIA does not accept any liability related to any default, damage, costs or problem which may be based on or attributable to: (i) the use of the NVIDIA product in any manner that is contrary to this guide, or (ii) customer product designs.

Other than the right for customer to use the information in this guide with the product, no other license, either expressed or implied, is hereby granted by NVIDIA under this guide. Reproduction of information in this guide is permissible only if reproduction is approved by NVIDIA in writing, is reproduced without alteration, and is accompanied by all associated conditions, limitations, and notices.

## Trademarks

NVIDIA, the NVIDIA logo, and cuBLAS, CUDA, cuDNN, cuFFT, cuSPARSE, DIGITS, DGX, DGX-1, Jetson, Kepler, NVIDIA Maxwell, NCCL, NVLink, Pascal, Tegra, TensorRT, and Tesla are trademarks and/or registered trademarks of NVIDIA Corporation in the United States and other countries. Other company and product names may be trademarks of the respective companies with which they are associated.

## Copyright

© 2018 NVIDIA Corporation. All rights reserved.