CUDNN

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API Guide

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Chapter 1. INTRODUCTION

cuDNN offers a context-based API that allows for easy multithreading and (optional) interoperability with CUDA streams. The cuDNN Datatypes Reference API describes all the types and enums of the cuDNN library API. The cuDNN API Reference describes the API of all the routines in the cuDNN library.

Chapter 2. CUDNN DATATYPES REFERENCE

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

2.1. cudnnActivationDescriptor_t

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

2.2. 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`

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

2.3. cudnnAttnDescriptor_t

`cudnnAttnDescriptor_t` is a pointer to an opaque structure holding parameters of the multi-head attention layer such as:

- weight and bias tensor shapes (vector lengths before and after linear projections)
- parameters that can be set in advance and do not change when invoking functions to evaluate forward responses and gradients (number of attention heads, softmax smoothing/sharpening coefficient)
- other settings that are necessary to compute temporary buffer sizes.

Use the cudnnCreateAttnDescriptor() function to create an instance of the attention descriptor object and cudnnDestroyAttnDescriptor() to delete the previously created descriptor. Use the cudnnSetAttnDescriptor() function to configure the descriptor.

2.4. cudnnBatchNormMode_t

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

Values

`CUDNN_BATCHNORM_PER_ACTIVATION`

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

`CUDNN_BATCHNORM_SPATIAL`

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

CUDNN_BATCHNORM_SPATIAL_PERSISTENT

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

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

The rest of this section applies to NCHW mode only:

This mode may use a scaled atomic integer reduction that is deterministic but imposes more restrictions on the input data range. When a numerical overflow occurs, the algorithm may produce NaN-s or Inf-s (infinity) in output buffers.

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

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

2.5. cudnnBatchNormOps_t

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

Values

CUDNN_BATCHNORM_OPS_BN

Only batch normalization is performed, per-activation.

CUDNN_BATCHNORM_OPS_BN_ACTIVATION

First, the batch normalization is performed, and then the activation is performed.

CUDNN_BATCHNORM_OPS_BN_ADD_ACTIVATION

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

2.6. 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. A significant workspace may be needed to store intermediate results. The results are deterministic.

2.7. cudnnConvolutionBwdDataAlgoPerf_t

cudnnConvolutionBwdDataAlgoPerf_t is a structure containing performance results returned by cudnnFindConvolutionBackwardDataAlgorithm() or heuristic results returned by cudnnGetConvolutionBackwardDataAlgorithm_v7().

Data Members

cudnnConvolutionBwdDataAlgo_t algo

The algorithm runs to obtain the associated performance metrics.

cudnnStatus_t status

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

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

float time

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

size_t memory

The workspace size (in bytes).

cudnnDeterminism_t determinism

The determinism of the algorithm.

cudnnMathType_t mathType

The math type provided to the algorithm.

int reserved[3]

Reserved space for future properties.

2.8. 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 cudnnGetConvolutionBackwardDataAlgorithm() is guaranteed to return an algorithm that does not require any extra workspace to be provided by the user.

CUDNN_CONVOLUTION_BWD_DATA_PREFER_FASTEST

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

CUDNN_CONVOLUTION_BWD_DATA_SPECIFY_WORKSPACE_LIMIT

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

2.9. 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. A significant workspace is needed to store intermediate results. The results are deterministic.

CUDNN_CONVOLUTION_BWD_FILTER_ALGO_3

This algorithm is similar to **CUDNN_CONVOLUTION_BWD_FILTER_ALGO_0** but uses some small workspace to 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. A significant workspace may be needed to store intermediate results. The results are deterministic.

CUDNN_CONVOLUTION_BWD_FILTER_ALGO_FFT_TILING

This algorithm uses the Fast-Fourier Transform approach to compute the convolution but splits the input tensor into tiles. A significant workspace may be needed to store intermediate results. The results are deterministic.

2.10. cudnnConvolutionBwdFilterAlgoPerf_t

cudnnConvolutionBwdFilterAlgoPerf_t is a structure containing performance results returned by cudnnFindConvolutionBackwardFilterAlgorithm() or heuristic results returned by cudnnGetConvolutionBackwardFilterAlgorithm_v7().

Data Members

cudnnConvolutionBwdFilterAlgo_t algo

The algorithm runs to obtain the associated performance metrics.

cudnnStatus_t status

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

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

float time

The execution time of cudnnConvolutionBackwardFilter() (in milliseconds).

size_t memory

The workspace size (in bytes).

cudnnDeterminism_t determinism

The determinism of the algorithm.

cudnnMathType_t mathType

The math type provided to the algorithm.

int reserved[3]

Reserved space for future properties.

2.11. 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 cudnnGetConvolutionBackwardFilterAlgorithm() is guaranteed to return an algorithm that does not require any extra workspace to be provided by the user.

CUDNN_CONVOLUTION_BWD_FILTER_PREFER_FASTEST

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

CUDNN_CONVOLUTION_BWD_FILTER_SPECIFY_WORKSPACE_LIMIT

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

2.12. cudnnConvolutionDescriptor_t

cudnnConvolutionDescriptor_t is a pointer to an opaque structure holding the description of a convolution operation. cudnnCreateConvolutionDescriptor() is used to create one instance, and cudnnSetConvolutionNdDescriptor() or cudnnSetConvolution2dDescriptor() must be used to initialize this instance.

2.13. cudnnConvolutionFwdAlgo_t

cudnnConvolutionFwdAlgo_t is an enumerated type that exposes the different algorithms available to execute the forward convolution operation.

Values

CUDNN_CONVOLUTION_FWD_ALGO_IMPLICIT_GEMM

This algorithm expresses the convolution as a matrix product without actually explicitly form the matrix that holds the input tensor data.

CUDNN_CONVOLUTION_FWD_ALGO_IMPLICIT_PRECOMP_GEMM

This algorithm expresses 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 (for example, without implicitly or explicitly doing a matrix multiplication).

CUDNN_CONVOLUTION_FWD_ALGO_FFT

This algorithm uses the Fast-Fourier Transform approach to compute the convolution. A significant memory workspace is needed to store intermediate results.

CUDNN_CONVOLUTION_FWD_ALGO_FFT_TILING

This algorithm uses the Fast-Fourier Transform approach but splits the inputs into tiles. A significant memory workspace is needed to store intermediate results but less than **CUDNN_CONVOLUTION_FWD_ALGO_FFT** for large size images.

CUDNN_CONVOLUTION_FWD_ALGO_WINOGRAD

This algorithm uses the Winograd Transform approach to compute the convolution. A reasonably sized workspace is needed to store intermediate results.

CUDNN_CONVOLUTION_FWD_ALGO_WINOGRAD_NONFUSED

This algorithm uses the Winograd Transform approach to compute the convolution. A significant workspace may be needed to store intermediate results.

2.14. cudnnConvolutionFwdAlgoPerf_t

cudnnConvolutionFwdAlgoPerf_t is a structure containing performance results returned by cudnnFindConvolutionForwardAlgorithm() or heuristic results returned by cudnnGetConvolutionForwardAlgorithm_v7().

Data Members

cudnnConvolutionFwdAlgo_t algo

The algorithm runs to obtain the associated performance metrics.

cudnnStatus_t status

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

- **CUDNN_STATUS_ALLOC_FAILED** if any error occurred during workspace allocation or if the provided workspace is insufficient.
- **CUDNN_STATUS_INTERNAL_ERROR** if any error occurred during timing calculations or workspace deallocation.

- Otherwise, this will be the return status of cudnnConvolutionForward().

float time

The execution time of cudnnConvolutionForward() (in milliseconds).

size_t memory

The workspace size (in bytes).

cudnnDeterminism_t determinism

The determinism of the algorithm.

cudnnMathType_t mathType

The math type provided to the algorithm.

int reserved[3]

Reserved space for future properties.

2.15. 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 of 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.

2.16. cudnnConvolutionMode_t

cudnnConvolutionMode_t is an enumerated type used by cudnnSetConvolution2dDescriptor() to configure a convolution descriptor. The filter used for the convolution can be applied in two different ways, corresponding mathematically to a convolution or to a cross-correlation. (A cross-correlation is equivalent to a convolution with its filter rotated by 180 degrees.)

Values

CUDNN_CONVOLUTION

In this mode, a convolution operation will be done when applying the filter to the images.

CUDNN_CROSS_CORRELATION

In this mode, a cross-correlation operation will be done when applying the filter to the images.

2.17. cudnnCTCLossAlgo_t

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

Values

CUDNN_CTC_LOSS_ALGO_DETERMINISTIC

Results are guaranteed to be reproducible

CUDNN_CTC_LOSS_ALGO_NON_DETERMINISTIC

Results are not guaranteed to be reproducible

2.18. cudnnCTCLossDescriptor_t

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

2.19. cudnnDataType_t

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

Values

CUDNN_DATA_FLOAT

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

CUDNN_DATA_DOUBLE

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

CUDNN_DATA_HALF

The data is a 16-bit floating-point.

CUDNN_DATA_INT8

The data is an 8-bit signed integer.

CUDNN_DATA_UINT8

The data is an 8-bit unsigned integer.

CUDNN_DATA_INT32

The data is a 32-bit signed integer.

CUDNN_DATA_INT8x4

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

CUDNN_DATA_INT8x32

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

CUDNN_DATA_UINT8x4

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

2.20. cudnnDeterminism_t

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

Values

CUDNN_NON_DETERMINISTIC

Results are not guaranteed to be reproducible.

CUDNN_DETERMINISTIC

Results are guaranteed to be reproducible.

2.21. cudnnDirectionMode_t

cudnnDirectionMode_t is an enumerated type used to specify the recurrence pattern in the cudnnRNNForwardInference(), cudnnRNNForwardTraining(), cudnnRNNBackwardData() and cudnnRNNBackwardWeights() routines.

Values

CUDNN_UNIDIRECTIONAL

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

CUDNN_BIDIRECTIONAL

Each layer of the network iterates recurrently from the first input to the last and separately from the last input to the first. The outputs of the two are concatenated at each iteration giving the output of the layer.

2.22. cudnnDivNormMode_t

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

Values

CUDNN_DIVNORM_PRECOMPUTED_MEANS

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

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

2.23. cudnnDropoutDescriptor_t

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

2.24. cudnnErrQueryMode_t

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

Values

`CUDNN_ERRQUERY_RAWCODE`

Read the error storage location regardless of the kernel completion status.

`CUDNN_ERRQUERY_NONBLOCKING`

Report if all tasks in the user stream of the cuDNN handle were completed. If that is the case, report the remote kernel error code.

`CUDNN_ERRQUERY_BLOCKING`

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

2.25. 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.

2.26. cudnnFoldingDirection_t

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

Data Member

`CUDNN_TRANSFORM_FOLD = 0U`

Selects folding.

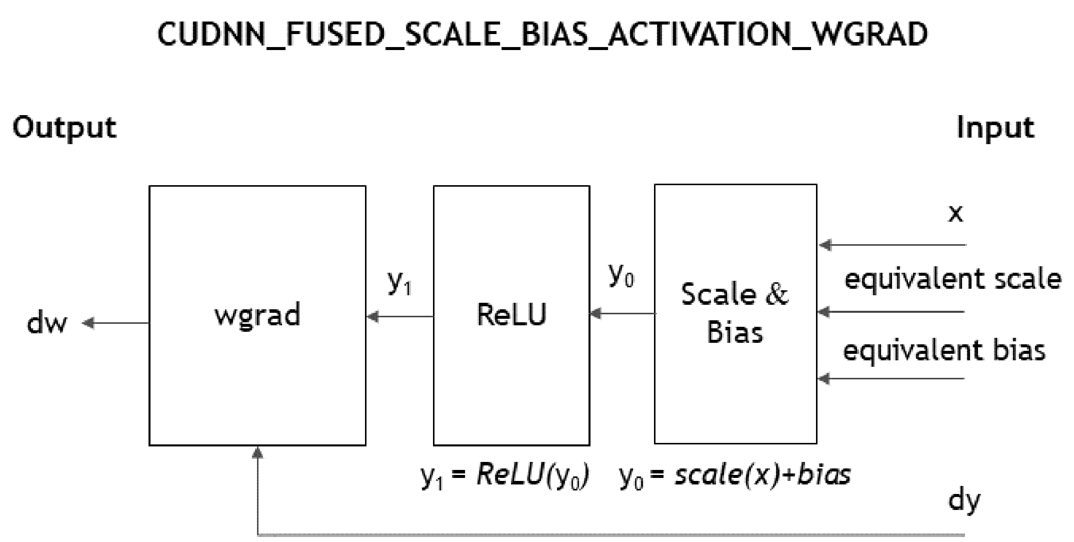
`CUDNN_TRANSFORM_UNFOLD = 1U`

Selects unfolding.

2.27. cudnnFusedOps_t

The **`cudnnFusedOps_t`** type is an enumerated type to select a specific sequence of computations to perform in the fused operations.

Member	Description
`CUDNN_FUSED_SCALE_BIAS_ACTIVATION_CONV_BNSTATS = 0`	On a per-channel basis, performs these operations in this order: scale, add bias, activation, convolution, and generate **`batchnorm`** statistics.
`CUDNN_FUSED_SCALE_BIAS_ACTIVATION_WGRAD = 1`	On a per-channel basis, performs these operations in this order: scale, add bias, activation, convolution backward weights, and generate **`batchnorm`** statistics.



`CUDNN_FUSED_BN_FINALIZE_STATISTICS_TRAINING = 2`	Computes the equivalent scale and bias from **`ySum`**, **`ySqSum`** and learned **`scale`**, **`bias`**. Optionally update running statistics and generate saved stats
`CUDNN_FUSED_BN_FINALIZE_STATISTICS_INFERENCE = 3`	Computes the equivalent scale and bias from the learned running statistics and the learned scale, bias.
`CUDNN_FUSED_CONV_SCALE_BIAS_ADD_ACTIVATION = 4`	On a per-channel basis, performs these operations in this order: convolution, scale, add bias, element-wise addition with another tensor, and activation.
`CUDNN_FUSED_SCALE_BIAS_ADD_ACTIVATION_GEN_BITMASK = 5`	On a per-channel basis, performs these operations in this order: scale and bias on one tensor, scale, and bias on a second tensor, element-wise addition

Member	Description
	of these two tensors, and on the resulting tensor perform activation, and generate activation bit mask.
CUDNN_FUSED_DACTIVATION_FORK_DBATCHNORM = 6	On a per-channel basis, performs these operations in this order: backward activation, fork (meaning, write out gradient for the residual branch), and backward batch norm.

2.28. cudnnFusedOpsConstParamLabel_t

The **cudnnFusedOpsConstParamLabel_t** is an enumerated type for the selection of the type of the **cudnnFusedOps** descriptor. For more information, see cudnnSetFusedOpsConstParamPackAttribute().

```
typedef enum {
 CUDNN_PARAM_XDESC                          = 0,
 CUDNN_PARAM_XDATA_PLACEHOLDER              = 1,
 CUDNN_PARAM_BN_MODE                        = 2,
 CUDNN_PARAM_BN_EQSCALEBIAS_DESC            = 3,
 CUDNN_PARAM_BN_EQSCALE_PLACEHOLDER         = 4,
 CUDNN_PARAM_BN_EQBIAS_PLACEHOLDER          = 5,
 CUDNN_PARAM_ACTIVATION_DESC                = 6,
 CUDNN_PARAM_CONV_DESC                      = 7,
 CUDNN_PARAM_WDESC                          = 8,
 CUDNN_PARAM_WDATA_PLACEHOLDER              = 9,
 CUDNN_PARAM_DWDESC                         = 10,
 CUDNN_PARAM_DWDATA_PLACEHOLDER             = 11,
 CUDNN_PARAM_YDESC                          = 12,
 CUDNN_PARAM_YDATA_PLACEHOLDER              = 13,
 CUDNN_PARAM_DYDESC                         = 14,
 CUDNN_PARAM_DYDATA_PLACEHOLDER             = 15,
 CUDNN_PARAM_YSTATS_DESC                    = 16,
 CUDNN_PARAM_YSUM_PLACEHOLDER               = 17,
 CUDNN_PARAM_YSQSUM_PLACEHOLDER             = 18,
 CUDNN_PARAM_BN_SCALEBIAS_MEANVAR_DESC      = 19,
 CUDNN_PARAM_BN_SCALE_PLACEHOLDER           = 20,
 CUDNN_PARAM_BN_BIAS_PLACEHOLDER            = 21,
 CUDNN_PARAM_BN_SAVED_MEAN_PLACEHOLDER      = 22,
 CUDNN_PARAM_BN_SAVED_INVSTD_PLACEHOLDER    = 23,
 CUDNN_PARAM_BN_RUNNING_MEAN_PLACEHOLDER    = 24,
 CUDNN_PARAM_BN_RUNNING_VAR_PLACEHOLDER     = 25,
 CUDNN_PARAM_ZDESC                          = 26,
 CUDNN_PARAM_ZDATA_PLACEHOLDER              = 27,
 CUDNN_PARAM_BN_Z_EQSCALEBIAS_DESC          = 28,
 CUDNN_PARAM_BN_Z_EQSCALE_PLACEHOLDER       = 29,
 CUDNN_PARAM_BN_Z_EQBIAS_PLACEHOLDER        = 30,
 CUDNN_PARAM_ACTIVATION_BITMASK_DESC        = 31,
 CUDNN_PARAM_ACTIVATION_BITMASK_PLACEHOLDER = 32,
 CUDNN_PARAM_DXDESC                         = 33,
 CUDNN_PARAM_DXDATA_PLACEHOLDER             = 34,
 CUDNN_PARAM_DZDESC                         = 35,
 CUDNN_PARAM_DZDATA_PLACEHOLDER             = 36,
 CUDNN_PARAM_BN_DSCALE_PLACEHOLDER          = 37,
 CUDNN_PARAM_BN_DBIAS_PLACEHOLDER           = 38,
 } cudnnFusedOpsConstParamLabel_t;
```

Short-form used	Stands for
Setter	cudnnSetFusedOpsConstParamPackAttribute()

Short-form used	Stands for
Getter	cudnnGetFusedOpsConstParamPackAttribute()
X_PointerPlaceHolder_t	cudnnFusedOpsPointerPlaceHolder_t
X_ prefix in the *Attribute* column	Stands for **CUDNN_PARAM_** in the enumerator name

Table 1 CUDNN_FUSED_SCALE_BIAS_ACTIVATION_CONV_BNSTATS

For the attribute **CUDNN_FUSED_SCALE_BIAS_ACTIVATION_CONV_BNSTATS** in **cudnnFusedOp_t**			
Attribute	**Expected Descriptor Type Passed in, in the Setter**	**Description**	**Default Value After Creation**
X_XDESC	In the setter, the ***param** should be **xDesc**, a pointer to a previously initialized **cudnnTensorDescriptor_t**.	Tensor descriptor describing the size, layout, and datatype of the **x** (input) tensor.	**NULL**
X_XDATA_PLACEHOLDER	In the setter, the ***param** should be a pointer to a previously initialized **X_PointerPlaceHolder_t***.	Describes whether **xData** pointer in the **VariantParamPack** will be **NULL**, or if not, user promised pointer alignment *****.	**CUDNN_PTR_NULL**
X_BN_MODE	In the setter, the ***param** should be a pointer to a previously initialized cudnnBatchNormMode_t*.	Describes the mode of operation for the scale, bias and the statistics. As of cuDNN 7.6.0, only **CUDNN_BATCHNORM_SPATIAL** and **CUDNN_BATCHNORM_SPATIAL_PERSISTENT** are supported, meaning, scale, bias, and statistics are all per-channel.	**CUDNN_BATCHNORM_PER_ACTIVATION**
X_BN_EQSCALEBIAS_DESC	In the setter, the ***param** should be a pointer to a previously initialized cudnnTensorDescriptor_t.	Tensor descriptor describing the size, layout, and datatype of the batchNorm equivalent scale and bias tensors. The shapes must match the mode specified in **CUDNN_PARAM_BN_MODE**. If set to **NULL**, both scale and bias operation will become a NOP.	**NULL**
X_BN_EQSCALE_PLACEHOLDER	In the setter, the ***param** should be a pointer to a previously initialized **X_PointerPlaceHolder_t***	Describes whether batchnorm equivalent scale pointer in the **VariantParamPack** will be **NULL**, or if not,	**CUDNN_PTR_NULL**

For the attribute CUDNN_FUSED_SCALE_BIAS_ACTIVATION_CONV_BNSTATS in cudnnFusedOp_t			
Attribute	Expected Descriptor Type Passed in, in the Setter	Description	Default Value After Creation
		user promised pointer alignment *. If set to CUDNN_PTR_NULL, then the scale operation becomes a NOP.	
X_BN_EQBIAS_PLACEHOLDER	In the setter, the *param should be a pointer to a previously initialized X_PointerPlaceHolder_t*.	Describes whether batchnorm equivalent bias pointer in the VariantParamPack will be NULL, or if not, user promised pointer alignment *. If set to CUDNN_PTR_NULL, then the bias operation becomes a NOP.	CUDNN_PTR_NULL
X_ACTIVATION_DESC	In the setter, the *param should be a pointer to a previously initialized cudnnActivationDescriptor_t*.	Describes the activation operation. As of 7.6.0, only activation mode of CUDNN_ACTIVATION_RELU and CUDNN_ACTIVATION_IDENTITY are supported. If set to NULL or if the activation mode is set to CUDNN_ACTIVATION_IDENTITY, then the activation in the op sequence becomes a NOP.	NULL
X_CONV_DESC	In the setter, the *param should be a pointer to a previously initialized cudnnConvolutionDescriptor_t*.	Describes the convolution operation.	NULL
X_WDESC	In the setter, the *param should be a pointer to a previously initialized cudnnFilterDescriptor_t*.	Filter descriptor describing the size, layout and datatype of the w (filter) tensor.	NULL
X_WDATA_PLACEHOLDER	In the setter, the *param should be a pointer to a previously initialized X_PointerPlaceHolder_t*.	Describes whether w (filter) tensor pointer in the VariantParamPack will be NULL, or if not, user promised pointer alignment *.	CUDNN_PTR_NULL

For the attribute `CUDNN_FUSED_SCALE_BIAS_ACTIVATION_CONV_BNSTATS` in `cudnnFusedOp_t`			
Attribute	**Expected Descriptor Type Passed in, in the Setter**	**Description**	**Default Value After Creation**
`X_YDESC`	In the setter, the `*param` should be a pointer to a previously initialized cudnnTensorDescriptor_t*.	Tensor descriptor describing the size, layout and datatype of the `y` (output) tensor.	`NULL`
`X_YDATA_PLACEHOLDER`	In the setter, the `*param` should be a pointer to a previously initialized `X_PointerPlaceHolder_t*`.	Describes whether `y` (output) tensor pointer in the `VariantParamPack` will be `NULL`, or if not, user promised pointer alignment `*`.	`CUDNN_PTR_NULL`
`X_YSTATS_DESC`	In the setter, the `*param` should be a pointer to a previously initialized `cudnnTensorDescriptor_t*`.	Tensor descriptor describing the size, layout and datatype of the sum of `y` and sum of `y` square tensors. The shapes need to match the mode specified in `CUDNN_PARAM_BN_MODE`. If set to `NULL`, the `y` statistics generation operation will be become a NOP.	`NULL`
`X_YSUM_PLACEHOLDER`	In the setter, the `*param` should be a pointer to a previously initialized `X_PointerPlaceHolder_t*`.	Describes whether sum of `y` pointer in the `VariantParamPack` will be `NULL`, or if not, user promised pointer alignment `*`. If set to `CUDNN_PTR_NULL`, the `y` statistics generation operation will be become a NOP.	`CUDNN_PTR_NULL`
`X_YSQSUM_PLACEHOLDER`	In the setter, the `*param` should be a pointer to a previously initialized `X_PointerPlaceHolder_t*`.	Describes whether sum of `y` square pointer in the `VariantParamPack` will be `NULL`, or if not, user promised pointer alignment `*`. If set to `CUDNN_PTR_NULL`, the `y` statistics generation	`CUDNN_PTR_NULL`

For the attribute CUDNN_FUSED_SCALE_BIAS_ACTIVATION_CONV_BNSTATS in cudnnFusedOp_t			
Attribute	**Expected Descriptor Type Passed in, in the Setter**	**Description**	**Default Value After Creation**
		operation will be become a NOP.	

- If the corresponding pointer placeholder in ConstParamPack is set to `CUDNN_PTR_NULL`, then the device pointer in the `VariantParamPack` need to be `NULL` as well.
- If the corresponding pointer placeholder in `ConstParamPack` is set to `CUDNN_PTR_ELEM_ALIGNED` or `CUDNN_PTR_16B_ALIGNED`, then the device pointer in the `VariantParamPack` may not be `NULL` and need to be at least element-aligned or 16 bytes-aligned, respectively.

As of cuDNN 7.6.0, if the conditions in Table 2 are met, then the fully fused fast path will be triggered. Otherwise, a slower partially fused path will be triggered.

Table 2 Conditions for Fully Fused Fast Path (Forward)

Parameter	Condition
Device compute capability	Need to be one of `7.0`, `7.2` or `7.5`.
`CUDNN_PARAM_XDESC` `CUDNN_PARAM_XDATA_PLACEHOLDER`	Tensor is 4 dimensional Datatype is `CUDNN_DATA_HALF` Layout is `NHWC` fully packed Alignment is `CUDNN_PTR_16B_ALIGNED` Tensor's `C` dimension is a multiple of 8.

`CUDNN_PARAM_BN_EQSCALEBIAS_DESC`
`CUDNN_PARAM_BN_EQSCALE_PLACEHOLDER`
`CUDNN_PARAM_BN_EQBIAS_PLACEHOLDER`
	If either one of scale and bias operation is not turned into a NOP:
	Tensor is 4 dimensional with shape 1xCx1x1
	Datatype is `CUDNN_DATA_HALF`
	Layout is fully packed
	Alignment is `CUDNN_PTR_16B_ALIGNED`

`CUDNN_PARAM_CONV_DESC`
`CUDNN_PARAM_WDESC`
`CUDNN_PARAM_WDATA_PLACEHOLDER`
	Convolution descriptor's mode needs to be `CUDNN_CROSS_CORRELATION`.
	Convolution descriptor's `dataType` needs to be `CUDNN_DATA_FLOAT`.
	Convolution descriptor's `dilationA` is (1,1).
	Convolution descriptor's group count needs to be `1`.
	Convolution descriptor's `mathType` needs to be `CUDNN_TENSOR_OP_MATH` or `CUDNN_TENSOR_OP_MATH_ALLOW_CONVERSION`.
	Filter is in `NHWC` layout

Parameter	Condition
	Filter's data type is **CUDNN_DATA_HALF** Filter's K dimension is a multiple of 32 Filter size RxS is either 1x1 or 3x3 If filter size RxS is 1x1, convolution descriptor's **padA** needs to be (0,0) and **filterStrideA** needs to be (1,1). Filter's alignment is **CUDNN_PTR_16B_ALIGNED**
CUDNN_PARAM_YDESC **CUDNN_PARAM_YDATA_PLACEHOLDER**	Tensor is 4 dimensional Datatype is **CUDNN_DATA_HALF** Layout is **NHWC** fully packed Alignment is **CUDNN_PTR_16B_ALIGNED**
CUDNN_PARAM_YSTATS_DESC **CUDNN_PARAM_YSUM_PLACEHOLDER** **CUDNN_PARAM_YSQSUM_PLACEHOLDER**	If the generate statistics operation is not turned into a NOP: Tensor is 4 dimensional with shape 1xKx1x1 Datatype is **CUDNN_DATA_FLOAT** Layout is fully packed Alignment is **CUDNN_PTR_16B_ALIGNED**

Table 3 CUDNN_FUSED_SCALE_BIAS_ACTIVATION_WGRAD

For the attribute **CUDNN_FUSED_SCALE_BIAS_ACTIVATION_WGRAD** in **cudnnFusedOp_t**			
Attribute	**Expected Descriptor Type Passed in, in the Setter**	**Description**	**Default Value After Creation**
X_XDESC	In the setter, the ***param** should be **xDesc**, a pointer to a previously initialized **cudnnTensorDescriptor_t**.	Tensor descriptor describing the size, layout and datatype of the **x** (input) tensor	**NULL**
X_XDATA_PLACEHOLDER	In the setter, the ***param** should be a pointer to a previously initialized **X_PointerPlaceHolder_t***.	Describes whether **xData** pointer in the **VariantParamPack** will be **NULL**, or if not, user promised pointer alignment *****.	**CUDNN_PTR_NULL**
X_BN_MODE	In the setter, the ***param** should be a pointer to a previously initialized cudnnBatchNormMode_t*.	Describes the mode of operation for the scale, bias and the statistics. As of cuDNN 7.6.0, only **CUDNN_BATCHNORM_SPATIAL** and **CUDNN_BATCHNORM_SPATIAL_PERSISTENT** are supported,	**CUDNN_BATCHNORM_PER_ACTIVATION**

For the attribute CUDNN_FUSED_SCALE_BIAS_ACTIVATION_WGRAD in cudnnFusedOp_t			
Attribute	**Expected Descriptor Type Passed in, in the Setter**	**Description**	**Default Value After Creation**
		meaning, scale, bias, and statistics are all per-channel.	
`X_BN_EQSCALEBIAS_DESC`	In the setter, the `*param` should be a pointer to a previously initialized cudnnTensorDescriptor_t	Tensor descriptor describing the size, layout and datatype of the batchNorm equivalent scale and bias tensors. The shapes must match the mode specified in `CUDNN_PARAM_BN_MODE`. If set to `NULL`, both scale and bias operation will become a NOP.	`NULL`
`X_BN_EQSCALE_PLACEHOLDER`	In the setter, the `*param` should be a pointer to a previously initialized `X_PointerPlaceHolder_t*`	Describes whether batchnorm equivalent scale pointer in the `VariantParamPack` will be `NULL`, or if not, user promised pointer alignment `*`. If set to `CUDNN_PTR_NULL`, then the scale operation becomes a NOP.	`CUDNN_PTR_NULL`
`X_BN_EQBIAS_PLACEHOLDER`	In the setter, the `*param` should be a pointer to a previously initialized `X_PointerPlaceHolder_t*`	Describes whether batchnorm equivalent bias pointer in the `VariantParamPack` will be `NULL`, or if not, user promised pointer alignment `*`. If set to `CUDNN_PTR_NULL`, then the bias operation becomes a NOP.	`CUDNN_PTR_NULL`
`X_ACTIVATION_DESC`	In the setter, the `*param` should be a pointer to a previously initialized cudnnActivationDescriptor_t*	Describes the activation operation. As of 7.6.0, only activation mode of `CUDNN_ACTIVATION_RELU` and `CUDNN_ACTIVATION_IDENTITY` is supported. If set to `NULL` or	`NULL`

For the attribute CUDNN_FUSED_SCALE_BIAS_ACTIVATION_WGRAD in cudnnFusedOp_t			
Attribute	**Expected Descriptor Type Passed in, in the Setter**	**Description**	**Default Value After Creation**
		if the activation mode is set to **CUDNN_ACTIVATION_IDENTITY**, then the activation in the op sequence becomes a NOP.	
X_CONV_DESC	In the setter, the ***param** should be a pointer to a previously initialized cudnnConvolutionDescriptor_t*.	Describes the convolution operation.	**NULL**
X_DWDESC	In the setter, the ***param** should be a pointer to a previously initialized cudnnFilterDescriptor_t*.	Filter descriptor describing the size, layout and datatype of the **dw** (filter gradient output) tensor.	**NULL**
X_DWDATA_PLACEHOLDER	In the setter, the ***param** should be a pointer to a previously initialized **X_PointerPlaceHolder_t***.	Describes whether **dw** (filter gradient output) tensor pointer in the **VariantParamPack** will be **NULL**, or if not, user promised pointer alignment *.	**CUDNN_PTR_NULL**
X_DYDESC	In the setter, the ***param** should be a pointer to a previously initialized cudnnTensorDescriptor_t*.	Tensor descriptor describing the size, layout and datatype of the **dy** (gradient input) tensor.	**NULL**
X_DYDATA_PLACEHOLDER	In the setter, the ***param** should be a pointer to a previously initialized **X_PointerPlaceHolder_t***.	Describes whether **dy** (gradient input) tensor pointer in the **VariantParamPack** will be **NULL**, or if not, user promised pointer alignment *.	**CUDNN_PTR_NULL**

- If the corresponding pointer placeholder in **ConstParamPack** is set to **CUDNN_PTR_NULL**, then the device pointer in the **VariantParamPack** needs to be **NULL** as well.
- If the corresponding pointer placeholder in **ConstParamPack** is set to **CUDNN_PTR_ELEM_ALIGNED** or **CUDNN_PTR_16B_ALIGNED**, then the device pointer in the **VariantParamPack** may not be **NULL** and needs to be at least element-aligned or 16 bytes-aligned, respectively.

As of cuDNN 7.6.0, if the conditions in Table 4 are met, then the fully fused fast path will be triggered. Otherwise a slower partially fused path will be triggered.

Table 4 Conditions for Fully Fused Fast Path (Backward)

Parameter	Condition
Device compute capability	Needs to be one of `7.0`, `7.2` or `7.5`.
`CUDNN_PARAM_XDESC` `CUDNN_PARAM_XDATA_PLACEHOLDER`	Tensor is 4 dimensional Datatype is `CUDNN_DATA_HALF` Layout is `NHWC` fully packed Alignment is `CUDNN_PTR_16B_ALIGNED` Tensor's `C` dimension is a multiple of 8.

`CUDNN_PARAM_BN_EQSCALEBIAS_DESC`
`CUDNN_PARAM_BN_EQSCALE_PLACEHOLDER`
`CUDNN_PARAM_BN_EQBIAS_PLACEHOLDER`
	If either one of scale and bias operation is not turned into a NOP:
	Tensor is 4 dimensional with shape 1xCx1x1
	Datatype is `CUDNN_DATA_HALF`
	Layout is fully packed
	Alignment is `CUDNN_PTR_16B_ALIGNED`

`CUDNN_PARAM_CONV_DESC`
`CUDNN_PARAM_DWDESC`
`CUDNN_PARAM_DWDATA_PLACEHOLDER`
	Convolution descriptor's mode needs to be `CUDNN_CROSS_CORRELATION`.
	Convolution descriptor's dataType needs to be `CUDNN_DATA_FLOAT`.
	Convolution descriptor's `dilationA` is (1,1)
	Convolution descriptor's group count needs to be `1`.
	Convolution descriptor's `mathType` needs to be `CUDNN_TENSOR_OP_MATH` or `CUDNN_TENSOR_OP_MATH_ALLOW_CONVERSION`.
	Filter gradient is in `NHWC` layout
	Filter gradient's data type is `CUDNN_DATA_HALF`
	Filter gradient's `K` dimension is a multiple of 32.
	Filter gradient size RxS is either 1x1 or 3x3
	If filter gradient size RxS is 1x1, convolution descriptor's `padA` needs to be (0,0) and `filterStrideA` needs to be (1,1).
	Filter gradient's alignment is `CUDNN_PTR_16B_ALIGNED`

`CUDNN_PARAM_DYDESC` `CUDNN_PARAM_DYDATA_PLACEHOLDER`	Tensor is 4 dimensional Datatype is `CUDNN_DATA_HALF` Layout is `NHWC` fully packed Alignment is `CUDNN_PTR_16B_ALIGNED`

Table 5 CUDNN_FUSED_BN_FINALIZE_STATISTICS_TRAINING

For the attribute CUDNN_FUSED_BN_FINALIZE_STATISTICS_TRAINING in cudnnFusedOp_t			
Attribute	**Expected Descriptor Type Passed in, in the Setter**	**Description**	**Default Value After Creation**
X_BN_MODE	In the setter, the *param should be a pointer to a previously initialized cudnnBatchNormMode_t*.	Describes the mode of operation for the scale, bias and the statistics. As of cuDNN 7.6.0, only CUDNN_BATCHNORM_SPATIAL and CUDNN_BATCHNORM_SPATIAL_PERSISTENT are supported, meaning, scale, bias and statistics are all per-channel.	CUDNN_BATCHNORM_PER_ACTIVATION
X_YSTATS_DESC	In the setter, the *param should be a pointer to a previously initialized cudnnTensorDescriptor_t.	Tensor descriptor describing the size, layout and datatype of the sum of y and sum of y square tensors. The shapes need to match the mode specified in CUDNN_PARAM_BN_MODE.	NULL
X_YSUM_PLACEHOLDER	In the setter, the *param should be a pointer to a previously initialized X_PointerPlaceHolder_t*.	Describes whether sum of y pointer in the VariantParamPack will be NULL, or if not, user promised pointer alignment *.	CUDNN_PTR_NULL
X_YSQSUM_PLACEHOLDER	In the setter, the *param should be a pointer to a previously initialized X_PointerPlaceHolder_t*.	Describes whether sum of y square pointer in the VariantParamPack will be NULL, or if not, user promised pointer alignment *.	CUDNN_PTR_NULL
X_BN_SCALEBIAS_MEANVAR_DESC	In the setter, the *param should be a pointer to a previously initialized cudnnTensorDescriptor_t.	A common tensor descriptor describing the size, layout and datatype of the batchNorm trained scale, bias and statistics tensors. The shapes need to match the mode specified in CUDNN_PARAM_BN_MODE (similar to the bnScaleBiasMeanVarDesc	NULL

For the attribute CUDNN_FUSED_BN_FINALIZE_STATISTICS_TRAINING in cudnnFusedOp_t			
Attribute	**Expected Descriptor Type Passed in, in the Setter**	**Description**	**Default Value After Creation**
		field in the **cudnnBatchNormalization*** API).	
X_BN_SCALE_PLACEHOLDER	In the setter, the ***param** should be a pointer to a previously initialized **X_PointerPlaceHolder_t***.	Describes whether the batchNorm trained scale pointer in the **VariantParamPack** will be **NULL**, or if not, user promised pointer alignment *. If the output of **BN_EQSCALE** is not needed, then this is not needed and may be **NULL**.	**CUDNN_PTR_NULL**
X_BN_BIAS_PLACEHOLDER	In the setter, the ***param** should be a pointer to a previously initialized **X_PointerPlaceHolder_t***.	Describes whether the batchNorm trained bias pointer in the **VariantParamPack** will be **NULL**, or if not, user promised pointer alignment *. If neither output of **BN_EQSCALE** or **BN_EQBIAS** is needed, then this is not needed and may be **NULL**.	**CUDNN_PTR_NULL**
X_BN_SAVED_MEAN_PLACEHOLDER	In the setter, the ***param** should be a pointer to a previously initialized **X_PointerPlaceHolder_t***.	Describes whether the batchNorm saved mean pointer in the **VariantParamPack** will be **NULL**, or if not, user promised pointer alignment *. If set to **CUDNN_PTR_NULL**, then the computation for this output becomes a NOP.	**CUDNN_PTR_NULL**
X_BN_SAVED_INVSTD_PLACEHOLDER	In the setter, the ***param** should be a pointer to a previously initialized **X_PointerPlaceHolder_t***.	Describes whether the batchNorm saved inverse standard deviation pointer in the **VariantParamPack** will be **NULL**, or if not, user promised pointer alignment *.	**CUDNN_PTR_NULL**

For the attribute CUDNN_FUSED_BN_FINALIZE_STATISTICS_TRAINING in cudnnFusedOp_t			
Attribute	**Expected Descriptor Type Passed in, in the Setter**	**Description**	**Default Value After Creation**
		If set to **CUDNN_PTR_NULL**, then the computation for this output becomes a NOP.	
X_BN_RUNNING_MEAN_PLACEHOLDER	In the setter, the ***param** should be a pointer to a previously initialized **X_PointerPlaceHolder_t***	Describes whether the batchNorm running mean pointer in the **VariantParamPack** will be **NULL**, or if not, user promised pointer alignment *****. If set to **CUDNN_PTR_NULL**, then the computation for this output becomes a NOP.	**CUDNN_PTR_NULL**
X_BN_RUNNING_VAR_PLACEHOLDER	In the setter, the ***param** should be a pointer to a previously initialized **X_PointerPlaceHolder_t***	Describes whether the batchNorm running variance pointer in the **VariantParamPack** will be **NULL**, or if not, user promised pointer alignment *****. If set to **CUDNN_PTR_NULL**, then the computation for this output becomes a NOP.	**CUDNN_PTR_NULL**
X_BN_EQSCALEBIAS_DESC	In the setter, the ***param** should be a pointer to a previously initialized cudnnTensorDescriptor_t*	Tensor descriptor describing the size, layout and datatype of the batchNorm equivalent scale and bias tensors. The shapes need to match the mode specified in **CUDNN_PARAM_BN_MODE**. If neither output of **BN_EQSCALE** or **BN_EQBIAS** is needed, then this is not needed and may be **NULL**.	**NULL**
X_BN_EQSCALE_PLACEHOLDER	In the setter, the ***param** should be a pointer to a previously initialized **X_PointerPlaceHolder_t***	Describes whether batchnorm equivalent scale pointer in the **VariantParamPack** will be **NULL**, or if not,	**CUDNN_PTR_NULL**

For the attribute CUDNN_FUSED_BN_FINALIZE_STATISTICS_TRAINING in cudnnFusedOp_t			
Attribute	**Expected Descriptor Type Passed in, in the Setter**	**Description**	**Default Value After Creation**
		user promised pointer alignment *. If set to CUDNN_PTR_NULL, then the computation for this output becomes a NOP.	
X_BN_EQBIAS_PLACEHOLDER	In the setter, the *param should be a pointer to a previously initialized X_PointerPlaceHolder_t*.	Describes whether batchnorm equivalent bias pointer in the VariantParamPack will be NULL, or if not, user promised pointer alignment *. If set to CUDNN_PTR_NULL, then the computation for this output becomes a NOP.	CUDNN_PTR_NULL

Table 6 CUDNN_FUSED_BN_FINALIZE_STATISTICS_INFERENCE

For the attribute CUDNN_FUSED_BN_FINALIZE_STATISTICS_INFERENCE in cudnnFusedOp_t			
Attribute	**Expected Descriptor Type Passed in, in the Setter**	**Description**	**Default Value After Creation**
X_BN_MODE	In the setter, the *param should be a pointer to a previously initialized cudnnBatchNormMode_t*.	Describes the mode of operation for the scale, bias and the statistics. As of cuDNN 7.6.0, only CUDNN_BATCHNORM_SPATIAL and CUDNN_BATCHNORM_SPATIAL_PERSISTENT are supported, meaning, scale, bias and statistics are all per-channel.	CUDNN_BATCHNORM_PER_ACTIVATION
X_BN_SCALEBIAS_MEANVAR_DESC	In the setter, the *param should be a pointer to a previously initialized cudnnTensorDescriptor_t.	A common tensor descriptor describing the size, layout and datatype of the batchNorm trained scale, bias and	NULL

For the attribute `CUDNN_FUSED_BN_FINALIZE_STATISTICS_INFERENCE` in `cudnnFusedOp_t`			
Attribute	**Expected Descriptor Type Passed in, in the Setter**	**Description**	**Default Value After Creation**
		statistics tensors. The shapes need to match the mode specified in `CUDNN_PARAM_BN_MODE` (similar to the `bnScaleBiasMeanVarDesc` field in the `cudnnBatchNormalization*` API).	
`X_BN_SCALE_PLACEHOLDER`	In the setter, the `*param` should be a pointer to a previously initialized `X_PointerPlaceHolder_t*`.	Describes whether the batchNorm trained scale pointer in the `VariantParamPack` will be `NULL`, or if not, user promised pointer alignment `*`.	`CUDNN_PTR_NULL`
`X_BN_BIAS_PLACEHOLDER`	In the setter, the `*param` should be a pointer to a previously initialized `X_PointerPlaceHolder_t*`.	Describes whether the batchNorm trained bias pointer in the `VariantParamPack` will be `NULL`, or if not, user promised pointer alignment `*`.	`CUDNN_PTR_NULL`
`X_BN_RUNNING_MEAN_PLACEHOLDER`	In the setter, the `*param` should be a pointer to a previously initialized `X_PointerPlaceHolder_t*`.	Describes whether the batchNorm running mean pointer in the `VariantParamPack` will be `NULL`, or if not, user promised pointer alignment `*`.	`CUDNN_PTR_NULL`
`X_BN_RUNNING_VAR_PLACEHOLDER`	In the setter, the `*param` should be a pointer to a previously initialized `X_PointerPlaceHolder_t*`.	Describes whether the batchNorm running variance pointer in the `VariantParamPack` will be `NULL`, or if not, user promised pointer alignment `*`.	`CUDNN_PTR_NULL`
`X_BN_EQSCALEBIAS_DESC`	In the setter, the `*param` should be a pointer to a previously initialized cudnnTensorDescriptor_t*.	Tensor descriptor describing the size, layout and datatype of the batchNorm equivalent scale and bias tensors. The shapes need to match the mode specified in `CUDNN_PARAM_BN_MODE`.	`NULL`
`X_BN_EQSCALE_PLACEHOLDER`	In the setter, the `*param` should	Describes whether batchnorm equivalent	`CUDNN_PTR_NULL`

For the attribute `CUDNN_FUSED_BN_FINALIZE_STATISTICS_INFERENCE` in `cudnnFusedOp_t`			
Attribute	**Expected Descriptor Type Passed in, in the Setter**	**Description**	**Default Value After Creation**
	be a pointer to a previously initialized `X_PointerPlaceHolder_t*`.	scale pointer in the `VariantParamPack` will be `NULL`, or if not, user promised pointer alignment `*`. If set to `CUDNN_PTR_NULL`, then the computation for this output becomes a NOP.	
`X_BN_EQBIAS_PLACEHOLDER`	In the setter, the `*param` should be a pointer to a previously initialized `X_PointerPlaceHolder_t*`.	Describes whether batchnorm equivalent bias pointer in the `VariantParamPack` will be `NULL`, or if not, user promised pointer alignment `*`. If set to `CUDNN_PTR_NULL`, then the computation for this output becomes a NOP.	`CUDNN_PTR_NULL`

2.29. cudnnFusedOpsConstParamPack_t

`cudnnFusedOpsConstParamPack_t` is a pointer to an opaque structure holding the description of the **`cudnnFusedOps`** constant parameters. Use the function cudnnCreateFusedOpsConstParamPack() to create one instance of this structure, and the function cudnnDestroyFusedOpsConstParamPack() to destroy a previously-created descriptor.

2.30. cudnnFusedOpsPlan_t

`cudnnFusedOpsPlan_t` is a pointer to an opaque structure holding the description of the **`cudnnFusedOpsPlan`**. This descriptor contains the plan information, including the problem type and size, which kernels should be run, and the internal workspace partition. Use the function cudnnCreateFusedOpsPlan() to create one instance of this structure, and the function cudnnDestroyFusedOpsPlan() to destroy a previously-created descriptor.

2.31. cudnnFusedOpsPointerPlaceHolder_t

`cudnnFusedOpsPointerPlaceHolder_t` is an enumerated type used to select the alignment type of the **cudnnFusedOps** descriptor pointer.

Member	Description
CUDNN_PTR_NULL = 0	Indicates that the pointer to the tensor in the **variantPack** will be **NULL**.
CUDNN_PTR_ELEM_ALIGNED = 1	Indicates that the pointer to the tensor in the **variantPack** will not be **NULL**, and will have element alignment.
CUDNN_PTR_16B_ALIGNED = 2	Indicates that the pointer to the tensor in the **variantPack** will not be **NULL**, and will have 16 byte alignment.

2.32. cudnnFusedOpsVariantParamLabel_t

The **cudnnFusedOpsVariantParamLabel_t** is an enumerated type that is used to set the buffer pointers. These buffer pointers can be changed in each iteration.

```
typedef enum {
 CUDNN_PTR_XDATA                              = 0,
 CUDNN_PTR_BN_EQSCALE                         = 1,
 CUDNN_PTR_BN_EQBIAS                          = 2,
 CUDNN_PTR_WDATA                              = 3,
 CUDNN_PTR_DWDATA                             = 4,
 CUDNN_PTR_YDATA                              = 5,
 CUDNN_PTR_DYDATA                             = 6,
 CUDNN_PTR_YSUM                               = 7,
 CUDNN_PTR_YSQSUM                             = 8,
 CUDNN_PTR_WORKSPACE                          = 9,
 CUDNN_PTR_BN_SCALE                           = 10,
 CUDNN_PTR_BN_BIAS                            = 11,
 CUDNN_PTR_BN_SAVED_MEAN                      = 12,
 CUDNN_PTR_BN_SAVED_INVSTD                    = 13,
 CUDNN_PTR_BN_RUNNING_MEAN                    = 14,
 CUDNN_PTR_BN_RUNNING_VAR                     = 15,
 CUDNN_PTR_ZDATA                              = 16,
 CUDNN_PTR_BN_Z_EQSCALE                       = 17,
 CUDNN_PTR_BN_Z_EQBIAS                        = 18,
 CUDNN_PTR_ACTIVATION_BITMASK                 = 19,
 CUDNN_PTR_DXDATA                             = 20,
 CUDNN_PTR_DZDATA                             = 21,
 CUDNN_PTR_BN_DSCALE                          = 22,
 CUDNN_PTR_BN_DBIAS                           = 23,
 CUDNN_SCALAR_SIZE_T_WORKSPACE_SIZE_IN_BYTES  = 100,
 CUDNN_SCALAR_INT64_T_BN_ACCUMULATION_COUNT   = 101,
 CUDNN_SCALAR_DOUBLE_BN_EXP_AVG_FACTOR        = 102,
 CUDNN_SCALAR_DOUBLE_BN_EPSILON               = 103,
 } cudnnFusedOpsVariantParamLabel_t;
```

Table 7 Legend For Tables in This Section

Short-form used	Stands for
Setter	cudnnSetFusedOpsVariantParamPackAttribute()
Getter	cudnnGetFusedOpsVariantParamPackAttribute()
`x_` prefix in the **Attribute key** column	Stands for `CUDNN_PTR_` or `CUDNN_SCALAR_` in the enumerator name.

Table 8 `CUDNN_FUSED_SCALE_BIAS_ACTIVATION_CONV_BNSTATS`

For the attribute `CUDNN_FUSED_SCALE_BIAS_ACTIVATION_CONV_BNSTATS` in `cudnnFusedOp_t`

Attribute key	Expected Descriptor Type Passed in, in the Setter	I/O Type	Description	Default Value
`X_XDATA`	`void *`	input	Pointer to `x` (input) tensor on device, need to agree with previously set `CUDNN_PARAM_XDATA_PLACEHOLDER` attribute *.	`NULL`
`X_BN_EQSCALE`	`void *`	input	Pointer to batchnorm equivalent scale tensor on device, need to agree with previously set `CUDNN_PARAM_BN_EQSCALE_PLACEHOLDER` attribute *.	`NULL`
`X_BN_EQBIAS`	`void *`	input	Pointer to batchnorm equivalent bias tensor on device, need to agree with previously set `CUDNN_PARAM_BN_EQBIAS_PLACEHOLDER` attribute *.	`NULL`
`X_WDATA`	`void *`	input	Pointer to `w` (filter) tensor on device, need to agree with previously set `CUDNN_PARAM_WDATA_PLACEHOLDER` attribute *.	`NULL`
`X_YDATA`	`void *`	output	Pointer to `y` (output) tensor on device, need to agree with previously set `CUDNN_PARAM_YDATA_PLACEHOLDER` attribute *.	`NULL`
`X_YSUM`	`void *`	output	Pointer to sum of `y` tensor on device, need to agree with previously set `CUDNN_PARAM_YSUM_PLACEHOLDER` attribute *.	`NULL`
`X_YSQSUM`	`void *`	output	Pointer to sum of `y` square tensor on device, need to	`NULL`

For the attribute **CUDNN_FUSED_SCALE_BIAS_ACTIVATION_CONV_BNSTATS** in **cudnnFusedOp_t**				
Attribute key	**Expected Descriptor Type Passed in, in the Setter**	**I/O Type**	**Description**	**Default Value**
			agree with previously set **CUDNN_PARAM_YSQSUM_PLACEHOLDER** attribute *.	
X_WORKSPACE	**void ***	input	Pointer to user allocated workspace on device. Can be **NULL** if the workspace size requested is 0.	**NULL**
X_SIZE_T_WORKSPACE_SIZE_IN_BYTES	**size_t ***	input	Pointer to a **size_t** value in host memory describing the user allocated workspace size in bytes. The amount needs to be equal or larger than the amount requested in **cudnnMakeFusedOpsPlan**.	0

- If the corresponding pointer placeholder in **ConstParamPack** is set to **CUDNN_PTR_NULL**, then the device pointer in the **VariantParamPack** needs to be **NULL** as well
- If the corresponding pointer placeholder in **ConstParamPack** is set to **CUDNN_PTR_ELEM_ALIGNED** or **CUDNN_PTR_16B_ALIGNED**, then the device pointer in the **VariantParamPack** may not be **NULL** and needs to be at least element-aligned or 16 bytes-aligned, respectively.

Table 9 **CUDNN_FUSED_SCALE_BIAS_ACTIVATION_WGRAD**

For the attribute **CUDNN_FUSED_SCALE_BIAS_ACTIVATION_WGRAD** in **cudnnFusedOp_t**				
Attribute key	**Expected Descriptor Type Passed in, in the Setter**	**I/O Type**	**Description**	**Default Value**
X_XDATA	**void ***	input	Pointer to **x** (input) tensor on device, need to agree with previously set **CUDNN_PARAM_XDATA_PLACEHOLDER** attribute *.	**NULL**
X_BN_EQSCALE	**void ***	input	Pointer to batchnorm equivalent scale tensor on device, need to agree with previously set	**NULL**

For the attribute `CUDNN_FUSED_SCALE_BIAS_ACTIVATION_WGRAD` in `cudnnFusedOp_t`				
Attribute key	**Expected Descriptor Type Passed in, in the Setter**	**I/O Type**	**Description**	**Default Value**
			`CUDNN_PARAM_BN_EQSCALE_PLACEHOLDER` attribute `*`.	
`X_BN_EQBIAS`	`void *`	input	Pointer to batchnorm equivalent bias tensor on device, need to agree with previously set `CUDNN_PARAM_BN_EQBIAS_PLACEHOLDER` attribute `*`.	`NULL`
`X_DWDATA`	`void *`	output	Pointer to `dw` (filter gradient output) tensor on device, need to agree with previously set `CUDNN_PARAM_WDATA_PLACEHOLDER` attribute `*`.	`NULL`
`X_DYDATA`	`void *`	input	Pointer to `dy` (gradient input) tensor on device, need to agree with previously set `CUDNN_PARAM_YDATA_PLACEHOLDER` attribute `*`.	`NULL`
`X_WORKSPACE`	`void *`	input	Pointer to user allocated workspace on device. Can be `NULL` if the workspace size requested is `0`.	`NULL`
`X_SIZE_T_WORKSPACE_SIZE_IN_BYTES`	`size_t *`	input	Pointer to a `size_t` value in host memory describing the user allocated workspace size in bytes. The amount needs to be equal or larger than the amount requested in `cudnnMakeFusedOpsPlan`.	`0`

- If the corresponding pointer placeholder in `ConstParamPack` is set to `CUDNN_PTR_NULL`, then the device pointer in the `VariantParamPack` needs to be `NULL` as well.
- If the corresponding pointer placeholder in `ConstParamPack` is set to `CUDNN_PTR_ELEM_ALIGNED` or `CUDNN_PTR_16B_ALIGNED`, then the device pointer in the `VariantParamPack` may not be `NULL` and needs to be at least element-aligned or 16 bytes-aligned, respectively.

Table 10 CUDNN_FUSED_BN_FINALIZE_STATISTICS_TRAINING

For the attribute CUDNN_FUSED_BN_FINALIZE_STATISTICS_TRAINING in cudnnFusedOp_t				
Attribute key	Expected Descriptor Type Passed in, in the Setter	I/O Type	Description	Default Value
X_YSUM	void *	input	Pointer to sum of y tensor on device, need to agree with previously set CUDNN_PARAM_YSUM_PLACEHOLDER attribute *.	NULL
X_YSQSUM	void *	input	Pointer to sum of y square tensor on device, need to agree with previously set CUDNN_PARAM_YSQSUM_PLACEHOLDER attribute *.	NULL
X_BN_SCALE	void *	input	Pointer to sum of y square tensor on device, need to agree with previously set CUDNN_PARAM_BN_SCALE_PLACEHOLDER attribute *.	NULL
X_BN_BIAS	void *	input	Pointer to sum of y square tensor on device, need to agree with previously set CUDNN_PARAM_BN_BIAS_PLACEHOLDER attribute *.	NULL
X_BN_SAVED_MEAN	void *	output	Pointer to sum of y square tensor on device, need to agree with previously set CUDNN_PARAM_BN_SAVED_MEAN_PLACEHOLDER attribute *.	NULL
X_BN_SAVED_INVSTD	void *	output	Pointer to sum of y square tensor on device, need to agree with previously set CUDNN_PARAM_BN_SAVED_INVSTD_PLACEHOLDER attribute *.	NULL
X_BN_RUNNING_MEAN	void *	input/ output	Pointer to sum of y square tensor on device, need to agree with previously set CUDNN_PARAM_BN_RUNNING_MEAN_PLACEHOLDER attribute *.	NULL
X_BN_RUNNING_VAR	void *	input/ output	Pointer to sum of y square tensor on device, need to agree with previously set CUDNN_PARAM_BN_RUNNING_VAR_PLACEHOLDER attribute *.	NULL

For the attribute `CUDNN_FUSED_BN_FINALIZE_STATISTICS_TRAINING` in `cudnnFusedOp_t`				
Attribute key	**Expected Descriptor Type Passed in, in the Setter**	**I/O Type**	**Description**	**Default Value**
`X_BN_EQSCALE`	`void *`	output	Pointer to batchnorm equivalent scale tensor on device, need to agree with previously set `CUDNN_PARAM_BN_EQSCALE_PLACEHOLDER` attribute `*`.	`NULL`
`X_BN_EQBIAS`	`void *`	output	Pointer to batchnorm equivalent bias tensor on device, need to agree with previously set `CUDNN_PARAM_BN_EQBIAS_PLACEHOLDER` attribute `*`.	`NULL`
`X_INT64_T_BN_ACCUMULATION_COUNT`	`int64_t *`	input	Pointer to a scalar value in `int64_t` on host memory. This value should describe the number of tensor elements accumulated in the sum of `y` and sum of `y` square tensors. For example, in the single GPU use case, if the mode is `CUDNN_BATCHNORM_SPATIAL` or `CUDNN_BATCHNORM_SPATIAL_PERSISTENT`, the value should be equal to N*H*W of the tensor from which the statistics are calculated. In multi-GPU use case, if all-reduce has been performed on the sum of `y` and sum of `y` square tensors, this value should be the sum of the single GPU accumulation count on each of the GPUs.	`0`
`X_DOUBLE_BN_EXP_AVG_FACTOR`	`double *`	input	Pointer to a scalar value in double on host memory. Factor used in the moving average computation. See **`exponentialAverageFactor`** in **`cudnnBatchNormalization*`** APIs.	`0.0`
`X_DOUBLE_BN_EPSILON`	`double *`	input	Pointer to a scalar value in double on host memory. A conditioning constant used in the batch normalization formula. Its value should be equal to or greater than the value defined	`0.0`

For the attribute CUDNN_FUSED_BN_FINALIZE_STATISTICS_TRAINING in cudnnFusedOp_t				
Attribute key	**Expected Descriptor Type Passed in, in the Setter**	**I/O Type**	**Description**	**Default Value**
			for CUDNN_BN_MIN_EPSILON in cudnn.h. See exponentialAverageFactor in cudnnBatchNormalization* APIs.	
X_WORKSPACE	void *	input	Pointer to user allocated workspace on device. Can be NULL if the workspace size requested is 0.	NULL
X_SIZE_T_WORKSPACE_SIZE_IN_BYTES	size_t *	input	Pointer to a size_t value in host memory describing the user allocated workspace size in bytes. The amount need to be equal or larger than the amount requested in cudnnMakeFusedOpsPlan.	0

- If the corresponding pointer placeholder in ConstParamPack is set to CUDNN_PTR_NULL, then the device pointer in the VariantParamPack need to be NULL as well.
- If the corresponding pointer placeholder in ConstParamPack is set to CUDNN_PTR_ELEM_ALIGNED or CUDNN_PTR_16B_ALIGNED, then the device pointer in the VariantParamPack may not be NULL and needs to be at least element-aligned or 16 bytes-aligned, respectively.

Table 11 **CUDNN_FUSED_BN_FINALIZE_STATISTICS_INFERENCE**

For the attribute CUDNN_FUSED_BN_FINALIZE_STATISTICS_INFERENCE in cudnnFusedOp_t				
Attribute key	**Expected Descriptor Type Passed in, in the Setter**	**I/O Type**	**Description**	**Default Value**
X_BN_SCALE	void *	input	Pointer to sum of y square tensor on device, need to agree with previously set	NULL

For the attribute CUDNN_FUSED_BN_FINALIZE_STATISTICS_INFERENCE in cudnnFusedOp_t				
Attribute key	Expected Descriptor Type Passed in, in the Setter	I/O Type	Description	Default Value
			CUDNN_PARAM_BN_SCALE_PLACEHOLDER attribute *.	
X_BN_BIAS	void *	input	Pointer to sum of y square tensor on device, need to agree with previously set CUDNN_PARAM_BN_BIAS_PLACEHOLDER attribute *.	NULL
X_BN_RUNNING_MEAN	void *	input/ output	Pointer to sum of y square tensor on device, need to agree with previously set CUDNN_PARAM_BN_RUNNING_MEAN_PLACEHOLDER attribute *.	NULL
X_BN_RUNNING_VAR	void *	input/ output	Pointer to sum of y square tensor on device, need to agree with previously set CUDNN_PARAM_BN_RUNNING_VAR_PLACEHOLDER attribute *.	NULL
X_BN_EQSCALE	void *	output	Pointer to batchnorm equivalent scale tensor on device, need to agree with previously set CUDNN_PARAM_BN_EQSCALE_PLACEHOLDER attribute *.	NULL
X_BN_EQBIAS	void *	output	Pointer to batchnorm equivalent bias tensor on device, need to agree with previously set CUDNN_PARAM_BN_EQBIAS_PLACEHOLDER attribute *.	NULL
X_DOUBLE_BN_EPSILON	double *	input	Pointer to a scalar value in double on host memory. A conditioning constant used in the batch normalization formula. Its value should be equal to or greater than the value defined for CUDNN_BN_MIN_EPSILON in cudnn.h. See exponentialAverageFactor in cudnnBatchNormalization* APIs.	0.0
X_WORKSPACE	void *	input	Pointer to user allocated workspace on device. Can be	NULL

For the attribute `CUDNN_FUSED_BN_FINALIZE_STATISTICS_INFERENCE` in `cudnnFusedOp_t`				
Attribute key	**Expected Descriptor Type Passed in, in the Setter**	**I/O Type**	**Description**	**Default Value**
			`NULL` if the workspace size requested is `0`.	
`X_SIZE_T_WORKSPACE_SIZE_IN_BYTES`	`size_t *`	input	Pointer to a `size_t` value in host memory describing the user allocated workspace size in bytes. The amount need to be equal or larger than the amount requested in `cudnnMakeFusedOpsPlan`.	`0`

- If the corresponding pointer placeholder in `ConstParamPack` is set to `CUDNN_PTR_NULL`, then the device pointer in the `VariantParamPack` needs to be `NULL` as well.
- If the corresponding pointer placeholder in `ConstParamPack` is set to `CUDNN_PTR_ELEM_ALIGNED` or `CUDNN_PTR_16B_ALIGNED`, then the device pointer in the `VariantParamPack` may not be `NULL` and needs to be at least element-aligned or 16 bytes-aligned, respectively.

2.33. cudnnFusedOpsVariantParamPack_t

`cudnnFusedOpsVariantParamPack_t` is a pointer to an opaque structure holding the description of the `cudnnFusedOps` variant parameters. Use the function cudnnCreateFusedOpsVariantParamPack() to create one instance of this structure, and the function cudnnDestroyFusedOpsVariantParamPack() to destroy a previously-created descriptor.

2.34. 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.

2.35. cudnnIndicesType_t

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

Values

CUDNN_32BIT_INDICES

Compute unsigned int indices.

CUDNN_64BIT_INDICES

Compute unsigned long indices.

CUDNN_16BIT_INDICES

Compute unsigned short indices.

CUDNN_8BIT_INDICES

Compute unsigned char indices.

2.36. cudnnLossNormalizationMode_t

cudnnLossNormalizationMode_t is an enumerated type that controls the input normalization mode for a loss function. This type can be used with cudnnSetCTCLossDescriptorEx().

Values

CUDNN_LOSS_NORMALIZATION_NONE

The input **probs** of cudnnCTCLoss() function is expected to be the normalized probability, and the output **gradients** is the gradient of loss with respect to the unnormalized probability.

CUDNN_LOSS_NORMALIZATION_SOFTMAX

The input **probs** of cudnnCTCLoss() function is expected to be the unnormalized activation from the previous layer, and the output **gradients** is the gradient with respect to the activation. Internally the probability is computed by softmax normalization.

2.37. 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]**.

2.38. cudnnMathType_t

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

Values

CUDNN_DEFAULT_MATH

Tensor Core operations are not used.

CUDNN_TENSOR_OP_MATH

The use of Tensor Core operations is permitted.

CUDNN_TENSOR_OP_MATH_ALLOW_CONVERSION

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

2.39. cudnnMultiHeadAttnWeightKind_t

cudnnMultiHeadAttnWeightKind_t is an enumerated type that specifies a group of weights or biases in the cudnnGetMultiHeadAttnWeights() function.

Values

CUDNN_MH_ATTN_Q_WEIGHTS

Selects the input projection weights for **queries**.

CUDNN_MH_ATTN_K_WEIGHTS

Selects the input projection weights for **keys**.

CUDNN_MH_ATTN_V_WEIGHTS

Selects the input projection weights for **values**.

CUDNN_MH_ATTN_O_WEIGHTS

Selects the output projection weights.

CUDNN_MH_ATTN_Q_BIASES

Selects the input projection biases for **queries**.

CUDNN_MH_ATTN_K_BIASES

Selects the input projection biases for **keys**.

CUDNN_MH_ATTN_V_BIASES

Selects the input projection biases for **values**.

CUDNN_MH_ATTN_O_BIASES

Selects the output projection biases.

2.40. 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.

2.41. cudnnOpTensorDescriptor_t

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

2.42. 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.

2.43. 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.

2.44. 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.

2.45. cudnnPoolingMode_t

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

Values

CUDNN_POOLING_MAX

The maximum value inside the pooling window is used.

CUDNN_POOLING_AVERAGE_COUNT_INCLUDE_PADDING

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

CUDNN_POOLING_AVERAGE_COUNT_EXCLUDE_PADDING

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

CUDNN_POOLING_MAX_DETERMINISTIC

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

2.46. 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.

2.47. cudnnReduceTensorIndices_t

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

Values

CUDNN_REDUCE_TENSOR_NO_INDICES

Do not compute indices.

CUDNN_REDUCE_TENSOR_FLATTENED_INDICES

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

2.48. cudnnReduceTensorOp_t

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

Values

CUDNN_REDUCE_TENSOR_ADD

The operation to be performed is addition.

CUDNN_REDUCE_TENSOR_MUL

The operation to be performed is multiplication.

CUDNN_REDUCE_TENSOR_MIN

The operation to be performed is a minimum comparison.

CUDNN_REDUCE_TENSOR_MAX

The operation to be performed is a maximum comparison.

CUDNN_REDUCE_TENSOR_AMAX

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

CUDNN_REDUCE_TENSOR_AVG

The operation to be performed is averaging.

CUDNN_REDUCE_TENSOR_NORM1

The operation to be performed is addition of absolute values.

CUDNN_REDUCE_TENSOR_NORM2

The operation to be performed is a square root of sum of squares.

CUDNN_REDUCE_TENSOR_MUL_NO_ZEROS

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

2.49. cudnnReorderType_t

```
typedef enum {
 CUDNN_DEFAULT_REORDER = 0,
 CUDNN_NO_REORDER      = 1,
 } cudnnReorderType_t;
```

cudnnReorderType_t is an enumerated type to set the convolution reordering type. The reordering type can be set by cudnnSetConvolutionReorderType() and its status can be read by cudnnGetConvolutionReorderType().

2.50. cudnnRNNAlgo_t

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

Values

CUDNN_RNN_ALGO_STANDARD

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

CUDNN_RNN_ALGO_PERSIST_STATIC

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

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

CUDNN_RNN_ALGO_PERSIST_DYNAMIC

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

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

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

2.51. cudnnRNNBiasMode_t

cudnnRNNBiasMode_t is an enumerated type used to specify the number of bias vectors for RNN functions. See the description of the cudnnRNNMode_t enumerated type for the equations for each cell type based on the bias mode.

Values

CUDNN_RNN_NO_BIAS

Applies RNN cell formulas that do not use biases.

CUDNN_RNN_SINGLE_INP_BIAS

Applies RNN cell formulas that use one input bias vector in the input GEMM.

CUDNN_RNN_DOUBLE_BIAS

Applies RNN cell formulas that use two bias vectors.

CUDNN_RNN_SINGLE_REC_BIAS

Applies RNN cell formulas that use one recurrent bias vector in the recurrent GEMM.

2.52. cudnnRNNClipMode_t

cudnnRNNClipMode_t is an enumerated type used to select the LSTM cell clipping mode. It is used with cudnnRNNSetClip(), cudnnRNNGetClip() functions, and internally within LSTM cells.

Values

CUDNN_RNN_CLIP_NONE

Disables LSTM cell clipping.

CUDNN_RNN_CLIP_MINMAX

Enables LSTM cell clipping.

2.53. cudnnRNNDataDescriptor_t

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

2.54. cudnnRNNDataLayout_t

cudnnRNNDataLayout_t is an enumerated type used to select the RNN data layout. It is used used in the API calls cudnnGetRNNDataDescriptor() and cudnnSetRNNDataDescriptor().

Values

CUDNN_RNN_DATA_LAYOUT_SEQ_MAJOR_UNPACKED

Data layout is padded, with outer stride from one time-step to the next.

CUDNN_RNN_DATA_LAYOUT_SEQ_MAJOR_PACKED

The sequence length is sorted and packed as in basic RNN API.

CUDNN_RNN_DATA_LAYOUT_BATCH_MAJOR_UNPACKED

Data layout is padded, with outer stride from one batch to the next.

2.55. 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.

2.56. 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.

2.57. cudnnRNNMode_t

cudnnRNNMode_t is an enumerated type used to specify the type of network used in the cudnnRNNForwardInference, cudnnRNNForwardTraining, cudnnRNNBackwardData and cudnnRNNBackwardWeights routines.

Values

CUDNN_RNN_RELU

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

In the forward pass, the output h_t for a given iteration can be computed from the recurrent input h_{t-1} and the previous layer input x_t, given the matrices **W, R** and the bias vectors, where **ReLU(x) = max(x, 0)**.

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

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

If **cudnnRNNBiasMode_t biasMode** in **rnnDesc** is **CUDNN_RNN_SINGLE_INP_BIAS** or **CUDNN_RNN_SINGLE_REC_BIAS**, then the following equation with bias **b** applies:

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

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

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

CUDNN_RNN_TANH

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

In the forward pass, the output h_t for a given iteration can be computed from the recurrent input h_{t-1} and the previous layer input x_t, given the matrices **W, R** and the bias vectors, and where **tanh** is the hyperbolic tangent function.

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

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

If **cudnnRNNBiasMode_t biasMode** in **rnnDesc** is **CUDNN_RNN_SINGLE_INP_BIAS** or **CUDNN_RNN_SINGLE_REC_BIAS**, then the following equation with bias **b** applies:

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

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

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

CUDNN_LSTM

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

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

In addition, the following applies:

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

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

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

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

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

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

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

CUDNN_GRU

A three-gate network consisting of Gated Recurrent Units.

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

In addition, the following applies:

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

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

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

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

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

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

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

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

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

2.58. cudnnRNNPaddingMode_t

cudnnRNNPaddingMode_t is an enumerated type used to enable or disable the padded input/output.

Values

CUDNN_RNN_PADDED_IO_DISABLED

Disables the padded input/output.

CUDNN_RNN_PADDED_IO_ENABLED

Enables the padded input/output.

2.59. cudnnSamplerType_t

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

Values

CUDNN_SAMPLER_BILINEAR

Selects the bilinear sampler.

2.60. cudnnSeqDataAxis_t

cudnnSeqDataAxis_t is an enumerated type that indexes active dimensions in the **dimA[]** argument that is passed to the cudnnSetSeqDataDescriptor() function to configure the sequence data descriptor of type cudnnSeqDataDescriptor_t.

cudnnSeqDataAxis_t constants are also used in the **axis[]** argument of the cudnnSetSeqDataDescriptor() call to define the layout of the sequence data buffer in memory.

See cudnnSetSeqDataDescriptor() for a detailed description on how to use the **cudnnSeqDataAxis_t** enumerated type.

The **CUDNN_SEQDATA_DIM_COUNT** macro defines the number of constants in the **cudnnSeqDataAxis_t** enumerated type. This value is currently set to **4**.

Values

`CUDNN_SEQDATA_TIME_DIM`

Identifies the **`TIME`** (sequence length) dimension or specifies the **`TIME`** in the data layout.

`CUDNN_SEQDATA_BATCH_DIM`

Identifies the **`BATCH`** dimension or specifies the **`BATCH`** in the data layout.

`CUDNN_SEQDATA_BEAM_DIM`

Identifies the **`BEAM`** dimension or specifies the **`BEAM`** in the data layout.

`CUDNN_SEQDATA_VECT_DIM`

Identifies the **`VECT`** (vector) dimension or specifies the **`VECT`** in the data layout.

2.61. cudnnSeqDataDescriptor_t

`cudnnSeqDataDescriptor_t` is a pointer to an opaque structure holding parameters of the sequence data container or buffer. The sequence data container is used to store fixed size vectors defined by the **`VECT`** dimension. Vectors are arranged in additional three dimensions: **`TIME`**, **`BATCH`** and **`BEAM`**.

The **`TIME`** dimension is used to bundle vectors into sequences of vectors. The actual sequences can be shorter than the **`TIME`** dimension, therefore, additional information is needed about each sequence length and how unused (padding) vectors should be saved.

It is assumed that the sequence data container is fully packed. The **`TIME`**, **`BATCH`** and **`BEAM`** dimensions can be in any order when vectors are traversed in the ascending order of addresses. Six data layouts (permutation of **`TIME`**, **`BATCH`** and **`BEAM`**) are possible.

The **`cudnnSeqDataDescriptor_t`** object holds the following parameters:

- data type used by vectors
- **`TIME`**, **`BATCH`**, **`BEAM`** and **`VECT`** dimensions
- data layout
- the length of each sequence along the **`TIME`** dimension
- an optional value to be copied to output padding vectors

Use the cudnnCreateSeqDataDescriptor() function to create one instance of the sequence data descriptor object and cudnnDestroySeqDataDescriptor() to delete a previously created descriptor. Use the cudnnSetSeqDataDescriptor() function to configure the descriptor.

This descriptor is used by multi-head attention API functions.

2.62. cudnnSoftmaxAlgorithm_t

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

Values

CUDNN_SOFTMAX_FAST

This implementation applies the straightforward softmax operation.

CUDNN_SOFTMAX_ACCURATE

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

CUDNN_SOFTMAX_LOG

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

2.63. cudnnSoftmaxMode_t

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

Values

CUDNN_SOFTMAX_MODE_INSTANCE

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

CUDNN_SOFTMAX_MODE_CHANNEL

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

2.64. cudnnSpatialTransformerDescriptor_t

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

2.65. 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.

2.66. cudnnTensorDescriptor_t

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

2.67. cudnnTensorFormat_t

cudnnTensorFormat_t is an enumerated type used by cudnnSetTensor4dDescriptor() to create a tensor with a pre-defined layout. For a detailed explanation of how these tensors are arranged in memory, see the Data Layout Formats section in the *cuDNN Developer Guide*.

Values

CUDNN_TENSOR_NCHW

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

CUDNN_TENSOR_NHWC

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

CUDNN_TENSOR_NCHW_VECT_C

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

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

2.68. cudnnTensorTransformDescriptor_t

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

2.69. cudnnWgradMode_t

cudnnWgradMode_t is an enumerated type that selects how buffers holding gradients of the loss function, computed with respect to trainable parameters, are updated. Currently, this type is used by the cudnnGetMultiHeadAttnWeights() function only.

Values

CUDNN_WGRAD_MODE_ADD

A weight gradient component corresponding to a new batch of inputs is added to previously evaluated weight gradients. Before using this mode, the buffer holding weight gradients should be initialized to zero. Alternatively, the first API call outputting to an uninitialized buffer should use the **CUDNN_WGRAD_MODE_SET** option.

CUDNN_WGRAD_MODE_SET

A weight gradient component, corresponding to a new batch of inputs, overwrites previously stored weight gradients in the output buffer.

Chapter 3. CUDNN API REFERENCE

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

3.1. cudnnActivationBackward()

```
cudnnStatus_t cudnnActivationBackward(
    cudnnHandle_t                    handle,
    cudnnActivationDescriptor_t      activationDesc,
    const void                      *alpha,
    const cudnnTensorDescriptor_t    yDesc,
    const void                      *y,
    const cudnnTensorDescriptor_t    dyDesc,
    const void                      *dy,
    const cudnnTensorDescriptor_t    xDesc,
    const void                      *x,
    const void                      *beta,
    const cudnnTensorDescriptor_t    dxDesc,
    void                            *dx)
```

This routine computes the gradient of a neuron activation function.

- In-place operation is allowed for this routine; meaning **dy** and **dx** pointers may be equal. However, this requires the corresponding tensor descriptors to be identical (particularly, the strides of the input and output must match for an in-place operation to be allowed).
- All tensor formats are supported for 4 and 5 dimensions, however, the best performance is obtained when the strides of **yDesc** and **xDesc** are equal and **HW-packed**. For more than 5 dimensions the tensors must have their spatial dimensions packed.

Parameters

handle

Input. Handle to a previously created cuDNN context. For more information, see cudnnHandle_t.

activationDesc

Input. Activation descriptor. See cudnnActivationDescriptor_t.

alpha, beta

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

```
dstValue = alpha[0]*result + beta[0]*priorDstValue
```

For more information, see Scaling Parameters in the *cuDNN Developer Guide*.

yDesc

Input. Handle to the previously initialized input tensor descriptor. For more information, see cudnnTensorDescriptor_t.

y

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

dyDesc

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

dy

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

xDesc

Input. Handle to the previously initialized output tensor descriptor.

x

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

dxDesc

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

dx

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

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 tensor 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 tensor differ.
- The **datatype** of the input tensor and output tensor 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.

3.2. 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; meaning, **xData** and **yData** pointers may be equal. However, this requires **xDesc** and **yDesc** descriptors to be identical (particularly, the strides of the input and output must match for an in-place operation to be allowed).
- All tensor formats are supported for 4 and 5 dimensions, however, the best performance is obtained when the strides of **xDesc** and **yDesc** are equal and **HW-packed**. For more than 5 dimensions the tensors must have their spatial dimensions packed.

Parameters

handle

Input. Handle to a previously created cuDNN context. For more information, see cudnnHandle_t.

activationDesc

Input. Activation descriptor. For more information, see cudnnActivationDescriptor_t.

alpha, beta

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

```
dstValue = alpha[0]*result + beta[0]*priorDstValue
```

For more information, see Scaling Parameters in the *cuDNN Developer Guide*.

xDesc

Input. Handle to the previously initialized input tensor descriptor. For more information, see cudnnTensorDescriptor_t.

x

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

yDesc

Input. Handle to the previously initialized output tensor descriptor.

y

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

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

CUDNN_STATUS_EXECUTION_FAILED

The function failed to launch on the GPU.

3.3. 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. For more information, see cudnnHandle_t.

alpha, beta

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

```
dstValue = alpha[0]*srcValue + beta[0]*priorDstValue
```

For more information, see Scaling Parameters in the *cuDNN Developer Guide*.

aDesc

Input. Handle to a previously initialized tensor descriptor. For more information, see cudnnTensorDescriptor_t.

A

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

cDesc

Input. Handle to a previously initialized tensor descriptor.

C

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

Returns

CUDNN_STATUS_SUCCESS

The function executed successfully.

CUDNN_STATUS_NOT_SUPPORTED

The function does not support the provided configuration.

CUDNN_STATUS_BAD_PARAM

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

CUDNN_STATUS_EXECUTION_FAILED

The function failed to launch on the GPU.

3.4. cudnnBatchNormalizationBackward()

```
cudnnStatus_t cudnnBatchNormalizationBackward(
      cudnnHandle_t                    handle,
      cudnnBatchNormMode_t             mode,
      const void                      *alphaDataDiff,
      const void                      *betaDataDiff,
      const void                      *alphaParamDiff,
      const void                      *betaParamDiff,
      const cudnnTensorDescriptor_t    xDesc,
      const void                      *x,
      const cudnnTensorDescriptor_t    dyDesc,
      const void                      *dy,
      const cudnnTensorDescriptor_t    dxDesc,
      void                            *dx,
      const cudnnTensorDescriptor_t    bnScaleBiasDiffDesc,
      const void                      *bnScale,
      void                            *resultBnScaleDiff,
      void                            *resultBnBiasDiff,
      double                           epsilon,
      const void                      *savedMean,
      const void                      *savedInvVariance)
```

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

- Only 4D and 5D tensors are supported.
- The **epsilon** value has to be the same during training, backpropagation, and inference.
- Higher performance can be obtained when **HW-packed** tensors are used for all of **x, dy, dx**.

For more information, see **cudnnDeriveBNTensorDescriptor()** for the secondary tensor descriptor generation for the parameters used in this function.

Parameters

handle

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

mode

Input. Mode of operation (spatial or per-activation). For more information, see cudnnBatchNormMode_t.

***alphaDataDiff**, ***betaDataDiff**

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

```
dstValue = alphaDataDiff[0]*resultValue + betaDataDiff[0]*priorDstValue
```

For more information, see Scaling Parameters in the *cuDNN Developer Guide*.

***alphaParamDiff**, ***betaParamDiff**

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

```
dstValue = alphaParamDiff[0]*resultValue + betaParamDiff[0]*priorDstValue
```

For more information, see Scaling Parameters.

xDesc, dxDesc, dyDesc

Inputs. Handles to the previously initialized tensor descriptors.

***x**

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

***dy**

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

***dx**

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

bnScaleBiasDiffDesc

Input. Shared tensor descriptor for the following five tensors: **bnScale, resultBnScaleDiff, resultBnBiasDiff, savedMean, savedInvVariance**. The dimensions for this tensor descriptor are dependent on normalization mode. For more information, see cudnnDeriveBNTensorDescriptor().

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

`*bnScale`

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

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

`resultBnScaleDiff`, `resultBnBiasDiff`

Outputs. Pointers in device memory for the resulting scale and bias differentials computed by this routine. Note that these scale and bias gradients are weight gradients specific to this batch normalization operation, and by definition are not backpropagated.

`epsilon`

Input. Epsilon value used in batch normalization formula. Its value should be equal to or greater than the value defined for **`CUDNN_BN_MIN_EPSILON`** in **`cudnn.h`**. The same **`epsilon`** value should be used in forward and backward functions.

`*savedMean`, `*savedInvVariance`

Inputs. Optional cache parameters containing saved intermediate results that were computed during the forward pass. For this to work correctly, the layer's **`x`** and **`bnScale`** data have to remain unchanged until this backward function is called.

> Both these parameters can be **`NULL`** but only at the same time. It is recommended to use this cache since the memory overhead is relatively small.

Returns

`CUDNN_STATUS_SUCCESS`

The computation was performed successfully.

`CUDNN_STATUS_NOT_SUPPORTED`

The function does not support the provided configuration.

`CUDNN_STATUS_BAD_PARAM`

At least one of the following conditions are met:

- Any of the pointers **`alpha, beta, x, dy, dx, bnScale, resultBnScaleDiff, resultBnBiasDiff`** is **NULL**.
- The number of **`xDesc`** or **`yDesc`** or **`dxDesc`** tensor descriptor dimensions is not within the range of [4,5] (only 4D and 5D tensors are supported).
- **`bnScaleBiasDiffDesc`** dimensions are not 1xCx1x1 for 4D and 1xCx1x1x1 for 5D for spatial, and are not 1xCxHxW for 4D and 1xCxDxHxW for 5D for per-activation mode.
- Exactly one of **`savedMean`**, **`savedInvVariance`** pointers is **NULL**.
- **`epsilon`** value is less than **`CUDNN_BN_MIN_EPSILON`**.

- Dimensions or data types mismatch for any pair of **xDesc, dyDesc, dxDesc**.

3.5. cudnnBatchNormalizationBackwardEx()

```
cudnnStatus_t cudnnBatchNormalizationBackwardEx (
    cudnnHandle_t                    handle,
    cudnnBatchNormMode_t             mode,
    cudnnBatchNormOps_t              bnOps,
    const void                       *alphaDataDiff,
    const void                       *betaDataDiff,
    const void                       *alphaParamDiff,
    const void                       *betaParamDiff,
    const cudnnTensorDescriptor_t    xDesc,
    const void                       *xData,
    const cudnnTensorDescriptor_t    yDesc,
    const void                       *yData,
    const cudnnTensorDescriptor_t    dyDesc,
    const void                       *dyData,
    const cudnnTensorDescriptor_t    dzDesc,
    void                             *dzData,
    const cudnnTensorDescriptor_t    dxDesc,
    void                             *dxData,
    const cudnnTensorDescriptor_t    dBnScaleBiasDesc,
    const void                       *bnScaleData,
    const void                       *bnBiasData,
    void                             *dBnScaleData,
    void                             *dBnBiasData,
    double                           epsilon,
    const void                       *savedMean,
    const void                       *savedInvVariance,
    const cudnnActivationDescriptor_t   activationDesc,
    void                             *workspace,
    size_t                           workSpaceSizeInBytes
    void                             *reserveSpace
    size_t                           reserveSpaceSizeInBytes);
```

This function is an extension of the cudnnBatchNormalizationBackward() for performing the backward batch normalization layer computation with a fast NHWC semi-persistent kernel. This API will trigger the new semi-persistent NHWC kernel when the following conditions are true:

- All tensors, namely, **x, y, dz, dy, dx** must be NHWC-fully packed, and must be of the type **CUDNN_DATA_HALF**.
- The tensor C dimension should be a multiple of 4.
- The input parameter **mode** must be set to **CUDNN_BATCHNORM_SPATIAL_PERSISTENT**.
- **workspace** is not **NULL**.
- **workSpaceSizeInBytes** is equal or larger than the amount required by cudnnGetBatchNormalizationBackwardExWorkspaceSize().
- **reserveSpaceSizeInBytes** is equal or larger than the amount required by cudnnGetBatchNormalizationTrainingExReserveSpaceSize().
- The content in **reserveSpace** stored by cudnnBatchNormalizationForwardTrainingEx() must be preserved.

If **workspace** is **NULL** and **workSpaceSizeInBytes** of zero is passed in, this API will function exactly like the non-extended function **cudnnBatchNormalizationBackward**.

This **workspace** is not required to be clean. Moreover, the **workspace** does not have to remain unchanged between the forward and backward pass, as it is not used for passing any information.

This extended function can accept a ***workspace** pointer to the GPU workspace, and **workSpaceSizeInBytes**, the size of the workspace, from the user.

The **bnOps** input can be used to set this function to perform either only the batch normalization, or batch normalization followed by activation, or batch normalization followed by element-wise addition and then activation.

Only 4D and 5D tensors are supported. The **epsilon** value has to be the same during the training, the backpropagation, and the inference.

When the tensor layout is NCHW, higher performance can be obtained when HW-packed tensors are used for **x, dy, dx**.

Parameters

handle

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

mode

Input. Mode of operation (spatial or per-activation). For more information, see cudnnBatchNormMode_t.

bnOps

Input. Mode of operation. Currently **CUDNN_BATCHNORM_OPS_BN_ACTIVATION** and **CUDNN_BATCHNORM_OPS_BN_ADD_ACTIVATION** are only supported in the NHWC layout. For more information, see cudnnBatchNormOps_t. This input can be used to set this function to perform either only the batch normalization, or batch normalization followed by activation, or batch normalization followed by element-wise addition and then activation.

***alphaDataDiff**, ***betaDataDiff**

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

```
dstValue = alpha[0]*resultValue + beta[0]*priorDstValue
```

For more information, see Scaling Parameters in the *cuDNN Developer Guide*.

***alphaParamDiff**, ***betaParamDiff**

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

```
dstValue = alpha[0]*resultValue + beta[0]*priorDstValue
```

For more information, see Scaling Parameters in the *cuDNN Developer Guide*.

xDesc, *x, yDesc, *yData, dyDesc, *dyData

Inputs. Tensor descriptors and pointers in the device memory for the layer's **x** data, backpropagated gradient input **dy**, the original forward output **y** data. **yDesc** and **yData** are not needed if **bnOps** is set to **CUDNN_BATCHNORM_OPS_BN**, user may pass **NULL**. For more information, see cudnnTensorDescriptor_t.

dzDesc, *dzData, dxDesc, *dxData

Outputs. Tensor descriptors and pointers in the device memory for the computed gradient output **dz**, and **dx**. **dzDesc** and ***dzData** are not needed when **bnOps** is **CUDNN_BATCHNORM_OPS_BN** or **CUDNN_BATCHNORM_OPS_BN_ACTIVATION**, user may pass **NULL**. For more information, see cudnnTensorDescriptor_t.

dBnScaleBiasDesc

Input. Shared tensor descriptor for the following six tensors: **bnScaleData**, **bnBiasData**, **dBnScaleData**, **dBnBiasData**, **savedMean**, and **savedInvVariance**. For more information, see cudnnDeriveBNTensorDescriptor().

The dimensions for this tensor descriptor are dependent on normalization mode.

Note: The data type of this tensor descriptor must be **float** for FP16 and FP32 input tensors and **double** for FP64 input tensors.

For more information, see cudnnTensorDescriptor_t.

***bnScaleData**

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

***bnBiasData**

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

***dBnScaleData, dBnBiasData**

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

epsilon

Input. Epsilon value used in batch normalization formula. Its value should be equal to or greater than the value defined for **CUDNN_BN_MIN_EPSILON** in **cudnn.h**. The same epsilon value should be used in forward and backward functions.

***savedMean, *savedInvVariance**

Inputs. Optional cache parameters containing saved intermediate results computed during the forward pass. For this to work correctly, the layer's **x** and **bnScaleData**, **bnBiasData** data has to remain unchanged until this backward function is called. Note that both these parameters can be **NULL** but only at the same time. It is recommended to use this cache since the memory overhead is relatively small.

activationDesc

Input. Descriptor for the activation operation. When the **bnOps** input is set to either **CUDNN_BATCHNORM_OPS_BN_ACTIVATION** or **CUDNN_BATCHNORM_OPS_BN_ADD_ACTIVATION** then this activation is used, otherwise user may pass **NULL**.

workspace

Input. Pointer to the GPU workspace. If **workspace** is **NULL** and **workSpaceSizeInBytes** of zero is passed in, then this API will function exactly like the non-extended function cudnnBatchNormalizationBackward().

workSpaceSizeInBytes

Input. The size of the workspace. It must be large enough to trigger the fast NHWC semi-persistent kernel by this function.

***reserveSpace**

Input. Pointer to the GPU workspace for the **reserveSpace**.

reserveSpaceSizeInBytes

Input. The size of the **reserveSpace**. It must be equal or larger than the amount required by cudnnGetBatchNormalizationTrainingExReserveSpaceSize().

Returns

CUDNN_STATUS_SUCCESS

The computation was performed successfully.

CUDNN_STATUS_NOT_SUPPORTED

The function does not support the provided configuration.

CUDNN_STATUS_BAD_PARAM

At least one of the following conditions are met:

- Any of the pointers **alphaDataDiff, betaDataDiff, alphaParamDiff, betaParamDiff, x, dy, dx, bnScale, resultBnScaleDiff, resultBnBiasDiff** is **NULL**.
- The number of **xDesc** or **yDesc** or **dxDesc** tensor descriptor dimensions is not within the range of [4,5] (only 4D and 5D tensors are supported).
- **dBnScaleBiasDesc** dimensions not 1xCx1x1 for 4D and 1xCx1x1x1 for 5D for spatial, and are not 1xCxHxW for 4D and 1xCxDxHxW for 5D for per-activation mode.
- Exactly one of **savedMean**, **savedInvVariance** pointers is **NULL**.
- **epsilon** value is less than **CUDNN_BN_MIN_EPSILON**.
- Dimensions or data types mismatch for any pair of **xDesc**, **dyDesc**, **dxDesc**.

3.6. cudnnBatchNormalizationForwardInference()

```
cudnnStatus_t cudnnBatchNormalizationForwardInference(
```

```
    cudnnHandle_t                    handle,
    cudnnBatchNormMode_t             mode,
    const void                      *alpha,
    const void                      *beta,
    const cudnnTensorDescriptor_t    xDesc,
    const void                      *x,
    const cudnnTensorDescriptor_t    yDesc,
    void                            *y,
    const cudnnTensorDescriptor_t    bnScaleBiasMeanVarDesc,
    const void                      *bnScale,
    const void                      *bnBias,
    const void                      *estimatedMean,
    const void                      *estimatedVariance,
    double                           epsilon)
```

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

- Only 4D and 5D tensors are supported.
- The input transformation performed by this function is defined as:

  ```
  y = beta*y + alpha *[bnBias + (bnScale * (x-estimatedMean)/
  sqrt(epsilon + estimatedVariance)]
  ```
- The **`epsilon`** value has to be the same during training, backpropagation and inference.
- For the training phase, use cudnnBatchNormalizationForwardTraining().
- Higher performance can be obtained when HW-packed tensors are used for all of **`x`** and **`dx`**.

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

Parameters

`handle`

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

`mode`

Input. Mode of operation (spatial or per-activation). For more information, see cudnnBatchNormMode_t.

`alpha, beta`

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

```
dstValue = alpha[0]*resultValue + beta[0]*priorDstValue
```

For more information, see Scaling Parameters in the *cuDNN Developer Guide*.

`xDesc, yDesc`

Input. Handles to the previously initialized tensor descriptors.

***x**

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

***y**

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

bnScaleBiasMeanVarDesc, bnScale, bnBias

Inputs. Tensor descriptors and pointers in device memory for the batch normalization scale and bias parameters (in the original paper bias is referred to as beta and scale as gamma).

estimatedMean, estimatedVariance

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

epsilon

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

Returns

CUDNN_STATUS_SUCCESS

The computation was performed successfully.

CUDNN_STATUS_NOT_SUPPORTED

The function does not support the provided configuration.

CUDNN_STATUS_BAD_PARAM

At least one of the following conditions are met:

- One of the pointers **alpha, beta, x, y, bnScale, bnBias, estimatedMean, estimatedInvVariance** is **NULL**.
- The number of **xDesc** or **yDesc** tensor descriptor dimensions is not within the range of [4,5] (only 4D and 5D tensors are supported.)
- **bnScaleBiasMeanVarDesc** dimensions are not 1xCx1x1 for 4D and 1xCx1x1x1 for 5D for spatial, and are not 1xCxHxW for 4D and 1xCxDxHxW for 5D for per-activation mode.
- **epsilon** value is less than **CUDNN_BN_MIN_EPSILON**.
- Dimensions or data types mismatch for **xDesc**, **yDesc**.

3.7. cudnnBatchNormalizationForwardTraining()

```
cudnnStatus_t cudnnBatchNormalizationForwardTraining(
      cudnnHandle_t                    handle,
      cudnnBatchNormMode_t             mode,
      const void                      *alpha,
      const void                      *beta,
      const cudnnTensorDescriptor_t    xDesc,
      const void                      *x,
      const cudnnTensorDescriptor_t    yDesc,
      void                            *y,
      const cudnnTensorDescriptor_t    bnScaleBiasMeanVarDesc,
      const void                      *bnScale,
      const void                      *bnBias,
      double                           exponentialAverageFactor,
      void                            *resultRunningMean,
      void                            *resultRunningVariance,
      double                           epsilon,
      void                            *resultSaveMean,
      void                            *resultSaveInvVariance)
```

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

- Only 4D and 5D tensors are supported.
- The `epsilon` value has to be the same during training, backpropagation, and inference.
- For the inference phase, use `cudnnBatchNormalizationForwardInference`.
- Higher performance can be obtained when HW-packed tensors are used for both `x` and `y`.

See cudnnDeriveBNTensorDescriptor() for the secondary tensor descriptor generation for the parameters used in this function.

Parameters

`handle`

Handle to a previously created cuDNN library descriptor. For more information, see cudnnHandle_t.

`mode`

Mode of operation (spatial or per-activation). For more information, see cudnnBatchNormMode_t.

`alpha, beta`

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

```
dstValue = alpha[0]*resultValue + beta[0]*priorDstValue
```

For more information, see Scaling Parameters in the *cuDNN Developer Guide*.

xDesc, yDesc

Tensor descriptors and pointers in device memory for the layer's **x** and **y** data. For more information, see cudnnTensorDescriptor_t.

***x**

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

***y**

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

bnScaleBiasMeanVarDesc

Shared tensor descriptor **desc** for the secondary tensor that was derived by cudnnDeriveBNTensorDescriptor(). The dimensions for this tensor descriptor are dependent on the normalization mode.

bnScale, bnBias

Inputs. Pointers in device memory for the batch normalization scale and bias parameters (in the original paper bias is referred to as beta and scale as gamma). Note that **bnBias** parameter can replace the previous layer's bias parameter for improved efficiency.

exponentialAverageFactor

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

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

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

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

This is proved below:

Writing

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

resultRunningMean, resultRunningVariance

Inputs/Outputs. Running mean and variance tensors (these have the same descriptor as the bias and scale). Both of these pointers can be **NULL** but only at the same time. The value stored in **resultRunningVariance** (or passed as an input in inference mode) is the sample variance and is the moving average of **variance[x]** where the variance is computed either over batch or spatial+batch dimensions depending on the mode. If these pointers are not **NULL**, the tensors should be initialized to some reasonable values or to 0.

epsilon

Input. Epsilon value used in the batch normalization formula. Its value should be equal to or greater than the value defined for **CUDNN_BN_MIN_EPSILON** in **cudnn.h**. The same **epsilon** value should be used in forward and backward functions.

resultSaveMean, resultSaveInvVariance

Outputs. Optional cache to save intermediate results computed during the forward pass. These buffers can be used to speed up the backward pass when supplied to the cudnnBatchNormalizationBackward() function. The intermediate results stored in **resultSaveMean** and **resultSaveInvVariance** buffers should not be used directly by the user. Depending on the batch normalization mode, the results stored in **resultSaveInvVariance** may vary. For the cache to work correctly, the input layer data must remain unchanged until the backward function is called. Note that both parameters can be **NULL** but only at the same time. In such a case, intermediate statistics will not be saved, and cudnnBatchNormalizationBackward() will have to re-compute them. It is recommended to use this cache as the memory overhead is relatively small because these tensors have a much lower product of dimensions than the data tensors.

Returns

CUDNN_STATUS_SUCCESS

The computation was performed successfully.

CUDNN_STATUS_NOT_SUPPORTED

The function does not support the provided configuration.

CUDNN_STATUS_BAD_PARAM

At least one of the following conditions are met:

- One of the pointers **alpha, beta, x, y, bnScale, bnBias** is **NULL**.
- The number of **xDesc** or **yDesc** tensor descriptor dimensions is not within the range of [4,5] (only 4D and 5D tensors are supported).
- **bnScaleBiasMeanVarDesc** dimensions are not 1xCx1x1 for 4D and 1xCx1x1x1 for 5D for spatial, and are not 1xCxHxW for 4D and 1xCxDxHxW for 5D for per-activation mode.
- Exactly one of **resultSaveMean**, **resultSaveInvVariance** pointers are **NULL**.
- Exactly one of **resultRunningMean**, **resultRunningInvVariance** pointers are **NULL**.
- **epsilon** value is less than **CUDNN_BN_MIN_EPSILON**.
- Dimensions or data types mismatch for **xDesc**, **yDesc**

3.8. cudnnBatchNormalizationForwardTrainingEx()

```
cudnnStatus_t cudnnBatchNormalizationForwardTrainingEx(
   cudnnHandle_t                    handle,
   cudnnBatchNormMode_t             mode,
   cudnnBatchNormOps_t              bnOps,
   const void                       *alpha,
   const void                       *beta,
   const cudnnTensorDescriptor_t    xDesc,
   const void                       *xData,
   const cudnnTensorDescriptor_t    zDesc,
   const void                       *zData,
   const cudnnTensorDescriptor_t    yDesc,
   void                             *yData,
   const cudnnTensorDescriptor_t    bnScaleBiasMeanVarDesc,
   const void                       *bnScaleData,
   const void                       *bnBiasData,
   double                           exponentialAverageFactor,
   void                             *resultRunningMeanData,
   void                             *resultRunningVarianceData,
   double                           epsilon,
   void                             *saveMean,
   void                             *saveInvVariance,
   const cudnnActivationDescriptor_t   activationDesc,
   void                             *workspace,
   size_t                           workSpaceSizeInBytes
   void                             *reserveSpace
   size_t                           reserveSpaceSizeInBytes);
```

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

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

- All tensors, namely, **x, y, dz, dy, dx** must be NHWC-fully packed and must be of the type **CUDNN_DATA_HALF**.
- The tensor **C** dimension should be a multiple of 4.
- The input parameter **mode** must be set to **CUDNN_BATCHNORM_SPATIAL_PERSISTENT**.
- **workspace** is not **NULL**.
- **workSpaceSizeInBytes** is equal or larger than the amount required by cudnnGetBatchNormalizationForwardTrainingExWorkspaceSize().
- **reserveSpaceSizeInBytes** is equal or larger than the amount required by cudnnGetBatchNormalizationTrainingExReserveSpaceSize().
- The content in **reserveSpace** stored by cudnnBatchNormalizationForwardTrainingEx() must be preserved.

If **workspace** is **NULL** and **workSpaceSizeInBytes** of zero is passed in, this API will function exactly like the non-extended function cudnnBatchNormalizationForwardTraining().

This workspace is not required to be clean. Moreover, the workspace does not have to remain unchanged between the forward and backward pass, as it is not used for passing any information.

This extended function can accept a ***workspace** pointer to the GPU workspace, and **workSpaceSizeInBytes**, the size of the workspace, from the user.

The **bnOps** input can be used to set this function to perform either only the batch normalization, or batch normalization followed by activation, or batch normalization followed by element-wise addition and then activation.

Only 4D and 5D tensors are supported. The **epsilon** value has to be the same during the training, the backpropagation, and the inference.

When the tensor layout is NCHW, higher performance can be obtained when HW-packed tensors are used for **x, dy, dx**.

Parameters

handle

Handle to a previously created cuDNN library descriptor. For more information, see cudnnHandle_t.

mode

Mode of operation (spatial or per-activation). For more information, see cudnnBatchNormMode_t.

bnOps

Input. Mode of operation for the fast NHWC kernel. See cudnnBatchNormOps_t. This input can be used to set this function to perform either only the batch normalization, or batch normalization followed by activation, or batch normalization followed by element-wise addition and then activation.

***alpha, *beta**

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

```
dstValue = alpha[0]*resultValue + beta[0]*priorDstValue
```

For more information, see Scaling Parameters in the *cuDNN Developer Guide*.

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

Tensor descriptors and pointers in device memory for the layer's input **x** and output **y**, and for the optional **z** tensor input for residual addition to the result of the batch normalization operation, prior to the activation. The optional **zDes** and ***zData** descriptors is only used when **bnOps** is **CUDNN_BATCHNORM_OPS_BN_ADD_ACTIVATION**, otherwise user may pass **NULL**. When in use, **z** should have exactly the same dimension as **x** and the final output **y**. For more information, see cudnnTensorDescriptor_t.

bnScaleBiasMeanVarDesc

Shared tensor descriptor **desc** for the secondary tensor that was derived by cudnnDeriveBNTensorDescriptor(). The dimensions for this tensor descriptor are dependent on the normalization mode.

***bnScaleData, *bnBiasData**

Inputs. Pointers in device memory for the batch normalization scale and bias parameters (in the original paper, bias is referred to as beta and scale as gamma). Note that **bnBiasData** parameter can replace the previous layer's bias parameter for improved efficiency.

exponentialAverageFactor

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

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

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

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

This is proved below:

Writing

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

***resultRunningMeanData, *resultRunningVarianceData**

Inputs/Outputs. Pointers to the running mean and running variance data. Both these pointers can be **NULL** but only at the same time. The value stored in **resultRunningVarianceData** (or passed as an input in inference mode) is the sample variance and is the moving average of **variance[x]** where the variance is computed either over batch or spatial+batch dimensions depending on the mode. If these pointers are not **NULL**, the tensors should be initialized to some reasonable values or to 0.

epsilon

Input. Epsilon value used in the batch normalization formula. Its value should be equal to or greater than the value defined for **CUDNN_BN_MIN_EPSILON** in **cudnn.h**. The same **epsilon** value should be used in forward and backward functions.

***saveMean, *saveInvVariance**

Outputs. Optional cache parameters containing saved intermediate results computed during the forward pass. For this to work correctly, the layer's **x** and **bnScaleData**, **bnBiasData** data has to remain unchanged until this backward function is called. Note that both these parameters can be **NULL** but only at the same time. It is recommended to use this cache since the memory overhead is relatively small.

activationDesc

Input. The tensor descriptor for the activation operation. When the **bnOps** input is set to either **CUDNN_BATCHNORM_OPS_BN_ACTIVATION** or **CUDNN_BATCHNORM_OPS_BN_ADD_ACTIVATION** then this activation is used, otherwise user may pass **NULL**.

`*workspace`, `workSpaceSizeInBytes`

Inputs. **`*workspace`** is a pointer to the GPU workspace, and **`workSpaceSizeInBytes`** is the size of the workspace. When **`*workspace`** is not **`NULL`** and **`*workSpaceSizeInBytes`** is large enough, and the tensor layout is NHWC and the data type configuration is supported, then this function will trigger a new semi-persistent NHWC kernel for batch normalization. The workspace is not required to be clean. Also, the workspace does not need to remain unchanged between the forward and backward passes.

`*reserveSpace`

Input. Pointer to the GPU workspace for the **`reserveSpace`**.

`reserveSpaceSizeInBytes`

Input. The size of the **`reserveSpace`**. Must be equal or larger than the amount required by cudnnGetBatchNormalizationTrainingExReserveSpaceSize().

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`**.
- The number of **`xDesc`** or **`yDesc`** tensor descriptor dimensions is not within the [4,5] range (only 4D and 5D tensors are supported).
- **`bnScaleBiasMeanVarDesc`** dimensions are not 1xCx1x1 for 4D and 1xCx1x1x1 for 5D for spatial, and are not 1xCxHxW for 4D and 1xCxDxHxW for 5D for per-activation mode.
- Exactly one of **`saveMean`**, **`saveInvVariance`** pointers are **`NULL`**.
- Exactly one of **`resultRunningMeanData`**, **`resultRunningInvVarianceData`** pointers are **`NULL`**.
- **`epsilon`** value is less than **`CUDNN_BN_MIN_EPSILON`**.
- Dimensions or data types mismatch for **`xDesc`**, **`yDesc`**

3.9. 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. For more information, see cudnnHandle_t.

`alpha, beta`

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

```
dstValue = alpha[0]*resultValue + beta[0]*priorDstValue
```

For more information, see Scaling Parameters in the *cuDNN Developer Guide*.

`dyDesc`

Input. Handle to the previously initialized input tensor descriptor. For more information, see cudnnTensorDescriptor_t.

`dy`

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

`dbDesc`

Input. Handle to the previously initialized output tensor descriptor.

`db`

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

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 is different.

3.10. cudnnConvolutionBackwardData()

```
cudnnStatus_t cudnnConvolutionBackwardData(
    cudnnHandle_t                       handle,
    const void                         *alpha,
    const cudnnFilterDescriptor_t       wDesc,
    const void                         *w,
    const cudnnTensorDescriptor_t       dyDesc,
    const void                         *dy,
    const cudnnConvolutionDescriptor_t  convDesc,
    cudnnConvolutionBwdDataAlgo_t       algo,
    void                               *workSpace,
    size_t                              workSpaceSizeInBytes,
    const void                         *beta,
    const cudnnTensorDescriptor_t       dxDesc,
    void                               *dx)
```

This function computes the convolution data gradient of the tensor **dy**, where **y** is the output of the forward convolution in cudnnConvolutionForward(). It uses the specified **algo**, and returns the results in the output tensor **dx**. Scaling factors **alpha** and **beta** can be used to scale the computed result or accumulate with the current **dx**.

Parameters

handle

Input. Handle to a previously created cuDNN context. For more information, see cudnnHandle_t.

alpha, beta

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

```
dstValue = alpha[0]*result + beta[0]*priorDstValue
```

For more information, see Scaling Parameters in the *cuDNN Developer Guide*.

wDesc

Input. Handle to a previously initialized filter descriptor. For more information, see cudnnFilterDescriptor_t.

w

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

dyDesc

Input. Handle to the previously initialized input differential tensor descriptor. For more information, see cudnnTensorDescriptor_t.

dy

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

convDesc

Input. Previously initialized convolution descriptor. For more information, see cudnnConvolutionDescriptor_t.

algo

Input. Enumerant that specifies which backward data convolution algorithm should be used to compute the results. For more information, see cudnnConvolutionBwdDataAlgo_t.

workSpace

Input. Data pointer to GPU memory to a workspace needed to able to execute the specified algorithm. If no workspace is needed for a particular algorithm, that pointer can be nil.

workSpaceSizeInBytes

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

dxDesc

Input. Handle to the previously initialized output tensor descriptor.

dx

Input/Output. Data pointer to GPU memory associated with the output tensor descriptor **dxDesc** that carries the result.

Supported configurations

This function supports the following combinations of data types for **wDesc**, **dyDesc**, **convDesc**, and **dxDesc**.

Data Type Configurations	wDesc, dyDesc and dxDesc Data Type	convDesc Data Type
TRUE_HALF_CONFIG (only supported on architectures with true FP16 support, meaning, compute capability 5.3 and later)	CUDNN_DATA_HALF	CUDNN_DATA_HALF
PSEUDO_HALF_CONFIG	CUDNN_DATA_HALF	CUDNN_DATA_FLOAT
FLOAT_CONFIG	CUDNN_DATA_FLOAT	CUDNN_DATA_FLOAT
DOUBLE_CONFIG	CUDNN_DATA_DOUBLE	CUDNN_DATA_DOUBLE

Supported algorithms

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

The table below shows the list of the supported 2D and 3D convolutions. The 2D convolutions are described first, followed by the 3D convolutions.

For the following terms, the short-form versions shown in the parentheses are used in the table below, for brevity:

- `CUDNN_CONVOLUTION_BWD_DATA_ALGO_0 (_ALGO_0)`
- `CUDNN_CONVOLUTION_BWD_DATA_ALGO_1 (_ALGO_1)`
- `CUDNN_CONVOLUTION_BWD_DATA_ALGO_FFT (_FFT)`
- `CUDNN_CONVOLUTION_BWD_DATA_ALGO_FFT_TILING (_FFT_TILING)`
- `CUDNN_CONVOLUTION_BWD_DATA_ALGO_WINOGRAD (_WINOGRAD)`
- `CUDNN_CONVOLUTION_BWD_DATA_ALGO_WINOGRAD_NONFUSED (_WINOGRAD_NONFUSED)`
- `CUDNN_TENSOR_NCHW (_NCHW)`
- `CUDNN_TENSOR_NHWC (_NHWC)`
- `CUDNN_TENSOR_NCHW_VECT_C (_NCHW_VECT_C)`

Table 12 For 2D convolutions: `wDesc: _NHWC`

Filter descriptor `wDesc: _NHWC` (see cudnnTensorFormat_t)					
Algo Name	Deterministic (Yes or No)	Tensor Formats Supported for `dyDesc`	Tensor Formats Supported for `dxDesc`	Data Type Configurations Supported	Important

`_ALGO_1`		NHWC HWC-packed	NHWC HWC-packed	`TRUE_HALF_CONFIG`
				`PSEUDO_HALF_CONFIG`
				`FLOAT_CONFIG`	

Table 13 For 2D convolutions: **wDesc: _NCHW**

Filter descriptor wDesc: _NCHW.					
Algo Name	**Deterministic (Yes or No)**	**Tensor Formats Supported for dyDesc**	**Tensor Formats Supported for dxDesc**	**Data Type Configurations Supported**	**Important**
_ALGO_0	No	NCHW CHW-packed	All except _NCHW_VECT_C.	PSEUDO_HALF_CONFIG FLOAT_CONFIG DOUBLE_CONFIG	**Dilation**: greater than 0 for all dimensions convDesc Group Count Support: Greater than 0
_ALGO_1	Yes	NCHW CHW-packed	All except _NCHW_VECT_C.	TRUE_HALF_CONFIG PSEUDO_HALF_CONFIG FLOAT_CONFIG DOUBLE_CONFIG	**Dilation**: greater than 0 for all dimensions convDesc Group Count Support: Greater than 0
_FFT	Yes	NCHW CHW-packed	NCHW HW-packed	PSEUDO_HALF_CONFIG FLOAT_CONFIG	**Dilation**: 1 for all dimensions convDesc Group Count Support: Greater than 0 dxDesc feature map height + 2 * convDesc zero-padding height must equal 256 or less dxDesc feature map width + 2 * convDesc zero-padding

Filter descriptor `wDesc: _NCHW`.					
Algo Name	Deterministic (Yes or No)	Tensor Formats Supported for `dyDesc`	Tensor Formats Supported for `dxDesc`	Data Type Configurations Supported	Important
					width must equal 256 or less `convDesc` vertical and horizontal filter stride must equal 1 `wDesc` filter height must be greater than `convDesc` zero-padding height `wDesc` filter width must be greater than `convDesc` zero-padding width

`_FFT_TILING`	Yes	NCHW CHW-packed	NCHW HW-packed	`PSEUDO_HALF_CONFIG`
				`FLOAT_CONFIG`
				`DOUBLE_CONFIG` is also supported when the task can be handled by 1D FFT, meaning, one of the filter dimensions, width or height is 1.
					Dilation: 1 for all dimensions
					`convDesc` Group Count Support: Greater than 0
					When neither of `wDesc` filter dimension is 1, the filter width and height must not be larger than 32
					When either of `wDesc` filter

Filter descriptor `wDesc: _NCHW`.					
Algo Name	Deterministic (Yes or No)	Tensor Formats Supported for `dyDesc`	Tensor Formats Supported for `dxDesc`	Data Type Configurations Supported	Important
					dimension is 1, the largest filter dimension should not exceed 256 `convDesc` vertical and horizontal filter stride must equal 1 when either the filter width or filter height is 1, otherwise, the stride can be 1 or 2 `wDesc` filter height must be greater than `convDesc` zero-padding height `wDesc` filter width must be greater than `convDesc` zero-padding width
`_WINOGRAD`	Yes	NCHW CHW-packed	All except `_NCHW_VECT_C`.	`PSEUDO_HALF_CONFIG` `FLOAT_CONFIG`	**Dilation:** 1 for all dimensions `convDesc` Group Count Support: Greater than 0

Filter descriptor `wDesc: _NCHW`.					
Algo Name	Deterministic (Yes or No)	Tensor Formats Supported for `dyDesc`	Tensor Formats Supported for `dxDesc`	Data Type Configurations Supported	Important
					`convDesc` vertical and horizontal filter stride must equal 1 `wDesc` filter height must be 3 `wDesc` filter width must be 3

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

Table 14 For 3D convolutions: **wDesc: _NCHW**

Filter descriptor wDesc: _NCHW.					
Algo Name	Deterministic (Yes or No)	Tensor Formats Supported for dyDesc	Tensor Formats Supported for dxDesc	Data Type Configurations Supported	Important
_ALGO_0	Yes	NCDHW CDHW-packed	All except _NCDHW_VECT_C	PSEUDO_HALF_CONFIG FLOAT_CONFIG DOUBLE_CONFIG	**Dilation:** greater than 0 for all dimensions convDesc Group Count Support: Greater than 0
_ALGO_1	Yes	NCDHW fully-packed	NCDHW fully-packed	TRUE_HALF_CONFIG PSEUDO_HALF_CONFIG FLOAT_CONFIGDOUBLE_CONFIG	**Dilation:** 1 for all dimensions convDesc Group Count Support: Greater than 0
_FFT_TILING	Yes	NCDHW CDHW-packed	NCDHW DHW-packed	PSEUDO_HALF_CONFIG FLOAT_CONFIG DOUBLE_CONFIG	**Dilation:** 1 for all dimensions convDesc Group Count Support: Greater than 0 wDesc filter height must equal 16 or less wDesc filter width must equal 16 or less wDesc filter depth must equal 16 or less convDesc must have all filter

Filter descriptor `wDesc: _NCHW.`					
Algo Name	Deterministic (Yes or No)	Tensor Formats Supported for `dyDesc`	Tensor Formats Supported for `dxDesc`	Data Type Configurations Supported	Important
					strides equal to 1 `wDesc` filter height must be greater than `convDesc` zero-padding height `wDesc` filter width must be greater than `convDesc` zero-padding width `wDesc` filter depth must be greater than `convDesc` zero-padding width

Returns

`CUDNN_STATUS_SUCCESS`

The operation was launched successfully.

`CUDNN_STATUS_BAD_PARAM`

At least one of the following conditions are met:

- At least one of the following is **`NULL`**: **`handle`**, **`dyDesc`**, **`wDesc`**, **`convDesc`**, **`dxDesc`**, **`dy`**, **`w`**, **`dx`**, **`alpha`**, **`beta`**
- **`wDesc`** and **`dyDesc`** have a non-matching number of dimensions
- **`wDesc`** and **`dxDesc`** have a non-matching number of dimensions
- **`wDesc`** has fewer than three number of dimensions
- **`wDesc`**, **`dxDesc`**, and **`dyDesc`** have a non-matching data type.
- **`wDesc`** and **`dxDesc`** have a non-matching number of input feature maps per image (or group in case of grouped convolutions).

- **dyDesc** spatial sizes do not match with the expected size as determined by **cudnnGetConvolutionNdForwardOutputDim**

CUDNN_STATUS_NOT_SUPPORTED

At least one of the following conditions are met:

- **dyDesc** or **dxDesc** have a negative tensor striding
- **dyDesc**, **wDesc** or **dxDesc** has a number of dimensions that is not 4 or 5
- The chosen algo does not support the parameters provided; see above for an exhaustive list of parameters that support each algo
- **dyDesc** or **wDesc** indicate an output channel count that isn't a multiple of group count (if group count has been set in **convDesc**).

CUDNN_STATUS_MAPPING_ERROR

An error occurs during the texture binding of the filter data or the input differential tensor data

CUDNN_STATUS_EXECUTION_FAILED

The function failed to launch on the GPU.

3.11. cudnnConvolutionBackwardFilter()

```
cudnnStatus_t cudnnConvolutionBackwardFilter(
    cudnnHandle_t                       handle,
    const void                         *alpha,
    const cudnnTensorDescriptor_t       xDesc,
    const void                         *x,
    const cudnnTensorDescriptor_t       dyDesc,
    const void                         *dy,
    const cudnnConvolutionDescriptor_t  convDesc,
    cudnnConvolutionBwdFilterAlgo_t     algo,
    void                               *workSpace,
    size_t                              workSpaceSizeInBytes,
    const void                         *beta,
    const cudnnFilterDescriptor_t       dwDesc,
    void                               *dw)
```

This function computes the convolution weight (filter) gradient of the tensor **dy**, where **y** is the output of the forward convolution in cudnnConvolutionForward(). It uses the specified **algo**, and returns the results in the output tensor **dw**. Scaling factors **alpha** and **beta** can be used to scale the computed result or accumulate with the current **dw**.

Parameters

handle

Input. Handle to a previously created cuDNN context. For more information, see cudnnHandle_t.

alpha, beta

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

```
dstValue = alpha[0]*result + beta[0]*priorDstValue
```

For more information, see Scaling Parameters in the *cuDNN Developer Guide*.

xDesc

Input. Handle to a previously initialized tensor descriptor. For more information, see cudnnTensorDescriptor_t.

x

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

dyDesc

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

dy

Input. Data pointer to GPU memory associated with the backpropagation gradient tensor descriptor **dyDesc**.

convDesc

Input. Previously initialized convolution descriptor. For more information, see cudnnConvolutionDescriptor_t.

algo

Input. Enumerant that specifies which convolution algorithm should be used to compute the results. For more information, see cudnnConvolutionBwdFilterAlgo_t.

workSpace

Input. Data pointer to GPU memory to a workspace needed to able to execute the specified algorithm. If no workspace is needed for a particular algorithm, that pointer can be nil.

workSpaceSizeInBytes

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

dwDesc

Input. Handle to a previously initialized filter gradient descriptor. For more information, see cudnnFilterDescriptor_t.

dw

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

Supported configurations

This function supports the following combinations of data types for **xDesc**, **dyDesc**, **convDesc**, and **dwDesc**.

Data Type Configurations	xDesc, dyDesc, and dwDesc Data Type	convDesc Data Type
TRUE_HALF_CONFIG (only supported on architectures with true FP16 support, meaning, compute capability 5.3 and later)	CUDNN_DATA_HALF	CUDNN_DATA_HALF
PSEUDO_HALF_CONFIG	CUDNN_DATA_HALF	CUDNN_DATA_FLOAT
FLOAT_CONFIG	CUDNN_DATA_FLOAT	CUDNN_DATA_FLOAT
DOUBLE_CONFIG	CUDNN_DATA_DOUBLE	CUDNN_DATA_DOUBLE

Supported algorithms

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

The table below shows the list of the supported 2D and 3D convolutions. The 2D convolutions are described first, followed by the 3D convolutions.

For the following terms, the short-form versions shown in the parentheses are used in the table below, for brevity:

- **CUDNN_CONVOLUTION_BWD_FILTER_ALGO_0 (_ALGO_0)**
- **CUDNN_CONVOLUTION_BWD_FILTER_ALGO_1 (_ALGO_1)**
- **CUDNN_CONVOLUTION_BWD_FILTER_ALGO_3 (_ALGO_3)**
- **CUDNN_CONVOLUTION_BWD_FILTER_ALGO_FFT (_FFT)**
- **CUDNN_CONVOLUTION_BWD_FILTER_ALGO_FFT_TILING (_FFT_TILING)**
- **CUDNN_CONVOLUTION_BWD_FILTER_ALGO_WINOGRAD_NONFUSED (_WINOGRAD_NONFUSED)**
- **CUDNN_TENSOR_NCHW (_NCHW)**
- **CUDNN_TENSOR_NHWC (_NHWC)**
- **CUDNN_TENSOR_NCHW_VECT_C (_NCHW_VECT_C)**

Table 15 For 2D convolutions: **dwDesc: _NHWC**

Filter descriptor dwDesc: _NHWC (see cudnnTensorFormat_t)					
Algo Name	**Deterministic (Yes or No)**	**Tensor Formats Supported for dyDesc**	**Tensor Formats Supported for dxDesc**	**Data Type Configurations Supported**	**Important**
_ALGO_0 and _ALGO_1		NHWC HWC-packed	NHWC HWC-packed	PSEUDO_HALF_CONFIG FLOAT_CONFIG	

Table 16 For 2D convolutions: **wDesc: _NCHW**

Filter descriptor wDesc: _NCHW					
Algo Name	**Deterministic (Yes or No)**	**Tensor Formats Supported for dyDesc**	**Tensor Formats Supported for dxDesc**	**Data Type Configurations Supported**	**Important**
_ALGO_0	No	All except _NCHW_VECT_C.	NCHW CHW-packed	PSEUDO_HALF_CONFIG FLOAT_CONFIG DOUBLE_CONFIG	**Dilation:** greater than 0 for all dimensions convDesc Group Count Support: Greater than 0 This algo is not supported if output is of type CUDNN_DATA_HALF and the number of elements in dw is odd.
_ALGO_1	Yes	_NCHW or _NHWC	NCHW CHW-packed	TRUE_HALF_CONFIG PSEUDO_HALF_CONFIG FLOAT_CONFIG DOUBLE_CONFIG	**Dilation:** 1 for all dimensions convDesc Group Count

Filter descriptor `wDesc: _NCHW`					
Algo Name	Deterministic (Yes or No)	Tensor Formats Supported for `dyDesc`	Tensor Formats Supported for `dxDesc`	Data Type Configurations Supported	Important
					Support: Greater than 0
`_FFT`	Yes	NCHW CHW-packed	NCHW CHW-packed	`PSEUDO_HALF_CONFIG` `FLOAT_CONFIG`	Dilation: 1 for all dimensions `convDesc` Group Count Support: Greater than 0 `xDesc` feature map height + 2 * `convDesc` zero-padding height must equal 256 or less `xDesc` feature map width + 2 * `convDesc` zero-padding width must equal 256 or less `convDesc` vertical and horizontal filter stride must equal 1 `dwDesc` filter height must be greater than `convDesc` zero-padding height `dwDesc` filter width must be

Filter descriptor `wDesc: _NCHW`					
Algo Name	**Deterministic (Yes or No)**	**Tensor Formats Supported for `dyDesc`**	**Tensor Formats Supported for `dxDesc`**	**Data Type Configurations Supported**	**Important**
					greater than `convDesc` zero-padding width
`_ALGO_3`	Yes	All except `_NCHW_VECT_C`	NCHW CHW-packed	`PSEUDO_HALF_CONFIG` `FLOAT_CONFIG` `DOUBLE_CONFIG`	**Dilation:** 1 for all dimensions `convDesc` Group Count Support: Greater than 0
`_WINOGRAD_NONFUSED`	Yes	All except `_NCHW_VECT_C`	NCHW CHW-packed	`TRUE_HALF_CONFIG` `PSEUDO_HALF_CONFIG` `FLOAT_CONFIG`	**Dilation:** 1 for all dimensions `convDesc` Group Count Support: Greater than 0 `convDesc` vertical and horizontal filter stride must equal 1 `wDesc` filter (height, width) must be (3,3) or (5,5) If `wDesc` filter (height, width) is (5,5), then the data type config `TRUE_HALF_CONFIG` is not supported.

Filter descriptor `wDesc: _NCHW`					
Algo Name	**Deterministic (Yes or No)**	**Tensor Formats Supported for `dyDesc`**	**Tensor Formats Supported for `dxDesc`**	**Data Type Configurations Supported**	**Important**

`_FFT_TILING`	Yes	NCHW CHW-packed	NCHW CHW-packed	`PSEUDO_HALF_CONFIG`
				`FLOAT_CONFIG`
				`DOUBLE_CONFIG`
					Dilation: 1 for all dimensions
					`convDesc` Group Count Support: Greater than 0
					`xDesc` width or height must equal 1
					`dyDesc` width or height must equal 1 (the same dimension as in `xDesc`). The other dimension must be less than or equal to 256, meaning, the largest 1D tile size currently supported.
					`convDesc` vertical and horizontal filter stride must equal 1
					`dwDesc` filter height must be greater than `convDesc` zero-padding height

Filter descriptor `wDesc: _NCHW`					
Algo Name	Deterministic (Yes or No)	Tensor Formats Supported for `dyDesc`	Tensor Formats Supported for `dxDesc`	Data Type Configurations Supported	Important
					`dwDesc` filter width must be greater than `convDesc` zero-padding width

Table 17 For 3D convolutions: **`wDesc: _NCHW`**

Filter descriptor `wDesc: _NCHW.`					
Algo Name (3D Convolutions)	Deterministic (Yes or No)	Tensor Formats Supported for `dyDesc`	Tensor Formats Supported for `dxDesc`	Data Type Configurations Supported	Important
`_ALGO_0`	No	All except `_NCDHW_VECT_C`.	NCDHW CDHW-packed	`PSEUDO_HALF_CONFIG` `FLOAT_CONFIG` `DOUBLE_CONFIG`	**Dilation:** greater than 0 for all dimensions `convDesc` Group Count Support: Greater than 0
`_ALGO_3`	No	NCDHW fully-packed	NCDHW fully-packed	`PSEUDO_HALF_CONFIG` `FLOAT_CONFIG` `DOUBLE_CONFIG`	**Dilation:** greater than 0 for all dimensions `convDesc` Group Count Support: Greater than 0

Returns

`CUDNN_STATUS_SUCCESS`

The operation was launched successfully.

CUDNN_STATUS_BAD_PARAM

At least one of the following conditions are met:

- At least one of the following is NULL: **handle**, **xDesc**, **dyDesc**, **convDesc**, **dwDesc**, **xData**, **dyData**, **dwData**, **alpha**, **beta**
- **xDesc** and **dyDesc** have a non-matching number of dimensions
- **xDesc** and **dwDesc** have a non-matching number of dimensions
- **xDesc** has fewer than three number of dimensions
- **xDesc**, **dyDesc**, and **dwDesc** have a non-matching data type.
- **xDesc** and **dwDesc** have a non-matching number of input feature maps per image (or group in case of grouped convolutions).
- **yDesc** or **wDesc** indicate an output channel count that isn't a multiple of group count (if group count has been set in **convDesc**).

CUDNN_STATUS_NOT_SUPPORTED

At least one of the following conditions are met:

- **xDesc** or **dyDesc** have negative tensor striding
- **xDesc**, **dyDesc** or **dwDesc** has a number of dimensions that is not 4 or 5
- The chosen algo does not support the parameters provided; see above for exhaustive list of parameter support for each algo

CUDNN_STATUS_MAPPING_ERROR

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

CUDNN_STATUS_EXECUTION_FAILED

The function failed to launch on the GPU.

3.12. cudnnConvolutionBiasActivationForward()

```
cudnnStatus_t cudnnConvolutionBiasActivationForward(
    cudnnHandle_t                          handle,
    const void                            *alpha1,
    const cudnnTensorDescriptor_t          xDesc,
    const void                            *x,
    const cudnnFilterDescriptor_t          wDesc,
    const void                            *w,
    const cudnnConvolutionDescriptor_t     convDesc,
    cudnnConvolutionFwdAlgo_t              algo,
    void                                  *workSpace,
    size_t                                 workSpaceSizeInBytes,
    const void                            *alpha2,
    const cudnnTensorDescriptor_t          zDesc,
    const void                            *z,
    const cudnnTensorDescriptor_t          biasDesc,
    const void                            *bias,
    const cudnnActivationDescriptor_t      activationDesc,
    const cudnnTensorDescriptor_t          yDesc,
    void                                  *y)
```

This function applies a bias and then an activation to the convolutions or cross-correlations of cudnnConvolutionForward(), returning results in **y**. The full computation follows the equation **y = act (alpha1 * conv(x) + alpha2 * z + bias)**.

- The routine cudnnGetConvolution2dForwardOutputDim() or cudnnGetConvolutionNdForwardOutputDim() can be used to determine the proper dimensions of the output tensor descriptor **yDesc** with respect to **xDesc**, **convDesc**, and **wDesc**.
- Only the **CUDNN_CONVOLUTION_FWD_ALGO_IMPLICIT_PRECOMP_GEMM** algo is enabled with **CUDNN_ACTIVATION_IDENTITY**. In other words, in the cudnnActivationDescriptor_t structure of the input **activationDesc**, if the mode of the cudnnActivationMode_t field is set to the enum value **CUDNN_ACTIVATION_IDENTITY**, then the input cudnnConvolutionFwdAlgo_t of this function cudnnConvolutionBiasActivationForward() must be set to the enum value **CUDNN_CONVOLUTION_FWD_ALGO_IMPLICIT_PRECOMP_GEMM**. For more information, see cudnnSetActivationDescriptor().

Parameters

handle

Input. Handle to a previously created cuDNN context. For more information, see cudnnHandle_t.

alpha1, alpha2

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

```
dstValue = alpha[0]*result + beta[0]*priorDstValue
```

For more information, see Scaling Parameters in the *cuDNN Developer Guide*.

xDesc

Input. Handle to a previously initialized tensor descriptor. For more information, see cudnnTensorDescriptor_t.

x

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

wDesc

Input. Handle to a previously initialized filter descriptor. For more information, see cudnnFilterDescriptor_t.

w

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

convDesc

Input. Previously initialized convolution descriptor. For more information, see cudnnConvolutionDescriptor_t.

algo

Input. Enumerant that specifies which convolution algorithm should be used to compute the results. For more information, see cudnnConvolutionFwdAlgo_t.

workSpace

Input. Data pointer to GPU memory to a workspace needed to able to execute the specified algorithm. If no workspace is needed for a particular algorithm, that pointer can be nil.

workSpaceSizeInBytes

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

zDesc

Input. Handle to a previously initialized tensor descriptor.

z

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

biasDesc

Input. Handle to a previously initialized tensor descriptor.

bias

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

activationDesc

Input. Handle to a previously initialized activation descriptor. For more information, see cudnnActivationDescriptor_t.

yDesc

Input. Handle to a previously initialized tensor descriptor.

y

Input/Output. Data pointer to GPU memory associated with the tensor descriptor **yDesc** that carries the result of the convolution.

For the convolution step, this function supports the specific combinations of data types for **xDesc**, **wDesc**, **convDesc**, and **yDesc** as listed in the documentation of cudnnConvolutionForward(). The following table specifies the supported combinations of data types for **x**, **y**, **z**, **bias**, and **alpha1/alpha2**.

Table 18 Supported combinations of data types (**X = CUDNN_DATA**)

x	w	y and z	bias	alpha1/alpha2
X_DOUBLE	X_DOUBLE	X_DOUBLE	X_DOUBLE	X_DOUBLE
X_FLOAT	X_FLOAT	X_FLOAT	X_FLOAT	X_FLOAT

x	w	y and z	bias	alpha1/alpha2
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

Returns

In addition to the error values listed by the documentation of cudnnConvolutionForward(), the possible error values returned by this function and their meanings are listed below.

CUDNN_STATUS_SUCCESS

The operation was launched successfully.

CUDNN_STATUS_BAD_PARAM

At least one of the following conditions are met:

- At least one of the following is **NULL**: **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. Some examples of non-supported configurations are as follows:

- 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.

3.13. 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. For more information, see cudnnHandle_t.

alpha, beta

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

```
dstValue = alpha[0]*result + beta[0]*priorDstValue
```

For more information, see Scaling Parameters in the *cuDNN Developer Guide*.

xDesc

Input. Handle to a previously initialized tensor descriptor. For more information, see cudnnTensorDescriptor_t.

x

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

wDesc

Input. Handle to a previously initialized filter descriptor. For more information, see cudnnFilterDescriptor_t.

w

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

convDesc

Input. Previously initialized convolution descriptor. For more information, see cudnnConvolutionDescriptor_t.

algo

Input. Enumerant that specifies which convolution algorithm should be used to compute the results. For more information, see cudnnConvolutionFwdAlgo_t.

workSpace

Input. Data pointer to GPU memory to a workspace needed to able to execute the specified algorithm. If no workspace is needed for a particular algorithm, that pointer can be nil.

workSpaceSizeInBytes

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

yDesc

Input. Handle to a previously initialized tensor descriptor.

y

Input/Output. Data pointer to GPU memory associated with the tensor descriptor **yDesc** that carries the result of the convolution.

Supported configurations

This function supports the following combinations of data types for **xDesc**, **wDesc**, **convDesc**, and **yDesc**.

Table 19 Supported configurations

Data Type Configurations	xDesc and wDesc	convDesc	yDesc
TRUE_HALF_CONFIG (only supported on architectures with true FP16 support, meaning, compute capability 5.3 and later)	CUDNN_DATA_HALF	CUDNN_DATA_HALF	CUDNN_DATA_HALF
PSEUDO_HALF_CONFIG	CUDNN_DATA_HALF	CUDNN_DATA_FLOAT	CUDNN_DATA_HALF
FLOAT_CONFIG	CUDNN_DATA_FLOAT	CUDNN_DATA_FLOAT	CUDNN_DATA_FLOAT

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

Data Type Configurations	`xDesc` and `wDesc`	`convDesc`	`yDesc`
on architectures with DP4A support, meaning, compute capability 6.1 and later)			

Supported algorithms

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

The table below shows the list of the supported 2D and 3D convolutions. The 2D convolutions are described first, followed by the 3D convolutions.

For the following terms, the short-form versions shown in the parenthesis are used in the table below, for brevity:

- `CUDNN_CONVOLUTION_FWD_ALGO_IMPLICIT_GEMM (_IMPLICIT_GEMM)`
- `CUDNN_CONVOLUTION_FWD_ALGO_IMPLICIT_PRECOMP_GEMM (_IMPLICIT_PRECOMP_GEMM)`
- `CUDNN_CONVOLUTION_FWD_ALGO_GEMM (_GEMM)`
- `CUDNN_CONVOLUTION_FWD_ALGO_DIRECT (_DIRECT)`
- `CUDNN_CONVOLUTION_FWD_ALGO_FFT (_FFT)`
- `CUDNN_CONVOLUTION_FWD_ALGO_FFT_TILING (_FFT_TILING)`
- `CUDNN_CONVOLUTION_FWD_ALGO_WINOGRAD (_WINOGRAD)`
- `CUDNN_CONVOLUTION_FWD_ALGO_WINOGRAD_NONFUSED (_WINOGRAD_NONFUSED)`
- `CUDNN_TENSOR_NCHW (_NCHW)`
- `CUDNN_TENSOR_NHWC (_NHWC)`
- `CUDNN_TENSOR_NCHW_VECT_C (_NCHW_VECT_C)`

Table 20 For 2D convolutions: **wDesc: _NCHW**

Filter descriptor `wDesc: _NCHW` (see cudnnTensorFormat_t) `convDesc` Group count support: Greater than 0, for all algos.				
Algo Name	**Tensor Formats Supported for `xDesc`**	**Tensor Formats Supported for `yDesc`**	**Data Type Configurations Supported**	**Important**

`_IMPLICIT_GEMM`	All except `_NCHW_VECT_C`.	All except `_NCHW_VECT_C`.	`PSEUDO_HALF_CONFIG`
			`FLOAT_CONFIG`
			`DOUBLE_CONFIG`
				Dilation: Greater than 0 for all dimensions

`_IMPLICIT_PRECOMP_GEMM`	All except `_NCHW_VECT_C`.	All except `_NCHW_VECT_C`.	`TRUE_HALF_CONFIG`
			`PSEUDO_HALF_CONFIG`
			`FLOAT_CONFIG`
			`DOUBLE_CONFIG`
				Dilation: 1 for all dimensions

`_GEMM`	All except `_NCHW_VECT_C`.	All except `_NCHW_VECT_C`.	`PSEUDO_HALF_CONFIG`
			`FLOAT_CONFIG`
			`DOUBLE_CONFIG`
				Dilation: 1 for all dimensions

`_FFT`	NCHW HW-packed	NCHW HW-packed	`PSEUDO_HALF_CONFIG` `FLOAT_CONFIG`	**Dilation:** 1 for all dimensions `xDesc` feature map height + 2 * `convDesc` zero-padding height must equal 256 or less `xDesc` feature map width + 2 * `convDesc` zero-padding width must equal 256 or less `convDesc` vertical and horizontal filter stride must equal 1 `wDesc` filter height must be greater

Filter descriptor `wDesc`: `_NCHW` (see cudnnTensorFormat_t) `convDesc` Group count support: Greater than 0, for all algos.				
Algo Name	Tensor Formats Supported for `xDesc`	Tensor Formats Supported for `yDesc`	Data Type Configurations Supported	Important
				than `convDesc` zero-padding height `wDesc` filter width must be greater than `convDesc` zero-padding width

`_FFT_TILING`			`PSEUDO_HALF_CONFIG`
			`FLOAT_CONFIG`
			`DOUBLE_CONFIG` is also supported when the task can be handled by 1D FFT, meaning, one of the filter dimension, width or height is 1.
				Dilation: 1 for all dimensions
				When neither of `wDesc` filter dimension is 1, the filter width and height must not be larger than 32
				When either of `wDesc` filter dimension is 1, the largest filter dimension should not exceed 256
				`convDesc` vertical and horizontal filter stride must equal 1 when either the filter width or filter height is 1, otherwise the stride can be a 1 or 2
				`wDesc` filter height must be greater than `convDesc`

Filter descriptor `wDesc`: `_NCHW` (see cudnnTensorFormat_t)

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

Algo Name	Tensor Formats Supported for `xDesc`	Tensor Formats Supported for `yDesc`	Data Type Configurations Supported	Important
				zero-padding height `wDesc` filter width must be greater than `convDesc` zero-padding width
`_WINOGRAD`	All except `_NCHW_VECT_C`.	All except `_NCHW_VECT_C`.	`PSEUDO_HALF_CONFIG` `FLOAT_CONFIG`	**Dilation:** 1 for all dimensions `convDesc` vertical and horizontal filter stride must equal 1 `wDesc` filter height must be 3 `wDesc` filter width must be 3

`_WINOGRAD_NONFUSED`			`TRUE_HALF_CONFIG`
			`PSEUDO_HALF_CONFIG`
			`FLOAT_CONFIG`
				Dilation: 1 for all dimensions
				`convDesc` vertical and horizontal filter stride must equal 1
				`wDesc` filter (height, width) must be (3,3) or (5,5)
				If `wDesc` filter (height, width) is (5,5), then data type config `TRUE_HALF_CONFIG` is not supported.

`_DIRECT`	Currently not implemented in cuDNN.			

Table 21 For 2D convolutions: `wDesc: _NCHWC`

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

`_IMPLICIT_PRECOMP_GEMM`	All except `_NCHW_VECT_C`.	All except `_NCHW_VECT_C`.	`INT8x4_CONFIG`
			`INT8x4_EXT_CONFIG`
			`UINT8x4_CONFIG`
			`UINT8x4_EXT_CONFIG`
				Dilation: 1 for all dimensions

Table 22 For 2D convolutions: `wDesc: _NHWC`

Filter descriptor `wDesc: _NHWC` `convDesc` Group count support: Greater than 0.				
Algo Name	`xDesc`	`yDesc`	Data Type Configurations Supported	Important

`_IMPLICIT_PRECOMP_GEMM`	NHWC	NHWC	`INT8_CONFIG`
			`INT8_EXT_CONFIG`
			`INT8x4_CONFIG`
			`INT8x4_EXT_CONFIG`
			`UINT8x4_CONFIG`
			`UINT8x4_EXT_CONFIG`
				Dilation: 1 for all dimensions
				Input and output feature maps must be a multiple of 4.

`_IMPLICIT_PRECOMP_GEMM`	NHWC HWC-packed.	NHWC HWC-packed.	`TRUE_HALF_CONFIG`
			`PSEUDO_HALF_CONFIG`
			`FLOAT_CONFIG`	

Table 23 For 3D convolutions: **`wDesc: _NCHW`**

Filter descriptor `wDesc: _NCHW` `convDesc` Group count support: Greater than 0, for all algos.				
Algo Name	**`xDesc`**	**`yDesc`**	**Data Type Configurations Supported**	**Important**

`_IMPLICIT_GEMM`	All except `_NCHW_VECT_C`.	All except `_NCHW_VECT_C`.	`PSEUDO_HALF_CONFIG`
			`FLOAT_CONFIG`
			`DOUBLE_CONFIG`
				Dilation: Greater than 0 for all dimensions

`_IMPLICIT_PRECOMP_GEMM`				**Dilation:** 1 for all dimensions
`_FFT_TILING`	NCDHW DHW-packed	NCDHW DHW-packed		**Dilation:** 1 for all dimensions `wDesc` filter height must equal 16 or less `wDesc` filter width must equal 16 or less `wDesc` filter depth must equal 16 or less `convDesc` must have all filter strides equal to 1 `wDesc` filter height must be greater than `convDesc` zero-padding height `wDesc` filter width must be greater than `convDesc` zero-padding width `wDesc` filter depth must be greater

Filter descriptor `wDesc`: `_NCHW` `convDesc` Group count support: Greater than 0, for all algos.				
Algo Name	**`xDesc`**	**`yDesc`**	**Data Type Configurations Supported**	**Important**
				than `convDesc` zero-padding width

> Tensors can be converted to and from **`CUDNN_TENSOR_NCHW_VECT_C`** with cudnnTransformTensor().

Returns

`CUDNN_STATUS_SUCCESS`

The operation was launched successfully.

`CUDNN_STATUS_BAD_PARAM`

At least one of the following conditions are met:

- At least one of the following is **`NULL`**: handle, **`xDesc`**, **`wDesc`**, **`convDesc`**, **`yDesc`**, **`xData`**, **`w`**, **`yData`**, **`alpha`**, **`beta`**
- **`xDesc`** and **`yDesc`** have a non-matching number of dimensions
- **`xDesc`** and **`wDesc`** have a non-matching number of dimensions
- **`xDesc`** has fewer than three number of dimensions
- **`xDesc`**'s number of dimensions is not equal to **`convDesc`** array length + 2
- **`xDesc`** and **`wDesc`** have a non-matching number of input feature maps per image (or group in case of grouped convolutions)
- **`yDesc`** or **`wDesc`** indicate an output channel count that isn't a multiple of group count (if group count has been set in **`convDesc`**).
- **`xDesc`**, **`wDesc`**, and **`yDesc`** have a non-matching data type
- For some spatial dimension, **`wDesc`** has a spatial size that is larger than the input spatial size (including zero-padding size)

`CUDNN_STATUS_NOT_SUPPORTED`

At least one of the following conditions are met:

- **`xDesc`** or **`yDesc`** have negative tensor striding
- **`xDesc`**, **`wDesc`**, or **`yDesc`** has a number of dimensions that is not 4 or 5
- **`yDesc`** spatial sizes do not match with the expected size as determined by cudnnGetConvolutionNdForwardOutputDim()
- The chosen algo does not support the parameters provided; see above for an exhaustive list of parameters supported for each algo

CUDNN_STATUS_MAPPING_ERROR

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

CUDNN_STATUS_EXECUTION_FAILED

The function failed to launch on the GPU.

3.14. cudnnCreate()

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

This function initializes the cuDNN library and creates a handle to an opaque structure holding the cuDNN library context. It allocates hardware resources on the host and device and must be called prior to making any other cuDNN library calls.

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

For a given device, multiple cuDNN handles with different configurations (for example, 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. For more information, see cudnnHandle_t.

Returns

CUDNN_STATUS_BAD_PARAM

Invalid (**NULL**) input pointer supplied.

CUDNN_STATUS_NOT_INITIALIZED

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

CUDNN_STATUS_ARCH_MISMATCH

NVIDIA GPU architecture is too old.

CUDNN_STATUS_ALLOC_FAILED

Host memory allocation failed.

CUDNN_STATUS_INTERNAL_ERROR

CUDA resource allocation failed.

CUDNN_STATUS_LICENSE_ERROR

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

CUDNN_STATUS_SUCCESS

cuDNN handle was created successfully.

3.15. cudnnCreateActivationDescriptor()

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

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

Returns

CUDNN_STATUS_SUCCESS

The object was created successfully.

CUDNN_STATUS_ALLOC_FAILED

The resources could not be allocated.

3.16. cudnnCreateAlgorithmDescriptor()

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

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.

3.17. cudnnCreateAlgorithmPerformance()

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

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.

3.18. cudnnCreateAttnDescriptor()

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

This function creates one instance of an opaque attention descriptor object by allocating the host memory for it and initializing all descriptor fields. The function writes **NULL** to **attnDesc** when the attention descriptor object cannot be allocated.

Use the cudnnSetAttnDescriptor() function to configure the attention descriptor and cudnnDestroyAttnDescriptor() to destroy it and release the allocated memory.

Parameters

attnDesc

Output. Pointer where the address to the newly created attention descriptor should be written.

Returns

CUDNN_STATUS_SUCCESS

The descriptor object was created successfully.

CUDNN_STATUS_BAD_PARAM

An invalid input argument was encountered (**attnDesc=NULL**).

CUDNN_STATUS_ALLOC_FAILED

The memory allocation failed.

3.19. cudnnCreateConvolutionDescriptor()

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

This function creates a convolution descriptor object by allocating the memory needed to hold its opaque structure. For more information, see cudnnConvolutionDescriptor_t.

Returns

CUDNN_STATUS_SUCCESS

The object was created successfully.

CUDNN_STATUS_ALLOC_FAILED

The resources could not be allocated.

3.20. cudnnCreateCTCLossDescriptor()

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

This function creates a CTC loss function descriptor.

Parameters

ctcLossDesc

Output. CTC loss descriptor to be set. For more information, see cudnnCTCLossDescriptor_t.

Returns

CUDNN_STATUS_SUCCESS

The function returned successfully.

CUDNN_STATUS_BAD_PARAM

CTC loss descriptor passed to the function is invalid.

CUDNN_STATUS_ALLOC_FAILED

Memory allocation for this CTC loss descriptor failed.

3.21. 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. For more information, see cudnnDropoutDescriptor_t.

Returns

CUDNN_STATUS_SUCCESS

The object was created successfully.

CUDNN_STATUS_ALLOC_FAILED

The resources could not be allocated.

3.22. cudnnCreateFilterDescriptor()

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

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

Returns

CUDNN_STATUS_SUCCESS

The object was created successfully.

CUDNN_STATUS_ALLOC_FAILED

The resources could not be allocated.

3.23. cudnnCreateFusedOpsConstParamPack()

```
cudnnStatus_t cudnnCreateFusedOpsConstParamPack(
 cudnnFusedOpsConstParamPack_t *constPack,
 cudnnFusedOps_t ops);
```

This function creates an opaque structure to store the various problem size information, such as the shape, layout and the type of tensors, and the descriptors for convolution and activation, for the selected sequence of **cudnnFusedOps** computations.

Parameters

constPack

Input. The opaque structure that is created by this function. For more information, see cudnnFusedOpsConstParamPack_t.

ops

Input. The specific sequence of computations to perform in the **cudnnFusedOps** computations, as defined in the enumerant type cudnnFusedOps_t.

Returns

CUDNN_STATUS_BAD_PARAM

If either **constPack** or **ops** is **NULL**.

CUDNN_STATUS_SUCCESS

If the descriptor is created successfully.

CUDNN_STATUS_NOT_SUPPORTED

If the **ops** enum value is not supported or reserved for future use.

3.24. cudnnCreateFusedOpsPlan()

```
cudnnStatus_t cudnnCreateFusedOpsPlan(
 cudnnFusedOpsPlan_t *plan,
 cudnnFusedOps_t ops);
```

This function creates the plan descriptor for the **cudnnFusedOps** computation. This descriptor contains the plan information, including the problem type and size, which kernels should be run, and the internal workspace partition.

Parameters

plan
Input. A pointer to the instance of the descriptor created by this function.

ops
Input. The specific sequence of fused operations computations for which this plan descriptor should be created. For more information, see cudnnFusedOps_t.

Returns

CUDNN_STATUS_BAD_PARAM
If either the input ***plan** is **NULL** or the **ops** input is not a valid **cudnnFusedOp** enum.

CUDNN_STATUS_NOT_SUPPORTED
The **ops** input provided is not supported.

CUDNN_STATUS_SUCCESS
The plan descriptor is created successfully.

3.25. cudnnCreateFusedOpsVariantParamPack()

```
cudnnStatus_t cudnnCreateFusedOpsVariantParamPack(
 cudnnFusedOpsVariantParamPack_t *varPack,
 cudnnFusedOps_t ops);
```

This function creates a descriptor for **cudnnFusedOps** constant parameters.

Parameters

varPack
Input. Pointer to the descriptor created by this function. For more information, see cudnnFusedOpsVariantParamPack_t.

ops
Input. The specific sequence of fused operations computations for which this descriptor should be created.

Returns

CUDNN_STATUS_SUCCESS

The descriptor is successfully created.

CUDNN_STATUS_BAD_PARAM

If any input is invalid.

3.26. 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.

3.27. cudnnCreateOpTensorDescriptor()

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

This function creates a tensor pointwise math descriptor. For more information, see cudnnOpTensorDescriptor_t.

Parameters

opTensorDesc

Output. Pointer to the structure holding the description of the Tensor Pointwise math such as add, multiply, and more.

Returns

CUDNN_STATUS_SUCCESS

The function returned successfully.

CUDNN_STATUS_BAD_PARAM

Tensor pointwise math descriptor passed to the function is invalid.

CUDNN_STATUS_ALLOC_FAILED

Memory allocation for this tensor pointwise math descriptor failed.

3.28. 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. For more information, see cudnnRNNDescriptor_t, cudnnDataType_t, and cudnnPersistentRNNPlan_t.

Returns

CUDNN_STATUS_SUCCESS

The object was created successfully.

CUDNN_STATUS_ALLOC_FAILED

The resources could not be allocated.

CUDNN_STATUS_RUNTIME_PREREQUISITE_MISSING

A prerequisite runtime library cannot be found.

CUDNN_STATUS_NOT_SUPPORTED

The current hyperparameters are invalid.

3.29. 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.

3.30. cudnnCreateReduceTensorDescriptor()

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

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

Returns

CUDNN_STATUS_SUCCESS

The object was created successfully.

CUDNN_STATUS_BAD_PARAM

reduceTensorDesc is a **NULL** pointer.

CUDNN_STATUS_ALLOC_FAILED

The resources could not be allocated.

3.31. cudnnCreateRNNDataDescriptor()

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

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

Returns

CUDNN_STATUS_SUCCESS

The RNN data descriptor object was created successfully.

CUDNN_STATUS_BAD_PARAM

RNNDataDesc is **NULL**.

CUDNN_STATUS_ALLOC_FAILED

The resources could not be allocated.

3.32. 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.

3.33. cudnnCreateSeqDataDescriptor()

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

This function creates one instance of an opaque sequence data descriptor object by allocating the host memory for it and initializing all descriptor fields. The function writes **NULL** to **seqDataDesc** when the sequence data descriptor object cannot be allocated.

Use the cudnnSetSeqDataDescriptor() function to configure the sequence data descriptor and cudnnDestroySeqDataDescriptor() to destroy it and release the allocated memory.

Parameters

seqDataDesc

Output. Pointer where the address to the newly created sequence data descriptor should be written.

Returns

CUDNN_STATUS_SUCCESS

The descriptor object was created successfully.

CUDNN_STATUS_BAD_PARAM

An invalid input argument was encountered (**seqDataDesc=NULL**).

CUDNN_STATUS_ALLOC_FAILED

The memory allocation failed.

3.34. 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.

3.35. 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 all zeros.

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.

3.36. cudnnCreateTensorTransformDescriptor()

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

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

Parameters

transformDesc

Output. A pointer to an uninitialized tensor transform descriptor.

Returns

CUDNN_STATUS_SUCCESS

The descriptor object was created successfully.

CUDNN_STATUS_BAD_PARAM

The **transformDesc** is **NULL**.

CUDNN_STATUS_ALLOC_FAILED

The memory allocation failed.

3.37. cudnnCTCLoss()

```
cudnnStatus_t cudnnCTCLoss(
    cudnnHandle_t                         handle,
    const   cudnnTensorDescriptor_t       probsDesc,
    const   void                         *probs,
    const   int                          *labels,
    const   int                          *labelLengths,
    const   int                          *inputLengths,
    void                                 *costs,
    const   cudnnTensorDescriptor_t       gradientsDesc,
    const   void                         *gradients,
    cudnnCTCLossAlgo_t                    algo,
    const   cudnnCTCLossDescriptor_t      ctcLossDesc,
    void                                 *workspace,
    size_t                               *workSpaceSizeInBytes)
```

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

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

Parameters

handle

Input. Handle to a previously created cuDNN context. For more information, see cudnnHandle_t.

probsDesc

Input. Handle to the previously initialized probabilities tensor descriptor. For more information, see cudnnTensorDescriptor_t.

probs

Input. Pointer to a previously initialized probabilities tensor. These input probabilities are normalized by softmax.

labels

Input. Pointer to a previously initialized labels list.

`labelLengths`

Input. Pointer to a previously initialized lengths list, to walk the above labels list.

`inputLengths`

Input. Pointer to a previously initialized list of the lengths of the timing steps in each batch.

`costs`

Output. Pointer to the computed costs of CTC.

`gradientsDesc`

Input. Handle to a previously initialized gradients tensor descriptor.

`gradients`

Output. Pointer to the computed gradients of CTC. These computed gradient outputs are with respect to the unnormalized activation.

`algo`

Input. Enumerant that specifies the chosen CTC loss algorithm. For more information, see cudnnCTCLossAlgo_t.

`ctcLossDesc`

Input. Handle to the previously initialized CTC loss descriptor. For more information, see cudnnCTCLossDescriptor_t.

`workspace`

Input. Pointer to GPU memory of a workspace needed to able to execute the specified algorithm.

`sizeInBytes`

Input. Amount of GPU memory needed as workspace to be able to execute the CTC loss computation with the specified **`algo`**.

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.

3.38. cudnnDeriveBNTensorDescriptor()

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

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

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

The resulting dimensions will be:

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

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

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

Parameters

derivedBnDesc

Output. Handle to a previously created tensor descriptor.

xDesc

Input. Handle to a previously created and initialized layer's **x** data descriptor.

mode

Input. Batch normalization layer mode of operation.

Returns

CUDNN_STATUS_SUCCESS

The computation was performed successfully.

CUDNN_STATUS_BAD_PARAM

Invalid Batch Normalization mode.

3.39. cudnnDestroy()

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

This function releases the 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.

3.40. cudnnDestroyActivationDescriptor()

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

This function destroys a previously created activation descriptor object.

Returns

CUDNN_STATUS_SUCCESS

The object was destroyed successfully.

3.41. cudnnDestroyAlgorithmDescriptor()

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

This function destroys a previously created algorithm descriptor object.

Returns

CUDNN_STATUS_SUCCESS

The object was destroyed successfully.

3.42. cudnnDestroyAlgorithmPerformance()

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

This function destroys a previously created algorithm descriptor object.

Returns

CUDNN_STATUS_SUCCESS

The object was destroyed successfully.

3.43. cudnnDestroyAttnDescriptor()

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

This function destroys the attention descriptor object and releases its memory. The **attnDesc** argument can be **NULL**. Invoking **cudnnDestroyAttnDescriptor()** with a **NULL** argument is a no operation (NOP).

The **cudnnDestroyAttnDescriptor()** function is not able to detect if the **attnDesc** argument holds a valid address. Undefined behavior will occur in case of passing an invalid pointer, not returned by the cudnnCreateAttnDescriptor() function, or in the double deletion scenario of a valid address.

Parameters

attnDesc

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

Returns

CUDNN_STATUS_SUCCESS

The descriptor was destroyed successfully.

3.44. cudnnDestroyConvolutionDescriptor()

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

This function destroys a previously created convolution descriptor object.

Returns

CUDNN_STATUS_SUCCESS

The descriptor was destroyed successfully.

3.45. 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.

3.46. 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.

3.47. cudnnDestroyFilterDescriptor()

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

This function destroys a previously created tensor 4D descriptor object.

Returns

CUDNN_STATUS_SUCCESS

The object was destroyed successfully.

3.48. cudnnDestroyFusedOpsConstParamPack()

```
cudnnStatus_t cudnnDestroyFusedOpsConstParamPack(
 cudnnFusedOpsConstParamPack_t constPack);
```

This function destroys a previously-created cudnnFusedOpsConstParamPack_t structure.

Parameters

constPack

Input. The cudnnFusedOpsConstParamPack_t structure that should be destroyed.

Returns

CUDNN_STATUS_SUCCESS

If the descriptor is destroyed successfully.

CUDNN_STATUS_INTERNAL_ERROR

If the ops enum value is not supported or invalid.

3.49. cudnnDestroyFusedOpsPlan()

```
cudnnStatus_t cudnnDestroyFusedOpsPlan(
 cudnnFusedOpsPlan_t plan);
```

This function destroys the plan descriptor provided.

Parameters

plan

Input. The descriptor that should be destroyed by this function.

Returns

CUDNN_STATUS_SUCCESS

If either the plan descriptor is **NULL** or the descriptor is successfully destroyed.

3.50. cudnnDestroyFusedOpsVariantParamPack()

```
cudnnStatus_t cudnnDestroyFusedOpsVariantParamPack(
```

```
cudnnFusedOpsVariantParamPack_t varPack);
```

This function destroys a previously-created descriptor for **cudnnFusedOps** constant parameters.

Parameters

varPack

Input. The descriptor that should be destroyed.

Returns

CUDNN_STATUS_SUCCESS

The descriptor is successfully destroyed.

3.51. 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.

3.52. 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.

3.53. 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.

3.54. 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.

3.55. 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.

3.56. cudnnDestroyRNNDataDescriptor()

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

This function destroys a previously created RNN data descriptor object.

Returns

CUDNN_STATUS_SUCCESS

The RNN data descriptor object was destroyed successfully.

3.57. 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.

3.58. cudnnDestroySeqDataDescriptor()

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

This function destroys the sequence data descriptor object and releases its memory. The **seqDataDesc** argument can be **NULL**. Invoking **cudnnDestroySeqDataDescriptor()** with a **NULL** argument is a no operation (NOP).

The **cudnnDestroySeqDataDescriptor()** function is not able to detect if the **seqDataDesc** argument holds a valid address. Undefined behavior will occur in case of passing an invalid pointer, not returned by the cudnnCreateSeqDataDescriptor() function, or in the double deletion scenario of a valid address.

Parameters

seqDataDesc

Input. Pointer to the sequence data descriptor object to be destroyed.

Returns

CUDNN_STATUS_SUCCESS

The descriptor was destroyed successfully.

3.59. 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.

3.60. 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.

3.61. cudnnDestroyTensorTransformDescriptor()

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

Destroys a previously created tensor transform descriptor.

Parameters

transformDesc

Input. The tensor transform descriptor to be destroyed.

Returns

CUDNN_STATUS_SUCCESS

The descriptor was destroyed successfully.

3.62. 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:

```
dstValue = alpha[0]*resultValue + beta[0]*priorDstValue
```

For more information, see Scaling Parameters in the *cuDNN Developer Guide*.

xDesc, x, means

Input. Tensor descriptor and pointers in device memory for the layer's x and means data. Note that the **means** tensor is expected to be precomputed by the user. It can also contain any valid values (not required to be actual **means**, and can be for instance a result of a convolution with a Gaussian kernel).

dy

Input. Tensor pointer in device memory for the layer's **dy** cumulative loss differential data (error backpropagation).

temp, temp2

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

dxDesc

Input. Tensor descriptor for **dx** and **dMeans**.

dx, dMeans

Output. Tensor pointers (in device memory) for the layers resulting cumulative gradients **dx** and **dMeans** (**dLoss/dx** and **dLoss/dMeans**). Both share the same descriptor.

Returns

CUDNN_STATUS_SUCCESS

The computation was performed successfully.

CUDNN_STATUS_BAD_PARAM

At least one of the following conditions are met:

- One of the tensor pointers **x, dx, temp, tmep2, dy** is **NULL**.
- Number of any of the input or output tensor dimensions is not within the [4,5] range.
- Either alpha or beta pointer is **NULL**.
- A mismatch in dimensions between **xDesc** and **dxDesc**.
- LRN descriptor parameters are outside of their valid ranges.
- Any of the tensor strides is negative.

CUDNN_STATUS_UNSUPPORTED

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

3.63. cudnnDivisiveNormalizationForward()

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

This function performs the forward spatial **DivisiveNormalization** layer computation. It divides every value in a layer by the standard deviation of its spatial neighbors as described in *What is the Best Multi-Stage Architecture for Object Recognition*, Jarrett 2009, Local Contrast Normalization Layer section. Note that **DivisiveNormalization** only implements the **x/max(c, sigma_x)** portion of the computation, where **sigma_x** is the variance over the spatial neighborhood of **x**. The full LCN (Local Contrastive Normalization) computation can be implemented as a two-step process:

```
x_m = x-mean(x);
y = x_m/max(c, sigma(x_m));
```

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

Supported tensor formats are NCHW for 4D and NCDHW for 5D with any non-overlapping non-negative strides. Only 4D and 5D tensors are supported.

Parameters

handle

Input. Handle to a previously created cuDNN library descriptor.

normDesc

Input. Handle to a previously 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:

```
dstValue = alpha[0]*resultValue + beta[0]*priorDstValue
```

For more information, see Scaling Parameters in the *cuDNN Developer Guide*.

xDesc, yDesc

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

x

Input. Input tensor data pointer in device memory.

means

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

temp, temp2

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

y

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

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, for example, any of the input and output tensor strides mismatch (for the same dimension) is a non-supported configuration.

3.64. cudnnDropoutBackward()

```
cudnnStatus_t cudnnDropoutBackward(
    cudnnHandle_t                      handle,
    const cudnnDropoutDescriptor_t     dropoutDesc,
    const cudnnTensorDescriptor_t      dydesc,
    const void                        *dy,
    const cudnnTensorDescriptor_t      dxdesc,
    void                              *dx,
    void                              *reserveSpace,
    size_t                             reserveSpaceSizeInBytes)
```

This function performs backward dropout operation over **dy** returning results in **dx**. If during forward dropout operation value from **x** was propagated to **y** then during backward operation value from **dy** will be propagated to **dx**, otherwise, **dx** value will be set to **0**.

Better performance is obtained for fully packed tensors.

Parameters

handle

Input. Handle to a previously created cuDNN context.

dropoutDesc

Input. Previously created dropout descriptor object.

dyDesc

Input. Handle to a previously initialized tensor descriptor.

dy

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

dxDesc

Input. Handle to a previously initialized tensor descriptor.

dx

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

reserveSpace

Input. Pointer to user-allocated GPU memory used by this function. It is expected that **reserveSpace** was populated during a call to **cudnnDropoutForward** and has not been changed.

reserveSpaceSizeInBytes

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

Returns

CUDNN_STATUS_SUCCESS

The call was successful.

CUDNN_STATUS_NOT_SUPPORTED

The function does not support the provided configuration.

CUDNN_STATUS_BAD_PARAM

At least one of the following conditions are met:

- The number of elements of input tensor and output tensors differ.
- The **datatype** of the input tensor and output tensors differs.
- The strides of the input tensor and output tensors differ and in-place operation is used (i.e., **x** and **y** pointers are equal).
- The provided **reserveSpaceSizeInBytes** is less then the value returned by **cudnnDropoutGetReserveSpaceSize**.
- **cudnnSetDropoutDescriptor** has not been called on **dropoutDesc** with the non-**NULL** **states** argument.

CUDNN_STATUS_EXECUTION_FAILED

The function failed to launch on the GPU.

3.65. cudnnDropoutForward()

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

This function performs forward dropout operation over **x** returning results in **y**. If **dropout** was used as a parameter to cudnnSetDropoutDescriptor(), the approximately **dropout** fraction of **x** values will be replaced by a **0**, and the rest will be scaled by

1/(1-dropout). This function should not be running concurrently with another **cudnnDropoutForward()** function using the same **states**.

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

Parameters

handle

Input. Handle to a previously created cuDNN context.

dropoutDesc

Input. Previously created dropout descriptor object.

xDesc

Input. Handle to a previously initialized tensor descriptor.

x

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

yDesc

Input. Handle to a previously initialized tensor descriptor.

y

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

reserveSpace

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

reserveSpaceSizeInBytes

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

Returns

CUDNN_STATUS_SUCCESS

The call was successful.

CUDNN_STATUS_NOT_SUPPORTED

The function does not support the provided configuration.

CUDNN_STATUS_BAD_PARAM

At least one of the following conditions are met:

- The number of elements of input tensor and output tensors differ.
- The **datatype** of the input tensor and output tensors differs.

- The strides of the input tensor and output tensors differ and in-place operation is used (meaning, **x** and **y** pointers are equal).
- The provided **reserveSpaceSizeInBytes** is less than the value returned by cudnnDropoutGetReserveSpaceSize().
- cudnnSetDropoutDescriptor() has not been called on **dropoutDesc** with the non-**NULL** **states** argument.

CUDNN_STATUS_EXECUTION_FAILED

The function failed to launch on the GPU.

3.66. cudnnDropoutGetReserveSpaceSize()

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

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

Parameters

xDesc

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

sizeInBytes

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

Returns

CUDNN_STATUS_SUCCESS

The query was successful.

3.67. cudnnDropoutGetStatesSize()

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

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

Parameters

handle

Input. Handle to a previously created cuDNN context.

sizeInBytes

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

Returns

CUDNN_STATUS_SUCCESS

The query was successful.

3.68. 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 algorithms available for cudnnConvolutionBackwardData(). It will attempt both the provided **convDesc mathType** and **CUDNN_DEFAULT_MATH** (assuming the two differ).

> Algorithms without the **CUDNN_TENSOR_OP_MATH** availability will only be tried with **CUDNN_DEFAULT_MATH**, and returned as such.

Memory is allocated via **cudaMalloc()**. The performance metrics are returned in the user-allocated array of cudnnConvolutionBwdDataAlgoPerf_t. These metrics are written in a sorted fashion where the first element has the lowest compute time. The total number of resulting algorithms can be queried through the API cudnnGetConvolutionBackwardDataAlgorithmMaxCount().

> - This function is host blocking.
> - It is recommended to run this function prior to allocating layer data; doing otherwise may needlessly inhibit some algorithm options due to resource usage.

Parameters

handle

Input. Handle to a previously created cuDNN context.

wDesc

Input. Handle to a previously initialized filter descriptor.

dyDesc

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

convDesc

Input. Previously initialized convolution descriptor.

dxDesc

Input. Handle to the previously initialized output tensor descriptor.

requestedAlgoCount

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

returnedAlgoCount

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

perfResults

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

Returns

CUDNN_STATUS_SUCCESS

The query was successful.

CUDNN_STATUS_BAD_PARAM

At least one of the following conditions are met:

- **handle** is not allocated properly.
- **wDesc**, **dyDesc**, or **dxDesc** is not allocated properly.
- **wDesc**, **dyDesc**, or **dxDesc** has fewer than 1 dimension.
- Either **returnedCount** or **perfResults** is nil.
- **requestedCount** is less than 1.

CUDNN_STATUS_ALLOC_FAILED

This function was unable to allocate memory to store sample input, filters and output.

CUDNN_STATUS_INTERNAL_ERROR

At least one of the following conditions are met:

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

3.69. cudnnFindConvolutionBackwardDataAlgorithmEx()

```
cudnnStatus_t cudnnFindConvolutionBackwardDataAlgorithmEx(
    cudnnHandle_t                          handle,
    const cudnnFilterDescriptor_t          wDesc,
    const void                            *w,
    const cudnnTensorDescriptor_t          dyDesc,
    const void                            *dy,
    const cudnnConvolutionDescriptor_t     convDesc,
    const cudnnTensorDescriptor_t          dxDesc,
    void                                  *dx,
    const int                              requestedAlgoCount,
    int                                   *returnedAlgoCount,
    cudnnConvolutionBwdDataAlgoPerf_t     *perfResults,
    void                                  *workSpace,
    size_t                                 workSpaceSizeInBytes)
```

This function attempts all algorithms available for cudnnConvolutionBackwardData(). It will attempt both the provided **convDesc mathType** and **CUDNN_DEFAULT_MATH** (assuming the two differ).

> Algorithms without the **CUDNN_TENSOR_OP_MATH** availability will only be tried with **CUDNN_DEFAULT_MATH**, and returned as such.

Memory is allocated via **cudaMalloc()**. The performance metrics are returned in the user-allocated array of cudnnConvolutionBwdDataAlgoPerf_t. These metrics are written in a sorted fashion where the first element has the lowest compute time. The total number of resulting algorithms can be queried through the API cudnnGetConvolutionBackwardDataAlgorithmMaxCount().

> 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**.

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.

3.70. 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 algorithms available for cudnnConvolutionBackwardFilter(). It will attempt both the provided **convDesc mathType** and **CUDNN_DEFAULT_MATH** (assuming the two differ).

> Algorithms without the **CUDNN_TENSOR_OP_MATH** availability will only be tried with **CUDNN_DEFAULT_MATH**, and returned as such.

Memory is allocated via **cudaMalloc()**. The performance metrics are returned in the user-allocated array of cudnnConvolutionBwdFilterAlgoPerf_t. These metrics are written in a sorted fashion where the first element has the lowest compute time. The total number of resulting algorithms can be queried through the API cudnnGetConvolutionBackwardFilterAlgorithmMaxCount().

> - This function is host blocking.
> - It is recommended to run this function prior to allocating layer data; doing otherwise may needlessly inhibit some algorithm options due to resource usage.

Parameters

handle

Input. Handle to a previously created cuDNN context.

xDesc

Input. Handle to the previously initialized input tensor descriptor.

dyDesc

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

convDesc

Input. Previously initialized convolution descriptor.

dwDesc

Input. Handle to a previously initialized filter descriptor.

requestedAlgoCount

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

returnedAlgoCount

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

perfResults

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

Returns

CUDNN_STATUS_SUCCESS

The query was successful.

CUDNN_STATUS_BAD_PARAM

At least one of the following conditions are met:

- **handle** is not allocated properly.
- **xDesc**, **dyDesc**, or **dwDesc** 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.

3.71. 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 algorithms available for cudnnConvolutionBackwardFilter(). It will attempt both the provided **convDesc mathType** and **CUDNN_DEFAULT_MATH** (assuming the two differ).

> Algorithms without the **CUDNN_TENSOR_OP_MATH** availability will only be tried with **CUDNN_DEFAULT_MATH**, and returned as such.

Memory is allocated via **cudaMalloc()**. The performance metrics are returned in the user-allocated array of cudnnConvolutionBwdFilterAlgoPerf_t. These metrics are written in a sorted fashion where the first element has the lowest compute time. The total number of resulting algorithms can be queried through the API cudnnGetConvolutionBackwardFilterAlgorithmMaxCount().

> 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**.

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.

3.72. 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 algorithms available for cudnnConvolutionForward(). It will attempt both the provided **convDesc mathType** and **CUDNN_DEFAULT_MATH** (assuming the two differ).

> Algorithms without the **CUDNN_TENSOR_OP_MATH** availability will only be tried with **CUDNN_DEFAULT_MATH**, and returned as such.

Memory is allocated via **cudaMalloc()**. The performance metrics are returned in the user-allocated array of cudnnConvolutionFwdAlgoPerf_t. These metrics are written in a sorted fashion where the first element has the lowest compute time. The total number of resulting algorithms can be queried through the API cudnnGetConvolutionForwardAlgorithmMaxCount().

> - This function is host blocking.
> - It is recommended to run this function prior to allocating layer data; doing otherwise may needlessly inhibit some algorithm options due to resource usage.

Parameters

handle

Input. Handle to a previously created cuDNN context.

xDesc

Input. Handle to the previously initialized input tensor descriptor.

wDesc

Input. Handle to a previously initialized filter descriptor.

convDesc

Input. Previously initialized convolution descriptor.

yDesc

Input. Handle to the previously initialized output tensor descriptor.

requestedAlgoCount

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

returnedAlgoCount

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

perfResults

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

Returns

CUDNN_STATUS_SUCCESS

The query was successful.

CUDNN_STATUS_BAD_PARAM

At least one of the following conditions are met:

- **handle** is not allocated properly.
- **xDesc**, **wDesc**, or **yDesc** 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.

3.73. 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 algorithms available for cudnnConvolutionForward(). It will attempt both the provided **convDesc mathType** and **CUDNN_DEFAULT_MATH** (assuming the two differ).

> Algorithms without the **CUDNN_TENSOR_OP_MATH** availability will only be tried with **CUDNN_DEFAULT_MATH**, and returned as such.

Memory is allocated via **cudaMalloc()**. The performance metrics are returned in the user-allocated array of cudnnConvolutionFwdAlgoPerf_t. These metrics are written in a sorted fashion where the first element has the lowest compute time. The total number of resulting algorithms can be queried through the API cudnnGetConvolutionForwardAlgorithmMaxCount().

> 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**.

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.

3.74. 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)
```

This function attempts all available cuDNN algorithms for cudnnRNNBackwardData(), using user-allocated GPU memory. It outputs the parameters that influence the performance of the algorithm to a user-allocated array of **cudnnAlgorithmPerformance_t**. These parameter metrics are written in sorted fashion where the first element has the lowest compute time.

Parameters

handle

Input. Handle to a previously created cuDNN context.

rnnDesc

Input. A previously initialized RNN descriptor.

seqLength

Input. Number of iterations to unroll over. The value of this **seqLength** must not exceed the value that was used in cudnnGetRNNWorkspaceSize() function for querying the workspace size required to execute the RNN.

yDesc

Input. An array of fully packed tensor descriptors describing the output from each recurrent iteration (one descriptor per iteration). The second dimension of the tensor depends on the **direction** argument passed to the cudnnSetRNNDescriptor() call used to initialize **rnnDesc**:

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

The first dimension of the tensor **n** must match the first dimension of the tensor **n** in **dyDesc**.

y

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

dyDesc

Input. An array of fully packed tensor descriptors describing the gradient at the output from each recurrent iteration (one descriptor per iteration). The second dimension of the tensor depends on the **direction** argument passed to the cudnnSetRNNDescriptor() call used to initialize **rnnDesc**:

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

The first dimension of the tensor **n** must match the second dimension of the tensor **n** in **dxDesc**.

dy

Input. Data pointer to GPU memory associated with the tensor descriptors in the array **dyDesc**.

dhyDesc

Input. A fully packed tensor descriptor describing the gradients at the final hidden state of the RNN. The first dimension of the tensor depends on the **direction** argument passed to the cudnnSetRNNDescriptor() call used to initialize **rnnDesc**:

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

The second dimension must match the first dimension of the tensors described in **dxDesc**. The third dimension must match the **hiddenSize** argument passed to the cudnnSetRNNDescriptor() call used to initialize **rnnDesc**. The tensor must be fully packed.

dhy

Input. Data pointer to GPU memory associated with the tensor descriptor **dhyDesc**. If a **NULL** pointer is passed, the gradients at the final hidden state of the network will be initialized to zero.

dcyDesc

Input. A fully packed tensor descriptor describing the gradients at the final cell state of the RNN. The first dimension of the tensor depends on the **direction** argument passed to the cudnnSetRNNDescriptor() call used to initialize **rnnDesc**:

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

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

cudnnSetRNNDescriptor() call used to initialize **rnnDesc**. The tensor must be fully packed.

dcy

Input. Data pointer to GPU memory associated with the tensor descriptor **dcyDesc**. If a **NULL** pointer is passed, the gradients at the final cell state of the network will be initialized to zero.

wDesc

Input. Handle to a previously initialized filter descriptor describing the weights for the RNN.

w

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

hxDesc

Input. A fully packed tensor descriptor describing the initial hidden state of the RNN. The first dimension of the tensor depends on the **direction** argument passed to the cudnnSetRNNDescriptor() call used to initialize **rnnDesc**:

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

The second dimension must match the first dimension of the tensors described in **dxDesc**. The third dimension must match the **hiddenSize** argument passed to the cudnnSetRNNDescriptor() call used to initialize **rnnDesc**. The tensor must be fully packed.

hx

Input. Data pointer to GPU memory associated with the tensor descriptor **hxDesc**. If a **NULL** pointer is passed, the initial hidden state of the network will be initialized to zero.

cxDesc

Input. A fully packed tensor descriptor describing the initial cell state for LSTM networks. The first dimension of the tensor depends on the **direction** argument passed to the cudnnSetRNNDescriptor() call used to initialize **rnnDesc**:

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

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

cudnnSetRNNDescriptor() call used to initialize **rnnDesc**. The tensor must be fully packed.

cx

Input. Data pointer to GPU memory associated with the tensor descriptor **cxDesc**. If a **NULL** pointer is passed, the initial cell state of the network will be initialized to zero.

dxDesc

Input. An array of fully packed tensor descriptors describing the gradient at the input of each recurrent iteration (one descriptor per iteration). The first dimension (batch size) of the tensors may decrease from element **n** to element **n+1** but may not increase. Each tensor descriptor must have the same second dimension (vector length).

dx

Output. Data pointer to GPU memory associated with the tensor descriptors in the array **dxDesc**.

dhxDesc

Input. A fully packed tensor descriptor describing the gradient at the initial hidden state of the RNN. The first dimension of the tensor depends on the **direction** argument passed to the cudnnSetRNNDescriptor() call used to initialize **rnnDesc**:

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

The second dimension must match the first dimension of the tensors described in **dxDesc**. The third dimension must match the **hiddenSize** argument passed to the cudnnSetRNNDescriptor() call used to initialize **rnnDesc**. The tensor must be fully packed.

dhx

Output. Data pointer to GPU memory associated with the tensor descriptor **dhxDesc**. If a **NULL** pointer is passed, the gradient at the hidden input of the network will not be set.

dcxDesc

Input. A fully packed tensor descriptor describing the gradient at the initial cell state of the RNN. The first dimension of the tensor depends on the **direction** argument passed to the cudnnSetRNNDescriptor() call used to initialize **rnnDesc**:

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

The second dimension must match the first dimension of the tensors described in **`dxDesc`**. The third dimension must match the **`hiddenSize`** argument passed to the cudnnSetRNNDescriptor() call used to initialize **`rnnDesc`**. The tensor must be fully packed.

`dcx`

Output. Data pointer to GPU memory associated with the tensor descriptor **`dcxDesc`**. If a **`NULL`** pointer is passed, the gradient at the cell input of the network will not be set.

`findIntensity`

Input.This input was previously unused in versions prior to 7.2.0. It is used in cuDNN 7.2.0 and later versions to control the overall runtime of the RNN find algorithms, by selecting the percentage of a large Cartesian product space to be searched.

- Setting **`findIntensity`** within the range (0,1.] will set a percentage of the entire RNN search space to search. When **`findIntensity`** is set to 1.0, a full search is performed over all RNN parameters.
- When **`findIntensity`** is set to 0.0f, a quick, minimal search is performed. This setting has the best runtime. However, in this case the parameters returned by this function will not correspond to the best performance of the algorithm; a longer search might discover better parameters. This option will execute up to three instances of the configured RNN problem. Runtime will vary proportionally to RNN problem size, as it will in the other cases, hence no guarantee of an explicit time bound can be given.
- Setting **`findIntensity`** within the range [-1.,0) sets a percentage of a reduced Cartesian product space to be searched. This reduced search space has been heuristically selected to have good performance. The setting of -1.0 represents a full search over this reduced search space.
- Values outside the range [-1,1] are truncated to the range [-1,1], and then interpreted as per the above.
- Setting **`findIntensity`** to 1.0 in cuDNN 7.2 and later versions is equivalent to the behavior of this function in versions prior to cuDNN 7.2.0.
- This function times the single RNN executions over large parameter spaces - one execution per parameter combination. The times returned by this function are latencies.

`requestedAlgoCount`

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

`returnedAlgoCount`

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

perfResults

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

workspace

Input. Data pointer to GPU memory to be used as a workspace for this call.

workSpaceSizeInBytes

Input. Specifies the size in bytes of the provided **workspace**.

reserveSpace

Input/Output. Data pointer to GPU memory to be used as a reserve space for this call.

reserveSpaceSizeInBytes

Input. Specifies the size in bytes of the provided **reserveSpace**.

Returns

CUDNN_STATUS_SUCCESS

The function launched successfully.

CUDNN_STATUS_NOT_SUPPORTED

The function does not support the provided configuration.

CUDNN_STATUS_BAD_PARAM

At least one of the following conditions are met:

- The descriptor **rnnDesc** is invalid.
- At least one of the descriptors **dhxDesc, wDesc, hxDesc, cxDesc, dcxDesc, dhyDesc, 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.

3.75. 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)
```

This function attempts all available cuDNN algorithms for cudnnRNNBackwardWeights(), using user-allocated GPU memory. It outputs the parameters that influence the performance of the algorithm to a user-allocated array of **cudnnAlgorithmPerformance_t**. These parameter metrics are written in sorted fashion where the first element has the lowest compute time.

Parameters

handle

Input. Handle to a previously created cuDNN context.

rnnDesc

Input. A previously initialized RNN descriptor.

seqLength

Input. Number of iterations to unroll over. The value of this **seqLength** must not exceed the value that was used in cudnnGetRNNWorkspaceSize() function for querying the workspace size required to execute the RNN.

xDesc

Input. An array of fully packed tensor descriptors describing the input to each recurrent iteration (one descriptor per iteration). The first dimension (batch size) of the tensors may decrease from element **n** to element **n+1** but may not increase. Each tensor descriptor must have the same second dimension (vector length).

x

Input. Data pointer to GPU memory associated with the tensor descriptors in the array **xDesc**.

hxDesc

Input. A fully packed tensor descriptor describing the initial hidden state of the RNN. The first dimension of the tensor depends on the **direction** argument passed to the cudnnSetRNNDescriptor() call used to initialize **rnnDesc**:

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

The second dimension must match the first dimension of the tensors described in **xDesc**. The third dimension must match the **hiddenSize** argument passed to the cudnnSetRNNDescriptor() call used to initialize **rnnDesc**. The tensor must be fully packed.

hx

Input. Data pointer to GPU memory associated with the tensor descriptor **hxDesc**. If a **NULL** pointer is passed, the initial hidden state of the network will be initialized to zero.

yDesc

Input. An array of fully packed tensor descriptors describing the output from each recurrent iteration (one descriptor per iteration). The second dimension of the tensor depends on the **direction** argument passed to the cudnnSetRNNDescriptor() call used to initialize **rnnDesc**:

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

The first dimension of the tensor **n** must match the first dimension of the tensor **n** in **dyDesc**.

y

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

findIntensity

Input.This input was previously unused in versions prior to 7.2.0. It is used in cuDNN 7.2.0 and later versions to control the overall runtime of the RNN find algorithms, by selecting the percentage of a large Cartesian product space to be searched.

- Setting **findIntensity** within the range (0,1.] will set a percentage of the entire RNN search space to search. When **findIntensity** is set to 1.0, a full search is performed over all RNN parameters.

- When **`findIntensity`** is set to 0.0f, a quick, minimal search is performed. This setting has the best runtime. However, in this case the parameters returned by this function will not correspond to the best performance of the algorithm; a longer search might discover better parameters. This option will execute up to three instances of the configured RNN problem. Runtime will vary proportionally to RNN problem size, as it will in the other cases, hence no guarantee of an explicit time bound can be given.
- Setting **`findIntensity`** within the range [-1.,0) sets a percentage of a reduced Cartesian product space to be searched. This reduced search space has been heuristically selected to have good performance. The setting of -1.0 represents a full search over this reduced search space.
- Values outside the range [-1,1] are truncated to the range [-1,1], and then interpreted as per the above.
- Setting **`findIntensity`** to 1.0 in cuDNN 7.2 and later versions is equivalent to the behavior of this function in versions prior to cuDNN 7.2.0.
- This function times the single RNN executions over large parameter spaces - one execution per parameter combination. The times returned by this function are latencies.

`requestedAlgoCount`

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

`returnedAlgoCount`

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

`perfResults`

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

`workspace`

Input. Data pointer to GPU memory to be used as a workspace for this call.

`workSpaceSizeInBytes`

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

`dwDesc`

Input. Handle to a previously initialized filter descriptor describing the gradients of the weights for the RNN.

`dw`

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

`reserveSpace`

Input. Data pointer to GPU memory to be used as a reserve space for this call.

reserveSpaceSizeInBytes

Input. Specifies the size in bytes of the provided **reserveSpace**.

Returns

CUDNN_STATUS_SUCCESS

The function launched successfully.

CUDNN_STATUS_NOT_SUPPORTED

The function does not support the provided configuration.

CUDNN_STATUS_BAD_PARAM

At least one of the following conditions are met:

- The descriptor **rnnDesc** is invalid.
- At least one of the descriptors **hxDesc, dwDesc** or one of the descriptors in **xDesc, yDesc** is invalid.
- The descriptors in one of **xDesc, hxDesc, yDesc, 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.

3.76. 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)
```

This function attempts all available cuDNN algorithms for cudnnRNNForwardInference(), using user-allocated GPU memory. It outputs the parameters that influence the performance of the algorithm to a user-allocated array of **cudnnAlgorithmPerformance_t**. These parameter metrics are written in sorted fashion where the first element has the lowest compute time.

Parameters

handle

Input. Handle to a previously created cuDNN context.

rnnDesc

Input. A previously initialized RNN descriptor.

seqLength

Input. Number of iterations to unroll over. The value of this **seqLength** must not exceed the value that was used in cudnnGetRNNWorkspaceSize() function for querying the workspace size required to execute the RNN.

xDesc

Input. An array of fully packed tensor descriptors describing the input to each recurrent iteration (one descriptor per iteration). The first dimension (batch size) of the tensors may decrease from element **n** to element **n+1** but may not increase. Each tensor descriptor must have the same second dimension (vector length).

x

Input. Data pointer to GPU memory associated with the tensor descriptors in the array **xDesc**. The data are expected to be packed contiguously with the first element of iteration **n+1** following directly from the last element of iteration **n**.

hxDesc

Input. A fully packed tensor descriptor describing the initial hidden state of the RNN. The first dimension of the tensor depends on the **direction** argument passed to the cudnnSetRNNDescriptor() call used to initialize **rnnDesc**:

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

The second dimension must match the first dimension of the tensors described in **xDesc**. The third dimension must match the **hiddenSize** argument passed to the cudnnSetRNNDescriptor() call used to initialize **rnnDesc**. The tensor must be fully packed.

hx

Input. Data pointer to GPU memory associated with the tensor descriptor **hxDesc**. If a **NULL** pointer is passed, the initial hidden state of the network will be initialized to zero.

cxDesc

Input. A fully packed tensor descriptor describing the initial cell state for LSTM networks. The first dimension of the tensor depends on the **direction** argument passed to the cudnnSetRNNDescriptor() call used to initialize **rnnDesc**:

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

The second dimension must match the first dimension of the tensors described in **xDesc**. The third dimension must match the **hiddenSize** argument passed to the cudnnSetRNNDescriptor() call used to initialize **rnnDesc**. The tensor must be fully packed.

cx

Input. Data pointer to GPU memory associated with the tensor descriptor **cxDesc**. If a **NULL** pointer is passed, the initial cell state of the network will be initialized to zero.

wDesc

Input. Handle to a previously initialized filter descriptor describing the weights for the RNN.

w

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

yDesc

Input. An array of fully packed tensor descriptors describing the output from each recurrent iteration (one descriptor per iteration). The second dimension of the tensor depends on the **direction** argument passed to the cudnnSetRNNDescriptor() call used to initialize **rnnDesc**:

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

The first dimension of the tensor **n** must match the first dimension of the tensor **n** in **xDesc**.

y

Output. Data pointer to GPU memory associated with the output tensor descriptor **yDesc**. The data are expected to be packed contiguously with the first element of iteration **n+1** following directly from the last element of iteration **n**.

hyDesc

Input. A fully packed tensor descriptor describing the final hidden state of the RNN. The first dimension of the tensor depends on the **direction** argument passed to the cudnnSetRNNDescriptor() call used to initialize **rnnDesc**:

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

The second dimension must match the first dimension of the tensors described in **xDesc**. The third dimension must match the **hiddenSize** argument passed to the cudnnSetRNNDescriptor() call used to initialize **rnnDesc**. The tensor must be fully packed.

hy

Output. Data pointer to GPU memory associated with the tensor descriptor **hyDesc**. If a **NULL** pointer is passed, the final hidden state of the network will not be saved.

cyDesc

Input. A fully packed tensor descriptor describing the final cell state for LSTM networks. The first dimension of the tensor depends on the **direction** argument passed to the cudnnSetRNNDescriptor() call used to initialize **rnnDesc**:

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

The second dimension must match the first dimension of the tensors described in **xDesc**. The third dimension must match the **hiddenSize** argument passed to the cudnnSetRNNDescriptor() call used to initialize **rnnDesc**. The tensor must be fully packed.

cy

Output. Data pointer to GPU memory associated with the tensor descriptor **cyDesc**. If a **NULL** pointer is passed, the final cell state of the network will not be saved.

findIntensity

Input.This input was previously unused in versions prior to 7.2.0. It is used in cuDNN 7.2.0 and later versions to control the overall runtime of the RNN find algorithms, by selecting the percentage of a large Cartesian product space to be searched.

- Setting **`findIntensity`** within the range (0,1.] will set a percentage of the entire RNN search space to search. When **`findIntensity`** is set to 1.0, a full search is performed over all RNN parameters.
- When **`findIntensity`** is set to 0.0f, a quick, minimal search is performed. This setting has the best runtime. However, in this case the parameters returned by this function will not correspond to the best performance of the algorithm; a longer search might discover better parameters. This option will execute up to three instances of the configured RNN problem. Runtime will vary proportionally to RNN problem size, as it will in the other cases, hence no guarantee of an explicit time bound can be given.
- Setting **`findIntensity`** within the range [-1.,0) sets a percentage of a reduced Cartesian product space to be searched. This reduced search space has been heuristically selected to have good performance. The setting of -1.0 represents a full search over this reduced search space.
- Values outside the range [-1,1] are truncated to the range [-1,1], and then interpreted as per the above.
- Setting **`findIntensity`** to 1.0 in cuDNN 7.2 and later versions is equivalent to the behavior of this function in versions prior to cuDNN 7.2.0.
- This function times the single RNN executions over large parameter spaces - one execution per parameter combination. The times returned by this function are latencies.

`requestedAlgoCount`

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

`returnedAlgoCount`

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

`perfResults`

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

`workspace`

Input. Data pointer to GPU memory to be used as a workspace for this call.

`workSpaceSizeInBytes`

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

Returns

`CUDNN_STATUS_SUCCESS`

The function launched successfully.

`CUDNN_STATUS_NOT_SUPPORTED`

The function does not support the provided configuration.

CUDNN_STATUS_BAD_PARAM

At least one of the following conditions are met:

- The descriptor **rnnDesc** is invalid.
- At least one of the descriptors **hxDesc, cxDesc, wDesc, hyDesc, 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.

3.77. 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)
```

This function attempts all available cuDNN algorithms for cudnnRNNForwardTraining(), using user-allocated GPU memory. It outputs the parameters that influence the performance of the algorithm to a user-allocated array of **cudnnAlgorithmPerformance_t**. These parameter metrics are written in sorted fashion where the first element has the lowest compute time.

Parameters

handle

Input. Handle to a previously created cuDNN context.

rnnDesc

Input. A previously initialized RNN descriptor.

xDesc

Input. An array of fully packed tensor descriptors describing the input to each recurrent iteration (one descriptor per iteration). The first dimension (batch size) of the tensors may decrease from element **n** to element **n+1** but may not increase. Each tensor descriptor must have the same second dimension (vector length).

seqLength

Input. Number of iterations to unroll over. The value of this **seqLength** must not exceed the value that was used in cudnnGetRNNWorkspaceSize() function for querying the workspace size required to execute the RNN.

x

Input. Data pointer to GPU memory associated with the tensor descriptors in the array **xDesc**.

hxDesc

Input. A fully packed tensor descriptor describing the initial hidden state of the RNN. The first dimension of the tensor depends on the **direction** argument passed to the cudnnSetRNNDescriptor() call used to initialize **rnnDesc**:

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

The second dimension must match the first dimension of the tensors described in **xDesc**. The third dimension must match the **hiddenSize** argument passed to the cudnnSetRNNDescriptor() call used to initialize **rnnDesc**. The tensor must be fully packed.

hx

Input. Data pointer to GPU memory associated with the tensor descriptor **hxDesc**. If a **NULL** pointer is passed, the initial hidden state of the network will be initialized to zero.

cxDesc

Input. A fully packed tensor descriptor describing the initial cell state for LSTM networks. The first dimension of the tensor depends on the **direction** argument passed to the cudnnSetRNNDescriptor() call used to initialize **rnnDesc**:

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

The second dimension must match the first dimension of the tensors described in **xDesc**. The third dimension must match the **hiddenSize** argument passed to the cudnnSetRNNDescriptor() call used to initialize **rnnDesc**. The tensor must be fully packed.

cx

Input. Data pointer to GPU memory associated with the tensor descriptor **cxDesc**. If a **NULL** pointer is passed, the initial cell state of the network will be initialized to zero.

wDesc

Input. Handle to a previously initialized filter descriptor describing the weights for the RNN.

w

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

yDesc

Input. An array of fully packed tensor descriptors describing the output from each recurrent iteration (one descriptor per iteration). The second dimension of the tensor depends on the **direction** argument passed to the cudnnSetRNNDescriptor() call used to initialize **rnnDesc**:

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

The first dimension of the tensor **n** must match the first dimension of the tensor **n** in **xDesc**.

y

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

hyDesc

Input. A fully packed tensor descriptor describing the final hidden state of the RNN. The first dimension of the tensor depends on the **direction** argument passed to the cudnnSetRNNDescriptor() call used to initialize **rnnDesc**:

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

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

The second dimension must match the first dimension of the tensors described in **`xDesc`**. The third dimension must match the **`hiddenSize`** argument passed to the cudnnSetRNNDescriptor() call used to initialize **`rnnDesc`**. The tensor must be fully packed.

`hy`

Output. Data pointer to GPU memory associated with the tensor descriptor **`hyDesc`**. If a **`NULL`** pointer is passed, the final hidden state of the network will not be saved.

`cyDesc`

Input. A fully packed tensor descriptor describing the final cell state for LSTM networks. The first dimension of the tensor depends on the **`direction`** argument passed to the cudnnSetRNNDescriptor() call used to initialize **`rnnDesc`**:

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

The second dimension must match the first dimension of the tensors described in **`xDesc`**. The third dimension must match the **`hiddenSize`** argument passed to the cudnnSetRNNDescriptor() call used to initialize **`rnnDesc`**. The tensor must be fully packed.

`cy`

Output. Data pointer to GPU memory associated with the tensor descriptor **`cyDesc`**. If a **`NULL`** pointer is passed, the final cell state of the network will not be saved.

`findIntensity`

Input.This input was previously unused in versions prior to 7.2.0. It is used in cuDNN 7.2.0 and later versions to control the overall runtime of the RNN find algorithms, by selecting the percentage of a large Cartesian product space to be searched.

- Setting **`findIntensity`** within the range (0,1.] will set a percentage of the entire RNN search space to search. When **`findIntensity`** is set to 1.0, a full search is performed over all RNN parameters.
- When **`findIntensity`** is set to 0.0f, a quick, minimal search is performed. This setting has the best runtime. However, in this case the parameters returned by this function will not correspond to the best performance of the algorithm; a longer search might discover better parameters. This option will execute up to three instances of the configured RNN problem. Runtime will vary proportionally to RNN problem size, as it will in the other cases, hence no guarantee of an explicit time bound can be given.

- Setting **`findIntensity`** within the range [-1.,0) sets a percentage of a reduced Cartesian product space to be searched. This reduced search space has been heuristically selected to have good performance. The setting of -1.0 represents a full search over this reduced search space.
- Values outside the range [-1,1] are truncated to the range [-1,1], and then interpreted as per the above.
- Setting **`findIntensity`** to 1.0 in cuDNN 7.2 and later versions is equivalent to the behavior of this function in versions prior to cuDNN 7.2.0.
- This function times the single RNN executions over large parameter spaces - one execution per parameter combination. The times returned by this function are latencies.

`requestedAlgoCount`

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

`returnedAlgoCount`

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

`perfResults`

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

`workspace`

Input. Data pointer to GPU memory to be used as a workspace for this call.

`workSpaceSizeInBytes`

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

`reserveSpace`

Input/Output. Data pointer to GPU memory to be used as a reserve space for this call.

`reserveSpaceSizeInBytes`

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

Returns

`CUDNN_STATUS_SUCCESS`

The function launched successfully.

`CUDNN_STATUS_BAD_PARAM`

At least one of the following conditions are met:

- The descriptor **`rnnDesc`** is invalid.
- At least one of the descriptors **`hxDesc, cxDesc, wDesc, hyDesc, 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.

3.78. cudnnFusedOpsExecute()

```
cudnnStatus_t cudnnFusedOpsExecute(
 cudnnHandle_t handle,
 const cudnnFusedOpsPlan_t plan,
 cudnnFusedOpsVariantParamPack_t varPack);
```

This function executes the sequence of **cudnnFusedOps** operations.

Parameters

handle

Input. Pointer to the cuDNN library context.

plan

Input. Pointer to a previously-created and initialized plan descriptor.

varPack

Input. Pointer to the descriptor to the variant parameters pack.

Returns

CUDNN_STATUS_BAD_PARAM

If the type of cudnnFusedOps_t in the plan descriptor is unsupported.

3.79. 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**.

Returns

CUDNN_STATUS_SUCCESS

The object was queried successfully.

3.80. cudnnGetAlgorithmDescriptor()

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

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.

3.81. cudnnGetAlgorithmPerformance()

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

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.

3.82. cudnnGetAlgorithmSpaceSize()

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

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**.

3.83. cudnnGetAttnDescriptor()

```
cudnnStatus_t cudnnGetAttnDescriptor(
 cudnnAttnDescriptor_t attnDesc,
 cudnnAttnQueryMap_t *queryMap,
 int *nHeads,
 double *smScaler,
 cudnnDataType_t *dataType,
 cudnnDataType_t *computePrec,
 cudnnMathType_t *mathType,
 cudnnDropoutDescriptor_t *attnDropoutDesc,
 cudnnDropoutDescriptor_t *postDropoutDesc,
 int *qSize,
 int *kSize,
 int *vSize,
 int *qProjSize,
 int *kProjSize,
 int *vProjSize,
 int *oProjSize,
 int *qoMaxSeqLength,
 int *kvMaxSeqLength,
 int *maxBatchSize,
 int *maxBeamSize);
```

This function retrieves settings from the previously created attention descriptor. The user can assign **NULL** to any pointer except **attnDesc** when the retrieved value is not needed.

Parameters

attnDesc

Input. Attention descriptor.

attnMode

Output. Pointer to the storage for binary attention flags.

nHeads

Output. Pointer to the storage for the number of attention heads.

smScaler

Output. Pointer to the storage for the softmax smoothing/sharpening coefficient.

dataType

Output. Data type for attention weights, sequence data inputs, and outputs.

computePrec

Output. Pointer to the storage for the compute precision.

mathType

Output. NVIDIA Tensor Core settings.

attnDropoutDesc
Output. Descriptor of the dropout operation applied to the softmax output.

postDropoutDesc
Output. Descriptor of the dropout operation applied to the multi-head attention output.

qSize, kSize, vSize
Output. **Q, K**, and **V** embedding vector lengths.

qProjSize, kProjSize, vProjSize
Output. **Q, K**, and **V** embedding vector lengths after input projections.

oProjSize
Output. Pointer to store the output vector length after projection.

qoMaxSeqLength
Output. Largest sequence length expected in sequence data descriptors related to **Q, O, dQ, dO** inputs and outputs.

kvMaxSeqLength
Output. Largest sequence length expected in sequence data descriptors related to **K, V, dK, dV** inputs and outputs.

maxBatchSize
Output. Largest batch size expected in the cudnnSeqDataDescriptor_t container.

maxBeamSize
Output. Largest beam size expected in the cudnnSeqDataDescriptor_t container.

Returns

CUDNN_STATUS_SUCCESS
Requested attention descriptor fields were retrieved successfully.

CUDNN_STATUS_BAD_PARAM
An invalid input argument was found.

3.84. cudnnGetBatchNormalizationBackwardExWorkspaceSi

```
cudnnStatus_t cudnnGetBatchNormalizationBackwardExWorkspaceSize(
    cudnnHandle_t                    handle,
    cudnnBatchNormMode_t             mode,
    cudnnBatchNormOps_t              bnOps,
    const cudnnTensorDescriptor_t    xDesc,
    const cudnnTensorDescriptor_t    yDesc,
    const cudnnTensorDescriptor_t    dyDesc,
    const cudnnTensorDescriptor_t    dzDesc,
    const cudnnTensorDescriptor_t    dxDesc,
    const cudnnTensorDescriptor_t    dBnScaleBiasDesc,
    const cudnnActivationDescriptor_t   activationDesc,
    size_t                           *sizeInBytes);
```

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

Parameters

handle

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

mode

Input. Mode of operation (spatial or per-activation). For more information, see cudnnBatchNormMode_t.

bnOps

Input. Mode of operation for the fast NHWC kernel. For more information, see cudnnBatchNormOps_t. This input can be used to set this function to perform either only the batch normalization, or batch normalization followed by activation, or batch normalization followed by element-wise addition and then activation.

xDesc, yDesc, dyDesc, dzDesc, dxDesc

Tensor descriptors and pointers in the device memory for the layer's **x** data, back propagated differential **dy** (inputs), the optional **y** input data, the optional **dz** output, and the **dx** output, which is the resulting differential with respect to **x**. For more information, see cudnnTensorDescriptor_t.

dBnScaleBiasDesc

Input. Shared tensor descriptor for the following six tensors: **bnScaleData, bnBiasData, dBnScaleData, dBnBiasData, savedMean,** and **savedInvVariance**. This is the shared tensor descriptor desc for the secondary tensor that was derived by cudnnDeriveBNTensorDescriptor(). The dimensions for this tensor descriptor are dependent on normalization mode. Note that the data type of this tensor descriptor must be **float** for FP16 and FP32 input tensors, and **double** for FP64 input tensors.

activationDesc

Input. Descriptor for the activation operation. When the **bnOps** input is set to either **CUDNN_BATCHNORM_OPS_BN_ACTIVATION** or **CUDNN_BATCHNORM_OPS_BN_ADD_ACTIVATION**, then this activation is used, otherwise user may pass **NULL**.

***sizeInBytes**

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

Returns

CUDNN_STATUS_SUCCESS

The computation was performed successfully.

CUDNN_STATUS_NOT_SUPPORTED

The function does not support the provided configuration.

CUDNN_STATUS_BAD_PARAM

At least one of the following conditions are met:

- Number of **xDesc**, **yDesc** or **dxDesc** tensor descriptor dimensions is not within the range of [4,5] (only 4D and 5D tensors are supported).
- **dBnScaleBiasDesc** dimensions not 1xCx1x1 for 4D and 1xCx1x1x1 for 5D for spatial, and are not 1xCxHxW for 4D and 1xCxDxHxW for 5D for per-activation mode.
- Dimensions or data types mismatch for any pair of **xDesc, dyDesc, dxDesc**.

3.85. cudnnGetBatchNormalizationForwardTrainingExWorks

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

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

Parameters

handle

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

mode

Input. Mode of operation (spatial or per-activation). For more information, see cudnnBatchNormMode_t.

bnOps

Input. Mode of operation for the fast NHWC kernel. For more information, see cudnnBatchNormOps_t. This input can be used to set this function to perform either only the batch normalization, or batch normalization followed by activation, or batch normalization followed by element-wise addition and then activation.

xDesc, zDesc, yDesc

Tensor descriptors and pointers in the device memory for the layer's **x** data, the optional **z** input data, and the **y** output. **zDesc** is only needed when **bnOps** is **CUDNN_BATCHNORM_OPS_BN_ADD_ACTIVATION**, otherwise the user may pass **NULL**. For more information, see cudnnTensorDescriptor_t.

bnScaleBiasMeanVarDesc

Input. Shared tensor descriptor for the following six tensors: **bnScaleData, bnBiasData, dBnScaleData, dBnBiasData, savedMean,** and **savedInvVariance**. This is the shared tensor descriptor desc for the secondary tensor that was derived by cudnnDeriveBNTensorDescriptor(). The dimensions for this tensor descriptor are dependent on normalization mode. Note that the data type of this tensor descriptor must be **float** for FP16 and FP32 input tensors, and **double** for FP64 input tensors.

activationDesc

Input. Descriptor for the activation operation. When the **bnOps** input is set to either **CUDNN_BATCHNORM_OPS_BN_ACTIVATION** or **CUDNN_BATCHNORM_OPS_BN_ADD_ACTIVATION** then this activation is used, otherwise the user may pass **NULL**.

***sizeInBytes**

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

Returns

CUDNN_STATUS_SUCCESS

The computation was performed successfully.

CUDNN_STATUS_NOT_SUPPORTED

The function does not support the provided configuration.

CUDNN_STATUS_BAD_PARAM

At least one of the following conditions are met:

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

- **dBnScaleBiasDesc** dimensions not 1xCx1x1 for 4D and 1xCx1x1x1 for 5D for spatial, and are not 1xCxHxW for 4D and 1xCxDxHxW for 5D for per-activation mode.
- Dimensions or data types mismatch for **xDesc, yDesc**.

3.86. cudnnGetBatchNormalizationTrainingExReserveSpaceS

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

This function returns the amount of reserve GPU memory workspace the user should allocate for the batch normalization operation, for the specified **bnOps** input setting. In contrast to the **workspace**, the reserved space should be preserved between the forward and backward calls, and the data should not be altered.

Parameters

handle

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

mode

Input. Mode of operation (spatial or per-activation). For more information, see cudnnBatchNormMode_t.

bnOps

Input. Mode of operation for the fast NHWC kernel. For more information, see cudnnBatchNormOps_t. This input can be used to set this function to perform either only the batch normalization, or batch normalization followed by activation, or batch normalization followed by element-wise addition and then activation.

xDesc

Tensor descriptors for the layer's **x** data. For more information, see cudnnTensorDescriptor_t.

activationDesc

Input. Descriptor for the activation operation. When the **bnOps** input is set to either **CUDNN_BATCHNORM_OPS_BN_ACTIVATION** or **CUDNN_BATCHNORM_OPS_BN_ADD_ACTIVATION** then this activation is used, otherwise user may pass **NULL**.

***sizeInBytes**

Output. Amount of GPU memory reserved.

Returns

CUDNN_STATUS_SUCCESS

The computation was performed successfully.

CUDNN_STATUS_NOT_SUPPORTED

The function does not support the provided configuration.

CUDNN_STATUS_BAD_PARAM

At least one of the following conditions are met:

- The **xDesc** tensor descriptor dimension is not within the [4,5] range (only 4D and 5D tensors are supported).

3.87. cudnnGetCallback()

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

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**.

3.88. 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.

Returns

CUDNN_STATUS_SUCCESS

The operation was successful.

CUDNN_STATUS_BAD_PARAM

The parameter **convDesc** is nil.

3.89. 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 follows:

```
    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.

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.

3.90. 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. Specifies 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

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.

3.91. 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 the fastest being index 0 of **perfResults**. For an exhaustive search for the fastest algorithm, use cudnnFindConvolutionBackwardDataAlgorithm(). The total number of resulting algorithms can be queried through the **returnedAlgoCount** variable.

Parameters

handle

Input. Handle to a previously created cuDNN context.

wDesc

Input. Handle to a previously initialized filter descriptor.

dyDesc

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

convDesc

Input. Previously initialized convolution descriptor.

dxDesc

Input. Handle to the previously initialized output tensor descriptor.

requestedAlgoCount

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

returnedAlgoCount

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

perfResults

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

Returns

CUDNN_STATUS_SUCCESS

The query was successful.

CUDNN_STATUS_BAD_PARAM

At least one of the following conditions are met:

- One of the parameters **handle**, **wDesc**, **dyDesc**, **convDesc**, **dxDesc**, **perfResults**, **returnedAlgoCount** is **NULL**.
- The numbers of feature maps of the input tensor and output tensor differ.
- The **dataType** of the two tensor descriptors or the filters are different.
- **requestedAlgoCount** is less than or equal to 0.

3.92. 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.

3.93. 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**.

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.

3.94. 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, 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.

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 filters are different.

3.95. 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, use cudnnFindConvolutionBackwardFilterAlgorithm(). The total number of resulting algorithms can be queried through the **returnedAlgoCount** variable.

Parameters

handle

Input. Handle to a previously created cuDNN context.

xDesc

Input. Handle to the previously initialized input tensor descriptor.

dyDesc

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

convDesc

Input. Previously initialized convolution descriptor.

dwDesc

Input. Handle to a previously initialized filter descriptor.

requestedAlgoCount

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

returnedAlgoCount

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

perfResults

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

Returns

CUDNN_STATUS_SUCCESS

The query was successful.

CUDNN_STATUS_BAD_PARAM

At least one of the following conditions are met:

- One of the parameters **handle**, **xDesc**, **dyDesc**, **convDesc**, **dwDesc**, **perfResults**, **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.

3.96. cudnnGetConvolutionBackwardFilterAlgorithmMaxCou

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

This function returns the maximum number of algorithms which can be returned from cudnnFindConvolutionBackwardFilterAlgorithm() and cudnnGetConvolutionForwardAlgorithm_v7(). This is the sum of all algorithms plus the sum of all algorithms with Tensor Core operations supported for the current device.

Parameters

handle

Input. Handle to a previously created cuDNN context.

count

Output. The resulting maximum count of algorithms.

Returns

CUDNN_STATUS_SUCCESS

The function was successful.

CUDNN_STATUS_BAD_PARAM

The provided handle is not allocated properly.

3.97. cudnnGetConvolutionBackwardFilterWorkspaceSize()

```
cudnnStatus_t cudnnGetConvolutionBackwardFilterWorkspaceSize(
    cudnnHandle_t                       handle,
    const cudnnTensorDescriptor_t       xDesc,
    const cudnnTensorDescriptor_t       dyDesc,
    const cudnnConvolutionDescriptor_t  convDesc,
    const cudnnFilterDescriptor_t       dwDesc,
    cudnnConvolutionBwdFilterAlgo_t     algo,
    size_t                             *sizeInBytes)
```

This function returns the amount of GPU memory workspace the user needs to allocate to be able to call cudnnConvolutionBackwardFilter() with the specified algorithm. The workspace allocated will then be passed to the routine cudnnConvolutionBackwardFilter(). The specified algorithm can be the result of the call to cudnnGetConvolutionBackwardFilterAlgorithm() or can be chosen arbitrarily by the user. Note that not every algorithm is available for every configuration of the input tensor and/or every configuration of the convolution descriptor.

Parameters

handle

Input. Handle to a previously created cuDNN context.

xDesc

Input. Handle to the previously initialized input tensor descriptor.

dyDesc

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

convDesc

Input. Previously initialized convolution descriptor.

dwDesc

Input. Handle to a previously initialized filter descriptor.

algo

Input. Enumerant that specifies the chosen convolution algorithm.

sizeInBytes

Output. Amount of GPU memory needed as workspace to be able to execute a forward convolution with the specified **algo**.

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.

3.98. 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, 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 an 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

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.

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

Parameters

handle

Input. Handle to a previously created cuDNN context.

xDesc

Input. Handle to the previously initialized input tensor descriptor.

wDesc

Input. Handle to a previously initialized convolution filter descriptor.

convDesc

Input. Previously initialized convolution descriptor.

yDesc

Input. Handle to the previously initialized output tensor descriptor.

requestedAlgoCount

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

returnedAlgoCount

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

perfResults

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

Returns

CUDNN_STATUS_SUCCESS

The query was successful.

CUDNN_STATUS_BAD_PARAM

At least one of the following conditions are met:

- One of the parameters **handle**, **xDesc**, **wDesc**, **convDesc**, **yDesc**, **perfResults**, **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.

3.100. cudnnGetConvolutionForwardAlgorithmMaxCount()

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

This function returns the maximum number of algorithms which can be returned from cudnnFindConvolutionForwardAlgorithm() and cudnnGetConvolutionForwardAlgorithm_v7(). This is the sum of all algorithms plus the sum of all algorithms with Tensor Core operations supported for the current device.

Parameters

handle

Input. Handle to a previously created cuDNN context.

count

Output. The resulting maximum number of algorithms.

Returns

CUDNN_STATUS_SUCCESS

The function was successful.

CUDNN_STATUS_BAD_PARAM

The provided handle is not allocated properly.

3.101. 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**.

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.

3.102. 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.

3.103. 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.

3.104. 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**.

3.105. cudnnGetConvolutionNdForwardOutputDim()

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

This function returns the dimensions of the resulting n-D tensor of a **nbDims-2-D** convolution, given the convolution descriptor, the input tensor descriptor and the filter descriptor This function can help to setup the output tensor and allocate the proper amount of memory prior to launch the actual convolution.

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

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

> The dimensions provided by this routine must be strictly respected when calling cudnnConvolutionForward() or cudnnConvolutionBackwardBias(). Providing a smaller or larger output tensor is not supported by the convolution routines.

Parameters

convDesc

Input. Handle to a previously created convolution descriptor.

inputTensorDesc

Input. Handle to a previously initialized tensor descriptor.

filterDesc

Input. Handle to a previously initialized filter descriptor.

nbDims

Input. Dimension of the output tensor

tensorOuputDimA

Output. Array of dimensions **nbDims** that contains on exit of this routine the sizes of the output tensor

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.

3.106. cudnnGetConvolutionReorderType()

```
cudnnStatus_t cudnnGetConvolutionReorderType(
 cudnnConvolutionDescriptor_t convDesc,
 cudnnReorderType_t *reorderType);
```

This function retrieves the convolution reorder type from the given convolution descriptor.

Parameters

convDesc

Input. The convolution descriptor from which the reorder type should be retrieved.

reorderType

Output. The retrieved reorder type. For more information, see cudnnReorderType_t.

Returns

CUDNN_STATUS_BAD_PARAM

One of the inputs to this function is not valid.

CUDNN_STATUS_SUCCESS

The reorder type is retrieved successfully.

3.107. cudnnGetCTCLossDescriptor()

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

This function returns the 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.

3.108. 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**.

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.

3.109. 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.

3.110. 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.

Returns

CUDNN_STATUS_SUCCESS

The call was successful.

CUDNN_STATUS_BAD_PARAM

One or more of the arguments was an invalid pointer.

3.111. cudnnGetErrorString()

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

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

Parameters

status

Input. cuDNN enumerant status code.

Returns

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

3.112. 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.

Returns

CUDNN_STATUS_SUCCESS

The object was set successfully.

3.113. 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.

Returns

CUDNN_STATUS_SUCCESS

The object was set successfully.

CUDNN_STATUS_BAD_PARAM

The parameter **nbDimsRequested** is negative.

3.114. cudnnGetFusedOpsConstParamPackAttribute()

```
cudnnStatus_t cudnnGetFusedOpsConstParamPackAttribute(
 const cudnnFusedOpsConstParamPack_t constPack,
 cudnnFusedOpsConstParamLabel_t paramLabel,
 void *param,
 int *isNULL);
```

This function retrieves the values of the descriptor pointed to by the **param** pointer input. The type of the descriptor is indicated by the enum value of **paramLabel** input.

Parameters

constPack

Input. The opaque cudnnFusedOpsConstParamPack_t structure that contains the various problem size information, such as the shape, layout and the type of tensors, and the descriptors for convolution and activation, for the selected sequence of cudnnFusedOps_t computations.

paramLabel

Input. Several types of descriptors can be retrieved by this getter function. The **param** input points to the descriptor itself, and this input indicates the type of the descriptor pointed to by the **param** input. The cudnnFusedOpsConstParamLabel_t enumerant type enables the selection of the type of the descriptor. Refer to the **param** description below.

param

Input. Data pointer to the host memory associated with the descriptor that should be retrieved. The type of this descriptor depends on the value of **paramLabel**. For the given **paramLabel**, if the associated value inside the **constPack** is set to **NULL** or by default **NULL**, then cuDNN will copy the value or the opaque structure in the **constPack** to the host memory buffer pointed to by **param**. For more information, see the table in cudnnFusedOpsConstParamLabel_t.

isNULL

Input/Output. User must pass a pointer to an integer in the host memory in this field. If the value in the **constPack** associated with the given **paramLabel** is by default **NULL** or previously set by the user to **NULL**, then cuDNN will write a non-zero value to the location pointed by **isNULL**.

Returns

CUDNN_STATUS_SUCCESS
The descriptor values are retrieved successfully.

CUDNN_STATUS_BAD_PARAM
If either **constPack**, **param** or **isNULL** is **NULL**; or if **paramLabel** is invalid.

3.115. cudnnGetFusedOpsVariantParamPackAttribute()

```
cudnnStatus_t cudnnGetFusedOpsVariantParamPackAttribute(
 const cudnnFusedOpsVariantParamPack_t varPack,
 cudnnFusedOpsVariantParamLabel_t paramLabel,
 void *ptr);
```

This function retrieves the settings of the variable parameter pack descriptor.

Parameters

varPack
Input. Pointer to the **cudnnFusedOps** variant parameter pack (**varPack**) descriptor.

paramLabel
Input. Type of the buffer pointer parameter (in the **varPack** descriptor). For more information, see cudnnFusedOpsConstParamLabel_t. The retrieved descriptor values vary according to this type.

ptr
Output. Pointer to the host or device memory where the retrieved value is written by this function. The data type of the pointer, and the host/device memory location, depend on the **paramLabel** input selection. For more information, see cudnnFusedOpsVariantParamLabel_t.

Returns

CUDNN_STATUS_SUCCESS
The descriptor values are retrieved successfully.

CUDNN_STATUS_BAD_PARAM
If either **varPack** or **ptr** is **NULL**, or if **paramLabel** is set to invalid value.

3.116. 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).

Returns

`CUDNN_STATUS_SUCCESS`

Function completed successfully.

3.117. cudnnGetMultiHeadAttnBuffers()

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

This function computes weight, work, and reserve space buffer sizes used by the following functions:

- **`cudnnMultiHeadAttnForward()`**
- **`cudnnMultiHeadAttnBackwardData()`**
- **`cudnnMultiHeadAttnBackwardWeights()`**

Assigning **`NULL`** to the **`reserveSpaceSizeInBytes`** argument indicates that the user does not plan to invoke multi-head attention gradient functions: cudnnMultiHeadAttnBackwardData() and cudnnMultiHeadAttnBackwardWeights(). This situation occurs in the inference mode.

> **`NULL`** cannot be assigned to **`weightSizeInBytes`** and **`workSpaceSizeInBytes`** pointers.

The user must allocate weight, work, and reserve space buffer sizes in the GPU memory using **`cudaMalloc()`** with the reported buffer sizes. The buffers can be also carved out from a larger chunk of allocated memory but the buffer addresses must be at least 16B aligned.

The work-space buffer is used for temporary storage. Its content can be discarded or modified after all GPU kernels launched by the corresponding API complete. The reserve-space buffer is used to transfer intermediate results from cudnnMultiHeadAttnForward() to cudnnMultiHeadAttnBackwardData(), and from cudnnMultiHeadAttnBackwardData() to cudnnMultiHeadAttnBackwardWeights(). The content of the reserve-space buffer cannot be modified until all GPU kernels launched by the above three multi-head attention API functions finish.

All multi-head attention weight and bias tensors are stored in a single weight buffer. For speed optimizations, the cuDNN API may change tensor layouts and their relative locations in the weight buffer based on the provided attention parameters. Use the cudnnGetMultiHeadAttnWeights() function to obtain the start address and the shape of each weight or bias tensor.

Parameters

`handle`

Input. The current cuDNN context handle.

`attnDesc`

Input. Pointer to a previously initialized attention descriptor.

`weightSizeInBytes`

Output. Minimum buffer size required to store all multi-head attention trainable parameters.

`workSpaceSizeInBytes`

Output. Minimum buffer size required to hold all temporary surfaces used by the forward and gradient multi-head attention API calls.

`reserveSpaceSizeInBytes`

Output. Minimum buffer size required to store all intermediate data exchanged between forward and backward (gradient) multi-head attention functions. Set this parameter to **`NULL`** in the inference mode indicating that gradient API calls will not be invoked.

Returns

`CUDNN_STATUS_SUCCESS`

The requested buffer sizes were computed successfully.

`CUDNN_STATUS_BAD_PARAM`

An invalid input argument was found.

3.118. cudnnGetMultiHeadAttnWeights()

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

This function obtains the shape of the weight or bias tensor. It also retrieves the start address of tensor data located in the **`weight`** buffer. Use the **`wKind`** argument to select a particular tensor. For more information, see cudnnMultiHeadAttnWeightKind_t for the description of the enumerant type.

Biases are used in the input and output projections when the **`CUDNN_ATTN_ENABLE_PROJ_BIASES`** flag is set in the attention descriptor. See cudnnSetAttnDescriptor() for the description of flags to control projection biases.

When the corresponding weight or bias tensor does not exist, the function writes **`NULL`** to the storage location pointed by **`wAddr`** and returns zeros in the **`wDesc`** tensor descriptor. The return status of the cudnnGetMultiHeadAttnWeights() function is **`CUDNN_STATUS_SUCCESS`** in this case.

The cuDNN **`multiHeadAttention`** sample code demonstrates how to access multi-head attention weights. Although the buffer with weights and biases should be allocated in the GPU memory, the user can copy it to the host memory and invoke the cudnnGetMultiHeadAttnWeights() function with the host weights address to obtain tensor pointers in the host memory. This scheme allows the user to inspect trainable parameters directly in the CPU memory.

Parameters

`handle`

Input. The current cuDNN context handle.

`attnDesc`

Input. A previously configured attention descriptor.

`wKind`

Input. Enumerant type to specify which weight or bias tensor should be retrieved.

`weightSizeInBytes`

Input. Buffer size that stores all multi-head attention weights and biases.

`weights`

Input. Pointer to the **`weight`** buffer in the host or device memory.

`wDesc`

Output. The descriptor specifying weight or bias tensor shape. For weights, the **`wDesc.dimA[]`** array has three elements: **`[nHeads, projected size, original size]`**. For biases, the **`wDesc.dimA[]`** array also has three elements: **`[nHeads, projected size, 1]`**. The **`wDesc.strideA[]`** array describes how tensor elements are arranged in memory.

`wAddr`

Output. Pointer to a location where the start address of the requested tensor should be written. When the corresponding projection is disabled, the address written to **`wAddr`** is **`NULL`**.

Returns

CUDNN_STATUS_SUCCESS

The weight tensor descriptor and the address of data in the device memory were successfully retrieved.

CUDNN_STATUS_BAD_PARAM

An invalid or incompatible input argument was encountered. For example, **wKind** did not have a valid value or **weightSizeInBytes** was too small.

3.119. cudnnGetOpTensorDescriptor()

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

This function returns the 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.

3.120. 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.

Returns

CUDNN_STATUS_SUCCESS

The object was set successfully.

3.121. 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 follows:

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

Parameters

`poolingDesc`

Input. Handle to a previously initialized pooling descriptor.

`inputDesc`

Input. Handle to the previously initialized input tensor descriptor.

`N`

Output. Number of images in the output.

`C`

Output. Number of channels in the output.

`H`

Output. Height of images in the output.

`W`

Output. Width of images in the output.

Returns

`CUDNN_STATUS_SUCCESS`

The function launched successfully.

`CUDNN_STATUS_BAD_PARAM`

At least one of the following conditions are met:

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

3.122. 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.

Returns

CUDNN_STATUS_SUCCESS

The object was queried successfully.

CUDNN_STATUS_NOT_SUPPORTED

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

3.123. 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 follows:

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

Parameters

poolingDesc

Input. Handle to a previously initialized pooling descriptor.

inputDesc

Input. Handle to the previously initialized input tensor descriptor.

nbDims

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

outDimA

Output. Array of **nbDims** output dimensions.

Returns

CUDNN_STATUS_SUCCESS

The function launched successfully.

CUDNN_STATUS_BAD_PARAM

At least one of the following conditions are met:

- **poolingDesc** has not been initialized.

- The value of **nbDims** is inconsistent with the dimensionality of **poolingDesc** and **inputDesc**.

3.124. 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. Enumerant 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.

3.125. cudnnGetReduceTensorDescriptor()

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

This function queries a previously initialized reduce tensor descriptor object.

Parameters

reduceTensorDesc

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

reduceTensorOp

Output. Enumerant to specify the reduce tensor operation.

reduceTensorCompType

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

reduceTensorNanOpt

Input. Enumerant to specify the Nan propagation mode.

reduceTensorIndices

Output. Enumerant to specify the reduce tensor indices.

reduceTensorIndicesType

Output. Enumerant to specify the reduce tensor indices type.

Returns

CUDNN_STATUS_SUCCESS

The object was queried successfully.

CUDNN_STATUS_BAD_PARAM

reduceTensorDesc is **NULL**.

3.126. cudnnGetReductionIndicesSize()

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

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

Parameters

handle

Input. Handle to a previously created cuDNN library descriptor.

reduceDesc

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

aDesc

Input. Pointer to the input tensor descriptor.

cDesc

Input. Pointer to the output tensor descriptor.

sizeInBytes

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

Returns

CUDNN_STATUS_SUCCESS

The index space size is returned successfully.

3.127. cudnnGetReductionWorkspaceSize()

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

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

Parameters

handle

Input. Handle to a previously created cuDNN library descriptor.

reduceDesc

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

aDesc

Input. Pointer to the input tensor descriptor.

cDesc

Input. Pointer to the output tensor descriptor.

sizeInBytes

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

Returns

CUDNN_STATUS_SUCCESS

The workspace size is returned successfully.

3.128. cudnnGetRNNBiasMode()

```
cudnnStatus_t cudnnGetRNNBiasMode(
   cudnnRNNDescriptor_t   rnnDesc,
   cudnnRNNBiasMode_t     *biasMode)
```

This function retrieves the RNN bias mode that was configured by cudnnSetRNNBiasMode(). The default value of **biasMode** in **rnnDesc** after cudnnCreateRNNDescriptor() is **CUDNN_RNN_DOUBLE_BIAS**.

Parameters

rnnDesc

Input. A previously created RNN descriptor.

***biasMode**

Input. Pointer to where RNN bias mode should be saved.

Returns

CUDNN_STATUS_BAD_PARAM

Either the **rnnDesc** or ***biasMode** is **NULL**.

CUDNN_STATUS_SUCCESS

The **biasMode** parameter was retrieved set successfully.

3.129. cudnnGetRNNDataDescriptor()

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

This function retrieves a previously created RNN data descriptor object.

Parameters

RNNDataDesc

Input. A previously created and initialized RNN descriptor.

dataType

Output. Pointer to the host memory location to store the datatype of the RNN data tensor.

layout

Output. Pointer to the host memory location to store the memory layout of the RNN data tensor.

maxSeqLength

Output. The maximum sequence length within this RNN data tensor, including the padding vectors.

batchSize

Output. The number of sequences within the mini-batch.

vectorSize

Output. The vector length (meaning, embedding size) of the input or output tensor at each time-step.

arrayLengthRequested

Input. The number of elements that the user requested for **seqLengthArray**.

seqLengthArray

Output. Pointer to the host memory location to store the integer array describing the length (meaning, number of time-steps) of each sequence. This is allowed to be a **NULL** pointer if **arrayLengthRequested** is 0.

paddingFill

Output. Pointer to the host memory location to store the user defined symbol. The symbol should be interpreted as the same data type as the RNN data tensor.

Returns

CUDNN_STATUS_SUCCESS

The parameters are fetched successfully.

CUDNN_STATUS_BAD_PARAM

Any one of these have occurred:

- Any of **RNNDataDesc**, **dataType**, **layout**, **maxSeqLength**, **batchSize**, **vectorSize**, **paddingFill** is **NULL**.
- **seqLengthArray** is **NULL** while **arrayLengthRequested** is greater than zero.
- **arrayLengthRequested** is less than zero.

3.130. cudnnGetRNNDescriptor()

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

This function retrieves RNN network parameters that were configured by cudnnSetRNNDescriptor(). All pointers passed to the function should be not-**NULL** or **CUDNN_STATUS_BAD_PARAM** is reported. The function does not check the validity of retrieved network parameters. The parameters are verified when they are written to the RNN descriptor.

Parameters

`handle`

Input. Handle to a previously created cuDNN library descriptor.

`rnnDesc`

Input. A previously created and initialized RNN descriptor.

`hiddenSize`

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

`numLayers`

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

`dropoutDesc`

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

`inputMode`

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

`direction`

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

`mode`

Output. Pointer to where RNN cell type should be saved.

`algo`

Output. Pointer to where RNN algorithm type should be stored.

`dataType`

Output. Pointer to where the data type of RNN weights/biases should be stored.

Returns

`CUDNN_STATUS_SUCCESS`

RNN parameters were successfully retrieved from the RNN descriptor.

`CUDNN_STATUS_BAD_PARAM`

At least one pointer passed to the cudnnGetRNNDescriptor() function is **`NULL`**.

3.131. cudnnGetRNNLinLayerBiasParams()

```
cudnnStatus_t cudnnGetRNNLinLayerBiasParams(
    cudnnHandle_t                     handle,
    const cudnnRNNDescriptor_t        rnnDesc,
    const int                         pseudoLayer,
    const cudnnTensorDescriptor_t     xDesc,
    const cudnnFilterDescriptor_t     wDesc,
    const void                       *w,
    const int                         linLayerID,
    cudnnFilterDescriptor_t           linLayerBiasDesc,
    void                            **linLayerBias)
```

This function is used to obtain a pointer and a descriptor of every RNN bias column vector in each pseudo-layer within the recurrent network defined by **rnnDesc** and its input width specified in **xDesc**.

> The cudnnGetRNNLinLayerBiasParams() function was changed in cuDNN version 7.1.1 to match the behavior of cudnnGetRNNLinLayerMatrixParams().

The cudnnGetRNNLinLayerBiasParams() function returns the RNN bias vector size in two dimensions: rows and columns.

Due to historical reasons, the minimum number of dimensions in the filter descriptor is three. In previous versions of the cuDNN library, the function returns the total number of vector elements in **linLayerBiasDesc** as follows:

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

For more information, see the description of the cudnnGetFilterNdDescriptor() function.

In v7.1.1, the format was changed to:

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

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

The RNN implementation in cuDNN uses two bias vectors before the cell non-linear function. Note that the RNN implementation in cuDNN depends on the number of bias vectors before the cell non-linear function. Refer to the equations in the cudnnRNNMode_t description, for the enumerant type based on the value of cudnnRNNBiasMode_t **biasMode** in **rnnDesc**. If nonexistent biases are referenced by **linLayerID**, then this function sets **linLayerBiasDesc** to a zeroed filter descriptor where:

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

and sets **linLayerBias** to **NULL**. Refer to the details for function parameter **linLayerID** to determine the relevant values of **linLayerID** based on **biasMode**.

Parameters

`handle`

Input. Handle to a previously created cuDNN library descriptor.

`rnnDesc`

Input. A previously initialized RNN descriptor.

`pseudoLayer`

Input. The pseudo-layer to query. In uni-directional RNNs, a pseudo-layer is the same as a physical layer (**`pseudoLayer=0`** is the RNN input layer, **`pseudoLayer=1`** is the first hidden layer). In bi-directional RNNs, there are twice as many pseudo-layers in comparison to physical layers.

- **`pseudoLayer=0`** refers to the forward part of the physical input layer
- **`pseudoLayer=1`** refers to the backward part of the physical input layer
- **`pseudoLayer=2`** is the forward part of the first hidden layer, and so on

`xDesc`

Input. A fully packed tensor descriptor describing the input to one recurrent iteration (to retrieve the RNN input width).

`wDesc`

Input. Handle to a previously initialized filter descriptor describing the weights for the RNN.

`w`

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

`linLayerID`

Input. The linear layer to obtain information about:

- - If **`mode`** in **`rnnDesc`** was set to **`CUDNN_RNN_RELU`** or **`CUDNN_RNN_TANH`**:
    - Value 0 references the bias applied to the input from the previous layer (relevant if **`biasMode`** in **`rnnDesc`** is **`CUDNN_RNN_SINGLE_INP_BIAS`** or **`CUDNN_RNN_DOUBLE_BIAS`**).
    - Value 1 references the bias applied to the recurrent input (relevant if **`biasMode`** in **`rnnDesc`** is **`CUDNN_RNN_DOUBLE_BIAS`** or **`CUDNN_RNN_SINGLE_REC_BIAS`**).
  - If **`mode`** in **`rnnDesc`** was set to **`CUDNN_LSTM`**:
    - Values of 0, 1, 2 and 3 reference bias applied to the input from the previous layer (relevant if **`biasMode`** in **`rnnDesc`** is **`CUDNN_RNN_SINGLE_INP_BIAS`** or **`CUDNN_RNN_DOUBLE_BIAS`**).

    - Values of 4, 5, 6 and 7 reference bias applied to the recurrent input (relevant if **biasMode** in **rnnDesc** is **CUDNN_RNN_DOUBLE_BIAS** or **CUDNN_RNN_SINGLE_REC_BIAS**).
    - Values and their associated gates:
        - Values 0 and 4 reference the input gate.
        - Values 1 and 5 reference the forget gate.
        - Values 2 and 6 reference the new memory gate.
        - Values 3 and 7 reference the output gate.
- If **mode** in **rnnDesc** was set to **CUDNN_GRU**:
    - Values of 0, 1 and 2 reference bias applied to the input from the previous layer (relevant if **biasMode** in **rnnDesc** is **CUDNN_RNN_SINGLE_INP_BIAS** or **CUDNN_RNN_DOUBLE_BIAS**).
    - Values of 3, 4 and 5 reference bias applied to the recurrent input (relevant if **biasMode** in **rnnDesc** is **CUDNN_RNN_DOUBLE_BIAS** or **CUDNN_RNN_SINGLE_REC_BIAS**).
    - Values and their associated gates:
        - Values 0 and 3 reference the reset gate.
        - Values 1 and 4 reference the update gate.
        - Values 2 and 5 reference the new memory gate.

For more information on modes and bias modes, see cudnnRNNMode_t.

linLayerBiasDesc

Output. Handle to a previously created filter descriptor.

linLayerBias

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

Returns

CUDNN_STATUS_SUCCESS

The query was successful.

CUDNN_STATUS_NOT_SUPPORTED

The function does not support the provided configuration.

CUDNN_STATUS_BAD_PARAM

At least one of the following conditions are met:

- One of the following arguments is **NULL**: **handle**, **rnnDesc**, **xDesc**, **wDesc**, **linLayerBiasDesc**, **linLayerBias**.
- A data type mismatch was detected between **rnnDesc** and other descriptors.

- Minimum requirement for the **w** pointer alignment is not satisfied.
- The value of **pseudoLayer** or **linLayerID** is out of range.

CUDNN_STATUS_INVALID_VALUE

Some elements of the **linLayerBias** vector are outside the **w** buffer boundaries as specified by the **wDesc** descriptor.

3.132. cudnnGetRNNLinLayerMatrixParams()

```
cudnnStatus_t cudnnGetRNNLinLayerMatrixParams(
cudnnHandle_t                     handle,
const cudnnRNNDescriptor_t        rnnDesc,
const int                         pseudoLayer,
const cudnnTensorDescriptor_t     xDesc,
const cudnnFilterDescriptor_t     wDesc,
const void                       *w,
const int                         linLayerID,
cudnnFilterDescriptor_t           linLayerMatDesc,
void                            **linLayerMat)
```

This function is used to obtain a pointer and a descriptor of every RNN weight matrix in each pseudo-layer within the recurrent network defined by **rnnDesc** and its input width specified in **xDesc**.

> The cudnnGetRNNLinLayerMatrixParams() function was enhanced in cuDNN version 7.1.1 without changing its prototype. Instead of reporting the total number of elements in each weight matrix in the **linLayerMatDesc** filter descriptor, the function returns the matrix size as two dimensions: rows and columns. Moreover, when a weight matrix does not exist, for example, due to **CUDNN_SKIP_INPUT** mode, the function returns **NULL** in **linLayerMat** and all fields of **linLayerMatDesc** are zero.

The cudnnGetRNNLinLayerMatrixParams() function returns the RNN matrix size in two dimensions: rows and columns. This allows the user to easily print and initialize RNN weight matrices. Elements in each weight matrix are arranged in the row-major order. Due to historical reasons, the minimum number of dimensions in the filter descriptor is three. In previous versions of the cuDNN library, the function returned the total number of weights in **linLayerMatDesc** as follows: **filterDimA[0]=total_size**, **filterDimA[1]=1**, **filterDimA[2]=1** (see the description of the cudnnGetFilterNdDescriptor() function). In 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 RNNs, a pseudo-layer is the same as a physical layer (**`pseudoLayer=0`** is the RNN input layer, **`pseudoLayer=1`** is the first hidden layer). In bi-directional RNNs, there are twice as many pseudo-layers in comparison to physical layers.

- **`pseudoLayer=0`** refers to the forward part of the physical input layer
- **`pseudoLayer=1`** refers to the backward part of the physical input layer
- **`pseudoLayer=2`** is the forward part of the first hidden layer, and so on

`xDesc`

Input. A fully packed tensor descriptor describing the input to one recurrent iteration (to retrieve the RNN input width).

`wDesc`

Input. Handle to a previously initialized filter descriptor describing the weights for the RNN.

`w`

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

`linLayerID`

Input. The linear layer to obtain information about:

- - If **`mode`** in **`rnnDesc`** was set to **`CUDNN_RNN_RELU`** or **`CUDNN_RNN_TANH`**:
    - Value 0 references the bias applied to the input from the previous layer (relevant if **`biasMode`** in **`rnnDesc`** is **`CUDNN_RNN_SINGLE_INP_BIAS`** or **`CUDNN_RNN_DOUBLE_BIAS`**).
    - Value 1 references the bias applied to the recurrent input (relevant if **`biasMode`** in **`rnnDesc`** is **`CUDNN_RNN_DOUBLE_BIAS`** or **`CUDNN_RNN_SINGLE_REC_BIAS`**).
  - If **`mode`** in **`rnnDesc`** was set to **`CUDNN_LSTM`**:
    - Values of 0, 1, 2 and 3 reference bias applied to the input from the previous layer (relevant if **`biasMode`** in **`rnnDesc`** is **`CUDNN_RNN_SINGLE_INP_BIAS`** or **`CUDNN_RNN_DOUBLE_BIAS`**).
    - Values of 4, 5, 6 and 7 reference bias applied to the recurrent input (relevant if **`biasMode`** in **`rnnDesc`** is **`CUDNN_RNN_DOUBLE_BIAS`** or **`CUDNN_RNN_SINGLE_REC_BIAS`**).
    - Values and their associated gates:
      - Values 0 and 4 reference the input gate.

    - Values 1 and 5 reference the forget gate.
    - Values 2 and 6 reference the new memory gate.
    - Values 3 and 7 reference the output gate.
- If **mode** in **rnnDesc** was set to **CUDNN_GRU**:
  - Values of 0, 1 and 2 reference bias applied to the input from the previous layer (relevant if **biasMode** in **rnnDesc** is **CUDNN_RNN_SINGLE_INP_BIAS** or **CUDNN_RNN_DOUBLE_BIAS**).
  - Values of 3, 4 and 5 reference bias applied to the recurrent input (relevant if **biasMode** in **rnnDesc** is **CUDNN_RNN_DOUBLE_BIAS** or **CUDNN_RNN_SINGLE_REC_BIAS**).
  - Values and their associated gates:
    - Values 0 and 3 reference the reset gate.
    - Values 1 and 4 reference the update gate.
    - Values 2 and 5 reference the new memory gate.

For more information on modes and bias modes, see cudnnRNNMode_t.

linLayerMatDesc

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

linLayerMat

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

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.

3.133. cudnnGetRNNPaddingMode()

```
cudnnStatus_t cudnnGetRNNPaddingMode(
    cudnnRNNDescriptor_t        rnnDesc,
    cudnnRNNPaddingMode_t       *paddingMode)
```

This function retrieves the RNN padding mode from the RNN descriptor.

Parameters

rnnDesc

Input/Output. A previously created RNN descriptor.

***paddingMode**

Input. Pointer to the host memory where the RNN padding mode is saved.

Returns

CUDNN_STATUS_SUCCESS

The RNN padding mode parameter was retrieved successfully.

CUDNN_STATUS_BAD_PARAM

Either the **rnnDesc** or ***paddingMode** is **NULL**.

3.134. 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.

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.

3.135. cudnnGetRNNProjectionLayers()

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

This function retrieves the current RNN projection parameters. By default, the projection feature is disabled so invoking this function 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.

3.136. cudnnGetRNNTrainingReserveSize()

```
cudnnStatus_t cudnnGetRNNTrainingReserveSize(
    cudnnHandle_t                handle,
    const cudnnRNNDescriptor_t   rnnDesc,
    const int                    seqLength,
    const cudnnTensorDescriptor_t  *xDesc,
    size_t                        *sizeInBytes)
```

This function is used to query the amount of reserved space required for training the RNN described by **rnnDesc** with inputs dimensions defined by **xDesc**. The same reserved space buffer must be passed to cudnnRNNForwardTraining(), cudnnRNNBackwardData() and cudnnRNNBackwardWeights(). Each of these calls overwrites the contents of the reserved space, however it can safely be backed up and restored between calls if reuse of the memory is desired.

Parameters

handle

Input. Handle to a previously created cuDNN library descriptor.

rnnDesc

Input. A previously initialized RNN descriptor.

seqLength

Input. Number of iterations to unroll over. The value of this **seqLength** must not exceed the value that was used in cudnnGetRNNWorkspaceSize() function for querying the workspace size required to execute the RNN.

xDesc

Input. An array of tensor descriptors describing the input to each recurrent iteration (one descriptor per iteration). The first dimension (batch size) of the tensors may decrease from element **n** to element **n+1** but may not increase. Each tensor descriptor must have the same second dimension (vector length).

sizeInBytes

Output. Minimum amount of GPU memory needed as reserve space to be able to train an RNN with the specified descriptor and input tensors.

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.

3.137. cudnnGetRNNWorkspaceSize()

```
cudnnStatus_t cudnnGetRNNWorkspaceSize(
    cudnnHandle_t                   handle,
    const cudnnRNNDescriptor_t      rnnDesc,
    const int                       seqLength,
    const cudnnTensorDescriptor_t  *xDesc,
    size_t                         *sizeInBytes)
```

This function is used to query the amount of work space required to execute the RNN described by **rnnDesc** with inputs dimensions defined by **xDesc**.

Parameters

handle

Input. Handle to a previously created cuDNN library descriptor.

rnnDesc

Input. A previously initialized RNN descriptor.

seqLength

Input. Number of iterations to unroll over. Workspace that is allocated, based on the size that this function provides, cannot be used for sequences longer than **seqLength**.

xDesc

Input. An array of tensor descriptors describing the input to each recurrent iteration (one descriptor per iteration). The first dimension (batch size) of the tensors may decrease from element **n** to element **n+1** but may not increase. For example, if you have multiple time series in a batch, they can be different lengths. This dimension is the batch size for the particular iteration of the sequence, and so it should decrease when a sequence in the batch has been terminated.

Each tensor descriptor must have the same second dimension (vector length).

sizeInBytes

Output. Minimum amount of GPU memory needed as workspace to be able to execute an RNN with the specified descriptor and input tensors.

Returns

CUDNN_STATUS_SUCCESS

The query was successful.

CUDNN_STATUS_BAD_PARAM

At least one of the following conditions are met:

- The descriptor **rnnDesc** is invalid.
- At least one of the descriptors in **xDesc** is invalid.
- The descriptors in **xDesc** have inconsistent second dimensions, strides or data types.
- The descriptors in **xDesc** have increasing first dimensions.
- The descriptors in **xDesc** is not fully packed.

CUDNN_STATUS_NOT_SUPPORTED

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

3.138. cudnnGetSeqDataDescriptor()

```
cudnnStatus_t cudnnGetSeqDataDescriptor(
 const cudnnSeqDataDescriptor_t seqDataDesc,
 cudnnDataType_t *dataType,
 int *nbDims,
 int nbDimsRequested,
 int dimA[],
 cudnnSeqDataAxis_t axes[],
 size_t *seqLengthArraySize,
```

```
size_t seqLengthSizeRequested,
int seqLengthArray[],
void *paddingFill);
```

This function retrieves settings from a previously created sequence data descriptor. The user can assign **NULL** to any pointer except **seqDataDesc** when the retrieved value is not needed. The **nbDimsRequested** argument applies to both **dimA[]** and **axes[]** arrays. A positive value of **nbDimsRequested** or **seqLengthSizeRequested** is ignored when the corresponding array, **dimA[]**, **axes[]**, or **seqLengthArray[]** is **NULL**.

The cudnnGetSeqDataDescriptor() function does not report the actual strides in the sequence data buffer. Those strides can be handy in computing the offset to any sequence data element. The user must precompute strides based on the **axes[]** and **dimA[]** arrays reported by the cudnnGetSeqDataDescriptor() function. Below is sample code that performs this task:

```
// Array holding sequence data strides.
size_t strA[CUDNN_SEQDATA_DIM_COUNT] = {0};

// Compute strides from dimension and order arrays.
size_t stride = 1;
for (int i = nbDims - 1; i >= 0; i--) {
 int j = int(axes[i]);
 if (unsigned(j) < CUDNN_SEQDATA_DIM_COUNT-1 && strA[j] == 0) {
    strA[j] = stride;
    stride *= dimA[j];
 } else {
     fprintf(stderr, "ERROR: invalid axes[%d]=%d\n\n", i, j);
     abort();
 }
}
```

Now, the **strA[]** array can be used to compute the index to any sequence data element, for example:

```
// Using four indices (batch, beam, time, vect) with ranges already checked.
size_t base = strA[CUDNN_SEQDATA_BATCH_DIM] * batch
         + strA[CUDNN_SEQDATA_BEAM_DIM]  * beam
         + strA[CUDNN_SEQDATA_TIME_DIM]  * time;
val = seqDataPtr[base + vect];
```

The above code assumes that all four indices (**batch, beam, time, vect**) are less than the corresponding value in the **dimA[]** array. The sample code also omits the **strA[CUDNN_SEQDATA_VECT_DIM]** stride because its value is always **1**, meaning, elements of one vector occupy a contiguous block of memory.

Parameters

seqDataDesc

Input. Sequence data descriptor.

dataType

Output. Data type used in the sequence data buffer.

nbDims

Output. The number of active dimensions in the **dimA[]** and **axes[]** arrays.

nbDimsRequested

Input. The maximum number of consecutive elements that can be written to **dimA[]** and **axes[]** arrays starting from index zero. The recommended value for this argument is **CUDNN_SEQDATA_DIM_COUNT**.

dimA[]

Output. Integer array holding sequence data dimensions.

axes[]

Output. Array of cudnnSeqDataAxis_t that defines the layout of sequence data in memory.

seqLengthArraySize

Output. The number of required elements in **seqLengthArray[]** to save all sequence lengths.

seqLengthSizeRequested

Input. The maximum number of consecutive elements that can be written to the **seqLengthArray[]** array starting from index zero.

seqLengthArray[]

Output. Integer array holding sequence lengths.

paddingFill

Output. Pointer to a storage location of **dataType** with the fill value that should be written to all padding vectors. Use **NULL** when an explicit initialization of output padding vectors was not requested.

Returns

CUDNN_STATUS_SUCCESS

Requested sequence data descriptor fields were retrieved successfully.

CUDNN_STATUS_BAD_PARAM

An invalid input argument was found.

CUDNN_STATUS_INTERNAL_ERROR

An inconsistent internal state was encountered.

3.139. 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 is 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.

3.140. 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.

Returns

CUDNN_STATUS_SUCCESS

The operation succeeded.

3.141. 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.

Returns

CUDNN_STATUS_SUCCESS

The results were returned successfully.

CUDNN_STATUS_BAD_PARAM

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

3.142. cudnnGetTensorSizeInBytes()

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

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

Parameters

tensorDesc

Input. Handle to a previously initialized tensor descriptor.

size

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

Returns

CUDNN_STATUS_SUCCESS

The results were returned successfully.

3.143. cudnnGetTensorTransformDescriptor()

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

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

Parameters

transformDesc
Input. A previously initialized tensor transform descriptor.

nbDimsRequested
Input. The number of dimensions to consider. For more information, see the Tensor Descriptor section in the *cuDNN Developer Guide*.

destFormat
Output. The transform format that will be returned.

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

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

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

direction
Output. The setting that selects folding or unfolding. For more information, see cudnnFoldingDirection_t.

Returns

CUDNN_STATUS_SUCCESS
The results were obtained successfully.

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

3.144. 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.

3.145. 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** first dimension
- **y_height/y_width** are computed from **cudnnGetConvolutionNdForwardOutputDim()**
- **input_channels** is **xDesc** second dimension
- **filter_height/filter_width** are **wDesc** third and fourth dimension

The **A** matrix is stored in format HW fully-packed in GPU memory.

Parameters

handle

Input. Handle to a previously created cuDNN context.

srcDesc

Input. Handle to a previously initialized tensor descriptor.

srcData

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

filterDesc

Input. Handle to a previously initialized filter descriptor.

convDesc

Input. Handle to a previously initialized convolution descriptor.

colBuffer

Output. Data pointer to GPU memory storing the output matrix.

Returns

CUDNN_STATUS_BAD_PARAM

srcData or **colBuffer** is **NULL**.

CUDNN_STATUS_NOT_SUPPORTED

Any of **srcDesc**, **filterDesc**, **convDesc** has **dataType** of **CUDNN_DATA_INT8**, **CUDNN_DATA_INT8x4**, **CUDNN_DATA_INT8** or **CUDNN_DATA_INT8x4 convDesc** has **groupCount** larger than 1.

CUDNN_STATUS_EXECUTION_FAILED

The CUDA kernel execution was unsuccessful.

CUDNN_STATUS_SUCCESS

The output data array is successfully generated.

3.146. cudnnInitTransformDest()

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

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

The returned tensor descriptor will be packed.

Parameters

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

srcDesc
Input. Handle to a previously initialized tensor descriptor.

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

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

Returns

CUDNN_STATUS_SUCCESS
The tensor descriptor was initialized successfully.

CUDNN_STATUS_BAD_PARAM
If either **srcDesc** or **destDesc** is **NULL**, or if the tensor descriptor's **nbDims** is incorrect. For more information, see the Tensor Descriptor section in the *cuDNN Developer Guide*.

CUDNN_STATUS_NOT_SUPPORTED
If the provided configuration is not 4D.

CUDNN_STATUS_EXECUTION_FAILED
Function failed to launch on the GPU.

3.147. 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:

```
dstValue = alpha[0]*resultValue + beta[0]*priorDstValue
```

For more information, see Scaling Parameters in the *cuDNN Developer Guide*.

`yDesc, y`

Input. Tensor descriptor and pointer in device memory for the layer's **`y`** data.

`dyDesc, dy`

Input. Tensor descriptor and pointer in device memory for the layer's input cumulative loss differential data **`dy`** (including error backpropagation).

`xDesc, x`

Input. Tensor descriptor and pointer in device memory for the layer's **`x`** data. Note that these values are not modified during backpropagation.

dxDesc, dx

Output. Tensor descriptor and pointer in device memory for the layer's resulting cumulative loss differential data **dx** (including error backpropagation).

Returns

CUDNN_STATUS_SUCCESS

The computation was performed successfully.

CUDNN_STATUS_BAD_PARAM

At least one of the following conditions are met:

- One of the tensor pointers **x**, **y** is **NULL**.
- Number of input tensor dimensions is 2 or less.
- LRN descriptor parameters are outside of their valid ranges.
- One of 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.

3.148. 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
```

For more information, see Scaling Parameters in the *cuDNN Developer Guide*.

`xDesc, yDesc`

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

`x`

Input. Input tensor data pointer in device memory.

`y`

Output. Output tensor data pointer in device memory.

Returns

`CUDNN_STATUS_SUCCESS`

The computation was performed successfully.

`CUDNN_STATUS_BAD_PARAM`

At least one of the following conditions are met:

- One of the tensor pointers **`x`**, **`y`** is **`NULL`**.
- Number of input tensor dimensions is 2 or less.
- LRN descriptor parameters are outside of their valid ranges.
- One of 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.

3.149. cudnnMakeFusedOpsPlan()

```
cudnnStatus_t cudnnMakeFusedOpsPlan(
 cudnnHandle_t handle,
 cudnnFusedOpsPlan_t plan,
 const cudnnFusedOpsConstParamPack_t constPack,
 size_t *workspaceSizeInBytes);
```

This function determines the optimum kernel to execute, and the workspace size the user should allocate, prior to the actual execution of the fused operations by cudnnFusedOpsExecute().

Parameters

handle

Input. Pointer to the cuDNN library context.

plan

Input. Pointer to a previously-created and initialized plan descriptor.

constPack

Input. Pointer to the descriptor to the const parameters pack.

workspaceSizeInBytes

Output. The amount of workspace size the user should allocate for the execution of this plan.

Returns

CUDNN_STATUS_BAD_PARAM

If any of the inputs is **NULL**, or if the type of cudnnFusedOps_t in the **constPack** descriptor is unsupported.

CUDNN_STATUS_SUCCESS

The function executed successfully.

3.150. cudnnMultiHeadAttnBackwardData()

```
cudnnStatus_t cudnnMultiHeadAttnBackwardData(
 cudnnHandle_t handle,
 const cudnnAttnDescriptor_t attnDesc,
 const int loWinIdx[],
 const int hiWinIdx[],
 const int devSeqLengthsDQDO[],
 const int devSeqLengthsDKDV[],
 const cudnnSeqDataDescriptor_t doDesc,
 const void *dout,
 const cudnnSeqDataDescriptor_t dqDesc,
 void *dqueries,
 const void *queries,
 const cudnnSeqDataDescriptor_t dkDesc,
```

```
void *dkeys,
const void *keys,
const cudnnSeqDataDescriptor_t dvDesc,
void *dvalues,
const void *values,
size_t weightSizeInBytes,
const void *weights,
size_t workSpaceSizeInBytes,
void *workSpace,
size_t reserveSpaceSizeInBytes,
void *reserveSpace);
```

This function computes exact, first-order derivatives of the multi-head attention block with respect to its inputs: **Q, K, V**. If **y**=*F*(**w**) is a vector-valued function that represents the multi-head attention layer and it takes some vector $x \in \mathbb{R}^n$ as an input (with all other parameters and inputs constant), and outputs vector $y \in \mathbb{R}^m$, then **cudnnMultiHeadAttnBackwardData()** computes the result of $\left(\partial y_i / \partial x_j\right)^T \delta_{\text{out}}$ where δ_{out} is the $m \times 1$ gradient of the loss function with respect to multi-head attention outputs. The δ_{out} gradient is back propagated through prior layers of the deep learning model. $\partial y_i / x_j$ is the $m \times n$ Jacobian matrix of *F*(**x**). The input is supplied via the **dout** argument and gradient results for **Q, K, V** are written to the **dqueries**, **dkeys**, and **dvalues** buffers.

The **cudnnMultiHeadAttnBackwardData()** function does not output partial derivatives for residual connections because this result is equal to δ_{out}. If the multi-head attention model enables residual connections sourced directly from **Q**, then the **dout** tensor needs to be added to **dqueries** to obtain the correct result of the latter. This operation is demonstrated in the cuDNN **multiHeadAttention** sample code.

The **cudnnMultiHeadAttnBackwardData()** function must be invoked after cudnnMultiHeadAttnForward(). The **loWinIdx[]**, **hiWinIdx[]**, **queries**, **keys**, **values**, **weights**, and **reserveSpace** arguments should be the same as in the cudnnMultiHeadAttnForward() call. **devSeqLengthsDQDO[]** and **devSeqLengthsDKDV[]** device arrays should contain the same start and end attention window indices as **devSeqLengthsQO[]** and **devSeqLengthsKV[]** arrays in the forward function invocation.

> **cudnnMultiHeadAttnBackwardData()** does not verify that sequence lengths stored in **devSeqLengthsDQDO[]** and **devSeqLengthsDKDV[]** contain the same settings as **seqLengthArray[]** in the corresponding sequence data descriptor.

Parameters

handle

Input. The current cuDNN context handle.

attnDesc

Input. A previously initialized attention descriptor.

`loWinIdx[],hiWinIdx[]`

Input. Two host integer arrays specifying the start and end indices of the attention window for each **Q** time-step. The start index in **K, V** sets is inclusive, and the end index is exclusive.

`devSeqLengthsDQDO[]`

Input. Device array containing a copy of the sequence length array from the **`dqDesc`** or **`doDesc`** sequence data descriptor.

`devSeqLengthsDKDV[]`

Input. Device array containing a copy of the sequence length array from the **`dkDesc`** or **`dvDesc`** sequence data descriptor.

`doDesc`

Input. Descriptor for the δ_{out} gradients (vectors of partial derivatives of the loss function with respect to the multi-head attention outputs).

`dout`

Pointer to δ_{out} gradient data in the device memory.

`dqDesc`

Input. Descriptor for **`queries`** and **`dqueries`** sequence data.

`dqueries`

Output. Device pointer to gradients of the loss function computed with respect to **`queries`** vectors.

`queries`

Input. Pointer to **`queries`** data in the device memory. This is the same input as in cudnnMultiHeadAttnForward().

`dkDesc`

Input. Descriptor for **`keys`** and **`dkeys`** sequence data.

`dkeys`

Output. Device pointer to gradients of the loss function computed with respect to **`keys`** vectors.

`keys`

Input. Pointer to **`keys`** data in the device memory. This is the same input as in cudnnMultiHeadAttnForward().

`dvDesc`

Input. Descriptor for **`values`** and **`dvalues`** sequence data.

dvalues

Output. Device pointer to gradients of the loss function computed with respect to **values** vectors.

values

Input. Pointer to **values** data in the device memory. This is the same input as in cudnnMultiHeadAttnForward().

weightSizeInBytes

Input. Size of the **weight** buffer in bytes where all multi-head attention trainable parameters are stored.

weights

Input. Address of the **weight** buffer in the device memory.

workSpaceSizeInBytes

Input. Size of the work-space buffer in bytes used for temporary API storage.

workSpace

Input/Output. Address of the work-space buffer in the device memory.

reserveSpaceSizeInBytes

Input. Size of the reserve-space buffer in bytes used for data exchange between forward and backward (gradient) API calls.

reserveSpace

Input/Output. Address to the reserve-space buffer in the device memory.

Returns

CUDNN_STATUS_SUCCESS

No errors were detected while processing API input arguments and launching GPU kernels.

CUDNN_STATUS_BAD_PARAM

An invalid or incompatible input argument was encountered.

CUDNN_STATUS_EXECUTION_FAILED

The process of launching a GPU kernel returned an error, or an earlier kernel did not complete successfully.

CUDNN_STATUS_INTERNAL_ERROR

An inconsistent internal state was encountered.

CUDNN_STATUS_NOT_SUPPORTED

A requested option or a combination of input arguments is not supported.

CUDNN_STATUS_ALLOC_FAILED

Insufficient amount of shared memory to launch a GPU kernel.

3.151. cudnnMultiHeadAttnBackwardWeights()

```
cudnnStatus_t cudnnMultiHeadAttnBackwardWeights(
 cudnnHandle_t handle,
 const cudnnAttnDescriptor_t attnDesc,
 cudnnWgradMode_t addGrad,
 const cudnnSeqDataDescriptor_t qDesc,
 const void *queries,
 const cudnnSeqDataDescriptor_t kDesc,
 const void *keys,
 const cudnnSeqDataDescriptor_t vDesc,
 const void *values,
 const cudnnSeqDataDescriptor_t doDesc,
 const void *dout,
 size_t weightSizeInBytes,
 const void *weights,
 void *dweights,
 size_t workSpaceSizeInBytes,
 void *workSpace,
 size_t reserveSpaceSizeInBytes,
 void *reserveSpace);
```

This function computes exact, first-order derivatives of the multi-head attention block with respect to its trainable parameters: projection weights and projection biases. If $\mathbf{y}=F(\mathbf{w})$ is a vector-valued function that represents the multi-head attention layer and it takes some vector $x \in \mathbb{R}^n$ of flatten weights or biases as an input (with all other parameters and inputs fixed), and outputs vector $y \in \mathbb{R}^m$, then **cudnnMultiHeadAttnBackwardWeights()** computes the result of $\left(\partial y_i / \partial x_j\right)^T \delta_{\text{out}}$ where δ_{out} is the $\mathrm{m} \times 1$ gradient of the loss function with respect to multi-head attention outputs. The δ_{out} gradient is back propagated through prior layers of the deep learning model. $\partial y_i / x_j$ is the $\mathrm{m} \times \mathrm{n}$ Jacobian matrix of $F(\mathbf{w})$. The δ_{out} input is supplied via the **dout** argument.

All gradient results with respect to weights and biases are written to the **dweights** buffer. The size and the organization of the **dweights** buffer is the same as the **weights** buffer that holds multi-head attention weights and biases. The cuDNN **multiHeadAttention** sample code demonstrates how to access those weights.

Gradient of the loss function with respect to weights or biases is typically computed over multiple batches. In such a case, partial results computed for each batch should be summed together. The **addGrad** argument specifies if the gradients from the current batch should be added to previously computed results or the **dweights** buffer should be overwritten with the new results.

The **cudnnMultiHeadAttnBackwardWeights()** function should be invoked after cudnnMultiHeadAttnBackwardData(). The **queries**, **keys**, **values**, **weights**, and **reserveSpace** arguments should be the same as in cudnnMultiHeadAttnForward() and cudnnMultiHeadAttnBackwardData() calls. The **dout** argument should be the same as in cudnnMultiHeadAttnBackwardData().

Parameters

`handle`

Input. The current cuDNN context handle.

`attnDesc`

Input. A previously initialized attention descriptor.

`addGrad`

Input. Weight gradient output mode.

`qDesc`

Input. Descriptor for the **`query`** sequence data.

`queries`

Input. Pointer to **`queries`** sequence data in the device memory.

`kDesc`

Input. Descriptor for the **`keys`** sequence data.

`keys`

Input. Pointer to **`keys`** sequence data in the device memory.

`vDesc`

Input. Descriptor for the **`values`** sequence data.

`values`

Input. Pointer to **`values`** sequence data in the device memory.

`doDesc`

Input. Descriptor for the δ_{out} gradients (vectors of partial derivatives of the loss function with respect to the multi-head attention outputs).

`dout`

Input. Pointer to δ_{out} gradient data in the device memory.

`weightSizeInBytes`

Input. Size of the **`weights`** and **`dweights`** buffers in bytes.

`weights`

Input. Address of the **`weight`** buffer in the device memory.

`dweights`

Output. Address of the weight gradient buffer in the device memory.

`workSpaceSizeInBytes`

Input. Size of the work-space buffer in bytes used for temporary API storage.

workSpace

Input/Output. Address of the work-space buffer in the device memory.

reserveSpaceSizeInBytes

Input. Size of the reserve-space buffer in bytes used for data exchange between forward and backward (gradient) API calls.

reserveSpace

Input/Output. Address to the reserve-space buffer in the device memory.

Returns

CUDNN_STATUS_SUCCESS

No errors were detected while processing API input arguments and launching GPU kernels.

CUDNN_STATUS_BAD_PARAM

An invalid or incompatible input argument was encountered.

CUDNN_STATUS_EXECUTION_FAILED

The process of launching a GPU kernel returned an error, or an earlier kernel did not complete successfully.

CUDNN_STATUS_INTERNAL_ERROR

An inconsistent internal state was encountered.

CUDNN_STATUS_NOT_SUPPORTED

A requested option or a combination of input arguments is not supported.

3.152. cudnnMultiHeadAttnForward()

```
cudnnStatus_t cudnnMultiHeadAttnForward(
 cudnnHandle_t handle,
 const cudnnAttnDescriptor_t attnDesc,
 int currIdx,
 const int loWinIdx[],
 const int hiWinIdx[],
 const int devSeqLengthsQO[],
 const int devSeqLengthsKV[],
 const cudnnSeqDataDescriptor_t qDesc,
 const void *queries,
 const void *residuals,
 const cudnnSeqDataDescriptor_t kDesc,
 const void *keys,
 const cudnnSeqDataDescriptor_t vDesc,
 const void *values,
 const cudnnSeqDataDescriptor_t oDesc,
       void *out,
 size_t weightSizeInBytes,
 const void *weights,
 size_t workSpaceSizeInBytes,
 void *workSpace,
```

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

The **cudnnMultiHeadAttnForward()** function computes the forward responses of the multi-head attention layer. When **reserveSpaceSizeInBytes=0** and **reserveSpace=NULL**, the function operates in the inference mode in which backward (gradient) functions are not invoked, otherwise, the training mode is assumed. In the training mode, the reserve space is used to pass intermediate results from **cudnnMultiHeadAttnForward()** to cudnnMultiHeadAttnBackwardData() and from cudnnMultiHeadAttnBackwardData() to cudnnMultiHeadAttnBackwardWeights().

In the inference mode, the **currIdx** specifies the time-step or sequence index of the embedding vectors to be processed. In this mode, the user can perform one iteration for time-step zero (**currIdx=0**), then update **Q, K, V** vectors and the attention window, and execute the next step (**currIdx=1**). The iterative process can be repeated for all time-steps.

When all **Q** time-steps are available (for example, in the training mode or in the inference mode on the encoder side in self-attention),the user can assign a negative value to **currIdx** and the **cudnnMultiHeadAttnForward()** API will automatically sweep through all **Q** time-steps.

The **loWinIdx[]** and **hiWinIdx[]** host arrays specify the attention window size for each **Q** time-step. In a typical self-attention case, the user must include all previously visited embedding vectors but not the current or future vectors. In this situation, the user should set:

```
currIdx=0: loWinIdx[0]=0; hiWinIdx[0]=0;  // initial time-step, no attention
 window
currIdx=1: loWinIdx[1]=0; hiWinIdx[1]=1;  // attention window spans one vector
currIdx=2: loWinIdx[2]=0; hiWinIdx[2]=2;  // attention window spans two vectors
(...)
```

When **currIdx** is negative in **cudnnMultiHeadAttnForward()**, the **loWinIdx[]** and **hiWinIdx[]** arrays must be fully initialized for all time-steps. When **cudnnMultiHeadAttnForward()** is invoked with **currIdx=0**, **currIdx=1**, **currIdx=2**, etc., then the user can update **loWinIdx[currIdx]** and **hiWinIdx[currIdx]** elements only before invoking the forward response function. All other elements in the **loWinIdx[]** and **hiWinIdx[]** arrays will not be accessed. Any adaptive attention window scheme can be implemented that way.

Use the following settings when the attention window should be the maximum size, for example, in cross-attention:

```
currIdx=0: loWinIdx[0]=0; hiWinIdx[0]=maxSeqLenK;
currIdx=1: loWinIdx[1]=0; hiWinIdx[1]=maxSeqLenK;
currIdx=2: loWinIdx[2]=0; hiWinIdx[2]=maxSeqLenK;
(...)
```

The **maxSeqLenK** value above should be equal to or larger than **dimA[CUDNN_SEQDATA_TIME_DIM]** in the **kDesc** descriptor. A good choice is to use **maxSeqLenK=INT_MAX** from **limits.h**.

> The actual length of any **K** sequence defined in **seqLengthArray[]** in cudnnSetSeqDataDescriptor() can be shorter than **maxSeqLenK**. The effective

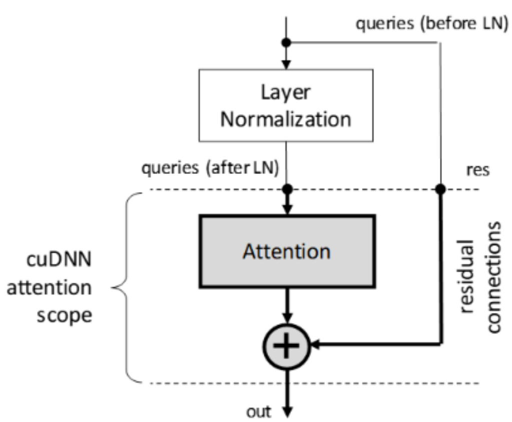
attention window span is computed based on **`seqLengthArray[]`** stored in the **K** sequence descriptor and indices held in **`loWinIdx[]`** and **`hiWinIdx[]`** arrays.

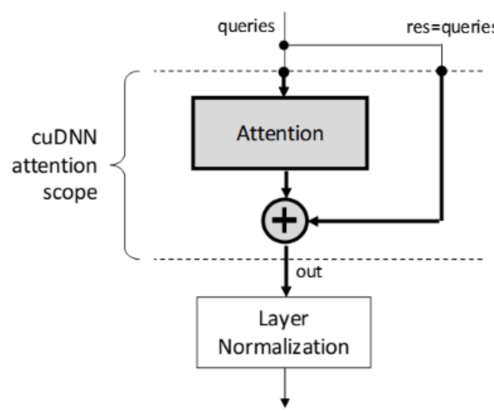
`devSeqLengthsQO[]` and **`devSeqLengthsKV[]`** are pointers to device (not host) arrays with **Q, O**, and **K, V** sequence lengths. Note that the same information is also passed in the corresponding descriptors of type cudnnSeqDataDescriptor_t on the host side. The need for extra device arrays comes from the asynchronous nature of cuDNN calls and limited size of the constant memory dedicated to GPU kernel arguments. When the **`cudnnMultiHeadAttnForward()`** API returns, the sequence length arrays stored in the descriptors can be immediately modified for the next iteration. However, the GPU kernels launched by the forward call may not have started at this point. For this reason, copies of sequence arrays are needed on the device side to be accessed directly by GPU kernels. Those copies cannot be created inside the **`cudnnMultiHeadAttnForward()`** function for very large **K, V** inputs without the device memory allocation and CUDA stream synchronization.

To reduce the **`cudnnMultiHeadAttnForward()`** API overhead, **`devSeqLengthsQO[]`** and **`devSeqLengthsKV[]`** device arrays are not validated to contain the same settings as **`seqLengthArray[]`** in the sequence data descriptors.

Sequence lengths in the **`kDesc`** and **`vDesc`** descriptors should be the same. Similarly, sequence lengths in the **`qDesc`** and **`oDesc`** descriptors should match. The user can define six different data layouts in the **`qDesc`**, **`kDesc`**, **`vDesc`** and **`oDesc`** descriptors. See the cudnnSetSeqDataDescriptor() function for the discussion of those layouts. All multi-head attention API calls require that the same layout is used in all sequence data descriptors.

In the transformer model, the multi-head attention block is tightly coupled with the layer normalization and residual connections. **`cudnnMultiHeadAttnForward()`** does not encompass the layer normalization but it can be used to handle residual connections as depicted in the following figure.





Queries and residuals share the same **`qDesc`** descriptor in **`cudnnMultiHeadAttnForward()`**. When residual connections are disabled, the residuals pointer should be **`NULL`**. When residual connections are enabled, the vector length in **`qDesc`** should match the vector length specified in the **`oDesc`** descriptor, so that a vector addition is feasible.

The **queries**, **keys**, and **values** pointers are not allowed to be **NULL**, even when **K** and **V** are the same inputs or **Q, K, V** are the same inputs.

Parameters

handle

Input. The current cuDNN context handle.

attnDesc

Input. A previously initialized attention descriptor.

currIdx

Input. Time-step in queries to process. When the **currIdx** argument is negative, all **Q** time-steps are processed. When **currIdx** is zero or positive, the forward response is computed for the selected time-step only. The latter input can be used in inference mode only, to process one time-step while updating the next attention window and **Q, R, K, V** inputs in-between calls.

loWinIdx[], hiWinIdx[]

Input. Two host integer arrays specifying the start and end indices of the attention window for each **Q** time-step. The start index in **K, V** sets is inclusive, and the end index is exclusive.

devSeqLengthsQO[]

Input. Device array specifying sequence lengths of query, residual, and output sequence data.

devSeqLengthsKV[]

Input. Device array specifying sequence lengths of key and value input data.

qDesc

Input. Descriptor for the query and residual sequence data.

queries

Input. Pointer to queries data in the device memory.

residuals

Input. Pointer to residual data in device memory. Set this argument to **NULL** if no residual connections are required.

kDesc

Input. Descriptor for the **keys** sequence data.

keys

Input. Pointer to **keys** data in device memory.

vDesc

Input. Descriptor for the **values** sequence data.

values

Input. Pointer to **values** data in device memory.

oDesc

Input. Descriptor for the multi-head attention output sequence data.

out

Output. Pointer to device memory where the output response should be written.

weightSizeInBytes

Input. Size of the weight buffer in bytes where all multi-head attention trainable parameters are stored.

weights

Input. Pointer to the weight buffer in device memory.

workSpaceSizeInBytes

Input. Size of the work-space buffer in bytes used for temporary API storage.

workSpace

Input/Output. Pointer to the work-space buffer in device memory.

reserveSpaceSizeInBytes

Input. Size of the reserve-space buffer in bytes used for data exchange between forward and backward (gradient) API calls. This parameter should be zero in the inference mode and non-zero in the training mode.

reserveSpace

Input/Output. Pointer to the reserve-space buffer in device memory. This argument should be **NULL** in inference mode and **non-NULL** in the training mode.

Returns

CUDNN_STATUS_SUCCESS

No errors were detected while processing API input arguments and launching GPU kernels.

CUDNN_STATUS_BAD_PARAM

An invalid or incompatible input argument was encountered. Some examples include:

- a required input pointer was **NULL**
- **currIdx** was out of bound
- the descriptor value for **attention**, **query**, **key**, **value**, and **output** were incompatible with one another

CUDNN_STATUS_EXECUTION_FAILED

The process of launching a GPU kernel returned an error, or an earlier kernel did not complete successfully.

CUDNN_STATUS_INTERNAL_ERROR

An inconsistent internal state was encountered.

CUDNN_STATUS_NOT_SUPPORTED

A requested option or a combination of input arguments is not supported.

CUDNN_STATUS_ALLOC_FAILED

Insufficient amount of shared memory to launch a GPU kernel.

3.153. cudnnOpTensor()

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

This function implements the equation **C = op(alpha1[0] * A, alpha2[0] * B) + beta[0] * C**, given the tensors **A**, **B**, and **C** and the scaling factors **alpha1**, **alpha2**, and **beta**. The **op** to use is indicated by the descriptor cudnnOpTensorDescriptor_t, meaning, the type of **opTensorDesc**. Currently-supported ops are listed by the cudnnOpTensorOp_t enum.

The following restrictions on the input and destination tensors apply:

- Each dimension of the input tensor **A** must match the corresponding dimension of the destination tensor **C**, and each dimension of the input tensor **B** must match the corresponding dimension of the destination tensor **C** or must be equal to 1. In the latter case, the same value from the input tensor **B** for those dimensions will be used to blend into the **C** tensor.
- The data types of the input Tensors **A** and **B**, and the destination Tensor C, must satisfy Table 24.

Table 24 Supported Datatypes

opTensorCompType in **opTensorDesc**	**A**	**B**	**C** (destination)
FLOAT	FLOAT	FLOAT	FLOAT
FLOAT	INT8	INT8	FLOAT

`opTensorCompType` in `opTensorDesc`	**A**	**B**	**C (destination)**
FLOAT	HALF	HALF	FLOAT
DOUBLE	DOUBLE	DOUBLE	DOUBLE
FLOAT	FLOAT	FLOAT	HALF
FLOAT	HALF	HALF	HALF
FLOAT	INT8	INT8	INT8
FLOAT	FLOAT	FLOAT	INT8

> All tensor formats up to dimension five (5) are supported. This routine does not support tensor formats beyond these dimensions.

Parameters

`handle`

Input. Handle to a previously created cuDNN context.

`opTensorDesc`

Input. Handle to a previously initialized op tensor descriptor.

`alpha1, alpha2, beta`

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

```
dstValue = alpha[0]*resultValue + beta[0]*priorDstValue
```

For more information, see Scaling Parameters in the *cuDNN Developer Guide*.

`aDesc, bDesc, cDesc`

Input. Handle to a previously initialized tensor descriptor.

`A, B`

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

`C`

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

Returns

`CUDNN_STATUS_SUCCESS`

The function executed successfully.

`CUDNN_STATUS_NOT_SUPPORTED`

The function does not support the provided configuration. 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 restrictions on the input and destination tensors, stated above, are not met.

`CUDNN_STATUS_EXECUTION_FAILED`

The function failed to launch on the GPU.

3.154. cudnnPoolingBackward()

```
cudnnStatus_t cudnnPoolingBackward(
    cudnnHandle_t                       handle,
    const cudnnPoolingDescriptor_t      poolingDesc,
    const void                         *alpha,
    const cudnnTensorDescriptor_t       yDesc,
    const void                         *y,
    const cudnnTensorDescriptor_t       dyDesc,
    const void                         *dy,
    const cudnnTensorDescriptor_t       xDesc,
    const void                         *xData,
    const void                         *beta,
    const cudnnTensorDescriptor_t       dxDesc,
    void                               *dx)
```

This function computes the gradient of a pooling operation.

As of cuDNN version 6.0, a deterministic algorithm is implemented for max backwards pooling. This algorithm can be chosen via the pooling mode enum of **`poolingDesc`**. The deterministic algorithm has been measured to be up to 50% slower than the legacy max backwards pooling algorithm, or up to 20% faster, depending upon the use case.

> All tensor formats are supported, best performance is expected when using **`HW-packed`** tensors. Only 2 and 3 spatial dimensions are allowed

Parameters

`handle`

Input. Handle to a previously created cuDNN context.

`poolingDesc`

Input. Handle to the previously initialized pooling descriptor.

`alpha, beta`

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

```
dstValue = alpha[0]*resultValue + beta[0]*priorDstValue
```

For more information, see Scaling Parameters in the *cuDNN Developer Guide*.

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**.

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.

3.155. 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 (meaning, the maximum or average of several adjacent values) to produce an output with smaller height and/or width.

- All tensor formats are supported, best performance is expected when using **HW-packed** tensors. Only 2 and 3 spatial dimensions are allowed.
- The dimensions of the output tensor **yDesc** can be smaller or bigger than the dimensions advised by the routine cudnnGetPooling2dForwardOutputDim() or cudnnGetPoolingNdForwardOutputDim().

Parameters

handle

Input. Handle to a previously created cuDNN context.

poolingDesc

Input. Handle to a previously initialized pooling descriptor.

alpha, beta

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

```
dstValue = alpha[0]*resultValue + beta[0]*priorDstValue
```

For more information, see Scaling Parameters in the *cuDNN Developer Guide*.

xDesc

Input. Handle to the previously initialized input tensor descriptor. Must be of type **FLOAT**, **DOUBLE**, **HALF** or **INT8**. For more information, see cudnnDataType_t.

x

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

yDesc

Input. Handle to the previously initialized output tensor descriptor. Must be of type **FLOAT**, **DOUBLE**, **HALF** or **INT8**. For more information, see cudnnDataType_t.

y

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

Returns

CUDNN_STATUS_SUCCESS

The function launched successfully.

CUDNN_STATUS_BAD_PARAM

At least one of the following conditions are met:

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

CUDNN_STATUS_NOT_SUPPORTED

The function does not support the provided configuration.

CUDNN_STATUS_EXECUTION_FAILED

The function failed to launch on the GPU.

3.156. 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** and **CUDNN_ERRQUERY_NONBLOCKING**) and one blocking mode **CUDNN_ERRQUERY_BLOCKING**.

CUDNN_ERRQUERY_RAWCODE reads the error storage location regardless of the kernel completion status. The kernel might not even 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, meaning, cudnnSetStream() is invoked between functions that report runtime kernel errors and the **cudnnQueryRuntimeError()** function.

The remote error status reported in **rstatus** can be set to: **CUDNN_STATUS_SUCCESS**, **CUDNN_STATUS_RUNTIME_IN_PROGRESS**, or **CUDNN_STATUS_RUNTIME_FP_OVERFLOW**. The remote kernel error is automatically cleared by **cudnnQueryRuntimeError()**.

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

Parameters

handle

Input. Handle to a previously created cuDNN context.

rstatus

Output. Pointer to the user's error code storage.

mode

Input. Remote error query mode.

tag

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

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.

3.157. cudnnReduceTensor()

```
cudnnStatus_t cudnnReduceTensor(
    cudnnHandle_t                              handle,
    const cudnnReduceTensorDescriptor_t        reduceTensorDesc,
    void                                      *indices,
    size_t                                     indicesSizeInBytes,
    void                                      *workspace,
    size_t                                     workspaceSizeInBytes,
    const void                                *alpha,
    const cudnnTensorDescriptor_t              aDesc,
    const void                                *A,
    const void                                *beta,
    const cudnnTensorDescriptor_t              cDesc,
    void                                      *C)
```

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

Each dimension of the output tensor **C** must match the corresponding dimension of the input tensor **A** or must be equal to 1. The dimensions equal to 1 indicate the dimensions of **A** to be reduced.

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

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

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

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

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

Parameters

`handle`

Input. Handle to a previously created cuDNN context.

`reduceTensorDesc`

Input. Handle to a previously initialized reduce tensor descriptor.

`indices`

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

`indicesSizeInBytes`

Input. Size of the above previously allocated space.

`workspace`

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

`workspaceSizeInBytes`

Input. Size of the above previously allocated space.

`alpha, beta`

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

```
dstValue = alpha[0]*resultValue + beta[0]*priorDstValue
```

For more information, see Scaling Parameters in the *cuDNN Developer Guide*.

`aDesc, cDesc`

Input. Handle to a previously initialized tensor descriptor.

`A`

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

`C`

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

Returns

`CUDNN_STATUS_SUCCESS`

The function executed successfully.

`CUDNN_STATUS_NOT_SUPPORTED`

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

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

CUDNN_STATUS_BAD_PARAM

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

CUDNN_INVALID_VALUE

The allocations for the indices or workspace are insufficient.

CUDNN_STATUS_EXECUTION_FAILED

The function failed to launch on the GPU.

3.158. cudnnReorderFilterAndBias()

```
cudnnStatus_t cudnnReorderFilterAndBias(
 cudnnHandle_t handle,
 const cudnnFilterDescriptor_t filterDesc,
 cudnnReorderType_t reorderType,
 const void *filterData,
 void *reorderedFilterData,
 int reorderBias,
 const void *biasData,
 void *reorderedBiasData);
```

This function cudnnReorderFilterAndBias() reorders the filter and bias values. It can be used to enhance the inference time by separating the reordering operation from convolution.

For example, convolutions in a neural network of multiple layers can require reordering of kernels at every layer, which can take up a significant fraction of the total inference time. Using this function, the reordering can be done one time on the filter and bias data followed by the convolution operations at the multiple layers, thereby enhancing the inference time.

Parameters

filterDesc

Input. Descriptor for the kernel dataset.

reorderType

Input. Setting to either perform reordering or not. For more information, see cudnnReorderType_t.

filterData

Input. Pointer to the filter (kernel) data location in the device memory.

reorderedFilterData

Input. Pointer to the location in the device memory where the reordered filter data will be written to, by this function.

reorderBias

Input. If > 0, then reorders the bias data also. If <= 0 then does not perform reordering operation on the bias data.

biasData

Input. Pointer to the bias data location in the device memory.

reorderedBiasData

Input. Pointer to the location in the device memory where the reordered bias data will be written to, by this function.

Returns

CUDNN_STATUS_SUCCESS

Reordering was successful.

CUDNN_STATUS_EXECUTION_FAILED

Either the reordering of the filter data or of the bias data failed.

3.159. cudnnRestoreAlgorithm()

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

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.

3.160. 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().

Returns

CUDNN_STATUS_SUCCESS

The call was successful.

CUDNN_STATUS_INVALID_VALUE

States buffer size (as indicated in **stateSizeInBytes**) is too small.

3.161. cudnnRNNBackwardData()

```
cudnnStatus_t cudnnRNNBackwardData(
    cudnnHandle_t                    handle,
    const cudnnRNNDescriptor_t       rnnDesc,
    const int                        seqLength,
    const cudnnTensorDescriptor_t   *yDesc,
    const void                      *y,
    const cudnnTensorDescriptor_t   *dyDesc,
    const void                      *dy,
    const cudnnTensorDescriptor_t    dhyDesc,
    const void                      *dhy,
    const cudnnTensorDescriptor_t    dcyDesc,
    const void                      *dcy,
    const cudnnFilterDescriptor_t    wDesc,
    const void                      *w,
    const cudnnTensorDescriptor_t    hxDesc,
    const void                      *hx,
    const cudnnTensorDescriptor_t    cxDesc,
    const void                      *cx,
    const cudnnTensorDescriptor_t   *dxDesc,
    void                            *dx,
    const cudnnTensorDescriptor_t    dhxDesc,
    void                            *dhx,
    const cudnnTensorDescriptor_t    dcxDesc,
    void                            *dcx,
    void                            *workspace,
    size_t                           workSpaceSizeInBytes,
    const void                      *reserveSpace,
    size_t                           reserveSpaceSizeInBytes)
```

This routine executes the recurrent neural network described by **rnnDesc** with output gradients **dy**, **dhy**, and **dhc**, weights **w** and input gradients **dx**, **dhx**, and **dcx**. **workspace** is required for intermediate storage. The data in **reserveSpace** must have previously been generated by cudnnRNNForwardTraining(). The same **reserveSpace** data must be used for future calls to cudnnRNNBackwardWeights() if they execute on the same input data.

Parameters

handle

Input. Handle to a previously created cuDNN context. For more information , see cudnnHandle_t.

rnnDesc

Input. A previously initialized RNN descriptor. For more information, see cudnnRNNDescriptor_t.

seqLength

Input. Number of iterations to unroll over. The value of this **seqLength** must not exceed the value that was used in the cudnnGetRNNWorkspaceSize() function for querying the workspace size required to execute the RNN.

yDesc

Input. An array of fully packed tensor descriptors describing the output from each recurrent iteration (one descriptor per iteration). For more information, see cudnnTensorDescriptor_t. The second dimension of the tensor depends on the **direction** argument passed to the cudnnSetRNNDescriptor() call used to initialize **rnnDesc**:

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

The first dimension of the tensor **n** must match the first dimension of the tensor **n** in **dyDesc**.

y

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

dyDesc

Input. An array of fully packed tensor descriptors describing the gradient at the output from each recurrent iteration (one descriptor per iteration). The second dimension of the tensor depends on the **direction** argument passed to the cudnnSetRNNDescriptor() call used to initialize **rnnDesc**:

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

The first dimension of the tensor **n** must match the first dimension of the tensor **n** in **dxDesc**.

dy

Input. Data pointer to GPU memory associated with the tensor descriptors in the array **dyDesc**.

dhyDesc

Input. A fully packed tensor descriptor describing the gradients at the final hidden state of the RNN. The first dimension of the tensor depends on the **direction** argument passed to the cudnnSetRNNDescriptor() call used to initialize **rnnDesc**:

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

The second dimension must match the first dimension of the tensors described in **xDesc**. The third dimension must match the **hiddenSize** argument passed to the cudnnSetRNNDescriptor() call used to initialize **rnnDesc**. The tensor must be fully packed.

dhy

Input. Data pointer to GPU memory associated with the tensor descriptor **dhyDesc**. If a **NULL** pointer is passed, the gradients at the final hidden state of the network will be initialized to zero.

dcyDesc

Input. A fully packed tensor descriptor describing the gradients at the final cell state of the RNN. The first dimension of the tensor depends on the **direction** argument passed to the cudnnSetRNNDescriptor() call used to initialize **rnnDesc**:

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

The second dimension must match the first dimension of the tensors described in **xDesc**. The third dimension must match the **hiddenSize** argument passed to the cudnnSetRNNDescriptor() call used to initialize **rnnDesc**. The tensor must be fully packed.

dcy

Input. Data pointer to GPU memory associated with the tensor descriptor **dcyDesc**. If a **NULL** pointer is passed, the gradients at the final cell state of the network will be initialized to zero.

wDesc

Input. Handle to a previously initialized filter descriptor describing the weights for the RNN. For more information, see cudnnFilterDescriptor_t.

w

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

hxDesc

Input. A fully packed tensor descriptor describing the initial hidden state of the RNN. The first dimension of the tensor depends on the **direction** argument passed to the cudnnSetRNNDescriptor() call used to initialize **rnnDesc**:

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

The second dimension must match the second dimension of the tensors described in **xDesc**. The third dimension must match the **hiddenSize** argument passed to the cudnnSetRNNDescriptor() call used to initialize **rnnDesc**. The tensor must be fully packed.

hx

Input. Data pointer to GPU memory associated with the tensor descriptor **hxDesc**. If a **NULL** pointer is passed, the initial hidden state of the network will be initialized to zero.

cxDesc

Input. A fully packed tensor descriptor describing the initial cell state for LSTM networks. The first dimension of the tensor depends on the **direction** argument passed to the cudnnSetRNNDescriptor() call used to initialize **rnnDesc**:

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

The second dimension must match the second dimension of the tensors described in **xDesc**. The third dimension must match the **hiddenSize** argument passed to the cudnnSetRNNDescriptor() call used to initialize **rnnDesc**. The tensor must be fully packed.

cx

Input. Data pointer to GPU memory associated with the tensor descriptor **cxDesc**. If a **NULL** pointer is passed, the initial cell state of the network will be initialized to zero.

dxDesc

Input. An array of fully packed tensor descriptors describing the gradient at the input of each recurrent iteration (one descriptor per iteration). The first dimension (batch size) of the tensors may decrease from element **n** to element **n+1** but may not increase. Each tensor descriptor must have the same second dimension (vector length).

dx

Output. Data pointer to GPU memory associated with the tensor descriptors in the array **dxDesc**.

dhxDesc

Input. A fully packed tensor descriptor describing the gradient at the initial hidden state of the RNN. The first dimension of the tensor depends on the **direction** argument passed to the cudnnSetRNNDescriptor() call used to initialize **rnnDesc**:

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

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

The second dimension must match the first dimension of the tensors described in **xDesc**. The third dimension must match the **hiddenSize** argument passed to the cudnnSetRNNDescriptor() call used to initialize **rnnDesc**. The tensor must be fully packed.

dhx

Output. Data pointer to GPU memory associated with the tensor descriptor **dhxDesc**. If a **NULL** pointer is passed, the gradient at the hidden input of the network will not be set.

dcxDesc

Input. A fully packed tensor descriptor describing the gradient at the initial cell state of the RNN. The first dimension of the tensor depends on the **direction** argument passed to the cudnnSetRNNDescriptor() call used to initialize **rnnDesc**:

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

The second dimension must match the first dimension of the tensors described in **xDesc**. The third dimension must match the **hiddenSize** argument passed to the cudnnSetRNNDescriptor() call used to initialize **rnnDesc**. The tensor must be fully packed.

dcx

Output. Data pointer to GPU memory associated with the tensor descriptor **dcxDesc**. If a **NULL** pointer is passed, the gradient at the cell input of the network will not be set.

workspace

Input. Data pointer to GPU memory to be used as a workspace for this call.

workSpaceSizeInBytes

Input. Specifies the size in bytes of the provided **workspace**.

reserveSpace

Input/Output. Data pointer to GPU memory to be used as a reserve space for this call.

reserveSpaceSizeInBytes

Input. Specifies the size in bytes of the provided **reserveSpace**.

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.

3.162. cudnnRNNBackwardDataEx()

```
cudnnStatus_t cudnnRNNBackwardDataEx(
    cudnnHandle_t                     handle,
    const cudnnRNNDescriptor_t        rnnDesc,
    const cudnnRNNDataDescriptor_t    yDesc,
    const void                        *y,
    const cudnnRNNDataDescriptor_t    dyDesc,
    const void                        *dy,
    const cudnnRNNDataDescriptor_t    dcDesc,
    const void                        *dcAttn,
    const cudnnTensorDescriptor_t     dhyDesc,
    const void                        *dhy,
    const cudnnTensorDescriptor_t     dcyDesc,
    const void                        *dcy,
    const cudnnFilterDescriptor_t     wDesc,
    const void                        *w,
    const cudnnTensorDescriptor_t     hxDesc,
    const void                        *hx,
    const cudnnTensorDescriptor_t     cxDesc,
    const void                        *cx,
    const cudnnRNNDataDescriptor_t    dxDesc,
    void                              *dx,
    const cudnnTensorDescriptor_t     dhxDesc,
    void                              *dhx,
    const cudnnTensorDescriptor_t     dcxDesc,
    void                              *dcx,
    const cudnnRNNDataDescriptor_t    dkDesc,
```

```
    void                                  *dkeys,
    void                                  *workSpace,
    size_t                                workSpaceSizeInBytes,
    void                                  *reserveSpace,
    size_t                                reserveSpaceSizeInBytes)
```

This routine is the extended version of the function cudnnRNNBackwardData(). This function **cudnnRNNBackwardDataEx()** allows the user to use unpacked (padded) layout for input **y** and output **dx**.

In the unpacked layout, each sequence in the mini-batch is considered to be of fixed length, specified by **maxSeqLength** in its corresponding **RNNDataDescriptor**. Each fixed-length sequence, for example, the **nth** sequence in the mini-batch, is composed of a valid segment specified by the **seqLengthArray[n]** in its corresponding **RNNDataDescriptor**; and a padding segment to make the combined sequence length equal to **maxSeqLength**.

With the unpacked layout, both sequence major (meaning, time major) and batch major are supported. For backward compatibility, the packed sequence major layout is supported. However, similar to the non-extended function cudnnRNNBackwardData(), the sequences in the mini-batch need to be sorted in descending order according to length.

Parameters

handle

Input. Handle to a previously created cuDNN context.

rnnDesc

Input. A previously initialized RNN descriptor.

yDesc

Input. A previously initialized RNN data descriptor. Must match or be the exact same descriptor previously passed into cudnnRNNForwardTrainingEx().

y

Input. Data pointer to the GPU memory associated with the RNN data descriptor **yDesc**. The vectors are expected to be laid out in memory according to the layout specified by **yDesc**. The elements in the tensor (including elements in the padding vector) must be densely packed, and no strides are supported. Must contain the exact same data previously produced by cudnnRNNForwardTrainingEx().

dyDesc

Input. A previously initialized RNN data descriptor. The **dataType**, **layout**, **maxSeqLength**, **batchSize**, **vectorSize**, and **seqLengthArray** need to match the **yDesc** previously passed to cudnnRNNForwardTrainingEx().

dy

Input. Data pointer to the GPU memory associated with the RNN data descriptor **dyDesc**. The vectors are expected to be laid out in memory according to the layout specified by **dyDesc**. The elements in the tensor (including elements in the padding vector) must be densely packed, and no strides are supported.

dhyDesc

Input. A fully packed tensor descriptor describing the gradients at the final hidden state of the RNN. The first dimension of the tensor depends on the **direction** argument passed to the cudnnSetRNNDescriptor() call used to initialize **rnnDesc**. Additionally:

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

The second dimension must match the **batchSize** parameter in **xDesc**. The third dimension depends on whether the RNN mode is **CUDNN_LSTM** and whether LSTM projection is enabled. Additionally:

- If the RNN mode is **CUDNN_LSTM** and LSTM projection is enabled, the third dimension must match the **recProjSize** argument passed to cudnnSetRNNProjectionLayers() call used to set **rnnDesc**.
- Otherwise, the third dimension must match the **hiddenSize** argument passed to the cudnnSetRNNDescriptor() call used to initialize **rnnDesc**.

dhy

Input. Data pointer to GPU memory associated with the tensor descriptor **dhyDesc**. If a **NULL** pointer is passed, the gradients at the final hidden state of the network will be initialized to zero.

dcyDesc

Input. A fully packed tensor descriptor describing the gradients at the final cell state of the RNN. The first dimension of the tensor depends on the **direction** argument passed to the cudnnSetRNNDescriptor() call used to initialize **rnnDesc**. Additionally:

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

The second dimension must match the first dimension of the tensors described in **xDesc**. The third dimension must match the **hiddenSize** argument passed to the cudnnSetRNNDescriptor() call used to initialize **rnnDesc**. The tensor must be fully packed.

dcy

Input. Data pointer to GPU memory associated with the tensor descriptor **dcyDesc**. If a **NULL** pointer is passed, the gradients at the final cell state of the network will be initialized to zero.

wDesc

Input. Handle to a previously initialized filter descriptor describing the weights for the RNN.

w

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

hxDesc

Input. A fully packed tensor descriptor describing the initial hidden state of the RNN. Must match or be the exact same descriptor previously passed into cudnnRNNForwardTrainingEx().

hx

Input. Data pointer to GPU memory associated with the tensor descriptor **hxDesc**. If a **NULL** pointer is passed, the initial hidden state of the network will be initialized to zero. Must contain the exact same data previously passed into cudnnRNNForwardTrainingEx(), or be **NULL** if **NULL** was previously passed to cudnnRNNForwardTrainingEx().

cxDesc

Input. A fully packed tensor descriptor describing the initial cell state for LSTM networks. Must match or be the exact same descriptor previously passed into cudnnRNNForwardTrainingEx().

cx

Input. Data pointer to GPU memory associated with the tensor descriptor **cxDesc**. If a **NULL** pointer is passed, the initial cell state of the network will be initialized to zero. Must contain the exact same data previously passed into cudnnRNNForwardTrainingEx(), or be **NULL** if **NULL** was previously passed to cudnnRNNForwardTrainingEx().

dxDesc

Input. A previously initialized RNN data descriptor. The **dataType**, **layout**, **maxSeqLength**, **batchSize**, **vectorSize** and **seqLengthArray** need to match that of **xDesc** previously passed to cudnnRNNForwardTrainingEx().

dx

Output. Data pointer to the GPU memory associated with the RNN data descriptor **dxDesc**. The vectors are expected to be laid out in memory according to the layout specified by **dxDesc**. The elements in the tensor (including elements in the padding vector) must be densely packed, and no strides are supported.

dhxDesc

Input. A fully packed tensor descriptor describing the gradient at the initial hidden state of the RNN. The descriptor must be set exactly the same way as **dhyDesc**.

dhx

Output. Data pointer to GPU memory associated with the tensor descriptor **dhxDesc**. If a **NULL** pointer is passed, the gradient at the hidden input of the network will not be set.

dcxDesc

Input. A fully packed tensor descriptor describing the gradient at the initial cell state of the RNN. The descriptor must be set exactly the same way as **dcyDesc**.

dcx

Output. Data pointer to GPU memory associated with the tensor descriptor **dcxDesc**. If a **NULL** pointer is passed, the gradient at the cell input of the network will not be set.

dkDesc

Reserved. User may pass in **NULL**.

dkeys

Reserved. User may pass in **NULL**.

workspace

Input. Data pointer to GPU memory to be used as a workspace for this call.

workSpaceSizeInBytes

Input. Specifies the size in bytes of the provided **workspace**.

reserveSpace

Input/Output. Data pointer to GPU memory to be used as a reserve space for this call.

reserveSpaceSizeInBytes

Input. Specifies the size in bytes of the provided **reserveSpace**.

Returns

CUDNN_STATUS_SUCCESS

The function launched successfully.

CUDNN_STATUS_NOT_SUPPORTED

At least one of the following conditions are met:

- Variable sequence length input is passed in while **CUDNN_RNN_ALGO_PERSIST_STATIC** or **CUDNN_RNN_ALGO_PERSIST_DYNAMIC** is used.

- **CUDNN_RNN_ALGO_PERSIST_STATIC** or **CUDNN_RNN_ALGO_PERSIST_DYNAMIC** is used on pre-Pascal devices.
- Double input/output is used for **CUDNN_RNN_ALGO_PERSIST_STATIC**.

CUDNN_STATUS_BAD_PARAM

At least one of the following conditions are met:

- The descriptor **rnnDesc** is invalid.
- At least one of the descriptors **yDesc**, **dxdesc**, **dydesc**, **dhxDesc**, **wDesc**, **hxDesc**, **cxDesc**, **dcxDesc**, **dhyDesc**, **dcyDesc** is invalid or has incorrect strides or dimensions.
- **workSpaceSizeInBytes** is too small.
- **reserveSpaceSizeInBytes** is too small.

CUDNN_STATUS_EXECUTION_FAILED

The function failed to launch on the GPU.

CUDNN_STATUS_ALLOC_FAILED

The function was unable to allocate memory.

3.163. cudnnRNNBackwardWeights()

```
cudnnStatus_t cudnnRNNBackwardWeights(
    cudnnHandle_t                    handle,
    const cudnnRNNDescriptor_t       rnnDesc,
    const int                        seqLength,
    const cudnnTensorDescriptor_t   *xDesc,
    const void                      *x,
    const cudnnTensorDescriptor_t    hxDesc,
    const void                      *hx,
    const cudnnTensorDescriptor_t   *yDesc,
    const void                      *y,
    const void                      *workspace,
    size_t                           workSpaceSizeInBytes,
    const cudnnFilterDescriptor_t    dwDesc,
    void                            *dw,
    const void                      *reserveSpace,
    size_t                           reserveSpaceSizeInBytes)
```

This routine accumulates weight gradients **dw** from the recurrent neural network described by **rnnDesc** with inputs **x**, **hx** and outputs **y**. The mode of operation in this case is additive, the weight gradients calculated will be added to those already existing in **dw**. **workspace** is required for intermediate storage. The data in **reserveSpace** must have previously been generated by cudnnRNNBackwardData().

Parameters

handle

Input. Handle to a previously created cuDNN context.

rnnDesc

Input. A previously initialized RNN descriptor.

seqLength

Input. Number of iterations to unroll over. The value of this **seqLength** must not exceed the value that was used in cudnnGetRNNWorkspaceSize() function for querying the workspace size required to execute the RNN.

xDesc

Input. An array of fully packed tensor descriptors describing the input to each recurrent iteration (one descriptor per iteration). The first dimension (batch size) of the tensors may decrease from element **n** to element **n+1** but may not increase. Each tensor descriptor must have the same second dimension (vector length).

x

Input. Data pointer to GPU memory associated with the tensor descriptors in the array **xDesc**.

hxDesc

Input. A fully packed tensor descriptor describing the initial hidden state of the RNN. The first dimension of the tensor depends on the **direction** argument passed to the cudnnSetRNNDescriptor() call used to initialize **rnnDesc**:

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

The second dimension must match the first dimension of the tensors described in **xDesc**. The third dimension must match the **hiddenSize** argument passed to the cudnnSetRNNDescriptor() call used to initialize **rnnDesc**. The tensor must be fully packed.

hx

Input. Data pointer to GPU memory associated with the tensor descriptor **hxDesc**. If a **NULL** pointer is passed, the initial hidden state of the network will be initialized to zero.

yDesc

Input. An array of fully packed tensor descriptors describing the output from each recurrent iteration (one descriptor per iteration). The second dimension of the tensor depends on the **direction** argument passed to the cudnnSetRNNDescriptor() call used to initialize **rnnDesc**:

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

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

The first dimension of the tensor **n** must match the first dimension of the tensor **n** in **dyDesc**.

y

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

workspace

Input. Data pointer to GPU memory to be used as a workspace for this call.

workSpaceSizeInBytes

Input. Specifies the size in bytes of the provided **workspace**.

dwDesc

Input. Handle to a previously initialized filter descriptor describing the gradients of the weights for the RNN.

dw

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

reserveSpace

Input. Data pointer to GPU memory to be used as a reserve space for this call.

reserveSpaceSizeInBytes

Input. Specifies the size in bytes of the provided **reserveSpace**.

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.

3.164. cudnnRNNBackwardWeightsEx()

```
cudnnStatus_t cudnnRNNBackwardWeightsEx(
    cudnnHandle_t                      handle,
    const cudnnRNNDescriptor_t         rnnDesc,
    const cudnnRNNDataDescriptor_t     xDesc,
    const void                         *x,
    const cudnnTensorDescriptor_t      hxDesc,
    const void                         *hx,
    const cudnnRNNDataDescriptor_t     yDesc,
    const void                         *y,
    void                               *workSpace,
    size_t                             workSpaceSizeInBytes,
    const cudnnFilterDescriptor_t      dwDesc,
    void                               *dw,
    void                               *reserveSpace,
    size_t                             reserveSpaceSizeInBytes)
```

This routine is the extended version of the function cudnnRNNBackwardWeights(). This function **cudnnRNNBackwardWeightsEx()** allows the user to use unpacked (padded) layout for input **x** and output **dw**.

In the unpacked layout, each sequence in the mini-batch is considered to be of fixed length, specified by **maxSeqLength** in its corresponding **RNNDataDescriptor**. Each fixed-length sequence, for example, the **nth** sequence in the mini-batch, is composed of a valid segment specified by the **seqLengthArray[n]** in its corresponding **RNNDataDescriptor**; and a padding segment to make the combined sequence length equal to **maxSeqLength**.

With the unpacked layout, both sequence major (meaning, time major) and batch major are supported. For backward compatibility, the packed sequence major layout is supported. However, similar to the non-extended function cudnnRNNBackwardWeights(), the sequences in the mini-batch need to be sorted in descending order according to length.

Parameters

handle

Input. Handle to a previously created cuDNN context.

rnnDesc

Input. A previously initialized RNN descriptor.

xDesc

Input. A previously initialized RNN data descriptor. Must match or be the exact same descriptor previously passed into cudnnRNNForwardTrainingEx().

x

Input. Data pointer to GPU memory associated with the tensor descriptors in the array **xDesc**. Must contain the exact same data previously passed into cudnnRNNForwardTrainingEx().

hxDesc

Input. A fully packed tensor descriptor describing the initial hidden state of the RNN. Must match or be the exact same descriptor previously passed into cudnnRNNForwardTrainingEx().

hx

Input. Data pointer to GPU memory associated with the tensor descriptor **hxDesc**. If a **NULL** pointer is passed, the initial hidden state of the network will be initialized to zero. Must contain the exact same data previously passed into cudnnRNNForwardTrainingEx(), or be **NULL** if **NULL** was previously passed to cudnnRNNForwardTrainingEx().

yDesc

Input. A previously initialized RNN data descriptor. Must match or be the exact same descriptor previously passed into cudnnRNNForwardTrainingEx().

y

Input. Data pointer to GPU memory associated with the output tensor descriptor **yDesc**. Must contain the exact same data previously produced by cudnnRNNForwardTrainingEx().

workspace

Input. Data pointer to GPU memory to be used as a workspace for this call.

workSpaceSizeInBytes

Input. Specifies the size in bytes of the provided **workspace**.

dwDesc

Input. Handle to a previously initialized filter descriptor describing the gradients of the weights for the RNN.

dw

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

reserveSpace

Input. Data pointer to GPU memory to be used as a reserve space for this call.

reserveSpaceSizeInBytes

Input. Specifies the size in bytes of the provided **reserveSpace**.

Returns

CUDNN_STATUS_SUCCESS

The function launched successfully.

CUDNN_STATUS_NOT_SUPPORTED

The function does not support the provided configuration.

CUDNN_STATUS_BAD_PARAM

At least one of the following conditions are met:

- The descriptor **rnnDesc** is invalid.
- At least one of the descriptors **xDesc**, **yDesc**, **hxDesc**, **dwDesc** is invalid, or has incorrect strides or dimensions.
- **workSpaceSizeInBytes** is too small.
- **reserveSpaceSizeInBytes** is too small.

CUDNN_STATUS_EXECUTION_FAILED

The function failed to launch on the GPU.

CUDNN_STATUS_ALLOC_FAILED

The function was unable to allocate memory.

3.165. 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**, and **cx**, weights **w** and outputs **y**, **hy**, and **cy**. **workspace** is required for intermediate storage. This function does not store intermediate data required for training; cudnnRNNForwardTraining() should be used for that purpose.

Parameters

handle

Input. Handle to a previously created cuDNN context.

rnnDesc

Input. A previously initialized RNN descriptor.

seqLength

Input. Number of iterations to unroll over. The value of this **seqLength** must not exceed the value that was used in cudnnGetRNNWorkspaceSize() function for querying the workspace size required to execute the RNN.

xDesc

Input. An array of **seqLength** fully packed tensor descriptors. Each descriptor in the array should have three dimensions that describe the input data format to one recurrent iteration (one descriptor per RNN time-step). The first dimension (batch size) of the tensors may decrease from iteration **n** to iteration **n+1** but may not increase. Each tensor descriptor must have the same second dimension (RNN input vector length, **inputSize**). The third dimension of each tensor should be 1. Input data are expected to be arranged in the column-major order so strides in **xDesc** should be set as follows:

```
strideA[0]=inputSize, strideA[1]=1, strideA[2]=1
```

x

Input. Data pointer to GPU memory associated with the array of tensor descriptors **xDesc**. The input vectors are expected to be packed contiguously with the first vector of iteration (time-step) **n+1** following directly from the last vector of iteration **n**. In other words, input vectors for all RNN time-steps should be packed in the contiguous block of GPU memory with no gaps between the vectors.

hxDesc

Input. A fully packed tensor descriptor describing the initial hidden state of the RNN. The first dimension of the tensor depends on the **direction** argument passed to the cudnnSetRNNDescriptor() call used to initialize **rnnDesc**:

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

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

cudnnSetRNNDescriptor() call used to initialize **rnnDesc**. The tensor must be fully packed.

hx

Input. Data pointer to GPU memory associated with the tensor descriptor **hxDesc**. If a **NULL** pointer is passed, the initial hidden state of the network will be initialized to zero.

cxDesc

Input. A fully packed tensor descriptor describing the initial cell state for LSTM networks. The first dimension of the tensor depends on the **direction** argument passed to the cudnnSetRNNDescriptor() call used to initialize **rnnDesc**:

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

The second dimension must match the first dimension of the tensors described in **xDesc**. The third dimension must match the **hiddenSize** argument passed to the cudnnSetRNNDescriptor() call used to initialize **rnnDesc**. The tensor must be fully packed.

cx

Input. Data pointer to GPU memory associated with the tensor descriptor **cxDesc**. If a **NULL** pointer is passed, the initial cell state of the network will be initialized to zero.

wDesc

Input. Handle to a previously initialized filter descriptor describing the weights for the RNN.

w

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

yDesc

Input. An array of fully packed tensor descriptors describing the output from each recurrent iteration (one descriptor per iteration). The second dimension of the tensor depends on the **direction** argument passed to the cudnnSetRNNDescriptor() call used to initialize **rnnDesc**:

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

The first dimension of the tensor **n** must match the first dimension of the tensor **n** in **xDesc**.

y

Output. Data pointer to GPU memory associated with the output tensor descriptor **yDesc**. The data are expected to be packed contiguously with the first element of iteration **n+1** following directly from the last element of iteration **n**.

hyDesc

Input. A fully packed tensor descriptor describing the final hidden state of the RNN. The first dimension of the tensor depends on the **direction** argument passed to the cudnnSetRNNDescriptor() call used to initialize **rnnDesc**:

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

The second dimension must match the first dimension of the tensors described in **xDesc**. The third dimension must match the **hiddenSize** argument passed to the cudnnSetRNNDescriptor() call used to initialize **rnnDesc**. The tensor must be fully packed.

hy

Output. Data pointer to GPU memory associated with the tensor descriptor **hyDesc**. If a **NULL** pointer is passed, the final hidden state of the network will not be saved.

cyDesc

Input. A fully packed tensor descriptor describing the final cell state for LSTM networks. The first dimension of the tensor depends on the **direction** argument passed to the cudnnSetRNNDescriptor() call used to initialize **rnnDesc**:

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

The second dimension must match the first dimension of the tensors described in **xDesc**. The third dimension must match the **hiddenSize** argument passed to the cudnnSetRNNDescriptor() call used to initialize **rnnDesc**. The tensor must be fully packed.

cy

Output. Data pointer to GPU memory associated with the tensor descriptor **cyDesc**. If a **NULL** pointer is passed, the final cell state of the network will 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**.

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.

3.166. cudnnRNNForwardInferenceEx()

```
cudnnStatus_t cudnnRNNForwardInferenceEx(
    cudnnHandle_t                   handle,
    const cudnnRNNDescriptor_t      rnnDesc,
    const cudnnRNNDataDescriptor_t  xDesc,
    const void                      *x,
    const cudnnTensorDescriptor_t   hxDesc,
    const void                      *hx,
    const cudnnTensorDescriptor_t   cxDesc,
    const void                      *cx,
    const cudnnFilterDescriptor_t   wDesc,
    const void                      *w,
    const cudnnRNNDataDescriptor_t  yDesc,
    void                            *y,
    const cudnnTensorDescriptor_t   hyDesc,
    void                            *hy,
    const cudnnTensorDescriptor_t   cyDesc,
    void                            *cy,
    const cudnnRNNDataDescriptor_t  kDesc,
    const void                      *keys,
    const cudnnRNNDataDescriptor_t  cDesc,
    void                            *cAttn,
    const cudnnRNNDataDescriptor_t  iDesc,
```

```
    void                               *iAttn,
    const cudnnRNNDataDescriptor_t  qDesc,
    void                               *queries,
    void                               *workSpace,
    size_t                             workSpaceSizeInBytes)
```

This routine is the extended version of the cudnnRNNForwardInference() function. The **cudnnRNNForwardTrainingEx()** allows the user to use unpacked (padded) layout for input **x** and output **y**. In the unpacked layout, each sequence in the mini-batch is considered to be of fixed length, specified by **maxSeqLength** in its corresponding **RNNDataDescriptor**. Each fixed-length sequence, for example, the **nth** sequence in the mini-batch, is composed of a valid segment, specified by the **seqLengthArray[n]** in its corresponding **RNNDataDescriptor**, and a padding segment to make the combined sequence length equal to **maxSeqLength**.

With unpacked layout, both sequence major (meaning, time major) and batch major are supported. For backward compatibility, the packed sequence major layout is supported. However, similar to the non-extended function cudnnRNNForwardInference(), the sequences in the mini-batch need to be sorted in descending order according to length.

Parameters

handle

Input. Handle to a previously created cuDNN context.

rnnDesc

Input. A previously initialized RNN descriptor.

xDesc

Input. A previously initialized RNN Data descriptor. The **dataType**, **layout**, **maxSeqLength**, **batchSize**, and **seqLengthArray** need to match that of **yDesc**.

x

Input. Data pointer to the GPU memory associated with the RNN data descriptor **xDesc**. The vectors are expected to be laid out in memory according to the layout specified by **xDesc**. The elements in the tensor (including elements in the padding vector) must be densely packed, and no strides are supported.

hxDesc

Input. A fully packed tensor descriptor describing the initial hidden state of the RNN. The first dimension of the tensor depends on the **direction** argument passed to the cudnnSetRNNDescriptor() call used to initialize **rnnDesc**:

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

The second dimension must match the **batchSize** parameter described in **xDesc**. The third dimension depends on whether RNN mode is **CUDNN_LSTM** and whether LSTM projection is enabled. Specifically:

- If RNN mode is **CUDNN_LSTM** and LSTM projection is enabled, the third dimension must match the **recProjSize** argument passed to cudnnSetRNNProjectionLayers() call used to set **rnnDesc**.
- Otherwise, the third dimension must match the **hiddenSize** argument passed to the cudnnSetRNNDescriptor() call used to initialize **rnnDesc**.

hx

Input. Data pointer to GPU memory associated with the tensor descriptor **hxDesc**. If a **NULL** pointer is passed, the initial hidden state of the network will be initialized to zero.

cxDesc

Input. A fully packed tensor descriptor describing the initial cell state for LSTM networks. The first dimension of the tensor depends on the **direction** argument passed to the cudnnSetRNNDescriptor() call used to initialize **rnnDesc**:

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

The second dimension must match the **batchSize** parameter in **xDesc**. The third dimension must match the **hiddenSize** argument passed to the cudnnSetRNNDescriptor() call used to initialize **rnnDesc**.

cx

Input. Data pointer to GPU memory associated with the tensor descriptor **cxDesc**. If a **NULL** pointer is passed, the initial cell state of the network will be initialized to zero.

wDesc

Input. Handle to a previously initialized filter descriptor describing the weights for the RNN.

w

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

yDesc

Input. A previously initialized RNN data descriptor. The **dataType**, **layout**, **maxSeqLength** , **batchSize**, and **seqLengthArray** must match that of **dyDesc** and **dxDesc**. The parameter **vectorSize** depends on whether RNN mode is **CUDNN_LSTM** and whether LSTM projection is enabled and whether the network is bidirectional. Specifically:

- For unidirectional network, if the RNN mode is **CUDNN_LSTM** and LSTM projection is enabled, the parameter **vectorSize** must match the **recProjSize** argument passed to cudnnSetRNNProjectionLayers() call used to set **rnnDesc**. If the network is bidirectional, then multiply the value by 2.
- Otherwise, for unidirectional network, the parameter **vectorSize** must match the **hiddenSize** argument passed to the cudnnSetRNNDescriptor() call used to initialize **rnnDesc**. If the network is bidirectional, then multiply the value by 2.

y

Output. Data pointer to the GPU memory associated with the RNN data descriptor **yDesc**. The vectors are expected to be laid out in memory according to the layout specified by **yDesc**. The elements in the tensor (including elements in the padding vector) must be densely packed, and no strides are supported.

hyDesc

Input. A fully packed tensor descriptor describing the final hidden state of the RNN. The descriptor must be set exactly the same way as **hxDesc**.

hy

Output. Data pointer to GPU memory associated with the tensor descriptor **hyDesc**. If a **NULL** pointer is passed, the final hidden state of the network will not be saved.

cyDesc

Input. A fully packed tensor descriptor describing the final cell state for LSTM networks. The descriptor must be set exactly the same way as **cxDesc**.

cy

Output. Data pointer to GPU memory associated with the tensor descriptor **cyDesc**. If a **NULL** pointer is passed, the final cell state of the network will not be saved.

kDesc

Reserved. User may pass in **NULL**.

keys

Reserved. User may pass in **NULL**.

cDesc

Reserved. User may pass in **NULL**.

cAttn

Reserved. User may pass in **NULL**.

iDesc

Reserved. User may pass in **NULL**.

iAttn

Reserved. User may pass in **NULL**.

qDesc

Reserved. User may pass in **NULL**.

queries

Reserved. User may pass in **NULL**.

workspace

Input. Data pointer to GPU memory to be used as a workspace for this call.

workSpaceSizeInBytes

Input. Specifies the size in bytes of the provided **workspace**.

Returns

CUDNN_STATUS_SUCCESS

The function launched successfully.

CUDNN_STATUS_NOT_SUPPORTED

At least one of the following conditions are met:

- Variable sequence length input is passed in while **CUDNN_RNN_ALGO_PERSIST_STATIC** or **CUDNN_RNN_ALGO_PERSIST_DYNAMIC** is used.
- **CUDNN_RNN_ALGO_PERSIST_STATIC** or **CUDNN_RNN_ALGO_PERSIST_DYNAMIC** is used on pre-Pascal devices.
- Double input/output is used for **CUDNN_RNN_ALGO_PERSIST_STATIC**.

CUDNN_STATUS_BAD_PARAM

At least one of the following conditions are met:

- The descriptor **rnnDesc** is invalid.
- At least one of the descriptors in **xDesc**, **yDesc**, **hxDesc**, **cxDesc**, **wDesc**, **hyDesc**, **cyDesc** is invalid, or have incorrect strides or dimensions.
- **reserveSpaceSizeInBytes** is too small.
- **workSpaceSizeInBytes** is too small.

CUDNN_STATUS_EXECUTION_FAILED

The function failed to launch on the GPU.

CUDNN_STATUS_ALLOC_FAILED

The function was unable to allocate memory.

3.167. 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**, and **cx**, weights **w** and outputs **y**, **hy**, and **cy**. **workspace** is required for intermediate storage. **reserveSpace** stores data required for training. The same **reserveSpace** data must be used for future calls to cudnnRNNBackwardData() and cudnnRNNBackwardWeights() if these execute on the same input data.

Parameters

handle

Input. Handle to a previously created cuDNN context.

rnnDesc

Input. A previously initialized RNN descriptor.

seqLength

Input. Number of iterations to unroll over. The value of this **seqLength** must not exceed the value that was used in cudnnGetRNNWorkspaceSize() function for querying the workspace size required to execute the RNN.

xDesc

Input. An array of **seqLength** fully packed tensor descriptors. Each descriptor in the array should have three dimensions that describe the input data format to one recurrent iteration (one descriptor per RNN time-step). The first dimension (batch size) of the tensors may decrease from iteration element n to iteration element **n+1** but may not increase. Each tensor descriptor must have the same second dimension (RNN input vector length, **inputSize**). The third dimension of each tensor should be 1. Input vectors are expected to be arranged in the column-major order so strides in **xDesc** should be set as follows:

```
strideA[0]=inputSize, strideA[1]=1, strideA[2]=1
```

x

Input. Data pointer to GPU memory associated with the array of tensor descriptors **xDesc**. The input vectors are expected to be packed contiguously with the first vector of iterations (time-step) **n+1** following directly the last vector of iteration **n**. In other words, input vectors for all RNN time-steps should be packed in the contiguous block of GPU memory with no gaps between the vectors.

hxDesc

Input. A fully packed tensor descriptor describing the initial hidden state of the RNN. The first dimension of the tensor depends on the **direction** argument passed to the cudnnSetRNNDescriptor() call used to initialize **rnnDesc**:

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

The second dimension must match the first dimension of the tensors described in **xDesc**. The third dimension must match the **hiddenSize** argument passed to the cudnnSetRNNDescriptor() call used to initialize **rnnDesc**. The tensor must be fully packed.

hx

Input. Data pointer to GPU memory associated with the tensor descriptor **hxDesc**. If a **NULL** pointer is passed, the initial hidden state of the network will be initialized to zero.

cxDesc

Input. A fully packed tensor descriptor describing the initial cell state for LSTM networks. The first dimension of the tensor depends on the **direction** argument passed to the cudnnSetRNNDescriptor() call used to initialize **rnnDesc**:

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

The second dimension must match the first dimension of the tensors described in **xDesc**. The third dimension must match the **hiddenSize** argument passed to the cudnnSetRNNDescriptor() call used to initialize **rnnDesc**. The tensor must be fully packed.

cx

Input. Data pointer to GPU memory associated with the tensor descriptor **cxDesc**. If a **NULL** pointer is passed, the initial cell state of the network will be initialized to zero.

wDesc

Input. Handle to a previously initialized filter descriptor describing the weights for the RNN.

w

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

yDesc

Input. An array of fully packed tensor descriptors describing the output from each recurrent iteration (one descriptor per iteration). The second dimension of the tensor depends on the **direction** argument passed to the cudnnSetRNNDescriptor() call used to initialize **rnnDesc**:

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

The first dimension of the tensor **n** must match the first dimension of the tensor **n** in **xDesc**.

y

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

hyDesc

Input. A fully packed tensor descriptor describing the final hidden state of the RNN. The first dimension of the tensor depends on the **direction** argument passed to the cudnnSetRNNDescriptor() call used to initialize **rnnDesc**:

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

The second dimension must match the first dimension of the tensors described in **xDesc**. The third dimension must match the **hiddenSize** argument passed to the cudnnSetRNNDescriptor() call used to initialize **rnnDesc**. The tensor must be fully packed.

hy

Output. Data pointer to GPU memory associated with the tensor descriptor **hyDesc**. If a **NULL** pointer is passed, the final hidden state of the network will not be saved.

cyDesc

Input. A fully packed tensor descriptor describing the final cell state for LSTM networks. The first dimension of the tensor depends on the **direction** argument passed to the cudnnSetRNNDescriptor() call used to initialize **rnnDesc**:

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

The second dimension must match the first dimension of the tensors described in **xDesc**. The third dimension must match the **hiddenSize** argument passed to the cudnnSetRNNDescriptor() call used to initialize **rnnDesc**. The tensor must be fully packed.

cy

Output. Data pointer to GPU memory associated with the tensor descriptor **cyDesc**. If a **NULL** pointer is passed, the final cell state of the network will not be saved.

workspace

Input. Data pointer to GPU memory to be used as a workspace for this call.

workSpaceSizeInBytes

Input. Specifies the size in bytes of the provided **workspace**.

reserveSpace

Input/Output. Data pointer to GPU memory to be used as a reserve space for this call.

reserveSpaceSizeInBytes

Input. Specifies the size in bytes of the provided **reserveSpace**.

Returns

CUDNN_STATUS_SUCCESS

The function launched successfully.

CUDNN_STATUS_BAD_PARAM

At least one of the following conditions are met:

- The descriptor **rnnDesc** is invalid.
- At least one of the descriptors **hxDesc, cxDesc, wDesc, hyDesc, cyDesc** or one of the descriptors in **xDesc, yDesc** is invalid.
- The descriptors in one of **xDesc, hxDesc, cxDesc, wDesc, yDesc, hyDesc, cyDesc** have incorrect strides or dimensions.
- **workSpaceSizeInBytes** is too small.
- **reserveSpaceSizeInBytes** is too small.

CUDNN_STATUS_EXECUTION_FAILED

The function failed to launch on the GPU.

CUDNN_STATUS_ALLOC_FAILED

The function was unable to allocate memory.

3.168. cudnnRNNForwardTrainingEx()

```
cudnnStatus_t cudnnRNNForwardTrainingEx(
    cudnnHandle_t                      handle,
    const cudnnRNNDescriptor_t         rnnDesc,
    const cudnnRNNDataDescriptor_t     xDesc,
    const void                         *x,
    const cudnnTensorDescriptor_t      hxDesc,
    const void                         *hx,
    const cudnnTensorDescriptor_t      cxDesc,
    const void                         *cx,
    const cudnnFilterDescriptor_t      wDesc,
    const void                         *w,
    const cudnnRNNDataDescriptor_t     yDesc,
    void                               *y,
    const cudnnTensorDescriptor_t      hyDesc,
    void                               *hy,
    const cudnnTensorDescriptor_t      cyDesc,
    void                               *cy,
    const cudnnRNNDataDescriptor_t     kDesc,
    const void                         *keys,
    const cudnnRNNDataDescriptor_t     cDesc,
    void                               *cAttn,
    const cudnnRNNDataDescriptor_t     iDesc,
    void                               *iAttn,
    const cudnnRNNDataDescriptor_t     qDesc,
    void                               *queries,
    void                               *workSpace,
    size_t                             workSpaceSizeInBytes,
    void                               *reserveSpace,
    size_t                             reserveSpaceSizeInBytes);
```

This routine is the extended version of the cudnnRNNForwardTraining() function. The **cudnnRNNForwardTrainingEx()** allows the user to use unpacked (padded) layout for input **x** and output **y**.

In the unpacked layout, each sequence in the mini-batch is considered to be of fixed length, specified by **maxSeqLength** in its corresponding **RNNDataDescriptor**. Each fixed-length sequence, for example, the **nth** sequence in the mini-batch, is composed of a valid segment specified by the **seqLengthArray[n]** in its corresponding **RNNDataDescriptor**; and a padding segment to make the combined sequence length equal to **maxSeqLength**.

With the unpacked layout, both sequence major (meaning, time major) and batch major are supported. For backward compatibility, the packed sequence major layout is supported. However, similar to the non-extended function cudnnRNNForwardTraining(), the sequences in the mini-batch need to be sorted in descending order according to length.

Parameters

handle

Input. Handle to a previously created cuDNN context.

rnnDesc

Input. A previously initialized RNN descriptor.

xDesc

Input. A previously initialized RNN Data descriptor. The **dataType**, **layout**, **maxSeqLength**, **batchSize**, and **seqLengthArray** need to match that of **yDesc**.

x

Input. Data pointer to the GPU memory associated with the RNN data descriptor **xDesc**. The input vectors are expected to be laid out in memory according to the layout specified by **xDesc**. The elements in the tensor (including elements in the padding vector) must be densely packed, and no strides are supported.

hxDesc

Input. A fully packed tensor descriptor describing the initial hidden state of the RNN.

The first dimension of the tensor depends on the **direction** argument passed to the cudnnSetRNNDescriptor() call used to initialize **rnnDesc**. Moreover:

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

The second dimension must match the **batchSize** parameter in **xDesc**. The third dimension depends on whether RNN mode is **CUDNN_LSTM** and whether **LSTM** projection is enabled. Additionally:

- If RNN mode is **CUDNN_LSTM** and **LSTM** projection is enabled, the third dimension must match the **recProjSize** argument passed to cudnnSetRNNProjectionLayers() call used to set **rnnDesc**.
- Otherwise, the third dimension must match the **hiddenSize** argument passed to the cudnnSetRNNDescriptor() call used to initialize **rnnDesc**.

hx

Input. Data pointer to GPU memory associated with the tensor descriptor **hxDesc**. If a **NULL** pointer is passed, the initial hidden state of the network will be initialized to zero.

cxDesc

Input. A fully packed tensor descriptor describing the initial cell state for LSTM networks.

The first dimension of the tensor depends on the **direction** argument passed to the cudnnSetRNNDescriptor() call used to initialize **rnnDesc**. Additionally:

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

The second dimension must match the first dimension of the tensors described in **xDesc**. The third dimension must match the **hiddenSize** argument passed to the cudnnSetRNNDescriptor() call used to initialize **rnnDesc**. The tensor must be fully packed.

cx

Input. Data pointer to GPU memory associated with the tensor descriptor **cxDesc**. If a **NULL** pointer is passed, the initial cell state of the network will be initialized to zero.

wDesc

Input. Handle to a previously initialized filter descriptor describing the weights for the RNN.

w

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

yDesc

Input. A previously initialized RNN data descriptor. The **dataType**, **layout**, **maxSeqLength**, **batchSize**, and **seqLengthArray** need to match that of **dyDesc** and **dxDesc**. The parameter **vectorSize** depends on whether the RNN mode is **CUDNN_LSTM** and whether LSTM projection is enabled and whether the network is bidirectional. Specifically:

- For unidirectional network, if the RNN mode is **CUDNN_LSTM** and LSTM projection is enabled, the parameter **vectorSize** must match the **recProjSize** argument passed to cudnnSetRNNProjectionLayers() call used to set **rnnDesc**. If the network is bidirectional, then multiply the value by 2.
- Otherwise, for unidirectional network, the parameter **vectorSize** must match the **hiddenSize** argument passed to the cudnnSetRNNDescriptor() call used to initialize **rnnDesc**. If the network is bidirectional, then multiply the value by 2.

y

Output. Data pointer to GPU memory associated with the RNN data descriptor **yDesc**. The input vectors are expected to be laid out in memory according to the layout specified by **yDesc**. The elements in the tensor (including elements in the padding vector) must be densely packed, and no strides are supported.

hyDesc

Input. A fully packed tensor descriptor describing the final hidden state of the RNN. The descriptor must be set exactly the same as **hxDesc**.

hy

Output. Data pointer to GPU memory associated with the tensor descriptor **hyDesc**. If a **NULL** pointer is passed, the final hidden state of the network will not be saved.

cyDesc

Input. A fully packed tensor descriptor describing the final cell state for LSTM networks. The descriptor must be set exactly the same as **cxDesc**.

cy

Output. Data pointer to GPU memory associated with the tensor descriptor **cyDesc**. If a **NULL** pointer is passed, the final cell state of the network will not be saved.

kDesc

Reserved. User may pass in **NULL**.

keys

Reserved. User may pass in **NULL**.

cDesc

Reserved. User may pass in **NULL**.

cAttn

Reserved. User may pass in **NULL**.

iDesc

Reserved. User may pass in **NULL**.

iAttn

Reserved. User may pass in **NULL**.

qDesc

Reserved. User may pass in **NULL**.

queries

Reserved. User may pass in **NULL**.

workspace

Input. Data pointer to GPU memory to be used as a workspace for this call.

workSpaceSizeInBytes

Input. Specifies the size in bytes of the provided **workspace**.

reserveSpace

Input/Output. Data pointer to GPU memory to be used as a reserve space for this call.

reserveSpaceSizeInBytes

Input. Specifies the size in bytes of the provided **reserveSpace**.

Returns

CUDNN_STATUS_SUCCESS

The function launched successfully.

CUDNN_STATUS_NOT_SUPPORTED

At least one of the following conditions are met:

- Variable sequence length input is passed in while **CUDNN_RNN_ALGO_PERSIST_STATIC** or **CUDNN_RNN_ALGO_PERSIST_DYNAMIC** is used.
- **CUDNN_RNN_ALGO_PERSIST_STATIC** or **CUDNN_RNN_ALGO_PERSIST_DYNAMIC** is used on pre-Pascal devices.
- Double input/output is used for **CUDNN_RNN_ALGO_PERSIST_STATIC**.

CUDNN_STATUS_BAD_PARAM

At least one of the following conditions are met:

- The descriptor **rnnDesc** is invalid.
- At least one of the descriptors **xDesc**, **yDesc**, **hxDesc**, **cxDesc**, **wDesc**, **hyDesc**, and **cyDesc** is invalid, or have incorrect strides or dimensions.
- **workSpaceSizeInBytes** is too small.
- **reserveSpaceSizeInBytes** is too small.

CUDNN_STATUS_EXECUTION_FAILED

The function failed to launch on the GPU.

CUDNN_STATUS_ALLOC_FAILED

The function was unable to allocate memory.

3.169. cudnnRNNGetClip()

```
cudnnStatus_t cudnnRNNGetClip(
    cudnnHandle_t                handle,
    cudnnRNNDescriptor_t         rnnDesc,
    cudnnRNNClipMode_t           *clipMode,
    cudnnNanPropagation_t        *clipNanOpt,
    double                       *lclip,
    double                       *rclip);
```

Retrieves the current LSTM cell clipping parameters, and stores them in the arguments provided.

Parameters

***clipMode**

Output. Pointer to the location where the retrieved **clipMode** is stored. The **clipMode** can be **CUDNN_RNN_CLIP_NONE** in which case no LSTM cell state clipping is being performed; or **CUDNN_RNN_CLIP_MINMAX**, in which case the cell state activation to other units are being clipped.

***lclip, *rclip**

Output. Pointers to the location where the retrieved LSTM cell clipping range **[lclip, rclip]** is stored.

***clipNanOpt**

Output. Pointer to the location where the retrieved **clipNanOpt** is stored.

Returns

CUDNN_STATUS_SUCCESS

The function launched successfully.

CUDNN_STATUS_BAD_PARAM

If any of the pointer arguments provided are **NULL**.

3.170. cudnnRNNSetClip()

```
cudnnStatus_t cudnnRNNSetClip(
    cudnnHandle_t                handle,
    cudnnRNNDescriptor_t         rnnDesc,
    cudnnRNNClipMode_t           clipMode,
    cudnnNanPropagation_t        clipNanOpt,
    double                       lclip,
    double                       rclip);
```

Sets the LSTM cell clipping mode. The LSTM clipping is disabled by default. When enabled, clipping is applied to all layers. This **cudnnRNNSetClip()** function may be called multiple times.

Parameters

clipMode

Input. Enables or disables the LSTM cell clipping. When **clipMode** is set to **CUDNN_RNN_CLIP_NONE** no LSTM cell state clipping is performed. When **clipMode** is **CUDNN_RNN_CLIP_MINMAX** the cell state activation to other units are clipped.

lclip, rclip

Input. The range **[lclip, rclip]** to which the LSTM cell clipping should be set.

clipNanOpt

Input. When set to **CUDNN_PROPAGATE_NAN** (see the description for cudnnNanPropagation_t), NaN is propagated from the LSTM cell, or it can be set to one of the clipping range boundary values, instead of propagating.

Returns

CUDNN_STATUS_SUCCESS

The function launched successfully.

CUDNN_STATUS_BAD_PARAM

Returns this value if **lclip** > **rclip**; or if either **lclip** or **rclip** is **NaN**.

3.171. cudnnSaveAlgorithm()

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

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.

3.172. 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 the host memory to a single value that all elements of the tensor will be scaled with. For more information, see Scaling Parameters in the *cuDNN Developer Guide*.

Returns

CUDNN_STATUS_SUCCESS

The function launched successfully.

CUDNN_STATUS_NOT_SUPPORTED

The function does not support the provided configuration.

CUDNN_STATUS_BAD_PARAM

One of the provided pointers is nil.

CUDNN_STATUS_EXECUTION_FAILED

The function failed to launch on the GPU.

3.173. 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. When the activation mode (see cudnnActivationMode_t) is set to **CUDNN_ACTIVATION_CLIPPED_RELU**, this input specifies the clipping threshold; and when the activation mode is set to **CUDNN_ACTIVATION_RELU**, this input specifies the upper bound.

Returns

CUDNN_STATUS_SUCCESS

The object was set successfully.

CUDNN_STATUS_BAD_PARAM

mode or **reluNanOpt** has an invalid enumerant value.

3.174. cudnnSetAlgorithmDescriptor()

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

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.

3.175. cudnnSetAlgorithmPerformance()

```
cudnnStatus_t cudnnSetAlgorithmPerformance(
    cudnnAlgorithmPerformance_t     algoPerf,
    cudnnAlgorithmDescriptor_t      algoDesc,
    cudnnStatus_t                   status,
    float                           time,
    size_t                          memory)
```

This function initializes a previously created generic algorithm performance object.

Parameters

algoPerf

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

algoDesc

Input. The algorithm descriptor which the performance results describe.

status

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

time

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

memory

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

Returns

CUDNN_STATUS_SUCCESS

The object was set successfully.

CUDNN_STATUS_BAD_PARAM

mode or **reluNanOpt** has an invalid enumerate value.

3.176. cudnnSetAttnDescriptor()

```
cudnnStatus_t cudnnSetAttnDescriptor(
 cudnnAttnDescriptor_t attnDesc,
 unsigned attnMode,
 int nHeads,
 double smScaler,
 cudnnDataType_t dataType,
```

```
cudnnDataType_t computePrec,
cudnnMathType_t mathType,
cudnnDropoutDescriptor_t attnDropoutDesc,
cudnnDropoutDescriptor_t postDropoutDesc,
int qSize,
int kSize,
int vSize,
int qProjSize,
int kProjSize,
int vProjSize,
int oProjSize,
int qoMaxSeqLength,
int kvMaxSeqLength,
int maxBatchSize,
int maxBeamSize);
```

This function configures a multi-head attention descriptor that was previously created using the cudnnCreateAttnDescriptor() function. The function sets attention parameters that are necessary to compute internal buffer sizes, dimensions of weight and bias tensors, or to select optimized code paths.

Input sequence data descriptors in cudnnMultiHeadAttnForward(), cudnnMultiHeadAttnBackwardData() and cudnnMultiHeadAttnBackwardWeights() functions are checked against the configuration parameters stored in the attention descriptor. Some parameters must match exactly while **`max`** arguments such as **`maxBatchSize`** or **`qoMaxSeqLength`** establish upper limits for the corresponding dimensions.

The multi-head attention model can be described by the following equations:

$$\mathbf{h}_i = \left(\mathbf{W}_{V,i}\mathbf{V}\right)\mathrm{softmax}\left(\mathrm{smScaler}\left(\mathbf{K}^T\mathbf{W}_{K,i}^T\right)\left(\mathbf{W}_{Q,i}\mathbf{q}\right)\right),\ \text{for } i = 0 \ldots \mathrm{nHeads}-1$$

$$\mathrm{MultiHeadAttn}\left(\mathbf{q}, \mathbf{K}, \mathbf{V}, \mathbf{W}_Q, \mathbf{W}_K, \mathbf{W}_V, \mathbf{W}_O\right) = \sum_{i=0}^{\mathrm{nHeads}-1}\mathbf{W}_{O,i}\mathbf{h}_i$$

Where:

- nHeads is the number of independent attention heads that evaluate $\mathbf{h}_i$ vectors.
- $\mathbf{q}$ is a primary input, a single **`query`** column vector.
- $\mathbf{K}$, $\mathbf{V}$ are two matrices of **`key`** and **`value`** column vectors.

For simplicity, the above equations are presented using a single embedding vector $\mathbf{q}$ but the cuDNN API can handle multiple $\mathbf{q}$ candidates in the beam search scheme, process $\mathbf{q}$ vectors from multiple sequences bundled into a batch, or automatically iterate through all embedding vectors (time-steps) of a sequence. Thus, in general, $\mathbf{q}$, $\mathbf{K}$, $\mathbf{V}$ inputs are tensors with additional pieces of information such as active length of each sequence or how unused padding vectors should be saved.

In some publications, $\mathbf{W}_{O,i}$ matrices are combined into one output projection matrix and $\mathbf{h}_i$ vectors are merged explicitly into a single vector. This is an equivalent notation. In the cuDNN library, $\mathbf{W}_{O,i}$ matrices are conceptually treated the same way as $\mathbf{W}_{\mathrm{Q},i}$, $\mathbf{W}_{\mathrm{K},i}$ or $\mathbf{W}_{\mathrm{V},i}$ input projection weights. See the description of the cudnnGetMultiHeadAttnWeights() function for more details.

Weight matrices $\mathbf{W}_{\mathrm{Q},i}$, $\mathbf{W}_{\mathrm{K},i}$, $\mathbf{W}_{\mathrm{V},i}$ and $\mathbf{W}_{O,i}$ play similar roles, adjusting vector lengths in $\mathbf{q}$, $\mathbf{K}$, $\mathbf{V}$ inputs and in the multi-head attention final output. The user can disable any or all projections by setting qProjSize, kProjSize, vProjSize or oProjSize arguments to zero.

Embedding vector sizes in **q**, **K**, **V** and the vector lengths after projections need to be selected in such a way that matrix multiplications described above are feasible. Otherwise, **`CUDNN_STATUS_BAD_PARAM`** is returned by the **`cudnnSetAttnDescriptor()`** function. All four weight matrices are used when it is desirable to maintain rank deficiency of $\mathbf{W}_{KQ,i} = \mathbf{W}_{K,i}^T \mathbf{W}_{Q,i}$ or $\mathbf{W}_{OV,i} = \mathbf{W}_{O,i} \mathbf{W}_{V,i}$ matrices to eliminate one or more dimensions during linear transformations in each head. This is a form of feature extraction. In such cases, the projected sizes are smaller than the original vector lengths.

For each attention head, weight matrix sizes are defined as follows:

- $\mathbf{W}_{Q,i}$ - size $[\mathrm{qProjSize}\ x\ \mathrm{qSize}],\ i = 0..\mathrm{nHeads}-1$
- $\mathbf{W}_{K,i}$ - size $[\mathrm{kProjSize}\ x\ \mathrm{kSize}],\ i = 0..\mathrm{nHeads}-1,\ \mathrm{kProjSize} = \mathrm{qProjSize}$
- $\mathbf{W}_{V,i}$ - size $[\mathrm{vProjSize}\ x\ \mathrm{vSize}],\ i = 0..\mathrm{nHeads}-1$
- $\mathbf{W}_{O,i}$ - size $[\mathrm{oProjSize}\ x\ (\mathrm{vProjSize} > 0\ ?\ \mathrm{vProjSize} : \mathrm{vSize})],\ i = 0..\mathrm{nHeads}-1$

When the output projection is disabled $(\mathrm{oProjSize} = 0)$, the output vector length is $\mathrm{nHeads} * (\mathrm{vProjSize} > 0\ ?\ \mathrm{vProjSize} : \mathrm{vSize})$, meaning, the output is a concatenation of all $\mathbf{h}_i$ vectors. In the alternative interpretation, a concatenated matrix $\mathbf{W}_O = [\mathbf{W}_{O,0}, \mathbf{W}_{O,1}, \mathbf{W}_{O,2}, ...]$ forms the identity matrix.

Softmax is a normalized, exponential vector function that takes and outputs vectors of the same size. The multi-head attention API utilizes softmax of the **`CUDNN_SOFTMAX_ACCURATE`** type to reduce the likelihood of the floating-point overflow.

The **`smScaler`** parameter is the softmax sharpening/smoothing coefficient. When **`smScaler=1.0`**, softmax uses the natural exponential function **`exp(x)`** or **`2.7183*`**. When **`smScaler<1.0`**, for example **`smScaler=0.2`**, the function used by the softmax block will not grow as fast because **`exp(0.2*x) ≈ 1.2214*`**.

The **`smScaler`** parameter can be adjusted to process larger ranges of values fed to softmax. When the range is too large (or **`smScaler`** is not sufficiently small for the given range), the output vector of the softmax block becomes categorical, meaning, one vector element is close to 1.0 and other outputs are zero or very close to zero. When this occurs, the Jacobian matrix of the softmax block is also close to zero so deltas are not back-propagated during training from output to input except through residual connections, if these connections are enabled. The user can set **`smScaler`** to any positive floating-point value or even zero. The **`smScaler`** parameter is not trainable.

The **`qoMaxSeqLength`**, **`kvMaxSeqLength`**, **`maxBatchSize`**, and **`maxBeamSize`** arguments declare the maximum sequence lengths, maximum batch size, and maximum beam size respectively, in the cudnnSeqDataDescriptor_t containers. The actual dimensions supplied to forward and backward (gradient) API functions should not exceed the **`max`** limits. The **`max`** arguments should be set carefully because too large values will result in excessive memory usage due to oversized work and reserve space buffers.

The **`attnMode`** argument is treated as a binary mask where various on/off options are set. These options can affect the internal buffer sizes, enforce certain argument checks, select optimized code execution paths, or enable attention variants that do not require additional numerical arguments. An example of such options is the inclusion of biases in input and output projections.

The **attnDropoutDesc** and **postDropoutDesc** arguments are descriptors that define two dropout layers active in the training mode. The first dropout operation defined by **attnDropoutDesc**, is applied directly to the softmax output. The second dropout operation, specified by **postDropoutDesc**, alters the multi-head attention output, just before the point where residual connections are added.

> The **cudnnSetAttnDescriptor()** function performs a shallow copy of **attnDropoutDesc** and **postDropoutDesc**, meaning, the addresses of both dropout descriptors are stored in the attention descriptor and not the entire structures. Therefore, the user should keep dropout descriptors during the entire life of the attention descriptor.

Parameters

attnDesc

Output. Attention descriptor to be configured.

attnMode

Input. Enables various attention options that do not require additional numerical values. See the table below for the list of supported flags. The user should assign a preferred set of bitwise **OR-ed** flags to this argument.

nHeads

Input. Number of attention heads.

smScaler

Input. Softmax smoothing (**1.0 >= smScaler >= 0.0**) or sharpening (**smScaler > 1.0**) coefficient. Negative values are not accepted.

dataType

Input. Data type used to represent attention inputs, attention weights and attention outputs.

computePrec

Input. Compute precision.

mathType

Input. NVIDIA Tensor Core settings.

attnDropoutDesc

Input. Descriptor of the dropout operation applied to the softmax output. See the table below for a list of unsupported features.

postDropoutDesc

Input. Descriptor of the dropout operation applied to the multi-head attention output, just before the point where residual connections are added. See the table below for a list of unsupported features.

`qSize, kSize, vSize`

Input. **Q**, **K**, **V** embedding vector lengths.

`qProjSize, kProjSize, vProjSize`

Input. **Q**, **K**, **V** embedding vector lengths after input projections. Use zero to disable the corresponding projection.

`oProjSize`

Input. The $\mathbf{h}_i$ vector length after the output projection. Use zero to disable this projection.

`qoMaxSeqLength`

Input. Largest sequence length expected in sequence data descriptors related to **Q**, **O**, **dQ** and **dO** inputs and outputs.

`kvMaxSeqLength`

Input. Largest sequence length expected in sequence data descriptors related to **K**, **V**, **dK** and **dV** inputs and outputs.

`maxBatchSize`

Input. Largest batch size expected in any cudnnSeqDataDescriptor_t container.

`maxBeamSize`

Input. Largest beam size expected in any cudnnSeqDataDescriptor_t container.

Supported `attnMode` flags

`CUDNN_ATTN_QUERYMAP_ALL_TO_ONE`

Forward declaration of mapping between **Q** and **K**, **V** vectors when the beam size is greater than one in the **Q** input. Multiple **Q** vectors from the same beam bundle map to the same **K**, **V** vectors. This means that beam sizes in the **K**, **V** sets are equal to one.

`CUDNN_ATTN_QUERYMAP_ONE_TO_ONE`

Forward declaration of mapping between **Q** and **K**, **V** vectors when the beam size is greater than one in the **Q** input. Multiple **Q** vectors from the same beam bundle map to different **K**, **V** vectors. This requires beam sizes in **K**, **V** sets to be the same as in the **Q** input.

`CUDNN_ATTN_DISABLE_PROJ_BIASES`

Use no biases in the attention input and output projections.

`CUDNN_ATTN_ENABLE_PROJ_BIASES`

Use extra biases in the attention input and output projections. In this case the projected $\overline{\mathbf{K}}$ vectors are computed as $\overline{\mathbf{K}}_i = \mathbf{W}_{K,i}\mathbf{K} + \mathbf{b} * [1, 1, ..., 1]_{1 \times n}$, where n is the number of columns in the **K** matrix. In other words, the same column vector **b** is added to all columns of **K** after the weight matrix multiplication.

Supported combinations of **dataType**, **computePrec**, and **mathType**

Table 25 Supported combinations

dataType	computePrec	mathType
CUDNN_DATA_DOUBLE	CUDNN_DATA_DOUBLE	CUDNN_DEFAULT_MATH
CUDNN_DATA_FLOAT	CUDNN_DATA_FLOAT	CUDNN_DEFAULT_MATH, CUDNN_TENSOR_OP_MATH_ALLOW_CONVERSION
CUDNN_DATA_HALF	CUDNN_DATA_HALF	CUDNN_DEFAULT_MATH, CUDNN_TENSOR_OP_MATH, CUDNN_TENSOR_OP_MATH_ALLOW_CONVERSION

Unsupported features

1. The dropout option is currently not supported by the multi-head attention API. Assign **NULL** to **attnDropoutDesc** and **postDropoutDesc** arguments when configuring the attention descriptor.
2. The **CUDNN_ATTN_ENABLE_PROJ_BIASES** option is not supported in the multi-head attention gradient functions.
3. The **paddingFill** argument in cudnnSeqDataDescriptor_t is currently ignored by all multi-head attention functions.

Returns

CUDNN_STATUS_SUCCESS

The attention descriptor was configured successfully.

CUDNN_STATUS_BAD_PARAM

An invalid input argument was encountered. Some examples include:

- post projection **Q** and **K** sizes were not equal
- **dataType**, **computePrec**, or **mathType** were invalid
- one or more of the following arguments were either negative or zero: **nHeads**, **qSize**, **kSize**, **vSize**, **qoMaxSeqLength**, **kvMaxSeqLength**, **maxBatchSize**, **maxBeamSize**
- one or more of the following arguments were negative: **qProjSize**, **kProjSize**, **vProjSize**, **smScaler**

CUDNN_STATUS_NOT_SUPPORTED

A requested option or a combination of input arguments is not supported.

3.177. cudnnSetCallback()

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

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

Parameters

mask

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

For example, when bit 3 is set to 1, the API logging is enabled. Currently only the log output of level **CUDNN_SEV_INFO** is functional; the others are not yet implemented. When used for turning on and off the logging with the default callback, the user may pass **NULL** to **udata** and **fptr**. In addition, the environment variable **CUDNN_LOGDEST_DBG** must be set. For more information, see the Backward compatibility and deprecation policy section in the *cuDNN Developer Guide*.

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

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

udata

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

fptr

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

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

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

Returns

CUDNN_STATUS_SUCCESS

The function launched successfully.

3.178. 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.

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.

3.179. 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

3.180. 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 the library routines associated with a given convolution descriptor.

Returns

CUDNN_STATUS_SUCCESS

The math type was set successfully.

CUDNN_STATUS_BAD_PARAM

Either an invalid convolution descriptor was provided or an invalid math type was specified.

3.181. 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 data type in which the computation will be done.

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**.

3.182. cudnnSetConvolutionReorderType()

```
cudnnStatus_t cudnnSetConvolutionReorderType(
 cudnnConvolutionDescriptor_t convDesc,
 cudnnReorderType_t reorderType);
```

This function sets the convolution reorder type for the given convolution descriptor.

Parameters

convDesc

Input. The convolution descriptor for which the reorder type should be set.

reorderType

Input. Set the reorder type to this value. For more information, see cudnnReorderType_t.

Returns

CUDNN_STATUS_BAD_PARAM

The reorder type supplied is not supported.

CUDNN_STATUS_SUCCESS

Reorder type is set successfully.

3.183. cudnnSetCTCLossDescriptor()

```
cudnnStatus_t cudnnSetCTCLossDescriptor(
    cudnnCTCLossDescriptor_t        ctcLossDesc,
    cudnnDataType_t                 compType)
```

This function sets a CTC loss function descriptor. See also the extended version cudnnSetCTCLossDescriptorEx() to set the input normalization mode.

When the extended version cudnnSetCTCLossDescriptorEx() is used with **normMode** set to **CUDNN_LOSS_NORMALIZATION_NONE** and the **gradMode** set to **CUDNN_NOT_PROPAGATE_NAN**, then it is the same as the current function **cudnnSetCTCLossDescriptor()**, meaning:

```
cudnnSetCtcLossDescriptor(*) = cudnnSetCtcLossDescriptorEx(*,
 normMode=CUDNN_LOSS_NORMALIZATION_NONE, gradMode=CUDNN_NOT_PROPAGATE_NAN)
```

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.

3.184. cudnnSetCTCLossDescriptorEx()

```
cudnnStatus_t cudnnSetCTCLossDescriptorEx(
    cudnnCTCLossDescriptor_t        ctcLossDesc,
    cudnnDataType_t                 compType,
    cudnnLossNormalizationMode_t    normMode,
    cudnnNanPropagation_t           gradMode)
```

This function is an extension of cudnnSetCTCLossDescriptor(). This function provides an additional interface **normMode** to set the input normalization mode for the CTC loss function, and **gradMode** to control the **NaN** propagation type.

When this function **cudnnSetCTCLossDescriptorEx()** is used with **normMode** set to **CUDNN_LOSS_NORMALIZATION_NONE** and the **gradMode** set to **CUDNN_NOT_PROPAGATE_NAN**, then it is the same as cudnnSetCTCLossDescriptor(), meaning:

```
cudnnSetCtcLossDescriptor(*) = cudnnSetCtcLossDescriptorEx(*,
 normMode=CUDNN_LOSS_NORMALIZATION_NONE, gradMode=CUDNN_NOT_PROPAGATE_NAN)
```

Parameters

ctcLossDesc

Output. CTC loss descriptor to be set.

compType

Input. Compute type for this CTC loss function.

normMode

Input. Input normalization type for this CTC loss function. For more information, see cudnnLossNormalizationMode_t.

gradMode

Input. NaN propagation type for this CTC loss function. For **L** the sequence length, **R** the number of repeated letters in the sequence, and **T** the length of sequential data, the following applies: when a sample with **L+R > T** is encountered during the gradient calculation, if **gradMode** is set to **CUDNN_PROPAGATE_NAN** (see cudnnNanPropagation_t), then the CTC loss function does not write to the gradient buffer for that sample. Instead, the current values, even not finite, are retained. If **gradMode** is set to **CUDNN_NOT_PROPAGATE_NAN**, then the gradient for that sample is set to zero. This guarantees finite gradient.

Returns

CUDNN_STATUS_SUCCESS

The function returned successfully.

CUDNN_STATUS_BAD_PARAM

At least one of input parameters passed is invalid.

3.185. 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 the **states** argument is equal to **NULL**, then the random number generator states won't be initialized, and only the **dropout** value will be set. No other function should be writing to the memory pointed at by the **states** argument while this function is running. The user is expected not to change the 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 the size in bytes of the provided memory for the states.

seed

Input. Seed used to initialize random number generator states.

Returns

CUDNN_STATUS_SUCCESS

The call was successful.

CUDNN_STATUS_INVALID_VALUE

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

CUDNN_STATUS_EXECUTION_FAILED

The function failed to launch on the GPU.

3.186. cudnnSetFilter4dDescriptor()

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

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

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

Parameters

filterDesc

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

datatype

Input. Data type.

format

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

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

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

k

Input. Number of output feature maps.

c

Input. Number of input feature maps.

h

Input. Height of each filter.

w

Input. Width of each filter.

Returns

CUDNN_STATUS_SUCCESS

The object was set successfully.

CUDNN_STATUS_BAD_PARAM

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

3.187. cudnnSetFilterNdDescriptor()

```
cudnnStatus_t cudnnSetFilterNdDescriptor(
    cudnnFilterDescriptor_t filterDesc,
    cudnnDataType_t         dataType,
    cudnnTensorFormat_t     format,
    int                     nbDims,
    const int               filterDimA[])
```

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

The tensor format **CUDNN_TENSOR_NHWC** has limited support in cudnnConvolutionForward(), cudnnConvolutionBackwardData(), and cudnnConvolutionBackwardFilter().

Parameters

filterDesc

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

datatype

Input. Data type.

format

Input.Type of the filter layout format. If this input is set to **CUDNN_TENSOR_NCHW**, which is one of the enumerant values allowed by cudnnTensorFormat_t descriptor, then the layout of the filter is as follows:

- For **N=4**, a 4D filter descriptor, the filter layout is in the form of **KCRS**:

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

- For **N=3**, a 3D filter descriptor, the number **S** (number of columns per filter) is omitted.
- For **N=5** and greater, the layout of the higher dimensions immediately follow **RS**.

On the other hand, if this input is set to **CUDNN_TENSOR_NHWC**, then the layout of the filter is as follows:

- For **N=4**, a 4D filter descriptor, the filter layout is in the form of **KRSC**.
- For **N=3**, a 3D filter descriptor, the number **S** (number of columns per filter) is omitted and the layout of **C** immediately follows **R**.
- For **N=5** and greater, the layout of the higher dimensions are inserted between **S** and **C**. For more information, see cudnnTensorFormat_t.

nbDims

Input. Dimension of the filter.

filterDimA

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

Returns

CUDNN_STATUS_SUCCESS

The object was set successfully.

CUDNN_STATUS_BAD_PARAM

At least one of the elements of the array **filterDimA** is negative or **dataType** or **format** has an invalid enumerant value.

CUDNN_STATUS_NOT_SUPPORTED

The parameter **nbDims** exceeds **CUDNN_DIM_MAX**.

3.188. cudnnSetFusedOpsConstParamPackAttribute()

```
cudnnStatus_t cudnnSetFusedOpsConstParamPackAttribute(
 cudnnFusedOpsConstParamPack_t constPack,
 cudnnFusedOpsConstParamLabel_t paramLabel,
 const void *param);
```

This function sets the descriptor pointed to by the **param** pointer input. The type of the descriptor to be set is indicated by the enum value of the `paramLabel` input.

Parameters

`constPack`
Input. The opaque cudnnFusedOpsConstParamPack_t structure that contains the various problem size information, such as the shape, layout and the type of tensors, the descriptors for convolution and activation, and settings for operations such as convolution and activation.

`paramLabel`
Input. Several types of descriptors can be set by this setter function. The **`param`** input points to the descriptor itself, and this input indicates the type of the descriptor pointed to by the **`param`** input. The cudnnFusedOpsConstParamLabel_t enumerant type enables the selection of the type of the descriptor.

`param`
Input. Data pointer to the host memory, associated with the specific descriptor. The type of the descriptor depends on the value of **`paramLabel`**. For more information, see the table in cudnnFusedOpsConstParamLabel_t.

If this pointer is set to **`NULL`**, then the cuDNN library will record as such. If not, then the values pointed to by this pointer (meaning, the value or the opaque structure underneath) will be copied into the **`constPack`** during **`cudnnSetFusedOpsConstParamPackAttribute()`** operation.

Returns

`CUDNN_STATUS_SUCCESS`
The descriptor is set successfully.

`CUDNN_STATUS_BAD_PARAM`
If **`constPack`** is **`NULL`**, or if **`paramLabel`** or the ops setting for **`constPack`** is invalid.

3.189. cudnnSetFusedOpsVariantParamPackAttribute()

```
cudnnStatus_t cudnnSetFusedOpsVariantParamPackAttribute(
 cudnnFusedOpsVariantParamPack_t varPack,
 cudnnFusedOpsVariantParamLabel_t paramLabel,
 void *ptr);
```

This function sets the variable parameter pack descriptor.

Parameters

`varPack`
Input. Pointer to the **`cudnnFusedOps`** variant parameter pack (**`varPack`**) descriptor.

`paramLabel`
Input. Type to which the buffer pointer parameter (in the **`varPack`** descriptor) is set by this function. For more information, see cudnnFusedOpsConstParamLabel_t.

ptr

Input. Pointer, to the host or device memory, to the value to which the descriptor parameter is set. The data type of the pointer, and the host/device memory location, depend on the **paramLabel** input selection. For more information, see cudnnFusedOpsVariantParamLabel_t.

Returns

CUDNN_STATUS_BAD_PARAM

If **varPack** is **NULL** or if **paramLabel** is set to an unsupported value.

CUDNN_STATUS_SUCCESS

The descriptor was set successfully.

3.190. cudnnSetLRNDescriptor()

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

This function initializes a previously created LRN descriptor object.

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

Parameters

normDesc

Output. Handle to a previously created LRN descriptor.

lrnN

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

lrnAlpha

Input. Value of the alpha variance scaling parameter in the normalization formula. Inside the library code, this value is divided by the window width for LRN and by

(window width)^#spatialDimensions for **DivisiveNormalization**. By default, this value is set to **1e-4** in cudnnCreateLRNDescriptor().

lrnBeta

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

lrnK

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

Returns

CUDNN_STATUS_SUCCESS

The object was set successfully.

CUDNN_STATUS_BAD_PARAM

One of the input parameters was out of valid range as described above.

3.191. 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.

3.192. 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**.

3.193. 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.

Returns

CUDNN_STATUS_SUCCESS

The object was set successfully.

CUDNN_STATUS_BAD_PARAM

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

3.194. cudnnSetPoolingNdDescriptor()

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

This function initializes a previously created generic pooling descriptor object.

Parameters

poolingDesc

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

mode

Input. Enumerant to specify the pooling mode.

maxpoolingNanOpt

Input. Enumerant to specify the Nan propagation mode.

nbDims

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

windowDimA

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

paddingA

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

strideA

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

Returns

CUDNN_STATUS_SUCCESS

The object was initialized successfully.

CUDNN_STATUS_NOT_SUPPORTED

If (**nbDims** > **CUDNN_DIM_MAX-2**).

CUDNN_STATUS_BAD_PARAM

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

3.195. 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).

3.196. cudnnSetRNNBiasMode()

```
cudnnStatus_t cudnnSetRNNBiasMode(
   cudnnRNNDescriptor_t   rnnDesc,
   cudnnRNNBiasMode_t     biasMode)
```

The **cudnnSetRNNBiasMode()** function sets the number of bias vectors for a previously created and initialized RNN descriptor. This function should be called after cudnnSetRNNDescriptor() to enable the specified bias mode in an RNN. The default value of **biasMode** in **rnnDesc** after cudnnCreateRNNDescriptor() is **CUDNN_RNN_DOUBLE_BIAS**.

Parameters

rnnDesc

Input/Output. A previously created RNN descriptor.

biasMode

Input. Sets the number of bias vectors. For more information, see cudnnRNNBiasMode_t.

Returns

CUDNN_STATUS_BAD_PARAM

Either the **rnnDesc** is **NULL** or **biasMode** has an invalid enumerant value.

CUDNN_STATUS_SUCCESS

The **biasMode** was set successfully.

CUDNN_STATUS_NOT_SUPPORTED

Non-default bias mode (an enumerated type besides **CUDNN_RNN_DOUBLE_BIAS**) applied to an RNN algo other than **CUDNN_RNN_ALGO_STANDARD**.

3.197. cudnnSetRNNDataDescriptor()

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

This function initializes a previously created RNN data descriptor object. This data structure is intended to support the unpacked (padded) layout for input and output of extended RNN inference and training functions. A packed (unpadded) layout is also supported for backward compatibility.

Parameters

RNNDataDesc

Input/Output. A previously created RNN descriptor. For more information, see cudnnRNNDataDescriptor_t.

dataType

Input. The datatype of the RNN data tensor. For more information, see cudnnDataType_t.

layout

Input. The memory layout of the RNN data tensor.

maxSeqLength

Input. The maximum sequence length within this RNN data tensor. In the unpacked (padded) layout, this should include the padding vectors in each sequence. In the packed (unpadded) layout, this should be equal to the greatest element in **seqLengthArray**.

batchSize

Input. The number of sequences within the mini-batch.

vectorSize

Input. The vector length (embedding size) of the input or output tensor at each time-step.

seqLengthArray

Input. An integer array with **batchSize** number of elements. Describes the length (number of time-steps) of each sequence. Each element in **seqLengthArray** must be greater than 0 but less than or equal to **maxSeqLength**. In the packed layout, the elements should be sorted in descending order, similar to the layout required by the non-extended RNN compute functions.

paddingFill

Input. A user-defined symbol for filling the padding position in RNN output. This is only effective when the descriptor is describing the RNN output, and the unpacked layout is specified. The symbol should be in the host memory, and is interpreted as the same data type as that of the RNN data tensor. If a **NULL** pointer is passed in, then the padding position in the output will be undefined.

Returns

CUDNN_STATUS_SUCCESS

The object was set successfully.

CUDNN_STATUS_NOT_SUPPORTED

dataType is not one of **CUDNN_DATA_HALF**, **CUDNN_DATA_FLOAT** or **CUDNN_DATA_DOUBLE**.

CUDNN_STATUS_BAD_PARAM

Any one of these have occurred:

- **RNNDataDesc** is **NULL**.
- Any one of **maxSeqLength**, **batchSize** or **vectorSize** is less than or equal to zero.
- An element of **seqLengthArray** is less than or equal to zero or greater than **maxSeqLength**.

- Layout is not one of **CUDNN_RNN_DATA_LAYOUT_SEQ_MAJOR_UNPACKED**, **CUDNN_RNN_DATA_LAYOUT_SEQ_MAJOR_PACKED** or **CUDNN_RNN_DATA_LAYOUT_BATCH_MAJOR_UNPACKED**.

CUDNN_STATUS_ALLOC_FAILED

The allocation of internal array storage has failed.

3.198. cudnnSetRNNDescriptor()

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

This function initializes a previously created RNN descriptor object.

> Larger networks, for example, longer sequences or 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, for example, bidirectional.

mode

Input. Specifies the type of RNN to compute.

mathPrec

Input. Math precision. This parameter is used for controlling the math precision in RNN. The following applies:

- For the input/output in FP16, the parameter **mathPrec** can be **CUDNN_DATA_HALF or CUDNN_DATA_FLOAT**.
- For the input/output in FP32, the parameter **mathPrec** can only be **CUDNN_DATA_FLOAT**.
- For the input/output in FP64, double type, the parameter **mathPrec** can only be **CUDNN_DATA_DOUBLE**.

Returns

CUDNN_STATUS_SUCCESS

The object was set successfully.

CUDNN_STATUS_BAD_PARAM

Either at least one of the parameters **hiddenSize** or **numLayers** was zero or negative, one of **inputMode**, **direction**, **mode**, or **dataType** has an invalid enumerant value, **dropoutDesc** is an invalid dropout descriptor or **rnnDesc** has not been created correctly.

3.199. cudnnSetRNNDescriptor_v5()

```
cudnnStatus_t cudnnSetRNNDescriptor_v5(
    cudnnRNNDescriptor_t     rnnDesc,
    int                      hiddenSize,
    int                      numLayers,
    cudnnDropoutDescriptor_t dropoutDesc,
    cudnnRNNInputMode_t      inputMode,
    cudnnDirectionMode_t     direction,
    cudnnRNNMode_t           mode,
    cudnnDataType_t          mathPrec)
```

This function initializes a previously created RNN descriptor object.

> Larger networks, for example, longer sequences or 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, for example, a single layer network will have no dropout applied.

inputMode

Input. Specifies the behavior at the input to the first layer

direction

Input. Specifies the recurrence pattern, for example, bidirectional.

mode

Input. Specifies the type of RNN to compute.

mathPrec

Input. Math precision. This parameter is used for controlling the math precision in RNN. The following applies:

- For the input/output in FP16, the parameter **mathPrec** can be **CUDNN_DATA_HALF** or **CUDNN_DATA_FLOAT**.
- For the input/output in FP32, the parameter **mathPrec** can only be **CUDNN_DATA_FLOAT**.
- For the input/output in FP64, double type, the parameter **mathPrec** can only be **CUDNN_DATA_DOUBLE**.

Returns

CUDNN_STATUS_SUCCESS

The object was set successfully.

CUDNN_STATUS_BAD_PARAM

Either at least one of the parameters **hiddenSize** or **numLayers** was zero or negative, one of **inputMode**, **direction**, **mode**, **algo** or **dataType** has an invalid enumerant value, **dropoutDesc** is an invalid dropout descriptor or **rnnDesc** has not been created correctly.

3.200. cudnnSetRNNDescriptor_v6()

```
cudnnStatus_t cudnnSetRNNDescriptor_v6(
 cudnnHandle_t                    handle,
 cudnnRNNDescriptor_t             rnnDesc,
 const int                        hiddenSize,
 const int                        numLayers,
 cudnnDropoutDescriptor_t         dropoutDesc,
```

```
cudnnRNNInputMode_t                inputMode,
cudnnDirectionMode_t               direction,
cudnnRNNMode_t                     mode,
cudnnRNNAlgo_t                     algo,
cudnnDataType_t                    mathPrec)
```

This function initializes a previously created RNN descriptor object.

> Larger networks, for example, longer sequences or more layers, are expected to be more efficient than smaller networks.

Parameters

`handle`

Input. Handle to a previously created cuDNN library descriptor.

`rnnDesc`

Input/Output. A previously created RNN descriptor.

`hiddenSize`

Input. Size of the internal hidden state for each layer.

`numLayers`

Input. Number of stacked layers.

`dropoutDesc`

Input. Handle to a previously created and initialized dropout descriptor. Dropout will be applied between layers, for example, a single layer network will have no dropout applied.

`inputMode`

Input. Specifies the behavior at the input to the first layer

`direction`

Input. Specifies the recurrence pattern, for example, bidirectional.

`mode`

Input. Specifies the type of RNN to compute.

`algo`

Input. Specifies which RNN algorithm should be used to compute the results.

`mathPrec`

Input. Math precision. This parameter is used for controlling the math precision in RNN. The following applies:

- For the input/output in FP16, the parameter **`mathPrec`** can be **`CUDNN_DATA_HALF`** or **`CUDNN_DATA_FLOAT`**.

- For the input/output in FP32, the parameter **`mathPrec`** can only be **`CUDNN_DATA_FLOAT`**.
- For the input/output in FP64, double type, the parameter **`mathPrec`** can only be **`CUDNN_DATA_DOUBLE`**.

Returns

`CUDNN_STATUS_SUCCESS`

The object was set successfully.

`CUDNN_STATUS_BAD_PARAM`

Either at least one of the parameters **`hiddenSize`** or **`numLayers`** was zero or negative, one of **`inputMode`**, **`direction`**, **`mode`**, **`algo`** or **`dataType`** has an invalid enumerant value, **`dropoutDesc`** is an invalid dropout descriptor or **`rnnDesc`** has not been created correctly.

3.201. cudnnSetRNNMatrixMathType()

```
cudnnStatus_t cudnnSetRNNMatrixMathType(
    cudnnRNNDescriptor_t    rnnDesc,
    cudnnMathType_t         mType)
```

This function sets the preferred option to use NVIDIA Tensor Cores accelerators on Volta GPUs (SM 7.0 or higher). When the **`mType`** parameter is **`CUDNN_TENSOR_OP_MATH`**, inference and training RNN APIs will attempt use Tensor Cores when weights/biases are of type **`CUDNN_DATA_HALF`** or **`CUDNN_DATA_FLOAT`**. When RNN weights/biases are stored in the **`CUDNN_DATA_FLOAT`** format, the original weights and intermediate results will be down-converted to **`CUDNN_DATA_HALF`** before they are used in another recursive iteration.

Parameters

`rnnDesc`

Input. A previously created and initialized RNN descriptor.

`mType`

Input. A preferred compute option when performing RNN GEMMs (general matrix-matrix multiplications). This option has an advisory status meaning that Tensor Cores may not be utilized, for example, due to specific GEMM dimensions.

Returns

`CUDNN_STATUS_SUCCESS`

The preferred compute option for the RNN network was set successfully.

CUDNN_STATUS_BAD_PARAM

An invalid input parameter was detected.

3.202. cudnnSetRNNPaddingMode()

```
cudnnStatus_t cudnnSetRNNPaddingMode(
    cudnnRNNDescriptor_t        rnnDesc,
    cudnnRNNPaddingMode_t       paddingMode)
```

This function enables or disables the padded RNN input/output for a previously created and initialized RNN descriptor. This information is required before calling the cudnnGetRNNWorkspaceSize() and cudnnGetRNNTrainingReserveSize() functions, to determine whether additional workspace and training reserve space is needed. By default, the padded RNN input/output is not enabled.

Parameters

rnnDesc

Input/Output. A previously created RNN descriptor.

paddingMode

Input. Enables or disables the padded input/output. For more information, see cudnnRNNPaddingMode_t.

Returns

CUDNN_STATUS_SUCCESS

The **paddingMode** was set successfully.

CUDNN_STATUS_BAD_PARAM

Either the **rnnDesc** is **NULL** or **paddingMode** has an invalid enumerant value.

3.203. cudnnSetRNNProjectionLayers()

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

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 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 (for example, **`NULL`** handles, negative values for projection parameters).

`CUDNN_STATUS_NOT_SUPPORTED`

Projection applied to RNN algo other than **`CUDNN_RNN_ALGO_STANDARD`**, cell type other than **`CUDNN_LSTM`**, **`recProjSize`** larger than **`hiddenSize`**.

3.204. cudnnSetSeqDataDescriptor()

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

This function initializes a previously created sequence data descriptor object. In the most simplified view, this descriptor defines dimensions (**dimA**) and the data layout (**axes**) of a four-dimensional tensor. All four dimensions of the sequence data descriptor have unique identifiers that can be used to index the **dimA[]** array:

```
CUDNN_SEQDATA_TIME_DIM
CUDNN_SEQDATA_BATCH_DIM
CUDNN_SEQDATA_BEAM_DIM
CUDNN_SEQDATA_VECT_DIM
```

For example, to express information that vectors in our sequence data buffer are five elements long, we need to assign **dimA[CUDNN_SEQDATA_VECT_DIM]=5** in the **dimA[]** array.

The number of active dimensions in the **dimA[]** and **axes[]** arrays is defined by the **nbDims** argument. Currently, the value of this argument should be four. The actual size of the **dimA[]** and **axes[]** arrays should be declared using the **CUDNN_SEQDATA_DIM_COUNT** macro.

The cudnnSeqDataDescriptor_t container is treated as a collection of fixed length vectors that form sequences, similarly to words (vectors of characters) constructing sentences. The **TIME** dimension spans the sequence length. Different sequences are bundled together in a batch. A **BATCH** may be a group of individual sequences or beams. A **BEAM** is a cluster of alternative sequences or candidates. When thinking about the beam, consider a translation task from one language to another. You may want to keep around and experiment with several translated versions of the original sentence before selecting the best one. The number of candidates kept around is the **BEAM** size.

Every sequence can have a different length, even within the same beam, so vectors toward the end of the sequence can be just padding. The **paddingFill** argument specifies how the padding vectors should be written in output sequence data buffers. The **paddingFill** argument points to one value of type **dataType** that should be copied to all elements in padding vectors. Currently, the only supported value for **paddingFill** is **NULL** which means this option should be ignored. In this case, elements of the padding vectors in output buffers will have undefined values.

It is assumed that a non-empty sequence always starts from the time index zero. The **seqLengthArray[]** must specify all sequence lengths in the container so the total size of this array should be **dimA[CUDNN_SEQDATA_BATCH_DIM] * dimA[CUDNN_SEQDATA_BEAM_DIM]**. Each element of the **seqLengthArray[]** array should have a non-negative value, less than or equal to **dimA[CUDNN_SEQDATA_TIME_DIM**; the maximum sequence length. Elements in

seqLengthArray[] are always arranged in the same batch-major order, meaning, when considering **BEAM** and **BATCH** dimensions, **BATCH** is the outer or the slower changing index when we traverse the array in ascending order of the addresses. Using a simple example, the **seqLengthArray[]** array should hold sequence lengths in the following order:

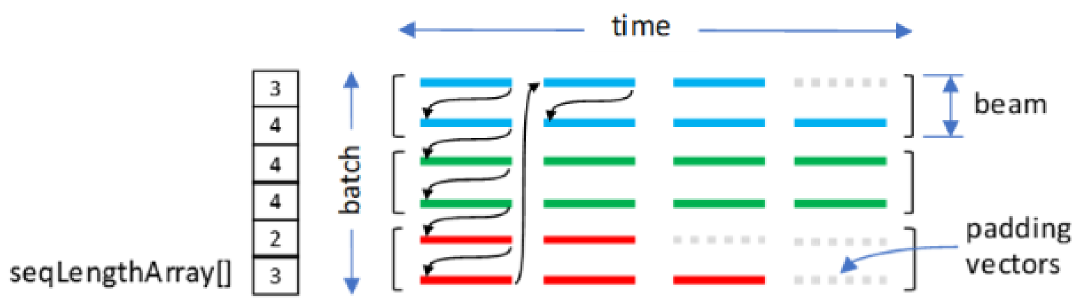
```
{batch_idx=0, beam_idx=0}
{batch_idx=0, beam_idx=1}
{batch_idx=1, beam_idx=0}
{batch_idx=1, beam_idx=1}
{batch_idx=2, beam_idx=0}
{batch_idx=2, beam_idx=1}
```

when **dimA[CUDNN_SEQDATA_BATCH_DIM]=3** and **dimA[CUDNN_SEQDATA_BEAM_DIM]=2**.

Data stored in the cudnnSeqDataDescriptor_t container must comply with the following constraints:

- All data are fully packed. There are no unused spaces or gaps between individual vector elements or consecutive vectors.
- The most inner dimension of the container is vector. In other words, the first contiguous group of **dimA[CUDNN_SEQDATA_VECT_DIM]** elements belongs to the first vector, followed by elements of the second vector, and so on.

The **axes** argument in the **cudnnSetSeqDataDescriptor()** function is a bit more complicated. This array should have the same capacity as **dimA[]**. The **axes[]** array specifies the actual data layout in the GPU memory. In this function, the layout is described in the following way: as we move from one element of a vector to another in memory by incrementing the element pointer, what is the order of **VECT**, **TIME**, **BATCH**, and **BEAM** dimensions that we encounter. Let us assume that we want to define the following data layout:



that corresponds to tensor dimensions:

```
int dimA[CUDNN_SEQDATA_DIM_COUNT];
dimA[CUDNN_SEQDATA_TIME_DIM]   = 4;
dimA[CUDNN_SEQDATA_BATCH_DIM]  = 3;
dimA[CUDNN_SEQDATA_BEAM_DIM]   = 2;
dimA[CUDNN_SEQDATA_VECT_DIM]   = 5;
```

Now, let's initialize the **axes[]** array. Note that the most inner dimension is described by the last active element of **axes[]**. There is only one valid configuration here as we always traverse a full vector first. Thus, we need to write **CUDNN_SEQDATA_VECT_DIM** in the last active element of **axes[]**.

```
cudnnSeqDataAxis_t axes[CUDNN_SEQDATA_DIM_COUNT];
axes[3] = CUDNN_SEQDATA_VECT_DIM;    // 3 = nbDims-1
```

Now, let's work on the remaining three elements of **axes[]**. When we reach the end of the first vector, we jump to the next beam, therefore:

```
axes[2] = CUDNN_SEQDATA_BEAM_DIM;
```

When we approach the end of the second vector, we move to the next batch, therefore:

```
axes[1] = CUDNN_SEQDATA_BATCH_DIM;
```

The last (outermost) dimension is **TIME**:

```
axes[0] = CUDNN_SEQDATA_TIME_DIM;
```

The four values of the **axes[]** array fully describe the data layout depicted in the figure.

The sequence data descriptor allows the user to select **3! = 6** different data layouts or permutations of **BEAM**, **BATCH** and **TIME** dimensions. The multi-head attention API supports all six layouts.

Parameters

seqDataDesc
Output. Pointer to a previously created sequence data descriptor.

dataType
Input. Data type of the sequence data buffer (**CUDNN_DATA_HALF**, **CUDNN_DATA_FLOAT** or **CUDNN_DATA_DOUBLE**).

nbDims
Input. Must be **4**. The number of active dimensions in **dimA[]** and **axes[]** arrays. Both arrays should be declared to contain at least **CUDNN_SEQDATA_DIM_COUNT** elements.

dimA[]
Input. Integer array specifying sequence data dimensions. Use the cudnnSeqDataAxis_t enumerated type to index all active **dimA[]** elements.

axes[]
Input. Array of cudnnSeqDataAxis_t that defines the layout of sequence data in memory. The first **nbDims** elements of **axes[]** should be initialized with the outermost dimension in **axes[0]** and the innermost dimension in **axes[nbDims-1]**.

seqLengthArraySize
Input. Number of elements in the sequence length array, **seqLengthArray[]**.

seqLengthArray[]
Input. An integer array that defines all sequence lengths of the container.

paddingFill
Input. Must be **NULL**. Pointer to a value of **dataType** that is used to fill up output vectors beyond the valid length of each sequence or **NULL** to ignore this setting.

Returns

CUDNN_STATUS_SUCCESS
All input arguments were validated and the sequence data descriptor was successfully updated.

CUDNN_STATUS_BAD_PARAM

An invalid input argument was found. Some examples include:

- **seqDataDesc=NULL**
- **dateType** was not a valid type of cudnnDataType_t
- **nbDims** was negative or zero
- **seqLengthArraySize** did not match the expected length
- some elements of **seqLengthArray[]** were invalid

CUDNN_STATUS_NOT_SUPPORTED

An unsupported input argument was encountered. Some examples include:

- **nbDims** is not equal to **4**
- **paddingFill** is not **NULL**

CUDNN_STATUS_ALLOC_FAILED

Failed to allocate storage for the sequence data descriptor object.

3.205. 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.

Returns

CUDNN_STATUS_SUCCESS

The call was successful.

CUDNN_STATUS_BAD_PARAM

At least one of the following conditions are met:

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

3.206. 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.

3.207. 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**.

Returns

CUDNN_STATUS_SUCCESS

The function launched successfully.

CUDNN_STATUS_NOT_SUPPORTED

The function does not support the provided configuration.

CUDNN_STATUS_BAD_PARAM

One of the provided pointers is nil.

CUDNN_STATUS_EXECUTION_FAILED

The function failed to launch on the GPU.

3.208. 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.

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.

3.209. 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 4D tensor object with an unsupported stride is used. cudnnTransformTensor() can be used to convert the data to a supported layout.
- The total size of a tensor including the potential padding between dimensions is limited to 2 Giga-elements of type **`datatype`**.

Parameters

`tensorDesc`

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

`datatype`

Input. Data type.

`n`

Input. Number of images.

`c`

Input. Number of feature maps per image.

`h`

Input. Height of each feature map.

`w`

Input. Width of each feature map.

`nStride`

Input. Stride between two consecutive images.

`cStride`

Input. Stride between two consecutive feature maps.

`hStride`

Input. Stride between two consecutive rows.

wStride

Input. Stride between two consecutive columns.

Returns

CUDNN_STATUS_SUCCESS

The object was set successfully.

CUDNN_STATUS_BAD_PARAM

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

CUDNN_STATUS_NOT_SUPPORTED

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

3.210. cudnnSetTensorNdDescriptor()

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

This function initializes a previously created generic tensor descriptor object.

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

Parameters

tensorDesc

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

datatype

Input. Data type.

nbDims

Input. Dimension of the tensor.

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

dimA

Input. Array of dimension **nbDims** that contain the size of the tensor for every dimension. Size along unused dimensions should be set to 1.

strideA

Input. Array of dimension **nbDims** that contain the stride of the tensor for every dimension.

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.

3.211. cudnnSetTensorNdDescriptorEx()

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

This function initializes an n-D tensor descriptor.

Parameters

tensorDesc

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

format

Input. Tensor format.

dataType

Input. Tensor data type.

nbDims

Input. Dimension of the tensor.

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

dimA

Input. Array containing the size of each dimension.

Returns

CUDNN_STATUS_SUCCESS

The function was successful.

CUDNN_STATUS_BAD_PARAM

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

CUDNN_STATUS_NOT_SUPPORTED

Dimension size requested is larger than maximum dimension size supported.

3.212. cudnnSetTensorTransformDescriptor()

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

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

Parameters

transformDesc

Output. The tensor transform descriptor to be initialized.

nbDims

Input. The dimensionality of the transform operands. Must be greater than 2. For more information, see the Tensor Descriptor section from the *cuDNN Developer Guide*.

destFormat

Input. The desired destination format.

padBeforeA[]

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

padAfterA[]

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

foldA[]

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

direction

Input. Selects folding or unfolding. This input has no effect when folding parameters are all <= 1. For more information, see cudnnFoldingDirection_t.

Returns

CUDNN_STATUS_SUCCESS

The function was launched successfully.

CUDNN_STATUS_BAD_PARAM

The parameter **transformDesc** is **NULL**, or if **direction** is invalid, or **nbDims** is <= 2.

CUDNN_STATUS_NOT_SUPPORTED

If the dimension size requested is larger than maximum dimension size supported (meaning, one of the **nbDims** is larger than **CUDNN_DIM_MAX**), or if **destFromat** is something other than **NCHW** or **NHWC**.

3.213. 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; meaning, **dy** and **dx** pointers may be equal. However, this requires **dyDesc** and **dxDesc** descriptors to be

> identical (particularly, the strides of the input and output must match for in-place operation to be allowed).
> - All tensor formats are supported for all modes and algorithms with 4 and 5D tensors. Performance is expected to be highest with **`NCHW fully-packed`** tensors. For more than 5 dimensions tensors must be packed in their spatial dimensions.

Parameters

`handle`

Input. Handle to a previously created cuDNN context.

`algorithm`

Input. Enumerant to specify the softmax algorithm.

`mode`

Input. Enumerant to specify the softmax mode.

`alpha, beta`

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

```
dstValue = alpha[0]*result + beta[0]*priorDstValue
```

For more information, see the Scaling Parameters section in the *cuDNN Developer Guide*.

`yDesc`

Input. Handle to the previously initialized input tensor descriptor.

`y`

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

`dyDesc`

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

`dy`

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

`dxDesc`

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

`dx`

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

Returns

CUDNN_STATUS_SUCCESS

The function launched successfully.

CUDNN_STATUS_NOT_SUPPORTED

The function does not support the provided configuration.

CUDNN_STATUS_BAD_PARAM

At least one of the following conditions are met:

- The dimensions **n**, **c**, **h**, **w** of the **yDesc**, **dyDesc** and **dxDesc** tensors differ.
- The strides **nStride**, **cStride**, **hStride**, **wStride** of the **yDesc** and **dyDesc** tensors differ.
- The **datatype** of the three tensors differs.

CUDNN_STATUS_EXECUTION_FAILED

The function failed to launch on the GPU.

3.214. cudnnSoftmaxForward()

```
cudnnStatus_t cudnnSoftmaxForward(
    cudnnHandle_t                    handle,
    cudnnSoftmaxAlgorithm_t          algorithm,
    cudnnSoftmaxMode_t               mode,
    const void                      *alpha,
    const cudnnTensorDescriptor_t    xDesc,
    const void                      *x,
    const void                      *beta,
    const cudnnTensorDescriptor_t    yDesc,
    void                            *y)
```

This routine computes the softmax function.

> All tensor formats are supported for all modes and algorithms with 4 and 5D tensors. Performance is expected to be highest with **NCHW fully-packed** tensors. For more than 5 dimensions tensors must be packed in their spatial dimensions

Parameters

handle

Input. Handle to a previously created cuDNN context.

algorithm

Input. Enumerant to specify the softmax algorithm.

mode

Input. Enumerant to specify the softmax mode.

alpha, beta

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

```
dstValue = alpha[0]*result + beta[0]*priorDstValue
```

For more information, see the Scaling Parameters section in the *cuDNN Developer Guide*.

xDesc

Input. Handle to the previously initialized input tensor descriptor.

x

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

yDesc

Input. Handle to the previously initialized output tensor descriptor.

y

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

Returns

CUDNN_STATUS_SUCCESS

The function launched successfully.

CUDNN_STATUS_NOT_SUPPORTED

The function does not support the provided configuration.

CUDNN_STATUS_BAD_PARAM

At least one of the following conditions are met:

- The dimensions **n**, **c**, **h**, **w** of the input tensor and output tensors differ.
- The **datatype** of the input tensor and output tensors differ.
- The parameters **algorithm** or **mode** have an invalid enumerant value.

CUDNN_STATUS_EXECUTION_FAILED

The function failed to launch on the GPU.

3.215. 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.

Returns

CUDNN_STATUS_SUCCESS

The call was successful.

CUDNN_STATUS_BAD_PARAM

At least one of the following conditions are met:

- **handle** is **NULL**.
- One of the parameters **dgrid** or **dtheta** is **NULL**.

CUDNN_STATUS_NOT_SUPPORTED

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

- The dimension of transformed tensor specified in **stDesc** > 4.

CUDNN_STATUS_EXECUTION_FAILED

The function failed to launch on the GPU.

3.216. 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`**.

Returns

`CUDNN_STATUS_SUCCESS`

The call was successful.

`CUDNN_STATUS_BAD_PARAM`

At least one of the following conditions are met:

- **`handle`** is **`NULL`**.
- One of the parameters **`grid`** or **`theta`** is **`NULL`**.

`CUDNN_STATUS_NOT_SUPPORTED`

The function does not support the provided configuration. 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.

3.217. cudnnSpatialTfSamplerBackward()

```
cudnnStatus_t cudnnSpatialTfSamplerBackward(
```

```
    cudnnHandle_t                                   handle,
    const cudnnSpatialTransformerDescriptor_t  stDesc,
    const void                                     *alpha,
    const cudnnTensorDescriptor_t                   xDesc,
    const void                                     *x,
    const void                                     *beta,
    const cudnnTensorDescriptor_t                   dxDesc,
    void                                           *dx,
    const void                                     *alphaDgrid,
    const cudnnTensorDescriptor_t                   dyDesc,
    const void                                     *dy,
    const void                                     *grid,
    const void                                     *betaDgrid,
    void                                           *dgrid)
```

This function computes the gradient of a sampling operation.

Only 2d transformation is supported.

Parameters

handle

Input. Handle to a previously created cuDNN context.

stDesc

Input. Previously created spatial transformer descriptor object.

alpha, beta

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

```
dstValue = alpha[0]*srcValue + beta[0]*priorDstValue
```

For more information, see the Scaling Parameters section in the *cuDNN Developer Guide*.

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
```

For more information, see the Scaling Parameters section in the *cuDNN Developer Guide*.

dyDesc

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

dy

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

grid

Input. A grid of coordinates generated by cudnnSpatialTfGridGeneratorForward().

dgrid

Output. Data pointer to GPU memory contains the output differential data.

Returns

CUDNN_STATUS_SUCCESS

The call was successful.

CUDNN_STATUS_BAD_PARAM

At least one of the following conditions are met:

- **handle** is **NULL**.
- One of the parameters **x**, **dx**, **y**, **dy**, **grid**, **dgrid** is **NULL**.
- The dimension of **dy** differs from those specified in **stDesc**.

CUDNN_STATUS_NOT_SUPPORTED

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

- The dimension of transformed tensor > 4.

CUDNN_STATUS_EXECUTION_FAILED

The function failed to launch on the GPU.

3.218. cudnnSpatialTfSamplerForward()

```
cudnnStatus_t cudnnSpatialTfSamplerForward(
    cudnnHandle_t                              handle,
    const cudnnSpatialTransformerDescriptor_t  stDesc,
    const void                                *alpha,
```

```
    const cudnnTensorDescriptor_t                xDesc,
    const void                                  *x,
    const void                                  *grid,
    const void                                  *beta,
    cudnnTensorDescriptor_t                      yDesc,
    void                                        *y)
```

This function performs a sampler operation and generates the output tensor using the grid given by the grid generator.

Only 2d transformation is supported.

Parameters

handle

Input. Handle to a previously created cuDNN context.

stDesc

Input. Previously created spatial transformer descriptor object.

alpha, beta

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

```
dstValue = alpha[0]*srcValue + beta[0]*priorDstValue
```

For more information, see the Scaling Parameters section in the *cuDNN Developer Guide*.

xDesc

Input. Handle to the previously initialized input tensor descriptor.

x

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

grid

Input. A grid of coordinates generated by cudnnSpatialTfGridGeneratorForward().

yDesc

Input. Handle to the previously initialized output tensor descriptor.

y

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

Returns

CUDNN_STATUS_SUCCESS

The call was successful.

CUDNN_STATUS_BAD_PARAM

At least one of the following conditions are met:

- **handle** is **NULL**.
- One of the parameters **x**, **y** or **grid** is **NULL**.

CUDNN_STATUS_NOT_SUPPORTED

The function does not support the provided configuration. 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.

3.219. 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 (meaning, tensors cannot be transformed in place). This function can be used to convert a tensor with an unsupported format to a supported one.

Parameters

handle

Input. Handle to a previously created cuDNN context.

alpha, beta

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

```
dstValue = alpha[0]*srcValue + beta[0]*priorDstValue
```

For more information, see the Scaling Parameters section in the *cuDNN Developer Guide*.

xDesc

Input. Handle to a previously initialized tensor descriptor. For more information, see cudnnTensorDescriptor_t.

x

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

yDesc

Input. Handle to a previously initialized tensor descriptor. For more information, see cudnnTensorDescriptor_t.

y

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

Returns

CUDNN_STATUS_SUCCESS

The function launched successfully.

CUDNN_STATUS_NOT_SUPPORTED

The function does not support the provided configuration.

CUDNN_STATUS_BAD_PARAM

The dimensions **n**, **c**, **h**, **w** or the **dataType** of the two tensor descriptors are different.

CUDNN_STATUS_EXECUTION_FAILED

The function failed to launch on the GPU.

3.220. cudnnTransformTensorEx()

```
cudnnStatus_t cudnnTransformTensorEx(
 cudnnHandle_t handle,
 const cudnnTensorTransformDescriptor_t transDesc,

 const void *alpha,
 const cudnnTensorDescriptor_t srcDesc,
 const void *srcData,
 const void *beta,
 const cudnnTensorDescriptor_t destDesc,
 void *destData);
```

This function converts the tensor layouts between different formats. It can be used to convert a tensor with an unsupported layout format to a tensor with a supported layout format.

This function copies the scaled data from the input tensor **srcDesc** to the output tensor **destDesc** with a different layout. The tensor descriptors of **srcDesc** and **destDesc** should have the same dimensions but need not have the same strides.

The **srcDesc** and **destDesc** tensors must not overlap in any way (meaning, tensors cannot be transformed in place).

> When performing a folding transform or a zero-padding transform, the scaling factors **(alpha,beta)** should be set to (1, 0). However, unfolding transforms support any **(alpha,beta)** values. This function is thread safe.

Parameters

handle

Input. Handle to a previously created cuDNN context. For more information, see cudnnHandle_t.

transDesc

Input. A descriptor containing the details of the requested tensor transformation. For more information, see cudnnTensorTransformDescriptor_t.

alpha, beta

Input. Pointers, in the host memory, to the scaling factors used to scale the data in the input tensor **srcDesc**. **beta** is used to scale the destination tensor, while **alpha** is used to scale the source tensor. For more information, see the Scaling Parameters section in the *cuDNN Developer Guide*.

The beta scaling value is not honored in the folding and zero-padding cases. Unfolding supports any (**alpha**, **beta**).

srcDesc, destDesc

Input. Handles to the previously initialed tensor descriptors. **srcDesc** and **destDesc** must not overlap. For more information, see cudnnTensorDescriptor_t.

srcData, destData

Input. Pointers, in the host memory, to the data of the tensor described by **srcDesc** and **destDesc** respectively.

Returns

CUDNN_STATUS_SUCCESS

The function was launched successfully.

CUDNN_STATUS_BAD_PARAM

A parameter is uninitialized or initialized incorrectly, or the number of dimensions is different between **srcDesc** and **destDesc**.

CUDNN_STATUS_NOT_SUPPORTED

Function does not support the provided configuration. Also, in the folding and padding paths, any value other than **A=1** and **B=0** will result in a **CUDNN_STATUS_NOT_SUPPORTED**.

CUDNN_STATUS_EXECUTION_FAILED

Function failed to launch on the GPU.

Notice

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