



NVIDIA cuDNN

Best Practices | NVIDIA Docs

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Chapter 1. Introduction



ATTENTION: These guidelines are applicable to 3D convolution and deconvolution functions starting in NVIDIA® CUDA® Deep Neural Network library (cuDNN) v7.6.3.

This document provides guidelines for setting the cuDNN library parameters to enhance the performance of 3D convolutions. Specifically, these guidelines are focused on settings such as filter sizes, padding and dilation settings. Additionally, an application-specific use-case, namely, medical imaging, is presented to demonstrate the performance enhancement of 3D convolutions with these recommended settings.

Specifically, these guidelines are applicable to the following functions and their associated data types:

- ▶ [cudnnConvolutionForward\(\)](#)
- ▶ [cudnnConvolutionBackwardData\(\)](#)
- ▶ [cudnnConvolutionBackwardFilter\(\)](#)

For more information, refer to the [NVIDIA cuDNN Developer Guide](#) and the [NVIDIA cuDNN API Reference](#).

Chapter 2. Best Practices For Medical Imaging

To optimize your performance in your model, ensure you meet the following general guidelines:

Layout

The layout is in NCHW format.

Filter size

The filter size is $T \times 1 \times 1$, $T \times 2 \times 2$, $T \times 3 \times 3$, $T \times 5 \times 5$, where T is a positive integer. There are additional limits for the value of T in `wgrad` and `strided dgrad`.

Stride

Arbitrary for forward and backward filter; `dgrad/deconv`: $1 \times 1 \times 1$ or $2 \times 2 \times 2$ with $2 \times 2 \times 2$ filter.

Dilation

The dilation is $1 \times 1 \times 1$.

Platform

The platform is NVIDIA Volta™, NVIDIA Turing™, and NVIDIA Ampere Architecture with input/output channels divisible by 8.

Batch/image size

cuDNN will fallback to non-Tensor Core kernel if it determines that the workspace required is larger than 256MB of GPU memory. The workspace required depends on many factors. For the Tensor Core kernels, the workspace size generally scales linearly with output tensor size. Therefore, this can be mitigated by using smaller image sizes or mini-batch sizes.

2.1. Recommended Settings In cuDNN While Performing 3D Convolutions

The following tables show the recommended settings in each release.

2.1.1. cuDNN 8.x.x Recommended Settings

Recommended settings while performing 3D convolutions for cuDNN 8.x.x.

	8.3.0 - 8.3.2	8.0.3 - 8.2.4	8.0.0 and 8.0.1 Preview - 8.0.2
Platform	NVIDIA Ampere Architecture NVIDIA Turing Architecture NVIDIA Volta Architecture		
Convolution (3D or 2D)	3D and 2D		
Convolution or deconvolution (fprop, dgrad, or wgrad)	fprop dgrad wgrad		
Grouped convolution size	C_per_group == K_per_group == {1, 4, 8, 16, 32, 64, 128, 256}	C_per_group == K_per_group == {4, 8, 16, 32}	C_per_group == K_per_group == {4, 8, 16, 32}
	Not supported for INT8		
Data layout format (NHWC/NCHW) ¹	NDHWC		
Input/output precision (FP16, FP32, INT8, or FP64)	FP16, FP32 ² , INT8 ³	FP16, FP32	
Accumulator (compute) precision (FP16, FP32, INT32 or FP64)	FP32, INT32	FP32	
Filter (kernel) sizes	No limitation		
Padding	No limitation		
Image sizes	2 GB limitation for a tensor		
Number of channels	C	0 mod 8 0 mod 16 (for INT8)	0 mod 8
	K	0 mod 8 0 mod 16 (for INT8)	0 mod 8
Convolution mode	Cross-correlation and convolution		
Strides	No limitation	dgrad: 1x1x1 or 2x2x2	
Dilation	No limitation		
Data pointer alignment	All data pointers are 16-bytes aligned.		

2.1.2. cuDNN 7.6.x Recommended Settings

Recommended settings while performing 3D convolutions for cuDNN 7.6.x.

¹ NHWC/NCHW corresponds to NDHWC/NCDHW in 3D convolution.

² With CUDNN_TENSOROP_MATH_ALLOW_CONVERSION pre-Ampere. Default TF32 math in NVIDIA Ampere Architecture.

³ INT8 does not support dgrad and wgrad.

		7.6.5	7.6.4	7.6.2	7.6.1
Platform		NVIDIA Turing NVIDIA Volta	NVIDIA Volta		
Convolution (3D or 2D)		3D and 2D	3D		
Convolution or deconvolution (fprop, dgrad, or wgrad)		fprop dgrad wgrad	fprop dgrad	fprop dgrad wgrad	
Grouped convolution	Yes or No	Yes	No		
	Group size	C_per_group == K_per_group == {4, 8, 16, 32}	NA		
Data layout format (NHWC/NCHW) ⁴		NCDHW			NCDHW ⁵
Input/output precision (FP16, FP32, or FP64)		FP16	FP16 or FP32	FP16 ⁶ or FP32 ⁷	
Accumulator (compute) precision (FP16, FP32, or FP64)		FP32	Better to be the same with input/output precision.	FP32	
Filter (kernel) sizes		2x2x2 T ⁸ x1x1 Tx2x2 Tx3x3 Tx5x5	1x1x1 2x2x2 3x3x3 5x5x5 Tx1x1 Tx2x2 Tx3x3 Tx5x5 Tx1x1 Tx2x2 Tx3x3 Tx5x5		
Padding		No limitation			Filter // 2 ⁹
Image sizes		256 MB WS limit	No limitation	256 MB WS limit	

⁴ NHWC/NCHW corresponds to NDHWC/NCDHW in 3D convolution.

⁵ With NCHW <> NHWC format transformation.

⁶ FP16: CUDNN_TENSOROP_MATH

⁷ FP32: CUDNN_TENSOROP_MATH_ALLOW_CONVERSION

⁸ An arbitrary positive value.

⁹ padding = filter // 2

		7.6.5	7.6.4	7.6.2	7.6.1
Number of channels	C	Arbitrary			0 mod 8
	K	Arbitrary			0 mod 8
Convolution mode		Cross-correlation for dgrad; otherwise, both modes		No limitation Cross-correlation	
Strides		1x1x1 and 2x2x2 strides for dgrad		2x2x2 Arbitrary stride	1x1x1
Dilation		1x1x1			

Chapter 3. Medical Imaging Performance

The following table shows the average speed-up of **unique cuDNN 3D convolution calls** for each network on V100 and A100 GPUs that satisfies the conditions in [Best Practices For Medical Imaging](#). The end-to-end training performance will depend on a number of factors, such as framework overhead, kernel run time, and model architecture type.

3.1. Average Speedup Of Unique cuDNN 3D Convolutions API Calls

3.1.1. cuDNN 8.x.x Average Speedup

We are deprecating the reporting of performance results here and will instead update the [cuDNN Release Notes](#) if there is anything interesting to report release-over-release. Starting with cuDNN 8.4.0, this section will be removed. For past performance tables, refer to the [cuDNN Archives](#) > *Best Practices For Using cuDNN 3D Convolutions*.

Chapter 4. Medical Imaging Limitations

Your application will be functional but could be less performant if the model has channel counts lower than 32 (gets worse the lower it is).

If the above is in the network, use `cuDNNFind` to get the best option.

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