



NVIDIA CUDA Toolkit

Release Notes for CUDA 11.4

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Chapter 1. CUDA 11.4 Release Notes

The release notes for the NVIDIA® CUDA® Toolkit can be found online at <http://docs.nvidia.com/cuda/cuda-toolkit-release-notes/index.html>.



Note: The release notes have been reorganized into two major sections: the general CUDA release notes, and the CUDA libraries release notes including historical information for 11.x releases.

1.1. CUDA Toolkit Major Component Versions

CUDA Components

Starting with CUDA 11, the various components in the toolkit are versioned independently. For CUDA 11.4, the table below indicates the versions:

Table 1. CUDA 11.4 Component Versions

Component Name	Version Information	Supported Architectures
CUDA Runtime (cudart)	11.4.148	x86_64, POWER, Arm64
cuobjdump	11.4.120	x86_64, POWER, Arm64
CUPTI	11.4.120	x86_64, POWER, Arm64
CUDA cuxxfilt (demangler)	11.4.120	x86_64, POWER, Arm64
CUDA Demo Suite	11.4.100	x86_64
CUDA GDB	11.4.120	x86_64, POWER, Arm64
CUDA Memcheck	11.4.120	x86_64, POWER
CUDA NVCC	11.4.152	x86_64, POWER, Arm64
CUDA nvdiasm	11.4.152	x86_64, POWER, Arm64
CUDA NVML Headers	11.4.120	x86_64, POWER, Arm64
CUDA nvprof	11.4.120	x86_64, POWER, Arm64
CUDA nvprune	11.4.120	x86_64, POWER, Arm64
CUDA NVRTC	11.4.152	x86_64, POWER, Arm64

Component Name	Version Information	Supported Architectures
CUDA NVTX	11.4.120	x86_64, POWER, Arm64
CUDA NWP	11.4.193	x86_64, POWER
CUDA Samples	11.4.120	x86_64, POWER, Arm64
CUDA Compute Sanitizer API	11.4.120	x86_64, POWER, Arm64
CUDA Thrust	11.4.122	x86_64, POWER, Arm64
CUDA cuBLAS	11.6.5.2	x86_64, POWER, Arm64
CUDA cuFFT	10.5.2.100	x86_64, POWER, Arm64
CUDA cuFile	1.0.2.10	x86_64
CUDA cuRAND	10.2.5.120	x86_64, POWER, Arm64
CUDA cuSOLVER	11.2.0.120	x86_64, POWER, Arm64
CUDA cuSPARSE	11.6.0.120	x86_64, POWER, Arm64
CUDA NPP	11.4.0.110	x86_64, POWER, Arm64
CUDA nvJPEG	11.5.2.120	x86_64, POWER, Arm64
Nsight Compute	2021.2.2.1	x86_64, POWER, Arm64 (CLI only)
NVTX	1.21018621	x86_64, POWER, Arm64
Nsight Systems	2021.3.2.4	x86_64, POWER, Arm64 (CLI only)
Nsight Visual Studio Edition (VSE)	2021.2.1.21205	x86_64 (Windows)
nvidia_fs ¹	2.7.53	x86_64
Visual Studio Integration	11.4.120	x86_64 (Windows)
NVIDIA Linux Driver	470.82.01	x86_64, POWER, Arm64
NVIDIA Windows Driver	472.50	x86_64 (Windows)

CUDA Driver

Running a CUDA application requires the system with at least one CUDA capable GPU and a driver that is compatible with the CUDA Toolkit. See [Table 3](#). For more information various GPU products that are CUDA capable, visit <https://developer.nvidia.com/cuda-gpus>.

Each release of the CUDA Toolkit requires a minimum version of the CUDA driver. The CUDA driver is backward compatible, meaning that applications compiled against a particular version of the CUDA will continue to work on subsequent (later) driver releases.

More information on compatibility can be found at <https://docs.nvidia.com/cuda/cuda-c-best-practices-guide/index.html#cuda-compatibility-and-upgrades>.

Note: Starting with CUDA 11.0, the toolkit components are individually versioned, and the toolkit itself is versioned as shown in the table below.

The minimum required driver version for CUDA enhanced compatibility is shown below. CUDA Enhanced Compatibility is described in detail in <https://docs.nvidia.com/deploy/cuda-compatibility/index.html>

¹ Only available on select Linux distros

Table 2. CUDA Toolkit and Minimum Required Driver Version for CUDA Enhanced Compatibility

CUDA Toolkit	Minimum Required Driver Version for CUDA Enhanced Compatibility	
	Linux x86_64 Driver Version	Windows x86_64 Driver Version
CUDA 11.4	>=450.80.02	>=456.38
CUDA 11.3	>=450.80.02	>=456.38
CUDA 11.2	>=450.80.02	>=456.38
CUDA 11.1 (11.1.0)	>=450.80.02	>=456.38
CUDA 11.0 (11.0.3)	>=450.36.06*	>=456.38

* *CUDA 11.0 was released with an earlier driver version, but by upgrading to 450.80.02 driver as indicated, minor version compatibility is possible across the CUDA 11.x family of toolkits.*

The version of the development NVIDIA GPU Driver packaged in each CUDA Toolkit release is shown below.

Table 3. CUDA Toolkit and Corresponding Driver Versions

CUDA Toolkit	Toolkit Driver Version	
	Linux x86_64 Driver Version	Windows x86_64 Driver Version
CUDA 11.4 Update 3	>=470.82.01	>=472.50
CUDA 11.4 Update 2	>=470.57.02	>=471.41
CUDA 11.4 Update 1	>=470.57.02	>=471.41
CUDA 11.4.0 GA	>=470.42.01	>=471.11
CUDA 11.3.1 Update 1	>=465.19.01	>=465.89
CUDA 11.3.0 GA	>=465.19.01	>=465.89
CUDA 11.2.2 Update 2	>=460.32.03	>=461.33
CUDA 11.2.1 Update 1	>=460.32.03	>=461.09
CUDA 11.2.0 GA	>=460.27.03	>=460.82
CUDA 11.1.1 Update 1	>=455.32	>=456.81
CUDA 11.1 GA	>=455.23	>=456.38
CUDA 11.0.3 Update 1	>= 450.51.06	>= 451.82
CUDA 11.0.2 GA	>= 450.51.05	>= 451.48
CUDA 11.0.1 RC	>= 450.36.06	>= 451.22
CUDA 10.2.89	>= 440.33	>= 441.22
CUDA 10.1 (10.1.105 general release, and updates)	>= 418.39	>= 418.96
CUDA 10.0.130	>= 410.48	>= 411.31

CUDA Toolkit	Toolkit Driver Version	
	Linux x86_64 Driver Version	Windows x86_64 Driver Version
CUDA 9.2 (9.2.148 Update 1)	>= 396.37	>= 398.26
CUDA 9.2 (9.2.88)	>= 396.26	>= 397.44
CUDA 9.1 (9.1.85)	>= 390.46	>= 391.29
CUDA 9.0 (9.0.76)	>= 384.81	>= 385.54
CUDA 8.0 (8.0.61 GA2)	>= 375.26	>= 376.51
CUDA 8.0 (8.0.44)	>= 367.48	>= 369.30
CUDA 7.5 (7.5.16)	>= 352.31	>= 353.66
CUDA 7.0 (7.0.28)	>= 346.46	>= 347.62

* Using a Minimum Required Version that is **different** from Toolkit Driver Version could be allowed in compatibility mode -- please read the CUDA Compatibility Guide for details.

For convenience, the NVIDIA driver is installed as part of the CUDA Toolkit installation. Note that this driver is for development purposes and is not recommended for use in production with Tesla GPUs.

For running CUDA applications in production with Tesla GPUs, it is recommended to download the latest driver for Tesla GPUs from the NVIDIA driver downloads site at <http://www.nvidia.com/drivers>.

During the installation of the CUDA Toolkit, the installation of the NVIDIA driver may be skipped on Windows (when using the interactive or silent installation) or on Linux (by using meta packages).

For more information on customizing the install process on Windows, see <http://docs.nvidia.com/cuda/cuda-installation-guide-microsoft-windows/index.html#install-cuda-software>.

For meta packages on Linux, see <https://docs.nvidia.com/cuda/cuda-installation-guide-linux/index.html#package-manager-metas>

1.2. General CUDA

11.4 Update 2

- ▶ Support for `NvSciBufGeneralAttrKey_EnableGpuCompression` in CUDA will be available in r470TRD2.
- ▶ Added support for Windows Server 2022.
- ▶ **CUDA Compiler:** Relocation models of GNU/Linux on many architectures, such as ARM AArch64 and AMD x86-64, have certain size limitations. While building a CUDA application or a shared library, if the device code crosses such size limitations, the host linker fails with a relocation truncation error.

A new option (`--host-linker-script`) under `nvcc` is provided to prepare a host linker script to enable the host linker support for relocatable device object files that are larger in size. Refer to `nvcc --help` or the CUDA Toolkit Documentation for more details.

11.4 Update 1

- ▶ Support for `NvSciBufAccessPerm_ReadOnly`, `NvSciBufGeneralAttrKey_EnableGpuCache`, and `NvsciBufGeneralAttrKey_GpuSwNeedCacheCoherency` in CUDA will be available in the next update to the [R470 Data Center Driver](#).
- ▶ Added support for Fedora 34 on `x86_64` platforms.
- ▶ **CUDA Compiler:** The following new compilers are supported as host compilers for the CUDA compiler (`nvcc`):
 - ▶ Gcc 11
 - ▶ Clang 12

11.4

- ▶ NVIDIA Magnum IO GPUDirect® Storage (GDS) is now part of CUDA. See <https://docs.nvidia.com/gpudirect-storage/index.html> for more information.
- ▶ MPS - Implemented a programmatic API to configure SM partitions.
- ▶ MPS - Also allow non-uniform SM partitioning using either MPS control daemon command `set_active_thread_percentage` or the environment variable `CUDA_MPS_ACTIVE_THREAD_PERCENTAGE`.
- ▶ MPS - Improve the information provided by the error codes returned by the MPS server and the error messages presented in the MPS server log.
- ▶ CUDA Forward compatibility is now supported on all DataCenter class GPUs, including Quadro.
- ▶ CUDA Graphs - Add support for memory allocation and memory free nodes. Allow capture of stream ordered allocation APIs.

1.3. CUDA Tools

For new features, improvements, and bug fixes in CUDA developer tools, refer to the tool-specific changelogs:

- ▶ Nsight Compute: [changelog](#)
- ▶ Visual Profiler: [changelog](#)
- ▶ CUPTI: [changelog](#)
- ▶ Compute Sanitizer: [changelog](#)
- ▶ CUDA-GDB: [changelog](#)

- ▶ CUDA-MEMCHECK: [changelog](#)

1.3.1. Nsight Eclipse Plugin

- ▶ Eclipse versions 4.16 and later are currently supported in CUDA 11.4 without any intervention. Note that as of Eclipse 4.17, the Java runtime must be at least version 11.
- ▶ Eclipse version 4.15 requires that the Docker support in Eclipse be updated to the latest. To do this:
 1. Open Eclipse 4.15.
 2. Select **Help** -> **Check for updates**.
 3. Select the C/C++ Docker Container Launch Support
 4. Update it so that it matches version 10.2.20201219171 or later.
- ▶ Eclipse version 4.14 and lower may work, but Docker support will not work if the version of the plugin is older than 10.2.20201219171.

1.3.2. CUDA-GDB

- ▶ Migrated CUDA-GDB from GDB 8.3.1 to GDB 10.1.
- ▶ Implemented pipe support for coredumps.
- ▶ Enabled python3 support in CUDA-GDB.
- ▶ Added support for relative return address in debug frame.

1.4. Resolved Issues

1.4.1. General CUDA

- ▶ The following Apache Log4J vulnerabilities have been fixed in CUDA 11.4 Update 4:
 - CVE-2021-44228
 - CVE-2021-45046
 - CVE-2021-45105
- ▶ In CUDA 11.4, the internal serialization of CUDA APIs operating on the same CUDA context on multiple CPU threads has been further relaxed, such that the driver serialization may be reduced when multiple CPU threads are using CUDA `memcpy` and `memset` APIs in distinct streams within the same context.

1.5. Deprecated Features

The following features are deprecated in the current release of the CUDA software. The features still work in the current release, but their documentation may have been removed, and they will become officially unsupported in a future release. We recommend that developers employ alternative solutions to these features in their software.

General CUDA

- ▶ Ubuntu 16.04 is no longer supported on the x86_64 platform.
- ▶ Support for Kepler is deprecated in CUDA 11.4.

CUDA Tools

- ▶ Nsight Eclipse Plugin:
 - ▶ Docker support for versions older than 10.2.20201219171 has been dropped in Eclipse 4.14 and earlier versions as of CUDA 11.4.
 - ▶ Eclipse version 4.9 is no longer supported.

1.6. Known Issues

1.6.1. General CUDA

- ▶ Intermittent crashes were seen when CUDA binaries were running on a system with a GLIBC version older than 2.17-106.el7_2.1. This is due to a known bug in older versions of GLIBC (Bug reference: https://bugzilla.redhat.com/show_bug.cgi?id=1293976) and has been fixed in later versions (\geq glibc-2.17-107.el7).
- ▶ Use of `cudaEglColorFormatRGB`, `cudaEglColorFormatBGR` or `cudaEglColorFormatYUV_ER` in `cudaEglFrame::cudaEglColorFormat` results in an error. These color formats will be removed in the future CUDA release.
- ▶ CUDA performance regression occurs in the `cuMemfree()` path during application teardown or explicit memory release calls. This occurs with driver version 470.26 and will be resolved in a later driver release.

1.6.2. CUDA-GDB

- ▶ CUDA-GDB has known issues with debugging on Fedora 34 and may not be reliable.

1.6.3. CUDA Profiling Tools Interface (CUPTI)

- ▶ For new features, improvements, and bug fixes in CUPTI, see the [changelog](#).

1.6.4. Nsight Compute

- ▶ For known issues in Nsight Compute, see the "[Known Issues](#)" section.

1.6.5. Compute Sanitizer

- ▶ For known issues in Compute Sanitizer, see the "[Known Issues](#)" section.

1.6.6. Nsight Eclipse Plugin

- ▶ When using Nsight Eclipse Plugin with Eclipse versions 4.17 or greater, a Java runtime of version 11 or greater is required. However, NVIDIA Visual Profiler (nvvp) requires Java runtime version 8. In order to launch nvvp from Nsight Eclipse running Eclipse 4.17 or beyond, install a Java 8 runtime and then explicitly modify the `/usr/local/cuda-11.4/bin/nvvp` shell script to include the path to the Java 8 runtime using the command argument `-vm <path-to-Java-8>`.

Chapter 2. CUDA Libraries

This section covers CUDA Libraries release notes for 11.x releases.

- ▶ CUDA Math Libraries toolchain uses C++11 features, and a C++11-compatible standard library (libstdc++ >= 20150422) is required on the host.
- ▶ CUDA Math libraries are no longer shipped for SM30 and SM32.
- ▶ Support for the following compute capabilities are deprecated for all libraries:
 - ▶ sm_35 (Kepler)
 - ▶ sm_37 (Kepler)

2.1. cuBLAS Library

2.1.1. cuBLAS: Release 11.4 Update 3

- ▶ **Resolved Issues**
 - ▶ Some cublas and cublasLt functions sometimes returned `CUBLAS_STATUS_EXECUTION_FAILED` if the dynamic library was loaded and unloaded several times during application lifetime within the same CUDA context. This issue has been resolved.

2.1.2. cuBLAS: Release 11.4 Update 2

- ▶ **New Features**
 - ▶ Vector (and batched) alpha support for per-row scaling in TN int32 math Matmul with int8 output. See `CUBLASLT_POINTER_MODE_ALPHA_DEVICE_VECTOR_BETA_HOST` and `CUBLASLT_MATMUL_DESC_ALPHA_VECTOR_BATCH_STRIDE`.
 - ▶ New epilogue options have been added to support fusion in DLtraining: `CUBLASLT_EPILOGUE_BGRADA` and `CUBLASLT_EPILOGUE_BGRADB` which compute bias gradients based on matrices A and B respectively.

- ▶ New auxiliary functions `cublasGetStatusName()`, `cublasGetStatusString()` have been added to cuBLAS that return the string representation and the description of the cuBLAS status (`cublasStatus_t`) respectively. Similarly, `cublasLtGetStatusName()`, `cublasLtGetStatusString()` have been added to cuBlasLt.
- ▶ **Known Issues**
 - ▶ [cublasGemmBatchedEx\(\)](#) and [cublas<t>gemmBatched\(\)](#) check the alignment of the input/output arrays of the pointers like they were the pointers to the actual matrices. These checks are irrelevant and will be disabled in future releases. This mostly affects half-precision inputGEMMs which might require 16-byte alignment, and array of pointers could only be aligned by 8-byte boundary.
- ▶ **Resolved Issues**
 - ▶ `cublasLtMatrixTransform` can now operate on matrices with dimensions greater than 65535.
 - ▶ Fixed out-of-bound access in GEMM and Matmul functions, when split K or non-default epilogue is used and leading dimension of the output matrix exceeds `int32_t` limit.
 - ▶ NVBLAS now uses lazy loading of the CPU BLAS library on Linux to avoid issues caused by preloading `libnvblas.so` in complex applications that use `fork` and similar APIs.
 - ▶ Resolved symbols name conflict when using cuBlasLt static library with static TensorRT or cuDNN libraries.

2.1.3. cuBLAS: Release 11.4

- ▶ **Resolved Issues**
 - ▶ Some `gemv` cases were producing incorrect results if the matrix dimension (n or m) was large, for example 2^{20} .

2.1.4. cuBLAS: Release 11.3 Update 1

- ▶ **New Features**
 - ▶ Some new kernels have been added for improved performance but have the limitation that only host pointers are supported for scalars (for example, alpha and beta parameters). This limitation is expected to be resolved in a future release.
 - ▶ New epilogues have been added to support fusion in ML training. These include:
 - ▶ ReLuBias and GeluBias epilogues that produce an auxiliary output which is used on backward propagation to compute the corresponding gradients.
 - ▶ DReLuBGrad and DGeluBGrad epilogues that compute the backpropagation of the corresponding activation function on matrix C, and produce bias gradient as a separate output. These epilogues require auxiliary input mentioned in the bullet above.
- ▶ **Resolved Issues**

- ▶ Some tensor core accelerated strided batched GEMM routines would result in misaligned memory access exceptions when batch stride wasn't a multiple of 8.
- ▶ Tensor core accelerated `cublasGemmBatchedEx` (pointer-array) routines would use slower variants of kernels assuming bad alignment of the pointers in the pointer array. Now it assumes that pointers are well aligned, as noted in the documentation.
- ▶ **Known Issues**
 - ▶ To be able to access the fastest possible kernels through `cublasLtMatmulAlgoGetHeuristic()` you need to set `CUBLASLT_MATMUL_PREF_POINTER_MODE_MASK` in search preferences to `CUBLASLT_POINTER_MODE_MASK_HOST` or `CUBLASLT_POINTER_MODE_MASK_NO_FILTERING`. By default, heuristics query assumes the pointer mode may change later and only returns algo configurations that support both `_HOST` and `_DEVICE` modes. Without this, newly added kernels will be excluded and it will likely lead to a performance penalty on some problem sizes.
- ▶ **Deprecated Features**
 - ▶ Linking with static `cublas` and `cublasLt` libraries on Linux now requires using `gcc-5.2` and compatible or higher due to C++11 requirements in these libraries.

2.1.5. cuBLAS: Release 11.3

- ▶ **Known Issues**
 - ▶ The planar complex matrix descriptor for batched matmul has inconsistent interpretation of batch offset.
 - ▶ Mixed precision operations with reduction scheme `CUBLASLT_REDUCTION_SCHEME_OUTPUT_TYPE` (might be automatically selected based on problem size by `cublasSgemmEx()` or `cublasGemmEx()` too, unless `CUBLAS_MATH_DISALLOW_REDUCED_PRECISION_REDUCTION` math mode bit is set) not only stores intermediate results in output type but also accumulates them internally in the same precision, which may result in lower than expected accuracy. Please use `CUBLASLT_MATMUL_PREF_REDUCTION_SCHEME_MASK` or `CUBLAS_MATH_DISALLOW_REDUCED_PRECISION_REDUCTION` if this results in numerical precision issues in your application.

2.1.6. cuBLAS: Release 11.2

- ▶ **Known Issues**
 - ▶ `cublas<s/d/c/z>Gemm()` with very large `n` and `m=k=1` may fail on Pascal devices.

2.1.7. cuBLAS: Release 11.1 Update 1

- ▶ **New Features**
 - ▶ `cuBLASLt` Logging is officially stable and no longer experimental. `cuBLASLt` Logging APIs are still experimental and may change in future releases.

► Resolved Issues

- `cublasLtMatmul` fails on Volta architecture GPUs with `CUBLAS_STATUS_EXECUTION_FAILED` when `n` dimension > 262,137 and epilogue bias feature is being used. This issue exists in 11.0 and 11.1 releases but has been corrected in 11.1 Update 1

2.1.8. cuBLAS: Release 11.1

► Resolved Issues

- A performance regression in the `cublasCgetrfBatched` and `cublasCgetriBatched` routines has been fixed.
- The IMMA kernels do not support padding in matrix C and may corrupt the data when matrix C with padding is supplied to `cublasLtMatmul`. A suggested work around is to supply matrix C with leading dimension equal to 32 times the number of rows when targeting the IMMA kernels: `computeType = CUDA_R_32I` and `CUBLASLT_ORDER_COL32` for matrices A,C,D, and `CUBLASLT_ORDER_COL4_4R2_8C` (on NVIDIA Ampere GPU architecture or Turing architecture) or `CUBLASLT_ORDER_COL32_2R_4R4` (on NVIDIA Ampere GPU architecture) for matrix B. Matmul descriptor must specify `CUBLAS_OP_T` on matrix B and `CUBLAS_OP_N` (default) on matrix A and C. The data corruption behavior was fixed so that `CUBLAS_STATUS_NOT_SUPPORTED` is returned instead.
- Fixed an issue that caused an Address out of bounds error when calling `cublasSgemm()`.
- A performance regression in the `cublasCgetrfBatched` and `cublasCgetriBatched` routines has been fixed.

2.1.9. cuBLAS: Release 11.0 Update 1

► New Features

- The cuBLAS API was extended with a new function, `cublasSetWorkspace()`, which allows the user to set the cuBLAS library workspace to a user-owned device buffer, which will be used by cuBLAS to execute all subsequent calls to the library on the currently set stream.
- cuBLASLt experimental logging mechanism can be enabled in two ways:
 - By setting the following environment variables before launching the target application:
 - `CUBLASLT_LOG_LEVEL=<level>` -- where `level` is one of the following levels:
 - "0" - Off - logging is disabled (default)
 - "1" - Error - only errors will be logged
 - "2" - Trace - API calls that launch CUDA kernels will log their parameters and important information

- ▶ "3" - Hints - hints that can potentially improve the application's performance
- ▶ "4" - Heuristics - heuristics log that may help users to tune their parameters
- ▶ "5" - API Trace - API calls will log their parameter and important information
- ▶ CUBLASLT_LOG_MASK=<mask> -- where mask is a combination of the following masks:
 - ▶ "0" - Off
 - ▶ "1" - Error
 - ▶ "2" - Trace
 - ▶ "4" - Hints
 - ▶ "8" - Heuristics
 - ▶ "16" - API Trace
- ▶ CUBLASLT_LOG_FILE=<value> -- where value is a file name in the format of "<file_name>.%i", %i will be replaced with process id. If CUBLASLT_LOG_FILE is not defined, the log messages are printed to stdout.
- ▶ By using the runtime API functions defined in the cublasLt header:
 - ▶ `typedef void(*cublasLtLoggerCallback_t)(int logLevel, const char* functionName, const char* message)` -- A type of callback function pointer.
 - ▶ `cublasStatus_t cublasLtLoggerSetCallback(cublasLtLoggerCallback_t callback)` -- Allows to set a call back functions that will be called for every message that is logged by the library.
 - ▶ `cublasStatus_t cublasLtLoggerSetFile(FILE* file)` -- Allows to set the output file for the logger. The file must be open and have write permissions.
 - ▶ `cublasStatus_t cublasLtLoggerOpenFile(const char* logFile)` -- Allows to give a path in which the logger should create the log file.
 - ▶ `cublasStatus_t cublasLtLoggerSetLevel(int level)` -- Allows to set the log level to one of the above mentioned levels.
 - ▶ `cublasStatus_t cublasLtLoggerSetMask(int mask)` -- Allows to set the log mask to a combination of the above mentioned masks.
 - ▶ `cublasStatus_t cublasLtLoggerForceDisable()` -- Allows to disable to logger for the entire session. Once this API is being called, the logger cannot be reactivated in the current session.

2.1.10. cuBLAS: Release 11.0

► New Features

- cuBLASLt Matrix Multiplication adds support for fused ReLU and bias operations for all floating point types except double precision (FP64).
- Improved batched TRSM performance for matrices larger than 256.

2.1.11. cuBLAS: Release 11.0 RC

► New Features

- Many performance improvements have been implemented for NVIDIA Ampere, Volta, and Turing Architecture based GPUs.
- The cuBLASLt logging mechanism can be enabled by setting the following environment variables before launching the target application:
 - CUBLASLT_LOG_LEVEL=<level> - while level is one of the following levels:
 - "0" - Off - logging is disabled (default)
 - "1" - Error - only errors will be logged
 - "2" - Trace - API calls will be logged with their parameters and important information
 - CUBLASLT_LOG_FILE=<value> - while value is a file name in the format of "<file_name>.%i", %i will be replaced with process id. If CUBLASLT_LOG_FILE is not defined, the log messages are printed to stdout.
- For matrix multiplication APIs:
 - `cublasGemmEx`, `cublasGemmBatchedEx`, `cublasGemmStridedBatchedEx` and `cublasLtMatmul` added new data type support for `__nv_bfloat16` (CUDA_R_16BF).
 - A new compute type `TensorFloat32` (TF32) has been added to provide tensor core acceleration for FP32 matrix multiplication routines with full dynamic range and increased precision compared to BFLOAT16.
 - New compute modes Default, Pedantic, and Fast have been introduced to offer more control over compute precision used.
 - Tensor cores are now enabled by default for half-, and mixed-precision- matrix multiplications.
 - Double precision tensor cores (DMMA) are used automatically.
 - Tensor cores can now be used for all sizes and data alignments and for all GPU architectures:

- ▶ Selection of these kernels through cuBLAS heuristics is automatic and will depend on factors such as math mode setting as well as whether it will run faster than the non-tensor core kernels.
 - ▶ Users should note that while these new kernels that use tensor cores for all unaligned cases are expected to perform faster than non-tensor core based kernels but slower than kernels that can be run when all buffers are well aligned.
- ▶ **Deprecated Features**
- ▶ Algorithm selection in `cublasGemmEx` APIs (including batched variants) is non-functional for NVIDIA Ampere Architecture GPUs. Regardless of selection it will default to a heuristics selection. Users are encouraged to use the `cublasLt` APIs for algorithm selection functionality.
 - ▶ The matrix multiply math mode `CUBLAS_TENSOR_OP_MATH` is being deprecated and will be removed in a future release. Users are encouraged to use the new `cublasComputeType_t` enumeration to define compute precision.

2.2. cuFFT Library

2.2.1. cuFFT: Release 11.4 Update 2

- ▶ **Resolved Issues**
- ▶ Since cuFFT 10.3.0 (CUDA Toolkit 11.1), cuFFT may require user to make sure that all operations on input and output buffers are complete before calling `cuFFT[Xt]Exec*` if:
 - ▶ sm70 or later, 3D FFT, batch > 1, total size of transform is greater than 4.5MB
 - ▶ FFT size for all dimensions is in the set of the following sizes: {2, 4, 8, 16, 32, 64, 128, 3, 9, 81, 243, 729, 2187, 6561, 5, 25, 125, 625, 3125, 6, 36, 216, 1296, 7776, 7, 49, 343, 2401, 11, 121}
 - ▶ Some V100 FFTs were slower than expected. This issue is resolved.
- ▶ **Known Issues**
- ▶ Some T4 FFTs are slower than expected.
 - ▶ Plans for FFTs of certain sizes in single precision (including some multiples of 1024 sizes, and some large prime numbers) could fail on future devices with less than 64 kB of shared memory. This issue will be fixed in an upcoming release.

2.2.2. cuFFT: Release 11.4 Update 1

- ▶ **Resolved Issues**
- ▶ Some cuFFT multi-GPU plans exhibited very long creation times.

- ▶ cuFFT sometimes produced incorrect results for real-to-complex and complex-to-real transforms when the total number of elements across all batches in a single execution exceeded 2147483647.
- ▶ **Known Issues**
 - ▶ Some V100 FFTs are slower than expected.
 - ▶ Some T4 FFTs are slower than expected.

2.2.3. cuFFT: Release 11.4

- ▶ **New Features**
 - ▶ Performance improvements.
- ▶ **Known Issues**
 - ▶ Some T4 FFTs are slower than expected.
 - ▶ cuFFT may produce incorrect results for real-to-complex and complex-to-real transforms when the total number of elements across all batches in a single execution exceeds 2147483647.
 - ▶ Some cuFFT multi-GPU plans may exhibit very long creation time. Issue will be fixed in the next update.
 - ▶ cuFFT may produce incorrect results for transforms with strides when the index of the last element across all batches exceeds 2147483647 (see [Advanced Data Layout](#)).
- ▶ **Deprecated Features**
 - ▶ Support for callback functionality using separately compiled device code is deprecated on all GPU architectures. Callback functionality will continue to be supported for all GPU architectures.

2.2.4. cuFFT: Release 11.3

- ▶ **New Features**
 - ▶ cuFFT shared libraries are now linked statically against libstdc++ on Linux platforms.
 - ▶ Improved performance of certain sizes (multiples of large powers of 3, powers of 11) in SM86.
- ▶ **Known Issues**
 - ▶ cuFFT planning and plan estimation functions may not restore correct context affecting CUDA driver API applications.
 - ▶ Plans with strides, primes larger than 127 in FFT size decomposition and total size of transform including strides bigger than 32GB produce incorrect results.

2.2.5. cuFFT: Release 11.2 Update 2

▶ Known Issues

- ▶ cuFFT planning and plan estimation functions may not restore correct context affecting CUDA driver API applications.
- ▶ Plans with strides, primes larger than 127 in FFT size decomposition and total size of transform including strides bigger than 32GB produce incorrect results.

2.2.6. cuFFT: Release 11.2 Update 1

▶ Resolved Issues

- ▶ Previously, reduced performance of power-of-2 single precision FFTs was observed on GPUs with sm_86 architecture. This issue has been resolved.
- ▶ Large prime factors in size decomposition and real to complex or complex to real FFT type no longer cause cuFFT plan functions to fail.

▶ Known Issues

- ▶ cuFFT planning and plan estimation functions may not restore correct context affecting CUDA driver API applications.
- ▶ Plans with strides, primes larger than 127 in FFT size decomposition and total size of transform including strides bigger than 32GB produce incorrect results.

2.2.7. cuFFT: Release 11.2

▶ New Features

- ▶ Multi-GPU plans can be associated with a stream using the `cufftSetStream` API function call.
- ▶ Performance improvements for R2C/C2C/C2R transforms.
- ▶ Performance improvements for multi-GPU systems.

▶ Resolved Issues

- ▶ cuFFT is no longer stuck in a bad state if previous plan creation fails with `CUFFT_ALLOC_FAILED`.
- ▶ Previously, single dimensional multi-GPU FFT plans ignored user input on `cufftXtSetGPUswhichGPUs` argument and assumed that GPUs IDs are always numbered from 0 to N-1. This issue has been resolved.
- ▶ Plans with primes larger than 127 in FFT size decomposition or FFT size being a prime number bigger than 4093 do not perform calculations on second and subsequent `cufftExecute*` calls. The regression was introduced in cuFFT 11.1.

▶ Known Issues

- ▶ cuFFT planning and plan estimation functions may not restore correct context affecting CUDA driver API applications.

2.2.8. cuFFT: Release 11.1

▶ New Features

- ▶ cuFFT is now L2-cache aware and uses L2 cache for GPUs with more than 4.5MB of L2 cache. Performance may improve in certain single-GPU 3D C2C FFT cases.
- ▶ After successfully creating a plan, cuFFT now enforces a lock on the `cufftHandle`. Subsequent calls to any planning function with the same `cufftHandle` will fail.
- ▶ Added support for very large sizes (3k cube) to multi-GPU cuFFT on DGX-2.
- ▶ Improved performance on multi-gpu cuFFT for certain sizes (1k cube).

▶ Resolved Issues

- ▶ Resolved an issue that caused cuFFT to crash when reusing a handle after clearing a callback.
- ▶ Fixed an error which produced incorrect results / NaN values when running a real-to-complex FFT in half precision.

▶ Known Issues

- ▶ cuFFT will always overwrite the input for out-of-place C2R transform.
- ▶ Single dimensional multi-GPU FFT plans ignore user input on the `whichGPUs` parameter of `cufftxSetGPUs()` and assume that GPU IDs are always numbered from 0 to N-1.

2.2.9. cuFFT: Release 11.0 RC

▶ New Features

- ▶ cuFFT now accepts `__nv_bfloat16` input and output data type for power-of-two sizes with single precision computations within the kernels.
- ▶ Reoptimized power of 2 FFT kernels on Volta and Turing architectures.

▶ Resolved Issues

- ▶ Reduced R2C/C2R plan memory usage to previous levels.
- ▶ Resolved bug introduced in 10.1 update 1 that caused incorrect results when using custom strides, batched 2D plans and certain sizes on Volta and later.

▶ Known Issues

- ▶ cuFFT modifies C2R input buffer for some non-strided FFT plans.
- ▶ There is a known issue with certain cuFFT plans that causes an assertion in the execution phase of certain plans. This applies to plans with all of the following

characteristics: real input to complex output (R2C), in-place, native compatibility mode, certain even transform sizes, and more than one batch.

2.3. cuRAND Library

2.3.1. cuRAND: Release 11.3

► Resolved Issues

- Fixed inconsistency between random numbers generated by GPU and host generators when `CURAND_ORDERING_PSEUDO_LEGACY` ordering is selected for certain generator types.

2.3.2. cuRAND: Release 11.0 Update 1

► Resolved Issues

- Fixed an issue that caused linker errors about the multiple definitions of `mtgp32dc_params_fast_11213` and `mtgpcdc_params_11213_num` when including `curand_mtgp32dc_p_11213.h` in different compilation units.

2.3.3. cuRAND: Release 11.0

► Resolved Issues

- Fixed an issue that caused linker errors about the multiple definitions of `mtgp32dc_params_fast_11213` and `mtgpcdc_params_11213_num` when including `curand_mtgp32dc_p_11213.h` in different compilation units.

2.3.4. cuRAND: Release 11.0 RC

► Resolved Issues

- Introduced `CURAND_ORDERING_PSEUDO_LEGACY` ordering. Starting with CUDA 10.0, the ordering of random numbers returned by MTGP32 and MRG32k3a generators are no longer the same as previous releases despite being guaranteed by the documentation for the `CURAND_ORDERING_PSEUDO_DEFAULT` setting. The `CURAND_ORDERING_PSEUDO_LEGACY` provides pre-CUDA 10.0 ordering for MTGP32 and MRG32k3a generators.
- Starting with CUDA 11.0 `CURAND_ORDERING_PSEUDO_DEFAULT` is the same as `CURAND_ORDERING_PSEUDO_BEST` for all generators except MT19937. Only `CURAND_ORDERING_PSEUDO_LEGACY` is guaranteed to provide the same for all future cuRAND releases.

2.4. cuSOLVER Library

2.4.1. cuSOLVER: Release 11.4

► New Features

- Introducing `cusolverDnXtrtri`, a new generic API for triangular matrix inversion (`trtri`).
- Introducing `cusolverDnXsytrs`, a new generic API for solving systems of linear equations using a given factorized symmetric matrix from SYTRF.

2.4.2. cuSOLVER: Release 11.3

► Known Issues

- For values $N \leq 16$, `cusolverDn[S|D|C|Z]syevjBatched` hits out-of-bound access and may deliver the wrong result. The workaround is to pad the matrix A with a diagonal matrix D such that the dimension of $[A \ 0; \ 0 \ D]$ is bigger than 16. The diagonal entry $D(j,j)$ must be bigger than maximum eigenvalue of A, for example, `norm(A, 'fro')`. After the `syevj`, `W(0:n-1)` contains the eigenvalues and `A(0:n-1,0:n-1)` contains the eigenvectors.

2.4.3. cuSOLVER: Release 11.2 Update 2

► New Features

- New singular value decomposition (GESVDR) is added. GESVDR computes partial spectrum with random sampling, an order of magnitude faster than GESVD.
- `libcusolver.so` no longer links `libcublas_static.a`; instead, it depends on `libcublas.so`. This reduces the binary size of `libcusolver.so`. However, it breaks backward compatibility. The user has to link `libcusolver.so` with the correct version of `libcublas.so`.

2.4.4. cuSOLVER: Release 11.2

► Resolved Issues

- `cusolverDnIRSXgels` sometimes returned `CUSOLVER_STATUS_INTERNAL_ERROR` when the precision is 'z'. This issue has been fixed in CUDA 11.2; now `cusolverDnIRSXgels` works for all precisions.
- `ZSYTRF` sometimes returned `CUSOLVER_STATUS_INTERNAL_ERROR` due to insufficient resources to launch the kernel. This issue has been fixed in CUDA 11.2.
- `GETRF` returned early without finishing the whole factorization when the matrix was singular. This issue has been fixed in CUDA 11.2.

2.4.5. cuSOLVER: Release 11.1 Update 1

► Resolved Issues

- `cusolverDnDDgels` reports `IRS_NOT_SUPPORTED` when $m > n$. The issue has been fixed in release 11.1 U1, so `cusolverDnDDgels` will support $m > n$.
- `cusolverMgDeviceSelect` can consume over 1GB device memory. The issue has been fixed in release 11.1 U1. The hidden memory allocation inside `cusolverMG` handle is about 30 MB per device.

► Known Issues

- `cusolverDnIRSXgels` may return `CUSOLVER_STATUS_INTERNAL_ERROR`. when the precision is 'z' due to insufficient workspace which causes illegal memory access.

The `cusolverDnIRSXgels_bufferSize()` does not report the correct size of workspace. To workaround the issue, the user has to add more workspace than what is reported by `cusolverDnIRSXgels_bufferSize()`. For example, if x is the size of workspace returned by `cusolverDnIRSXgels_bufferSize()`, then the user has to allocate $(x + \min(m, n) * \text{sizeof}(\text{cuDoubleComplex}))$ bytes.

2.4.6. cuSOLVER: Release 11.1

► New Features

- Added new 64-bit APIs:
 - `cusolverDnXpotrf_bufferSize`
 - `cusolverDnXpotrf`
 - `cusolverDnXpotrs`
 - `cusolverDnXgeqrf_bufferSize`
 - `cusolverDnXgeqrf`
 - `cusolverDnXgetrf_bufferSize`
 - `cusolverDnXgetrf`
 - `cusolverDnXgetrs`
 - `cusolverDnXsyevd_bufferSize`
 - `cusolverDnXsyevd`
 - `cusolverDnXsyevdx_bufferSize`
 - `cusolverDnXsyevdx`
 - `cusolverDnXgesvd_bufferSize`

- ▶ `cusolverDnXgesvd`
- ▶ Added a new SVD algorithm based on polar decomposition, called GESVDP which uses the new 64-bit API, including `cusolverDnXgesvdp_bufferSize` and `cusolverDnXgesvdp`.
- ▶ **Deprecated Features**
The following 64-bit APIs are deprecated:
 - ▶ `cusolverDnPotrf_bufferSize`
 - ▶ `cusolverDnPotrf`
 - ▶ `cusolverDnPotrs`
 - ▶ `cusolverDnGeqrf_bufferSize`
 - ▶ `cusolverDnGeqrf`
 - ▶ `cusolverDnGetrf_bufferSize`
 - ▶ `cusolverDnGetrf`
 - ▶ `cusolverDnGetrs`
 - ▶ `cusolverDnSyevd_bufferSize`
 - ▶ `cusolverDnSyevd`
 - ▶ `cusolverDnSyevdx_bufferSize`
 - ▶ `cusolverDnSyevdx`
 - ▶ `cusolverDnGesvd_bufferSize`
 - ▶ `cusolverDnGesvd`

2.4.7. cuSOLVER: Release 11.0

- ▶ **New Features**
 - ▶ Add 64-bit API of GESVD. The new routine `cusolverDnGesvd_bufferSize()` fills the missing parameters in 32-bit API `cusolverDn[S|D|C|Z]gesvd_bufferSize()` such that it can estimate the size of the workspace accurately.
 - ▶ Added the single process multi-GPU Cholesky factorization capabilities POTRF, POTRS and POTRI in `cusolverMG` library.
- ▶ **Resolved Issues**
 - ▶ Fixed an issue where SYEVD/SYGVD would fail and return error code 7 if the matrix is zero and the dimension is bigger than 25.

2.5. cuSPARSE Library

2.5.1. cuSPARSE: Release 11.4 Update 1

► Resolved Issues

- `cusparseSpSV` and `cusparseSpSM` could produce wrong results
- `cusparseSpSV` and `cusparseSpSM` do not work correctly when `vecX == vecY` or `matB == matC`.

2.5.2. cuSPARSE: Release 11.4

► Known Issues

- `cusparseSpSV` and `cusparseSpSM` could produce wrong results
- `cusparseSpSV` and `cusparseSpSM` do not work correctly when `vecX == vecY` or `matB == matC`.

2.5.3. cuSPARSE: Release 11.3 Update 1

► New Features

- Introduced a new routine for sparse matrix - sparse matrix multiplication (`cusparseSpGEMMreuse`) where the output matrix structure is reused for multiple computation. The new routine supports CSR storage format and mixed-precision computation.
- Sparse triangular solver adds support for COO format.
- Introduced a new routine for sparse triangular solver with multiple right-hand sides `cusparseSpSM()`.
- `cusparseDenseToSparse()` routine adds the conversion from dense matrix (row-major/column-major) to Blocked-ELL format.
- Blocked-ELL format now support empty blocks
- Better performance for Blocked-ELL SpMM with block size > 64, double data type, and alignments smaller than 128-byte on NVIDIA Ampere sm80.
- All cuSPARSE APIs are now asynchronous on platforms that support stream ordered memory allocators <https://docs.nvidia.com/cuda/cuda-c-programming-guide/index.html#stream-ordered-querying-memory-support>.
- Improved NTVX trace with distinction between light calls and kernel routines

► Resolved Issues

- ▶ `cusparseCnnz_compress` produced wrong results when the number of rows are greater than $128 * \text{resident CTAs}$.
- ▶ `cusparseSnnz` produced wrong results for some particular sparsity pattern.
- ▶ **Deprecated Features**
 - ▶ `cusparseXcsrsm2_zeroPivot`, `cusparseXcsrsm2_solve`, `cusparseXcsrsm2_analysis`, and `cusparseScsrsm2_bufferSizeExt` have been deprecated in favor of `cusparseSpSM` Generic APIs

2.5.4. cuSPARSE: Release 11.3

▶ New Features

Added new routine `cusparseSpSV` for sparse triangular solver with better performance. The new Generic API supports:

- ▶ CSR storage format
- ▶ Non-transpose, transpose, and transpose-conjugate operations
- ▶ Upper, lower fill mode
- ▶ Unit, non-unit diagonal type
- ▶ 32-bit and 64-bit indices
- ▶ Uniform data type computation
- ▶ **Deprecated Features**
 - ▶ `cusparseScsrsv2_analysis`, `cusparseScsrsv2_solve`, `cusparseXcsrsv2_zeroPivot`, and `cusparseScsrsv2_bufferSize` have been deprecated in favor of `cusparseSpSV`.

2.5.5. cuSPARSE: Release 11.2 Update 2

▶ Resolved Issues

- ▶ `cusparseDestroy(NULL)` no longer crashes on Windows.

▶ Known Issues

- ▶ `cusparseDestroySpVec`, `cusparseDestroyDnVec`, `cusparseDestroySpMat`, `cusparseDestroyDnMat`, `cusparseDestroy` with `NULL` argument could cause segmentation fault on Windows.

2.5.6. cuSPARSE: Release 11.2 Update 1

▶ New Features

- ▶ New Tensor Core-accelerated Block Sparse Matrix - Matrix Multiplication (`cusparseSpMM`) and introduction of the Blocked-Ellpack storage format.

- ▶ New algorithms for CSR/COO Sparse Matrix - Vector Multiplication (`cusparseSpMV`) with better performance.
- ▶ Extended functionalities for `cusparseSpMV`:
 - ▶ Support for the CSC format.
 - ▶ Support for regular/complex bfloat16 data types for both uniform and mixed-precision computation.
 - ▶ Support for mixed regular-complex data type computation.
 - ▶ Support for deterministic and non-deterministic computation.
- ▶ New algorithm (`CUSPARSE_SPMM_CSR_ALG3`) for Sparse Matrix - Matrix Multiplication (`cusparseSpMM`) with better performance especially for small matrices.
- ▶ New routine for Sampled Dense Matrix - Dense Matrix Multiplication (`cusparseSDDMM`) which deprecated `cusparseConstrainedGEMM` and provides better performance.
- ▶ Better accuracy of `cusparseAxpby`, `cusparseRot`, `cusparseSpVV` for bfloat16 and half regular/complex data types.
- ▶ All routines support NVTX annotation for enhancing the profiler time line on complex applications.
- ▶ **Resolved Issues**
 - ▶ `cusparseAxpby`, `cusparseGather`, `cusparseScatter`, `cusparseRot`, `cusparseSpVV`, `cusparseSpMV` now support zero-size matrices.
 - ▶ `cusparseCsr2cscEx2` now correctly handles empty matrices (`nnz = 0`).
 - ▶ `cusparseXcsr2csr_compress` now uses 2-norm for the comparison of complex values instead of only the real part.
- ▶ **Known Issues**

`cusparseDestroySpVec`, `cusparseDestroyDnVec`, `cusparseDestroySpMat`, `cusparseDestroyDnMat`, `cusparseDestroy` with `NULL` argument could cause segmentation fault on Windows.
- ▶ **Deprecated Features**
 - ▶ `cusparseConstrainedGEMM` has been deprecated in favor of `cusparseSDDMM`.
 - ▶ `cusparseCsrnvEx` has been deprecated in favor of `cusparseSpMV`.
 - ▶ COO Array of Structure (CooAoS) format has been deprecated including `cusparseCreateCooAoS`, `cusparseCooAoSGet`, and its support for `cusparseSpMV`.

2.5.7. cuSPARSE: Release 11.2

- ▶ **Known Issues**
 - ▶ `cusparseXdense2csr` provides incorrect results for some matrix sizes.

2.5.8. cuSPARSE: Release 11.1 Update 1

▶ New Features

- ▶ `cusparseSparseToDense`
 - ▶ CSR, CSC, or COO conversion to dense representation
 - ▶ Support row-major and column-major layouts
 - ▶ Support all data types
 - ▶ Support 32-bit and 64-bit indices
 - ▶ Provide performance 3x higher than `cusparseXcsc2dense`, `cusparseXcsr2dense`
- ▶ `cusparseDenseToSparse`
 - ▶ Dense representation to CSR, CSC, or COO
 - ▶ Support row-major and column-major layouts
 - ▶ Support all data types
 - ▶ Support 32-bit and 64-bit indices
 - ▶ Provide performance 3x higher than `cusparseXcsc2dense`, `cusparseXcsr2dense`

▶ Known Issues

- ▶ `cusparseXdense2csr` provides incorrect results for some matrix sizes.

▶ Deprecated Features

- ▶ Legacy conversion routines: `cusparseXcsc2dense`, `cusparseXcsr2dense`, `cusparseXdense2csc`, `cusparseXdense2csr`

2.5.9. cuSPARSE: Release 11.0

▶ New Features

- ▶ Added new Generic APIs for Axbpy (`cusparseAxbpy`), Scatter (`cusparseScatter`), Gather (`cusparseGather`), Givens rotation (`cusparseRot`). `__nv_bfloat16/ __nv_bfloat162` data types and 64-bit indices are also supported.
- ▶ This release adds the following features for `cusparseSpMM`:
 - ▶ Support for row-major layout for `cusparseSpMM` for both CSR and COO format
 - ▶ Support for 64-bit indices
 - ▶ Support for `__nv_bfloat16` and `__nv_bfloat162` data types
 - ▶ Support for the following strided *batch* mode:

- ▶ $C_i = A \cdot B_i$
- ▶ $C_i = A_i \cdot B$
- ▶ $C_i = A_i \cdot B_i$

2.5.10. cuSPARSE: Release 11.0 RC

▶ New Features

- ▶ Added new Generic APIs for Axpby (cusparseAxpby), Scatter (cusparseScatter), Gather (cusparseGather), Givens rotation (cusparseRot). `__nv_bfloat16/ __nv_bfloat162` data types and 64-bit indices are also supported.
- ▶ This release adds the following features for cusparseSpMM:
 - ▶ Support for row-major layout for cusparseSpMM for both CSR and COO format
 - ▶ Support for 64-bit indices
 - ▶ Support for `__nv_bfloat16` and `__nv_bfloat162` data types
 - ▶ Support for the following strided *batch* mode:
 - ▶ $C_i = A \cdot B_i$
 - ▶ $C_i = A_i \cdot B$
 - ▶ $C_i = A_i \cdot B_i$
- ▶ Added new generic APIs and improved performance for sparse matrix-sparse matrix multiplication (SpGEMM): `cusparseSpGEMM_workEstimation`, `cusparseSpGEMM_compute`, and `cusparseSpGEMM_copy`.
- ▶ SpVV: added support for `__nv_bfloat16`.

▶ Deprecated Features

The following functions have been removed:

- ▶ `cusparse<t>gemmi ()`
- ▶ `cusparseXaxpyi`, `cusparseXgthr`, `cusparseXgthrz`, `cusparseXroti`, `cusparseXsctr`
- ▶ Hybrid format enums and helper functions: `cusparseHybPartition_t`, `cusparseHybPartition_t`, `cusparseCreateHybMat`, `cusparseDestroyHybMat`
- ▶ Triangular solver enums and helper functions: `cusparseSolveAnalysisInfo_t`, `cusparseCreateSolveAnalysisInfo`, `cusparseDestroySolveAnalysisInfo`
- ▶ Sparse dot product: `cusparseXdoti`, `cusparseXdotci`
- ▶ Sparse matrix-vector multiplication: `cusparseXcsrvmv`, `cusparseXcsrvmv_mp`

- ▶ Sparse matrix-matrix multiplication: `cusparseXcsrmm`, `cusparseXcsrmm2`
- ▶ Sparse triangular-single vector solver: `cusparseXcsrsv_analysis`, `cusparseCsrsv_analysisEx`, `cusparseXcsrsv_solve`, `cusparseCsrsv_solveEx`
- ▶ Sparse triangular-multiple vectors solver: `cusparseXcsrsm_analysis`, `cusparseXcsrsm_solve`
- ▶ Sparse hybrid format solver: `cusparseXhybsv_analysis`, `cusparseShybsv_solve`
- ▶ Extra functions: `cusparseXcsrgeamNnz`, `cusparseScsrgeam`, `cusparseXcsrgeammNnz`, `cusparseXcsrgeamm`
- ▶ Incomplete Cholesky Factorization, level 0: `cusparseXcsric0`
- ▶ Incomplete LU Factorization, level 0: `cusparseXcsrilu0`, `cusparseCsrilu0Ex`
- ▶ Tridiagonal Solver: `cusparseXgtsv`, `cusparseXgtsv_nopivot`
- ▶ Batched Tridiagonal Solver: `cusparseXgtsvStridedBatch`
- ▶ Reordering: `cusparseXcsc2hyb`, `cusparseXcsr2hyb`, `cusparseXdense2hyb`, `cusparseXhyb2csc`, `cusparseXhyb2csr`, `cusparseXhyb2dense`

The following functions have been deprecated:

- ▶ SpGEMM: `cusparseXcsrgeamm2_bufferSizeExt`, `cusparseXcsrgeamm2Nnz`, `cusparseXcsrgeamm2`

2.6. Math Library

2.6.1. CUDA Math: Release 11.3

▶ Resolved Issues

- ▶ Previous releases of CUDA were potentially delivering incorrect results in some Linux distributions for the following host Math APIs: `sinpi`, `cospi`, `sincospi`, `sinpif`, `cospif`, `sincospif`. If passed huge inputs like `7.3748776e+15` or `8258177.5` the results were not equal to 0 or 1. These have been corrected with this release.

2.6.2. CUDA Math: Release 11.1

▶ New Features

- ▶ Added host support for `half` and `nv_bfloat16` converts to/from integer types.

- ▶ Added `__hcmadd()` device only API for fast half2 and `nv_bfloat162` based complex multiply-accumulate.

2.6.3. CUDA Math: Release 11.0 Update 1

▶ Resolved Issues

- ▶ `nv_bfloat16` comparison functions could trigger a fault with misaligned addresses.
- ▶ Performance improvements in half and `nv_bfloat16` basic arithmetic implementations.

2.6.4. CUDA Math: Release 11.0 RC

▶ New Features

- ▶ Add arithmetic support for `__nv_bfloat16` floating-point data type with 8 bits of exponent, 7 explicit bits of mantissa.
- ▶ Performance and accuracy improvements in single precision math functions: `fmodf`, `expf`, `exp10f`, `sinhf`, and `coshf`.

▶ Resolved Issues

- ▶ Corrected documented maximum ulp error thresholds in `erfcinvf` and `powf`.
- ▶ Improved `cuda_fp16.h` interoperability with Visual Studio C++ compiler.
- ▶ Updated libdevice user guide and CUDA math API definitions for `j1`, `j1f`, `fmod`, `fmodf`, `ilogb`, and `ilogbf` math functions.

2.7. NVIDIA Performance Primitives (NPP)

2.7.1. NPP: Release 11.4

▶ New Features

- ▶ New API `FindContours.FindContours` can be explained simply as a curve joining all the continuous points (along the boundary), having the same color or intensity. The contours are a useful tool for shape analysis and object detection and recognition.

2.7.2. NPP: Release 11.3

▶ New Features

- ▶ Added `nppiDistanceTransformPBA` functions.

2.7.3. NPP: Release 11.2 Update 2

► New Features

- Added `nppiDistanceTransformPBA` functions.

2.7.4. NPP: Release 11.2 Update 1

► New Features

New APIs added to compute Distance Transform using Parallel Banding Algorithm (PBA):

- `nppiDistanceTransformPBA_XXXX_C1R_Ctx()` – where `XXXX` specifies the input and output combination: `8u16u`, `8s16u`, `16u16u`, `16s16u`, `8u32f`, `8s32f`, `16u32f`, `16s32f`
- `nppiSignedDistanceTransformPBA_32f_C1R_Ctx()`

► Resolved Issues

- Fixed the issue in which Label Markers adds zero pixel as object region.

2.7.5. NPP: Release 11.0

► New Features

- Batched Image Label Markers Compression that removes sparseness between marker label IDs output from `LabelMarkers` call.
- Image Flood Fill functionality fills a connected region of an image with a specified new value.
- Stability and performance fixes to Image Label Markers and Image Label Markers Compression.

2.7.6. NPP: Release 11.0 RC

► New Features

- Batched Image Label Markers Compression that removes sparseness between marker label IDs output from `LabelMarkers` call.
- Image Flood Fill functionality fills a connected region of an image with a specified new value.
- Added batching support for `nppiLabelMarkersUF` functions.
- Added the `nppiCompressMarkerLabelsUF_32u_C1IR` function.
- Added `nppiSegmentWatershed` functions.
- Added sample apps on GitHub demonstrating the use of NPP application managed stream contexts along with watershed segmentation and batched and compressed UF image label markers functions.

- ▶ Added support for non-blocking streams.
- ▶ **Resolved Issues**
 - ▶ Stability and performance fixes to Image Label Markers and Image Label Markers Compression.
 - ▶ Improved quality of `nppiLabelMarkersUF` functions.
 - ▶ `nppiCompressMarkerLabelsUF_32u_C1IR` can now handle a huge number of labels generated by the `nppiLabelMarkersUF` function.
- ▶ **Known Issues**
 - ▶ The `nppiCopy` API is limited by CUDA thread for large image size. Maximum image limits is a minimum of $16 * 65,535 = 1,048,560$ horizontal pixels of any data type and number of channels and $8 * 65,535 = 524,280$ vertical pixels for a maximum total of 549,739,036,800 pixels.

2.8. nvJPEG Library

2.8.1. nvJPEG: Release 11.4

- ▶ **Resolved Issues**
 - ▶ Additional subsampling added to solve the `NVJPEG_CSS_2x4`.

2.8.2. nvJPEG: Release 11.2 Update 1

- ▶ **New Features**

nvJPEG decoder added new APIs to support region of interest (ROI) based decoding for batched hardware decoder:

 - ▶ `nvjpegDecodeBatchedEx()`
 - ▶ `nvjpegDecodeBatchedSupportedEx()`

2.8.3. nvJPEG: Release 11.1 Update 1

- ▶ **New Features**
 - ▶ Added error handling capabilities for nonstandard JPEG images.

2.8.4. nvJPEG: Release 11.0 Update 1

- ▶ **Known Issues**
 - ▶ `NVJPEG_BACKEND_GPU_HYBRID` has an issue when handling bit-streams which have corruption in the scan.

2.8.5. nvJPEG: Release 11.0

► New Features

- nvJPEG allows the user to allocate separate memory pools for each chroma subsampling format. This helps avoid memory re-allocation overhead. This can be controlled by passing the newly added flag `NVJPEG_FLAGS_ENABLE_MEMORY_POOLS` to the `nvjpegCreateEx` API.
- nvJPEG encoder now allow compressed bitstream on the GPU Memory.

2.8.6. nvJPEG: Release 11.0 RC

► New Features

- nvJPEG allows the user to allocate separate memory pools for each chroma subsampling format. This helps avoid memory re-allocation overhead. This can be controlled by passing the newly added flag `NVJPEG_FLAGS_ENABLE_MEMORY_POOLS` to the `nvjpegCreateEx` API.
- nvJPEG encoder now allow compressed bitstream on the GPU Memory.
- Hardware accelerated decode is now supported on NVIDIA A100.
- The nvJPEG decode API ([nvjpegDecodeJpeg\(\)](#)) now has the flexibility to select the backend when creating `nvjpegJpegDecoder_t` object. The user has the option to call this API instead of making three separate calls to `nvjpegDecodeJpegHost()`, `nvjpegDecodeJpegTransferToDevice()`, and `nvjpegDecodeJpegDevice()`.

► Known Issues

- `NVJPEG_BACKEND_GPU_HYBRID` has an issue when handling bit-streams which have corruption in the scan.

► Deprecated Features

The following multiphase APIs have been removed:

- `nvjpegStatus_t NVJPEGAPI nvjpegDecodePhaseOne`
- `nvjpegStatus_t NVJPEGAPI nvjpegDecodePhaseTwo`
- `nvjpegStatus_t NVJPEGAPI nvjpegDecodePhaseThree`
- `nvjpegStatus_t NVJPEGAPI nvjpegDecodeBatchedPhaseOne`
- `nvjpegStatus_t NVJPEGAPI nvjpegDecodeBatchedPhaseTwo`

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