NVIDIA CUDA Toolkit

Release Notes for CUDA 11.7
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<td>nvJPEG: Release 11.4</td>
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<tr>
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<td>2.8.5.</td>
<td>nvJPEG: Release 11.1 Update 1</td>
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<tr>
<td>2.8.6.</td>
<td>nvJPEG: Release 11.0 Update 1</td>
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<td>2.8.7.</td>
<td>nvJPEG: Release 11.0</td>
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Chapter 1. CUDA 11.7 Release Notes

The release notes for the NVIDIA® CUDA® Toolkit can be found online at https://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 11.7, the table below indicates the versions:

Table 1. CUDA 11.7 Update 1 Component Versions

<table>
<thead>
<tr>
<th>Component Name</th>
<th>Version Information</th>
<th>Supported Architectures</th>
</tr>
</thead>
<tbody>
<tr>
<td>CUDA C++ Core Compute Libraries</td>
<td>11.7.91</td>
<td>x86_64, POWER, AArch64</td>
</tr>
<tr>
<td>CUDA Runtime (cudart)</td>
<td>11.7.99</td>
<td>x86_64, POWER, AArch64</td>
</tr>
<tr>
<td>cuobjdump</td>
<td>11.7.91</td>
<td>x86_64, POWER, AArch64</td>
</tr>
<tr>
<td>CUPTI</td>
<td>11.7.101</td>
<td>x86_64, POWER, AArch64</td>
</tr>
<tr>
<td>CUDA cuxxfilt (demangler)</td>
<td>11.7.91</td>
<td>x86_64, POWER, AArch64</td>
</tr>
<tr>
<td>CUDA Demo Suite</td>
<td>11.7.91</td>
<td>x86_64</td>
</tr>
<tr>
<td>CUDA GDB</td>
<td>11.7.91</td>
<td>x86_64, POWER, AArch64</td>
</tr>
<tr>
<td>CUDA Memcheck</td>
<td>11.7.91</td>
<td>x86_64, POWER</td>
</tr>
<tr>
<td>CUDA Nsight</td>
<td>11.7.91</td>
<td>x86_64</td>
</tr>
<tr>
<td>CUDA NVCC</td>
<td>11.7.99</td>
<td>x86_64, POWER, AArch64</td>
</tr>
<tr>
<td>CUDA nvdisasm</td>
<td>11.7.91</td>
<td>x86_64, POWER, AArch64</td>
</tr>
<tr>
<td>CUDA NVML Headers</td>
<td>11.7.91</td>
<td>x86_64, POWER, AArch64</td>
</tr>
</tbody>
</table>
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.


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

---

Only available on select Linux distros
The minimum required driver version for CUDA minor version compatibility is shown below. CUDA minor version compatibility is described in detail in https://docs.nvidia.com/deploy/cuda-compatibility/index.html

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

<table>
<thead>
<tr>
<th>CUDA Toolkit</th>
<th>Minimum Required Driver Version for CUDA Minor Version Compatibility*</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Linux x86_64 Driver Version</td>
</tr>
<tr>
<td>CUDA 11.7.x</td>
<td>&gt;=450.80.02</td>
</tr>
<tr>
<td>CUDA 11.6.x</td>
<td></td>
</tr>
<tr>
<td>CUDA 11.5.x</td>
<td></td>
</tr>
<tr>
<td>CUDA 11.4.x</td>
<td></td>
</tr>
<tr>
<td>CUDA 11.3.x</td>
<td></td>
</tr>
<tr>
<td>CUDA 11.2.x</td>
<td></td>
</tr>
<tr>
<td>CUDA 11.1 [11.1.0]</td>
<td></td>
</tr>
<tr>
<td>CUDA 11.0 [11.0.3]</td>
<td>&gt;=450.36.06**</td>
</tr>
</tbody>
</table>

* 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.

** CUDA 11.0 was released with an earlier driver version, but by upgrading to Tesla Recommended Drivers 450.80.02 [Linux] / 452.39 [Windows], 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

<table>
<thead>
<tr>
<th>CUDA Toolkit</th>
<th>Toolkit Driver Version</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Linux x86_64 Driver Version</td>
</tr>
<tr>
<td>CUDA 11.7 Update 1</td>
<td>&gt;=515.65.01</td>
</tr>
<tr>
<td>CUDA 11.7 GA</td>
<td>&gt;=515.43.04</td>
</tr>
<tr>
<td>CUDA 11.6 Update 2</td>
<td>&gt;=510.47.03</td>
</tr>
<tr>
<td>CUDA 11.6 Update 1</td>
<td>&gt;=510.47.03</td>
</tr>
<tr>
<td>CUDA 11.6 GA</td>
<td>&gt;=510.39.01</td>
</tr>
<tr>
<td>CUDA 11.5 Update 2</td>
<td>&gt;=495.29.05</td>
</tr>
<tr>
<td>CUDA 11.5 Update 1</td>
<td>&gt;=495.29.05</td>
</tr>
<tr>
<td>CUDA 11.5 GA</td>
<td>&gt;=495.29.05</td>
</tr>
</tbody>
</table>
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 [https://www.nvidia.com/drivers](https://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 https://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

11.7 Update 1

- Added support for RHEL 9.0

11.7

- To best ensure the security and reliability of our RPM and Debian package repositories, NVIDIA is updating and rotating the signing keys used by apt, dnf/yum, and zypper package managers beginning April 27, 2022. Failure to update your repository signing keys will result in package management errors when attempting to access or install packages from CUDA repositories.

  To ensure continued access to the latest NVIDIA software, please follow the instructions here: https://developer.nvidia.com/blog/updating-the-cuda-linux-gpg-repository-key/.


- Lazy Loading: Delay kernel loading from host to GPU to the point where the kernel is called. This also only loads used kernels, which may result in a significant device-side memory savings. This also defers load latency from the beginning of the application to the point where a kernel is first called—overall binary load latency is usually significantly reduced, but is also shifted to later points in the application.

  To enable this feature, set the environment variable CUDA_MODULE_LOADING=LAZY before launching your process.

  Note that this feature is only compatible with libraries compiled with CUDA versions >= 11.7.

1.3. CUDA Compilers

11.7

- Grid private constants

- NVCC host compiler support for clang13
1.4. CUDA Developer Tools

- For changes to nvprof and Visual Profiler, see the [changelog](#).
- For new features, improvements, and bug fixes in CUPTI, see the [changelog](#).
- For new features, improvements, and bug fixes in Nsight Compute, see the [changelog](#).
- For new features, improvements, and bug fixes in Compute Sanitizer, see the [changelog](#).
- For new features, improvements, and bug fixes in CUDA-GDB, see the [changelog](#).

1.5. Resolved Issues

1.5.1. General CUDA

11.7 Update 1

- During ongoing testing, NVIDIA identified that due to an algorithm error in a very small number of hardest-to-round cases (less than 0.000007% of tested combinations), the results of 64-bit floating-point division in default round-to-nearest-even mode can differ from the IEEE754 standard by 1 least-significant bit in default round-to-nearest-even mode.

Floating-point computations have many sources of error accumulation and most algorithms will not have encountered this discrepancy. NVIDIA recommends that all developers requiring strict IEEE754 compliance update to CUDA Toolkit 11.7 Update 1 or newer.

The affected algorithm is present in both offline compilation as well as just-in-time (JIT) compilation. As JIT compilation is handled by the driver, NVIDIA recommends updating to driver version 515.65.01 when IEEE754 compliance is required and when using JIT.

This is a software algorithm fix and is not tied to specific hardware.

11.7

- All color formats are now supported for Vulkan-CUDA interop on L4T and Android.
- Resolved a linking issue that could be encountered on some systems when using libnvfm.so.

1.5.2. CUDA Compilers

11.7

- There was a compiler bug due to which a function marked `__forceinline__` in a CUDA C++ program or a function marked with the NVVM IR `alwaysinline` attribute for libNVVM
compilation) was incorrectly given static linkage by the compiler in certain compilation modes. This incorrect behavior has been fixed and the compiler will not change the linkage in these compilation modes. As a result, if the static linkage is appropriate for such a function, then the program itself should set the linkage.

- Updated the libNVVM API documentation to include the library version and a note regarding thread safety.

### 1.6. 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**

- CentOS Linux 8 has reached End-of-Life on December 31, 2021. Support for this OS is now removed from the CUDA Toolkit and is replaced by Rocky Linux 8.
- Server 2016 support has been deprecated and shall be removed in a future release.

**CUDA Compiler**

- NVCC is deprecating 32-bit compilation for ALL GPUs, and it will be removed in future release. Older CUDA toolkits will continue to support it.
- The NVVM IR spec no longer allows static initialization of shared variables. These were allowed and ignored in earlier CUDA releases. Use "undefined" initialization instead.

### 1.7. Known Issues

#### 1.7.1. CUDA Compiler

- In 11.7, the ISO C++ 20 standard is not supported yet.

#### 1.7.2. CUDA Tools

- Nsight Profiler launch has known performance regression with GSP driver architecture both with the closed and open kernel modules.
- NVIDIA Visual Profiler can’t remote into a target machine running Ubuntu 20.04.
- Lazy loading: Nsight Compute, Compute Sanitizer and cuda-gdb force-disable lazy loading in this release. Late-attaching with cuda-gdb to an application executing with lazy loading enabled is unsupported in this release. Full support for Nsight Compute, Compute Sanitizer and cuda-gdb will be added in a later release.
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 11.6 Update 2

- **New Features**
  - Performance improvements for batched GEMV.
  - Performance improvements for the following BLAS Level 3 routines on NVIDIA Ampere GPU architecture (SM80): \{(D,Z)\{SYRK,SYMM,TRMM\}, Z\{HERK,HEMM\}\}.

- **Known Issues**
  - The `cublasGetVersion()` API return value was updated due to cuBLAS minor version >= 10 and therefore, depending on how the API is used, version checks based on this API can lead to warnings or errors. Use cases such as `cublasGetVersion()` >= CUBLAS_VERSION will not break based on how the API was updated. The `cublasGetProperty()` API still returns correct values.

- **Resolved Issues**
  - Fixed incorrect bias gradient computations for `CUBLASLT_EPILOGUE_BGAD\{A,B\}` when the corresponding matrix (A or B) size is greater than $2^{31}$.
  - Fixed a potential cuBLAS hang when cuBLAS API is called with different CUDA streams but which are the same value-wise (e.g. this could happen in a loop that creates CUDA stream, calls cuBLAS with it, and then deletes the stream).
If cuBLAS uses internal CUDA streams, their priority now matches the priority of the stream with which cuBLAS API was called.

2.1.2. cuBLAS: Release 11.6

- **New Features**
  - New epilogue options have been added to support fusion in DLtraining: `CUBLASLT_EPILOGUE_{DRELU,DGELU}` which are similar to `CUBLASLT_EPILOGUE_{DRELU,DGELU}_BGRAD` but don’t compute bias gradient.

- **Resolved Issues**
  - Some syrk-related functions (`cublas{D,Z}syrk, cublas{D,Z}syr2k, cublas{D,Z}syrkx`) may fail for matrices which size is greater than $2^{31}$.

2.1.3. 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.

2.1.4. 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 \texttt{int32\_t} limit.
- NVBLAS now uses lazy loading of the CPU BLAS library on Linux to avoid issues caused by preloading \texttt{libnvblas.so} in complex applications that use \texttt{fork} and similar APIs.
- Resolved symbols name conflict when using cuBlasLt static library with static TensorRT or cuDNN libraries.

### 2.1.5. cuBLAS: Release 11.4

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

### 2.1.6. 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 \texttt{cublasLtMatmulAlgoGetHeuristic()} you need to set \texttt{CUBLASLT\_MATMUL\_PREF\_POINTER\_MODE\_MASK} in search preferences to \texttt{CUBLASLT\_POINTER\_MODE\_MASK\_HOST} or \texttt{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.

### 2.1.7. 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.

### 2.1.8. 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.

### 2.1.9. 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**
  - cublasLt Matmul 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

### 2.1.10. 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_R2_8C` (on NVIDIA Ampere GPU architecture or Turing architecture) or `CUBLASLT_ORDER_COL32_R2_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.

2.1.11. 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
CUDA Libraries

‣ “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.

2.1.12. 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.

2.1.13. 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 11.7**

- **Known Issues**
  - cuFFT fails to deallocate some internal structures if the active CUDA context at program finalization is not the same used to create the cuFFT plan. This memory leak is constant per context, and will be fixed in an upcoming release.

2.2.2. **cuFFT: Release 11.5**

- **Known Issues**
  - FFTs of certain sizes in single and double precision (multiples of size 6) could fail on future devices. This issue will be fixed in an upcoming release.

2.2.3. **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.

2.2.4. **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.

### 2.2.5. 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](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.

### 2.2.6. 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.
2.2.7. 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.

2.2.8. 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.

2.2.9. 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 `cufftXtSetGPUs whichGPUs` 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**
CUDA Libraries

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

2.2.10. 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 cufftXtSetGPUs() and assume that GPUs IDs are always numbered from 0 to N-1.

2.2.11. 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 11.5 Update 1

- **New Features**
  - Improved performance of `CURAND_RNG_PSEUDO_MRG32K3A` pseudorandom number generator when using ordering `CURAND_ORDERING_PSEUDO_DEFAULT` or `CURAND_ORDERING_PSEUDO_BEST`.
  - Added a new type of order parameter: `CURAND_ORDERING_PSEUDO_DYNAMIC`.
  - Supported PRNGs:
    - `CURAND_RNG_PSEUDO_XORWOW`
    - `CURAND_RNG_PSEUDO_MRG32K3A`
    - `CURAND_RNG_PSEUDO_MTGP32`
    - `CURAND_RNG_PSEUDO_PHILOX4_32_10`
  - Improved performance compared to `CURAND_ORDERING_PSEUDO_DEFAULT`, especially on NVIDIA Ampere architecture GPUs.
  - The output ordering of generated random numbers for `CURAND_ORDERING_PSEUDO_DYNAMIC` depends on the number of SMs on a GPU, and thus can be different on different GPUs.
  - The `CURAND_ORDERING_PSEUDO_DYNAMIC` ordering can't be used with a host generator created using `curandCreateGeneratorHost()`.

- **Resolved Issues**
  - Added information about cuRAND thread safety.

- **Known Issues**
  - `CURAND_RNG_PSEUDO_XORWOW` with ordering `CURAND_ORDERING_PSEUDO_DYNAMIC` can produce incorrect results on architectures newer than SM86.

2.3.2. 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.
2.3.3. 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 `mtgpdc_params_11213_num` when including `curand_mtgp32dc_p_11213.h` in different compilation units.

2.3.4. cuRAND: Release 11.0

Resolved Issues

- Fixed an issue that caused linker errors about the multiple definitions of `mtgp32dc_params_fast_11213` and `mtgpdc_params_11213_num` when including `curand_mtgp32dc_p_11213.h` in different compilation units.

2.3.5. 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 $N \leq 16$, $\text{cusolverDn}[S|D|C|Z]\text{syevjBatched}$ 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, $\text{norm}(A, \text{‘fro’})$. After the $\text{syevj}$, $W(0:n-1)$ 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.
  - $\text{libcusolver.so}$ no longer links $\text{libcublas_static.a}$; instead, it depends on $\text{libcublas.so}$. This reduces the binary size of $\text{libcusolver.so}$. However, it breaks backward compatibility. The user has to link $\text{libcusolver.so}$ with the correct version of $\text{libcublas.so}$.

2.4.4. cuSOLVER: Release 11.2

- **Resolved Issues**
  - $\text{cusolverDnIRSXgels}$ sometimes returned $\text{CUSOLVER\_STATUS\_INTERNAL\_ERROR}$ when the precision is ‘z’. This issue has been fixed in CUDA 11.2; now $\text{cusolverDnIRSXgels}$ works for all precisions.
  - $\text{ZSYTRF}$ sometimes returned $\text{CUSOLVER\_STATUS\_INTERNAL\_ERROR}$ due to insufficient resources to launch the kernel. This issue has been fixed in CUDA 11.2.
  - $\text{GETRF}$ 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**
  - $\text{cusolverDnDDgels}$ reports $\text{IRS\_NOT\_SUPPORTED}$ when $m > n$. The issue has been fixed in release 11.1 U1, so $\text{cusolverDnDDgels}$ will support $m > n$.
  - $\text{cusolverMgDeviceSelect}$ can consume over 1GB device memory. The issue has been fixed in release 11.1 U1. The hidden memory allocation inside $\text{cusolverMG}$ handle is about 30 MB per device.

- **Known Issues**
  - $\text{cusolverDnIRSXgels}$ may return $\text{CUSOLVER\_STATUS\_INTERNAL\_ERROR}$ when the precision is ‘z’ due to insufficient workspace which causes illegal memory access. The $\text{cusolverDnIRSXgels\_bufferSize()}$ does not report the correct size of workspace. To workaround the issue, the user has to add more workspace than what is reported by $\text{cusolverDnIRSXgels\_bufferSize()}$. For example, if $x$ is the size of
workspace returned by `cusolverDnIRSxgels_bufferSize()`, then the user has to allocate $(x + \min(m,n) \times \text{sizeof} \text{(cuDoubleComplex)})$ 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`
CUDA Libraries

- 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 11.7 Update 1

- **New Features**
  - cusparseSDDMM now supports batched computation.
  - Improved COO cusparseSpMM Alg2 with support for batched computation, custom row/col-major layout for B/C, and mixed-precision computation.
  - Further improved error handling for JIT LTOcusparseSpMMOp.
  - Better performance for cusparseSpMM COO Alg3 and cusparseSpSM.

- **Resolved Issues**
  - Batched cusparseSpMM produced wrong results when the number of columns of B/C is one.
Known Issues

- `cusparseSpSV`, `cusparseSpSM` could produce wrong results if the output vector/matrix is not zero-initialized.

2.5.2. cuSPARSE: Release 11.7

- **New Features**
  - Added a new utility to get the data associated to the CSC descriptor: `cusparseCscGet()`.

- **Resolved Issues**
  - Fixed a rare correctness bug of `cusparseSpMM` with `CUSPARSE_SPMM_CSR_ALG1` when the number of rows in the sparse matrix is 2.

Known Issues

- `cusparseSpSV`, `cusparseSpSM` could produce wrong results if the output vector/matrix is not zero-initialized.

2.5.3. cuSPARSE: Release 11.6 Update 1

- **New Features**
  - Improved CSR `cusparseSpMM` Alg1:
    - Better performance
    - Support for batched computation, custom row/col-major layout for B/C, and mixed-precision computation
  - Improved COO `cusparseSpMM` Alg3 with support for batched computation, custom row/col-major layout for B/C, and mixed-precision computation.
  - Improved mixed-precision computation of CSR/COO `cusparseSpMV`.
  - Added CSC format support for `cusparseSpMV` and `cusparseSpMM`.
  - Better error handling for JIT LTO `cusparseSpMMOp`.
  - `cusparseSpMM` now supports batches of sparse matrices.

- **Resolved Issues**
  - `cusparseDenseToSparse` produced wrong results when the input matrix contained the floating-point value -0.0
  - `std::locale` is no longer modified by cuSPARSE during the initialization.
  - Added a note in `cusparseSpMMOp` to report that the routine is not compatible with old CUDA driver version and Android platform.

- **Known Issues**
- `cusparseSpSV`, `cusparseSpSM` could produce wrong results if the output vector/matrix is not zero-initialized.

### 2.5.4. cuSPARSE: Release 11.6

- **New Features**
  - Better performance for `cusparseSpGEMM`, `cusparseSpGEMMreuse`, `cusparseCsr2cscEx2`, and `cusparseDenseToSparse` routines.

- **Resolved Issues**
  - Fixed forward compatibility issues with `axpby`, `rot`, `spvv`, `scatter`, `gather`.
  - Fixed incorrect results in COO SpMM Alg1 which occurred in some rare cases.

### 2.5.5. cuSPARSE: Release 11.5 Update 1

- **New Features**

- **Resolved Issues**
  - Added memory requirements, graph capture, and asynchronous notes for `cusparseXcsrsm2_analysis`.
  - CSR, CSC, and COO format descriptions wrongly reported sorted column indices requirement. All routines support unsorted column indices, except where strictly indicated.
  - Clarified `cusparseSpSV` and `cusparseSpSM` memory management.
  - `cusparseSpSM` produced wrong results in some cases when the `matB` operation is `CUSPARSE_OPERATION_NON_TRANSPOSE` or `CUSPARSE_OPERATION_CONJUGATE_TRANSPOSE`.
  - `cusparseSpSM` produced wrong results in some cases when the matrix layout is row-major.

### 2.5.6. cuSPARSE: Release 11.4 Update 1

- **Resolved Issues**
  - `cusparseSpSV` and `cusparseSpSM` could produce wrong results
CUDA Libraries

- cusparseSpSV and cusparseSpSM did not work correctly when vecX == vecY or matB == matC.

2.5.7. 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.

2.5.8. 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.
  - Blocke-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 * 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
2.5.9. cuSPARSE: Release 11.3

- **New Features**
  
  Added new routine `cusparesSpSV` 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`.

2.5.10. 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.

2.5.11. 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.
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Support for mixed regular-complex data type computation.
Support for deterministic and non-deterministic computation.


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.
cusparseCsrmvEx has been deprecated in favor of cusparseSpMV.
COO Array of Structure [CooAoS] format has been deprecated including cusparseCreateCooAoS, cusparseCooAoSGet, and its support for cusparseSpMV.

2.5.12. cuSPARSE: Release 11.2

Known Issues

cusparseXdense2csr provides incorrect results for some matrix sizes.

2.5.13. 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

**2.5.14. cuSPARSE: Release 11.0**

**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:
    - Ci=A-Bi
    - Ci=Ai-B
    - Ci=Ai-Bi
2.5.15. 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:
      - Ci=A·Bi
      - Ci=Ai·B
      - Ci=Ai·Bi
  - 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: cusparseXcsrmv, cusparseXcsrmv_mp
    - Sparse matrix-matrix multiplication: cusparseXcsrmm, cusparseXcsrmm2
    - Sparse triangular-single vector solver: cusparseXcsrcsv_analysis, cusparseCsrcsv_analysisEx, cusparseXcsrcsv_solve, cusparseCsrcsv_solveEx
    - Sparse triangular-multiple vectors solver: cusparseXcsrcsm_analysis, cusparseXcsrcsm_solve
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- Sparse hybrid format solver: cusparseXhybsv_analysis, cusparseShybsv_solve
- Extra functions: cusparseXcsrgemmnNnz, cusparseScsrgemn, cusparseXcsrgemmNnz, cusparseXcsrgemm
- Incomplete Cholesky Factorization, level 0: cusparseXcsric0
- Incomplete LU Factorization, level 0: cusparseCsrilu0, cusparseCsrilu0Ex
- Tridiagonal Solver: cusparseXgtsv, cusparseXgtsv_nopivot
- Batched Tridiagonal Solver: cusparseXgtsvStridedBatch
- Reordering: cusparseXcsc2hyb, cusparseXcsr2hyb, cusparseXdense2hyb, cusparseXhyb2csc, cusparseXhyb2csr, cusparseXhyb2dense

The following functions have been deprecated:
- SpGEMM: cusparseXcsrgemm2_bufferSizeExt, cusparseXcsrgemm2Nnz, cusparseXcsrgemm2

2.6. Math Library

2.6.1. CUDA Math: Release 11.6

- New Features
  - New half and bfloat16 APIs for addition/multiplication in round-to-nearest-even mode that do not get contracted into an fma instruction. Please see __hadd_rn, __hsub_rn, __hmul_rn, __hadd2_rn, __hsub2_rn, and __hmul2_rn in https://docs.nvidia.com/cuda/cuda-math-api/index.html.

2.6.2. CUDA Math: Release 11.5

- Deprecations
  - The following undocumented CUDA Math APIs are deprecated and will be removed in a future release. Please consider switching to similar intrinsic APIs documented here: https://docs.nvidia.com/cuda/cuda-math-api/index.html
    - __device__ int mulhi(const int a, const int b)
    - __device__ unsigned int mulhi(const unsigned int a, const unsigned int b)
    - __device__ unsigned int mulhi(const int a, const unsigned int b)
    - __device__ unsigned int mulhi(const unsigned int a, const int b)
    - __device__ long long int mul64hi(const long long int a, const long long int b)
CUDA Libraries

```c
__device__ unsigned long long int mul64hi(const unsigned long long int a, const unsigned long long int b)

__device__ unsigned long long int mul64hi(const long long int a, const unsigned long long int b)

__device__ unsigned long long int mul64hi(const unsigned long long int a, const long long int b)

__device__ int float_as_int(const float a)

__device__ float int_as_float(const int a)

__device__ unsigned int float_as_uint(const float a)

__device__ float uint_as_float(const unsigned int a)

__device__ float saturate(const float a)

__device__ int mul24(const int a, const int b)

__device__ unsigned int umul24(const unsigned int a, const unsigned int b)

__device__ int float2int(const float a, const enum cudaRoundMode mode = cudaRoundZero)

__device__ unsigned int float2uint(const float a, const enum cudaRoundMode mode = cudaRoundZero)

__device__ float int2float(const int a, const enum cudaRoundMode mode = cudaRoundNearest)

__device__ float uint2float(const unsigned int a, const enum cudaRoundMode mode = cudaRoundNearest)
```

# 2.6.3. CUDA Math: Release 11.4

Beginning in 2022, the NVIDIA Math Libraries official hardware support will follow an N-2 policy, where N is an x100 series GPU.

# 2.6.4. 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.

# 2.6.5. CUDA Math: Release 11.1

## New Features
- Added host support for half and \textit{nv\_bf\textsubscript{loat16}} converts to/from integer types.
- Added \texttt{\_hcmadd()} device only API for fast half2 and \textit{nv\_bf\textsubscript{loat16}} based complex multiply-accumulate.

### 2.6.6. CUDA Math: Release 11.0 Update 1

- **Resolved Issues**
  - \textit{nv\_bf\textsubscript{loat16}} comparison functions could trigger a fault with misaligned addresses.
  - Performance improvements in half and \textit{nv\_bf\textsubscript{loat16}} basic arithmetic implementations.

### 2.6.7. CUDA Math: Release 11.0 RC

- **New Features**
  - Add arithmetic support for \textit{\_nv\_bf\textsubscript{loat16}} floating-point data type with 8 bits of exponent, 7 explicit bits of mantissa.
  - Performance and accuracy improvements in single precision math functions: \texttt{fmodf}, \texttt{expf}, \texttt{exp10f}, \texttt{sinhf}, and \texttt{coshf}.
- **Resolved Issues**
  - Corrected documented maximum ulp error thresholds in \texttt{erfcinvf} and \texttt{powf}.
  - Improved \texttt{cuda\_fp16.h} interoperability with Visual Studio C++ compiler.
  - Updated libdevice user guide and CUDA math API definitions for \texttt{j1}, \texttt{j1f}, \texttt{fmod}, \texttt{fmodf}, \texttt{ilogb}, and \texttt{ilogbf} math functions.

### 2.7. NVIDIA Performance Primitives (NPP)

#### 2.7.1. NPP: Release 11.7

- **New Features**
  - Constant arithmetic functions that use a constant that is in device memory.
- **Resolved Issues**
  - Bilinear interpolation results for floating point values do not match with CPU results.
  - NPP remap for 64-bit float does not match expected values from manual calculation, nor does it match IPP result.
Compressed Marker Labels Info returns -1000 (NPP_CUDA_KERNEL_EXECUTION_ERROR); resulting rectangles contains corrupt data.

LabelMarkers 8Way function can occasionally incorrectly connect contours that should remain separate.

Wiener Border fixes for customer image.

nppsIntegral_32s fails cuda-memcheck for certain input sizes.

2.7.2. NPP: Release 11.6 Update 2

Resolved Issues

- Improved Wiener filter to produce output similar to the IPP version.
- Enhanced Boxfilter improved performance for large kernel sizes.
- An issue that caused the FilterUnsharpNew() function to blur images is resolved.
- Modified the correlation coefficient calculation to support double precision and aligned the results with OpenCV/IPP.
- Added double precision support for Normalized correlation coefficients.

2.7.3. NPP: Release 11.5

New Features

- New APIs added to compute Signed Anti-aliased Distance Transform using PBA, the anti-aliased Euclidean distance between pixel sites in images. This will improve the accuracy of distance transform.

  - `nppiSignedDistanceTransformAbsPBA_xxxxx_C1R_Ctx()` – Input and output combination supports {xxxxxx} - 32f, 32f64f, 64f

- New API for Absolute Manhattan distance transform; another method to improve the accuracy of distance transform using Manhattan distance transform between pixels.

  - `nppiDistanceTransformAbsPBA_xxxxx_C1R_Ctx()` – Input and output combination supports {xxxxxx} - 8u16u, 8s16u, 16u16u, 16s16u, 8u32f, 8s32f, 16u32f, 16s32f, 8u64f, 8s64f, 16u64f, 16s64f, 32f64f, 64f

Resolved Issues

- Fixed an issue in FilterMedian() API with add interpolation when mask even size.
- Improved Contour function performance by parallelizing more of it and also improving quality.
- Resolved an issue with Alpha composition used to accumulate output buffers multiple times.
Resolved an issue with `nppiLabelMarkersUF_8u32u_C1R` column processing incorrect results.

2.7.4. 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.

2.7.5. NPP: Release 11.3

- **New Features**
  - Added `nppiDistanceTransformPBA` functions.

2.7.6. NPP: Release 11.2 Update 2

- **New Features**
  - Added `nppiDistanceTransformPBA` functions.

2.7.7. NPP: Release 11.2 Update 1

- **New Features**
  - New APIs added to compute Distance Transform using Parallel Banding Algorithm (PBA):
    - `nppiDistanceTransformPBA_xxxxx_C1R_Ctx()` – where `xxxxx` 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.

2.7.8. 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.
2.7.9. 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 $16 \times 65,535 = 1,048,560$ horizontal pixels of any data type and number of channels and $8 \times 65,535 = 524,280$ vertical pixels for a maximum total of $549,739,036,800$ pixels.

2.8. nvJPEG Library

2.8.1. nvJPEG: Release 11.6 Update 2

- **Resolved Issues**
  - Enhanced the encoder to work asynchronously.
  - Fixed a minor issue in EXIF parser in which it was unable to decode one of the ImageNet bitstreams.
2.8.2. nvJPEG: Release 11.5 Update 1

- Resolved Issues
  - Fixed the issue in which `nvcuvid()` released uncompressed frames causing a memory leak.

2.8.3. nvJPEG: Release 11.4

- Resolved Issues
  - Additional subsampling added to solve the NVJPEG_CSS_2x4.

2.8.4. 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()`

2.8.5. nvJPEG: Release 11.1 Update 1

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

2.8.6. 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.

2.8.7. 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.
2.8.8. 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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