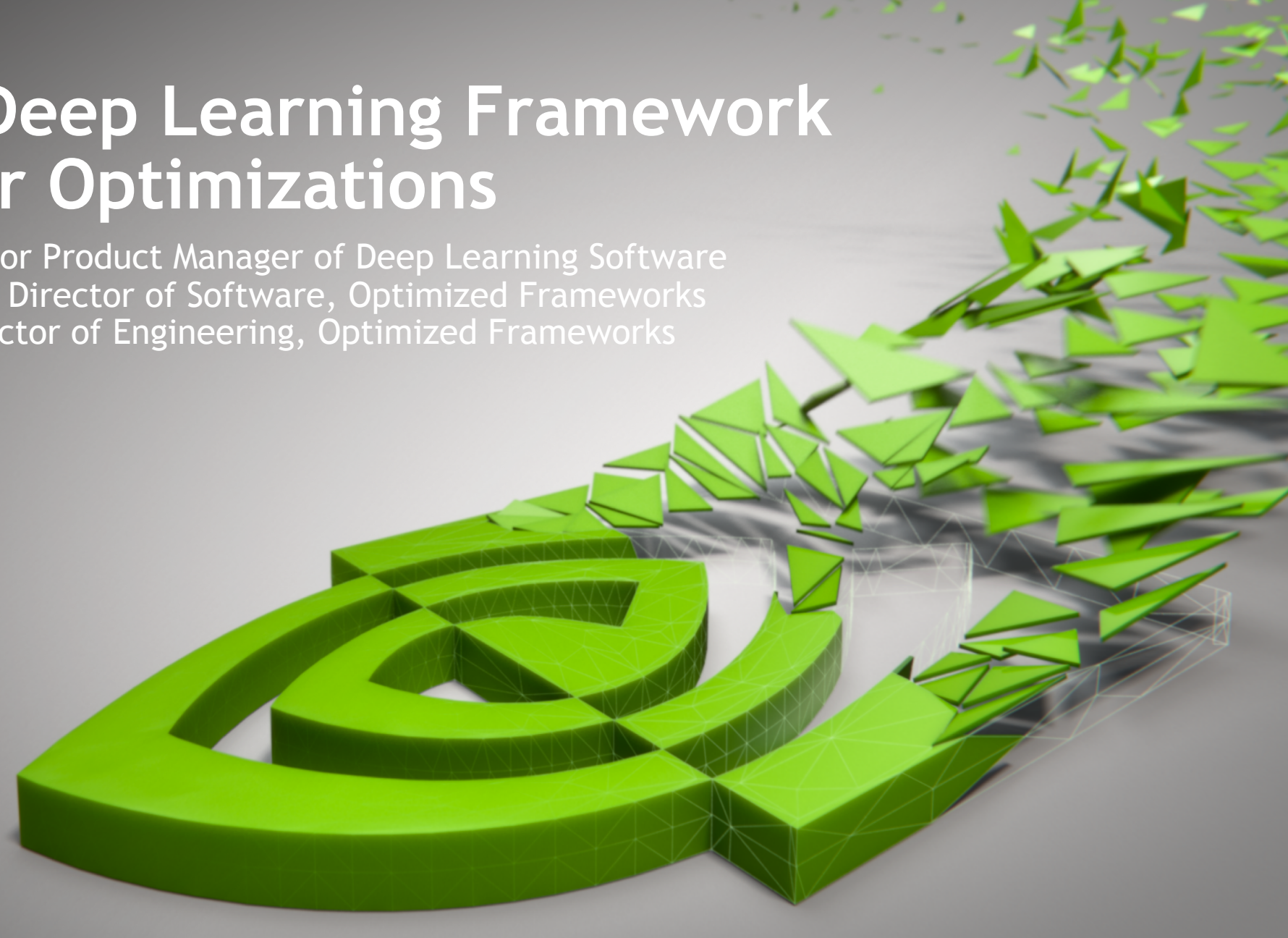
S9500 - Deep Learning Framework Container Optimizations

Joey Conway, Senior Product Manager of Deep Learning Software
Michael O'Connor, Director of Software, Optimized Frameworks
Cliff Woolley, Director of Engineering, Optimized Frameworks

NVIDIA



AGENDA

Deep Learning Framework Container Highlights

- Deep Learning Framework Team
- Overview
  - Best Performance
  - Latest Features
  - Best Practices
- Additional Resources

NVIDIA Deep Learning Frameworks Team

Overview of community interactions

TensorFlow

PYTORCH

mxnet

Caffe

Open-source Framework Community

DGX and NGC customers

Upstream work

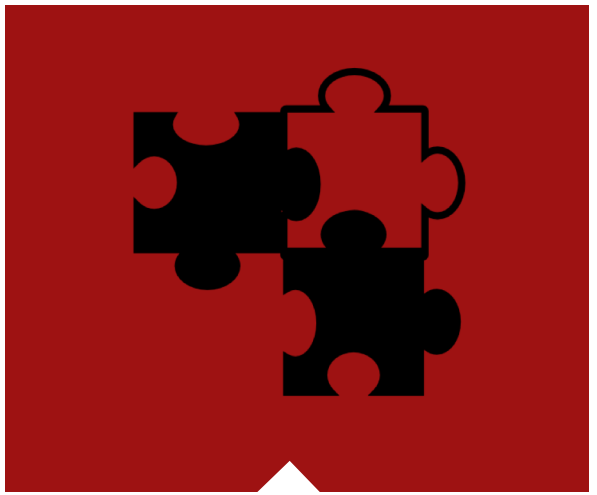
Containerize work

NVIDIA

Deep Learning Frameworks Team

Challenges with Deep Learning

Performance



Version Compatibility

Resources & Best Practices

Deep Learning Frameworks Highlights

Best NVIDIA Performance

Deep Learning Frameworks optimizations for NVIDIA hardware

Volta Tensor Cores support for mixed-precision (FP16) across TensorFlow, MXNet, PyTorch, and NVCaffe

Latest NVIDIA Features

Latest NVIDIA Deep Learning libraries incorporated cuDNN, cuBLAS, and NCCL

Automatic Mixed-Precision for TensorFlow, PyTorch and MXNet

Best Practices & QA Verified

Improved documentation with best practices and monthly release notes

Thorough monthly quality assurance testing

Multi-node support updated

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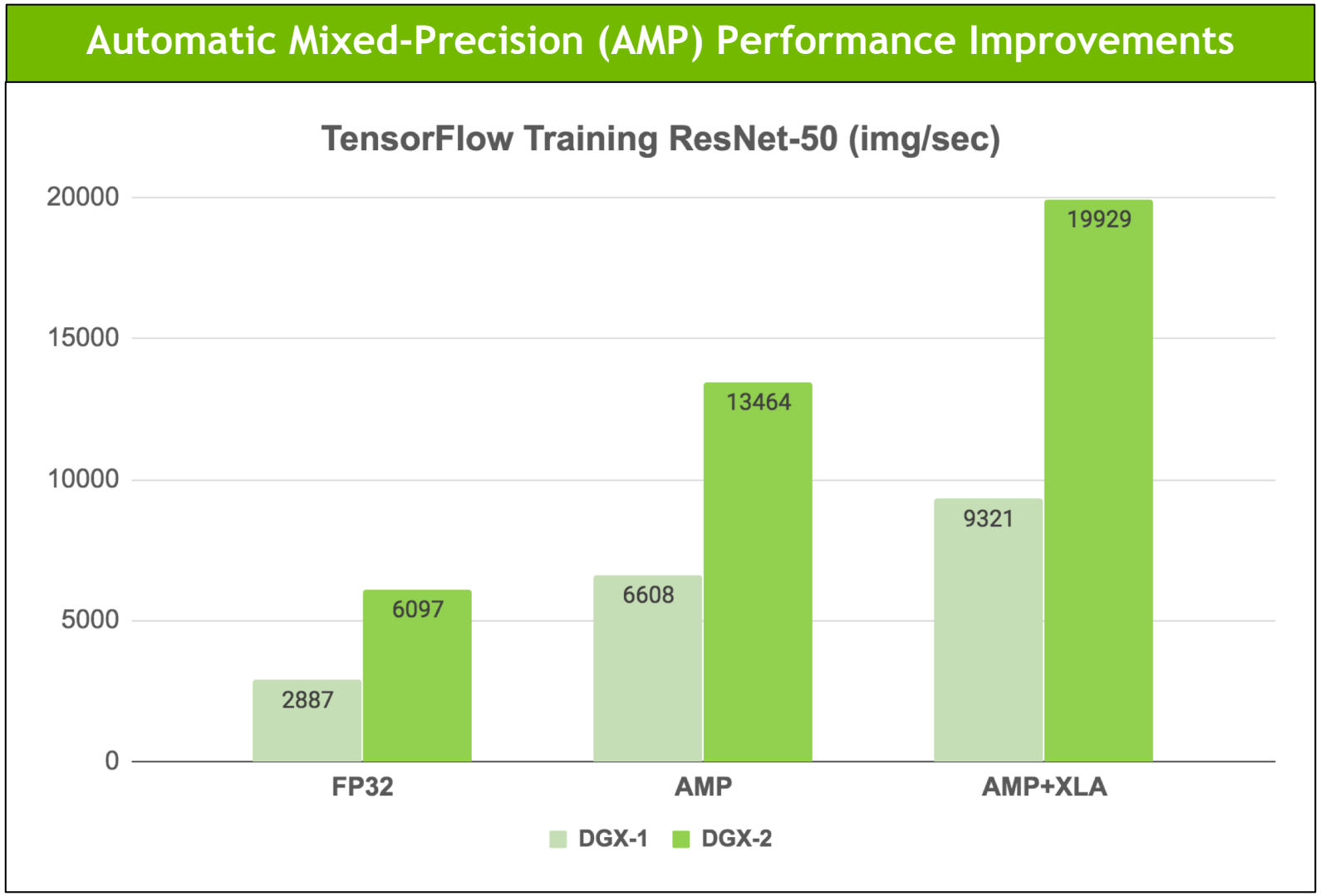
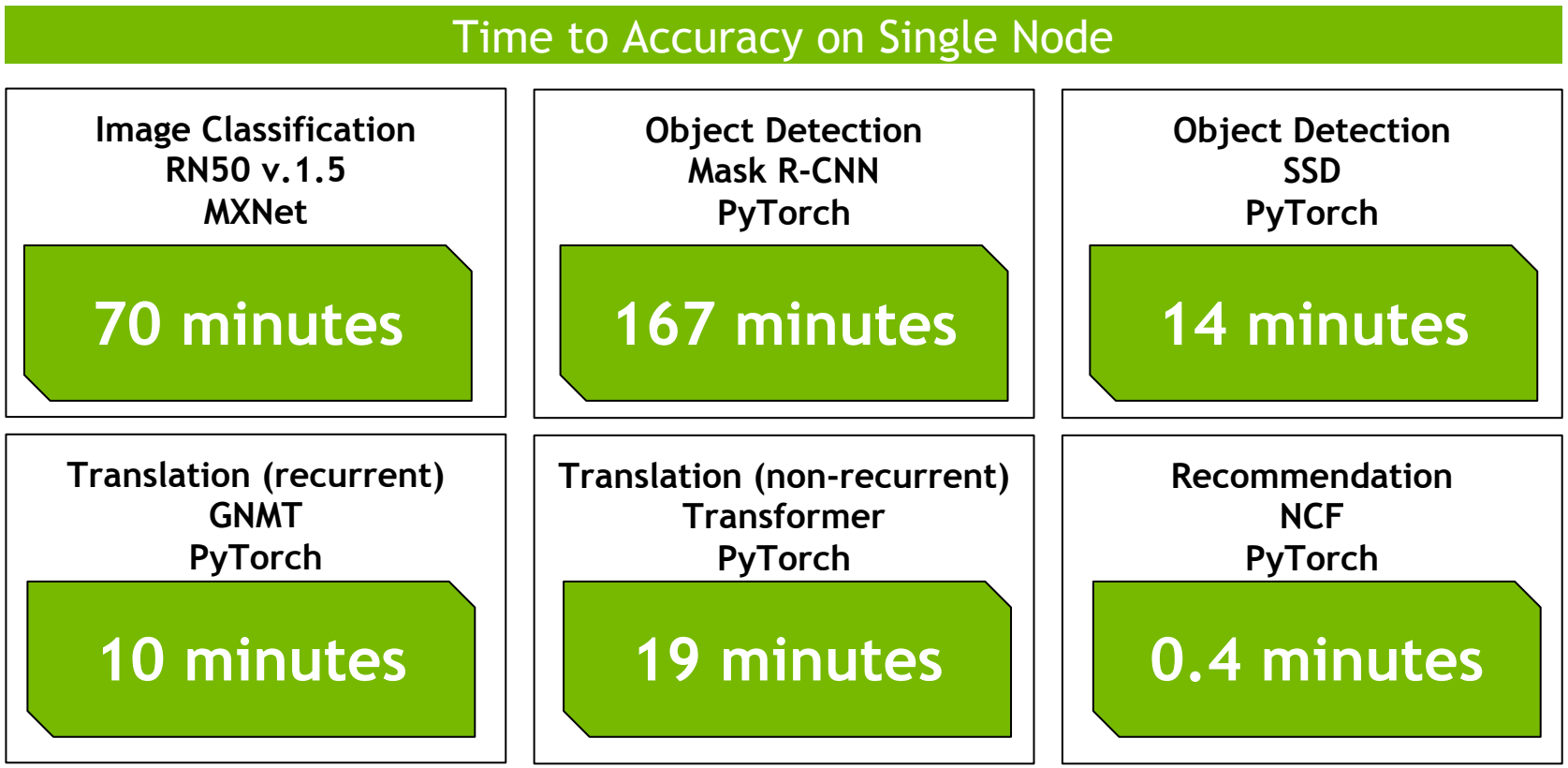
TensorFlow Performance on ResNet-50 with DGX



DGX Mixed-Precision Led MLPerf

World's Fastest Industry-Wide AI Benchmark Achieved on NVIDIA GPUs



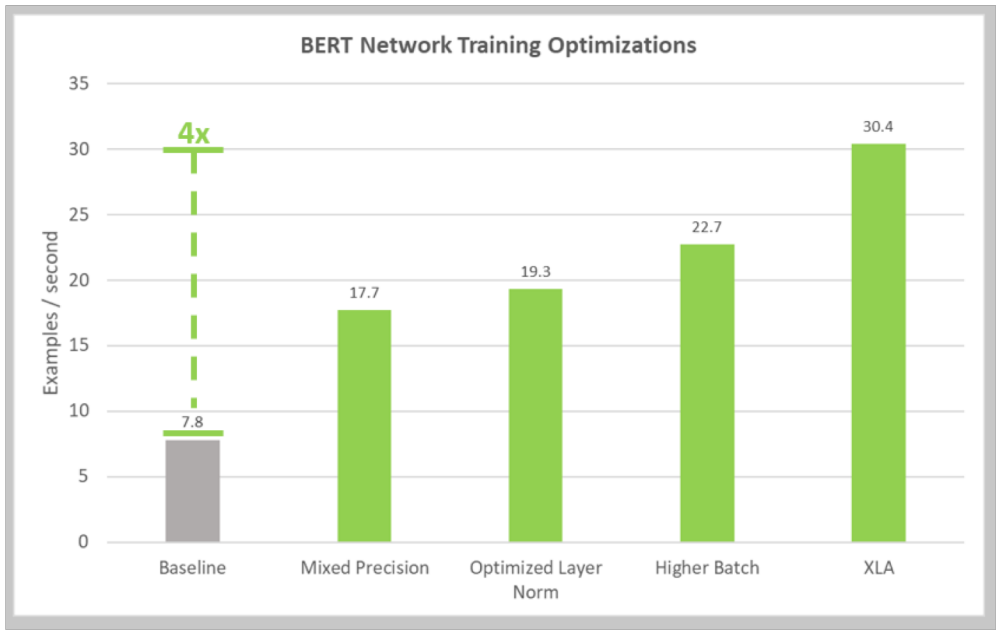
Test Platform: DGX-2H - Dual-Socket Xeon Platinum 8174, 1.5TB system RAM, 16 x 32 GB Tesla V100 SXM-3 GPUs connected via NVSwitch

NVIDIA

BERT

Performance improvements from MLPerf Transformer carries over to BERT

- State-of-the-art model for NLP tasks
- Compute intensive Transformer-like workload
- Optimizations from MLPerf carry over in both PyTorch and TF
- TF Training scripts released here: https://github.com/NVIDIA/DeepLearningExamples/tree/master/TensorFlow/LanguageModeling/BERT
    - Pretraining (Wikipedia)
    - Q&A fine-tuning (SQuAD)
- Mixed Precision using Tensor Cores



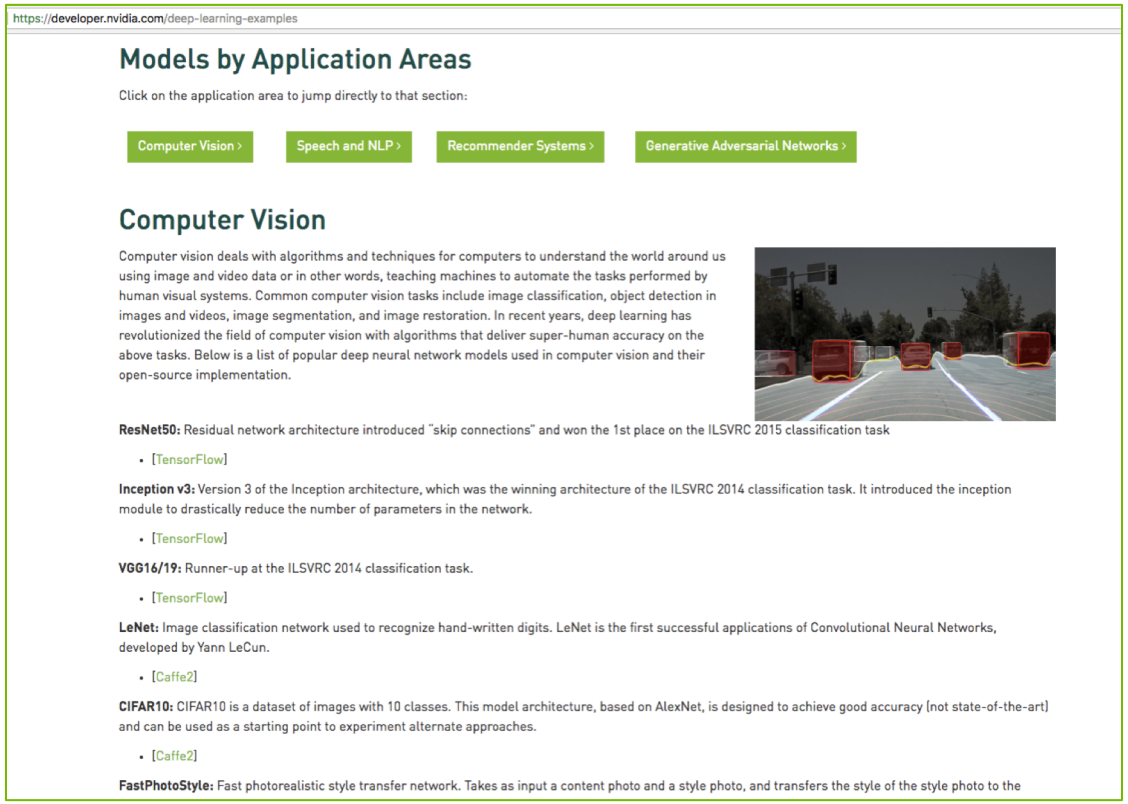
Tensor Core Examples: Developer Page

https://developer.nvidia.com/deep-learning-examples

New Deep Learning Training Scripts
- Tensor Core optimized performance
- State-of-the-art accuracy using Tensor Cores

Serve as a quick start guide
- How we implemented mixed-precision
- Exposing hyperparameters for further adjustment

Code examples on
- GitHub https://www.github.com/NVIDIA/deeplearningexamples
- NGC DL Framework containers
- NGC Model Scripts registry



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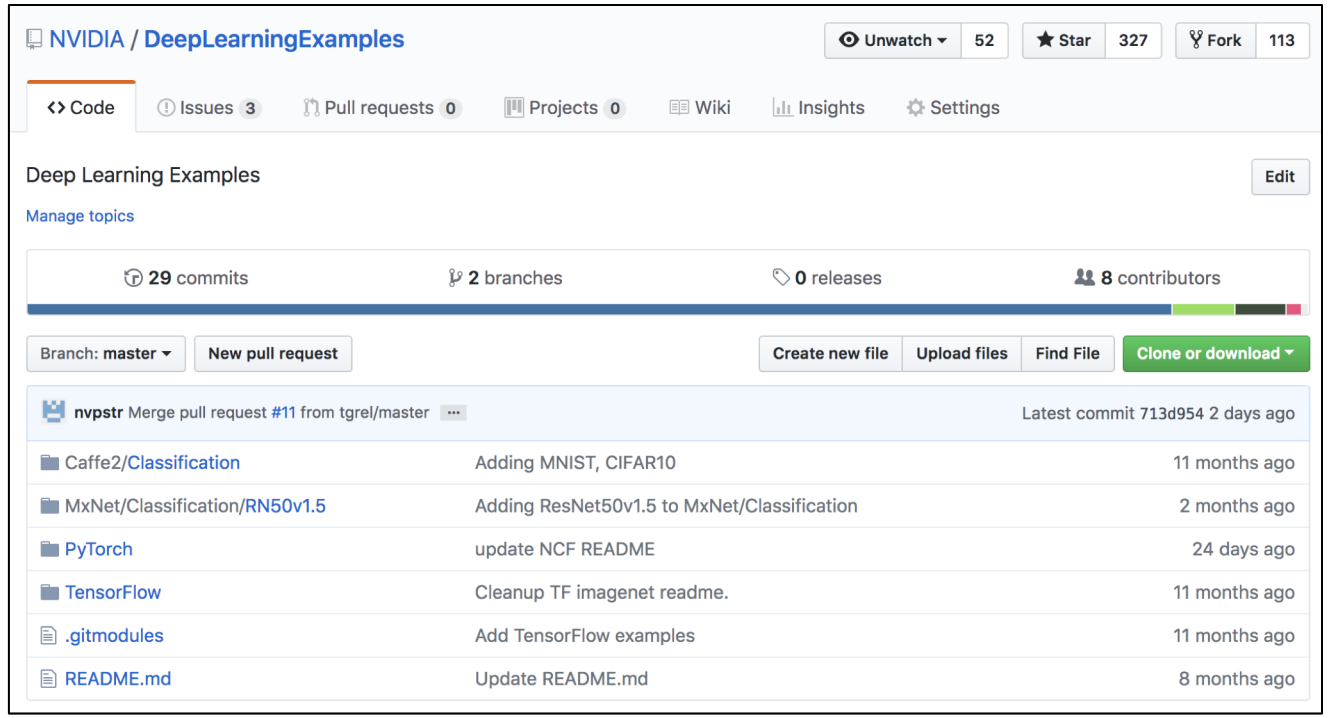
Available model training scripts

- Image Classification
  - ResNet-50v1.5
- Object Detection:
  - SSD with RN50
  - Mask R-CNN with RN50
- Translation
  - GNMT
  - Transformer
- Recommender
  - NCF
- Text-to-Speech
  - Tacotron2 and Waveglow



PyTorch GNMT Performance

https://developer.nvidia.com/deep-learning-examples

DGX-1V 16G

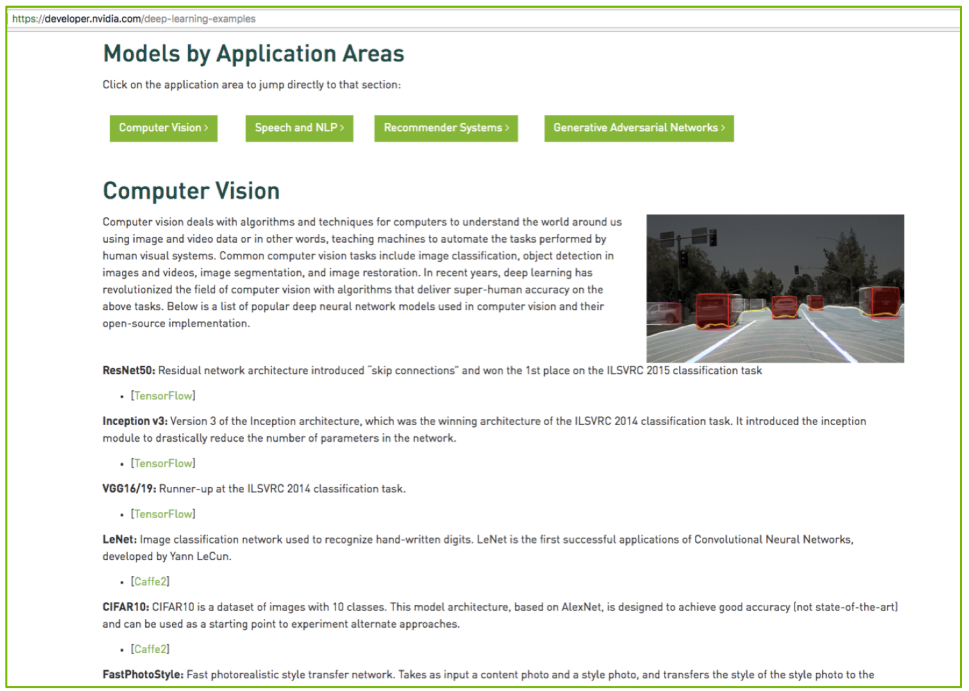
Time to Accuracy: 46 minutes

BLEU score (accuracy): 24.45

Tokens per second: 387,282

Data set: WMT16 English to German

NGC 19.01 PyTorch container



https://developer.nvidia.com/deep-learning-examples

Models by Application Areas

Click on the application area to jump directly to that section:

Computer Vision › | Speech and NLP › | Recommender Systems › | Generative Adversarial Networks ›

Computer Vision

Computer vision deals with algorithms and techniques for computers to understand the world around us using image and video data or in other words, teaching machines to automate the tasks performed by human visual systems. Common computer vision tasks include image classification, object detection in images and videos, image segmentation, and image restoration. In recent years, deep learning has revolutionized the field of computer vision with algorithms that deliver super-human accuracy on the above tasks. Below is a list of popular deep neural network models used in computer vision and their open-source implementation.

ResNet50: Residual network architecture introduced "skip connections" and won the 1st place on the ILSVRC 2015 classification task

- [TensorFlow]

Inception v3: Version 3 of the Inception architecture, which was the winning architecture of the ILSVRC 2014 classification task. It introduced the inception module to drastically reduce the number of parameters in the network.

- [TensorFlow]

VGG16/19: Runner-up at the ILSVRC 2014 classification task.

- [TensorFlow]

LeNet: Image classification network used to recognize hand-written digits. LeNet is the first successful applications of Convolutional Neural Networks, developed by Yann LeCun.

- [Caffe2]

CIFAR10: CIFAR10 is a dataset of images with 10 classes. This model architecture, based on AlexNet, is designed to achieve good accuracy (not state-of-the-art) and can be used as a starting point to experiment alternate approaches.

- [Caffe2]

FastPhotoStyle: Fast photorealistic style transfer network. Takes as input a content photo and a style photo, and transfers the style of the style photo to the

Source: https://github.com/NVIDIA/DeepLearningExamples/tree/master/PyTorch/Translation/GNMT

PyTorch GNMT Performance

https://developer.nvidia.com/deep-learning-examples

DGX-2 32G

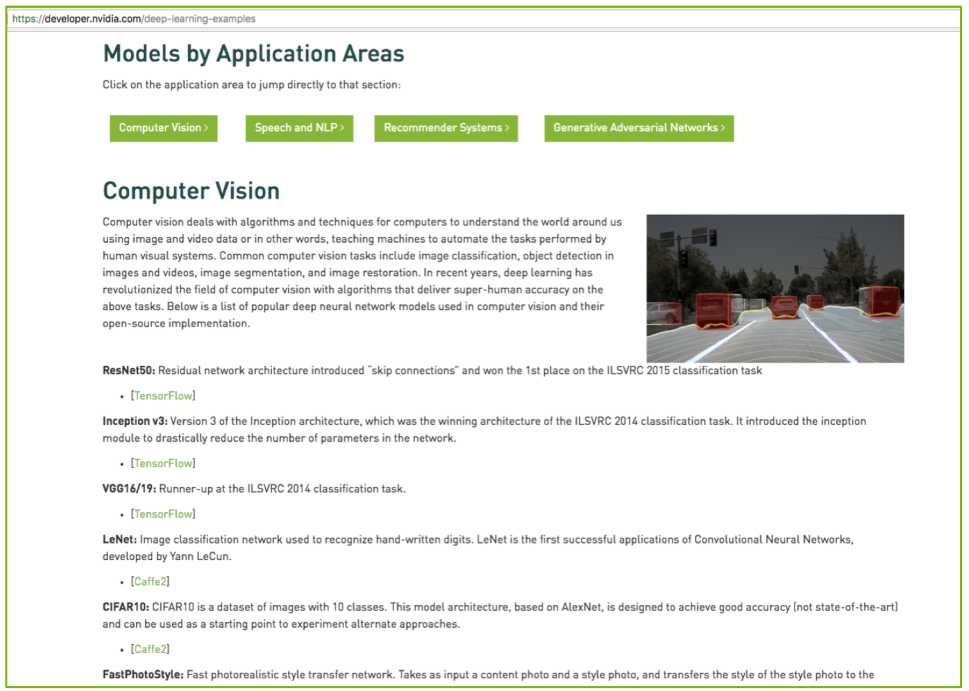
Time to Accuracy: 26.3 minutes

BLEU score (accuracy): 24.22

Tokens per second: 738,521

Data set: WMT16 English to German

NGC 19.01 PyTorch container



Source: https://github.com/NVIDIA/DeepLearningExamples/tree/master/PyTorch/Translation/GNMT

MXNet RN50 Performance

https://developer.nvidia.com/deep-learning-examples

DGX-1V 16G

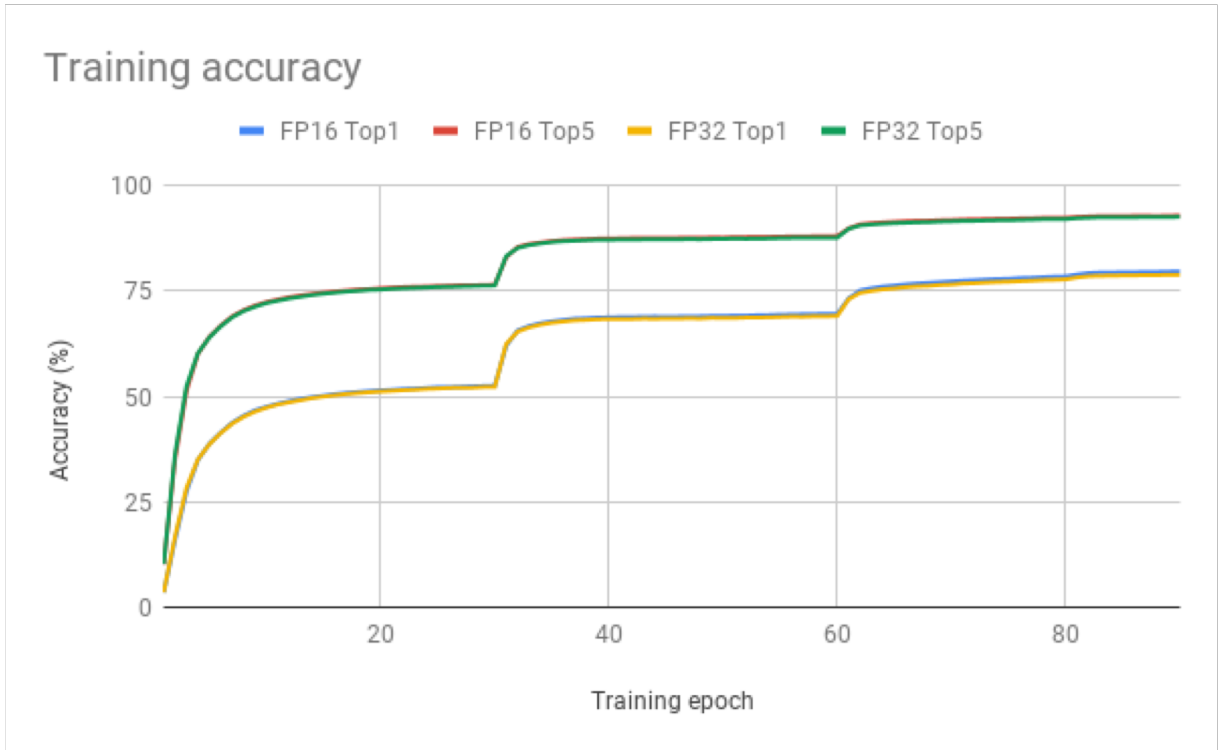
Time to Train: 3.3 hours

Top 1% (accuracy): 76.49

Images per second: 10,263

Data set: ImageNet

NGC 18.12 MXNet container



Source: https://github.com/NVIDIA/DeepLearningExamples/tree/master/MxNet/Classification/RN50v1.5

PyTorch NCF Performance

https://developer.nvidia.com/deep-learning-examples

DGX-1V 16G

Time to Accuracy: < 1 minute

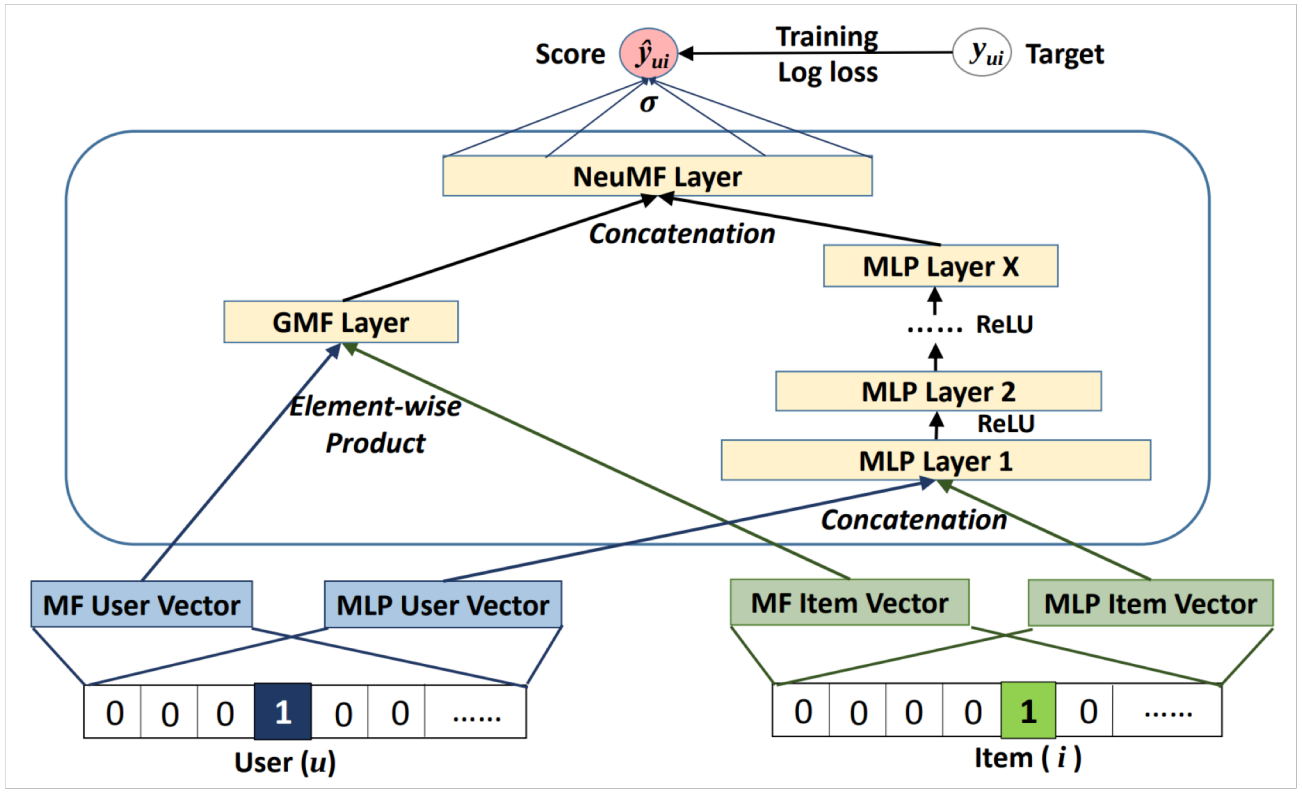
Hit Rate at 10 (accuracy): 0.96

Samples per second:

99,332,230

Data set: MovieLens 20M

NGC 18.12 PyTorch container



Source: https://github.com/NVIDIA/DeepLearningExamples/tree/master/MxNet/Classification/RN50v1.5

Tensor Core Examples: Coming next

Top Use Cases

- Adding existing models to more frameworks
- Optimizing more models for Tensor Cores
- Releasing externally and maintaining

More efforts in-progress!

Top Use Cases
Classification
Object detection
Segmentation: Medical Imaging
Segmentation: Manufacturing
Audio speech recognition (ASR)
Text to speech (TTS)
Natural Language Processing (NLP)
Recommendation System

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Latest NVIDIA Features

MXNet

- Multi-node support w/ Horovod
- NHWC support
- MXNet-AMP
- Mixed Precision support to TensorRT

PyTorch

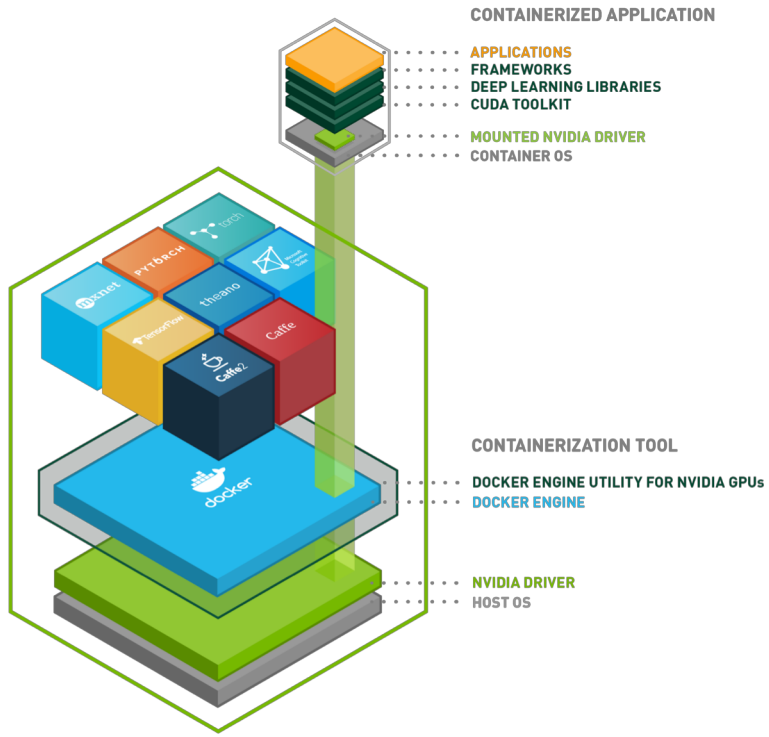
- PyTorch-AMP: unified mixed precision interface
- Automatic fusion for elementwise ops

TensorFlow

- TensorFlow-AMP
- More TensorRT op coverage
- Added cuDNN RNN features
- Jetson releases

Overall

- Mixed Precision tools
- Tensor Core optimized examples with trained models
- TensorRT integration
- Added Jupyter & JupyterLab



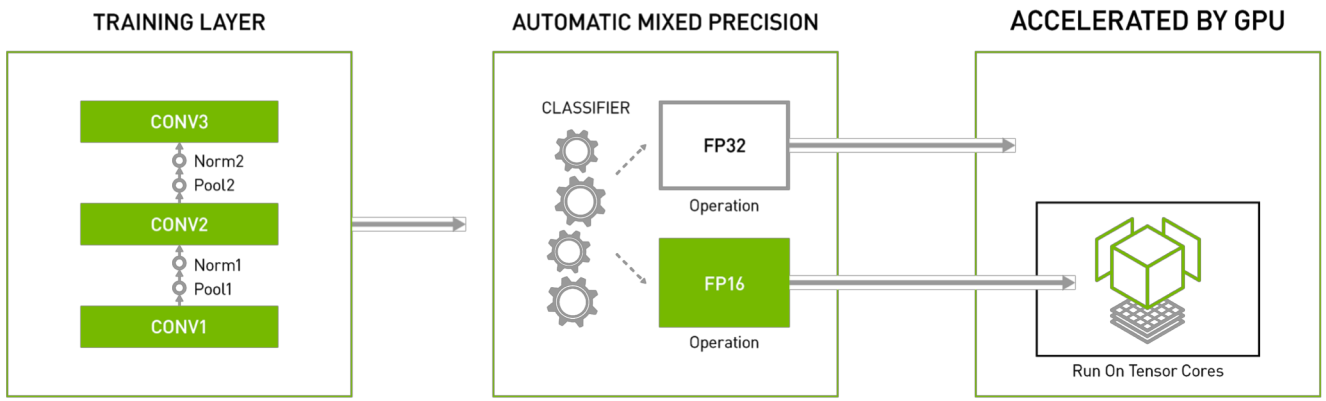
AUTOMATIC MIXED PRECISION (AMP)

Utilize Tensor Cores for Mixed Precision Training

Insert two lines of code to introduce Automatic Mixed-Precision in your training layers for up to a 3x performance improvement.

The Automatic Mixed Precision feature uses a graph optimization technique to determine FP16 operations and FP32 operations

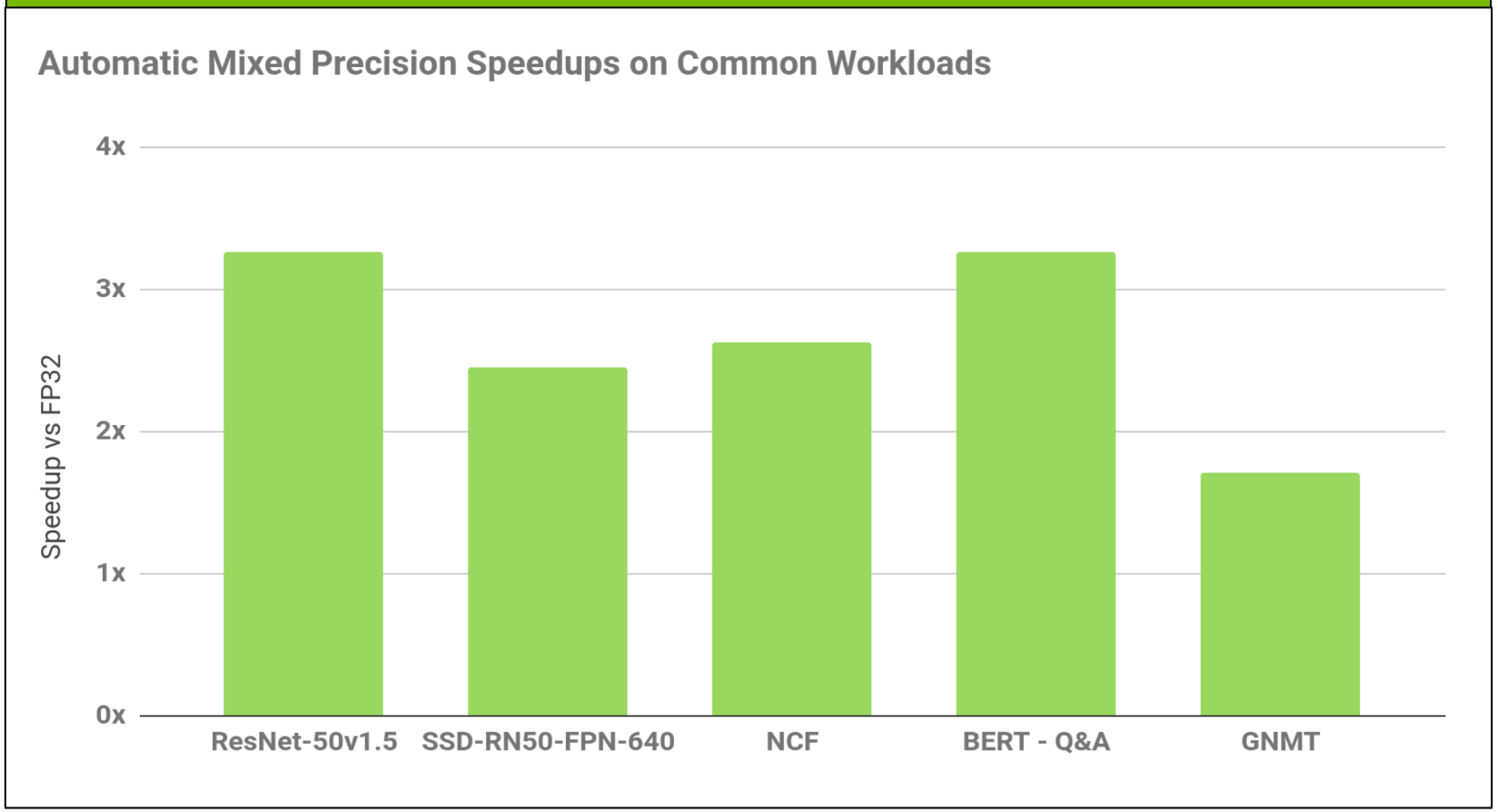
Available in TensorFlow, PyTorch and MXNet via our NGC Deep Learning Framework Containers



More details: https://developer.nvidia.com/automatic-mixed-precision

Automatic Mixed-Precision Performance for Common Workloads

TensorFlow Performance Improvements on 1 x V100 on DGX-1V w/XLA



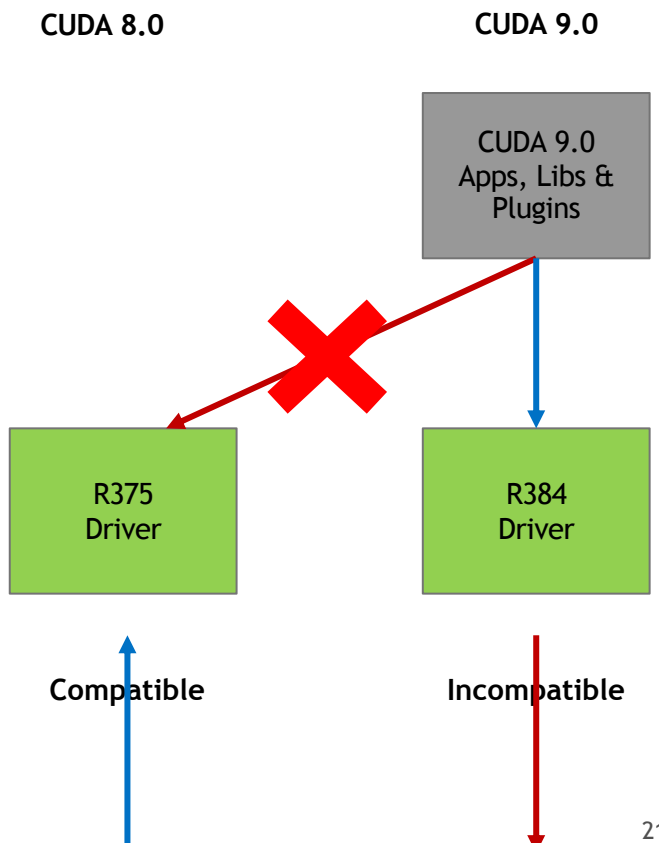
All models can be found at https://github.com/NVIDIA/DeepLearningExamples/tree/master/TensorFlow, except for ssd-rn50-fpn-640.
All performance collected on 1xV100-16GB, except bert-squadqa on 1xV100-32GB.
Batch sizes measured as follows. rn50 (v1.5): 128 for FP32, 256 for AMP+XLA; ssd-rn50-fpn-640: 8 for FP32, 16 for AMP+XLA; ncf: 1M for FP32 and AMP+XLA; bert-squadqa: 4 for FP32, 10 for AMP+XLA; gnmt: 128 for FP32, 192 for AMP.

CUDA COMPATIBILITY - CUDA 9.x

Newer CUDA Version **DID NOT** Run on *Older* Display Driver

CUDA driver API is backward compatible but not forward compatible

- Each CUDA release has a minimum driver requirement
- Applications compiled against a particular version of CUDA API will work on later driver releases
- E.g.
  - CUDA 8.0 needs >= R375
  - CUDA 9.0 needs >= R384



CUDA COMPATIBILITY - CUDA 10.x

Starting with CUDA 10.0

New compatibility platform upgrade path available

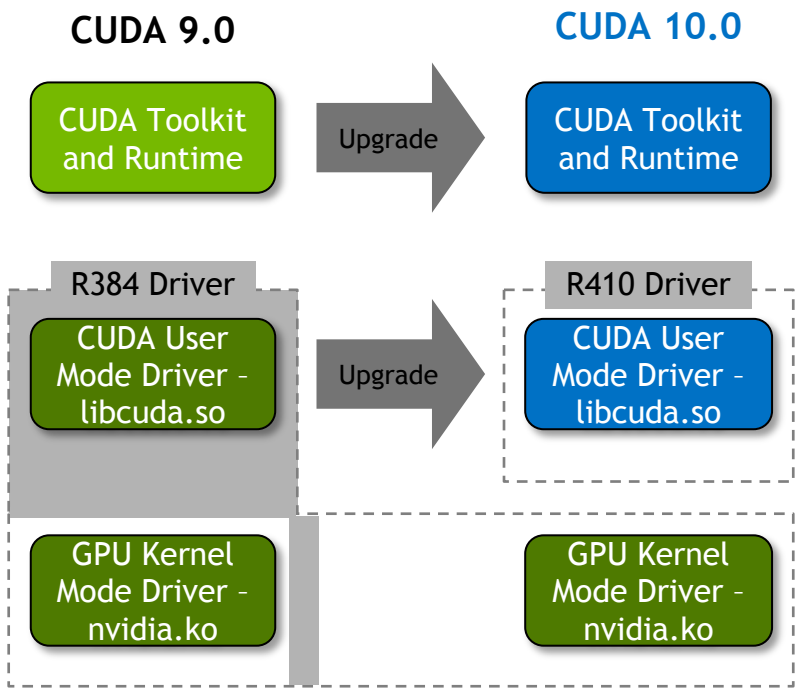
- Use newer CUDA toolkits on older driver installs
- Compatibility only with specific older driver versions

System requirements

- Tesla GPU support only – no Quadro or GeForce
- Only available on Linux

NEW Forward Compatibility *Option*

Upgrade *only* user-mode CUDA components*



*requires new 'cuda-compat-10-0' package

ALWAYS UP-TO-DATE

Monthly releases and CUDA 10.1 in 19.03 containers

		19.03	18.09	18.08
Supported Platform	**DGX OS**	4.0 and 3.1.2	4.0.1 and 3.1.2+	4.0.1 and 3.1.2+
	NVIDIA Driver	418, 410, and 384	410 and 384	384
Base Image	**Ubuntu**	16.04	16.04	16.04
	CUDA	10.1.105	10.0.130	9.0.176
	cuBLAS	10.1.0.105	10.0.130	9.0.425
	cuDNN	7.5.0.56	7.3.0	7.2.1
	NCCL	2.4.3	2.3.4	2.2.13
NVIDIA Optimized Frameworks	**NVCaffe**	0.17.3	0.17.1	0.17.1
	MXNet	1.4.0	1.3.0	1.2.0
	PyTorch	1.1.0a0	0.4.1+	0.4.1
	TensorFlow	1.13.1+	1.10.0	1.9.0
	TensorRT	5.1.2.2	5.0.0	4.0.1
	TensorRT Server	1.0	0.6	0.5.0 Beta

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Significant Documentation Updates

Customers requested more documentation for deep learning containers

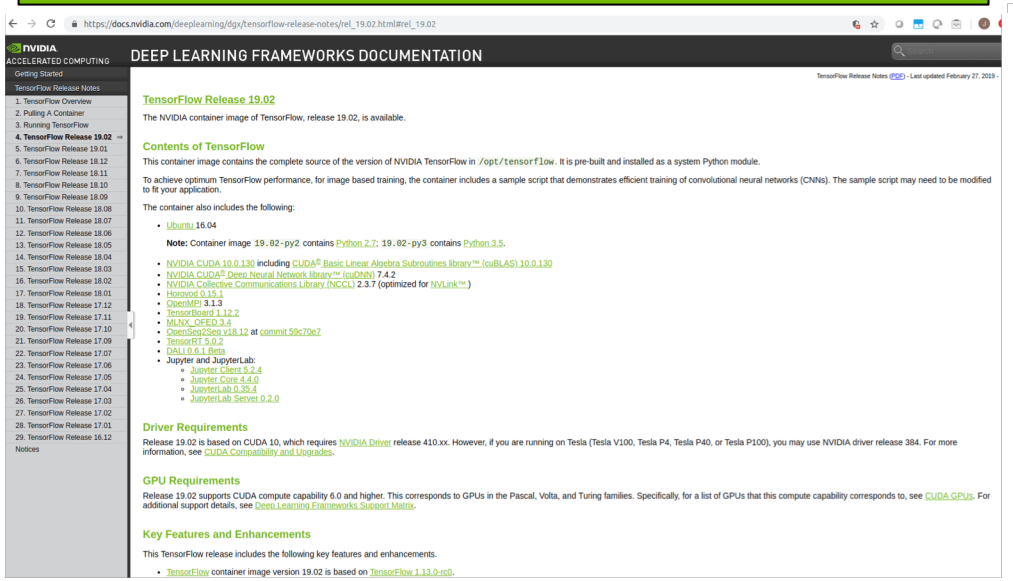
Monthly Release Notes

Release Notes for: TensorFlow, PyTorch, MXNet, and NVCaffe

User Guides and Best Practices

User Guides for: Keras, TensorFlow, NVCaffe, and DIGITS
Best Practices: Containers, Frameworks, DGX, and NGC

TensorFlow 19.02 Release Notes



Deep Learning Software Stack Matrix

Table 1. Software stack packaged with the 18.xx container images

	Container Image	18.02	18.01	17.12	17.11	17.10
Supported Platform	DGX OS	3.1.2+ and 2.1.1+	3.1.2+ and 2.1.1+	3.1.2+ and 2.1.1+	3.1.2+ and 2.1.1+	3.1.2+ and 2.1.1+
	NVIDIA Driver	384	384	384	384	384
Base Image	Ubuntu	16.04	16.04	16.04	16.04	16.04
	CUDA	9.0.176	9.0.176	9.0.176	9.0.176	9.0
	cuBLAS	9.0.282 Patch 2 <<and cuBLAS 9.0.234 Patch 1>>	9.0.282 Patch 2	9.0.234	9.0.234	
	cuDNN	7.0.5	7.0.5	7.0.5	7.0.4	7.0.3
	NCCL	2.1.2	2.1.2	2.1.2	2.1.2	2.0.5
	NVCaffe	0.16.5 including Python 2.7	0.16.5 including Python 2.7	0.16.4	0.16.4	0.16.4
NVIDIA Optimized Frameworks	Caffe2	0.8.1 including Python 2.7 or Python 3.5	0.8.1 including Python 2.7 or Python 3.5	0.8.1	0.8.1	0.8.1
	DIGITS	<<6.1.0>>	6.0.0	6.0.0	6.0.0	6.0.0
	Microsoft Cognitive Toolkit	2.3.1 including Python 3.4 and OpenMPI 3.0.0	2.3.1 including Python 3.4 and OpenMPI 3.0.0	2.2 and OpenMPI 3.0.0	2.2 and OpenMPI 3.0.0	2.2
	MXNet	1.0.0 including Python 2.7 or Python 3.5	1.0.0 including Python 2.7 or Python 3.5	1.0.0	0.12.0	0.11.0
	PyTorch	0.3.0 including Python 3.6	0.3.0 including Python 3.6	0.2.0	0.2.0	0.2.0
	TensorFlow	1.4.0 including Python 2.7 or Python 3.5 and Horovod 0.11.2	1.4.0 including Python 2.7 or Python 3.5 and Horovod 0.11.2	1.4.0	1.3.0	1.3.0
	TensorRT	<<3.0.4>> including Python 2.7	3.0.1 including Python 2.7	3.0.1		
	Theano	1.0.1 including Python 2.7	1.0.1 including Python 2.7	1.0.0rc1	1.0.0rc1	0.10beta3
	Torch	7 including Python 2.7	7 including Python 2.7	7	7	7

DL Training with Tensor Cores: More resources

Examples
New mixed-precision model examples: https://developer.nvidia.com/deep-learning-examples
GitHub: https://github.com/NVIDIA/DeepLearningExamples
TensorFlow ResNet-50 mixed-precision video: https://www.youtube.com/watch?v=i1fIBtdhjIg
PyTorch GNMT mixed-precision how-to video: https://www.youtube.com/watch?v=Dkzp05cpdpw

Tools
TensorFlow and MXNet Automatix Mixed-Precision: https://developer.nvidia.com/automatic-mixed-precision
PyTorch APEX: https://nvidia.github.io/apex/fp16_utils.html & NVIDIA developer news article

Further information
Mixed-precision blog: https://devblogs.nvidia.com/mixed-precision-training-deep-neural-networks/
Mixed-precision best practices: https://docs.nvidia.com/deeplearning/sdk/mixed-precision-training/index.html
Mixed-precision arVix paper: https://arxiv.org/abs/1710.03740
GTC 2018 Sessions: Training with Mixed Precision: Theory and Practice and Training with Mixed Precision: Real Examples

Available today

DGX/NGC Registry: Latest versions of the software stack and Tensor Core optimized examples (https://ngc.nvidia.com)

Improved Multi-node Support

Additional updates for multi-node support

Support added:

- Tensorflow and MXNet distributed training via Horovod.
  - Partnered w/ Amazon to port Horovod to MXNet and to optimize Horovod NCCL integration.
- PyTorch distributed training via NVIDIA Apex DistributedDataParallel or native PyTorch.
- NVIDIA Caffe distributed training via OpenMPI+NCCL.

Bundled inside the containers:

- Horovod+OpenMPI 3.x pre-installed for use with TensorFlow, MXNet, and NVIDIA Caffe.
- Containers pre-configured w/ Mellanox OpenFabrics drivers to enable GPUDirect RDMA.

Connect with Deep Learning Experts

Deep Learning Basics
- Tuesday at 3:00
- Wednesday at 12:00 AND 5:00

Deep Learning with Tensor Cores
- Tuesday at 2:00
- Wednesday at 2:00

Deep Learning Libraries (cuDNN, cuBLAS, CUTLASS)
- Tuesday at 1:00
- Wednesday at 1:00

Deep Learning with Fast Data Pre-Processing (DALI)
- Tuesday at 3:00
- Wednesday at 2:00

Advanced Deep Learning
- Tuesday at 1:00
- Wednesday at 4:00

Deep Learning with TensorRT
- Tuesday at 5:00
- Thursday at 11:00

Deep Learning Inference with Reduced Precision
- Tuesday at 4:00

Deep Learning Inference Solutions on Windows
- Tuesday at 2:00

Deep Learning with TensorRT Inference Server
- Wednesday at 12:00

Deep Learning Deployment
- Tuesday at 4:00
- Wednesday at 3:00

AND MORE

Thank you