S9925: FAST AI DATA PRE-PROCESSING WITH NVIDIA DALI

Janusz Lisiecki, Michał Zientkiewicz, 2019-03-18

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THE PROBLEM

CPU BOTTLENECK OF DL TRAINING

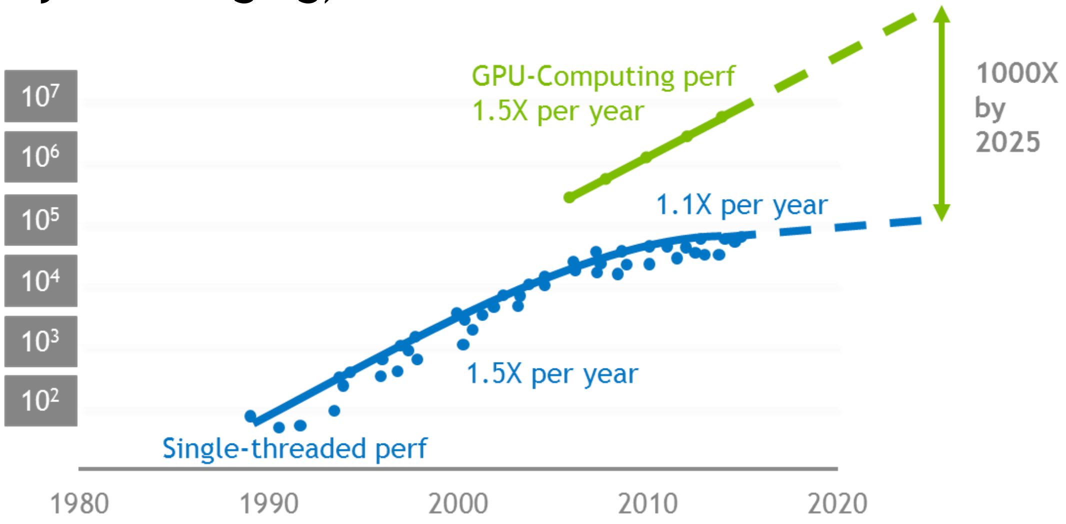
CPU : GPU ratio

Half precision arithmetic, multi-GPU, dense systems are now common (DGX1V, DGX2)

Can't easily scale CPU cores (expensive, technically challenging)

Falling CPU to GPU ratio:

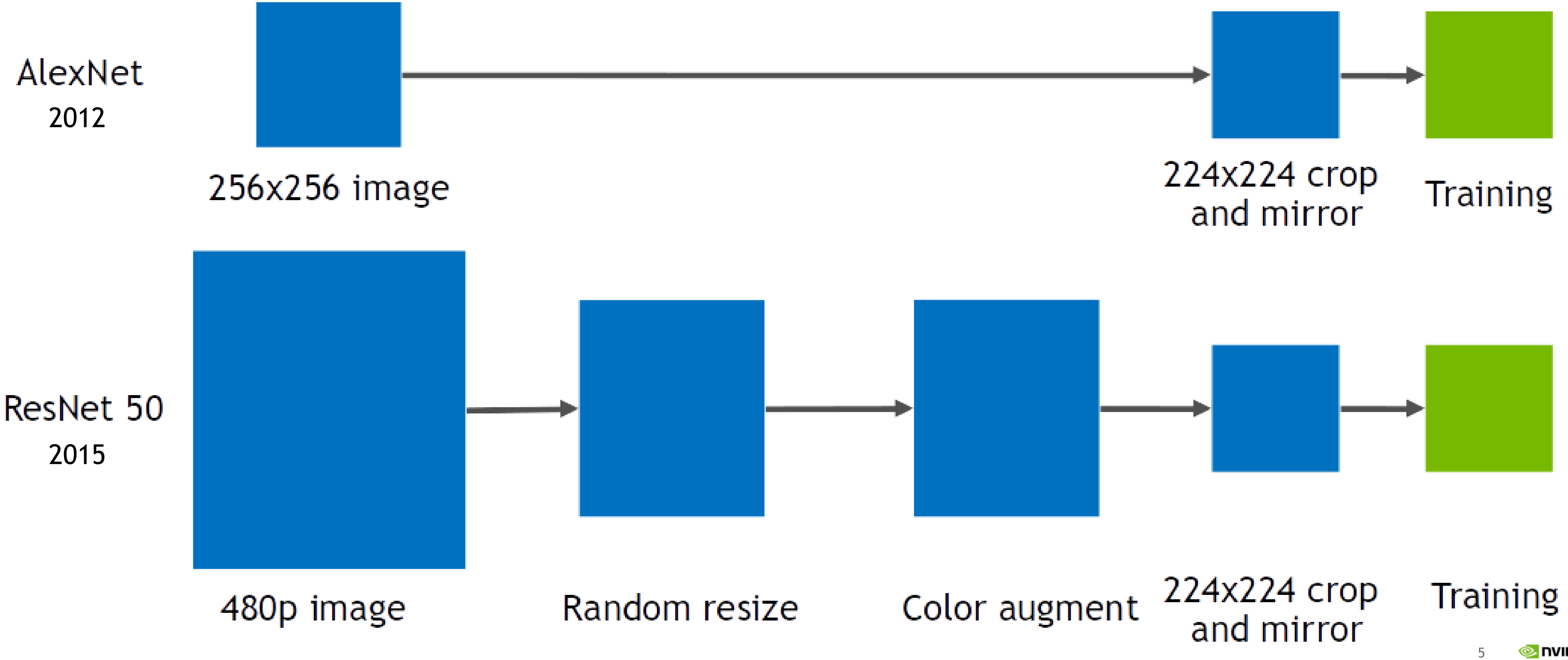
- DGX1V: 40 cores, 8 GPUs, 5 cores/ GPU
- DGX2: 48 cores↑, 16 GPUs↑, 3 cores/ GPU↓



Original data up to the year 2010 collected and plotted by M. Horowitz, F. Labonte, O. Shacham, K. Olukotun, L. Hammond, and C. Batten New plot and data collected for 2010-2015 by K. Rupp

CPU BOTTLENECK OF DL TRAINING

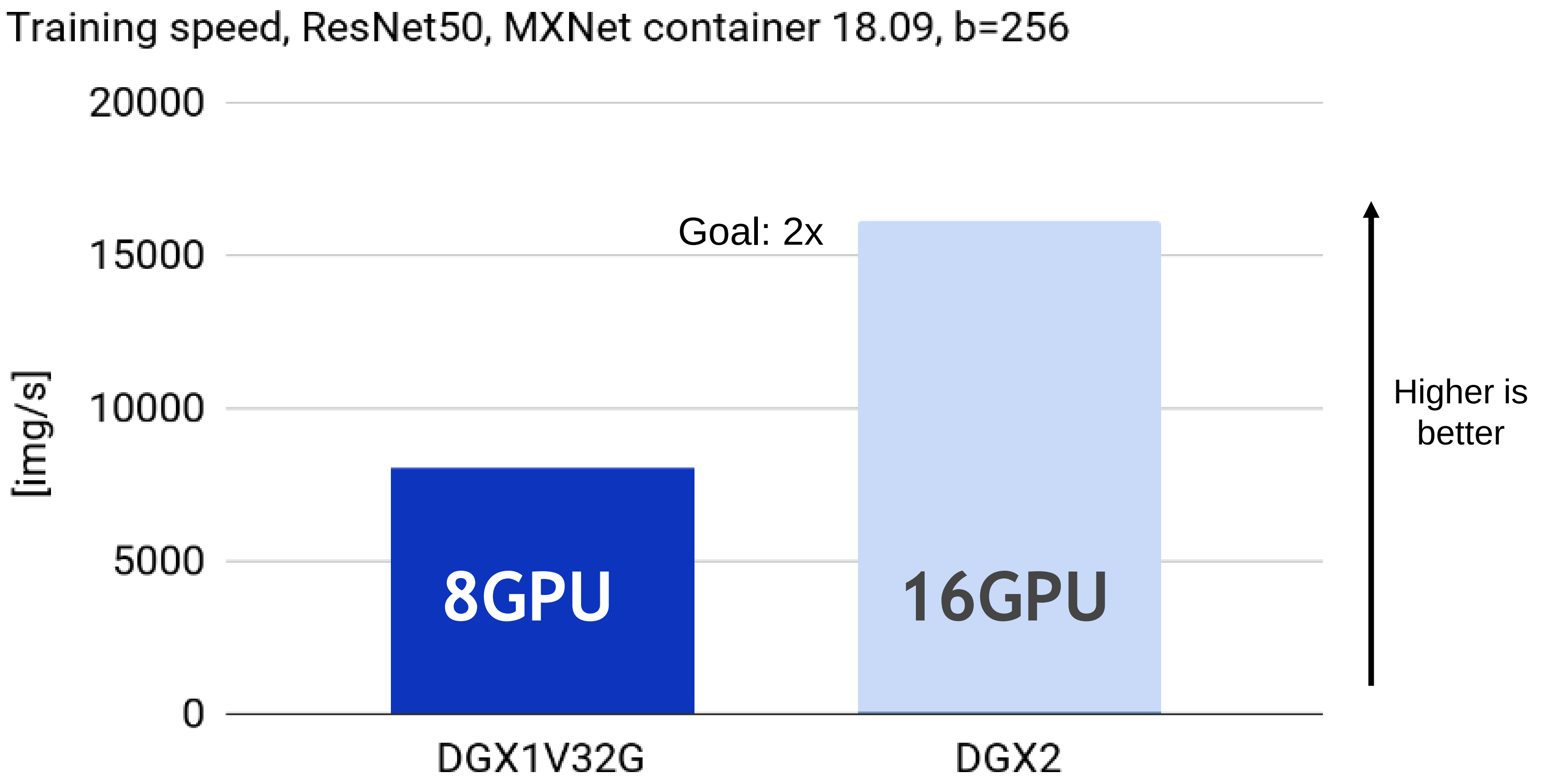
Complexity of I/O pipeline



CPU BOTTLENECK OF DL TRAINING

In practice

When we put 2x GPU we don't get adequate perf improvement



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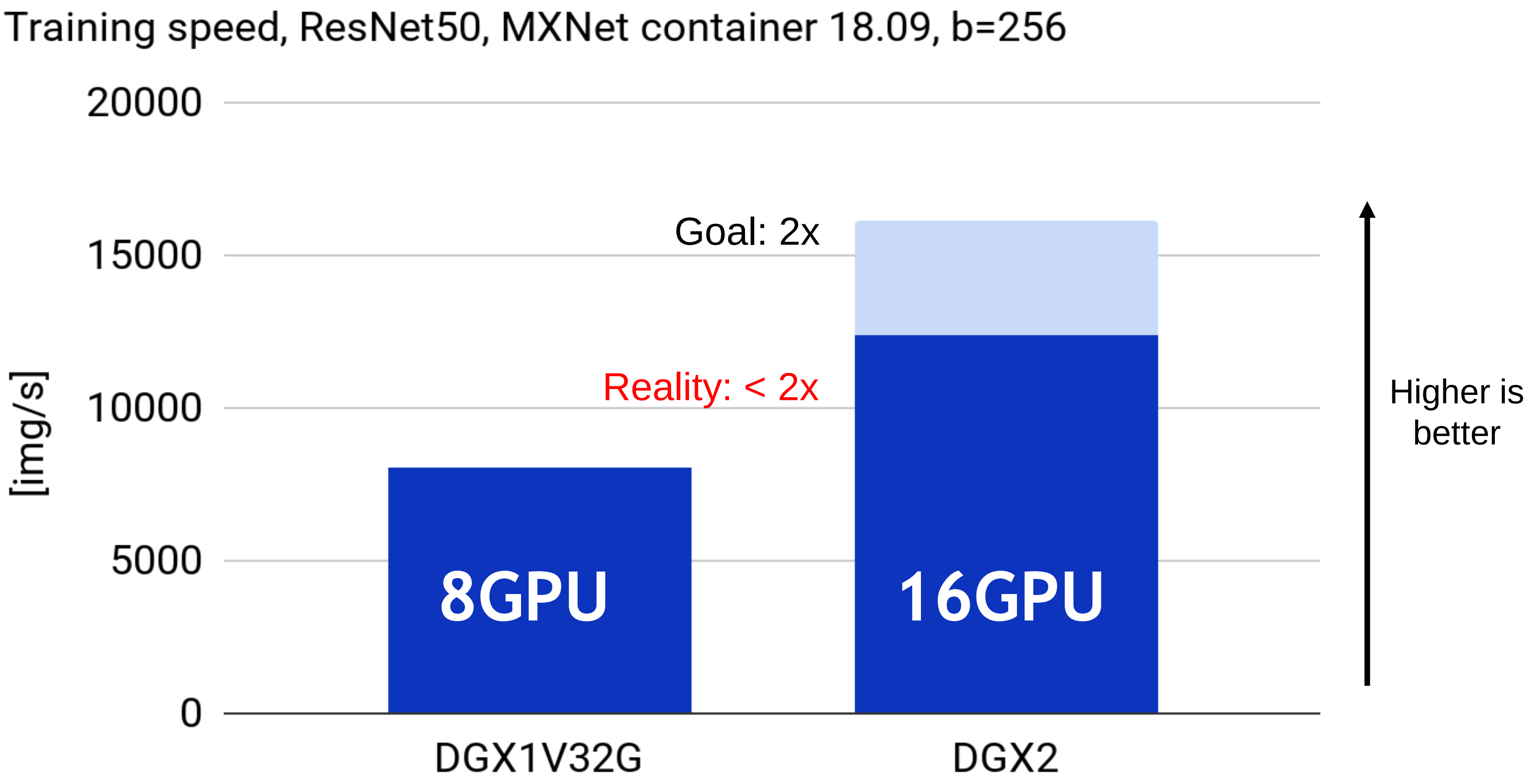
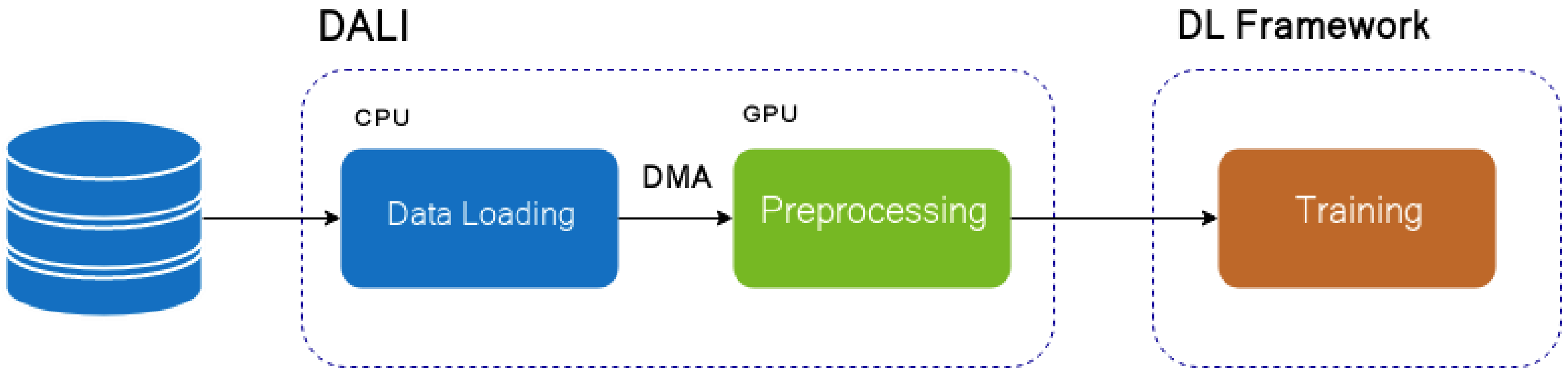


DALI TO THE RESCUE

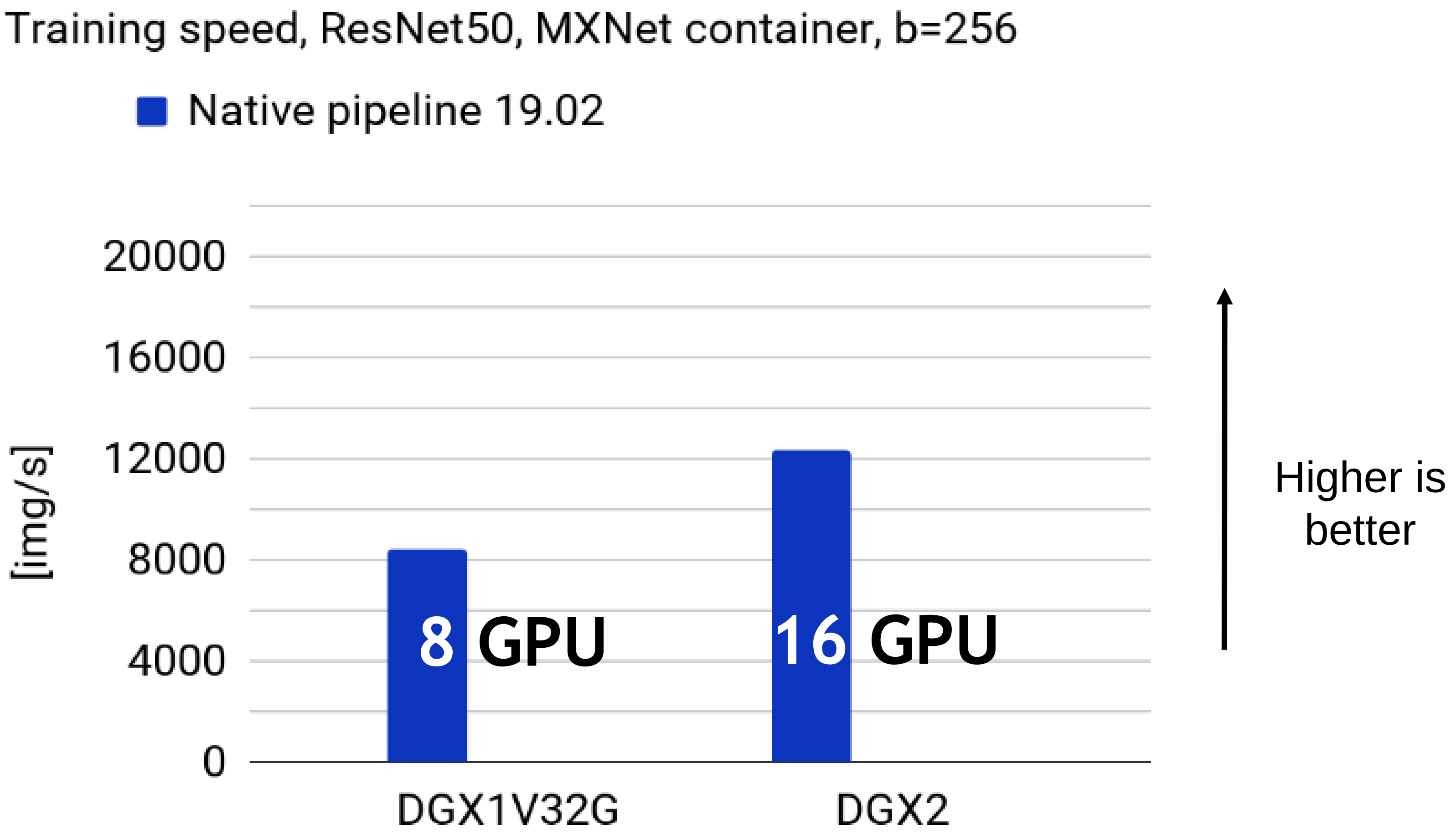
WHAT IS DALI?

High Performance Data Processing Library



DALI RESULTS

RN50 MXNet



DALI RESULTS

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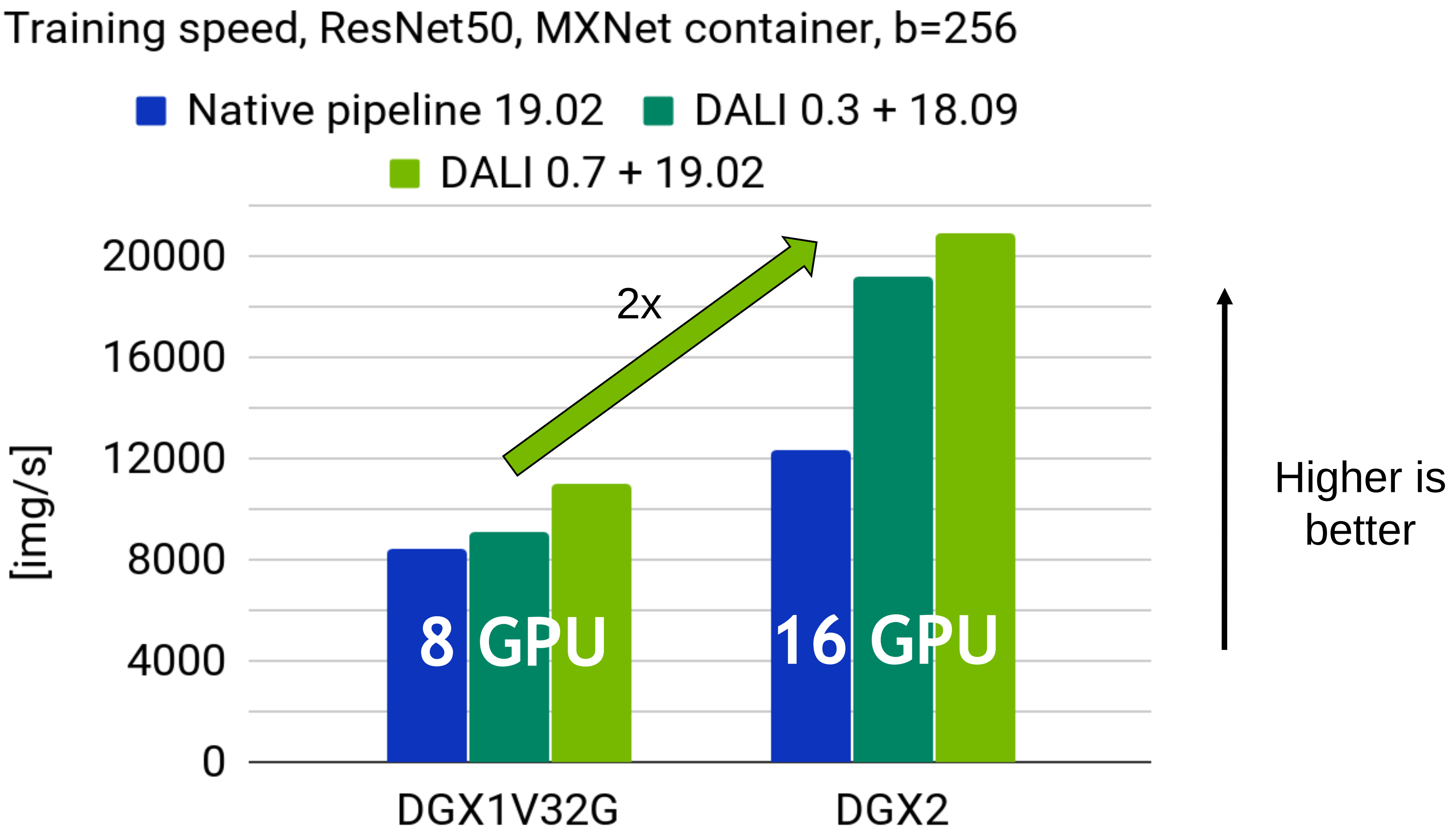
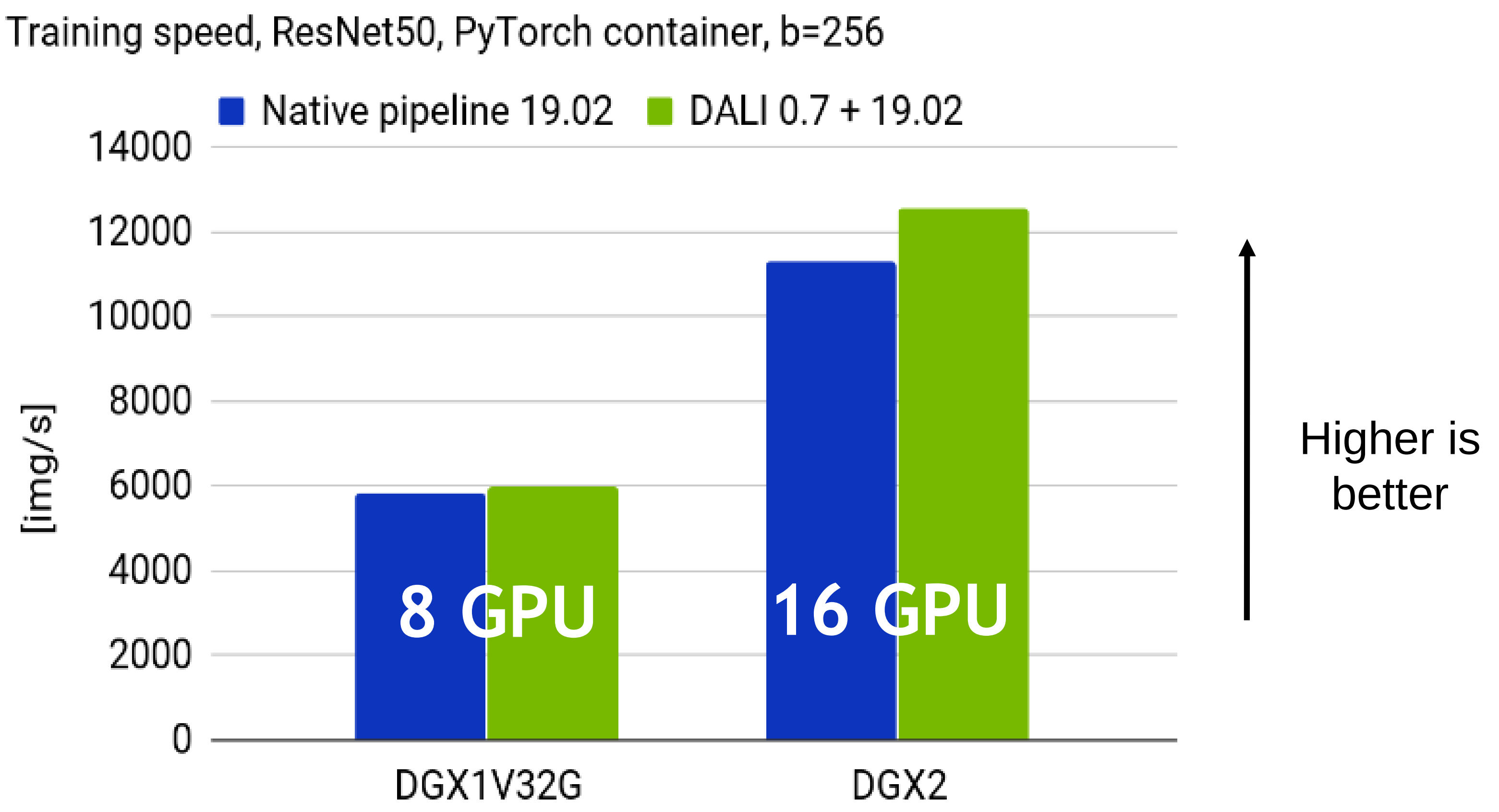


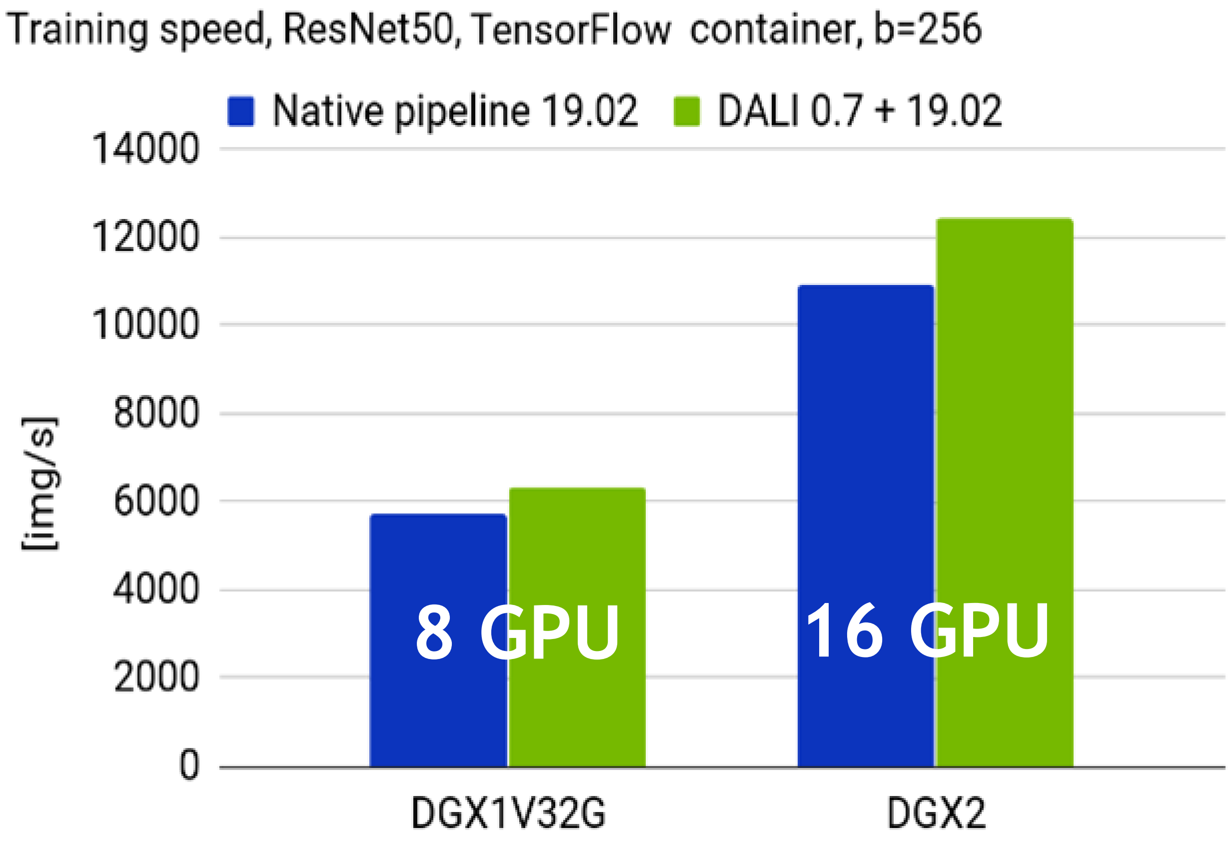
DALI RESULTS

RN50 PyTorch



DALI RESULTS

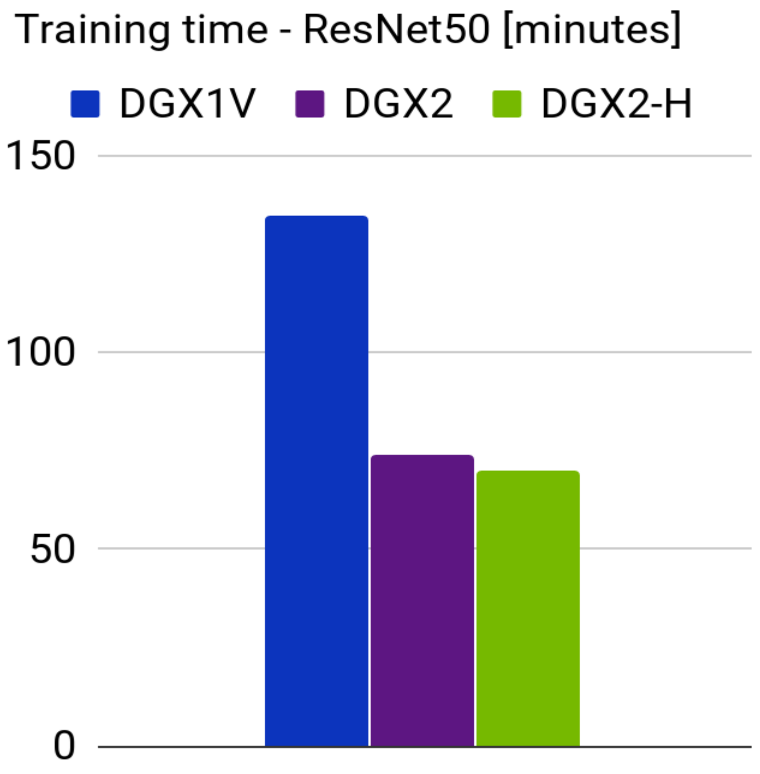
RN50 TensorFlow

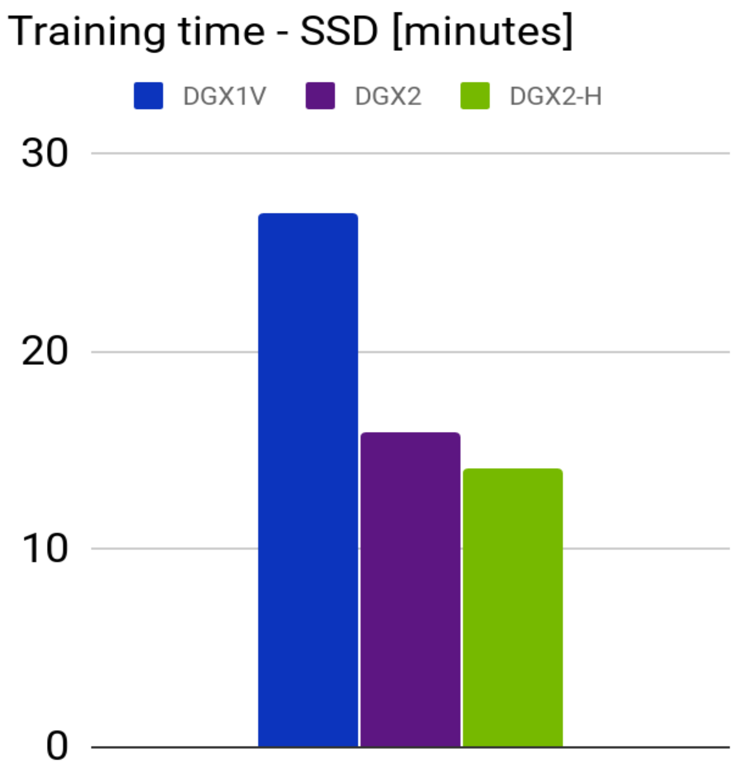


Higher is better

DALI RESULTS - MLPERF

Perfect scaling

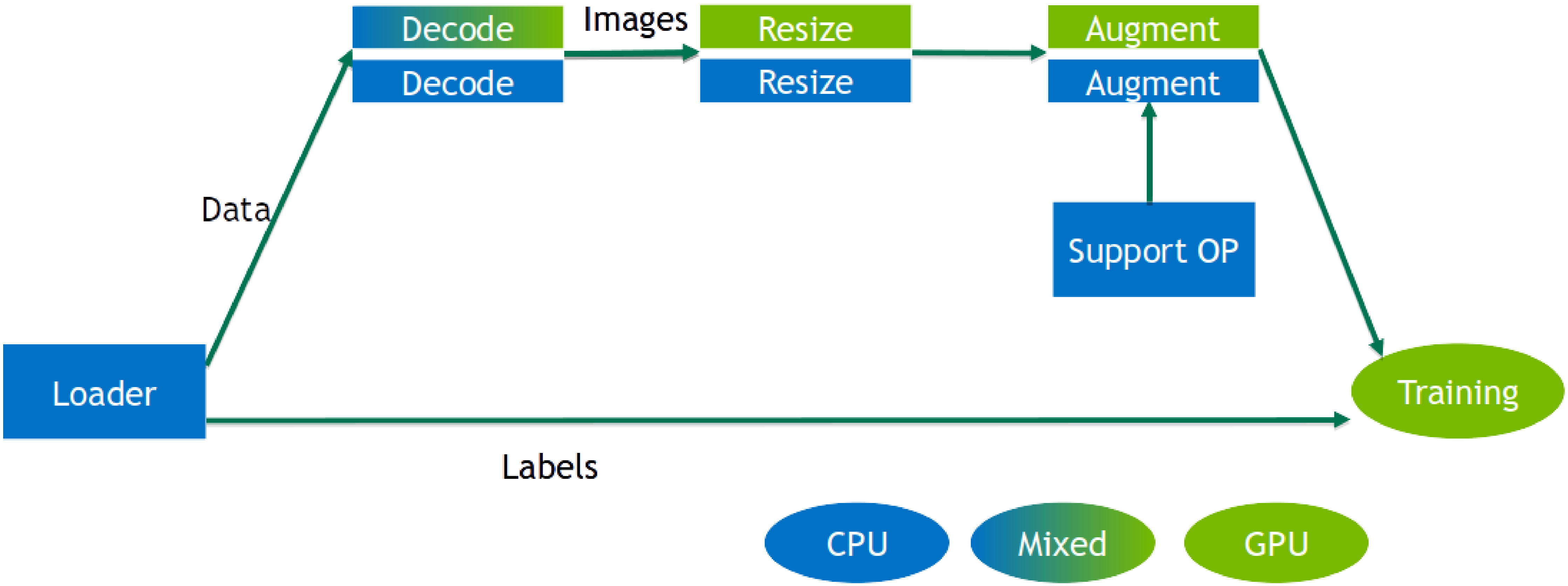




https://mlperf.org/results

INSIDE DALI

DALI: CURRENT ARCHITECTURE



HOW TO USE DALI

Define Graph

Instantiate operators

```
def __init__(self, batch_size, num_threads, device_id):
    super(SimplePipeline, self).__init__(batch_size, num_threads, device_id)
    self.input = ops.FileReader(file_root = image_dir)
    self.decode = ops.nvJPEGDecoder(device = "mixed", output_type = types.RGB)
    self.resize = ops.Resize(device = "gpu", resize_x = 224, resize_y = 224)
```

Define graph in imperative way

```
def define_graph(self):
    jpegs, labels = self.input()
    images = self.decode(jpegs)
    images = self.resize(images)
    return (images, labels)
```

Use it

```
pipe.build()
images, labels = pipe.run()
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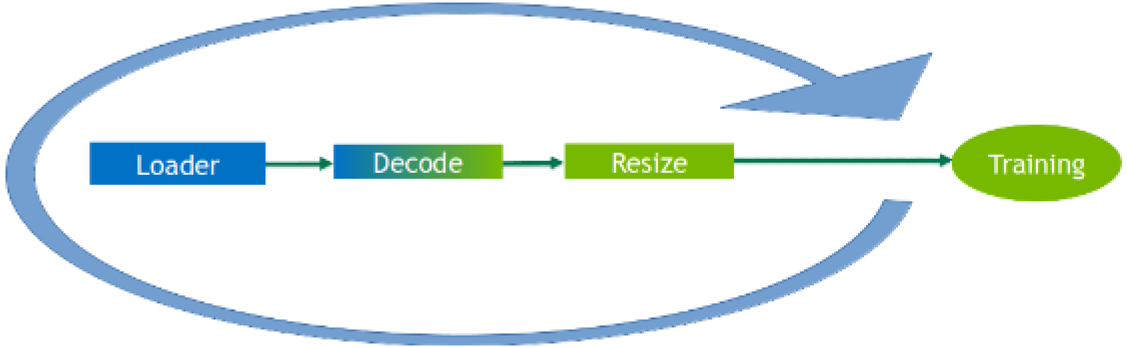

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Use it

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images, labels = pipe.run()
```

HOW TO USE DALI

Use in PyTorch

PyTorch DataLoader

```
train_loader = torch.utils.data.DataLoader(...)
prefetcher = data_prefetcher(train_loader)
input, target = prefetcher.next()
i = -1
while input is not None:
    i += 1
    (...)
    input, target = prefetcher.next()
```

DALI iterator

```
dali_pipe = TrainPipe(...)
train_loader = DALIClassificationIterator(dali_pipe)


for i, data in enumerate(train_loader):
    input = data[0]["data"]
    target = data[0]["label"].squeeze()
    (...)
```

HOW TO USE DALI

Use in MXNet

MXNet DataIter and DataBatch

```
train_data = SyntheticDataIter(...)


for i, batches in enumerate(train_data):
   data = [b.data[0] for b in batches]
   label = [b.label[0].as_in_context(b.data[0].context)
for b in batches]
   (...)
```

DALI iterator

```
dali_pipes = [TrainPipe(...) for gpu_id in gpus]
train_data = DALIClassificationIterator(dali_pipe)

for i, batches in enumerate(train_data):
   data = [b.data[0] for b in batches]
   label = [b.label[0].as_in_context(b.data[0].context) for
b in batches]
   (...)
```

HOW TO USE DALI

Use in TensorFlow

TensorFlow Dataset

```
def get_data():
    ds = tf.data.Dataset.from_tensor_slices(files)
    ds.define_operations(...)
    return ds


classifier.train(input_fn=get_data,...)
```

DALI TensorFlow operator

```
def get_data():
    dali_pipe = TrainPipe(...)
    daliop = dali_tf.DALIIterator()
    with tf.device("/gpu:0"):
        img, labels = daliop(pipeline=dali_pipe, ...)
    return img, labels

classifier.train(input_fn=get_data,...)
```

NEW USE CASES

OBJECT DETECTION

Single Shot Multibox Detector Model (SSD)

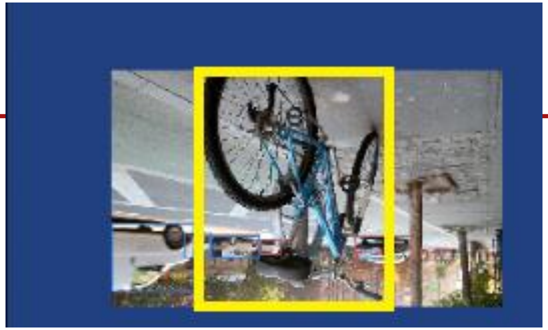
Use operators in the DALI graph:

```
images = self.paste(images, paste_x = px, paste_y = py, ratio = ratio)
bboxes = self.bbpaste(bboxes, paste_x = px, paste_y = py, ratio = ratio)

crop_begin, crop_size, bboxes, labels = self.prospective_crop(bboxes, labels)
images = self.slice(images, crop_begin, crop_size)

images = self.flip(images, horizontal = rng, vertical = rng2)
bboxes = self.bbflip(bboxes, horizontal = rng, vertical = rng2)

return (images, bboxes, labels)
```



VIDEO

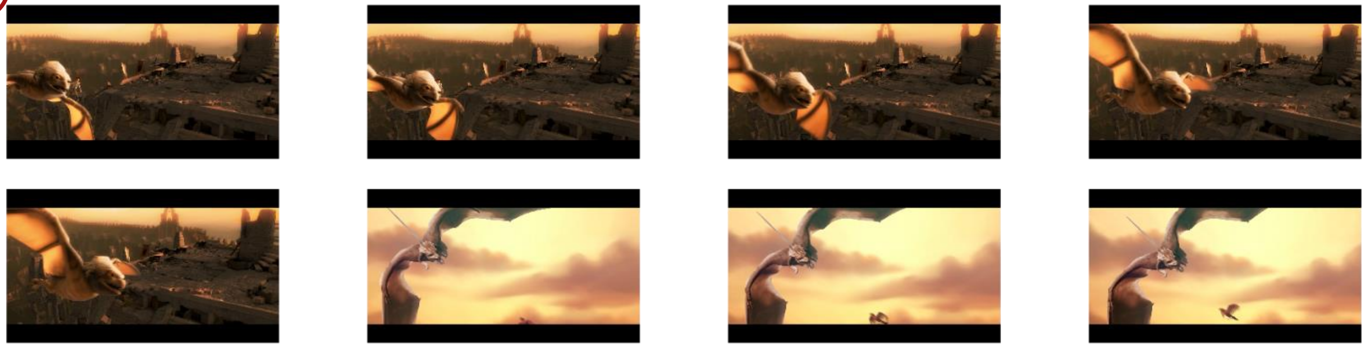
Video Pipeline Example

Instantiate operator:

```
self.input = ops.VideoReader(device="gpu", filenames=data, sequence_length=len)
```

Use it in the DALI graph:

```
frames = self.input(name="Reader")
output_frames = self.Crop(frames)
return output_frames
```



VIDEO

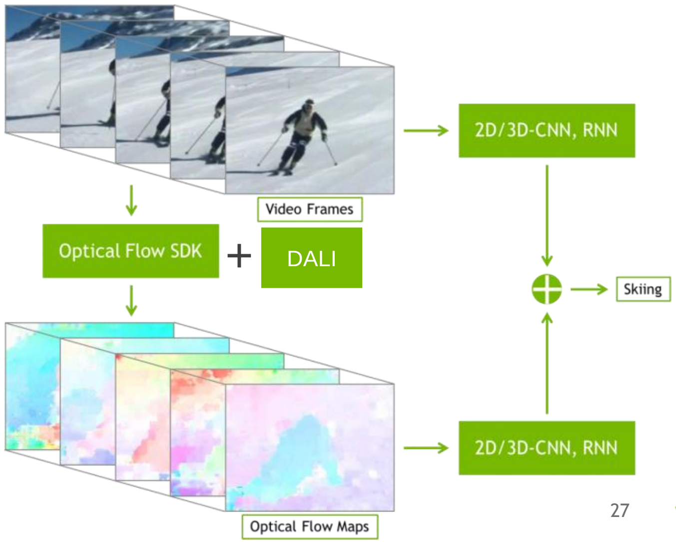
Optical Flow Example

Instantiate operator:

```
self.input = ops.VideoReader(file_root = video_files, sequence_length = len, step = step)
self.opticalFlow = ops.OpticalFlow()
self.takeFirst = ops.ElementExtract(element_map = [0])
```

Use it in the DALI graph:

```
frames = self.input()
flow = self.opticalFlow(frames)
first = self.takeFirst(frames)
return first, flow
```



MAKING LIFE EASIER

MORE EXAMPLES

Help you get started

ResNet50 for PyTorch, MXNet, TensorFlow

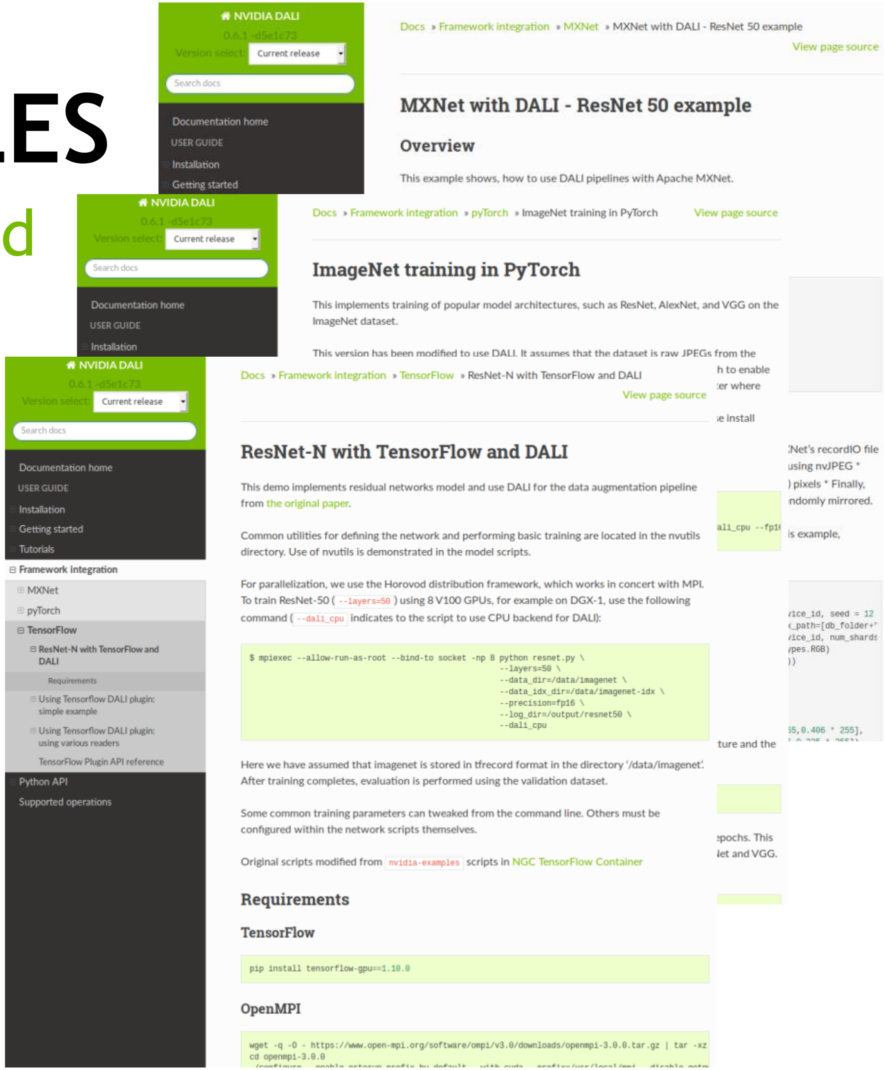
How to read data in various frameworks

How to create custom operators

Pipeline for the detection

Video pipeline

More to come...



Documentation available online:

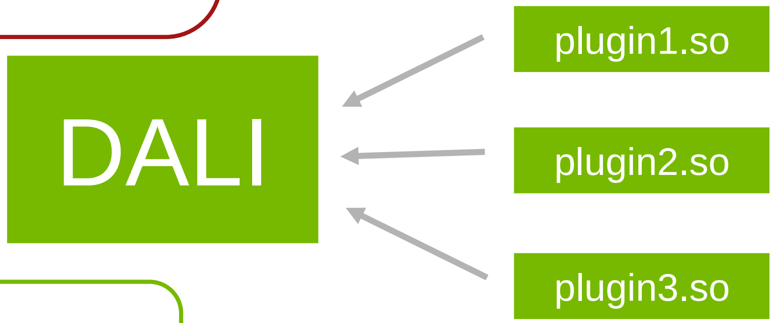
https://docs.nvidia.com/deeplearning/sdk/dali-developer-guide/docs/index.html

PLUGIN MANAGER

Adds Extensibility

Create operator

```
template<>
void Dummy<GPUBackend>::RunImpl(DeviceWorkspace *ws, const int idx) {
(...)
}
DALI_REGISTER_OPERATOR(CustomDummy, Dummy<GPUBackend>, GPU);
```



Load Plugin from python

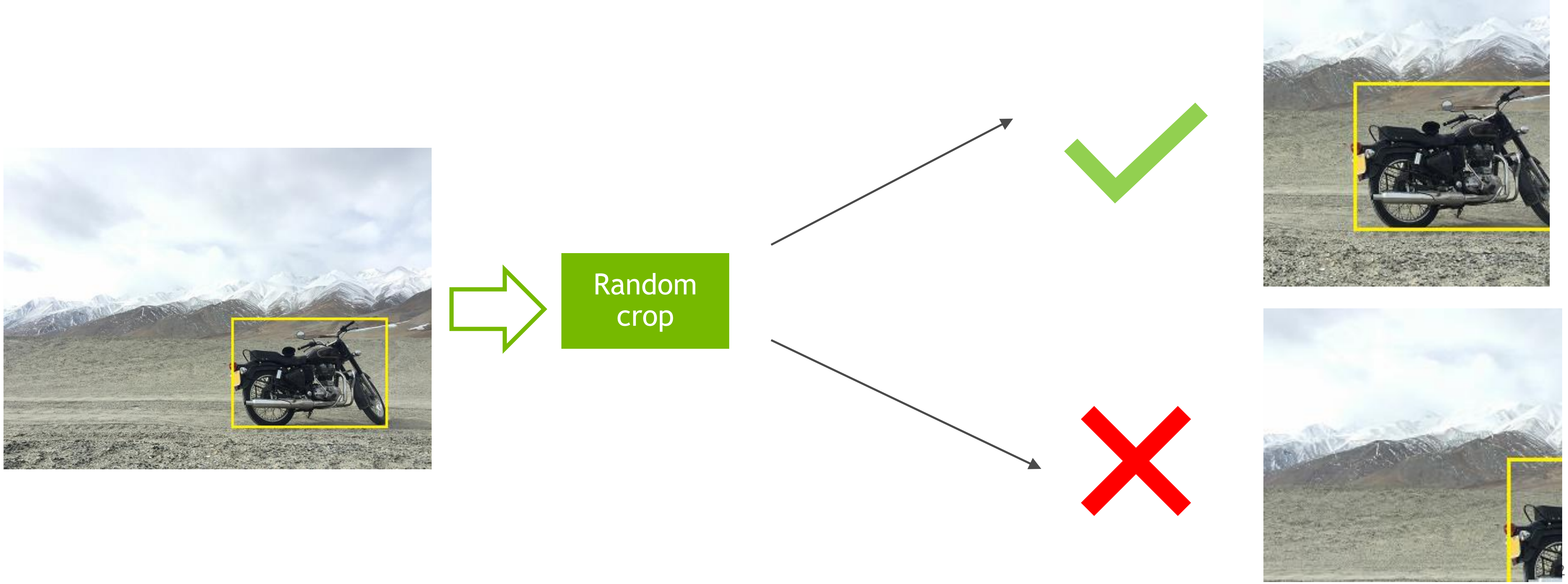
```
import nvidia.dali.plugin_manager as plugin_manager
plugin_manager.load_library('./customdummy/build/libcustomdummy.so')
ops.CustomDummy(...)
```

CHALLENGES

CHALLENGES

Object Detection

Data-dependent random transformation



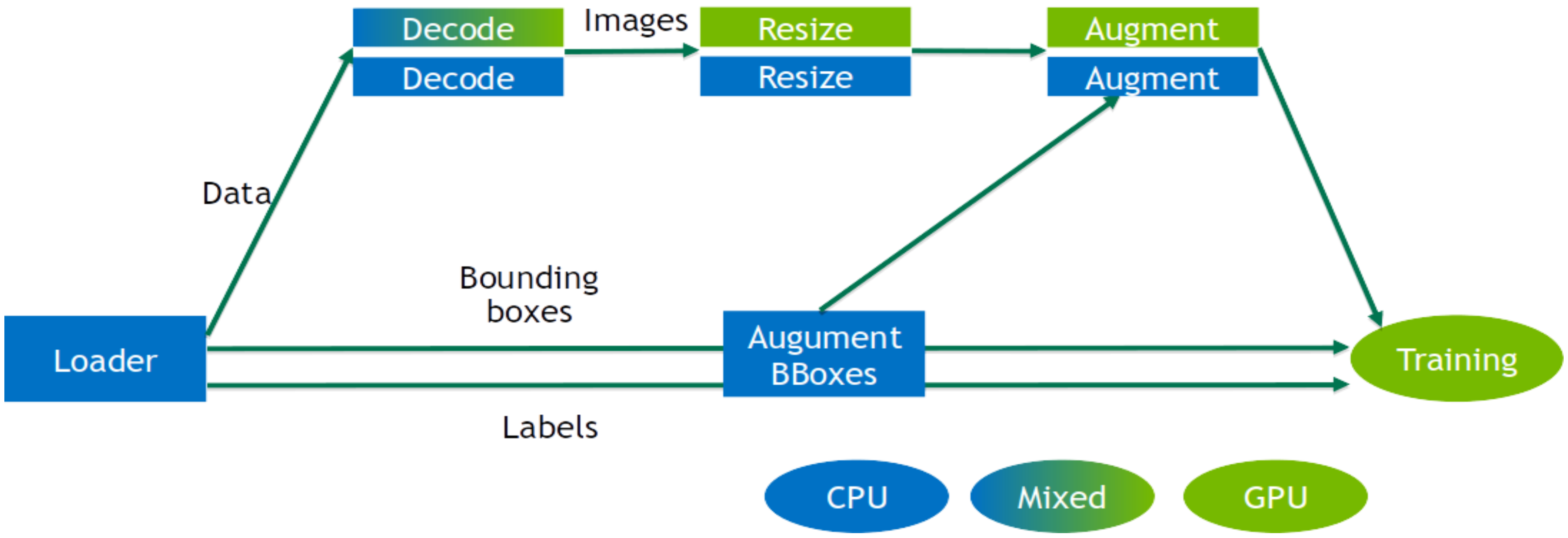
CHALLENGES

Object Detection

More types of data, not only images and labels - bounding boxes as well

Previously only images were processed

Now processing of bounding boxes drives image processing

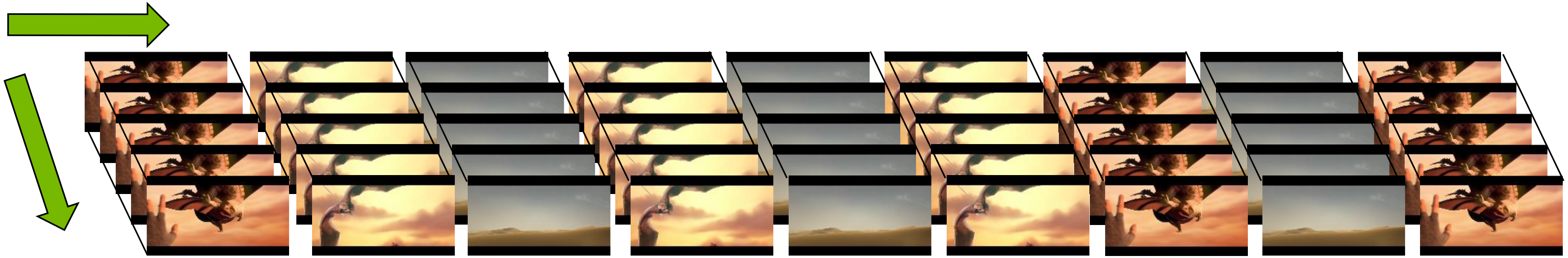


CHALLENGES

Video

Integrated NVDEC to utilize H.264 and HEVC

Samples are no longer single image - sequence (N**F**HWC<->NC**F**HW)



Reuse operators - flatten the sequence

CHALLENGES

CPU based pipeline

CPU/GPU high or network traffic consumes GPU cycles

- CPU operators coverage

Sweet spot for SSD mixed pipeline - part CPU, part GPU

- Test what works best for you

Operator name	CPU	GPU
ColorSpaceConversion	✓	✓
ColorTwist	✓	✓
Contrast	✓	✓
Copy	✓	✓
Crop	✓	✓

CHALLENGES

Memory Consumption

DGX - “works for me”

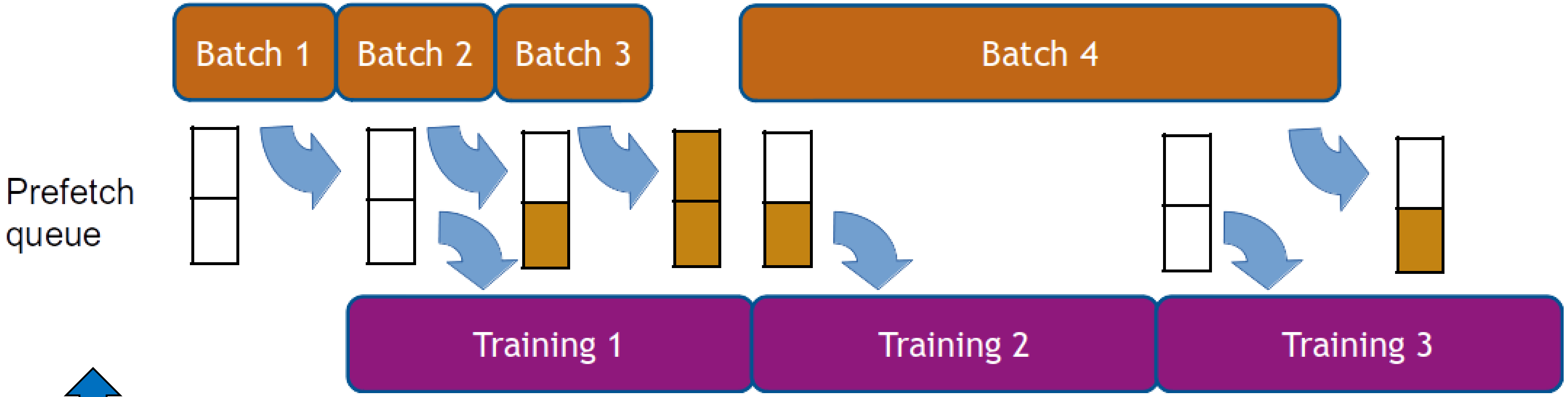
A lot of non-DGX users started using DALI

- Want to use CPU operators
- Memory consumption on the CPU side matters
- Usability more important than speed

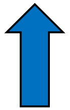
CHALLENGES

Memory Consumption

Multiple buffering



...but memory consumption



- Caching allocators?
- Subbatches?

CHALLENGES

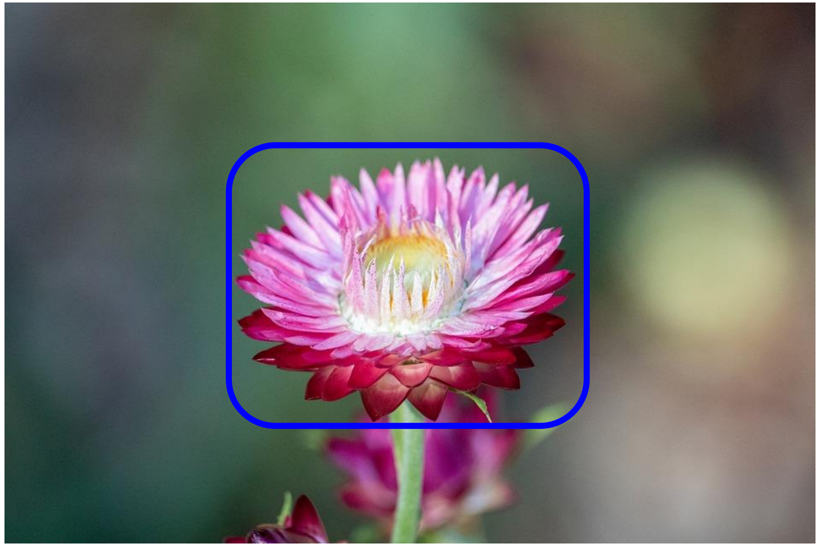
Decoding Time

Significant image decoding time

- CPU decoding already pushed to the limits

Can we do better?

- nvJPEG - huge improvement
- ROI decoding



CHALLENGES

TensorFlow Forward Compatibility

PyTorch and MXNet integration

- Python API - “easy-peasy”

TensorFlow - custom operator needed

- Frequent changes to TensorFlow C++ API
- Cannot preserve forward compatibility at the binary level
- DALI TF plug-in package is now available - compile your TensorFlow DALI op

CHALLENGES

Discrepancies Between Frameworks

Bilinear filter – OpenCV vs Pillow

Bicubic filter – TensorFlow vs PIllow

initial image
[16px x 16px]

tf.image.resize_bicubic
[4px x 4px]

PIL.Image.resize
[4px x 4px]

https://hackernoon.com/how-tensorflows-tf-image-resize-stole-60-days-of-my-life-aba5eb093f35

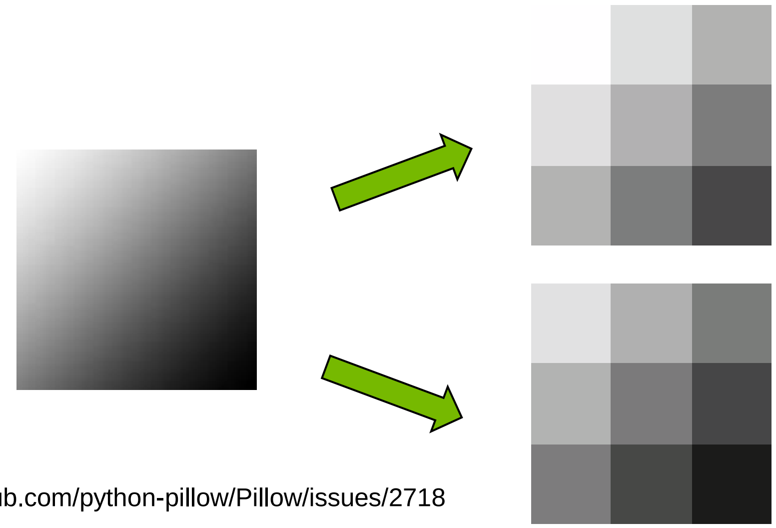
CHALLENGES

Discrepancies Between Frameworks

- MXNet is based on OpenCV
- PyTorch uses Pillow
- TensorFlow has its own augmentation operators

We want portability between frameworks,

but what about pre-trained models?



https://github.com/python-pillow/Pillow/issues/2718

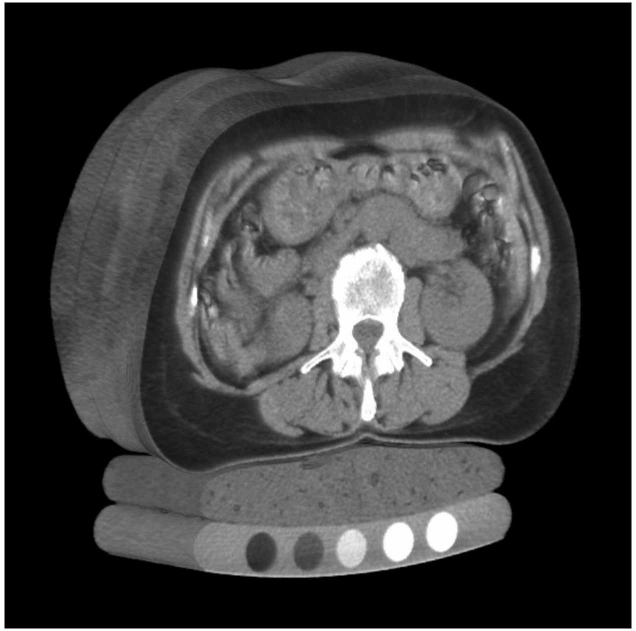
NEXT STEPS

NEW USE CASES

Medical imaging (Volumetric data)

- Performant 3D augmentations library

Segmentation?



NEW USE CASES

Extract augmentation operators in a separate library

- Inference - the same augmentation operation can be used in custom inference pipeline where full feature DALI is not required (i.e. embedded platform)
- Ability to use operator directly from Python code

```
import nvidia.dali.standaloneOps as standaloneOps
import cv2

image = cv2.imread('test.jpg',0)
standaloneOps.Rotate(image, device="gpu", angle=45, interp_type = types.INTERP_LINEAR)
cv2.imwrite("./img_tf.png", image)
```

DALI

Summary

- Open source, GPU-accelerated data augmentation and image loading library
  - Over 1100 GitHub stars
  - [1] Top 50 ML/DL Projects (out of 22,000 in 2018)
- Full pre-processing data pipeline ready for training and inference
- Easy framework integration
- Portable training workflows

[1] https://github.com/Mybridge/amazing-machine-learning-opensource-2019

NVIDIA

DALI

Summary

More questions? Connect with Experts Sessions: DALI Tue 19th, Wed 20th, 2pm (Expo Hall)

Meet us P9291 - Fast Data Pre-processing with DALI (Mon 18th, 6-8pm)

Attend S9818 - TensorRT with DALI on Xavier to learn about TensorRT inference workflow with DALI graphs and customer operators

We want to hear from you

Dali-Team@nvidia.com

https://github.com/NVIDIA/DALI

https://developer.nvidia.com/dali

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Pablo Ribalta
Cliff Woolley
DL Frameworks @ NVIDIA

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