University of Sheffield

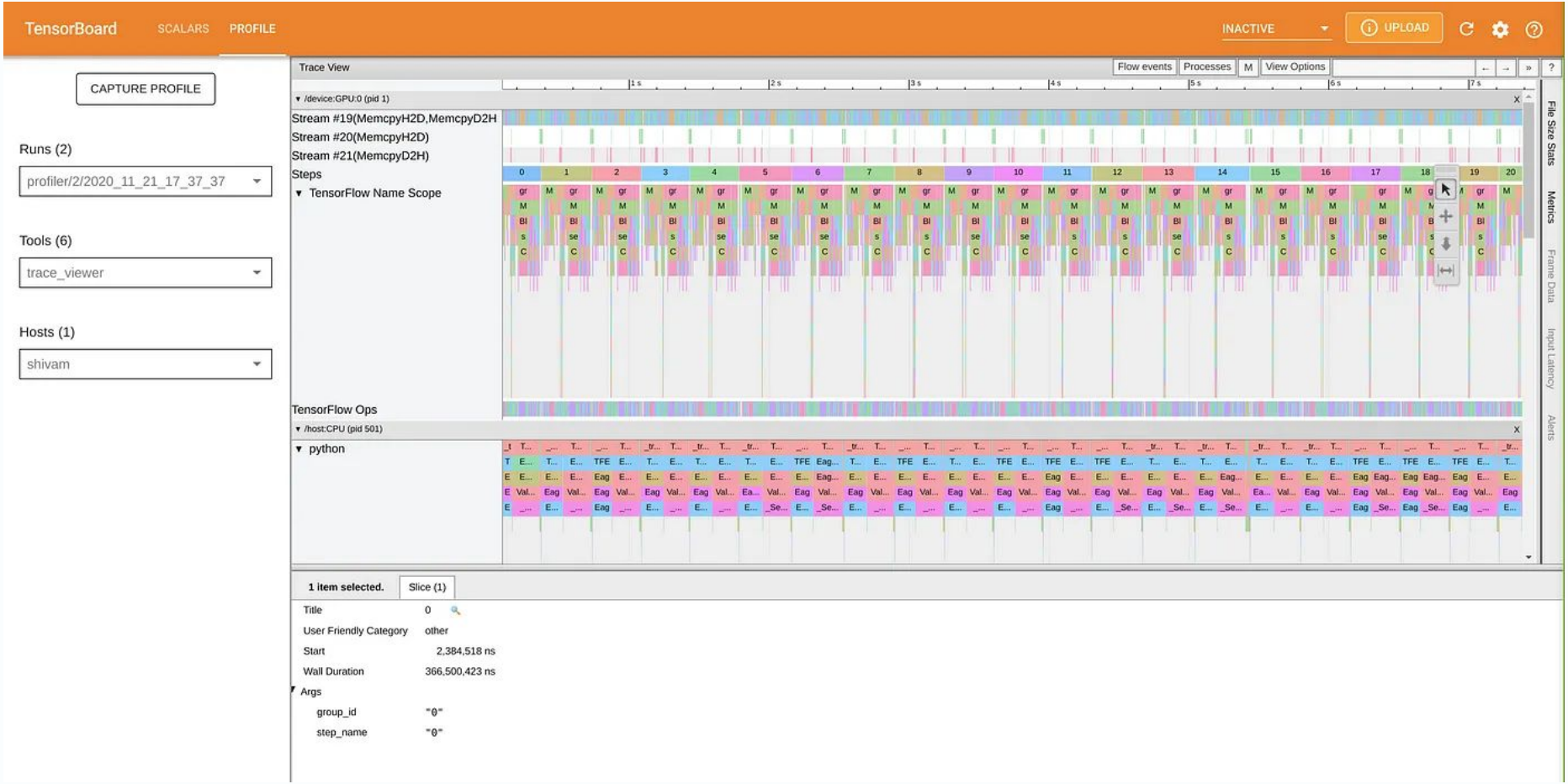
Profiling GPU-driven machine learning code

Why is my machine learning code slow?

Edwin Brown

05/07/2024

Whatuni? Student Choice Awards
UNIVERSITY OF THE YEAR 2024


TensorBoard
SCALARS
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INACTIVE
UPLOAD
CAPTURE PROFILE
Runs (2)
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Tools (6)
trace_viewer
Hosts (1)
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Trace View
Flow events
Processes
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View Options
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Stream #20(MemcpyH2D)
Stream #21(MemcpyD2H)
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Alerts
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Slice (1)
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Hosts (1)
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mysqld`row_sel_get_..
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mysqld`ha_innobase::general_fetch
mysqld`ha_innobase::index_next_..
mysqld`handler::read_range_next
my..
mysqld`handler::read_multi_range..
mys..
mysqld`QUICK_RANGE_SELECT::get_n..
mys..
mysqld`find_all_keys
mysqld`filesort
mysqld`create_sort_index
mysqld`JOIN::exec
mysqld`mysql_select
mysqld`handle_select
mysqld`execute_sqlcom_select
mysqld`mysql_execute_command
libc..
my..
mysqld`mysql_parse
mysqld`dispatch_command
mysqld`do_command
mysqld`handle_one_connection
libc.so.1`_thrp_setup
libc.so.1`_lwp_start
mysqld`eval..
mysqld`sub_select
mysqld`do_select
mysqld`row_search_for_mysql
mysqld`ha_innobase::general_fetch
mysqld`ha_innobase::index_prev
mysqld`join_read_prev
mysqld`row_..
mysqld`ro..
Function: mysqld`filesort (108,672 samples, 31.19%)
File Size Stats
Metrics
Frame Data
Input Latency
Alerts


TensorBoard
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Hosts (1)
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File Size Stats
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Input Latency
Alerts

Profiling - What is it?

Profiling is a way of analysing how code is running

Statistical data is collected by a profiler when running code

Data can include what processes were run, how long they took and memory usage

Profiling - Why is it important?

Accessible—allows code to use fewer resources (less $$$)

Sustainable—reduce energy consumption (and CO2 emissions)

Scalable—efficiently utilise supercomputer resources

In particular, Machine Learning algorithms often rely on the use of GPUs which are particularly in demand and power hungry.

Profiling - How do I do it (Pytorch)?

```
my_schedule = schedule(skip_first=5, wait=2, warmup=2, active=5)
```


PyTorch Profiler — PyTorch Tutorials 2.3.0+cu121 documentation

Profiling - How do I do it (Pytorch)?

```
my_schedule = schedule(skip_first=5, wait=2, warmup=2, active=5)

profiler = torch.profiler.profile(
    schedule=my_schedule,
    on_trace_ready=torch.profiler.tensorboard_trace_handler('logs/test1'))
```


PyTorch Profiler — PyTorch Tutorials 2.3.0+cu121 documentation

Profiling - How do I do it (Pytorch)?

```
my_schedule = schedule(skip_first=5, wait=2, warmup=2, active=5)

profiler = torch.profiler.profile(
    schedule=my_schedule,
    on_trace_ready=torch.profiler.tensorboard_trace_handler('logs/test1'))

profiler.start()
for data in train_loader:
    train_step(data)
    profiler.step()
profiler.stop()
```

***.pt.trace.json file is saved to disk!**

Profiling - How do I view the logs?

Perfetto - Browser based trace viewer

Tensorboard - Application for viewing training and profiling statistics developed by TensorFlow.

Holistic Trace Analysis - Open source library for interpreting logs output from pytorch profiler.

Experiment

- Train a computer vision model (Simple Unet model) to perform segmentation on 64,000 images (32,000 image and mask respectively) in Pytorch.

- Images are stored as .png files on disk. Image pipeline loads these images and masks from disk and does some pre-processing (rotation, resizing, etc.).

- **Can we use Profiling to find and remove bottlenecks to speed up our training?**

Hardware

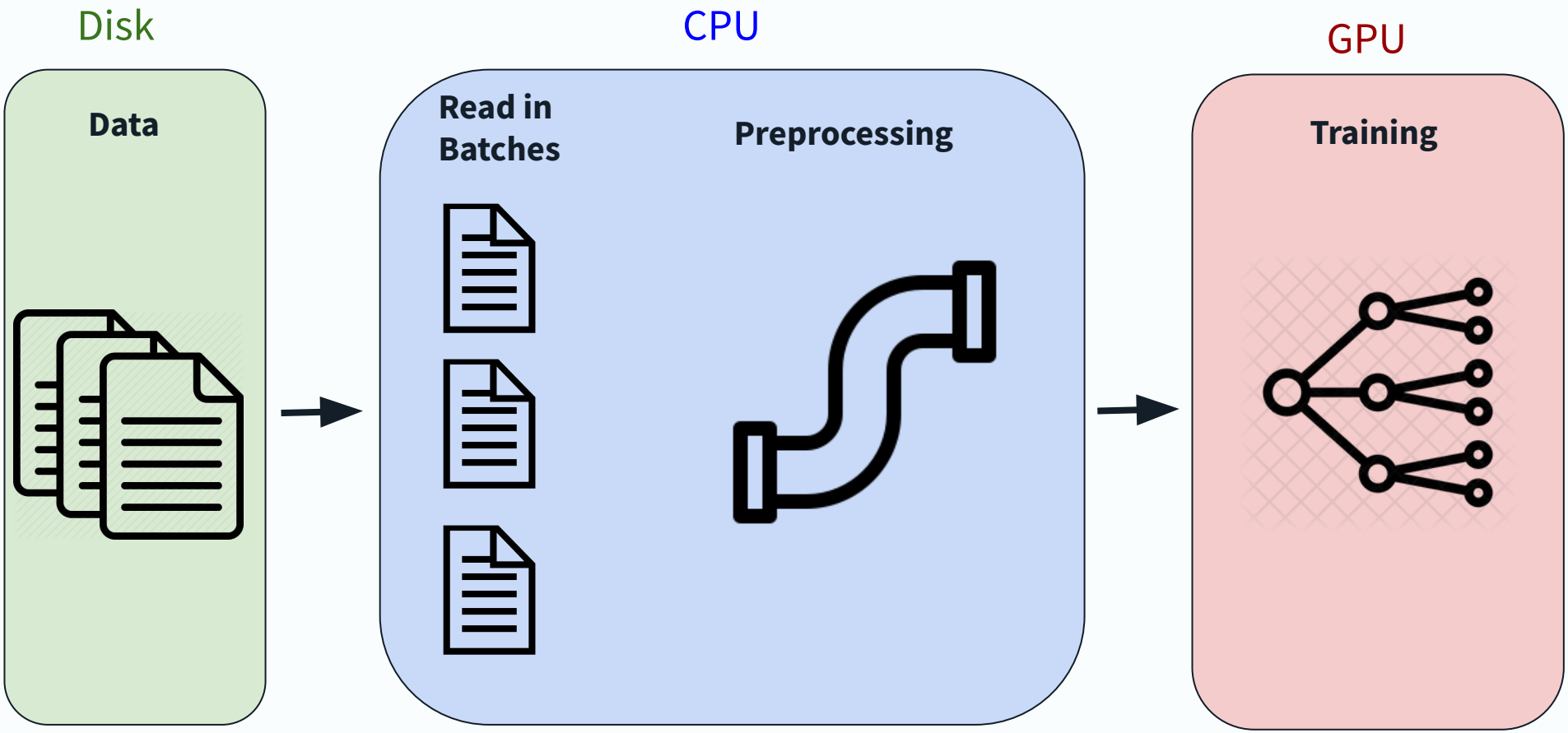
Virtual Machine

Intel i7-5930K, 6 cores, 12 threads

64GB Memory

GPUs:

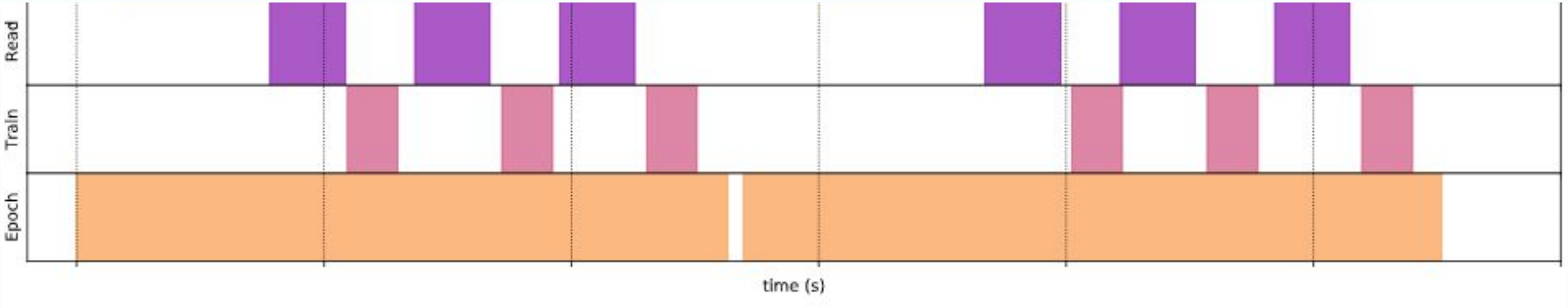
- Geforce RTX 3090 (CUDA Device 0)
- Geforce RTX 3090 (CUDA Device 1)


Disk
CPU
GPU
Data
Read in Batches
Preprocessing
Training

Test 1 - Default

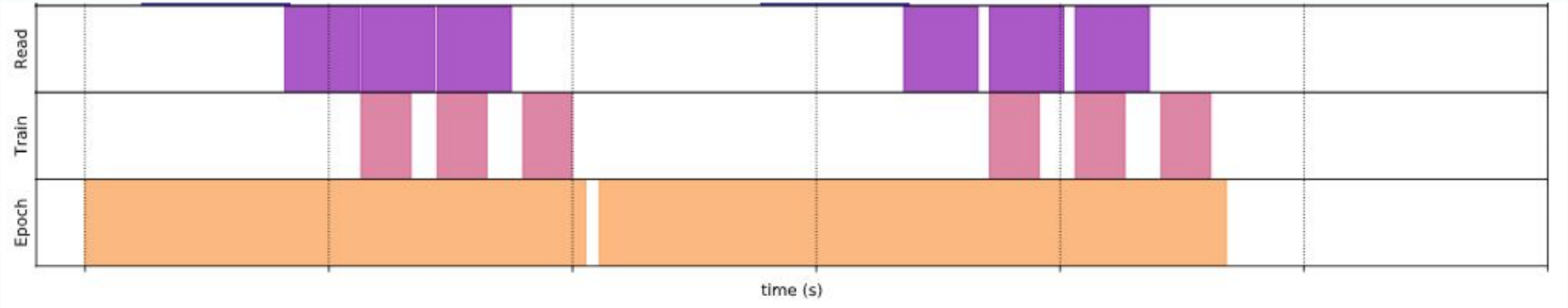
```
train_loader = DataLoader(train_dataset, batch_size=256)

for data in train_loader:
    inputs, masks = data[0].to('cuda'), data[1].to('cuda')

    outputs = model(inputs)
    loss = criterion(outputs, masks)

    loss.backward()
    optimizer.step()
```

Sequential Pipeline



https://www.tensorflow.org/guide/data_performance

Prefetching



https://www.tensorflow.org/guide/data_performance

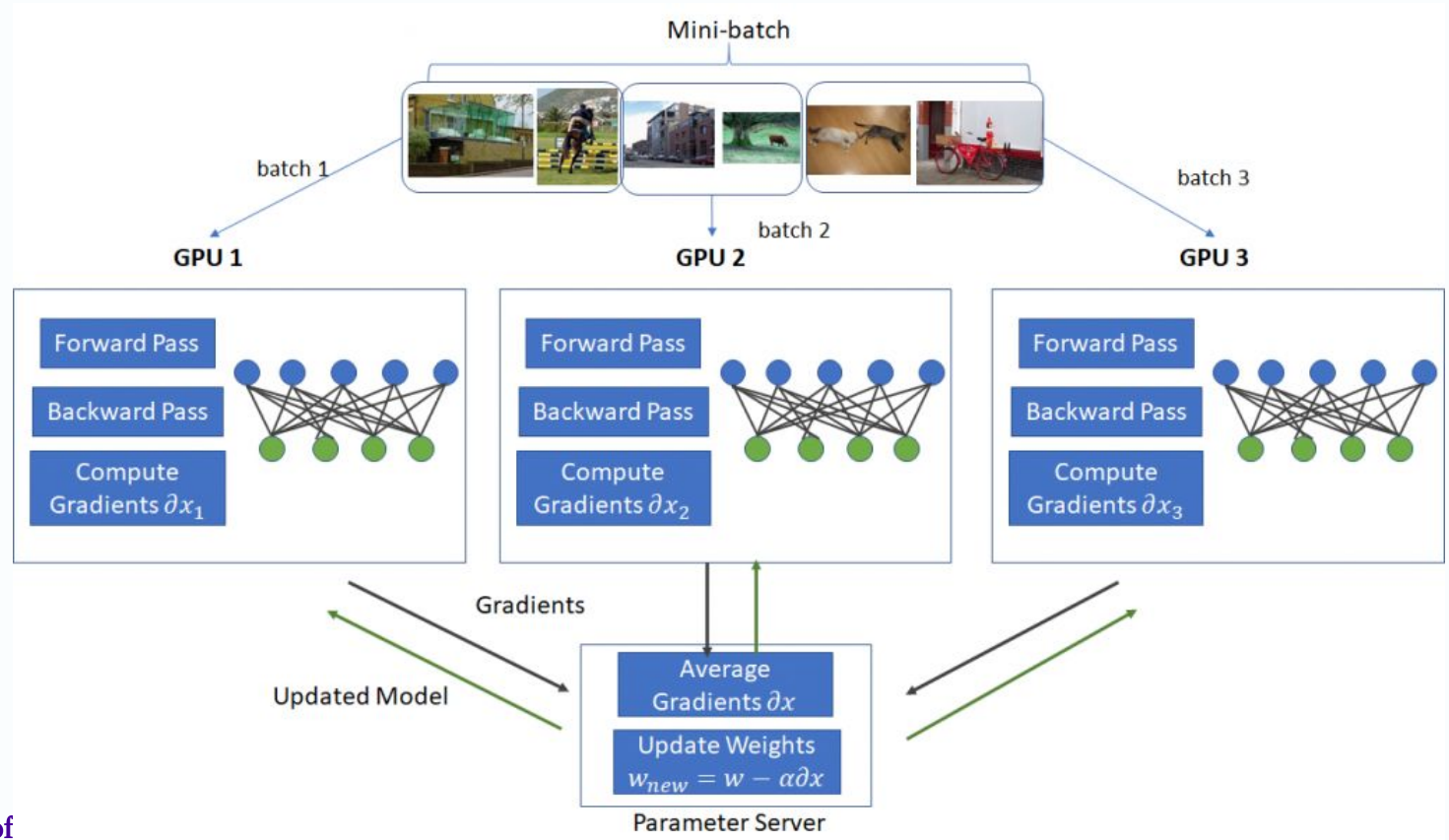
Test 2 - Multiprocessing DataLoader

```
train_loader = DataLoader(train_dataset, batch_size=256,
                          num_workers=4)
for data in train_loader:
    inputs, masks = data[0].to('cuda'), data[1].to('cuda')

    outputs = model(inputs)
    loss = criterion(outputs, masks)

    loss.backward()
    optimizer.step()
```

Test 3 - Automatic Mixed Precision

```
train_loader = DataLoader(train_dataset, batch_size=256,
                          num_workers=4)
for data in train_loader:
    inputs, masks = data[0].to('cuda'), data[1].to('cuda')
    with autocast():
        outputs = model(inputs)
        loss = criterion(outputs, masks)

    loss.backward()
    optimizer.step()
```

Test 4 - Distributed Data-Parallel



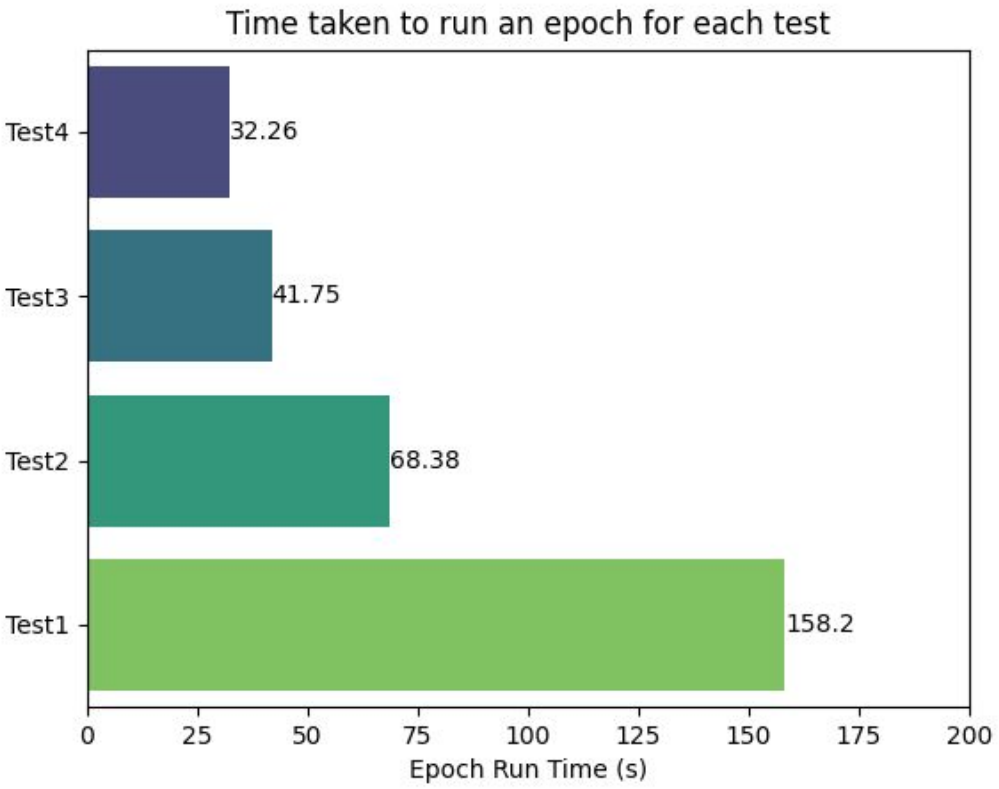
Test Comparison

Multi-Processed DataLoader
+ Mixed Precision + DDP

Multi-Processed DataLoader
+ Mixed Precision

Multi-Processed DataLoader

Default



Other test ideas

- Is there a better way of storing the data on disk other than big lists of PNGs?

- Torch compile

- Passing more of the CPU workload to the GPU?

- Performance Tuning Guide — PyTorch Tutorials 2.3.0+cu121 documentation

Conclusions

Profiling can help find bottlenecks in machine learning workflows

After bottlenecks have been identified, then simple changes can be made to speed up training

Repository here

Contact

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Alan Turing Institute REG Group