Tools in action – an example with Pytorch

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Agenda

1. Intro to Pytorch and its dependencies
2. Controlling affinity
3. Profiling – rocprof and omnitools.
4. Debugging

Pytorch highlight

- Official page: https://pytorch.org/
- Code: https://github.com/pytorch/pytorch
- Python™-based framework for machine learning
  - Auto-differentiation on tensor types
- GPU-enabled
  - ROCm support for MI250x (and others)
  - Hipification as part of the build system
    - C/C++ libraries with proper bindings for Python
  - Python code doesn't need changing – using the same CUDA conventions
- Other related packages:
  - Torch vision/audio, many others
  - APEX – multiprecision library
    - https://github.com/ROCmSoftwarePlatform/apex

Pytorch install – base environment

```
module purge
module load CrayEnv
module load PrgEnv-cray/8.3.3
module load craype-accel-amd-gfx90a
module load cray-python

# Default ROCm – more recent versions are preferable (e.g. ROCm 5.6.0)
module load rocm/5.2.3.lua
```

Pytorch install – system python

- Natively
  - cray-python module
  - pip3 install -t $(pwd)/pip-installs2 --pre torch==1.13.1 --extra-index-url https://download.pytorch.org/whl/rocm5.2/
  - PYTHONPATH=$(pwd)/pip-installs2 python -c 'import torch; print(torch.cuda.device_count())'

Example 01

Pytorch install – virtual env

- virtual env
  - cray-python module
  - python -m venv --system-site-packages cray-python-virtualenv
  - source cray-python-virtualenv/bin/activate
  - pip3 install --pre torch==1.13.1 --extra-index-url https://download.pytorch.org/whl/rocm5.2/
  - python -c 'import torch; print(torch.cuda.device_count())'

Example 02

Pytorch install – conda env

- conda env
  - https://repo.anaconda.com/miniconda/Miniconda3-latest-Linux-x86_64.sh
  - bash Miniconda3-latest-Linux-x86_64.sh
  - source miniconda3/bin/activate
  - conda create -n pytorch python=3.8
  - conda activate pytorch
  - conda install --only-deps pytorch
  - pip3 install --pre torch==1.13.1 --extra-index-url https://download.pytorch.org/whl/rocm5.2/
  - python -c 'import torch; print(torch.cuda.device_count())'

Example 03

Pytorch install – conda env – from source

- conda env
  - https://repo.anaconda.com/miniconda/Miniconda3-latest-Linux-x86_64.sh
  - bash Miniconda3-latest-Linux-x86_64.sh
  - source miniconda3/bin/activate
  - conda create -n pytorch-build python=3.8
  - conda activate pytorch-build
  - conda install --only-deps pytorch
  - conda install -y cmake mkl-include
  - Load source and build:

```
git clone -b v1.13.1 --recursive https://github.com/pytorch/pytorch
cd pytorch
git submodule sync
git submodule update --init --recursive --jobs 0


nice python3 tools/amd_build/build_amd.py
CMAKE_PREFIX_PATH=$CONDA_PREFIX:$CMAKE_PREFIX_PATH \
  PYTORCH_ROCM_ARCH=gfx90a \
  CMAKE_MODULE_PATH=$CMAKE_MODULE_PATH:$(pwd)/pytorch/cmake/Modules_CUDA_fix \
  LIBRARY_PATH=$CONDA_PREFIX/lib:$LIBRARY_PATH LDFLAGS="-ltinfo" \
  PYTORCH_ROCM_ARCH="gfx90a" \
  RCCL_PATH=$ROCM_PATH/rccl \
  RCCL_DIR=$ROCM_PATH/rccl/lib/cmake \
  hip_DIR=${ROCM_PATH}/hip/cmake/ \
  REL_WITH_DEB_INFO=1 \
  nice python3 setup.py bdist_wheel
```

  - conda create -n pytorch-from-source --clone pytorch-build
  - conda activate pytorch-from-source
  - pip install dist/torch-*.whl L
  - LD_LIBRARY_PATH=$CONDA_PREFIX/lib:$LD_LIBRARY_PATH python -c 'import torch; print(torch.cuda.device_count())'

Example 04

[Public]

Pytorch install – containers - Singularity

- Control better the Pytorch environment
- Less strain on the filesystem
  - All application installation is loaded as a single file
- Enable more recent ROCm versions
- Transferable and arguably more portable
- Some containers unofficially available under:
  - /pfs/lustrep2/projappl/project_462000125/samantao-public/containers

- Any cons?
  - Updating the environment and installing more packages may require rebuild the container
  - Containers can't currently be build on LUMI:
    - Needs containers to be built elsewhere and copied to the system
  - Submitting work has to be done more carefully.

```
SIF=<myimage.sif>

srun --jobid=$jobid -n1 \
singularity exec \
            -B /var/spool/slurmd:/var/spool/slurmd \
            -B /opt/cray:/opt/cray \
            -B /usr/lib64/libcxi.so.1:/usr/lib64/libcxi.so.1 \
            -B $wd:/workdir \
            $SIF /workdir/run-me.sh
```

Make relevant pieces of native environment visible inside the container

Make my work directory visible inside the container

The container image

Use helper script to spin the application

Example 05

Controlling device visibility

- Controlling visibility
  - HIP_VISIBLE_DEVICES=0,1,2,3 python -c 'import torch; print(torch.cuda.device_count())'
  - ROCR_VISIBLE_DEVICES=0,1,2,3 python -c 'import torch; print(torch.cuda.device_count())’
  - SLURM sets ROCR_VISIBLE_DEVICES
  - Implications of both ways of setting visibility – blit kernels and/or DMA

  - Considerations:
    - Does my app expects GPU visibility to be set in the environment?
    - Does my app expects arguments to define target GPUs
    - Does my app make any assumption on the device based on other information:
      - MPI rank
      - CPU-range
      - Auto-determined
    - How many processes using the same GPU:
      - Contention vs occupancy
      - Runtime scheduling limits
      - Increased scheduling complexity
      - Imbalance

Most Pytorch applications and driver scripts assume the GPU to be used corresponds to the local rank!!!

Testing affinity

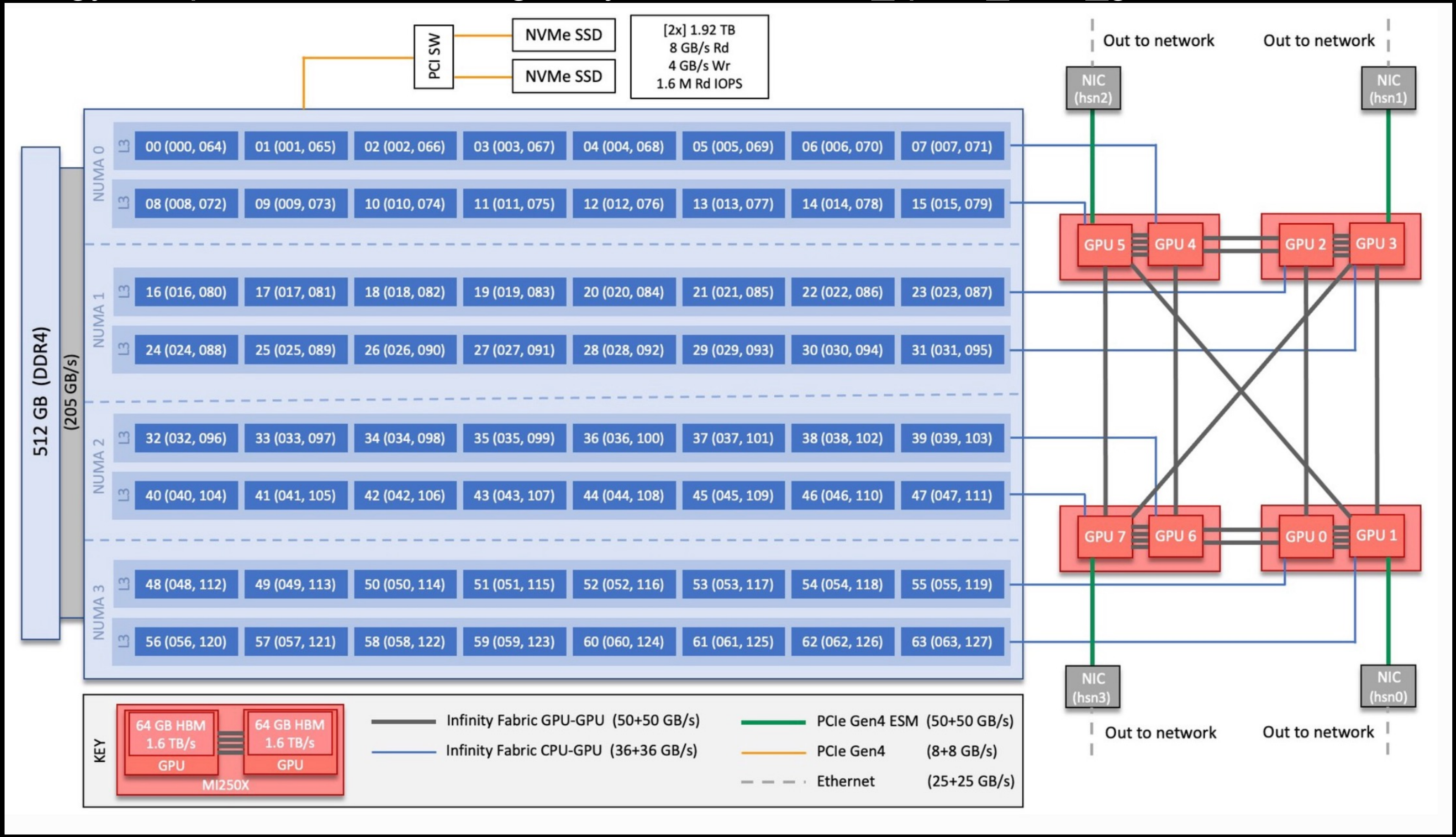
- What CPUs I have available and their NUMA domain?
  - lscpu
- What GPUs I have
  - rocm-smi –showtopo

NUMA node0 CPU(s):	0-15,64-79
NUMA node1 CPU(s):	16-31,80-95
NUMA node2 CPU(s):	32-47,96-111
NUMA node3 CPU(s):	48-63,112-127

GPU[0]	: (Topology) Numa Node: 3
GPU[0]	: (Topology) Numa Affinity: 3
GPU[1]	: (Topology) Numa Node: 3
GPU[1]	: (Topology) Numa Affinity: 3
GPU[2]	: (Topology) Numa Node: 1
GPU[2]	: (Topology) Numa Affinity: 1
GPU[3]	: (Topology) Numa Node: 1
GPU[3]	: (Topology) Numa Affinity: 1
GPU[4]	: (Topology) Numa Node: 0
GPU[4]	: (Topology) Numa Affinity: 0
GPU[5]	: (Topology) Numa Node: 0
GPU[5]	: (Topology) Numa Affinity: 0
GPU[6]	: (Topology) Numa Node: 2
GPU[6]	: (Topology) Numa Affinity: 2
GPU[7]	: (Topology) Numa Node: 2
GPU[7]	: (Topology) Numa Affinity: 2

Testing affinity

- ORNL topology - https://docs.olcf.ornl.gov/systems/crusher_quick_start_guide.html



Testing affinity

- Check what SLURM is giving us:
  - `N=2 ; salloc -p small-g --threads-per-core 1 --exclusive -N $N --gpus $((N*8)) -t 2:00:00 --account project_465000524 --mem 0`
  - `srun -c 7 -N 2 -n 16 --gpus 16 bash -c 'echo "$SLURM_PROCID -- GPUS $ROCR_VISIBLE_DEVICES -- $(taskset -p $$)"'`

```
0 -- GPUS 0,1,2,3,4,5,6,7 -- pid 54249's current affinity mask: fe
1 -- GPUS 0,1,2,3,4,5,6,7 -- pid 54250's current affinity mask: fe00
2 -- GPUS 0,1,2,3,4,5,6,7 -- pid 54251's current affinity mask: fe0000
3 -- GPUS 0,1,2,3,4,5,6,7 -- pid 54252's current affinity mask: fe000000
4 -- GPUS 0,1,2,3,4,5,6,7 -- pid 54253's current affinity mask: fe00000000
5 -- GPUS 0,1,2,3,4,5,6,7 -- pid 54254's current affinity mask: fe0000000000
6 -- GPUS 0,1,2,3,4,5,6,7 -- pid 54255's current affinity mask: fe000000000000
7 -- GPUS 0,1,2,3,4,5,6,7 -- pid 54256's current affinity mask: fe00000000000000
8 -- GPUS 0,1,2,3,4,5,6,7 -- pid 110083's current affinity mask: fe
9 -- GPUS 0,1,2,3,4,5,6,7 -- pid 110084's current affinity mask: fe00
10 -- GPUS 0,1,2,3,4,5,6,7 -- pid 110085's current affinity mask: fe0000
11 -- GPUS 0,1,2,3,4,5,6,7 -- pid 110086's current affinity mask: fe000000
12 -- GPUS 0,1,2,3,4,5,6,7 -- pid 110087's current affinity mask: fe00000000
13 -- GPUS 0,1,2,3,4,5,6,7 -- pid 110088's current affinity mask: fe0000000000
14 -- GPUS 0,1,2,3,4,5,6,7 -- pid 110089's current affinity mask: fe000000000000
15 -- GPUS 0,1,2,3,4,5,6,7 -- pid 110090's current affinity mask: fe00000000000000
```

Example 06

Careful! Allocations do not follow GPU ranking!!

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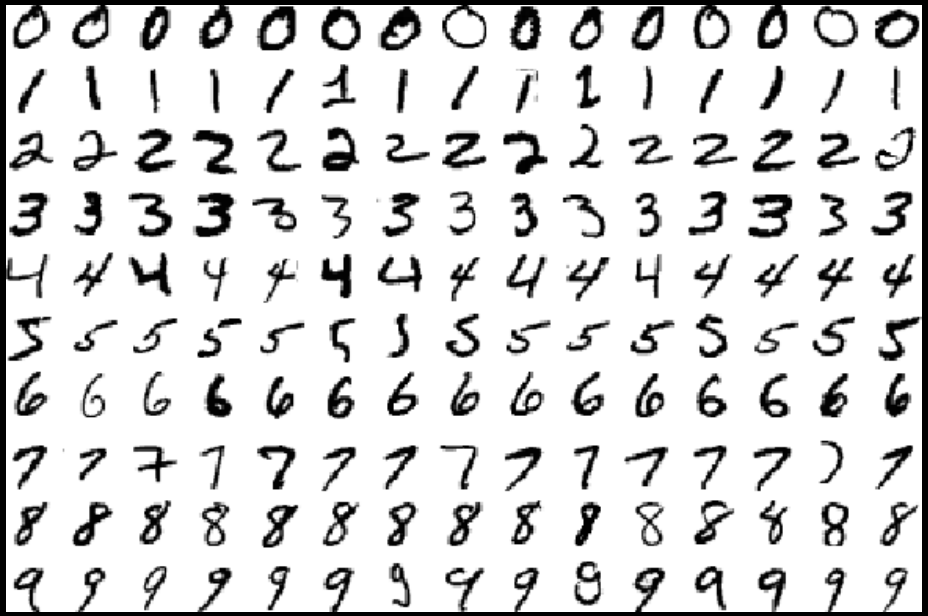
Pytorch example app – MNIST distributed learning

- Popular computer vision training dataset
  - Select the container image
  - Translate SLURM environment to Pytorch distributed environment
  - Smoke test on GPU availability
  - MIOpen caches
  - Set RCCL interfaces
  - Use CPU bind masks to match GPU ranking
  - Assess what in the host needs to be available in the container
  - Invoke singularity from SLURM and in turn invoke helper script
  - Use rocprof to get some insights about your application

Examples 07-08



RCCL attempt using only high-speed-interfaces

- The problem – on startup we see:
  NCCL error in: /pfs/lustrep2/projappl/project_462000125/samantao/pytorch-example/pytorch/torch/csrc/distributed/c10d/ProcessGroupNCCL.cpp:1269, unhandled system error, NCCL version 2.12.12

- Checking error origin:
  - export NCCL_DEBUG=INFO
  - NCCL INFO NET/Socket : Using **[0]nmn0:10.120.116.65<0>** [1]hsn0:10.253.6.67<0> [2]hsn1:10.253.6.68<0> [3]hsn2:10.253.2.12<0> [4]hsn3:10.253.2.11<0>
  - NCCL INFO /long_pathname_so_that_rpms_can_package_the_debug_info/data/driver/rccl/src/init.cc:1292

- The fix:
  - export NCCL_SOCKET_IFNAME=hsn0,hsn1,hsn2,hsn3

Comms are important - RCCL AWS-CXI plugin

- RCCL relies on runtime plugin-ins to connect with some transport layers
  - Libfabric – provider for Slingshot

- Hipified plugin adapted from AWS OpenFabrics support available
- https://github.com/ROCmSoftwarePlatform/aws-ofi-rccl
- 3-4x faster collectives

- Plugin needs to be pointed at by the loading environment

```
module use /pfs/lustrep2/projappl/project_462000125/samantao-public/mymodules
module load aws-ofi-rccl/rocm-5.2.3.lua
Or
export LD_LIBRARY_PATH=/pfs/lustrep2/projappl/project_462000125/samantao-public/apps-rocm-5.2.3/aws-ofi-rccl
(will detect librccl-net.so)
```

- Verify the plugin is detected.

```
export NCCL_DEBUG=INFO
export NCCL_DEBUG_SUBSYS=INIT
# and search the logs for:
[0] NCCL INFO NET/OFI Using aws-ofi-rccl 1.4.0
```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Omnitrace

- Obtain more thorough trace information and visualization
  - https://github.com/AMDResearch/omnitrace
  - OpenSUSE 15.4 build mainly compatible with LUMI environment

- Module files to help load the tool, e.g.

```
module use /pfs/lustrep2/projappl/project_462000125/samantao-public/mymodules
module load rocm/5.5.3 omnitrace/1.10.3-rocm-5.5.x
```

- Configuration file:
  - omnitrace-avail -G omnitrace.cfg –all
  - Use OMNITRACE_CONFIG_FILE environment variable to point to it
  - Override environment with command line arguments

- Sampling the Python™ and C/C++ parts of the code
  - omnitrace-python-3.8 -c <configuration path>/omnitrace.cfg – script.py"
  - omnitrace-sample --trace –c <configuration path>/omnitrace.cfg -- python –u ./scripts.py
  - Match omnitrace-python with your Python version.

Example 09-10

Omniperf

- Obtain detail kernel performance counters
  - https://github.com/AMDResearch/omniperf
  - OpenSUSE 15.4 build mainly compatible with LUMI environment
- Module files to help assist, e.g.

```
module use /pfs/lustrep2/projappl/project_462000125/samantao-public/mymodules
module load rocm/5.5.3 omniperf/1.0.10-rocm-5.5.x
```

- Configuration and build:
  - Omniperf requirements must be installed in a Python version and environment compatible with the one used by the target app.
  - E.g. make sure omniperf requirements exist within same conda environment.
  - Sampling the Python and C/C++ parts of the code
- Omniperf needs replaying the application
  - Complicated to profile individual ranks as all need replaying.
- Profile with:
  - omniperf profile -n pytorch --device 0 --roof-only -- $(which python) -u
- Analyze with:
  - omniperf analyze -p workloads/pytorch/mi200/ --gui

Example 11

Rocgdb

- Debugging requires proper driver support: can’t run debugger effectively from incompatible containers.
- https://github.com/ROCm-Developer-Tools/ROCgdb/
  - Branches for given ROCm releases: e.g. rocm-5.2.x
- Two main use cases
  - Connecting into a hanging process
  - Progress up to breakpoint or segfault
- ROCm provides rocgdb – you may need your own gdbserver.
- Using gdbserver is possible
  - gdbserver can be issued conveniently as a profile tool
  - Launch with:
    - gdbserver --once $(hostname):12345 ./my_command
  - Attach with
    - rocgdb -x gdb.commands ./my_command
  - Leverage gdb commands file to automate startup
    - target remote target_host:12345
- Examples:
  - Hanging in collective (RCCL)
- Limitations
  - GPU pending breakpoints over gdbserver may not work.
- Staring session in specific nodes to attach
  - srun --interactive --pty /bin/bash (only works for first node of allocation)
  - srun --pty --jobid <jobid> -w <target_node> --mem=0 --oversubscribe –interactive -n 1 -c 63 --gpus-per-task=0 /usr/bin/bash (GPU’s won’t be visible)

Example 12

Wave details

```
agent-id:queue-id:dispatch-num:wave-id (work-group-x,work-group-y,work-group-z)/work-group-thread-index
```

```
(gdb) i th
  Id   Target Id                                         Frame
  1    Thread 0x7ffff7fe6e80 (LWP 16912) "saxpy" 0x00007fffee0fc4c0 in rocr::core::InterruptSignal::
t) () from /opt/rocm-5.2.0/lib/libhsa-runtime64.so.1
  2    Thread 0x7fffed428700 (LWP 16916) "saxpy" 0x00007ffff5e1972b in ioctl () from /lib64/libc.so.
  4    Thread 0x7fffecaff700 (LWP 16938) "saxpy" 0x00007fffee0fc4af in rocr::core::InterruptSignal::
t) () from /opt/rocm-5.2.0/lib/libhsa-runtime64.so.1
* 5    AMDGPU Wave 1:2:1:1 (0,0,0)/0 "saxpy"     saxpy (n=256, x=0x7fffec700000, incx=1, y=0x7fffec7
  6    AMDGPU Wave 1:2:1:2 (0,0,0)/1 "saxpy"     saxpy (n=256, x=0x7fffec700000, incx=1, y=0x7fffec7
  7    AMDGPU Wave 1:2:1:3 (1,0,0)/0 "saxpy"     saxpy (n=256, x=0x7fffec700000, incx=1, y=0x7fffec7
  8    AMDGPU Wave 1:2:1:4 (1,0,0)/1 "saxpy"     saxpy (n=256, x=0x7fffec700000, incx=1, y=0x7fffec7
```

agent (GPU) ID

(HSA) queue ID

dispatch number

wave ID

workgroup (x, y, z)

wave ID (within group)

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