



Scalability of Deep Learning Frameworks

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HPC readiness of Deep Learning Frameworks

Author	Framework	Distributed Communication Mechanism	Link
Google	Tensorflow 1.10	Parameter Server + MPI allreduce using Uber's Horovod https://eng.uber.com/horovod/	https://www.tensorflow.org/deploy/distributed
Facebook	Caffe2	MPI rendezvous using Facebook's Gloo https://caffe2.ai/docs/distributed-training.html	https://caffe2.ai
Google	Tensorflow 2.0	Launches in 2019. High expectation of MPI rendezvous still working	https://www.tensorflow.org/deploy/distributed
Facebook AI Research, Twitter, Uber, NVIDIA and many others	Pytorch 1.0 (Pytorch + Caffe2)	Launches in 2019. MPI rendezvous using Gloo https://github.com/facebookincubator/gloo	https://pytorch.org/2018/05/02/road-to-1.0.html
Apache	MXNet	No MPI rendezvous yet. But found a feature request! The progress can be tracked here: https://github.com/apache/incubator-mxnet/pull/10696	https://mxnet.apache.org
Open Source	Keras	High-level deep learning API which works on top of TensorFlow, Microsoft Cognitive Toolkit and Theano. Uses Distributed backend from them.	https://keras.io

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MILA	Theano	An implementation exists on mpi4py, can perform multi-node multi-gpu distribution using MPI https://github.com/uoguelph-mlrg/Theano-MPI	http://deeplearning.net/software/theano/
Microsoft	Cognitive Toolkit (CNTK)	HPC ready! It also had examples for multi-node and multi-GPUs training. https://docs.microsoft.com/en-us/cognitive-toolkit/multiple-gpus-and-machines	https://www.microsoft.com/en-us/cognitive-toolkit/
IBM	Watson Machine Learning	It is a cloud-based enterprise platform similar to AWS	https://www.ibm.com/cloud/machine-learning
CMU (Acquired by Apple)	Turi	No MPI rendezvous yet	https://turi.com
Preferred Networks	Chainer	Have developed a package for Distributed Deep Learning called ChainerMN. Trained ImageNet dataset on ResNet-50 network in 15 minutes, which is four times faster than the previous record held by Facebook. https://github.com/chainer/chainermn	https://chainer.org
Amazon	DSSTNE	Does not have multi-node support	https://github.com/amzn/amazon-dsstne

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H2O.ai	H2O	Has a distributed product called Deep Water, which doesn't seem to use MPI, probably uses shared location for communication. Poorly documented! https://github.com/h2oai/deepwater	https://www.h2o.ai
Facebook, Google Deepmind	Torch	An implementation by Facebook AI Research that can perform multi-node multi-gpu distribution using MPI. https://github.com/facebookresearch/TorchMPI	http://torch.ch
CMU	DyNet	This is a pull request that successfully provided Multi-node support to DyNet. Doesn't seem to use MPI though https://github.com/clab/dynet/pull/704	http://dynet.io
Artelnics	OpenNN	Uses MPI	http://www.opennn.net
Apache	SINGA	Uses MPI! https://svn.apache.org/repos/infra/websites/production/singa/content/v0.1.0/communication.html	https://singa.apache.org/en/index.html
Hao Dong	TensorLayer	Another Wrapper Library on top of TensorFlow. Supports MPI. https://github.com/tensorlayer/tensorlayer/tree/master/examples/distributed.training	https://tensorlayer.readthedocs.io/en/stable/
Baidu	PaddlePaddle	Uses Parameter Server and MPI rendezvous https://github.com/PaddlePaddle/Paddle	http://www.paddlepaddle.org/en

Initial Quest



Motivation behind evaluating Caffe2

facebook

announced they have trained

ResNet-50

on

IMAGENET

with a minibatch size of 8192 using 256 GPUs

in just 1 hour

using



and



- Search for Deep Learning Frameworks that have options for distributed training using MPI
- Building Caffe2 (and it's dependencies) without MPI for a single GPU node

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- Building Caffe2 using Docker (Gloo+MPICH)

Download an image with CUDA and cuDNN support

Screenshot of a Docker Hub repository page for `caffe2ai/caffe2`.

The page includes:

- PUBLIC REPOSITORY**
- caff2ai/caffe2** (with a star icon)
- Last pushed: a year ago
- Repo info** (selected) and **Tags** tabs
- Short Description**: Deep Learning Framework with Python for flexibility and C++ for speed.
- Docker Pull Command**: `docker pull caffe2ai/caffe2`
- Full Description**: Note: use `nvidia-docker` to run all GPU builds.
- Owner**:  **caff2ai**
- Latest** build information:
 - `docker pull caffe2ai/caffe2`
 - Comes with GPU support, CUDA 8.0, cuDNN 7, all options, and tutorial files. Uses Caffe2 v0.8.1.
- GPU images (for use with nvidia-docker)**: All GPU builds come with Ubuntu 16.04 and fully loaded with optional dependencies like OpenCV. Minimal builds and Ubuntu 14.04 can be found in the CPU section.
 - Caffe2 v0.8.1, CUDA 8, cuDNN 7: `docker pull caffe2ai/caffe2:c2v0.8.1.cuda8.cudnn7.ubuntu16.04`
 - Caffe2 v0.8.0, CUDA 8, cuDNN 6: `docker pull caffe2ai/caffe2:c2v0.8.0.cuda8.cudnn6.ubuntu16.04`
 - Caffe2 v0.7.0, CUDA 8, cuDNN 6: `docker pull caffe2ai/c2.cuda8.cudnn6.ubuntu16.04`
 - Caffe2 v0.7.0, CUDA 8, cuDNN 5: `docker pull caffe2ai/c2.cuda8.cudnn5.ubuntu16.04`

Or build it from a dockerfile

<https://github.com/pytorch/pytorch/blob/master/docker/caffe2/ubuntu-16.04-cuda8-cudnn7-all-options/Dockerfile>

```
1  FROM nvidia/cuda:8.0-cudnn7-devel-ubuntu16.04
2  LABEL maintainer="baronmarkham@fb.com"
3
4  # caffe2 install with gpu support
5
6  RUN apt-get update && apt-get install -y --no-install-recommends \
7      build-essential \
8      cmake \
9      git \
10     libbflags-dev \
11     libgoogle-glog-dev \
12     libgtest-dev \
13     libim2p-dev \
14     libleveldb-dev \
15     liblmdb-dev \
16     libopencv-dev \
17     libopenmpi-dev \
18     libprotobuf-dev \
19     libsnappy-dev \
20     openmpi-bin \
21     openmpi-doc \
22     protobuf-compiler \
23     python-dev \
24     python-numpy \
25     python-pip \
26     python-pydot \
27     python-setuptools \
28     python-scipy \
29     wget \
30     && rm -rf /var/lib/apt/lists/*
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52 ##### INSTALLATION STEPS #####
53 RUN git clone --branch master --recursive https://github.com/pytorch/pytorch.git
54 RUN cd pytorch && mkdir build && cd build \
55     && cmake .. \
56     -DCUDA_ARCH_NAME=Manual \
57     -DCUDA_ARCH_BIN="35 52 60 61" \
58     -DCUDA_ARCH_PTX="61" \
59     -DUSE_NNPACK=OFF \
60     -DUSE_ROCKSDB=OFF \
61     && make "-j$(nproc)" install \
62     && ldconfig \
63     && make clean \
64     && cd .. \
65     && rm -rf build
66
67 ENV PYTHONPATH /usr/local
```

Replace these with equivalent
MPICH libraries

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- Building Caffe2 using Docker (Gloo+MPICH) : Failed (Runtime Error)

Current state of Distributed Caffe2

- We changed the source code for Caffe2 and Gloo, so that they can be compiled with MPICH
- After resolving several issues with the build process, we reached a dead end when we met a **SIGSEGV** error caused by one of the binary files in Gloo
- We raised a case with the Caffe2 developers on Github. One of the prominent contributors from Facebook AI Research team replied:

gyani91 changed the title from [Issue] Unable to use MPI rendezvous in Caffe2 to [Caffe2] Unable to use MPI rendezvous in Caffe2 11 days ago

teng-li commented 11 days ago • edited

Contributor + ...

We are writing the new distributed backend for Caffe2 and pytorch. We can make this one of the init_method.

1 like

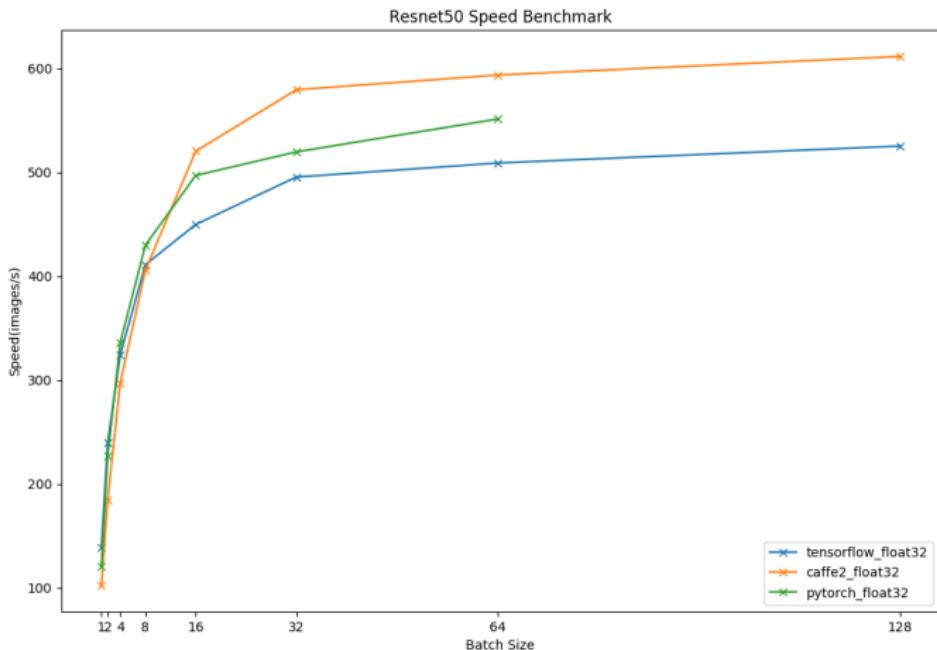
This screenshot shows a GitHub issue comment. The user gyani91 has changed the title from "[Issue] Unable to use MPI rendezvous in Caffe2" to "[Caffe2] Unable to use MPI rendezvous in Caffe2". Below this, another user, teng-li, has commented 11 days ago, mentioning they are writing a new distributed backend for Caffe2 and pytorch, and that this could be one of the init_methods. There is a like button with 1 like.

Conclusion regarding Caffe2

- Caffe2 has poor version control. TensorFlow has gone through 11 major version changes from TensorFlow 1.0 to 1.10 in a matter of $1\frac{1}{2}$ years. While Caffe2 neither have any sub versioning nor it has any **pip packages** that you can install. You always have to `git clone --recursive` and then make it using cmake. It works somedays, and on other days you have to find git checkouts from a few days back in order to have a buildable version
- Facebook has just announced that they would be combining both their deep learning libraries *Caffe2* and *Pytorch* to a single library called **Pytorch 1.0**. The fast changing source code and the improper version control are the major reasons for the distributed backends of both these libraries not currently working

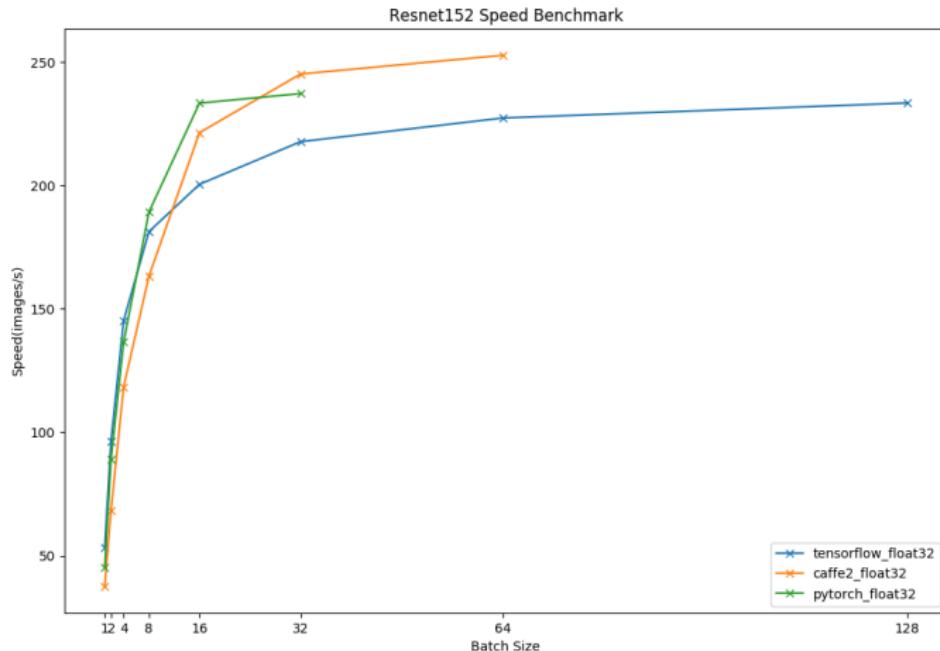
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- Running benchmark on a single node of Piz Daint

Performance benchmark of TensorFlow, Caffe2 and Pytorch



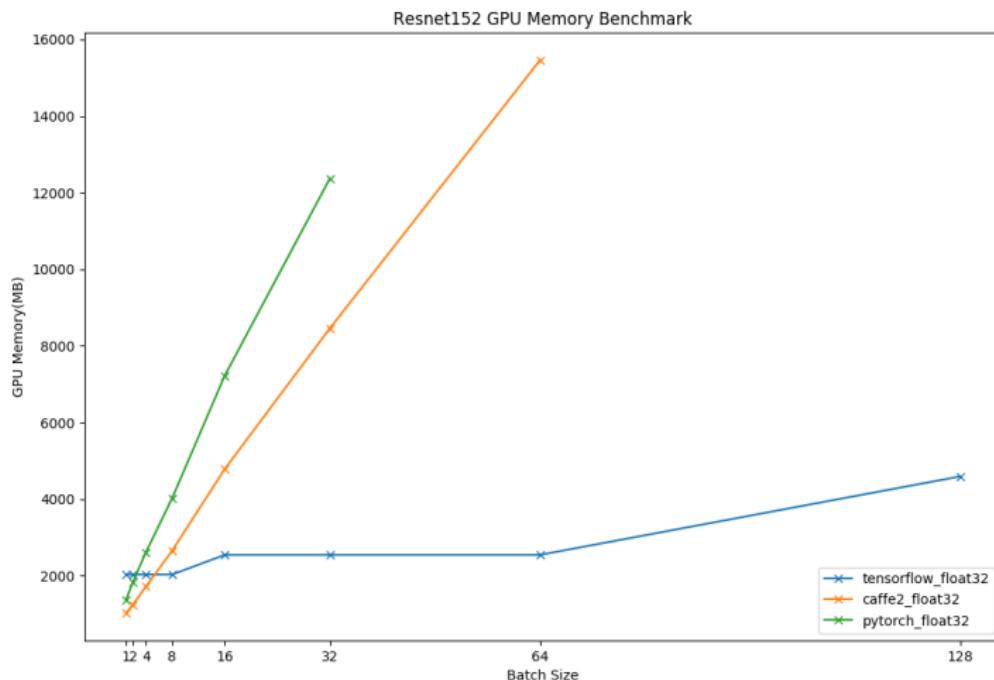
1 GPU node of Piz Daint has 1 Tesla P100-PCIE-16GB

Performance benchmark of TensorFlow, Caffe2 and Pytorch



1 GPU node of Piz Daint has 1 Tesla P100-PCIE-16GB

Memory requirement of TensorFlow, Caffe2 and Pytorch



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- Running benchmark on a single node of Piz Daint
- Building an alternative communication framework

Communication Frameworks for Deep Learning Libraries





Compiled for Tensorflow 1.3.0

Tensorflow

Proprietary Software

Need expertise to scale your existing code

For instance, several changes were made to `tf_cnn_benchmarks` scripts in order to run the scalability tests. The changes can be found at

`/opt/cray/pe/craype-ml-plugin-py3/
1.0.1/examples/tf_cnn_benchmarks`

`--variable_update=ps_ml_comm`



Tensorflow 1.10.0 (**always latest**)

Tensorflow, Keras & Pytorch

Open Source

Easier to scale your code due to help from deep learning frameworks

For instance, in order to run benchmarks with `tf_cnn_benchmarks` scripts

`--variable_update=horovod`

Easily built using the Dockerfile

<https://github.com/uber/horovod/blob/master/Dockerfile>

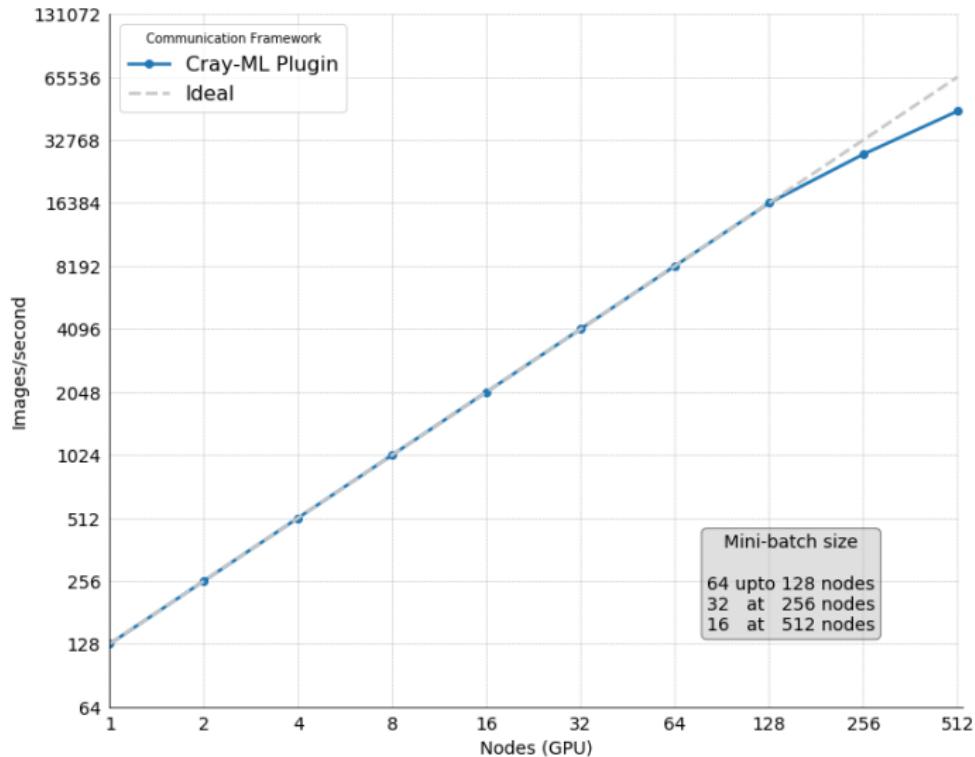
```
# Install Open MPI
RUN mkdir /tmp/openmpi && \
    cd /tmp/openmpi && \
    wget https://www.open-mpi.org/software/ompi/v3.0/downloads/openmpi-3.0.0.tar.gz && \
    tar zxf openmpi-3.0.0.tar.gz && \
    cd openmpi-3.0.0 && \
    ./configure --enable-orterun-prefix-by-default && \
    make -j $(nproc) all && \
    make install && \
    ldconfig && \
    rm -rf /tmp/openmpi
```



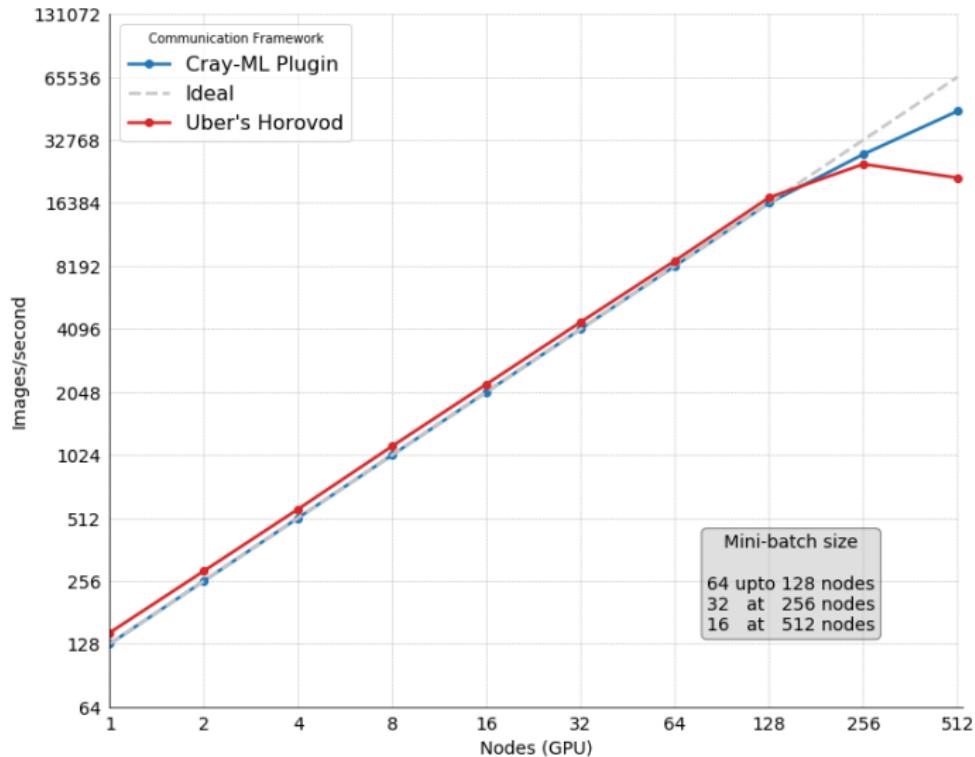
```
# Install mpich
RUN wget -q http://www.mpich.org/static/downloads/3.1.4/mpich-3.1.4.tar.gz \
    && tar xf mpich-3.1.4.tar.gz \
    && cd mpich-3.1.4 \
    && ./configure --disable-fortran --enable-fast=all,03 --prefix=/usr \
    && make -j$(nproc) \
    && make install \
    && ldconfig \
    && cd .. \
    && rm -rf mpich-3.1.4 \
    && rm mpich-3.1.4.tar.gz
```

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- Running benchmark on a single node of Piz Daint
- Building an alternative communication framework : Successful
- Running benchmark for Horovod on Piz Daint

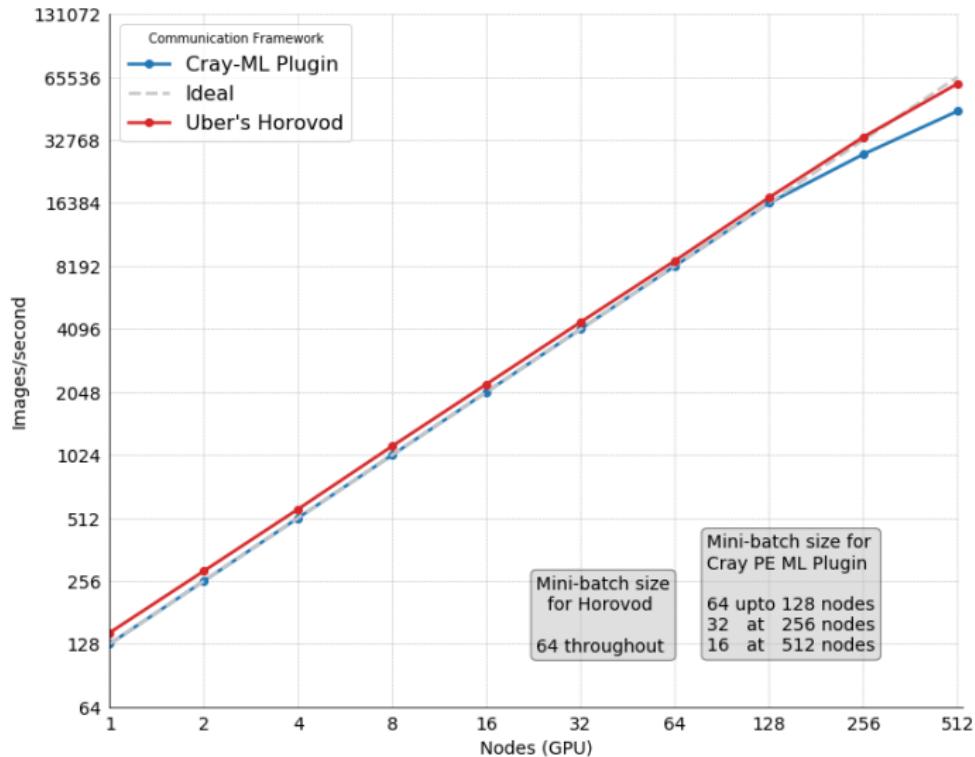
Cray PE ML Plugin's Performance in training Inception v3 with TensorFlow on Piz Daint



Horovod's Performance in training Inception v3 with TensorFlow on Piz Daint

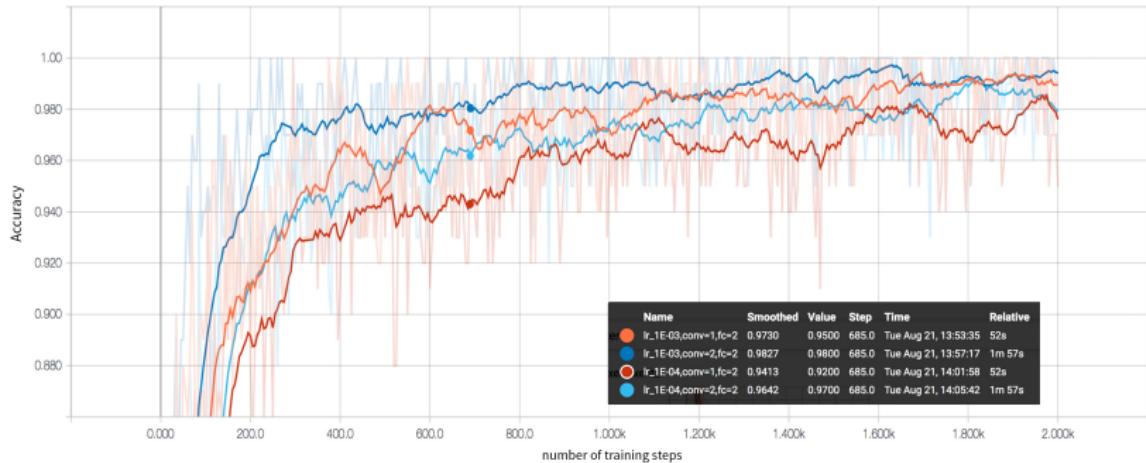


Horovod's Performance in training Inception v3 with TensorFlow on Piz Daint



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- Running benchmark on a single node of Piz Daint
- Building an alternative communication framework : Successful
- Running benchmark for Horovod on Piz Daint
- Impact on accuracy while scaling

Accuracy on a single node of Piz Daint



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- Running benchmark on a single node of Piz Daint
- Building an alternative communication framework : Successful
- Running benchmark for Horovod on Piz Daint
- Impact on accuracy while scaling : To be continued...

Conclusions

- Caffe2 is faster than TensorFlow (at least on a single node) but at the same time it is very resource greedy and has a much higher memory requirement than that of TensorFlow
- Distributed training in Caffe2 and Pytorch are not worth exploring until we get proper benchmarks from Facebook AI Research after they have launched Pytorch 1.0
- Getting these benchmarks still doesn't guarantee that Pytorch 1.0 would work with MPICH
- Horovod is a great alternative to Cray PE ML Plugin. It has the support of major Deep Learning Frameworks. It is open source, which means it would be rigorously used and contributed to

- dicarboxylate
 $\text{HA} = \text{molecule}$
 $\nabla V(r) \psi(r)$
 E_{Vdw}
 $\Delta P = \frac{\partial P}{\partial V} = \frac{F}{dV} = \frac{F}{dA \cdot C}$
 $F(X) = -\nabla U(X) = M V(t)$
 $Q_j = \frac{d}{dt} \left(\frac{\partial U}{\partial X_j} \right)$
 import random
 guesses made = 0
 name = raw_input("Hello! \n")
 number = random.randint(1, 20)
 print "Well, fog, 1 and 20.", format(name)
 function $E = \frac{P^2}{2m} + V(r,t) =$
 $X = \text{float}(x)$ coordinates
 $E = \frac{P^2}{2m} + V(r,t) =$

Thank you for your attention :)