Opportunities of ML-based data analytics in ABCI

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INTRODUCTION OF ABCI SYSTEM
AIST Booth #2409

ABCI: Open Innovation Platform for advancing AI Research & Deployment

0.550 EFlops (FP16), 37.2 PFlops (FP64)
19.88 PFlops (Peak), Ranked #7 in Top500
14.423 GFlops/W, Ranked #4 in Green500
ImageNet training in 224 seconds (world record)

System (32 Racks)
Rack (17 Chassis)

Node Chassis (2 Compute Nodes)
Compute Node (4 GPUs, 2 CPUs)

Chips (GPU, CPU)

1088 Compute Nodes 4352 GPUs

GPU:
- 7.8 TFlops (FP64)
- 125 TFlops (FP16)

CPU:
- 1.53 TFlops (FP64)
- 3.07 TFlops (FP32)

TFlops:
- 34.2 TFlops (FP64)
- 506 TFlops (FP16)

PFlops:
- 68.5 PFlops (FP64)
- 1.01 PFlops (FP16)

GFlops/W:
- 1.16 PFlops (FP64)
- 17.2 PFlops (FP16)
- 0.55 EFlops (FP16)
# ABCI achieves ultra-dense packaged rack

<table>
<thead>
<tr>
<th>Organization</th>
<th>AAIC</th>
<th>TSUBAME3.0</th>
<th>ABCI</th>
<th>Summit</th>
<th>TPU 3.0 Pod</th>
</tr>
</thead>
<tbody>
<tr>
<td>Start of operation</td>
<td>2017</td>
<td>2017</td>
<td>2018</td>
<td>2018</td>
<td>2018</td>
</tr>
<tr>
<td>Number of nodes</td>
<td>50</td>
<td>540</td>
<td>1088</td>
<td>4608</td>
<td>unknown</td>
</tr>
<tr>
<td>Throughput</td>
<td>NVIDIA Tesla P100</td>
<td>NVIDIA Tesla P100</td>
<td>NVIDIA Tesla V100</td>
<td>NVIDIA Tesla V100</td>
<td>TPU 3.0</td>
</tr>
<tr>
<td>Processor (TP)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Number of TP</td>
<td>400</td>
<td>2160</td>
<td>4352</td>
<td>27648</td>
<td>unknown</td>
</tr>
<tr>
<td>Theoretical Perf. (FP64)</td>
<td>2.2 PF</td>
<td>12.2 PF</td>
<td>37.2 PF</td>
<td>200 PF</td>
<td>unknown</td>
</tr>
<tr>
<td>Theoretical Perf. (DL)</td>
<td>8.6 PF</td>
<td>47.2 PF</td>
<td>550 PF</td>
<td>3.3 EF</td>
<td>100 PF / Pod</td>
</tr>
<tr>
<td>TOP500*</td>
<td>287</td>
<td>19</td>
<td>5</td>
<td>1</td>
<td>unknown</td>
</tr>
<tr>
<td>GREEN500*</td>
<td>7</td>
<td>6</td>
<td>8</td>
<td>5</td>
<td>unknown</td>
</tr>
<tr>
<td>#Nodes / Rack</td>
<td>6</td>
<td>36</td>
<td>34</td>
<td>16</td>
<td>unknown</td>
</tr>
<tr>
<td>#GPU / Rack</td>
<td>48</td>
<td>144</td>
<td>136</td>
<td>96</td>
<td>unknown</td>
</tr>
<tr>
<td>kW / Rack</td>
<td>22 kW</td>
<td>64.8 kW</td>
<td>67.33 kW</td>
<td>45-55 kW (est.)</td>
<td>unknown</td>
</tr>
<tr>
<td>DL Perf. / Rack</td>
<td>0.9 PF</td>
<td>3.1 PF</td>
<td>17 PF</td>
<td>12 PF</td>
<td>12.5 PF (100 PF / 8 rack)</td>
</tr>
</tbody>
</table>

*June 2018
AI Datacenter
“Commoditizing supercomputer cooling technologies to Cloud (70kW/rack)”

- Single floor, cost effective building
- Hard concrete floor 2t/m² weight tolerance for racks and cooling pods
- Number of Racks
  - Initial: 90 (ABCI uses 41 racks)
  - Max: 144
- Power capacity: 3.25 MW
  - ABCI uses 2.3MW max
- Cooling capacity: 3.2MW
  - 70kW/rack: 60kW water + 10kW air
Free cooling with hybrid air/water cooling system
Optimizing AI data center operation using ML

Develop a framework for optimizing the operation of AI data center by self-adapting ML/DL technologies

World leading supercomputing systems for big data / AI

Data center generates huge amount of sensor data

Monitoring data (job log and facility sensor data)

Data analytics

Learning/Inference

Train and apply parameters for improving the operation

Data Store

• Reduce power consumption
• Improve resource utilization
• Reduce HW maintenance fee using failure prediction

Developing a framework for optimizing the operation of AI data center by self-adapting ML/DL technologies

Data-driven operation
Monitoring mechanism

Data Analytics / ML tools

Grafana

MariaDB

Prometheus (Time series DB)

Job logs, accounting info.

Sensors (server, facility)

ABCi Facility Monitoring through Grafana
# Collecting sensor data

<table>
<thead>
<tr>
<th>Location</th>
<th>#items</th>
<th>Sampling rate</th>
<th>Sensors</th>
</tr>
</thead>
<tbody>
<tr>
<td>Server</td>
<td>873</td>
<td>1 min.~1 hour</td>
<td>CPU/GPU usage, memory usage, I/O usage, temperature, power consumption, etc</td>
</tr>
<tr>
<td>IB/Ethernet</td>
<td>6245</td>
<td>1 min.~1 hour</td>
<td></td>
</tr>
<tr>
<td>Switch</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Job scheduler</td>
<td>26</td>
<td>-</td>
<td>Job ID, account ID, group ID, job type, resource type, walltime, application info., etc</td>
</tr>
<tr>
<td>AI data center</td>
<td>408</td>
<td>1 sec.</td>
<td>Temperature (hot/cold aisle), rack inlet air temperature, humidity, power consumption</td>
</tr>
<tr>
<td>Site</td>
<td>8</td>
<td>1 min.</td>
<td>Water temperature, volume of water flow, power consumption of pump, status, CDU</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Temperature, humidity, wind speed/direction, rainfall</td>
</tr>
</tbody>
</table>
# ABCI Software Stack

## Software

<table>
<thead>
<tr>
<th>Category</th>
<th>Details</th>
</tr>
</thead>
<tbody>
<tr>
<td>Operating System</td>
<td>CentOS, RHEL</td>
</tr>
<tr>
<td>Job Scheduler</td>
<td>Univa Grid Engine</td>
</tr>
<tr>
<td>Container Engine</td>
<td>Docker, Singularity</td>
</tr>
<tr>
<td>MPI</td>
<td>OpenMPI, MVAPICH2, Intel MPI</td>
</tr>
<tr>
<td>Deep Learning</td>
<td>Caffe, Caffe2, TensorFlow, Theano, Torch, PyTorch, CNTK, MXnet, Chainer, Keras, etc.</td>
</tr>
<tr>
<td>Big Data Processing</td>
<td>Hadoop, Spark</td>
</tr>
</tbody>
</table>

## Container support

- Containers enable users to instantly try the state-of-the-art software developed in AI community.
- ABCI supports two container technologies:
  - **Docker**, having a large user community
  - **Singularity**, recently accepted HPC community
- ABCI provides various single-node/distributed deep learning framework container images optimized to achieve high performance on ABCI
Use Case 1:

EFFICIENT FACILITY CONTROL
100% free cooling is possible in high summer

- The first ABCI grand challenge was held on 22-26 July 2018.
- The peak power consumption reached about 1.5MW.

Cooling Water (From ABCI): <40°C

Cooling Water (To ABCI): <32°C

Max./min. temperature in Kashiwa in July 2018
Use case 1: More efficient and smarter facility control

- Cooling towers cannot so quickly adjust the water temperature with server load fluctuation.
  - The longer water circuit loop, the slower response.
  - In some HPC/data centers, it might be serious.
- There is a chance of applying ML to improve utilization.
  - Workload prediction is enable to generate cooler water before coming heavy workload. That means...
  - Job scheduler executes more jobs under temperature constraint
  - GPU/CPU runs more higher frequency.
Use case 2:

EFFICIENT JOB SCHEDULING
Preliminary data analysis for efficient deep learning job scheduling in AAIC (prototype system of ABCI)

- Analyze 55,127 jobs submitted on AAIC from 07/14/2017 to 12/31/2017
- 95% jobs are Single GPU jobs and WRA is too low, 0.103 on average.

1 GPU/ Multi GPU / Multi Node Jobs

1 Node, Multi GPU Jobs

Multi Node Jobs

Walltime Request Accuracy (WRA)

\[
WRA_i = \frac{\text{Walltime}_i}{\text{Walltime Request}_i}
\]
Use case 2: Efficient job scheduling

- Predicting job execution time and user incentive design to improve WRA are important for efficient job scheduling.

Machine Learning Predictions for Underestimation of Job Runtime on HPC System [Guo2018]

Predicting Performance Using Collaborative Filtering [Salaria2018]

Collaborative filtering (CF) based algorithms handle this by identifying inter-dependencies linking benchmarks with systems.
Use case 2: Efficient job scheduling

- Future work: Job scripts contain important information including package dependencies, program parameters, container image, which will greatly affect the efficiency and execution time of jobs.
  - E.g., Use CNN to process job scripts [Wyatt2018]
Thank you for your attention!

More Information is available! https://abci.ai/

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