Acceleration of Deep Learning using Intel® Distribution of OpenVINO™ toolkit: 3D Seismic Case Study

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September 2020
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experiences

DEVELOPER TOOLS
App Developers
SW Platform Developer

TOPOLOGIES & MODELS
Data Scientist

FRAMEWORKS
Data Scientist

GRAPH
ML Performance Engineer

KERNEL
ML Performance Engineer

MACHINE LEARNING
Intel Distribution for Python
(Sklearn, Pandas)

DEEP LEARNING
TensorFlow
PyTorch

MANAGEMENT TOOLS
Containers

Containers

Deep Learning
Reference Stack

Deep Learning
Reference Stack

Architect & DevOps

Managed Stack

Metal Stack

CPU = GPU = FPGA = DEDICATED

Intel® Math Kernel Library

Intel® Data Analytics Acceleration Library
(Intel DAAL)

Intel® Machine Learning Scaling Library (Intel MLL)

Intel® Deep Neural Network Library (DNNL)

Intel® Movidius Stack

Intel® System Studio

Intel® SDK for OpenCL™ Applications

Intel® Media SDK

Intel® Parallel Studio XE

Intel® Distribution for Python

Intel® Distribution for OpenVINO™ toolkit

Intel® nGraph™ Compiler

Intel® Parallel Studio XE

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Seismic Analysis is the estimation of shapes and physical properties of Earth’s subsurface layers from the returns of sound waves that are propagated through the Earth.

HPC-AI convergence on CPUs

- Perform Inference where your data is
- Eliminate moving and staging large volumes (in Petabytes) of seismic data
- Eliminate data silos
Objective: General purpose Intel® Xeon® can be used for both HPC and AI workloads in oil and gas – show optimization in AI pipeline

• Full stack solution: Increase performance of DL models for oil & gas datasets on Intel® Xeon® processor using Intel® Distribution of OpenVINO™ toolkit

• A well-cited 3D seismic use-case was used to show this performance boost
Tool Suite for High-Performance, Deep Learning Inference

Faster, more accurate real-world results using high-performance, AI and computer vision inference deployed into production across Intel® architecture from edge to cloud

1. **Build**
   - Trained Model
   - Open Model Zoo
     - 100+ open sourced and optimized pre-trained models; 80+ supported public models

2. **Optimize**
   - Model Optimizer
     - Converts and optimizes trained model using a supported framework
   - IR Data
     - Intermediate Representation (.xml, .bin)
   - Read, Load, Infer

3. **Deploy**
   - Inference Engine
     - Common API that abstracts low-level programming for each hardware
   - Deployment Manager
   - Code Samples & Demos
     - (e.g. Benchmark app, Accuracy Checker, Model Downloader)
The Compounding Effect of Both Hardware and Software

Improvements Means Exponential Performance

- Baseline Performance
- Additional Software Performance

Comparison of Frames Per Second utilizing Mobilenet SSD, Batch 1.

The Compounding Effect in Production Deployment

Powered by the Intel® Distribution of OpenVINO™ toolkit

Improvements made by pairing together Intel® architecture-based systems and deep learning acceleration powered by the Intel® Distribution of OpenVINO™ toolkit

- Sewer pipe inspection analysis
  - Inference time was improved with a reduction of up to 80% using Intel Xeon processors with the OpenVINO toolkit

- Cardiac Examination
  - Cardiac magnetic resonance imaging (MRI) exams to evaluate heart function, heart chamber volumes and myocardial tissue accelerated by 5.5X. Learn more

- Medical Imaging
  - Medical imaging accelerated bone age prediction model by 188X and lung segmentation model by 38X in inference performance. Learn more

- Security Against Social and Digital Attacks
  - Performance improvements of up to 2.3x faster, reducing latency by up to 50 percent for threat detection and remediation to protect businesses against targeted social and digital attacks.

- Operational Improvement
  - 11X increase in performance on Intel® architecture and 19X with Intel® Vision Accelerator that lead to operational improvements in manufacturing. Learn more

- Autonomous Sea Navigation
  - Autonomous and assisted sea navigation for autonomous ships delivered 4.8X image throughput compared to unoptimized baseline. Learn more

Success Stories ➤ https://intel.com/openvino-success-stories

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Deep Learning Seismic Workflow

Seismic Data Collection

Data labeling, DL Model Selection & Training

DL Inference (Salt-body identification) via Intel® Distribution of OpenVINO™
toolkit

Pre-trained Model

Model Optimizer (MO)

Inference Engine (IE)

Training

Inference/Deployment

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Use-case: Salt Identification in 3D Seismic

• Data used
  • 3D seismic data of F3 Dutch block

Source: dGB

• Model used
  • CNN for ASI by Waldeland, 2018*

Why Salts are important:

- Salt-bodies are important subsurface structures with significant implications for hydrocarbon accumulation and sealing in offshore petroleum reservoirs.
- If Salts are not recognized prior to drilling, they can lead to number of complications if encountered unexpectedly while drilling the well.

Figure is modified from: https://www.sciencedirect.com/topics/earth-and-planetary-sciences/salt-dome
The full 3D cube is partitioned into smaller mini cubes of $65 \times 65 \times 65$ samples, which are input into the network – to predict the class of the center pixel.

## Performance Result

<table>
<thead>
<tr>
<th>CNN model</th>
<th>System type</th>
<th>OpenVINO™ used (base model)</th>
<th>Inference time* (ms)</th>
<th>Numerical difference in accuracy between OpenVINO™ and base model</th>
</tr>
</thead>
<tbody>
<tr>
<td>5 layers of 3D convolutions</td>
<td>Intel Xeon Gold 6252 CPU @ 2.10 GHz (24 cores)</td>
<td>No (PyTorch)</td>
<td>70.20</td>
<td>1.1445E-05</td>
</tr>
<tr>
<td>(PyTorch model)</td>
<td></td>
<td>Yes</td>
<td>4.14</td>
<td></td>
</tr>
</tbody>
</table>

*Inference time for one 65*65*65 cube

- Intel® Distribution of OpenVINO™ toolkit provides over 15X boost on 2\textsuperscript{nd} generation Xeons
- Details of benchmarking:
  - Data used: 1 Gb 3D seismic data of F3 Dutch block
  - OpenVino: 2019 R2 release (latest version)
  - Python version: 3.6
  - Py-torch version: 1.1.0
  - Cuda version 9.90
  - Compiler : GCC 7.4.0
  - OS: Ubuntu

Configurations and benchmark details can be found on Appendix 1. For more complete information about performance and benchmark results, visit www.intel.com/benchmarks. Performance results are based on testing as shown in configuration and may not reflect all publically available security updates. No product can be absolutely secure. See configuration disclosure for details. Optimization Notice: Intel's compilers may or may not optimize to the same degree for non-Intel microprocessors for optimizations that are not unique to Intel microprocessors. These optimizations include SSE2, SSE3, and SSSE3 instruction sets and other optimizations. Intel does not guarantee the availability, functionality, or effectiveness of any optimization on microprocessors not manufactured by Intel. Microprocessor-dependent optimizations in this product are intended for use with Intel microprocessors. Certain optimizations not specific to Intel microarchitecture are reserved for Intel microprocessors. Please refer to the applicable product User and Reference Guides for more information regarding the specific instruction sets covered by this notice.
**Performance Result**

### Performance boost using OpenVINO™

- **2nd Gen Intel Xeon CPU**
- **Intel Distribution of OpenVINO Toolkit + 2nd Gen Intel Xeon CPU**

**Size of inference cube (65*65*65)**

- **Inference time (s) for 1 cube**

<table>
<thead>
<tr>
<th>Inference time (s) for 1 cube</th>
</tr>
</thead>
<tbody>
<tr>
<td>No OpenVINO™</td>
</tr>
<tr>
<td>With OpenVINO™</td>
</tr>
</tbody>
</table>

**Optimization Techniques**

- Node merging, Constant folding, Horizontal fusion, Batch Norm fusion, Fold Scale Shift convolutions, Dropout
- Fp16/Int8 quantization
- Can add scaling, normalization, cut sub-graphs

**Concern:** Do we want int8 for seismic?
- Larger tiles boosts accuracy far exceeding the loss from quantization
- DL Boost Technology (VNNI) in 2\(^{nd}\) gen
  - Int8 convolutions – not utilized yet

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Intel R&D: Small V/S Large Tiles — Accuracy is Better With Larger!

"Tiling the input to CNN models—while perhaps necessary to overcome the memory limitations in computer hardware—may lead to undesirable and unpredictable errors”

https://www.ncbi.nlm.nih.gov/pmc/articles/PMC7020775/
Larger Seismic tile gives better definition for Inference

- Larger tiles boost accuracy
- Spatial context is imp in seismic

Research:
- Int8 performance on seismic: blog 3 in Resource slide
- Int8 on larger tiles! – white paper coming

Key Takeaway

The general-purpose 2nd generation Intel® Xeon® Scalable Processor together with Intel® Distribution of OpenVINO™ toolkit provides DL performance that is well suited for Oil and Gas datasets

- Use OpenVINO™ toolkit to boost inference performance for oil and gas datasets on Intel® Xeon® processor
- Int 8 quantization with larger tiles on 2nd generation Intel® Xeon® processor gives even better performance boost for seismic data – see blog 3 in Resources slide
- Scale DL on existing CPUs that are used for HPC
- Use CPUs for other workloads when not doing DL
Resources for OpenVINO™ toolkit

OpenVINO™ toolkit guide

Download OpenVINO™ toolkit

Resource for Seismic

Seismic model used in this work

Blogs published on OpenVINO™ toolkit + seismic

Blog 1: Accelerating fault detection in 3D Seismic

Blog 2: Accelerating seismic Interpretation using OpenVINO™

Blog 3: Lower Precision Pipeline for Seismic Interpretation

2020 Embedded Vision Summit

Intel Booth
Workshops and demos to visit

General Session Speaker:
- Bill Pearson, VP IOTG, GM Developer Enabling, Intel, Tuesday, September 15, 10:00 a.m. to 10:30 a.m. PDT: Streamline, Simplify and Solve for the Edge of the Future

In-depth technical workshops
- Friday, September 18, 9:00 a.m. to 1:30 p.m. PDT: Using the Intel® Distribution of the OpenVINO™ Toolkit for Deploying Accelerated Deep Learning Applications
- Monday, September 21, 9:00 a.m. to 1:30 p.m. PDT: Intel’s Edge AI for Retail
- Wednesday, September 23, 9:00 a.m. to 1:30 p.m. PDT: Intel’s Edge AI for Industrial

Technical presentations
- Alexander Kozlov, Deep Learning R&D engineer, Intel: Recent Advances in Post-Training Quantization
- Dr. Manas Pathak, Global AI lead for oil and gas, Intel: Acceleration of Deep Learning for 3D Seismic
- Gary Brown, Director of AI Marketing, Intel: Getting Efficient DL Inference Performance: Is It Really All About The TOPS?
- Rama Karamsetty, Edge AI Marketing Manager, Intel: Edge Inferencing-- Scaling w/ Vision Accelerator Cards
- Vaidyanathan Krishnamoorthy, edge inference solutions architect, Intel: Federated Edge Inferencing

Dedicated demos and networking space