Intel in HPC - Intel Software Development Tools

eXtreme XQCD
Bern
Aug 5th, 2013

Edmund Preiss
Manager Business Development, EMEA
Topics Covered Today

- Intel’s offerings to HPC
- Update on Intel Architecture Roadmap
- Overview on Intel Development Tools for (hybrid) HPC and SMP Systems
- Intel Development Support for Intel Xeon Processors and Intel Xeon Phi Coprocessor
  - Considerations of Porting existing X86 Applications
  - Programming Models
  - How to start with MIC Architecture
- More Details and Benefits of Intel Development Tools
Intel in HPC
The Three Pillars of Modern Science, Research & Engineering

 experimentation, observation

 theory

 numerical simulation

 HPC
Intel’s Assets for HPC

**Processors**
Intel® Xeon® Processor

**Co-Processor**
Intel® Many Integrated Core

**Network & Fabrics**

**Storage**

**Software & Services**

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Efficiency at Scale in Supercomputing

Top500* (1997 – 2012)

Driven by Moore’s Law and Architecture Innovation

1500X More Performance

100X Reduction $/FLOP

4X Power Increase

Source: Intel Analysis / Top500

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#1 TOP500 June 2013

54.9 PFLOPS – 33.8 PFLOPS HPL

'Milky Way-2' in Guangzhou, China
Intel Architecture Multicore and Manycore

<table>
<thead>
<tr>
<th>Core(s)</th>
<th>1</th>
<th>2</th>
<th>4</th>
<th>6</th>
<th>8</th>
<th>12</th>
<th>TBD</th>
</tr>
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<tbody>
<tr>
<td>Threads</td>
<td>2</td>
<td>2</td>
<td>8</td>
<td>12</td>
<td>16</td>
<td>24</td>
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</table>

**Intel® Xeon Phi™ Coprocessor** extends established CPU architecture and programming concepts to highly parallel applications.
Next Intel® Xeon Phi™ Processor: Knights Landing

- Designed using Intel’s cutting-edge 14nm process
- Not bound by “offloading” bottlenecks
- Standalone CPU or PCIe Coprocessor
- Leadership compute & memory bandwidth
- Integrated On-Package Memory

All products, computer systems, dates and figures specified are preliminary based on current expectations, and are subject to change without notice.

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Typical Platform with Intel® Xeon Phi Coprocessor

Intel® Xeon® Host Platform

IBA, 10GbE

Intel® Xeon Phi™ Co-Processor(s)

DDR3

QPI

x16 PCIe

1-2 CPUs per node

1-4 per node

GDDR5

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Intro to Intel Software Dev Tools & Usefulness for Intel Xeon and Intel Xeon Phi
Intel Development Tools for Diverse Needs

Shared Memory

MPI HPC-Cluster

Intel® Parallel Studio XE 2013 and Intel® Cluster Studio XE 2013

More Cores
Multicore (8+)
Many-Core (60)

Wider SIMD/Vector

Scaling Performance Efficiently
Serial
Task & Data Parallel
Distributed

Industry Leading Software Tools
High-Performance from advanced compilers
Comprehensive libraries
Parallel programming models
Insightful analysis tools

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### What are the Intel Development Components for?

<table>
<thead>
<tr>
<th>Phase</th>
<th>Product</th>
<th>Feature</th>
<th>Benefit</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Build</strong></td>
<td><strong>Intel® Advisor XE</strong></td>
<td>Threading design assistant (Studio products only)</td>
<td>• Simplifies, demystifies, and speeds parallel application design</td>
</tr>
<tr>
<td></td>
<td><strong>Intel® Composer XE</strong></td>
<td>• C/C++ and Fortran compilers • Intel® Threading Building Blocks • Intel® Cilk™ Plus • Intel® Integrated Performance Primitives • Intel® Math Kernel Library</td>
<td>• Enabling solution to achieve the application performance and scalability benefits of multicore and forward scale to many-core</td>
</tr>
<tr>
<td></td>
<td><strong>Intel® MPI Library†</strong></td>
<td>High Performance Message Passing (MPI) Library</td>
<td>• Enabling High Performance Scalability, Interconnect Independence, Runtime Fabric Selection, and Application Tuning Capability</td>
</tr>
<tr>
<td><strong>Verify</strong></td>
<td><strong>Intel® VTune™ Amplifier XE</strong></td>
<td>Performance Profiler for optimizing application performance and scalability</td>
<td>• Remove guesswork, saves time, makes it easier to find performance and scalability bottlenecks</td>
</tr>
<tr>
<td></td>
<td><strong>Intel® Inspector XE</strong></td>
<td>Memory &amp; threading dynamic analysis for code quality • Static Analysis for code quality</td>
<td>• Increased productivity, code quality, and lowers cost, finds memory, threading, and security defects before they happen</td>
</tr>
<tr>
<td></td>
<td><strong>Intel® Trace Analyzer &amp; Collector</strong></td>
<td>MPI Performance Profiler for understanding application correctness &amp; behavior</td>
<td>• Analyze performance of MPI programs and visualize parallel application behavior and communications patterns to identify hotspots</td>
</tr>
</tbody>
</table>

**Code Creation ➔ Performance ➔ Correctness & Stability**
Big Gains for Highly Parallel Applications

Highly parallel and vectorized applications will run even faster on Intel® Xeon Phi™ Coprocessors.

Most applications will still run best on multicore Intel® Xeon® processors.

Optimizing code often delivers significant performance gains.

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Highly Parallel Applications

Efficient vectorization, threading, and parallel execution drives higher performance for suitable applications.

Theoretical acceleration of a highly parallel processor over a Intel® Xeon® parallel processor (<1: Intel® Xeon® faster) – For illustration only.
DEMONSTRATED PERFORMANCE BENEFITS
Intel® Xeon Phi™ Coprocessor

Finite Element Analysis
- Sandia National Labs
- UP TO 2x

Seismic
- Acceleware 8th Order Isotropic Variable Velocity
- China Oil & Gas Geoeast Pre-stack Time Migration
- UP TO 2.23x
- UP TO 3.54x

1. 8 node cluster, each node with 2S Xeon® (comparison is cluster performance with and without 1 Xeon Phi® per node) (Hetero)
2. 2S Xeon® vs. 1 Xeon Phi® (preproduction HW/SW & Application running 100% on coprocessor (unless otherwise noted)
3. 2S Xeon® vs. 2S Xeon® + 2 Xeon Phi® (offload)
DEMONSTRATED PERFORMANCE BENEFITS
Intel® Xeon Phi™ Coprocessor

Embree Ray Tracing
Intel Labs Ray Tracing
SPEED-UP
2.11x

Physics
Jefferson Lab Lattice QCD
UP TO
2.7x

Finance
Black-Scholes SP
Monte Carlo SP
UP TO
7x
UP TO
10.75x

Notes:
1. 25 Xeon® vs. 1 Xeon Phi® (preproduction HW/SW & Application running 100% on coprocessor unless otherwise noted)
3. Includes additional FLOPS from transcendental function unit

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Single Source Code

Compiler Libraries Parallel Modes

Multicore

Many-core

Cluster

Eliminate Need for Dual Programming Software Architecture

For illustration only, potential future options subject to change without notice.

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Flexible Execution Models
Optimized Performance for all Workloads

- **Compilers, Libraries, Runtime Systems**

![Diagram](image_url)

- **MAIN()**
  - **XEON®**
  - **RESULTS**

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  - **XEON®**
  - **RESULTS**

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  - **RESULTS**

- **MAIN()**
  - **XEON®**
  - **RESULTS**

**Multicore Only**

**Multicore Hosted with Many-Core Offload**

**Symmetric**

**Many-Core Only (Native)**
How to get Started with Xeon Phi
Get Started

Download the programming guide to find out whether your workload can benefit from Intel® Xeon Phi™ coprocessors:

[software.intel.com/mic-developer](http://software.intel.com/mic-developer)

Link to Best Practices (for Xeon Phi)

<table>
<thead>
<tr>
<th>Resource</th>
<th>Link</th>
</tr>
</thead>
</table>
Books for Parallelisation and Xeon Phi Programming

*Structured Parallel Programming*
Michael McCool, Arch D. Robinson, and James Reinders,

*Intel Xeon Phi Coprocessor High Performance Programming*
Jim Jeffers and James Reinders (Morgan Kaufmann)
Books for Parallelisation and Xeon Phi Programming

*Parallel Programming and Optimization with Intel® Xeon Phi™ Coprocessors [517 Pages]*

Handbook on the Development and Optimization of Parallel Applications for Intel® Xeon® Processors and Intel® Xeon Phi™ Coprocessors

ISBN 9780988523418


*Parallel Programming with Intel Parallel Studio XE*

Handbook on the Development and Optimization of Parallel Applications for Intel X86 CPUs using Shared Memory Programming Models

( Textbook for Intel Parallel Studio XE )

2012, publisher: Worx
Highly recommended reading:

An Overview of Programming for Intel® Xeon® processors and Intel® Xeon Phi™ coprocessors

Submitted by James Reinders on Mon, 11/12/2012 - 12:59

http://software.intel.com/mic-developer
Key Elements of Intel Tools Functionality

• Performance Optimisation

• Parallelisation

• Correctness of Applications
# Fortran Compiler Comparison – Intel CPU (3rd party)

## Fortran Execution Time Benchmarks - 64-bit Scientific Linux on Intel Core i5 2500k

<table>
<thead>
<tr>
<th></th>
<th>Absoft</th>
<th>G95</th>
<th>GFortran</th>
<th>Intel</th>
<th>Lahey</th>
<th>PGI</th>
<th>Sun</th>
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<tr>
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<td>11.13</td>
<td>0.93</td>
<td>4.72</td>
<td>13.0</td>
<td>8.10b</td>
<td>12.9</td>
<td>8.6</td>
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<tr>
<td>AC</td>
<td>4.41</td>
<td>9.60</td>
<td>5.92</td>
<td>4.94</td>
<td>8.00</td>
<td>7.13</td>
<td>21.99</td>
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<td>AERMOD</td>
<td>11.95</td>
<td>25.99</td>
<td>18.99</td>
<td>10.53</td>
<td>11.27</td>
<td>11.91</td>
<td>10.30</td>
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<td>AIR</td>
<td>3.46</td>
<td>5.95</td>
<td>3.10</td>
<td>2.34</td>
<td>2.71</td>
<td>3.85</td>
<td>2.51</td>
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<tr>
<td>CHANNEL2</td>
<td>102.78</td>
<td>272.72</td>
<td>84.26</td>
<td>85.39</td>
<td>122.19</td>
<td>105.71</td>
<td>84.83</td>
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<td>DODUC</td>
<td>17.24</td>
<td>24.05</td>
<td>17.51</td>
<td>14.10</td>
<td>17.45</td>
<td>17.30</td>
<td>14.15</td>
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<td>FATIGUE2</td>
<td>68.78</td>
<td>374.38</td>
<td>101.73</td>
<td>72.12</td>
<td>110.88</td>
<td>87.30</td>
<td>75.28</td>
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<td>GAS_DYN2</td>
<td>84.14</td>
<td>320.04</td>
<td>86.71</td>
<td>69.01</td>
<td>107.03</td>
<td>66.20</td>
<td>84.39</td>
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<td>INDUCT2</td>
<td>73.67</td>
<td>147.53</td>
<td>66.57</td>
<td>67.00</td>
<td>93.29</td>
<td>118.24</td>
<td>125.91</td>
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<td>LINPK</td>
<td>5.57</td>
<td>6.21</td>
<td>5.77</td>
<td>4.88</td>
<td>5.67</td>
<td>5.37</td>
<td>5.11</td>
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<td>MDBX</td>
<td>8.88</td>
<td>8.88</td>
<td>7.32</td>
<td>6.03</td>
<td>7.85</td>
<td>8.35</td>
<td>7.41</td>
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<td>MP_PROP_DESIGN</td>
<td>74.41</td>
<td>419.95</td>
<td>103.67</td>
<td>60.22</td>
<td>126.05</td>
<td>86.13</td>
<td>161.97</td>
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<tr>
<td>NF</td>
<td>7.69</td>
<td>13.40</td>
<td>7.79</td>
<td>7.30</td>
<td>10.36</td>
<td>7.71</td>
<td>8.16</td>
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<tr>
<td>PROTEIN</td>
<td>19.88</td>
<td>27.43</td>
<td>20.33</td>
<td>18.12</td>
<td>35.68</td>
<td>20.75</td>
<td>20.44</td>
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<td>RNFLOW</td>
<td>13.77</td>
<td>25.90</td>
<td>15.47</td>
<td>11.67</td>
<td>14.58</td>
<td>16.66</td>
<td>15.72</td>
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<tr>
<td>TEST_FPU2</td>
<td>72.11</td>
<td>103.38</td>
<td>42.94</td>
<td>43.73</td>
<td>61.17</td>
<td>42.77</td>
<td>57.41</td>
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<td>TFFT2</td>
<td>55.10</td>
<td>60.04</td>
<td>54.16</td>
<td>53.49</td>
<td>55.74</td>
<td>55.36</td>
<td>55.07</td>
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| Geometric Mean | 22.18  | 43.13| 22.94    | 18.95 | 26.07 | 23.25| 25.04|

Source: [http://www.polyhedron.com](http://www.polyhedron.com)

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Intel Family of Parallel Programming Models

- **Intel® Cilk™ Plus**
  - C/C++ language extensions to simplify parallelism
  - *Open sourced & Also an Intel product*

- **Intel® Threading Building Blocks**
  - Widely used C++ template library for parallelism
  - *Open sourced & Also an Intel product*

- **Domain-Specific Libraries**
  - Intel® Integrated Performance Primitives
  - Intel® Math Kernel Library

- **Established Standards**
  - Message Passing Interface (MPI)
    - OpenMP®
  - Coarray Fortran
    - OpenCL®

- **Research and Development**
  - Intel® Concurrent Collections
  - Offload Extensions
  - Intel® SPMD Parallel Compiler

*Choice of high-performance parallel programming models*

*Applicable to Multicore and Many-core Programming*
Intel® VTune™ Amplifier XE
Performance Profiler

Where is my application...

**Spending Time?**
- Focus tuning on functions taking time
- See call stacks
- See time on source

**Wasting Time?**
- See cache misses on your source
- See functions sorted by # of cache misses

**Waiting Too Long?**
- See locks by wait time
- Red/Green for CPU utilization during wait

- Windows & Linux
- Low overhead
- No special recompiles

Advanced Profiling for Scalable Multicore Performance
Scale Performance
Tune Hybrid Cluster MPI and Thread Performance

**Intel® Trace Analyzer and Collector**

- **Tune cross-node MPI**
  - Visualize MPI behavior
  - Evaluate MPI load balancing
  - Find communication hotspots

**Intel® VTune™ Amplifier XE**

- **Tune single node threading**
  - Visualize thread behavior
  - Evaluate thread load balancing
  - Find thread sync. bottlenecks
Dynamic Analysis Finds Memory & Threading Errors
Intel® Inspector XE 2013

- **Find and eliminate errors**
  - Memory leaks, invalid access...
  - Races & deadlocks
  - Analyze hybrid MPI cluster apps
  - Heap growth analysis

- **Faster & Easier to use**
  - Debugger breakpoints
  - Break on selected errors
  - Run faster to known error
  - Pause/resume collection
  - Narrow analysis focus
  - Better performance
  - Improved error suppression

Find Errors Early When They are Less Expensive
Static Analysis Finds Coding and Security Errors

- **Find over 250 error types e.g.:**
  - Incorrect directives
  - Security errors

- **Easier to use**
  - Choose your priority:
    - Minimize false errors
    - Maximize error detection

- **Increased Accuracy & Speed**
  - Detect errors without all source files
  - Better scaling with large code bases

**Code Complexity Metrics**
- Find code likely to be less reliable

Find Errors and Harden your Security

*Static Analysis is only available in Studio XE bundles. It is not sold separately.*

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Pointer Checker

- Finds buffer overflows and dangling pointers before memory corruption occurs
- Powerful error reporting
- Integrates into standard debuggers (Microsoft, gdb, Intel)

Dangling pointer

```c
char *p, *q;
p = malloc(10);
q = p;
free(p);
*q = 0;
```

Buffer Overflow

```c
char *my_chp = "abc";
char *an_chp = (char *) malloc (strlen((char *)my_chp));
memset (an_chp, '0', strlen((char *)my_chp));
```

CHKP: Bounds check error

```
 Traceback:
./a.out(main+0x1b2) [0x402d7a] in file mems.c at line 13
```

Pointer Checker Highlights Programming Errors For More Secure Applications
Conditional Numerical Reproducibility

- Intel® Math Kernel Library:
  - New deterministic task scheduling and code path selection options
- OpenMP:
  - New deterministic reduction option
- Intel® Threading Building Blocks
  - New parallel deterministic reduce option

Help Achieve Reproducible Results, Despite Non-associative Floating Point Math
Win a Lenovo Notebook

• Come to our stand and fill in Raffle card
• Join the Raffle Drawing
  
  Tuesday 6\textsuperscript{th} August
  
  3:45 PM
  
  @ Intel Stand

• You need to be present at Drawing in order to win
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- Relative performance is calculated by assigning a baseline value of 1.0 to one benchmark result, and then dividing the actual benchmark result for the baseline platform into each of the specific benchmark results of each of the other platforms, and assigning them a relative performance number that correlates with the performance improvements reported.

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Notice revision #20101101
Thank You.