INTEL® VTUNE™ AMPLIFIER
PERFORMANCE PROFILER
Faster, Scalable Code, Faster
Intel® VTune™ Amplifier Performance Profiler

Accurate Data - Low Overhead
- CPU, GPU, FPU, threading, bandwidth...

Meaningful Analysis
- Threading, OpenMP region efficiency
- Memory access, storage device

Easy
- Data displayed on the source code
- Easy set-up, no special compiles

“Last week, Intel® VTune™ Amplifier helped us find almost 3X performance improvement. This week it helped us improve the performance another 3X.”

Claire Cates
Principal Developer
SAS Institute Inc.

http://intel.ly/vtune-amplifier-xe
## Two Great Ways to Collect Data
Intel® VTune™ Amplifier

<table>
<thead>
<tr>
<th>Software Collector</th>
<th>Hardware Collector</th>
</tr>
</thead>
<tbody>
<tr>
<td>Uses OS interrupts</td>
<td>Uses the on chip Performance Monitoring Unit (PMU)</td>
</tr>
<tr>
<td>Collects from a single process tree</td>
<td>Collect system wide or from a single process tree.</td>
</tr>
<tr>
<td>~10ms default resolution</td>
<td>~1ms default resolution (finer granularity - finds small functions)</td>
</tr>
<tr>
<td>Either an Intel® or a compatible processor</td>
<td>Requires a genuine Intel® processor for collection</td>
</tr>
<tr>
<td>Call stacks show calling sequence</td>
<td>Optionally collect call stacks</td>
</tr>
<tr>
<td>Works in virtual environments</td>
<td>Works in a VM only when supported by the VM (e.g., vSphere*, KVM)</td>
</tr>
<tr>
<td>No driver required</td>
<td>Requires a driver</td>
</tr>
</tbody>
</table>

- Easy to install on Windows
- Linux requires root (or use default perf driver)

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**No special recompiles - C, C++, C#, Fortran, Java, Assembly**
## A Rich Set of Performance Data

**Intel® VTune™ Amplifier**

<table>
<thead>
<tr>
<th>Software Collector</th>
<th>Hardware Collector</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Basic Hotspots</strong></td>
<td><strong>Advanced Hotspots</strong></td>
</tr>
<tr>
<td>Which functions use the most time?</td>
<td>Which functions use the most time?</td>
</tr>
<tr>
<td></td>
<td>Where to inline? – Statistical call counts</td>
</tr>
<tr>
<td><strong>Concurrency</strong></td>
<td><strong>General Exploration</strong></td>
</tr>
<tr>
<td>Tune parallelism.</td>
<td>Where is the biggest opportunity?</td>
</tr>
<tr>
<td>Colors show number of cores used.</td>
<td>Cache misses? Branch mispredictions?</td>
</tr>
<tr>
<td><strong>Locks and Waits</strong></td>
<td><strong>Advanced Analysis</strong></td>
</tr>
<tr>
<td>Tune the #1 cause of slow threaded performance: – waiting with idle cores.</td>
<td>Memory-access, HPC Characterization, etc...</td>
</tr>
</tbody>
</table>

Any IA86 processor, any VM, no driver

Higher res., lower overhead, system wide

No special recompiles - C, C++, C#, Fortran, Java, Assembly
PERFORMANCE ANALYSIS WITH INTEL® VTUNE™ AMPLIFIER
Analysis Workflow

- Identify Hotspots
- Resolve Performance Problems
- Identify Performance Problems
VTUNE BY EXAMPLE
Example: Hotspots Analysis

Summary View

Option: Hotspots Analysis

- Elapsed Time: 5.554s
  - CPU Time: 10.504s
  - Instructions Retired: 21,638,000,000
  - CPI Rate: 1.257
  - CPU Frequency Ratio: 1.041
  - Total Threads Count: 9
  - Paused Time: 0s

Top Hotspots:
This section lists the most active functions in your application. Optimizing these hotspot functions typically results in improving overall application performance.

<table>
<thead>
<tr>
<th>Function</th>
<th>Module</th>
<th>CPU Time</th>
</tr>
</thead>
<tbody>
<tr>
<td>grid_interact</td>
<td>3_techyom_omp.exe</td>
<td>5.539s</td>
</tr>
<tr>
<td>sphere_interact</td>
<td>3_techyom_omp.exe</td>
<td>3.247s</td>
</tr>
<tr>
<td>func@0x10020e59d</td>
<td>libomp5msmd.dll</td>
<td>0.145s</td>
</tr>
<tr>
<td>shader</td>
<td>3_techyom_omp.exe</td>
<td>0.117s</td>
</tr>
<tr>
<td>KeaDelayExecutionThread</td>
<td>ntoskml.exe</td>
<td>0.081s</td>
</tr>
<tr>
<td>Others</td>
<td>N/A</td>
<td>1.581s</td>
</tr>
</tbody>
</table>

*N/A is applied to non-suitable metrics.

Average Bandwidth:

<table>
<thead>
<tr>
<th>Package</th>
<th>Total GB/sec</th>
<th>Read GB/sec</th>
<th>Write GB/sec</th>
</tr>
</thead>
<tbody>
<tr>
<td>package_0</td>
<td>5.715</td>
<td>3.504</td>
<td>2.212</td>
</tr>
</tbody>
</table>

CPU Usage Histogram:
This histogram displays a percentage of the wall time the specific number of CPUs were running simultaneously. Spin and Overhead time adds to the idle CPU usage value.

Collection and Platform Info:
This section provides information about this collection, including result set size and collection platform data.
Example: Concurrency Analysis
Bottom-up View
Example: General Exploration

Bottom-up View

Find real CPU stalls due to cache misses, instruction fetch misses, branch misprediction, and a lot more.
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Tune Applications for Scalable Multicore Performance

Agenda
- Data Collection – Rich set of performance data
- Data Analysis - Find answers fast
- Flexible workflow – User i/f and command line
  - Compare results
  - Remote collection
- Additional Features
- Summary
Find Answers Fast
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Adjust Data Grouping
- Function - Call Stack
- Module - Function - Call Stack
- Source File - Function - Call Stack
- Thread - Function - Call Stack
... (Partial list shown)

Double Click Function to View Source
Click [+] for Call Stack
Filter by Timeline Selection (or by Grid Selection)

Filter by Process & Other Controls
Tuning Opportunities Shown in Pink. Hover for Tips
See Profile Data On Source / Asm
Double Click from Grid or Timeline

View Source / Asm or both

CPU Time

Right click for instruction reference manual

Quick Asm navigation:
Select source to highlight Asm

Scroll Bar “Heat Map” is an overview of hot spots

Click jump to scroll Asm
Timeline Visualizes Thread Behavior

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Transitions
Locks & Waits

Optional: Use API to mark frames and user tasks
Optional: Add a mark during collection
Visualize Parallel Performance Issues
Look for Common Patterns

- Coarse Grain Locks
- High Lock Contention
- Load Imbalance

Low Concurrency
Tune OpenMP for Efficiency and Scalability

Fast Answers: Is My OpenMP Scalable? How Much Faster Could It Be?

1) Is the serial time of my application significant enough to prevent scaling?
2) How much performance can be gained by tuning OpenMP?
3) Which OpenMP regions / loops / barriers will benefit most from tuning?
4) What are the inefficiencies with each region? (click the link to see details)

Optimization Notice

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Command Line Interface

Automate analysis

`amplxe-cl` is the command line:

- **Windows**: `C:\Program Files (x86)\Intel\VTune Amplifier XE \bin[32|64]\amplxe-cl.exe`
- **Linux**: `/opt/intel/vtune_amplifier_xe/bin[32|64]/amplxe-cl`

**Help**: `amplxe-cl -help`

Use UI to setup
1) Configure analysis in UI
2) Press “Command Line...” button
3) Copy & paste command

Great for regression analysis – send results file to developer

Command line results can also be opened in the UI
MPI Analysis

Command line:
> mpirun -n 16 -ppn 4 -l amplxe-cl -collect advanced-hotspots -trace-mpi -result-dir my_result -- my_app.a

Or use gtool:
> mpirun -gtool "amplxe-cl -collect memory-access -result-dir my_result:7,5" my_app.a

Each process data is presented for each node they were running on:
my_result.host_name1 (rank 0-3)
my_result.host_name2 (rank 4-7)
my_result.host_name3 (rank 8-11)
my_result.host_name4 (rank 12-15)
Interactive Remote Data Collection

Performance analysis of remote systems just got a lot easier

Interactive analysis
1) Configure SSH to a remote Linux* target
2) Choose and run analysis with the UI

Command line analysis
1) Run command line remotely on Windows* or Linux* target
2) Copy results back to host and open in UI

Conveniently use your local UI to analyze remote systems
Compare Results Quickly - Sort By Difference

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Quickly identify cause of regressions.

- Run a command line analysis daily
- Identify the function responsible so you know who to alert

Compare 2 optimizations – What improved?

Compare 2 systems – What didn’t speed up as much?
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Tune Applications for Scalable Multicore Performance

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Java Analysis

- Multiple simultaneous JVMs
- Sampling is fast / unobtrusive
- Mixed Java / C++ / Fortran
- See results on the Java source
Optimize Private Cloud-Based Applications

Profile Enterprise Applications
- Native C, C++, Fortran*
- Attach to running Java* services (e.g., Mail)
- Profile Java daemons without restart

Accurate, Low-Overhead Data Collection
- Advanced hotspots and hardware events
- Memory analysis
- Accurate stack information for Java and HHVM*

Popular Containers Supported
- Docker*
- Mesos*

Software collectors (e.g., locks & waits) and Python* profiling are not currently available for containers.

No container configuration required
Detection of the container is automatic
Optimize Memory Access
Memory Access Analysis - Intel® VTune™ Amplifier 2017

Tune data structures for performance
- Attribute cache misses to data structures (not just the code causing the miss)
- Support for custom memory allocators

Optimize NUMA latency & scalability
- True & false sharing optimization
- Auto detect max system bandwidth
- Easier tuning of inter-socket bandwidth

Easier install, Latest processors
- No special drivers required on Linux*
- Intel® Xeon Phi™ processor MCDRAM (high bandwidth memory) analysis
Storage Device Analysis (HDD, SATA or NVMe SSD)
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Are You I/O Bound or CPU Bound?
- Explore imbalance between I/O operations (async & sync) and compute
- Storage accesses mapped to the source code
- See when CPU is waiting for I/O
- Measure bus bandwidth to storage

Latency analysis
- Tune storage accesses with latency histogram
- Distribution of I/O over multiple devices
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Tune Applications for Scalable Multicore Performance

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Intel® VTune™ Amplifier

Faster, Scalable Code Faster

Get the Data You Need
- Hotspot (Statistical call tree), Call counts (Statistical)
- Thread Profiling – Concurrency and Lock & Waits Analysis
- Cache miss, Bandwidth analysis...
- GPU Offload and OpenCL™ Kernel Tracing

Find Answers Fast
- View Results on the Source / Assembly
- OpenMP Scalability Analysis, Graphical Frame Analysis
- Filter Out Extraneous Data – Organize Data with Viewpoints
- Visualize Thread & Task Activity on the Timeline

Easy to Use
- No Special Compiles – C, C++, C#, Fortran, Java, ASM
- Visual Studio* Integration or Stand Alone
- Local & Remote Data Collection, Command Line
- Analyze Windows* & Linux* data on OS X*

Optimization Notice
1 Events vary by processor. 2 No data collection on OS X*

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