INTEL® PARALLEL STUDIO XE
Michael Steyer – Technical Consulting Engineer
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Software and workloads used in performance tests may have been optimized for performance only on Intel microprocessors. Performance tests, such as SYSmark and MobileMark, are measured using specific computer systems, components, software, operations and functions. Any change to any of those factors may cause the results to vary. You should consult other information and performance tests to assist you in fully evaluating your contemplated purchases, including the performance of that product when combined with other products. For more complete information visit www.intel.com/benchmarks.

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What’s Inside Intel® Parallel Studio XE
Comprehensive Software Development Tool Suite

**COMPOSER EDITION**

**BUILD**
Compilers & Libraries
- Intel® Math Kernel Library
- Intel® Data Analytics Acceleration Library
- Intel Threading Building Blocks
  - C++ Threading
- Intel® Integrated Performance Primitives
  - Image, Signal & Data Processing
- Intel® Distribution for Python*
  - High Performance Python

**PROFESSIONAL EDITION**

**ANALYZE**
Analysis Tools
- Intel® VTune™ Amplifier
  - Performance Profiler
- Intel® Inspector
  - Memory & Thread Debugger
- Intel® Advisor
  - Vectorization Optimization
  - Thread Prototyping
  - & Flow Graph Analysis

**SCALE**
Cluster Tools
- Intel® MPI Library
  - Message Passing Interface Library
- Intel® Trace Analyzer & Collector
  - MPI Tuning & Analysis
- Intel® Cluster Checker
  - Cluster Diagnostic Expert System

**CLUSTER EDITION**

Operating System: Windows*, Linux*, MacOS†*

Intel® Architecture Platforms

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*Available only in the Composer Edition.

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INTEL® PARALLEL STUDIO XE
TOOLS DETAILS

BUILD
- Intel® C++ Compiler
- Intel® Fortran Compiler
- Intel® Distribution for Python®
- Intel® Math Kernel Library
- Intel® Integrated Performance Primitives
- Intel® Threading Building Blocks
- Intel® Data Analytics Acceleration Library
  *Included in Composer Edition*

ANALYZE
- Intel® VTune™ Amplifier
- Intel® Advisor
- Intel® Inspector
  *Part of the Professional Edition*

SCALE
- Intel® MPI Library
- Intel® Trace Analyzer & Collector
- Intel® Cluster Checker
  *Part of the Cluster Edition*
What’s New in Intel® Compilers 2019 (19.0)

Updates to All Versions

Advance Support for Intel® Architecture—use Intel® Compilers to generate optimized code for Intel Atom® processor through Intel® Xeon® Scalable processors.

Achieve Superior Parallel Performance—vectorize & thread your code (using OpenMP*) to take advantage of the latest SIMD-enabled hardware, including Intel® Advanced Vector Extensions 512 (Intel® AVX-512).

What's New in C++

Additional C++17 Standard feature support
- Enjoy improvements to lambda & constant expression support
- Improved GNU C++ & Microsoft C++ compiler compatibility

Standards-driven parallelization for C++ developers
- Partial OpenMP* 5¹ support
- Modernize your code by using the latest parallelization specifications

What's New in Fortran

Substantial Fortran 2018 support including
- Coarray features: EVENTS & COSHAPE
- IMPORT statement enhancements
- Default module accessibility

Complete OpenMP 4.5 support; user-defined reductions
- Check shape option for runtime array conformance checking

¹OpenMP 5 is currently a draft
Faster Python* with Intel® Distribution for Python*

Advance Performance Closer to Native Code
- Accelerated NumPy, SciPy, Scikit-learn for scientific computing, machine learning & data analytics
- Drop-in replacement for existing Python—no code changes required
- Highly optimized for the latest Intel® processors

What's New in the 2019 Release
- Faster machine learning with Scikit-learn: Support Vector Machine (SVM) & K-means prediction, accelerated with Intel® Data Analytics Acceleration Library
- Includes machine learning XGBoost library (Linux* only)
- Also available as easy command line standalone install

Close to Native Code Scikit-learn* Performance with Intel® Distribution for Python* 2019
Compared to stock Python packages on Intel® Xeon® processors

Performance efficiency measured against native code with Intel® DAAL

Comparison:
- Stock Python: python 3.6.6 hc3d631a_0 installed from conda, NumPy 1.15, numba 0.39.0, llvmlite 0.24.0, scipy 1.1.0, scikit-learn 0.19.2 installed from pip; Intel Python: Intel® Distribution for Python* 2019 Gold: python 3.6.5 intel_11, NumPy 1.14.3 intel_py36_5, mkl 2019.0 intel_101, mkl_fft 1.0.2 intel_np114py36_6, scikit-learn 0.19.1 intel_np114py36_35; OS: CentOS Linux 7.3.1611, kernel 3.10.0-514.el7.x86_64; Hardware: Intel(R) Xeon(R) Gold 6140 CPU @ 2.30GHz (2 sockets, 18 cores/socket, HT:off), 256 GB of DDR4 RAM, 16 DIMMs of 16 GB@2666MHz

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# What’s Inside Intel® Math Kernel Library

## Linear Algebra
- BLAS
- LAPACK
- ScaLAPACK
- Sparse BLAS
- Iterative sparse solvers
- PARDISO®
- Cluster Sparse Solver

## FFTS
- Multidimensional
- FFTW interfaces
- Cluster FFT

## Vector RNGs
- Congruential
- Wichmann-Hill
- Mersenne Twister
- Sobol
- Neiderreiter
- Non-deterministic

## Summary Statistics
- Kurtosis
- Variation coefficient
- Order statistics
- Min/max
- Variance-covariance

## Vector Math
- Trigonometric
- Hyperbolic
- Exponential
- Log
- Power
- Root

## & More
- Splines
- Interpolation
- Trust Region
- Fast Poisson Solver

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1Available only in Intel® Parallel Studio Composer Edition.
What's Inside Intel® Integrated Performance Primitives

High Performance, Easy-to-Use & Production Ready APIs

- Image Processing
- Computer Vision
- Color Conversion
- Signal Processing
- Vector Math
- Data Compression
- Cryptography
- String Processing

Operating Systems: Windows*, Linux*, MacOS†*

Intel® Architecture Platforms

†Available only in Intel® Parallel Studio Composer Edition.

*Other names and brands may be claimed as the property of others.
What’s Inside Threading Building Blocks

Parallel Execution Interfaces
- Flow Graph
- Generic Parallel Patterns
- Parallel STL

Low-Level Interfaces
- Tasks
- Task arenas
- Global Control

Interfaces Independent of Execution Model
- Concurrent Containers
  - Hash Tables
  - Queues
  - Vectors
- Memory Allocation
  - Scalable Allocator
  - Cache Aligned Allocator
- Primitives and Utilities
  - Synchronization Primitives
  - Thread Local Storage
Speedup Analytics & Machine Learning with Intel® Data Analytics Acceleration Library (Intel® DAAL)

- Highly tuned functions for classical machine learning & analytics performance from datacenter to edge running on Intel® processor-based devices
- Simultaneously ingests data & computes results for highest throughput performance
- Supports batch, streaming & distributed usage models to meet a range of application needs
- Includes Python®, C++, Java® APIs, & connectors to popular data sources including Spark® & Hadoop

What’s New in the 2019 Release

New Algorithms

- **Logistic Regression**, most widely-used classification algorithm
- **Extended Gradient Boosting Functionality** for inexact split calculations & user-defined callback canceling for greater flexibility
- **User-defined Data Modification Procedure** supports a wide range of feature extraction & transformation techniques

Learn More: software.intel.com/daal
INTEL® PARALLEL STUDIO XE COMPONENT TOOLS

BUILD
Intel® C++ Compiler
Intel® Fortran Compiler
Intel® Distribution for Python®
Intel® Math Kernel Library
Intel® Integrated Performance Primitives
Intel® Threading Building Blocks
Intel® Data Analytics Acceleration Library
Included in Composer Edition

ANALYZE
Intel® VTune™ Amplifier
Intel® Advisor
Intel® Inspector
Part of the Professional Edition

SCALE
Intel® MPI Library
Intel® Trace Analyzer & Collector
Intel® Cluster Checker
Part of the Cluster Edition
Save Time Optimizing Code

- Accurately profile C, C++, Fortran*, Python*, Go*, Java*, or any mix
- Optimize CPU, threading, memory, cache, storage & more
- Save time: rich analysis leads to insight

What’s New in 2019 Release (partial list)

- Enhanced Application Performance Snapshot: Focus on useful data with new data selection & pause/resume options (Linux*)
- Analyze CPU utilization of physical cores
- Improved JIT profiling for server-side/cloud applications
- A more accessible user interface provides a simplified profiling workflow

Learn More: software.intel.com/intel-vtune-amplifier-xe
Rich Set of Profiling Capabilities for Multiple Markets
Intel® VTune Amplifier

**Single Thread**
Optimize single-threaded performance.

**Multithreaded**
Effectively use all available cores.

**System**
See a system-level view of application performance.

**Media & OpenCL™ Applications**
Deliver high-performance image and video processing pipelines.

**HPC & Cloud**
Access specialized, in-depth analyses for HPC and cloud computing.

**Memory & Storage Management**
Diagnose memory, storage, and data plane bottlenecks.

**Analyze & Filter Data**
Mine data for answers.

**Environment**
Fits your environment and workflow.
Better, Faster Application Performance Snapshot

Intel® VTune™ Amplifier

Better Answers
- CPU utilization analysis of physical cores

Less Overhead
- Lower MPI trace overhead & faster result processing
- New data selection & pause/resume let you focus on useful data

Easier to Use
- Visualize rank-to-rank & node-to-node MPI communications
- Easily configure profiling for Intel® Trace Analyzer & Collector
Modernize Your Code with Intel® Advisor
Optimize Vectorization, Prototype Threading, Create & Analyze Flow Graphs

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Performance Increases Scale with Each New Hardware Generation

Modern Performant Code
- Vectorized (uses Intel® AVX-512/AVX2)
- Efficient memory access
- Threaded

Capabilities
- Adds & optimizes vectorization
- Analyzes memory patterns
- Quickly prototypes threading

New for 2019 Release (partial list)
- Enhanced hierarchical roofline analysis
- Shareable HTML roofline
- Flow graph analysis

Performance results are based on testing as of August 2017 and may not reflect all publicly available security updates. See configuration disclosure for details. No product can be absolutely secure. For more complete information about performance and benchmark results, visit www.intel.com/benchmarks. See Vectorize & Thread or Performance Dies Configurations for 2010-2017 Benchmarks in Backup. Testing by Intel as of August 2017.

Get Breakthrough Vectorization Performance

Intel® Advisor—Vectorization Advisor

Faster Vectorization Optimization
- Vectorize where it will pay off most
- Quickly ID what is blocking vectorization
- Tips for effective vectorization
- Safely force compiler vectorization
- Optimize memory stride

Data & Guidance You Need
- Compiler diagnostics + Performance Data + SIMD efficiency
- Detect problems & recommend fixes
- Loop-Carried Dependency Analysis
- Memory Access Patterns Analysis

Optimize for Intel® Advanced Vector Extensions 512 (Intel® AVX-512) with or without access to Intel AVX-512 hardware
Find Effective Optimization Strategies
Intel® Advisor—Cache-aware Roofline Analysis

Roofline Performance Insights
- Highlights poor performing loops
- Shows performance ‘headroom’ for each loop
  - Which can be improved
  - Which are worth improving
- Shows likely causes of bottlenecks
- Suggests next optimization steps

“I am enthusiastic about the new "integrated roofline" in Intel® Advisor. It is now possible to proceed with a step-by-step approach with the difficult question of memory transfers optimization & vectorization which is of major importance.”

Nicolas Alferez, Software Architect
Onera – The French Aerospace Lab
Debug Memory & Threading with Intel® Inspector
Find & Debug Memory Leaks, Corruption, Data Races, Deadlocks

Correctness Tools Increase ROI by 12%–21%¹
- Errors found earlier are less expensive to fix
- Races & deadlocks not easily reproduced
- Memory errors are hard to find without a tool

Debugger Integration Speeds Diagnosis
- Breakpoint set just before the problem
- Examine variables and threads with the debugger

What’s New in 2019 Release
Find Persistent Memory Errors
- Missing / redundant cache flushes
- Missing store fences
- Out-of-order persistent memory stores
- PMDK transaction redo logging errors

Learn More: intel.ly/inspector-xe

INTEL® PARALLEL STUDIO XE COMPONENT TOOLS

BUILD
- Intel® C++ Compiler
- Intel® Fortran Compiler
- Intel® Distribution for Python*
- Intel® Math Kernel Library
- Intel® Integrated Performance Primitives
- Intel® Threading Building Blocks
- Intel® Data Analytics Acceleration Library
  - Included in Composer Edition

ANALYZE
- Intel® VTune™ Amplifier
- Intel® Advisor
- Intel® Inspector
  - Part of the Professional Edition

SCALE
- Intel® MPI Library
- Intel® Trace Analyzer & Collector
- Intel® Cluster Checker
  - Part of the Cluster Edition
Boost Distributed Application Performance with Intel® MPI Library
Performance, Scalability & Fabric Flexibility

Standards Based Optimized MPI Library for Distributed Computing

- Built on open source MPICH Implementation
- Tuned for low latency, high bandwidth & scalability
- Multi-fabric support for flexibility in deployment

What’s New in 2019 Release

- New MPI code base- MPI-CH4 (on the path to Exascale & beyond)
- Greater scalability & shortened CPU paths
- Superior MPI Multi-threaded performance
- Supports the latest Intel® Xeon® Scalable processor

Learn More: software.intel.com/intel-mpi-library
Efficiently Profile MPI Applications
Intel® Trace Analyzer & Collector

Helps Developers
- Visualize & understand parallel application behavior
- Evaluate profiling statistics & load balancing
- Identify communication hotspots

Features
- Event-based approach
- Low overhead
- Excellent scalability
- Powerful aggregation & filtering functions
- Idealizer
- Scalable
Use an Extensive Diagnostic Toolset for High Performance Compute Clusters—Intel® Cluster Checker (for Linux*)

Ensure Cluster Systems Health

- Expert system approach providing cluster systems expertise - verifies system health: find issues, offers suggested actions
- Provides extensible framework, API for integrated support
- Check 100+ characteristics that may affect operation & performance – improve uptime & productivity

New in 2019 Release: Output & Features Improve Usability & Capabilities

- Simplified execution with a single command
- New output format with overall summary
  - Simplified issue assessment for 'CRITICAL', 'WARNING', or 'INFORMATION'
  - Extended output to logfile with details on issue, diagnoses, observations
- Added auto-node discovery when using Slurm*
- Cluster State 2 snapshot comparison identifies changes
- And more...

For application developers, cluster architects & users, & system administrators
ANALYSIS TOOLS WORKFLOW
Code Modernization

Stage 1: Use Optimized Libraries

Stage 2: Compile with Architecture-specific Optimizations

Stage 3: Analysis and Tuning

Stage 4: Check Correctness
Tuning Workflow

- **Intel® VTune™ Amplifier's Application Performance Snapshot**
  - **Intel® VTune™ Amplifier**
    - **Intel® Advisor**
      - Threading
      - Vectorization
    - **Intel® VTune™ Amplifier**
    - **CPU Bound**
    - **Memory Bound**
    - **Thread-level scalability issues (OpenMP analysis)**
  - **Thread-level serial time parallelization**
    - **FPU underutilization (vector efficiency issues)**
  - **MPI Bound**
  - **MPI Imbalance**
    - **Intel® Trace Analyzer and Collector**
    - **Intel® MPI Tuner**

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Optimizing Performance on Parallel Hardware

Intel® Parallel Studio XE—It’s an iterative process...

Cluster Scalable? N → Tune MPI

Effective threading? Y → Vectorize

Memory Bandwidth Sensitive? Y → Optimize Bandwidth

Thread

Possible System Configuration Issues? Y → Intel® Cluster Checker

Ignore if you are not targeting clusters.
Performance Analysis Tools for Diagnosis

Intel® Parallel Studio

- Intel® VTune™ Amplifier
- Intel® Advisor
- Intel® Trace Analyzer & Collector
- Intel® MPI Tuner

Cluster Scalable?
- Y: Tune MPI
- N: Intel® Trace Analyzer & Collector

Effective threading?
- Y: Vectorize
- N: Thread

Memory Bandwidth Sensitive?
- Y: Optimize Bandwidth
- N: Intel® VTune™ Amplifier

Intel® VTune™ Amplifier's Application Performance Snapshot
Tools for High Performance Implementation

Intel® Parallel Studio XE

Cluster Scalable?

Y

N

Tune MPI

Effective threading?

Y

N

Vectorize

Memory Bandwidth Sensitive?

Y

N

Thread

Optimize Bandwidth

Possible System Configuration Issues?

Y

Intel® MPI Library
Intel® MPI Benchmarks

Intel® Compiler

Intel® Math Kernel Library
Intel® Integrated Performance Primitives – Media & Data Library
Intel® Data Analytics Acceleration Library
Intel® OpenMP*

Intel® Cluster Checker

Threading Building Blocks – Threading Library

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# The Long & Short of Performance Analysis

Get the big picture first with a Snapshot or Platform Profiler

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<td><strong>- System-wide sampling</strong></td>
</tr>
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</table>

- **L** = long (hours)
- **M** = medium (minutes)
- **S** = short (seconds-few minutes)

**Intel® VTune™ Amplifier**
- Many profiles
- Vectorization
- MPI Optimization

**Intel® Advisor**
- Vectorization

**Intel® Trace Analyzer and Collector**
- MPI Optimization

**Platform Profiler**
- System-wide sampling