OPTIMIZING FOR LATEST PROCESSORS
WITH INTEL® PARALLEL STUDIO XE 2018

Intel Software Developer Conference – Frankfurt, 2017
Dr. Heinrich Bockhorst  Intel
AGENDA

• What’s Inside Intel® Parallel Studio XE

• Which tool should I use – tuning workflow

• Intel® Parallel studio XE component tools (Build, Analyze, Scale)
What’s Inside Intel® Parallel Studio XE
Comprehensive Software Development Tool Suite

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Intel® Architecture Platforms

Operating System: Windows®, Linux®, MacOS®

More Power for Your Code - software.intel.com/intel-parallel-studio-xe
Take Advantage of Intel Priority Support

- Paid licenses of Intel® Software Development Tools include Priority Support for one year from your date of purchase, with options to extend support at a highly discounted rate.

- **Benefits**
  - **Direct & private** interaction with Intel engineers. Submit confidential inquiries & code samples via the Online Service Center.
  - **Responsive help** with your technical questions & other product needs.
  - **Free access** to all new product updates & access to older versions.

**Additional Resources**
- Learn from other experts via community product forums
- Access to a vast library of self-help documents that build off decades of experience with creating high performance code.
WHICH TOOL SHOULD I USE?
Optimizing Performance on Parallel Hardware
Intel® Parallel Studio XE

It’s an Iterative Process...

Cluster Scalable?

Tune MPI

Ignore if you are not targeting clusters.

Effective threading?

Vectorize

Memory Bandwidth Sensitive?

Optimize Bandwidth

Thread

It's an Iterative Process…
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 XE
- 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 2018

Updates to All Versions

• **Advance Support for Intel® Architecture** – Use Intel compiler to generate optimized code for Intel Atom® through Intel® Xeon® Scalable and Xeon Phi™ processor families

• **Achieve Superior Parallel Performance** – Vectorize & thread your code (using OpenMP*) to take full advantage of the latest SIMD-enabled hardware, including AVX-512 instructions

• **Develop Smart Code with Confidence** – Access extensive compiler diagnostics to study code generation characteristics, use with Intel® VTune™ Amplifier & Intel® Advisor for further analysis

• **Faster Compile Time** – Memory management improvements reduce application compile time without sacrificing runtime performance

• **Lightweight Hardware-based Profile-guided Optimization** alternative – Experience many benefits of profile information without the overhead of instrumentation¹

**What’s New in C++**

Initial C++17, OpenMP* 5; full C++ 14 support

- Standards-driven parallelization for C++ developers

**What’s New in Fortran**

Full Fortran 2008 support

- Submodules, BLOCK, superior coarray performance

Initial Fortran 2015 support (draft standard)

- Further C interoperability (ISO/IEC TS 29113:2012)

Full OpenMP* 4.5 support; initial OpenMP 5

- Thread & vectorize your code using standard APIs

¹Requires Intel® VTune™ Amplifier
Adoption of Python continues to grow among domain experts & developers for its productivity benefits.

**Challenge#1**
- Domain experts are not professional software programmers

**Challenge#2**
- Python performance limits migration to production systems
Python* Landscape
Intel® Distribution for Python*

• Challenge#1
  • Domain experts are not professional software programmers

• Challenge#2
  • Python performance limits migration to production systems

Adoption of Python continues to grow among domain experts & developers for its productivity benefits

Intel's Python Tools
- Accelerate Python performance
- Enable easy access
- Empower the community

Most Popular Coding Languages of 2016

- Python 26.7%
- Java 22.6%
- C++ 9.9%
- C# 9.4%
- C 7.37%
- Java 6.9%
- Ruby 5.9%
- JavaScript (JS) 5.
- PHP 3.8%
- RoR 3.2%
- Groovy 1.2%
- ColdFusion 1.2%
- Perl 1.2%
- Groovy 1.2%
- R 1.2%
- C# 9.4%

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For more complete information about compiler optimizations, see our Optimization Notice. 
What’s Inside Intel® Distribution for Python
High Performance Python* for Scientific Computing, Data Analytics, Machine & Deep Learning

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<th>GREATER PRODUCTIVITY</th>
<th>ECOSYSTEM COMPATIBILITY</th>
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<td><strong>Performance Libraries, Parallelism, Multithreading, Language Extensions</strong></td>
<td><strong>Prebuilt &amp; Accelerated Packages</strong></td>
<td><strong>Supports Conda &amp; PIP</strong></td>
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<td>Accelerated NumPy/SciPy/scikit-learn with Intel® MKL¹ &amp; Intel® DAAL²</td>
<td>Prebuilt &amp; optimized packages for numerical computing, machine/deep learning, HPC, &amp; data analytics</td>
<td>Compatible &amp; powered by Anaconda*, supports conda &amp; pip</td>
</tr>
<tr>
<td>Data analytics, machine learning &amp; deep learning with scikit-learn, pyDAAL, Caffe*, Theano*</td>
<td>Drop in replacement for existing Python - No code changes required</td>
<td>Distribution &amp; individual optimized packages also available at conda &amp; Anaconda.org, YUM/APT, Docker image on DockerHub</td>
</tr>
<tr>
<td>Scale with Numba* &amp; Cython*</td>
<td>Jupyter* notebooks, Matplotlib included</td>
<td>Optimizations upstreamed to main Python trunk</td>
</tr>
<tr>
<td>Includes optimized mpi4py, works with Dask* &amp; PySpark*</td>
<td>Free download &amp; free for all uses including commercial deployment</td>
<td>Priority Support through Intel® Parallel Studio XE</td>
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<td>Optimized for latest Intel® architecture</td>
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**Intel® Architecture Platforms**

Operating System: Windows*, Linux*, MacOS¹*

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1 Intel® Math Kernel Library
2 Intel® Data Analytics Acceleration Library
³Available only in Intel® Parallel Studio Composer Edition.

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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 2018 edition
  - Updated to support Python 3.6
  - Optimized scikit-learn for machine learning speedups
  - Conda build recipes for custom infrastructure

Learn More: software.intel.com/distribution-for-python

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 information go to http://www.intel.com/performance. Benchmark Source: Intel Corporation.
Fast, Scalable Code with Intel® Math Kernel Library (Intel® MKL)

- Highly optimized, threaded, & vectorized math functions that maximize performance on each processor family
- Utilizes industry-standard C and Fortran APIs for compatibility with popular BLAS, LAPACK, and FFTW functions—no code changes required
- Dispatches optimized code for each processor automatically without the need to branch code

- What's New in the 2018 edition
  - Improved small matrix multiplication performance in GEMM & LAPACK
  - Improved ScaLAPACK performance for distributed computation
  - 24 new vector math functions
  - Simplified license for easier adoption & redistribution
  - Additional distributions via YUM, APT-GET, & Conda

Learn More: software.intel.com/mkl
What’s Inside Intel® Math Kernel Library

Accelerate HPC, Enterprise, Cloud & IoT Applications

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

FFT
- Multidimensional
- FFTW interfaces
- Cluster FFT

Neural Networks
- Convolution
- Pooling
- Normalization
- ReLU
- Inner Product

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

Intel® Architecture Platforms

Operating System: Windows®, Linux®, macOS®

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Available only in Intel® Parallel Studio Composer Edition.

For more complete information about compiler optimizations, see our Optimization Notice.
Get the Benefits of Advanced Threading with Intel® Threading Building Blocks

Use Threading Techniques to fully Leverage Multicore Performance & Heterogeneous Computing

- Parallelize computationally intensive work across CPUs, GPUs & FPGAs,—deliver higher-level & simpler solutions using C++
- Most feature-rich & comprehensive solution for parallel application development
- Highly portable, composable, affordable, & approachable—future-proof scalability

What’s New in 2018 edition

- New capabilities in Flow Graph improve concurrency and heterogeneity
- Improves insight into parallelism inefficiencies for Intel® VTune Amplifier 2018
- Support for Cmake file

Learn More: software.intel.com/intel-tbb
### Speedup Analytics & Machine Learning with Intel® Data Analytics Acceleration Library (Intel® DAAL)

- Highly tuned functions for classical machine learning and analytics performance across a spectrum of Intel® architecture devices
- Optimizes data ingestion together with algorithmic computation for highest analytics throughput
- Includes Python*, C++, Java* APIs, and connectors to popular data sources including Spark* and Hadoop*

### What’s New in the 2018 Edition

- **New Algorithms**
  - Classification & Regression Decision Tree and Forest
  - K-NN
  - Ridge Regression
- **Spark** MLlib-compatible API wrappers for easy substitution of faster Intel® DAAL functions
- **Improved APIs** for ease of use
- **Repository distribution** via YUM, APT-GET, and Conda

### Pre-processing
- Decompression, Filtering, Normalization

### Transformation
- Aggregation, Dimension Reduction

### Analysis
- Summary Statistics
- Clustering, etc.

### Modeling
- Machine Learning (Training)
- Parameter Estimation
- Simulation

### Validation
- Hypothesis Testing
- Model Errors

### Decision Making
- Forecasting
- Decision Trees, etc.

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 XE
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
Application Performance Snapshot Adds MPI
Data in One Place: MPI+OpenMP+Memory Floating Point—Intel® VTune™ Amplifier

Quick & Easy Performance Overview
- Does the app need performance tuning?

MPI & non-MPI Apps†
- Distributed MPI with or without threading
- Shared memory applications

Popular MPI Implementations Supported
- Intel® MPI Library
- MPICH & Cray MPI

Richer Metrics on Computation Efficiency
- CPU (processor stalls, memory access)
- FPU (vectorization metrics)

†MPI supported only on Linux*
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

New for 2018 edition (partial list)

- Quick metrics for shared & distributed memory apps
- Cross-OS analysis – e.g. analyze Linux* from Windows* or macOS*
- Profile inside containers

Learn More: software.intel.com/intel-vtune-amplifier-xe
Rich Set of Profiling Features for Multiple Markets
Intel® VTune™ Amplifier—Performance Profiler

**Basic Profiling**
- Hotspots

**Threading Analysis**
- Concurrency, Locks & Waits
- OpenMP, Intel® Threading Building Blocks

**Micro Architecture Analysis**
- Cache, branch prediction, ...

**Vectorization + Intel® Advisor**
- FLOPS estimates

**MPI + Intel® Trace Analyzer & Collector**
- Scalability, imbalance, overhead

**Use Memory Efficiently**
- Tune data structures & NUMA

**Optimize for High Speed Storage**
- I/O and compute imbalance

**Intel® Media SDK Integration**
- Meaningful media stack metrics

**Low Overhead Java*, Python*, Go***
- Managed + native code

**Containers**
- Docker*, Mesos*, LXC*
‘Automatic’ Vectorization is Often Not Enough
A good compiler can still benefit greatly from vectorization optimization—Intel® Advisor

Compiler will not always vectorize
- Check for Loop Carried Dependencies using Intel® Advisor
- All clear? Force vectorization. C++ use: pragma simd, Fortran use: SIMD directive

Not all vectorization is efficient vectorization
- Stride of 1 is more cache efficient than stride of 2 & greater. Analyze with Intel® Advisor
- Consider data layout changes Intel® SIMD Data Layout Templates can help

Arrays of structures are great for intuitively organizing data, but are less efficient than structures of arrays. Use Intel® SIMD Data Layout Templates to map data into a more efficient layout for vectorization.
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® AVX-512 with or without access to AVX-512 hardware
Find Effective Optimization Strategies
Cache-aware Roofline Analysis—Intel® Advisor

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
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 2018 edition
- Fewer false positives
- C++ 17 std::shared_mutex added
- Windows SRW Locks added

¹Cost Factors – Square Project Analysis - CERT: U.S. Computer Emergency Readiness Team, and Carnegie Mellon CyLab NIST: National Institute of Standards & Technology; Square Project Results
INTEL® PARALLEL STUDIO XE COMPONENT TOOLS

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Intel® Data Analytics Acceleration Library
Included in Composer Edition

ANALYZE
Intel® VTune™ Amplifier XE
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
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 2018 edition¹

- Up to 11x faster in job start-up time
- Up to 25% reduction in job finalization time
- Supports the latest Intel® Xeon® Scalable processor

Learn More: software.intel.com/intel-mpi-library

¹See following benchmarks slide for more details
Intel® MPI Library Features

Optimized MPI Application Performance
- Application-specific tuning
- Automatic tuning
- Support for latest Intel® Xeon® & Intel® Xeon Phi™ Processors
- Support for Intel® Omni-Path Architecture Fabric

Multi-vendor Interoperability & Lower Latency
- Performance optimized support for the fabric capabilities through OpenFabrics* (OFI)
- Industry leading latency

Faster MPI Communication - Optimized collectives

Sustainable Scalability
Native InfiniBand* interface support allows for lower latencies, higher bandwidth, and reduced memory requirements

More Robust MPI Applications
Seamless interoperability with Intel® Trace Analyzer & Collector

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Profile & Analyze High Performance MPI Applications
Intel® Trace Analyzer & Collector

Powerful Profiler, Analysis & Visualization Tool for MPI Applications

- Low overhead for accurate profiling, analysis & correctness checking
- Easily visualize process interactions, hotspots & load balancing for tuning & optimization
- Workflow flexibility: Compile, Link or Run

What’s New in 2018 edition

- Support of OpenSHMEM* applications
- Supports the latest Intel® Xeon® Scalable and Intel® Xeon Phi™ processors

Learn More: software.intel.com/intel-trace-analyzer
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
Intel® Cluster Checker 2018
For Linux* High Performance Compute Clusters

- Clusters are Complex Systems!
- Challenge is to reduce this complexity barrier for
  - Application developers
  - Cluster architects
  - Cluster users
  - System administrators

- Intel® Cluster Checker is an expert system approach that provides cluster systems expertise
  - Verifies system health
  - Offers suggested actions
  - Provides extensible framework
  - API for integrated support
What’s New in Intel® Cluster Checker 2018
Ensure Your HPC Cluster Components Work Together

- New Features Improve Usability & Checking Capabilities
  - Adds support for new Intel silicon & platform elements (processors, fabric, memory, storage, cluster provisioning, HPC platforms)
  - Introduces simplified grouping of checks for extensibility
  - Improves diagnostic output
  - Validates Intel® Scalable System Framework Classic HPC Cluster Reference Architectures
  - Check Intel® Omni-Path in-depth
  - Analyze data from multiple database sources
CODE THAT PERFORMS AND OUTPERFORMS

Download a free, 30-day trial of Intel® Parallel Studio XE 2018 today

software.intel.com/en-us/parallel-studio-xe

AND DON’T FORGET...

To fill out the evaluation survey via a URL that will be provided at the end of the day
OR
Watch your email for a link to the survey

P.S.

Everyone who fills out the survey will receive a personalized certificate indicating completion of the training!
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Notice revision #20110804
Backup: APS for a scientific application

†MPI supported only on Linux®