Intel Cluster Studio
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TECHNISCHE UNIVERSITÄT DARMSTADT

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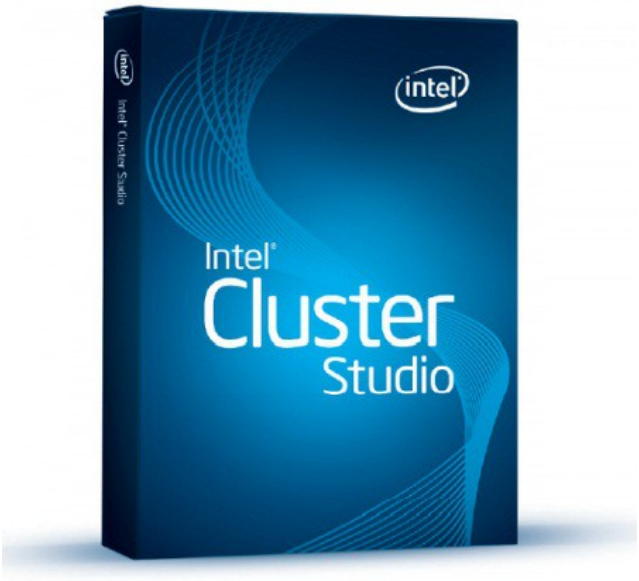

SCIENTIFIC COMPUTING

Agenda

- What is the Intel Cluster Studio?
- Planning with help of Intel Advisor
- Optimizations with the help of Intel Compiler
- Searching errors with Intel Inspector
- Finding MPI problems: Intel Trace Analyzer
- Analyzing code with Vtune Amplifier
- Summary

What is the Intel Cluster Studio?

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- Collection of different tools
- Should cover the hole software development process
- Different packages for different platforms

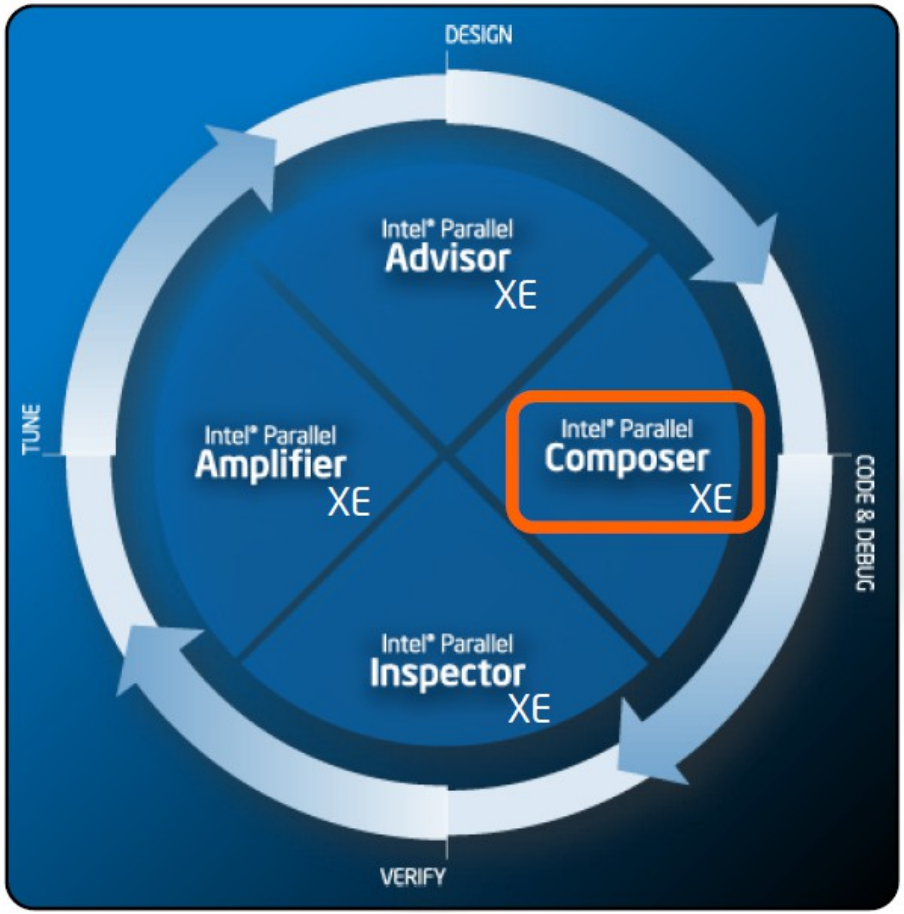
Advanced Performance

C++ and Fortran Compilers, MKL Libraries & Analysis Tools for Windows*, Linux* developers on IA based multi-core and many-core nodes

Distributed Performance

MPI Cluster Tools with C++ and Fortran Compiler, MKL Libraries and Analysis Tools for Windows*, Linux* developers on IA based clusters

What is the Intel Cluster Studio?

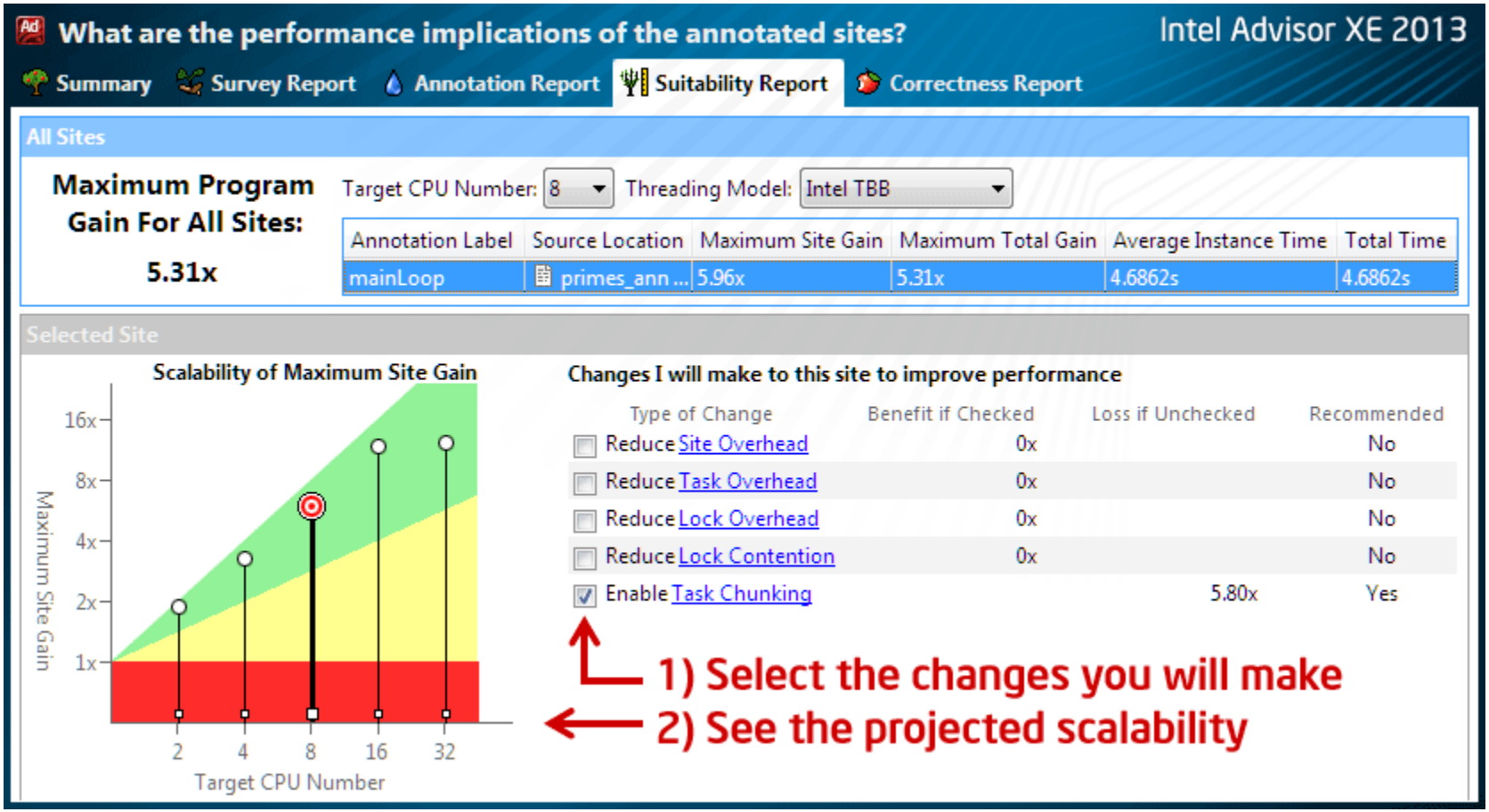


- **Advisor:** Help to parallelize code
- **Composer**: No IDE, compiler, libraries
- **Inspector**: Correctnesschecking
- **Analyzer**: Correctnesschecking (MPI)
- **Amplifier**: Parallel/serial tuning

Intel Advisor

- Threading assistant for C (++/#) and Fortran
- Should lead through the process of designing software
- Parallelize existing code
- Compare different alternatives before implementing it
- Help in finding locks and points for synchronization
- Short demo in a few moments

Intel Advisor



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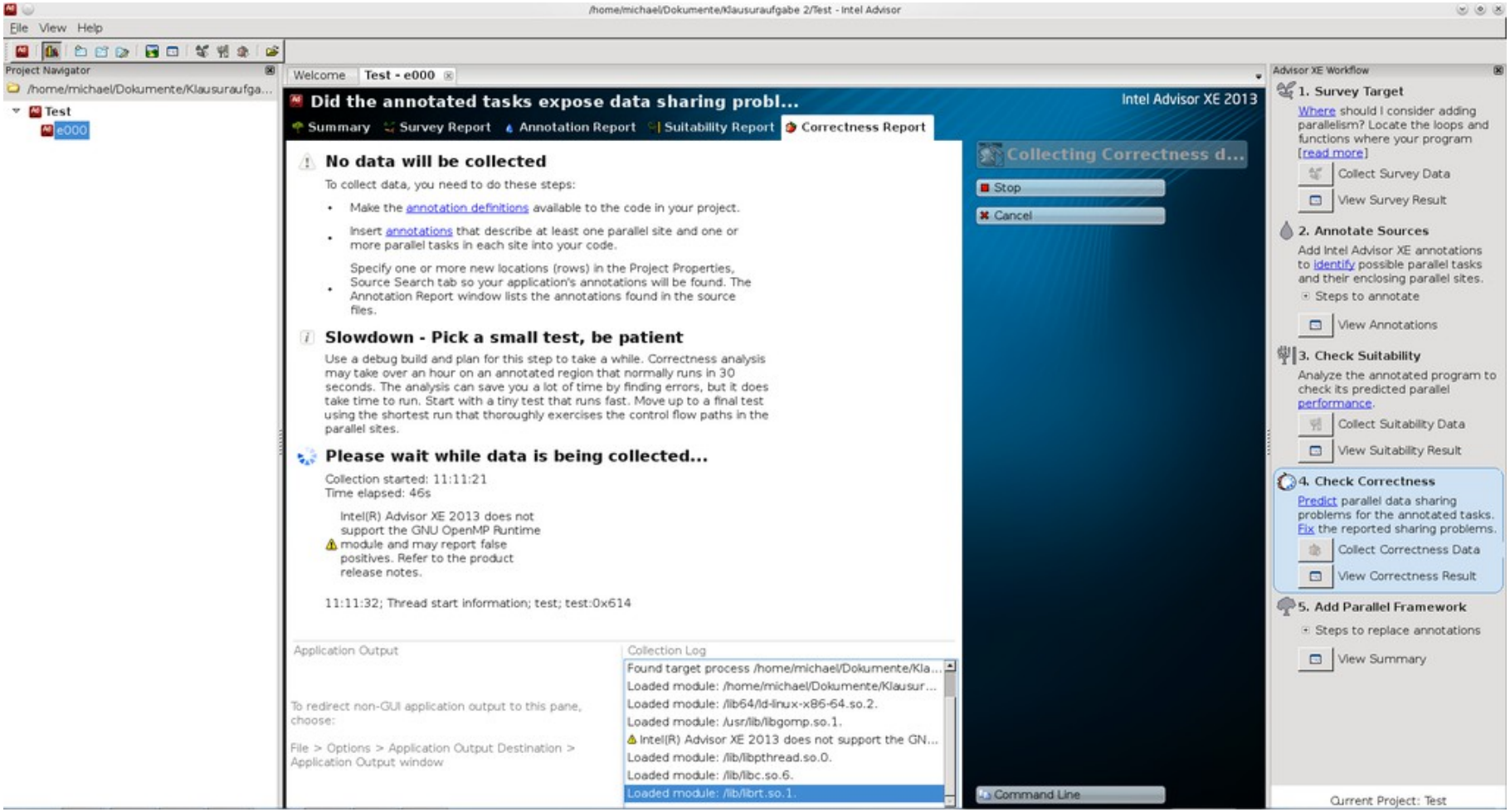
Intel Advisor



Intel (Parallel) Composer

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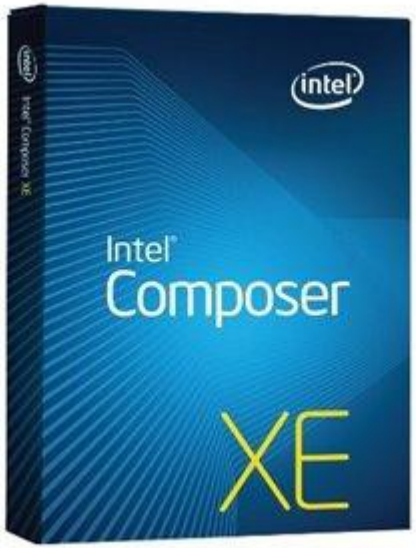
- Contains compiler (icc/ifort)
- „Special“ support for Intel processors
- *„Intel’s compilers may or may not optimize to the same degree for non-Intel microprocessors for optimizations that are not unique to Intel microprocessors. Intel does not guarantee the availability, functionality, or effectiveness of any optimization on microprocessors not manufactured by Intel. Microprocessor-dependent optimizations in this product are intended for use with Intel microprocessors.“*



Intel (Parallel) Composer

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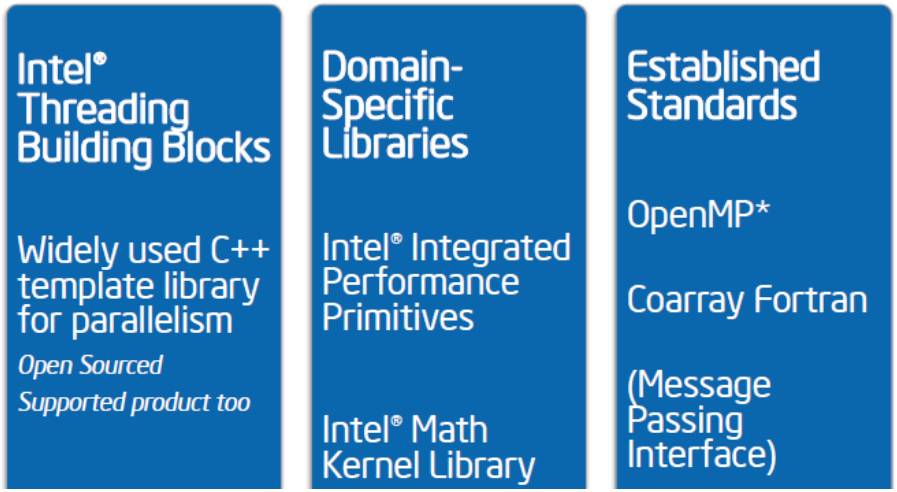
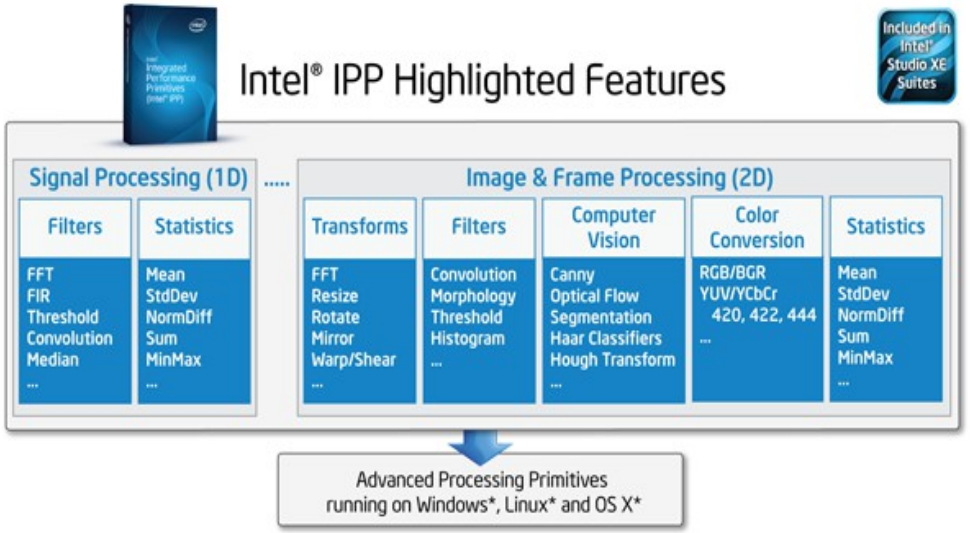
- Support of C++ and Fortran. Additionally contains:
  - Template Library: Intel Threading Building Blocks (TBB)
  - Library: Intel Integrated Performance Primitives (IPP)
  - Library: Intel Math Kernel Libraries (MKL)
  - OpenMP / Intel MPI Support





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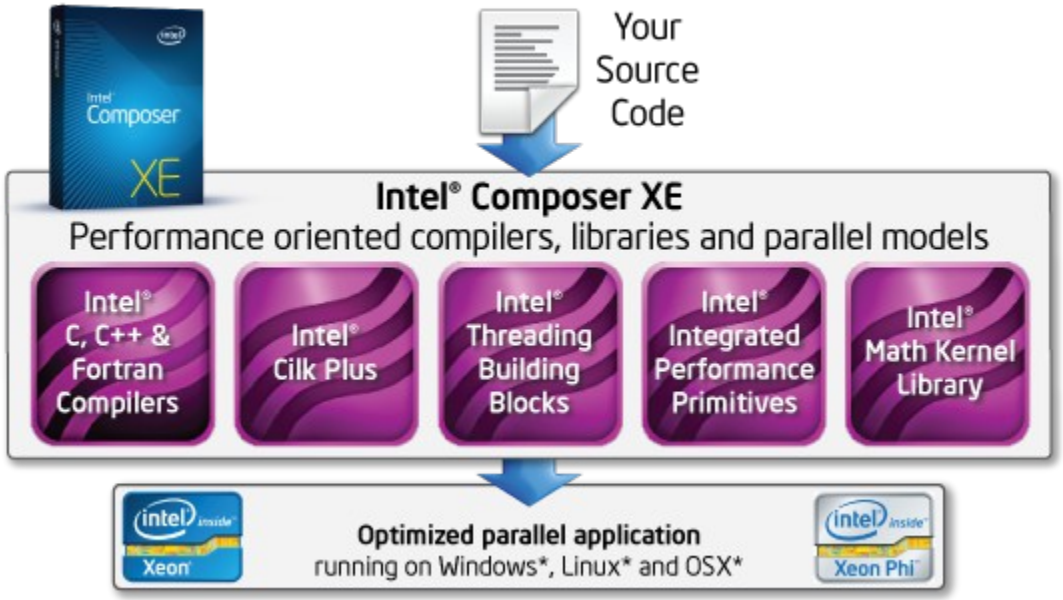
Intel (Parallel) Composer

- The wish / aim:
- Use as much existing libraries and automatization as possible



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Intel (Parallel) Composer

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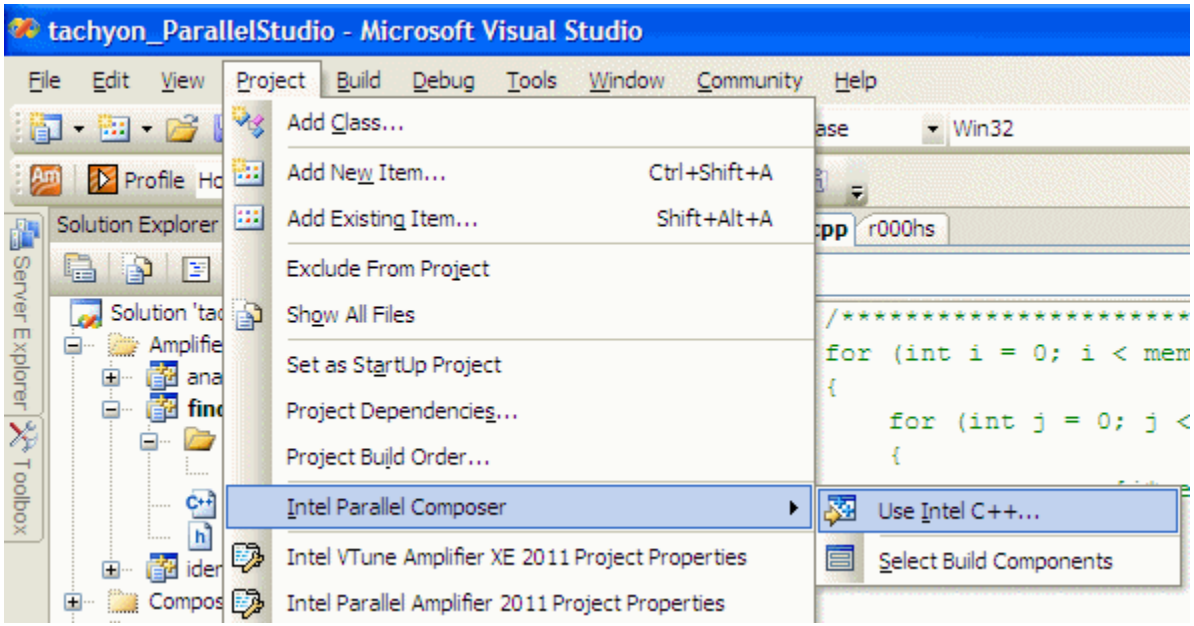
- For Windows:
- Microsoft Visual Studio is prerequisite for composer
- Integration in existing IDE (**DEMO**):



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Intel (Parallel) Composer

- In Linux:
- Supports GNU tool chain
  - Integration in eclipse possible (tutorials online*)
  - Demo
  - Or use command line

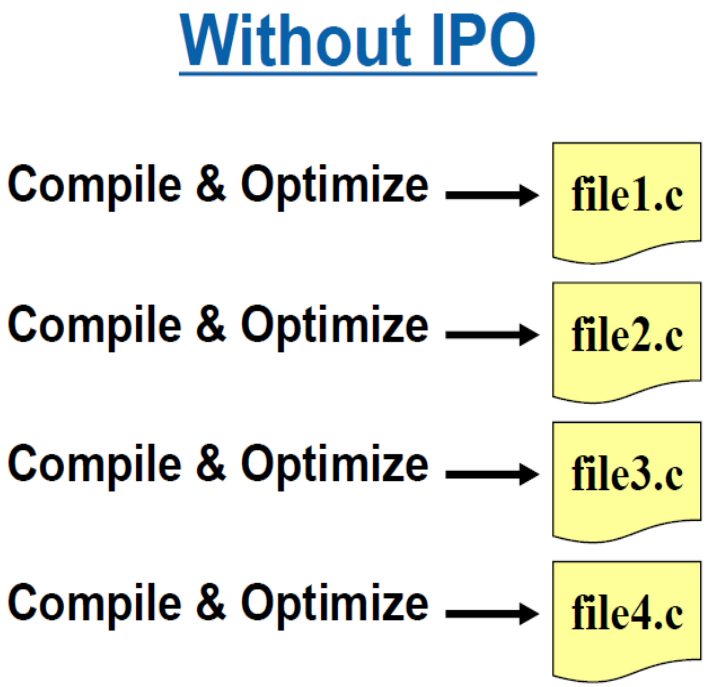
* http://software.intel.com/en-us/articles/intel-c-compiler-for-linux-using-intel-compilers-with-the-eclipse-ide-pdf#installing

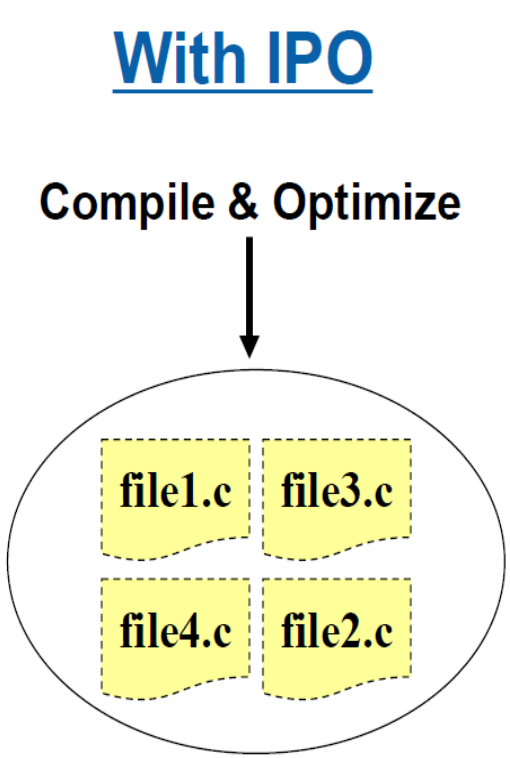
Intel (Parallel) Composer

- It may already help to change the / optimize with compiler:
  - More performance through appropriate flags
  - Indication of problematic parts by reports

Intel (Parallel) Composer

- standardflags: - O3 / Ox
- - vec
- - parallel
- - ip / ipo
- - fast





Intel (Parallel) Composer

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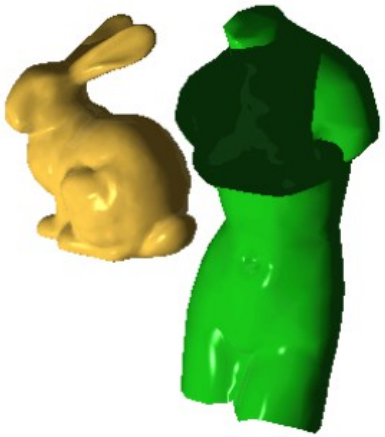

Modell	MSVC (2008)	ICC (11)
Venus (7200)	27,02 sec	19,76 sec
Fishes (20000)	52,36 sec	42,82 sec
Fertility (55000)	211,35 sec	186,66

Intel (Parallel) Composer

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- Reports
  - i.e. vectorization-report
    - -vec-report3
  - optimization-report
    - Contains Vec-Report
    - Inlining
    - Loop unrolling / fusing
    - ...

```
/sipsol.F(194): (col. 10) remark: loop was not vectorized: vectorization possible but seems inefficient.
/sipsol.F(206): (col. 12) remark: loop was not vectorized: existence of vector dependence.
/sipsol.F(296): (col. 7) remark: vector dependence: assumed OUTPUT dependence between fi_n line 296 and fi_n line 309.
/sipsol.F(309): (col. 7) remark: vector dependence: assumed OUTPUT dependence between fi_n line 309 and fi_n line 296.
```

Intel (Parallel) Composer

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```
35:     subroutine fd( y )
36:     integer :: i
37:     real, dimension(10), intent(inout) :: y
38:     do i=2,10
39:        y(i) = y(i-1) + 1
40:     end do
41:     end subroutine fd
```

```
novec.f90(38): (col. 3) remark: loop was not vectorized: existence of
vector dependence.
novec.f90(39): (col. 5) remark: vector dependence: proven FLOW
dependence between y line 39, and y line 39.
novec.f90(38:3-38:3):VEC:MAIN_:  loop was not vectorized: existence of
vector dependence
```

DEMO: Intel (Parallel) Composer

- **Show** how to turn on reporting!
- **Compile** code as RELEASE
- **Explain** dependecies
- **Remove** by reversing loop
- **Explain** ivdep

Intel Inspector

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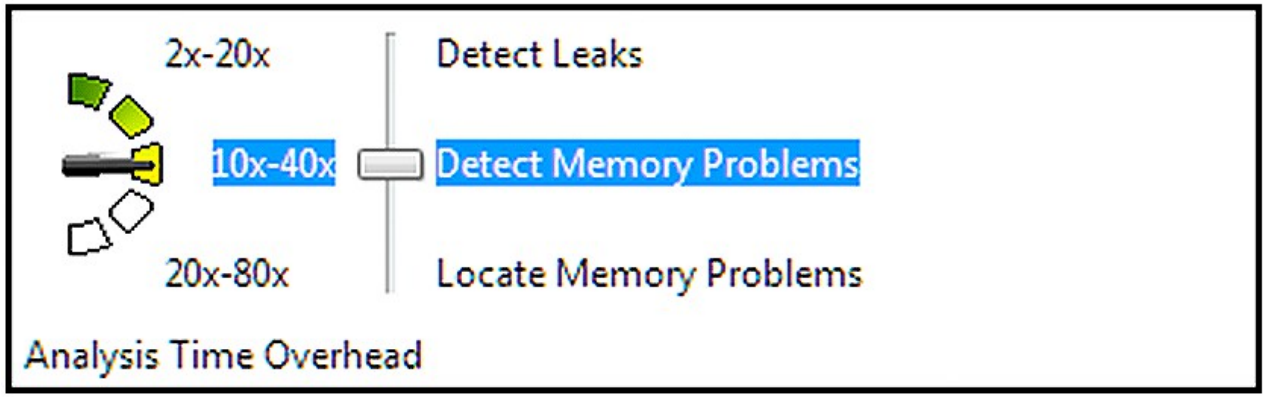
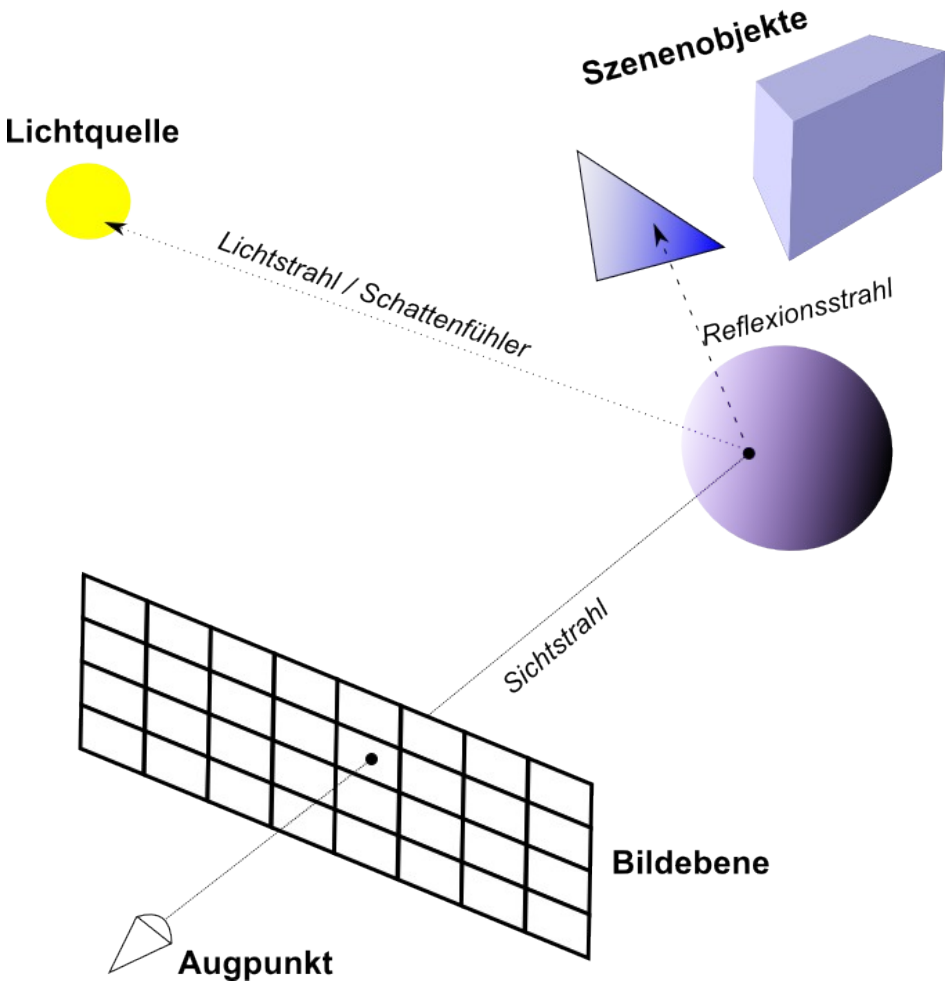
- Memory error checker (**DEMO**)
  - Leaks, corruption
- Threading checker
  - Data races, deadlocks



Vtune Amplifier im Einsatz



1. Calculate eye ray
2. Test intersection with objects
3. Find nearest intersection point
4. Create reflection and shadow rays
5. Calculate local color
6. Repeat steps 2-5 with reflection rays

Intel Trace Analyzer and Collector

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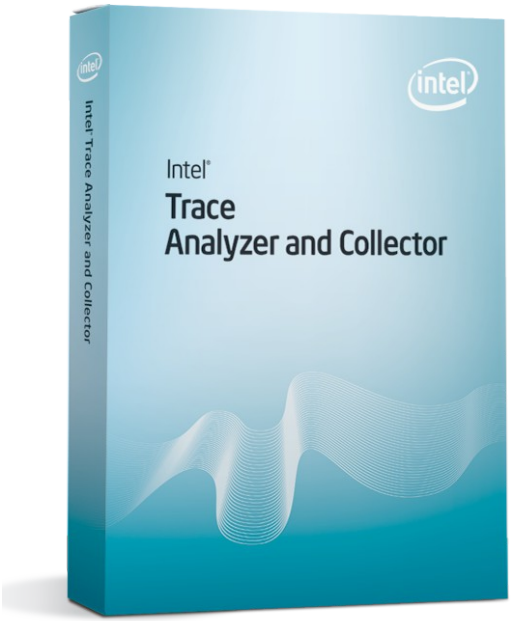
- Analyzing MPI behavior
- Search for bottlenecks, deadlocks, data corruption
- Debugging (call stack, debug infos)
- Supports „Intel architecture based cluster systems“
- Only guaranteed to work with Intel MPI



Intel Trace Analyzer and Collector

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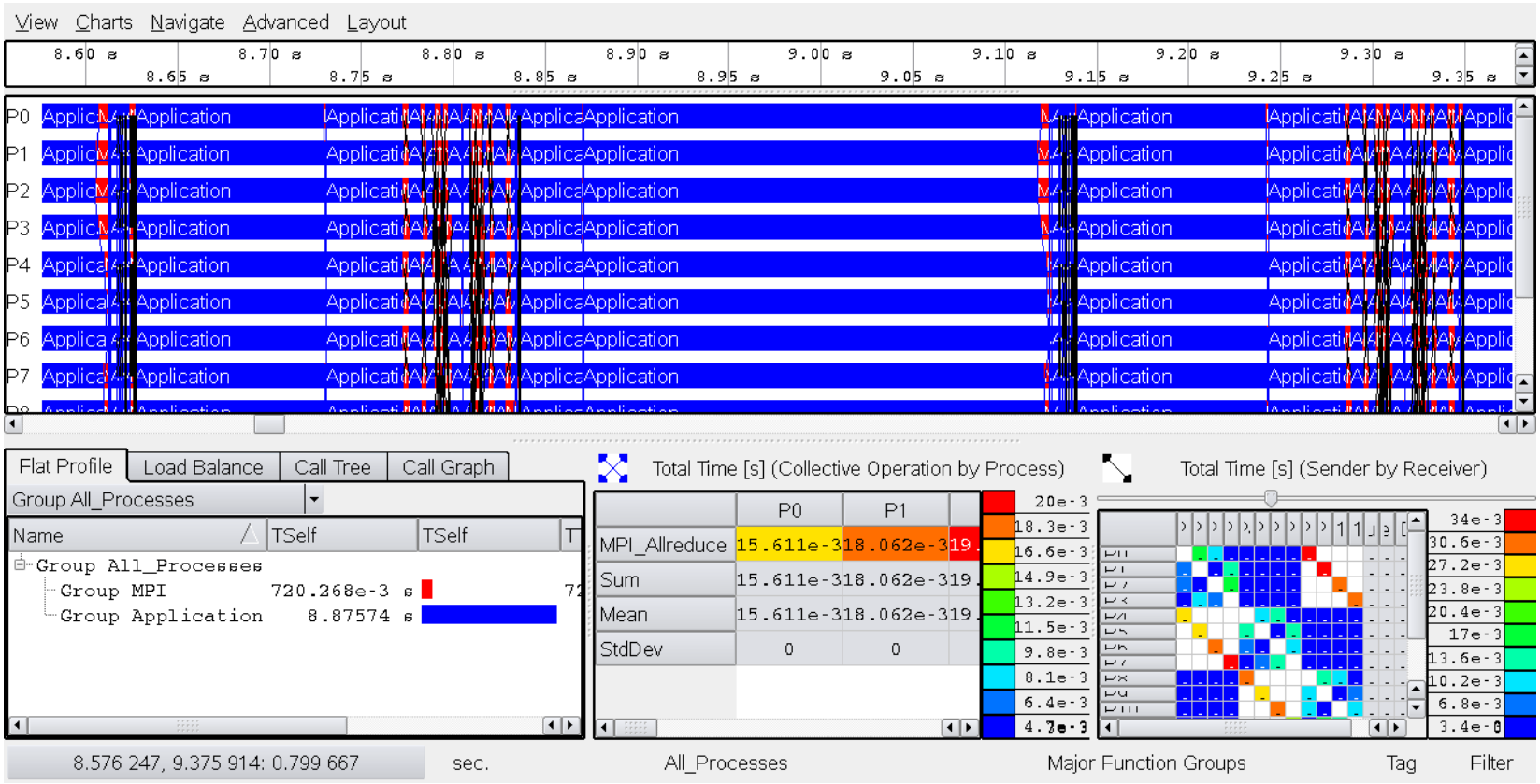
- Analyzer example screenshot:



SCIENTIFIC COMPUTING

Intel Vtune Amplifier

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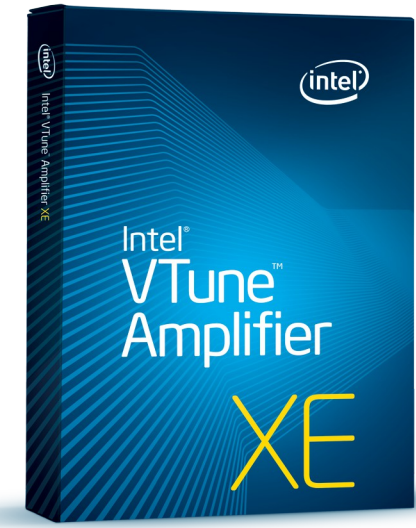
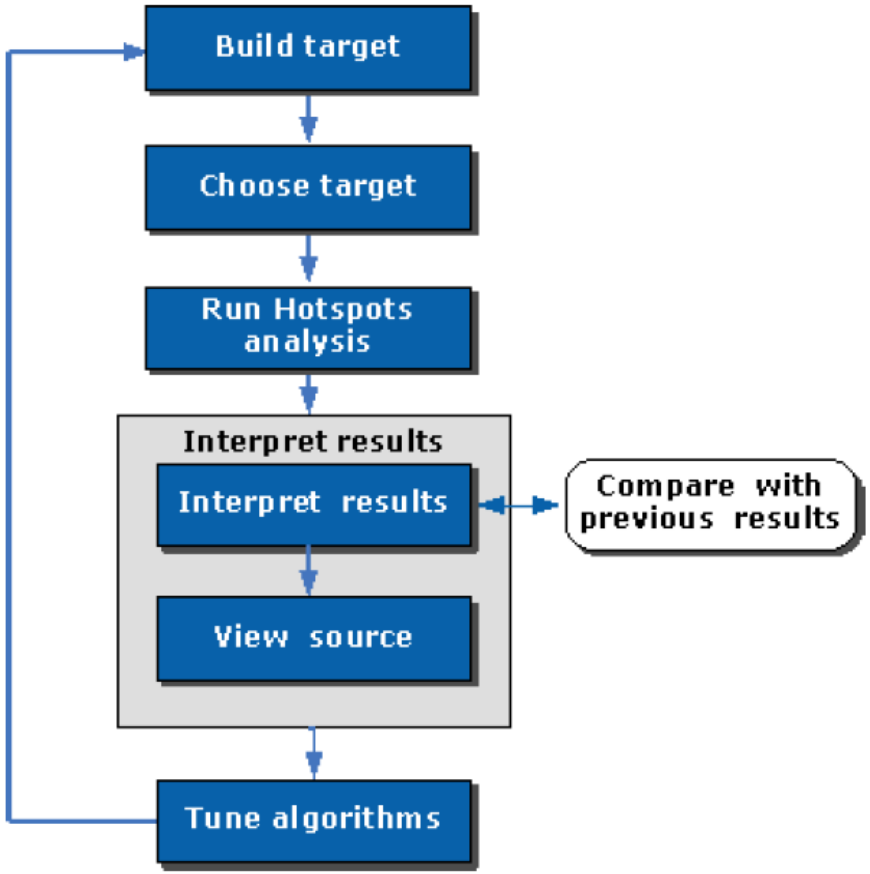
- Supports C (++/#), Fortran, Assembler, Java
- Serial and parallel tuning
- Sample based
- Normal build with -g can be analyzed

  → Use releasebuild
- Graphical or commando line based execution
- Less overhead → real runtimes and results



Intel Vtune Amplifier



- Workflow for optimizing
- Different types of analyses (see next slides)
- Questions:
  - Why optimizing?
  - What should be optimized?
  - Aim of optimizing?
  - How to optimize?

Intel Vtune Amplifier

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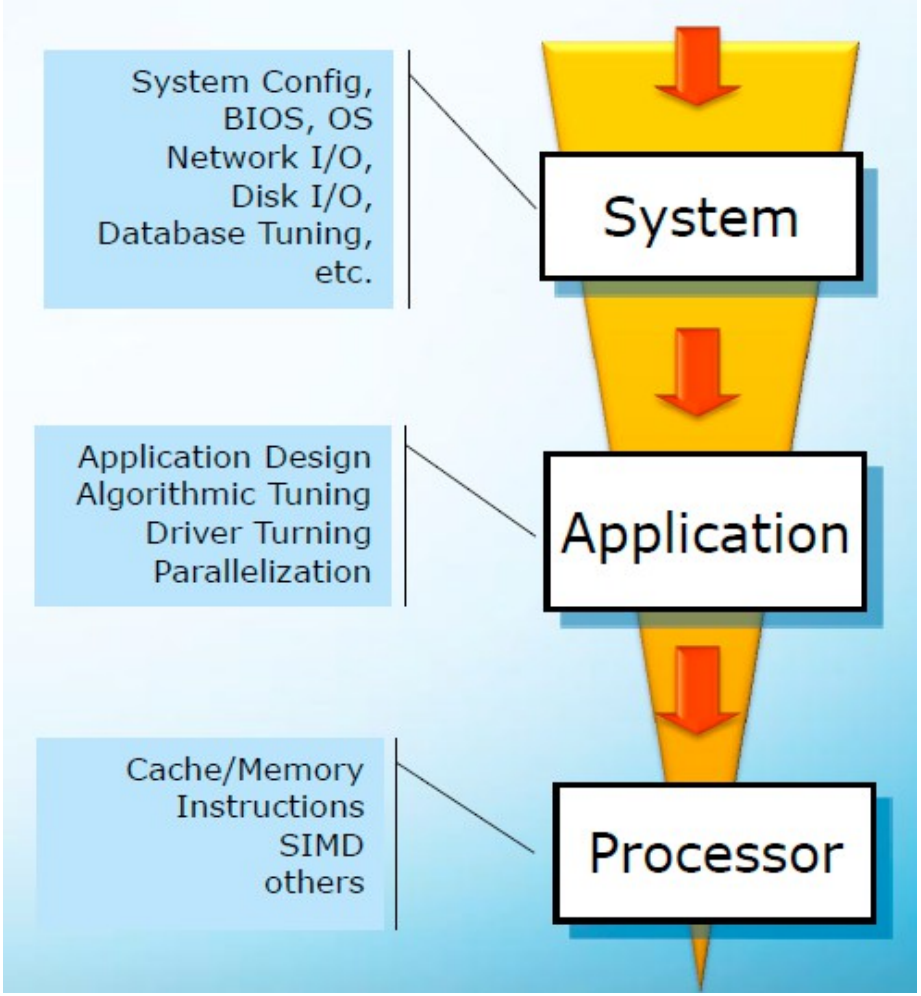
- Use top-down-method
- Amount of work increases with the depth of the level
- Aditional aims
  - Portability
  - Code readability
  - Maintainability
  - Reliability



Intel Vtune Amplifier

- **Scale** and **Vectorize**
- Example: 9-point stencil image blur filter

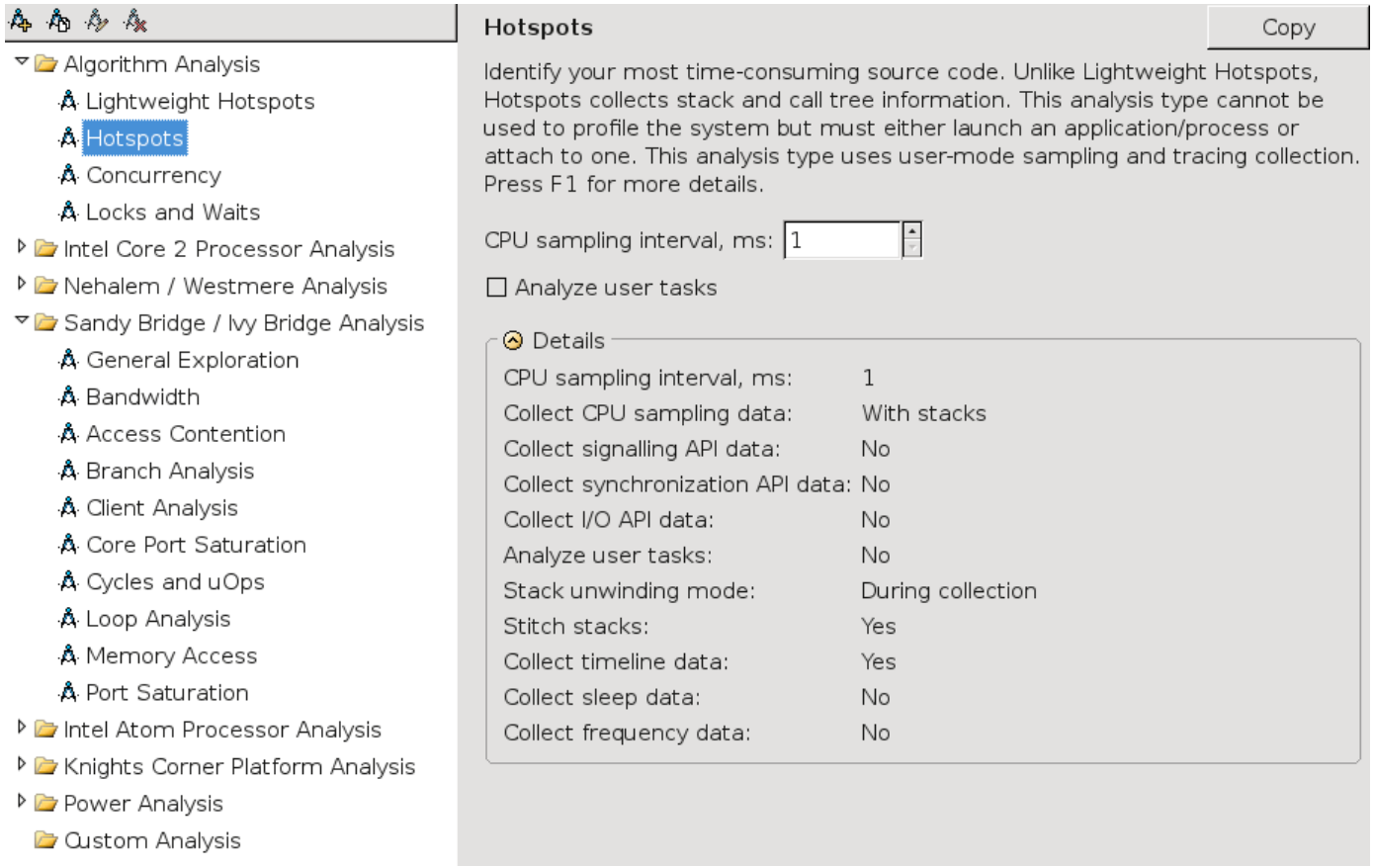
	Single Thread	1 Thread & Vectorized	122 Threads & Vectorized
Xeon Phi	2838,342 s	623,302 s	8,772 s
Xeon	244,178 s	186,585 s	43,862 a

- Example: Diffusion Simulation from Maruyama

	Single Thread	183 Threads	244 Threads & Vectorized
Xeon Phi	5699,55 s	84,622 s	18,664 s

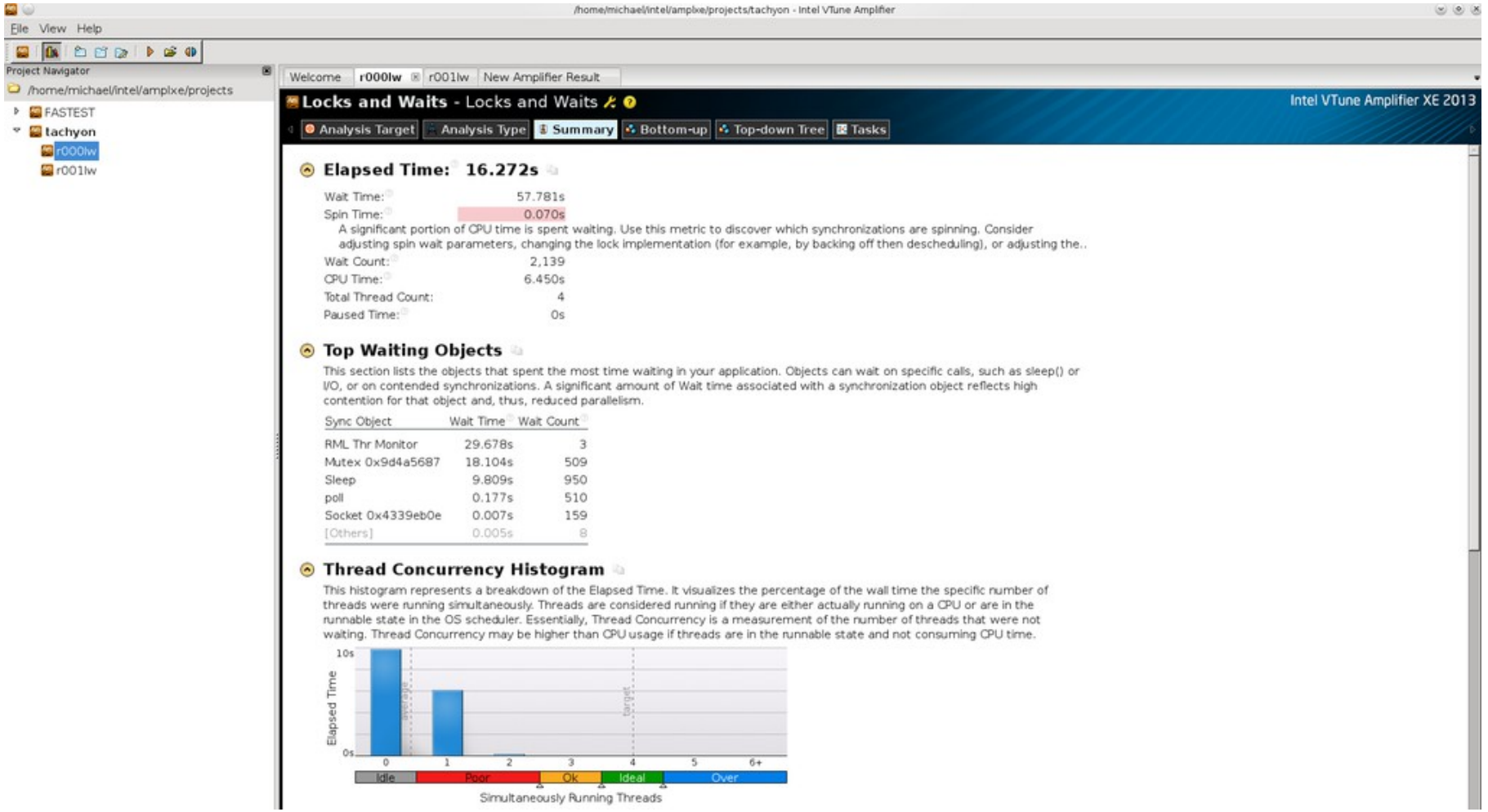
Taken from: "Intel Xeon Phi Coprocessor High-Performance Programming"

Intel Vtune Amplifier



- Depends on underlying architecture
- Our new Cluster: Sandybridge

Intel Vtune Amplifier



Vtune Amplifier im Einsatz

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- Intel delivers code samples with the Amplifier
- Considered here:
  - The Tachyon-Raytracer
  - Matrix Matrix Multiplication
- Include intentional errors / problems
- Little changes result in big impacts on performance

Vtune Amplifier: DEMO

- **DEMO**
  - Raytracer with hotspots und locs
  - Matrix-Multiplivation and LL-Cache Misses
    - Also on Xeon Phi
    - Hotspots / Assembler
    - (Hardwarecounter)

Vtune Amplifier: DEMO

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- Xeon Phi also supported
- 240 Threads, 60 cores, 8 GB GDDR5 RAM, PCI-E 2.0

Vtune Amplifier: DEMO

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- First compile the program and copy to Phi

```
mburger@mice:~/matrix/linux$ source /opt/intel/bin/compilervars.sh intel64
mburger@mice:~/matrix/linux$ make mic
icc -g -O3 -debug inline-debug-info -vec-report0 -mmic -c ../src/util.c -D_ICC -D_LINUX
icc -g -O3 -debug inline-debug-info -vec-report0 -mmic -c ../src/multiply.c -D_ICC -D_LINUX
icc -g -O3 -debug inline-debug-info -vec-report0 -mmic -c ../src/matrix.c -D_ICC -D_LINUX
icc -g -O3 -debug inline-debug-info -vec-report0 -mmic util.o multiply.o matrix.o  -o matrix.mic -lpthre
ad -lm
scp matrix.mic mic0:/tmp
Enter passphrase for key '/home/mburger/.ssh/id_rsa':
matrix.mic                                                    100%   32KB  31.5KB/s   00:00
touch mic-pushed
mburger@mice:~/matrix/linux$
```


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Vtune Amplifier: DEMO

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- Run in native mode:

```
mburger@mice:~/matrix/linux$ ssh mic0
Enter passphrase for key '/home/mburger/.ssh/id_rsa':
[mburger@mice-mic0 mburger]$ cd /tmp/
[mburger@mice-mic0 /tmp]$ ./matrix.mic
Addr of buf1 = 0x0x7fa3f72cd010
Offs of buf1 = 0x0x7fa3f72cd180
Addr of buf2 = 0x0x7fa3f024c010
Offs of buf2 = 0x0x7fa3f024c1c0
Addr of buf3 = 0x0x7fa3e91cb010
Offs of buf3 = 0x0x7fa3e91cb100
Matrix size: 3840
Using multiply kernel: multiply1
Threads #: 240, Execution time = 26.170 seconds
[mburger@mice-mic0 /tmp]$
```

Vtune Amplifier: DEMO

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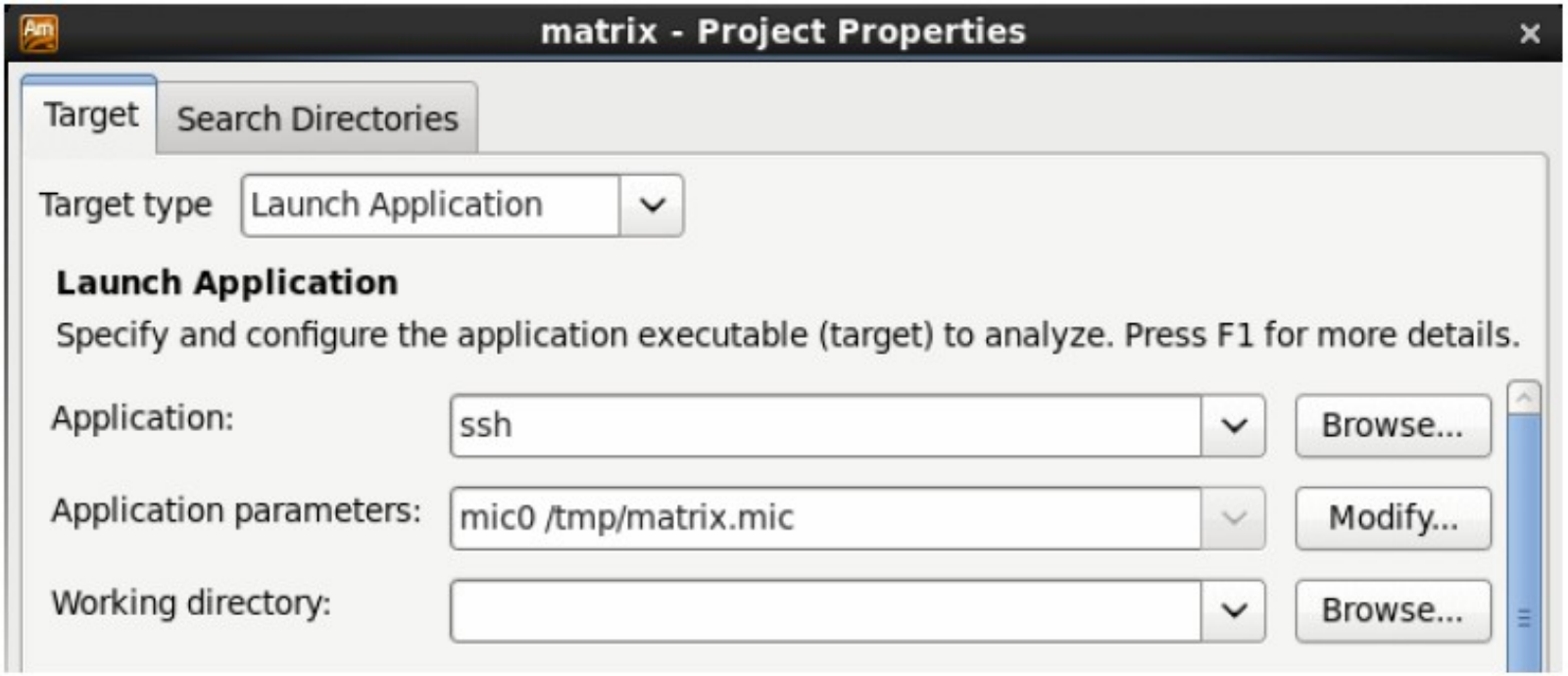
- Setup project correctly:



Vtune Amplifier: DEMO

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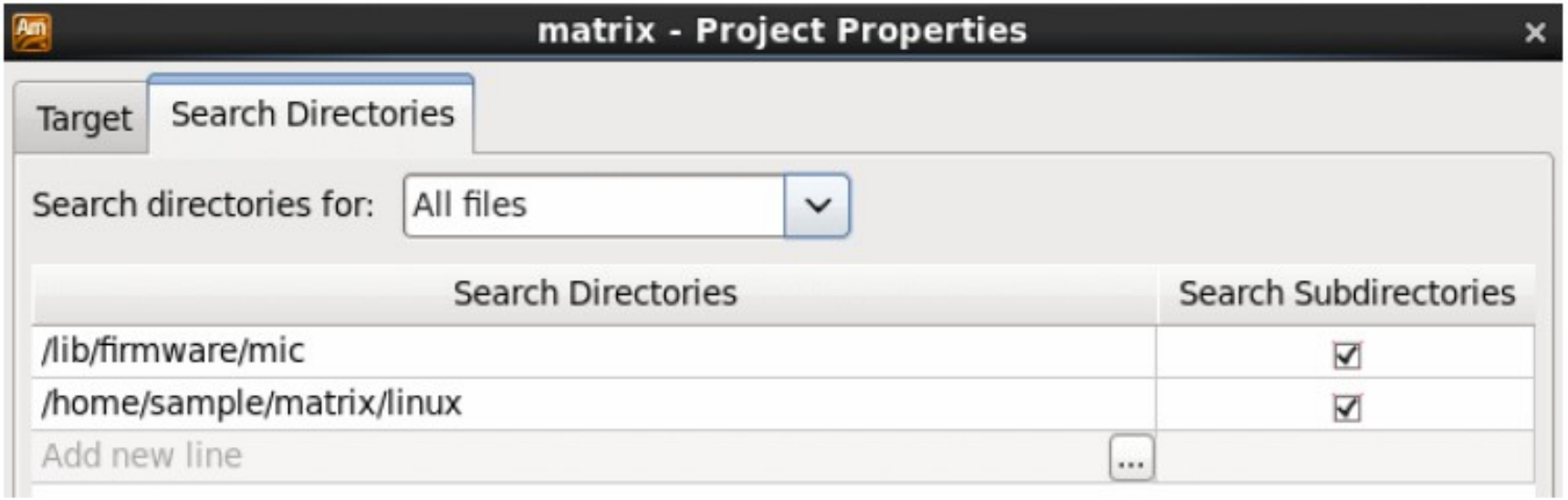
- Setup project correctly:



Vtune Amplifier: DEMO

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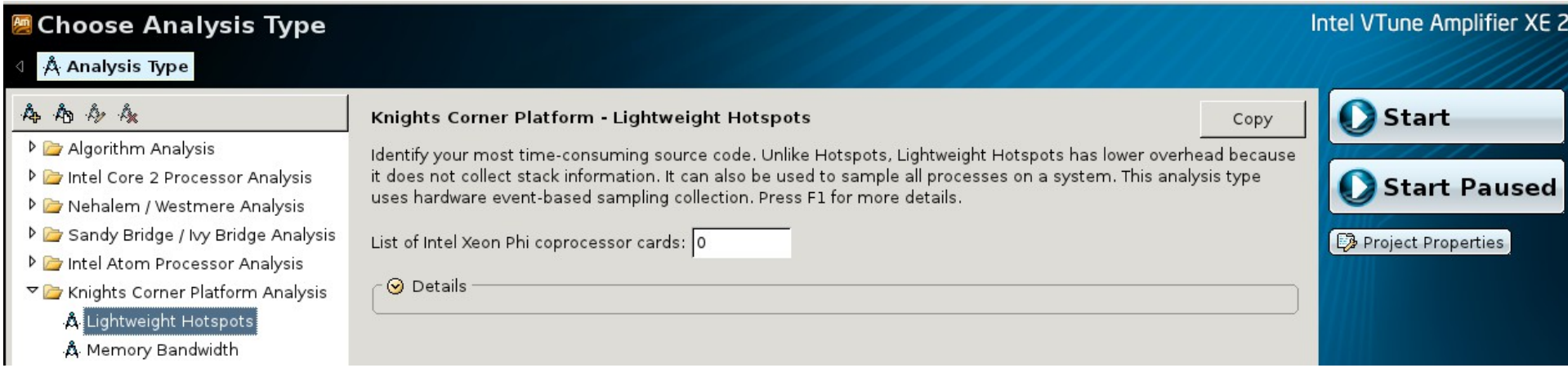
- Start correct analyses type
- Sample driver must be loaded and configured correctly



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Vtune Amplifier: DEMO

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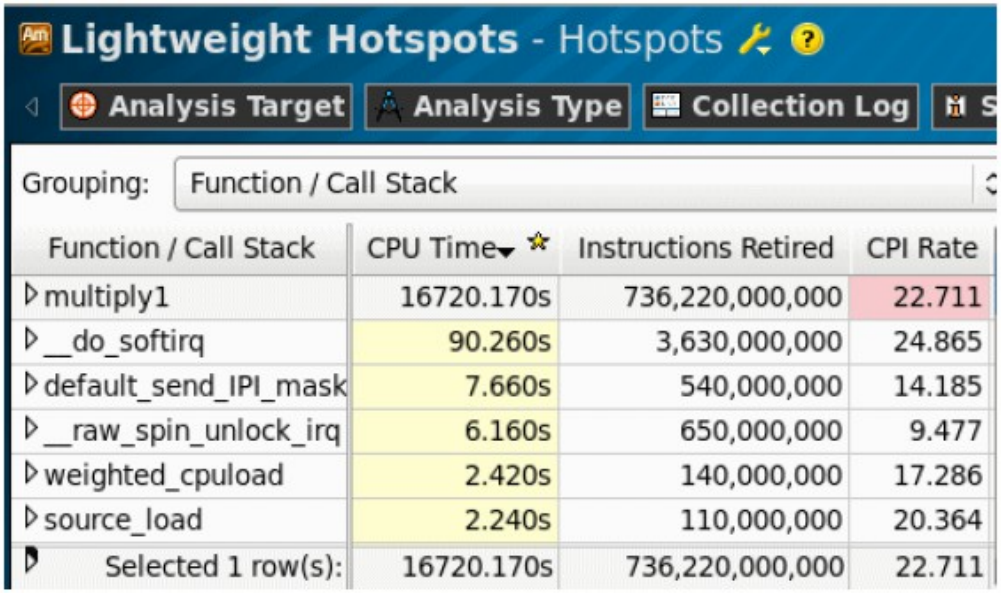
- Look at the results
- Summary
- Tree View
- Clock ticks per instruction



Function / Call Stack	CPU Time	Instructions Retired	CPI Rate
multiply1	16720.170s	736,220,000,000	22.711
__do_softirq	90.260s	3,630,000,000	24.865
default_send_IPI_mask	7.660s	540,000,000	14.185
__raw_spin_unlock_irq	6.160s	650,000,000	9.477
weighted_cpuload	2.420s	140,000,000	17.286
source_load	2.240s	110,000,000	20.364
Selected 1 row(s):	16720.170s	736,220,000,000	22.711

Vtune Amplifier: DEMO

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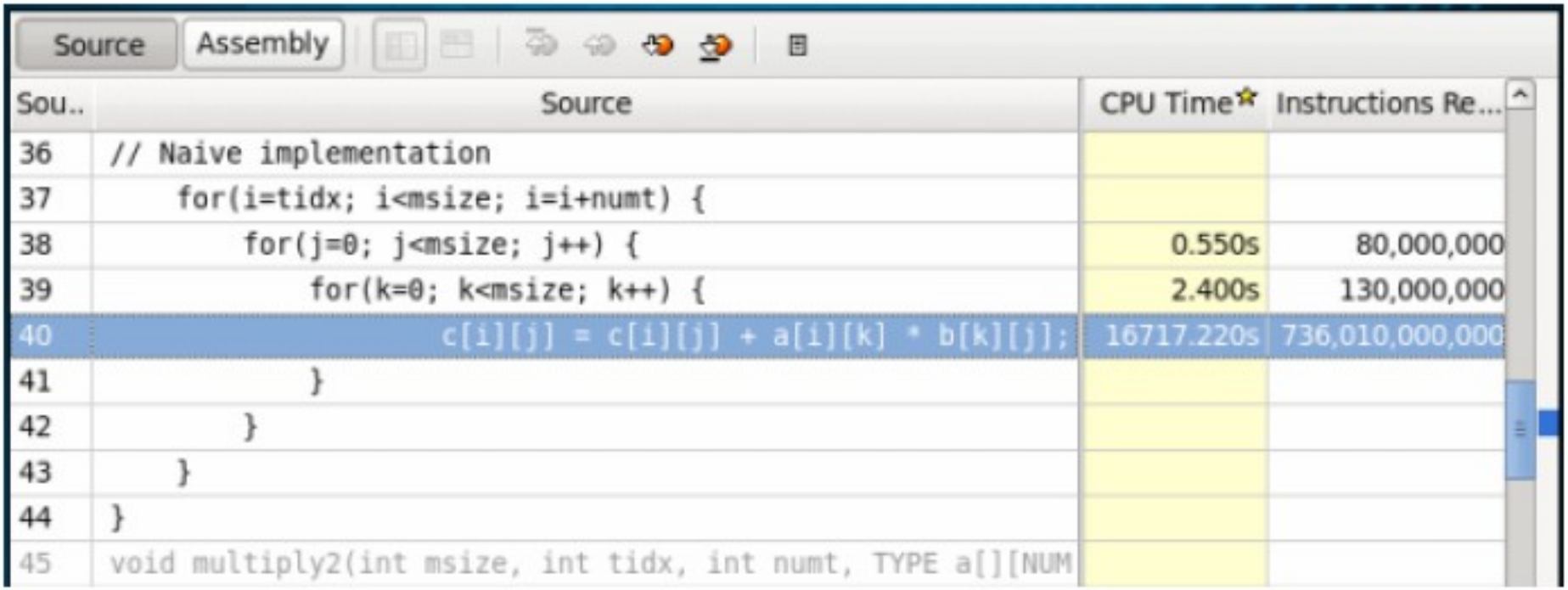
- Look in the code:



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Vtune Amplifier: DEMO

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- Change the code:

matrix.c | multiply.c

```
34 // Select which multiply kernel to use via the following macro so that the
35 // kernel being used can be reported when the test is run.
36 #define MULTIPLY multiply1
37
38 int NTHREADS = MAXTHREADS;
39
40 //static TYPE  a[NUM][NUM], b[NUM][NUM], c[NUM][NUM];
41 typedef TYPE array[NUM];
42 typedef unsigned long long  UINT64;
```

Vtune Amplifier: DEMO

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- Change the code:

matrix.c | multiply.c

```
45 void multiply2(int msize, int tidx, int numt, TYPE a[][NUM], TYPE b[]
   [NUM], TYPE c[][NUM])
46 {
47         int i,j,k;
48
49 // Loop interchange
50         for(i=tidx; i<msize; i=i+numt) {
51                 for(k=0; k<msize; k++) {
52 #pragma ivdep
53                         for(j=0; j<msize; j++) {
54                                 c[i][j] = c[i][j] + a[i][k] * b[k][j];
55                         }
56                 }
57         }
58 }
```


SCIENTIFIC COMPUTING

Vtune Amplifier: DEMO

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- Test if problem is resolved:

```
[mburger@mice-mic0 /tmp]$ ./matrix.mic
Addr of buf1 = 0x0x7fdb838ce010
Offs of buf1 = 0x0x7fdb838ce180
Addr of buf2 = 0x0x7fdb7c84d010
Offs of buf2 = 0x0x7fdb7c84d1c0
Addr of buf3 = 0x0x7fdb757cc010
Offs of buf3 = 0x0x7fdb757cc100
Matrix size: 3840
Using multiply kernel: multiply2
Threads #: 240, Execution time = 3.563 seconds
[mburger@mice-mic0 /tmp]$
```

Vtune Amplifier im Einsatz

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- Approach for the investigation of the MMM-problems:
  - Hardware counter
- Count certain „events“:
  - Cache / Memory accesses
  - Using of INT / FP-Units
  - SIMD instructions
  - ….

  → must be supported by hardware!

Summary

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- Cluster Studio is an extensive collection of tools
- Assists in a lot of parts of software development process
- Several pitfalls are still there however
- Only minimal examples covered here

The End :)

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Thanks for your attention !

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