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Center for Information Services and High Performance Computing

Score-P & Vampir

Comprehensive Multi-Paradigm Performance Analysis

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Introduction > Methods

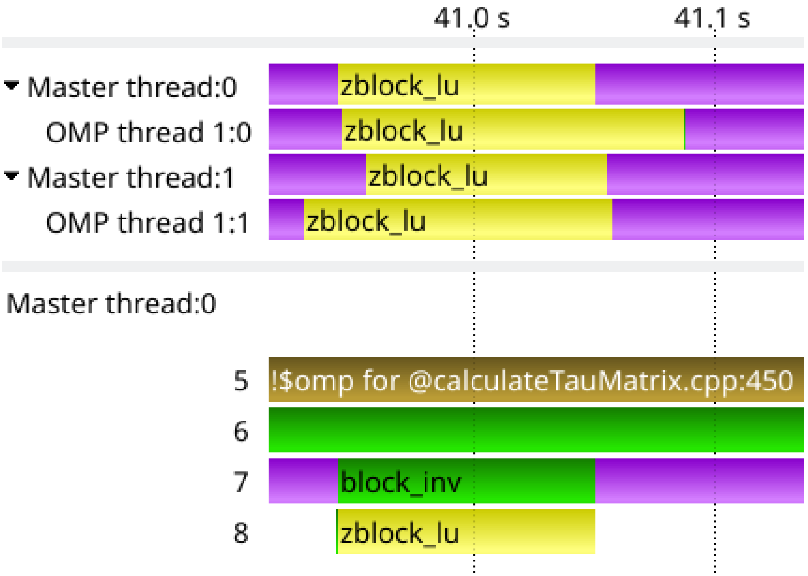
Profile

- Information accumulated into buckets
- Typically small overhead
- Static representation

Trace

- Event log
- Possibly large overhead
- Interactive presentation

Time		Function name
(%)	(s)	
5.44	1.21	QListData::isEmpty
2.96	0.66	QHash::findNode
2.67	0.60	QList::last
1.71	0.38	handleEnter
0.58	0.13	QHash::find



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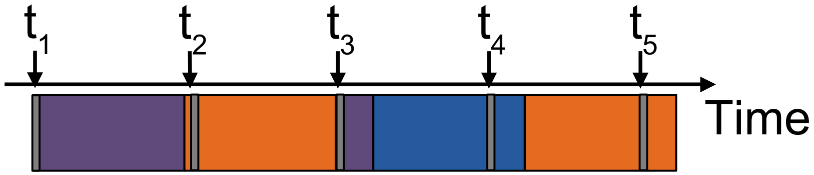
Introduction > Methods

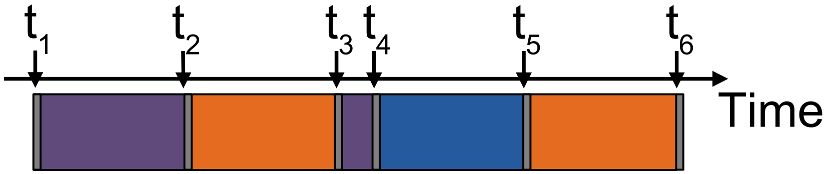
Sampling



- Interrupt with given interval (typically ~10ms)

- Statistical garuantees

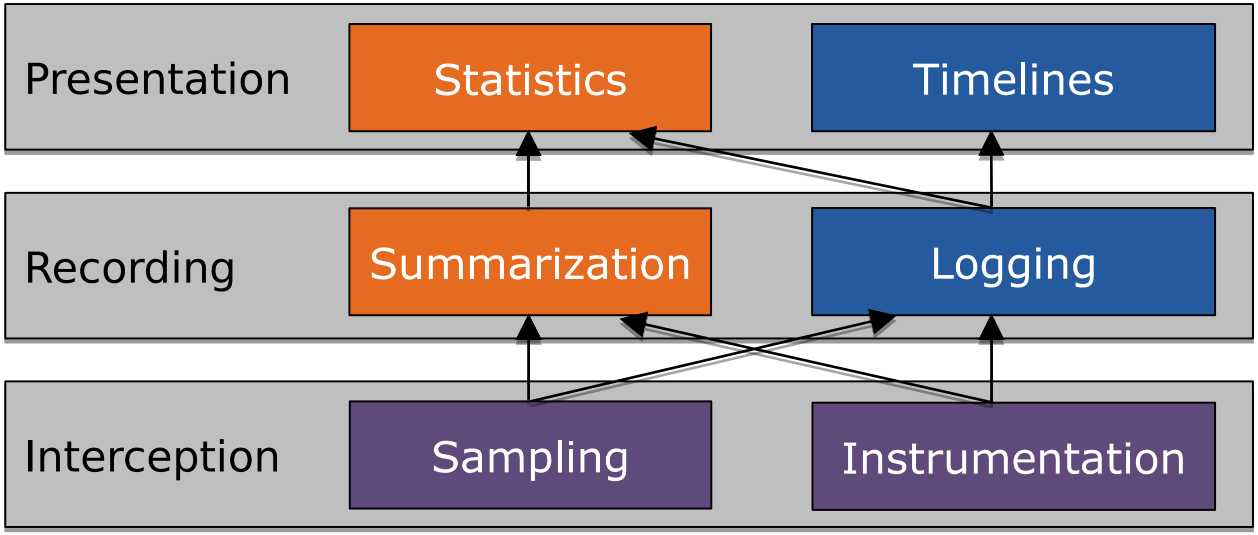
Instrumentation



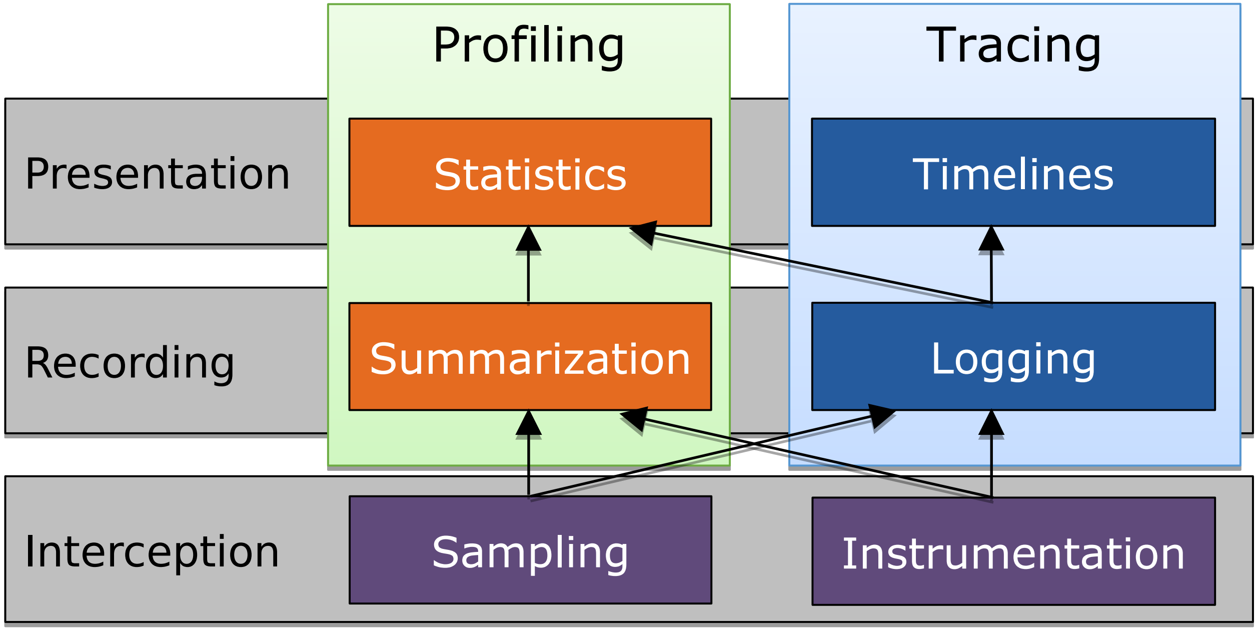
- Callback before/after event

- Exact time and call counts
- Wrappers have access to function arguments

Introduction > Methods



Introduction > Methods



Introduction > Methods

- Myth 1: Tracing has a giant overhead
    - **It depends on the event rate**
        - E.g. an MPI-only trace has very low overhead
    - Admittedly:
        - Main problem 1: Compiler instrumentation
            - → Compiler plugins to the rescue
            - Wrappers are mostly fine and widely used
        - Main problem 2: Filtering workflows are inconvenient
            - Tool-specific problem, not a general „Tracing“-problem

Introduction > Methods

- Myth 2: Tracing produces giant recordings
  - Analogous to Myth 1: It depends on the number of events
  - Score-P has a simple filtering workflow that copes with that
  - The majority of our archived tracefiles are below 1 GB
  - Personally, I always configure Score-P so that the trace is easy to handle on my laptop

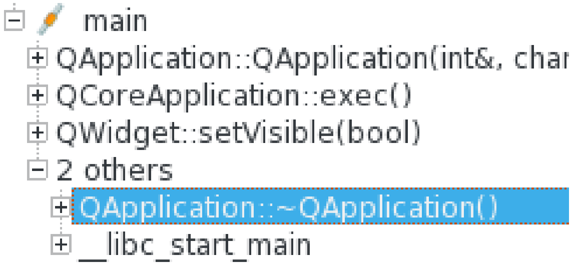
Introduction > Methods

- Myth 3: One technique is superior
  - **Not true**

- Sampling:
  - Does not give an absolutely accurate picture of a run

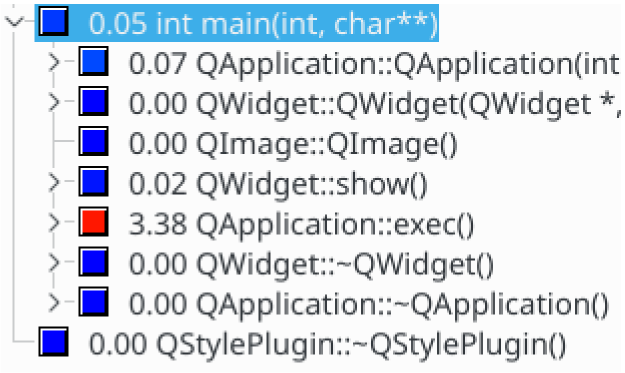
```
int main(int   argc,
    char** args ) {
  QApplication app(argc,
      argv);
  QWidget w;
  QImage i;
  w.show( );
  return app.exec( );
}
```

Sampling



```
⊟ main
  ⊞ QApplication::QApplication(int&, char
  ⊞ QCoreApplication::exec()
  ⊞ QWidget::setVisible(bool)
  ⊟ 2 others
    ⊞ QApplication::~QApplication()
    ⊞ __libc_start_main
```

Instrumentation



```
⌄ 🟦 0.05 int main(int, char**)
    › 🟦 0.07 QApplication::QApplication(int
    › 🟦 0.00 QWidget::QWidget(QWidget *,
      🟦 0.00 QImage::QImage()
    › 🟦 0.02 QWidget::show()
    › 🟥 3.38 QApplication::exec()
    › 🟦 0.00 QWidget::~QWidget()
    › 🟦 0.00 QApplication::~QApplication()
  🟦 0.00 QStylePlugin::~QStylePlugin()
```

Introduction > Methods

- Myth 3: One technique is superior
  - **Not true**

- Sampling:
  - Does not give an absolutely accurate picture of a run
  - Cannot count function calls
  - Cannot record exact timings
  - Cannot record exact performance counters
  - It is **statistical sampling**

  - It cannot capture semantics of APIs, i.e. it cannot follow API usage and analyze passed arguments, e.g. transferred bytes

Introduction > Methods

- Myth 3: One technique is superior
  - **Not true**

- Instrumentation/Tracing:
  - Typically more difficult than using a profiler
  - Does not garuantee anything about overhead or recording size
    - (But it‘s not inconcievable to achieve this)

Introduction > Methods

- In practice, most tools use a combination
  - Coarse-grained sampling + call stack unwinding
  - Wrappers for library functions of interest (MPI_Send, cudaMalloc, dlopen)

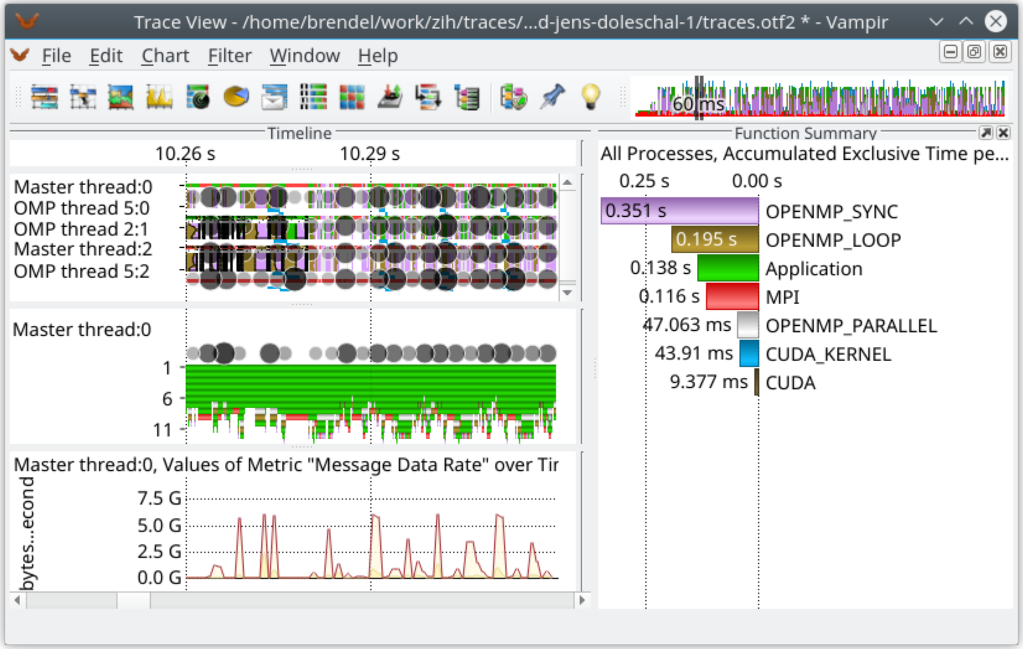
Introduction

Introduction > Vampir

http://vampir.eu

- Comprehensive, powerful performance data visualization
- Developed since 1996
- Commercial

VAMPIR



0.351 s	OPENMP_SYNC
0.195 s	OPENMP_LOOP
0.138 s	Application
0.116 s	MPI
47.063 ms	OPENMP_PARALLEL
43.91 ms	CUDA_KERNEL
9.377 ms	CUDA

GWT forschung+innovation

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ZIH Center for Information Services & High Performance Computing

Introduction > Score-P

http://score-p.org

- Jointly developed next-generation performance data collector
- Developed since 2009
- Open-source (3-clause BSD)
- Partners:
  - TU Dresden, GER
  - FZ Jülich, GER
  - TU München, GER
  - University of Oregon, USA
  - RWTH Aachen; TU Darmstadt;

    Gesellschaft für numerische Simulation mbH;

    German Research School for Simulation Sciences GmbH (all GER)

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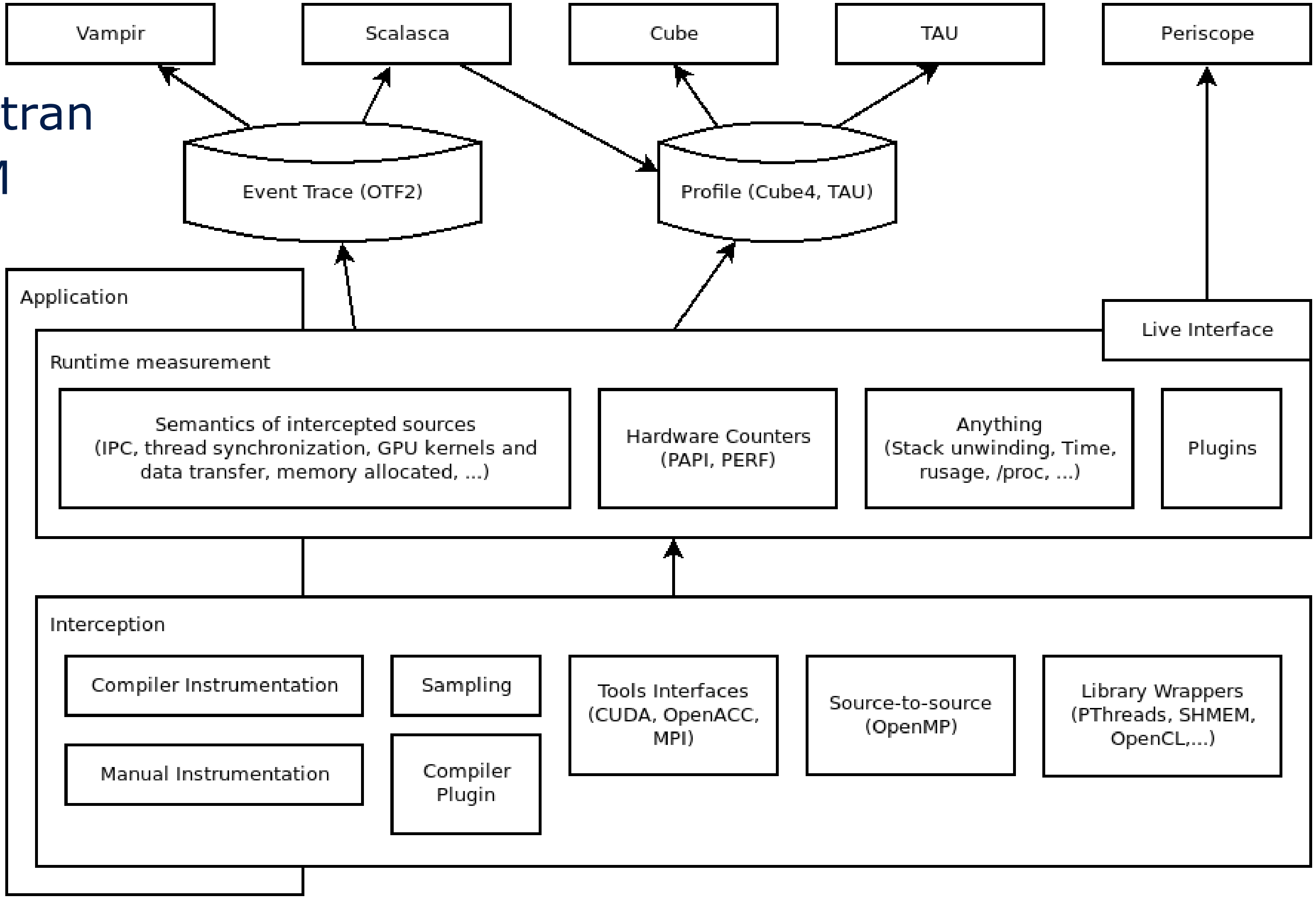
Introduction > Score-P

- Supports:
  - C, C++, Fortran
  - MPI, SHMEM
  - OpenMP, PThreads
  - CUDA, OpenACC, OpenCL

  - Compilers: Cray, GNU, IBM, Intel, Pathscale, PGI, LLVM


Vampir
Scalasca
Cube
TAU
Periscope
Event Trace (OTF2)
Profile (Cube4, TAU)
Application
Live Interface
Runtime measurement
Semantics of intercepted sources (IPC, thread synchronization, GPU kernels and data transfer, memory allocated, ...)
Hardware Counters (PAPI, PERF)
Anything (Stack unwinding, Time, rusage, /proc, ...)
Plugins
Interception
Compiler Instrumentation
Sampling
Tools Interfaces (CUDA, OpenACC, MPI)
Source-to-source (OpenMP)
Library Wrappers (PThreads, SHMEM, OpenCL,...)
Manual Instrumentation
Compiler Plugin

Tutorial

Tutorial > Usage

- Load Score-P (ANL)

```
$ module load scorep
```

```
$ echo "+vampir" >> ~/.soft && resoft
```

- Compile & Link (with MPI) (with SHMEM)

```
$ scorep … gcc …  main.c
```

```
$ scorep mpicc main.c
```

```
$ scorep oshcc main.c
```

- CMake

```
$ SCOREP_WRAPPER=OFF cmake -DCMAKE_C_COMPILER=scorep-gcc ..
$ SCOREP_WRAPPER_INSTRUMENTER_FLAGS="…" SCOREP_WRAPPER_COMPILER_FLAGS="…" make
```

- Autotools

```
$ SCOREP_WRAPPER=OFF ../configure CC=scorep-gcc MPICC=scorep-mpicc ..
$ SCOREP_WRAPPER_INSTRUMENTER_FLAGS="…" SCOREP_WRAPPER_COMPILER_FLAGS="…" make
```

Tutorial > Usage

- Execute

```
$ ./a.out
```

```
$ mpirun -np 2 ./a.out
```

```
$ shmemrun -np 2 ./a.out
```

- Inspect

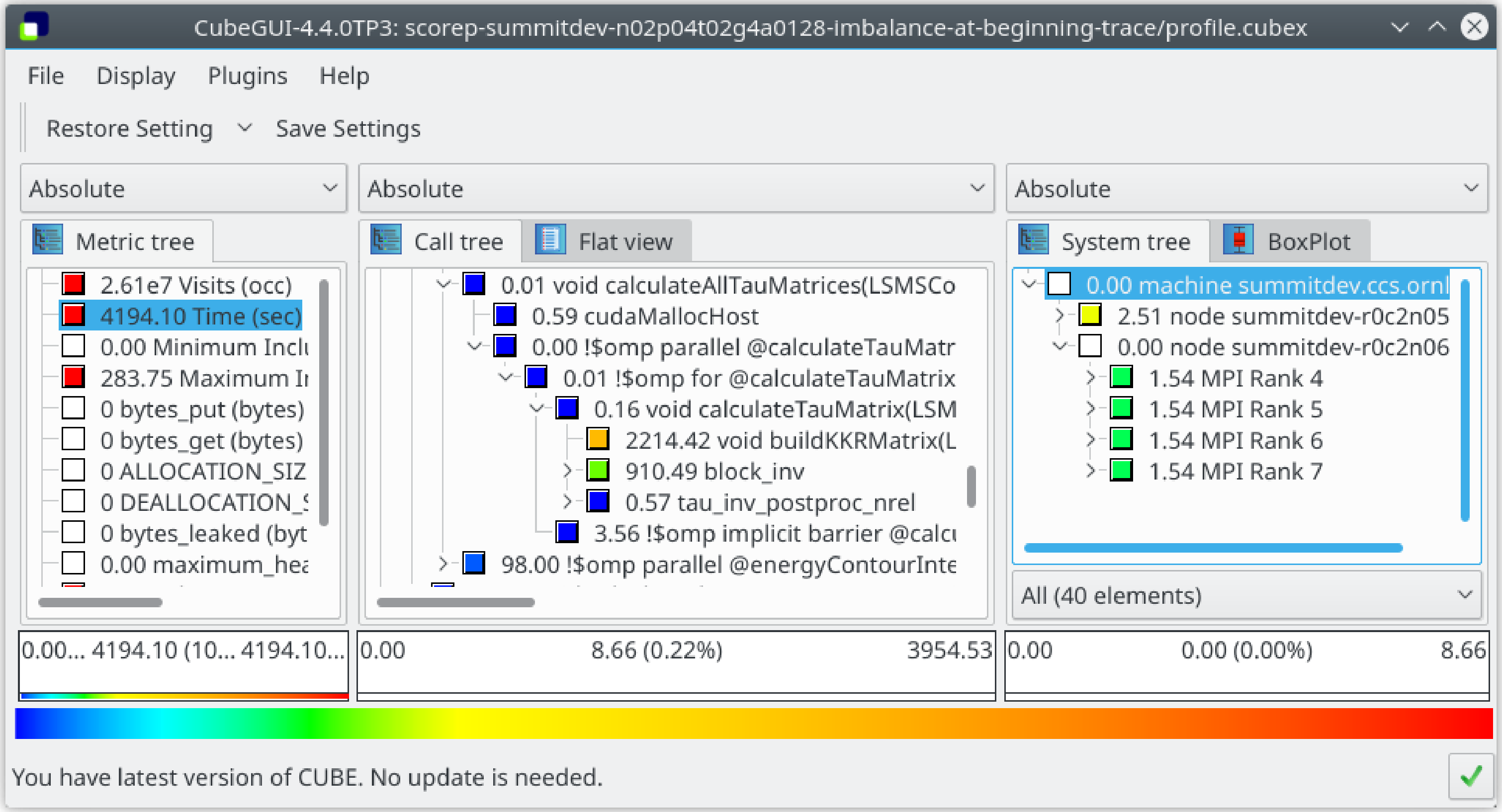
```
$ ls -R
scorep-20170323_1309_7243761919249966  a.out

./scorep-20170323_1309_7243761919249966:
profile.cubex  scorep.cfg
```

- Inspect > Cube

```
$ cube scorep-20170323_1309_7243761919249966/profile.cubex
```

Tutorial > Usage

- Inspect > Cube



CubeGUI-4.4.0TP3: scorep-summitdev-n02p04t02g4a0128-imbalance-at-beginning-trace/profile.cubex

Metric tree:

```
2.61e7 Visits (occ)
4194.10 Time (sec)
0.00 Minimum Inclı
283.75 Maximum Iı
0 bytes_put (bytes)
0 bytes_get (bytes)
0 ALLOCATION_SIZ
0 DEALLOCATION_S
0 bytes_leaked (byt
0.00 maximum_hea
```

Call tree:

```
0.01 void calculateAllTauMatrices(LSMSCo
  0.59 cudaMallocHost
  0.00 !$omp parallel @calculateTauMatr
    0.01 !$omp for @calculateTauMatrix
      0.16 void calculateTauMatrix(LSM
        2214.42 void buildKKRMatrix(L
        910.49 block_inv
        0.57 tau_inv_postproc_nrel
      3.56 !$omp implicit barrier @calcu
98.00 !$omp parallel @energyContourInte
```

System tree:

```
0.00 machine summitdev.ccs.ornl
  2.51 node summitdev-r0c2n05
  0.00 node summitdev-r0c2n06
    1.54 MPI Rank 4
    1.54 MPI Rank 5
    1.54 MPI Rank 6
    1.54 MPI Rank 7
```

All (40 elements)

```
0.00... 4194.10 (10... 4194.10...
0.00          8.66 (0.22%)          3954.53
0.00          0.00 (0.00%)          8.66
```

You have latest version of CUBE. No update is needed.

Tutorial > Usage

- Runtime Options
  - Profiling (default)

    ```
    $ export SCOREP_ENABLE_PROFILING=true
    ```

  - Tracing

    ```
    $ export SCOREP_ENABLE_TRACING=true
    ```

  - Performance counters

    ```
    $ export SCOREP_METRIC_PAPI=PAPI_L2_TCM,…
    ```

  - Filtering

    ```
    $ export SCOREP_FILTERING_FILE=my.filt
    ```

  - Memory (default: 16M)

    ```
    $ export SCOREP_TOTAL_MEMORY=1G
    ```

  - And many more...

    ```
    $ scorep-info config-vars
    ```

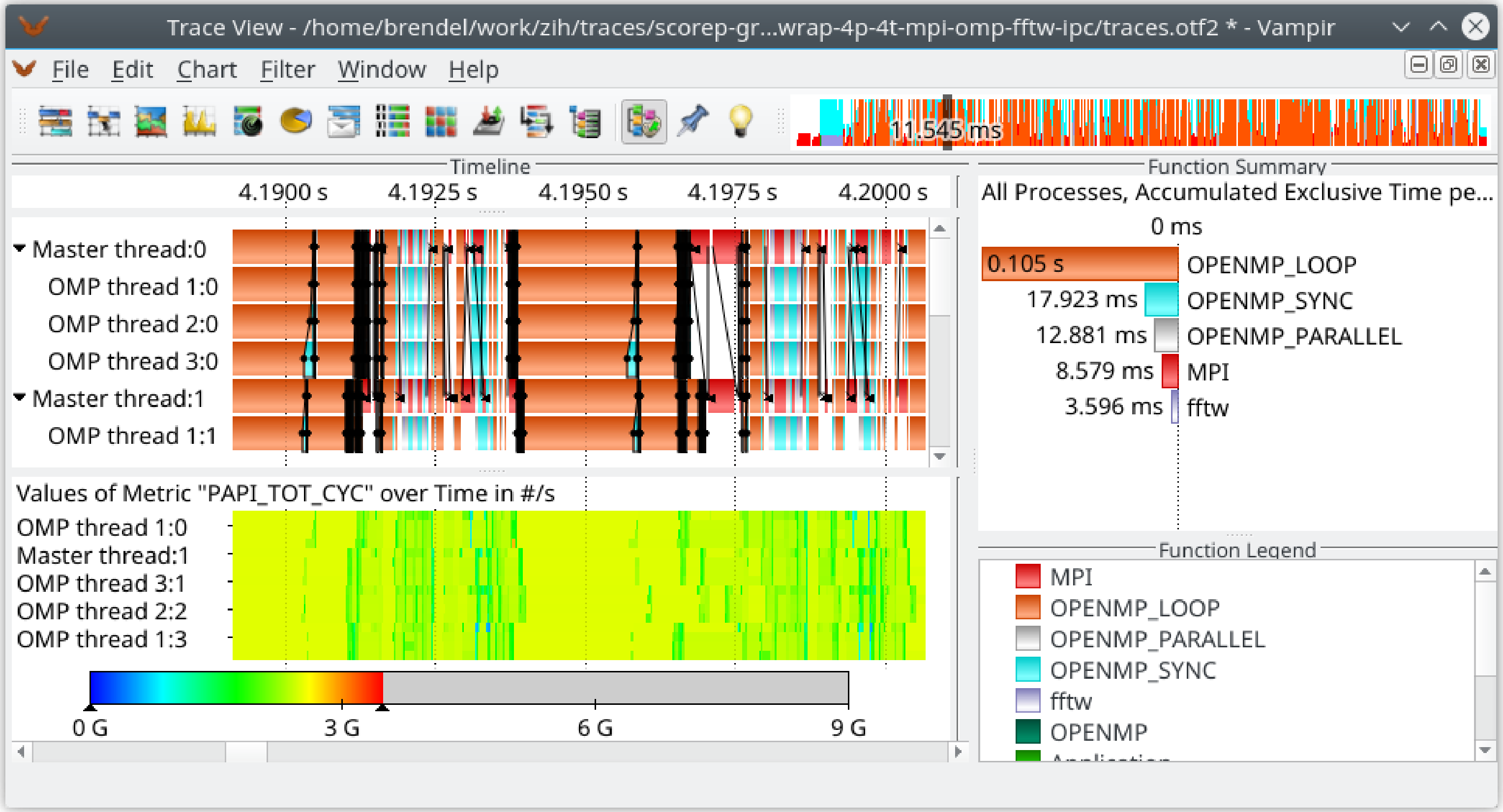
Tutorial > Usage

- Inspect > Vampir

```
$ export SCOREP_ENABLE_PROFILING=false
$ export SCOREP_ENABLE_TRACING=true
$ export SCOREP_METRIC_PAPI=PAPI_TOT_INS,PAPI_TOT_CYC

$ mpirun -np 4 ./a.out

$ ls -R
scorep-20170323_1309_7243761919249966  a.out

./scorep-20170323_1309_7243761919249966:
scorep.cfg  traces/  traces.def  traces.otf2

$ module load vampir

$ vampir scorep-20170323_1309_7243761919249966/traces.otf2
```

Tutorial > Usage

- Inspect > Vampir



Trace View - /home/brendel/work/zih/traces/scorep-gr...wrap-4p-4t-mpi-omp-fftw-ipc/traces.otf2 * - Vampir

Function Summary

All Processes, Accumulated Exclusive Time pe...

0 ms	
0.105 s	OPENMP_LOOP
17.923 ms	OPENMP_SYNC
12.881 ms	OPENMP_PARALLEL
8.579 ms	MPI
3.596 ms	fftw

Values of Metric "PAPI_TOT_CYC" over Time in #/s

Tutorial > Overhead

- Trace size and overhead varies greatly with event rate
  - Make a reference run and check wall clock time!
  - Rule of thumb: Try to stay below 10% overhead

→ Filtering is an integral part of Score-P’s workflow

Tutorial > Profiling Workflow

1) Instrument & build
2) Execute
3) Analyze profile using Cube

Mind that overhead can be too high. Runtime filtering does not help, if the event rate is extremely high

→ Compile-time filtering with our GCC instrumentation compiler plugin solves this

```
$ scorep --instrument-filter=<filter_file> gcc main.c
```

Tutorial > Tracing Workflow

1) Instrument & build
2) Execute (profiling)
3) Analyze overhead

   If the estimated trace size is too large, filter and goto (3)
4) Execute using the filter (tracing)
5) Analyze trace using Vampir

Tutorial > Tracing Workflow

3) Analyze Overhead

```
$ scorep-score scorep-20170323_1309_7243761919249966/profile.cubex

Estimated aggregate size of event trace:                   40GB
Estimated requirements for largest trace buffer (max_buf): 6GB
Estimated memory requirements (SCOREP_TOTAL_MEMORY):       6GB
(warning: The memory requirements cannot be satisfied by Score-P to avoid
 intermediate flushes when tracing. Set SCOREP_TOTAL_MEMORY=4G to get the
 maximum supported memory or reduce requirements using USR regions filters.)

flt     type    max_buf[B]        visits time[s] time[%] time/visit[us]  region
         ALL 5,383,272,006 1,635,443,611   579.23   100.0            0.35  ALL
         USR 5,358,738,138 1,631,138,913   253.00    43.7            0.16  USR
         OMP    23,580,522     4,089,856   318.79    55.0           77.95  OMP
         COM       665,210       182,120     0.90     0.2            4.95  COM
         MPI       288,136        32,722     6.55     1.1          200.11  MPI
```

Tutorial > Tracing Workflow

3) Analyze Overhead

```
$ scorep-score -r scorep-20170323_1309_7243761919249966/profile.cubex
  [...]

flt      type    max_buf[B]        visits time[s] time[%] time/visit[us]  region
          ALL 5,383,272,006 1,635,443,611  579.23   100.0           0.35  ALL
          USR 5,358,738,138 1,631,138,913  253.00    43.7           0.16  USR
          OMP    23,580,522     4,089,856  318.79    55.0          77.95  OMP
          COM       665,210       182,120    0.90     0.2           4.95  COM
          MPI       288,136        32,722    6.55     1.1         200.11  MPI

          USR 1,716,505,830   522,844,416   79.32    13.7           0.15  matmul_sub_
          USR 1,716,505,830   522,844,416   53.44     9.2           0.10  matvec_sub_
          USR 1,716,505,830   522,844,416  111.47    19.2           0.21  binvcrhs_
          USR    76,195,080    22,692,096    2.76     0.5           0.12  binvrhs_
          USR    76,195,080    22,692,096    4.37     0.8           0.19  lhsinit_
          USR    56,825,184    17,219,840    1.63     0.3           0.09  exact_solution_
```

Tutorial > Tracing Workflow

3) Filter

```
$ cat myfilter.filt
SCOREP_REGION_NAMES_BEGIN
  EXCLUDE
    matmul_sub*
    matvec_sub*
    binvcrhs*
    Binvrhs*
    exact_solution*
    lhs*init*
    timer_*
SCOREP_REGION_NAMES_END

$ scorep-score -f myfilter.filt scorep-20170323*/profile.cubex

Estimated aggregate size of event trace:                   409MB
Estimated requirements for largest trace buffer (max_buf): 58MB
Estimated memory requirements (SCOREP_TOTAL_MEMORY):       70MB
(hint: When tracing set SCOREP_TOTAL_MEMORY=70M to avoid
[...]
```

Tutorial > Tracing Workflow

4) Execute using the filter (Tracing)

```
$ export SCOREP_ENABLE_TRACING=true
$ export SCOREP_TOTAL_MEMORY=70M
$ export SCOREP_FILTERING_FILE=myfilter.filt

$ mpirun -np 8 ./a.out
```

4) GCC-only: Compile-time filtering

```
$ scorep --instrument-filter=myfilter.filt gcc main.c

$ export SCOREP_ENABLE_TRACING=true
$ export SCOREP_TOTAL_MEMORY=70M

$ mpirun -np 8 ./a.out          # no runtime filtering needed
```

Tutorial > Vampir Demo (Live)

Tutorial > Getting Help

- `$ scorep --help`
- `$ scorep-wrapper --help`
- `$ scorep-info config-vars`

http://score-p.org
http://vampir.eu

- Manuals: `$SCOREP_DIR/share/doc/scorep/pdf/scorep.pdf`
  `$VAMPIR_ROOT/doc/vampir-manual.pdf`
- https://www.alcf.anl.gov/vampir
- support@score-p.org, service@vampir.eu

- VI-HPS offers trainings (Invite them!)
  - http://www.vi-hps.org/training/tws/
  - http://www.vi-hps.org/training/material/

Conclusions

- Holistic, powerful and detailed software performance analysis
  - Everything in one picture
  - Extremely customizable
  - Extremely scalable

  - Advanced features
  - Very active in adopting new features

- Active research community

- Continuously selected by OLCF
- **Enabler for science at extreme scale**

Future Work

- User library wrapping
- I/O analysis (POSIX, ADIOS, HDF5, NetCDF)
- Non-volatile memory analysis
- POWER8/9 & Clang support
- Instrumentation compiler plugin for LLVM
- OpenMP tools interface (OMPT)
- MPI RMA analysis
- KNL-specific metrics and topology information

Sponsors & Projects

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of Education
and Research

OAK
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Commission

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for Research & Innovation

U.S. DEPARTMENT OF
ENERGY

Office of
Science

INDIANA UNIVERSITY

Microsoft

POP

READEX

nextgenio

ELP

HAEC

Score-E

LMAC

SILC

ITEA 2

eeClust

SEVENTH FRAMEWORK PROGRAMME

//ParMA

//H4H

Contributors

- Score-P

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- Vampir

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Hands-On

- Prepared example:

```
ssh -Y titan
cp -r /lustre/atlas/world-shared/stf010/brendel/heat ~
cd ~/heat
less instructions.txt
```

- https://www.alcf.anl.gov/vampir
  - **Please install Vampir on your laptop**

- (https://www.olcf.ornl.gov/kb_articles/software-scorep/)