Introduction to OmniTrace

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Profiling

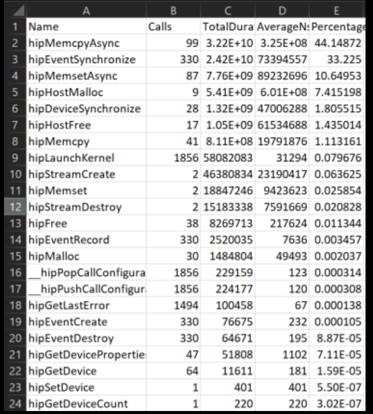
Background – AMD Profilers

ROC-profiler (rocprof)

Hardware Counters	Raw collection of GPU counters and traces	
	Counter collection with user input files	Counter results printed to a CSV

Traces and timelines	Trace collection support for			
	CPU copy	HIP API	HSA API	GPU Kernels

Visualisation	Traces visualized with Perfetto



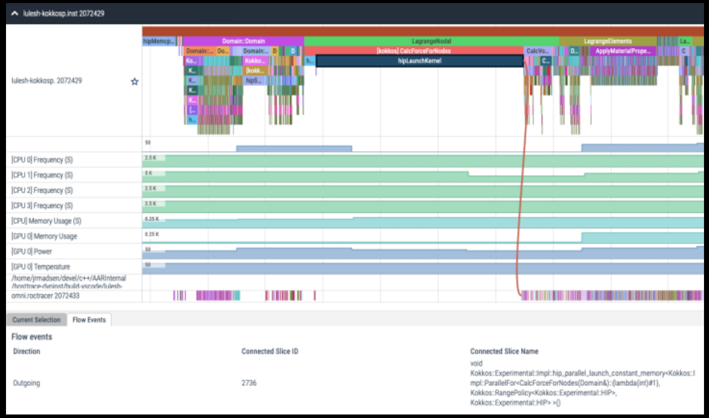
	A	B	C	D	E
1	Name	Calls	TotalDura	AverageN:	Percentage
2	hipMemcpyAsync	99	3.22E+10	3.25E+08	44.14872
3	hipEventSynchronize	330	2.42E+10	73394557	33.225
4	hipMemsetAsync	87	7.76E+09	89232696	10.64953
5	hipHostMalloc	9	5.41E+09	6.01E+08	7.415198
6	hipDeviceSynchronize	28	1.32E+09	47006288	1.805515
7	hipHostFree	17	1.05E+09	61534688	1.435014
8	hipMemcpy	41	8.11E+08	19791876	1.113161
9	hipLaunchKernel	1856	58082083	31294	0.079676
10	hipStreamCreate	2	46380834	23190417	0.063625
11	hipMemset	2	18847246	9423623	0.025854
12	hipStreamDestroy	2	15183338	7591669	0.020828
13	hipFree	38	8269713	217624	0.011344
14	hipEventRecord	330	2520035	7636	0.003457
15	hipMalloc	30	1484804	49493	0.002037
16	__hipPopCallConfigura	1856	229159	123	0.000314
17	__hipPushCallConfigur	1856	224177	120	0.000308
18	hipGetLastError	1494	100458	67	0.000138
19	hipEventCreate	330	76675	232	0.000105
20	hipEventDestroy	330	64671	195	8.87E-05
21	hipGetDevicePropertie	47	51808	1102	7.11E-05
22	hipGetDevice	64	11611	181	1.59E-05
23	hipSetDevice	1	401	401	5.50E-07
24	hipGetDeviceCount	1	220	220	3.02E-07

Omnitrace

Trace collection	Comprehensive trace collection	
	CPU	GPU

Supports	CPU copy	HIP API	HSA API	GPU Kernels	
	OpenMP®	MPI	Kokkos	p-threads	multi-GPU

Visualisation	Traces visualized with Perfetto

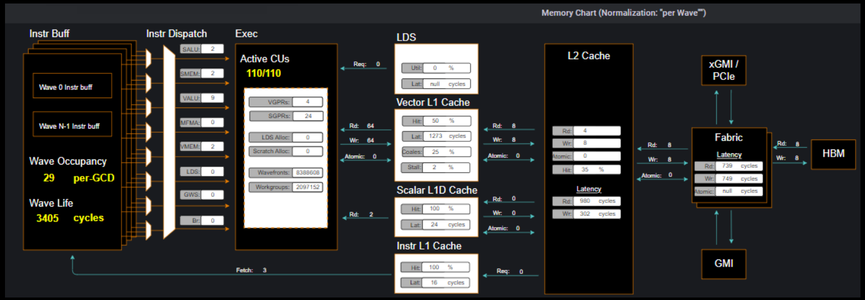


Omniperf

Performance Analysis	Automated collection of hardware counters	
	Analysis	Visualisation

Supports	Speed of Light	Memory chart	Rooflines	Kernel comparison

Visualisation	With Grafana or standalone GUI



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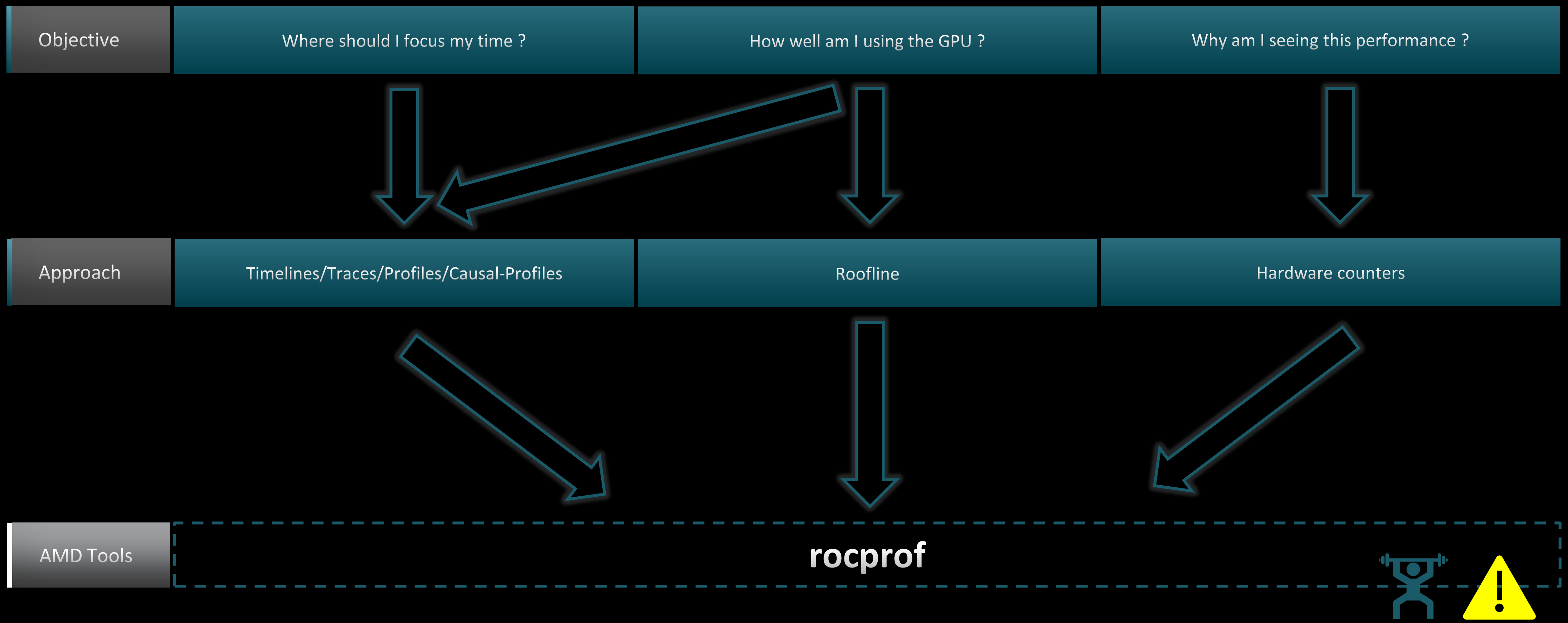
Background – AMD Profilers


Objective
Where should I focus my time ?
How well am I using the GPU ?
Why am I seeing this performance ?
Approach
Timelines/Traces/Profiles/Causal-Profiles
Roofline
Hardware counters
AMD Tools
rocprof

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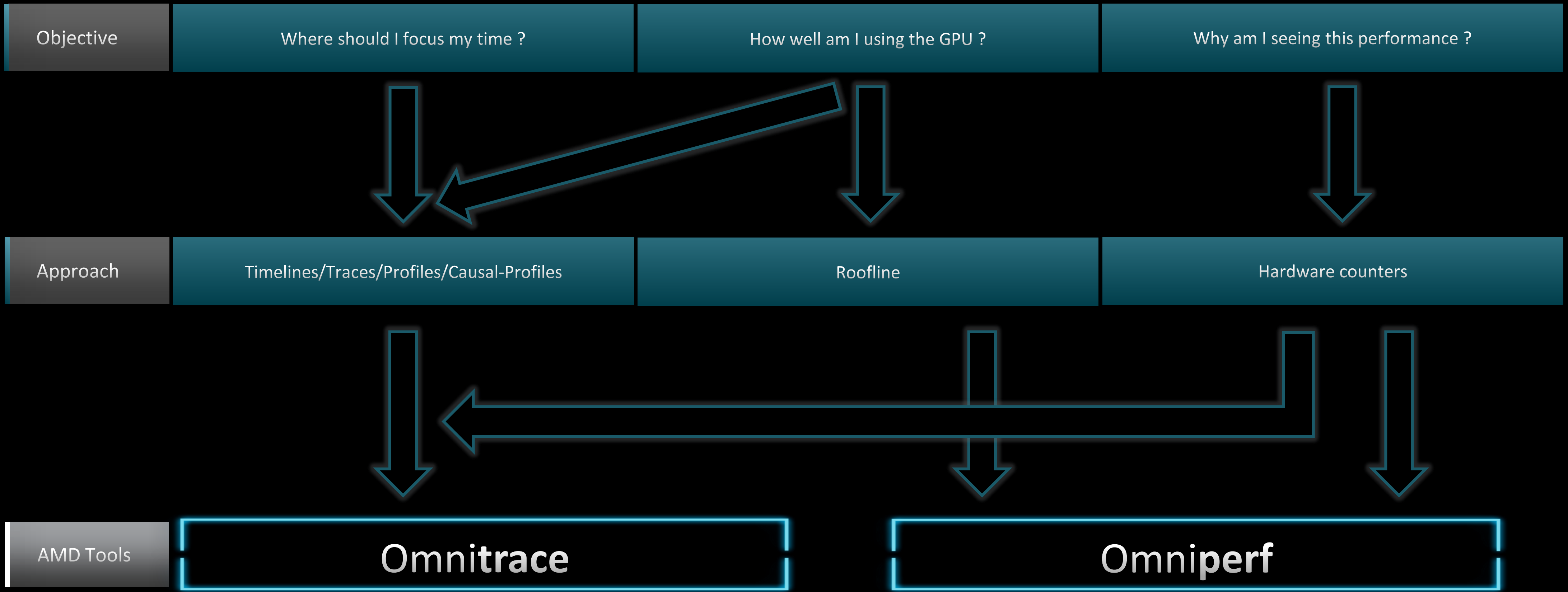
Background – AMD Profilers


Objective
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Hardware counters
AMD Tools
Omnitrace
Omniperf

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OmniTrace

Omnitrace: Application Profiling, Tracing, and Analysis

AMD Research Tool	Repository: https://github.com/AMDResearch/omnitrace					
	✗ Not part of ROCm stack					
Language Support	C/C++	Fortran	Python	OpenCL ™		
Data Collection Modes	Dynamic instrumentation	Statistical/process sampling	Causal Profiling			
Data Analysis	High-level summary	Comprehensive trace	Critical trace analysis			
Parallelism Support	MPI	OpenMP®	Pthreads	HIP	HSA	Kokkos
GPU Metrics	HW counters	HSA API	HIP API	HIP trace	HSA trace	Memory & thermal
CPU Metrics	HW counters	Timing metrics	Memory access	Network	I/O	more…

Refer to current documentation for recent updates

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Installation (if required)

To use pre-built binaries, select the version that matches your operating system, ROCm version, etc.

Select OpenSuse operating system for HPE/AMD system:

omnitrace-1.7.4-opensuse-15.4-ROCm-50400-PAPI-OMPT-Python3.sh

There are .rpm and .deb files for installation also. In future versions, binary installers for RHEL also available.

Full documentation: https://amdresearch.github.io/omnitrace/

```
export OMNITRACE_VERSION=latest
export ROCM_VERSION=5.4.3
export OMNITRACE_INSTALL_DIR=</path/to/your/omnitrace/install>
wget https://github.com/AMDResearch/omnitrace/releases/${OMNITRACE_VERSION}/download/omnitrace-install.py
python3 omnitrace-install.py -p ${OMNITRACE_INSTALL_DIR} --rocm ${ROCM_VERSION}

Set up environment:
source ${OMNITRACE_INSTALL_DIR}/share/omnitrace/setup-env.sh
```

Note: If installing from source, remember to clone the omnitrace repo recursively

Omnitrace instrumentation Modes

Runtime Instrumentation	Dynamic binary instrumentation		
	Characterize performance	Sample every invocation	Large overheads
Sampling Instrumentation	Periodic sampling of entire application		
	Statistical sampling	Process sampling	

Basic command-line syntax:

```
$ omnitrace [omnitrace-options] -- <CMD> <ARGS>
```

For more information or help use -h/--help/? flags:

```
$ omnitrace -h
```

Can also execute on systems using a job scheduler. For example, with SLURM, an interactive session can be used as:

```
$ srun [options] omnitrace [omnitrace-options] -- <CMD> <ARGS>
```

For problems, create an issue here: https://github.com/AMDResearch/omnitrace/issues
Documentation: https://amdresearch.github.io/omnitrace/

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Omnitrace Configuration

```
$ omnitrace-avail --categories [options]
```

Get more information about run-time settings, data collection capabilities, and available hardware counters. For more information or help use -h/--help flags:

```
$ omnitrace-avail -h
```

Collect information for omnitrace-related settings using shorthand -c for --categories :

```
$ omnitrace-avail –c perfetto
```

```
$ omnitrace-avail -c perfetto
|-------------------------------------|-----------------|---------------------------------------------------------------------------|
|        ENVIRONMENT VARIABLE         |      VALUE      |                                CATEGORIES                                 |
|-------------------------------------|-----------------|---------------------------------------------------------------------------|
| OMNITRACE_PERFETTO_BACKEND          |    inprocess    | custom, libomnitrace, omnitrace, perfetto                                 |
| OMNITRACE_PERFETTO_BUFFER_SIZE_KB   |     1024000     | custom, data, libomnitrace, omnitrace, perfetto                           |
| OMNITRACE_PERFETTO_FILL_POLICY      |     discard     | custom, data, libomnitrace, omnitrace, perfetto                           |
| OMNITRACE_TRACE_DELAY               |        0        | custom, libomnitrace, omnitrace, perfetto, profile, timemory, trace       |
| OMNITRACE_TRACE_DURATION            |        0        | custom, libomnitrace, omnitrace, perfetto, profile, timemory, trace       |
| OMNITRACE_TRACE_PERIODS             |                 | custom, libomnitrace, omnitrace, perfetto, profile, timemory, trace       |
| OMNITRACE_TRACE_PERIOD_CLOCK_ID     |  CLOCK_REALTIME | custom, libomnitrace, omnitrace, perfetto, profile, timemory, trace       |
| OMNITRACE_USE_PERFETTO              |      true       | backend, custom, libomnitrace, omnitrace, perfetto                        |
|-------------------------------------|-----------------|---------------------------------------------------------------------------|
```

Shows all runtime settings that may be tuned for perfetto

Omnitrace Configuration

```
$ omnitrace-avail --categories [options]
```

Get more information about run-time settings, data collection capabilities, and available hardware counters. For more information or help use -h/--help/? flags:

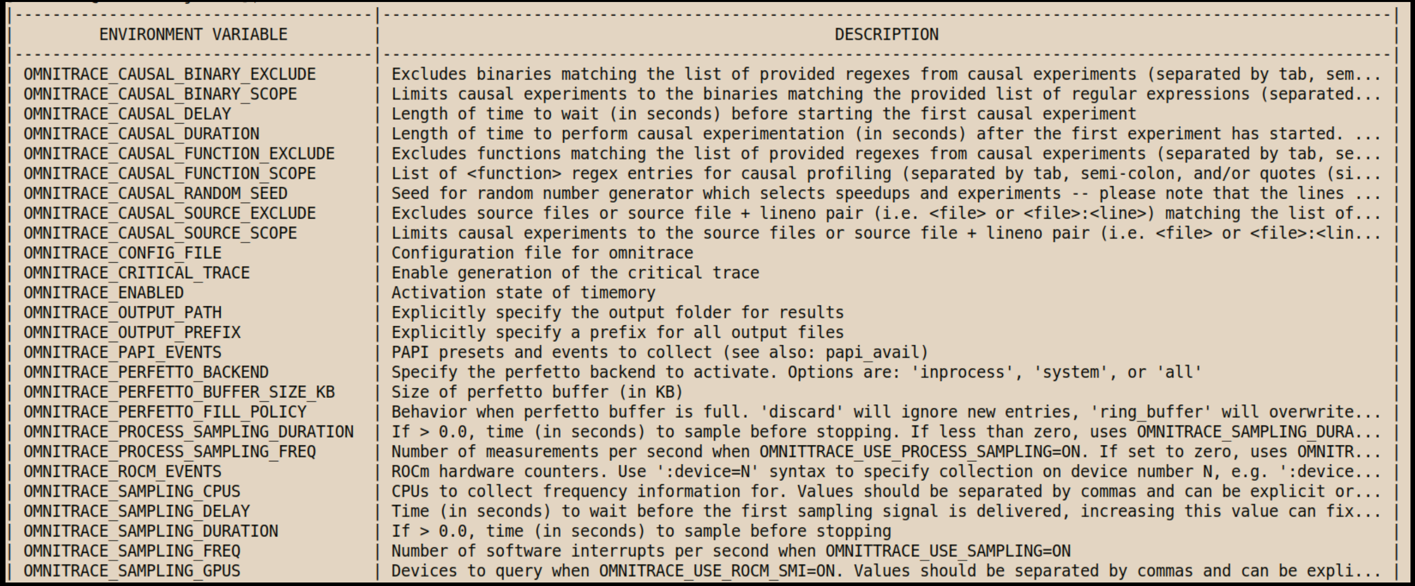
```
$ omnitrace-avail -h
```

Collect information for omnitrace-related settings using shorthand -c for --categories :

```
$ omnitrace-avail –c omnitrace
```

For brief description, use the options:

```
$ omnitrace-avail –bd
```



```
|---------------------------------------|----------------------------------------------------------------------------------------------------------|
|          ENVIRONMENT VARIABLE         |                                               DESCRIPTION                                                |
|---------------------------------------|----------------------------------------------------------------------------------------------------------|
| OMNITRACE_CAUSAL_BINARY_EXCLUDE       | Excludes binaries matching the list of provided regexes from causal experiments (separated by tab, sem... |
| OMNITRACE_CAUSAL_BINARY_SCOPE         | Limits causal experiments to the binaries matching the provided list of regular expressions (separated... |
| OMNITRACE_CAUSAL_DELAY                | Length of time to wait (in seconds) before starting the first causal experiment                          |
| OMNITRACE_CAUSAL_DURATION             | Length of time to perform causal experimentation (in seconds) after the first experiment has started. ... |
| OMNITRACE_CAUSAL_FUNCTION_EXCLUDE     | Excludes functions matching the list of provided regexes from causal experiments (separated by tab, se... |
| OMNITRACE_CAUSAL_FUNCTION_SCOPE       | List of <function> regex entries for causal profiling (separated by tab, semi-colon, and/or quotes (si... |
| OMNITRACE_CAUSAL_RANDOM_SEED          | Seed for random number generator which selects speedups and experiments -- please note that the lines ... |
| OMNITRACE_CAUSAL_SOURCE_EXCLUDE       | Excludes source files or source file + lineno pair (i.e. <file> or <file>:<line>) matching the list of... |
| OMNITRACE_CAUSAL_SOURCE_SCOPE         | Limits causal experiments to the source files or source file + lineno pair (i.e. <file> or <file>:<lin... |
| OMNITRACE_CONFIG_FILE                 | Configuration file for omnitrace                                                                         |
| OMNITRACE_CRITICAL_TRACE              | Enable generation of the critical trace                                                                  |
| OMNITRACE_ENABLED                     | Activation state of timemory                                                                             |
| OMNITRACE_OUTPUT_PATH                 | Explicitly specify the output folder for results                                                         |
| OMNITRACE_OUTPUT_PREFIX               | Explicitly specify a prefix for all output files                                                         |
| OMNITRACE_PAPI_EVENTS                 | PAPI presets and events to collect (see also: papi_avail)                                                |
| OMNITRACE_PERFETTO_BACKEND            | Specify the perfetto backend to activate. Options are: 'inprocess', 'system', or 'all'                   |
| OMNITRACE_PERFETTO_BUFFER_SIZE_KB     | Size of perfetto buffer (in KB)                                                                          |
| OMNITRACE_PERFETTO_FILL_POLICY        | Behavior when perfetto buffer is full. 'discard' will ignore new entries, 'ring_buffer' will overwrite... |
| OMNITRACE_PROCESS_SAMPLING_DURATION   | If > 0.0, time (in seconds) to sample before stopping. If less than zero, uses OMNITRACE_SAMPLING_DURA... |
| OMNITRACE_PROCESS_SAMPLING_FREQ       | Number of measurements per second when OMNITTRACE_USE_PROCESS_SAMPLING=ON. If set to zero, uses OMNITR... |
| OMNITRACE_ROCM_EVENTS                 | ROCm hardware counters. Use ':device=N' syntax to specify collection on device number N, e.g. ':device... |
| OMNITRACE_SAMPLING_CPUS               | CPUs to collect frequency information for. Values should be separated by commas and can be explicit or... |
| OMNITRACE_SAMPLING_DELAY              | Time (in seconds) to wait before the first sampling signal is delivered, increasing this value can fix... |
| OMNITRACE_SAMPLING_DURATION           | If > 0.0, time (in seconds) to sample before stopping                                                    |
| OMNITRACE_SAMPLING_FREQ               | Number of software interrupts per second when OMNITTRACE_USE_SAMPLING=ON                                 |
| OMNITRACE_SAMPLING_GPUS               | Devices to query when OMNITRACE_USE_ROCM_SMI=ON. Values should be separated by commas and can be expli... |
```

Create a config file

Create a config file in $HOME:

```
$ omnitrace-avail –G $HOME/.omnitrace.cfg
```

To add description of all variables and settings, use:

```
$ omnitrace-avail –G $HOME/.omnitrace.cfg --all
```

Modify the config file $HOME/.omnitrace.cfg as desired to enable and change settings:

```
<snip>
OMNITRACE_USE_PERFETTO                          = true
OMNITRACE_USE_TIMEMORY                          = true
OMNITRACE_USE_SAMPLING                          = false
OMNITRACE_USE_ROCTRACER                         = true
OMNITRACE_USE_ROCM_SMI                          = true
OMNITRACE_USE_KOKKOSP                           = false
OMNITRACE_USE_CAUSAL                            = false
OMNITRACE_USE_MPIP                              = true
OMNITRACE_USE_PID                               = true
OMNITRACE_USE_ROCPROFILER                       = true
OMNITRACE_USE_ROCTX
<snip>
```

Contents of the config file

Declare which config file to use by setting the environment:

```
$ export OMNITRACE_CONFIG_FILE=/path-
to/.omnitrace.cfg
```

Dynamic Instrumentation

Runtime Instrumentation

Dynamic Instrumentation – Jacobi Example

Clone jacobi example:

```
$ git clone https://github.com/amd/HPCTrainingExamples.git
$ cd HPCTrainingExamples/HIP/jacobi
```

Requires ROCm and MPI install, compile:

```
$ make
```

Run the non-instrumented code on a single GPU as:

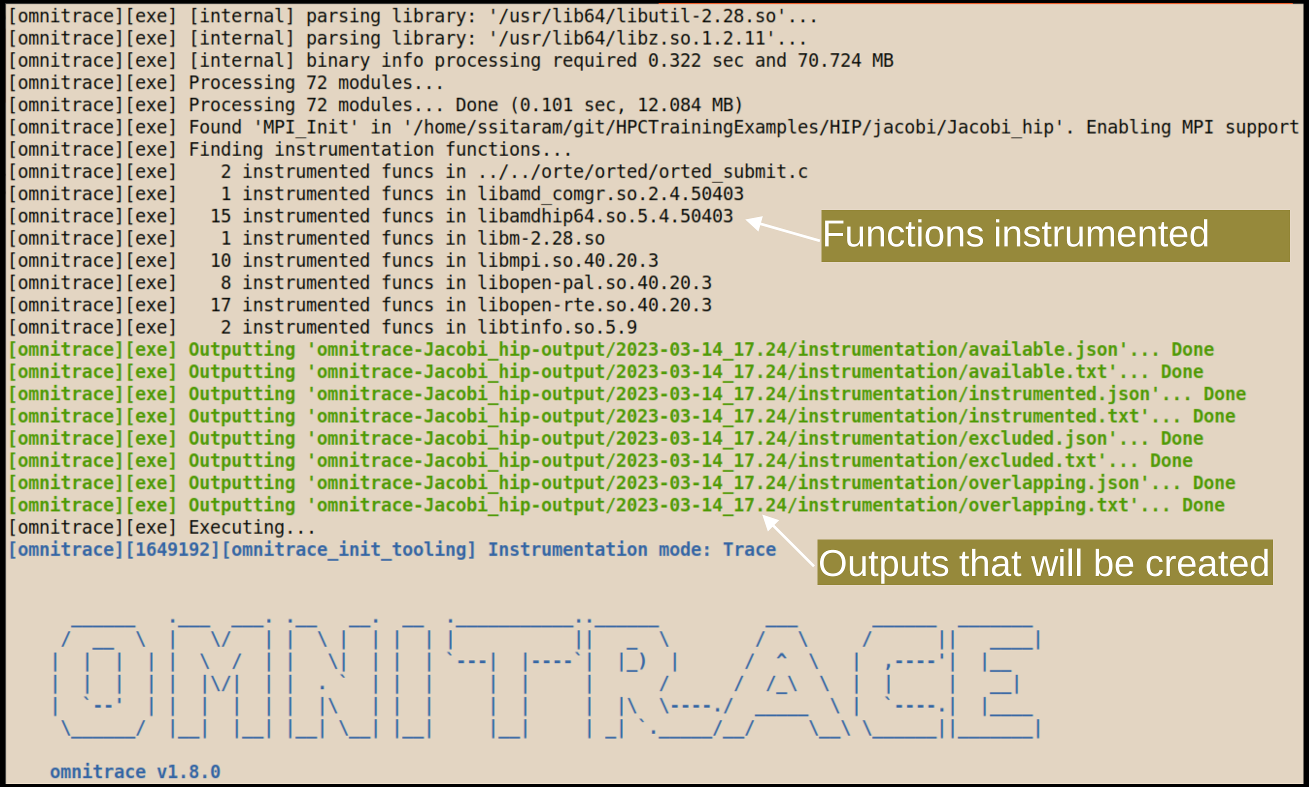
```
 $ time .mpirun -np 1 ./Jacobi_hip -g 1 1
real    0m2.115s
```

Dynamic instrumentation

```
 $ time mpirun -np 1 omnitrace-instrument -- ./Jacobi_hip
-g 1 1

 real 1m45.742s
```

Extra time is the overhead of dyninst reading every binary that is loaded, not overhead of omnitrace during app execution

Parsing libraries



```
[omnitrace][exe] [internal] parsing library: '/usr/lib64/libutil-2.28.so'...
[omnitrace][exe] [internal] parsing library: '/usr/lib64/libz.so.1.2.11'...
[omnitrace][exe] [internal] binary info processing required 0.322 sec and 70.724 MB
[omnitrace][exe] Processing 72 modules...
[omnitrace][exe] Processing 72 modules... Done (0.101 sec, 12.084 MB)
[omnitrace][exe] Found 'MPI_Init' in '/home/ssitaram/git/HPCTrainingExamples/HIP/jacobi/Jacobi_hip'. Enabling MPI support
[omnitrace][exe] Finding instrumentation functions...
[omnitrace][exe]    2 instrumented funcs in ../../orte/orted/orted_submit.c
[omnitrace][exe]    1 instrumented funcs in libamd_comgr.so.2.4.50403
[omnitrace][exe]   15 instrumented funcs in libamdhip64.so.5.4.50403
[omnitrace][exe]    1 instrumented funcs in libm-2.28.so
[omnitrace][exe]   10 instrumented funcs in libmpi.so.40.20.3
[omnitrace][exe]    8 instrumented funcs in libopen-pal.so.40.20.3
[omnitrace][exe]   17 instrumented funcs in libopen-rte.so.40.20.3
[omnitrace][exe]    2 instrumented funcs in libtinfo.so.5.9
[omnitrace][exe] Outputting 'omnitrace-Jacobi_hip-output/2023-03-14_17.24/instrumentation/available.json'... Done
[omnitrace][exe] Outputting 'omnitrace-Jacobi_hip-output/2023-03-14_17.24/instrumentation/available.txt'... Done
[omnitrace][exe] Outputting 'omnitrace-Jacobi_hip-output/2023-03-14_17.24/instrumentation/instrumented.json'... Done
[omnitrace][exe] Outputting 'omnitrace-Jacobi_hip-output/2023-03-14_17.24/instrumentation/instrumented.txt'... Done
[omnitrace][exe] Outputting 'omnitrace-Jacobi_hip-output/2023-03-14_17.24/instrumentation/excluded.json'... Done
[omnitrace][exe] Outputting 'omnitrace-Jacobi_hip-output/2023-03-14_17.24/instrumentation/excluded.txt'... Done
[omnitrace][exe] Outputting 'omnitrace-Jacobi_hip-output/2023-03-14_17.24/instrumentation/overlapping.json'... Done
[omnitrace][exe] Outputting 'omnitrace-Jacobi_hip-output/2023-03-14_17.24/instrumentation/overlapping.txt'... Done
[omnitrace][exe] Executing...
[omnitrace][1649192][omnitrace_init_tooling] Instrumentation mode: Trace

   omnitrace v1.8.0
```

Functions instrumented

Outputs that will be created

Dynamic Instrumentation – Jacobi Example

Clone jacobi example:

```
$ git clone https://github.com/amd/HPCTrainingExamples.git
$ cd HPCTrainingExamples/HIP/jacobi
```

Requires ROCm and MPI install, compile:

```
$ make
```

Run the non-instrumented code on a single GPU as:

```
 $ time .mpirun -np 1 ./Jacobi_hip -g 1 1
real    0m2.115s
```

Dynamic instrumentation

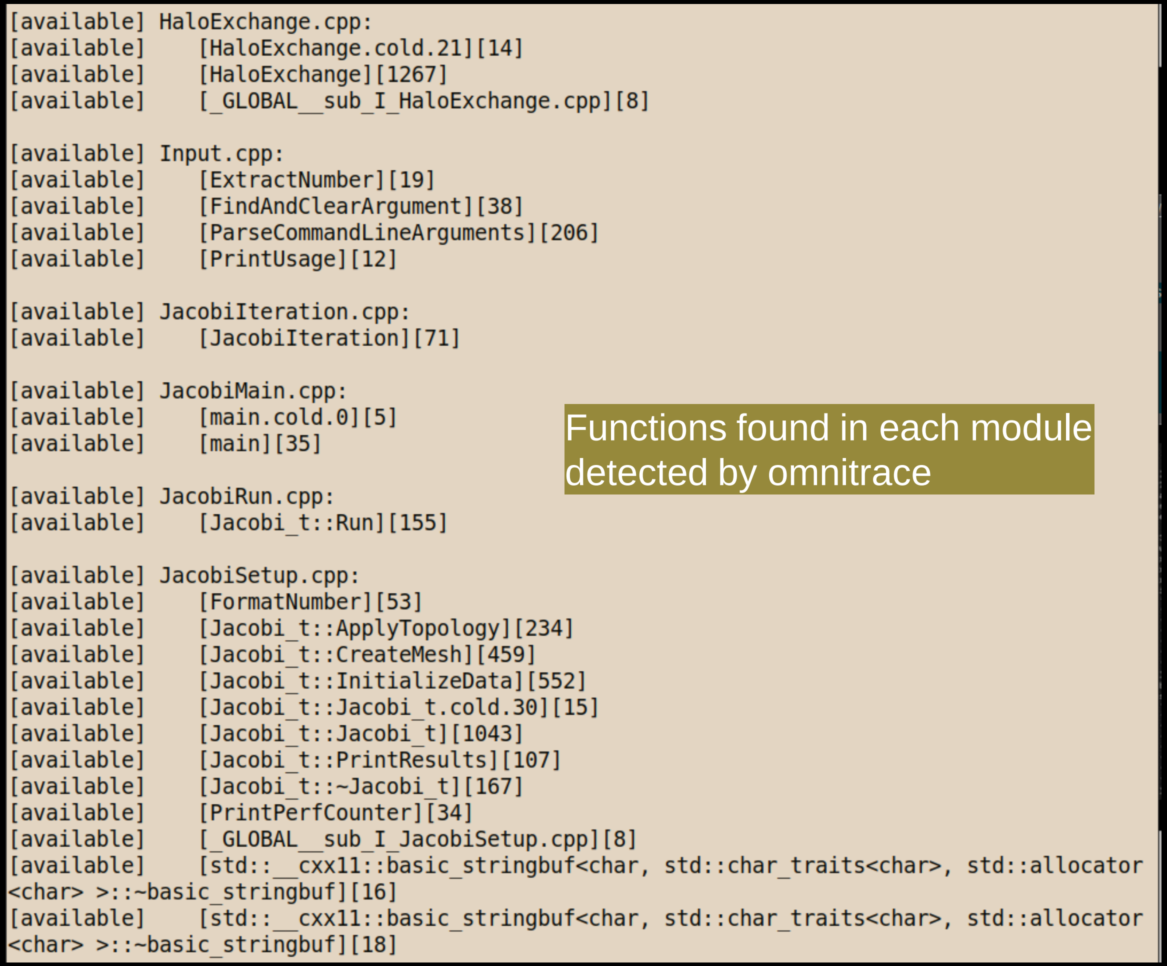
```
 $ time mpirun -np 1 omnitrace-instrument -- ./Jacobi_hip
-g 1 1

 real 1m45.742s
```

Available functions to instrument:

```
 $ mpirun -np 1 omnitrace-instrument -v 1 --simulate --
print-available functions -- ./Jacobi_hip -g 1 1
```

Here, -v gives a verbose output from omnitrace

The simulate flag does not run the executable, but only demonstrates the available functions



```
[available] HaloExchange.cpp:
[available]    [HaloExchange.cold.21][14]
[available]    [HaloExchange][1267]
[available]    [_GLOBAL__sub_I_HaloExchange.cpp][8]

[available] Input.cpp:
[available]    [ExtractNumber][19]
[available]    [FindAndClearArgument][38]
[available]    [ParseCommandLineArguments][206]
[available]    [PrintUsage][12]

[available] JacobiIteration.cpp:
[available]    [JacobiIteration][71]

[available] JacobiMain.cpp:
[available]    [main.cold.0][5]
[available]    [main][35]

[available] JacobiRun.cpp:
[available]    [Jacobi_t::Run][155]

[available] JacobiSetup.cpp:
[available]    [FormatNumber][53]
[available]    [Jacobi_t::ApplyTopology][234]
[available]    [Jacobi_t::CreateMesh][459]
[available]    [Jacobi_t::InitializeData][552]
[available]    [Jacobi_t::Jacobi_t.cold.30][15]
[available]    [Jacobi_t::Jacobi_t][1043]
[available]    [Jacobi_t::PrintResults][107]
[available]    [Jacobi_t::~Jacobi_t][167]
[available]    [PrintPerfCounter][34]
[available]    [_GLOBAL__sub_I_JacobiSetup.cpp][8]
[available]    [std::__cxx11::basic_stringbuf<char, std::char_traits<char>, std::allocator
<char> >::~basic_stringbuf][16]
[available]    [std::__cxx11::basic_stringbuf<char, std::char_traits<char>, std::allocator
<char> >::~basic_stringbuf][18]
```

Functions found in each module detected by omnitrace

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Dynamic Instrumentation – Jacobi Example

Clone jacobi example:

```
$ git clone https://github.com/amd/HPCTrainingExamples.git
$ cd HPCTrainingExamples/HIP/jacobi
```

Requires ROCm and MPI install, compile:

```
$ make
```

Run the non-instrumented code on a single GPU as:

```
 $ time .mpirun -np 1 ./Jacobi_hip -g 1 1
real    0m2.115s
```

Dynamic instrumentation

```
 $ time mpirun -np 1 omnitrace-instrument -- ./Jacobi_hip
-g 1 1

 real 1m45.742s
```

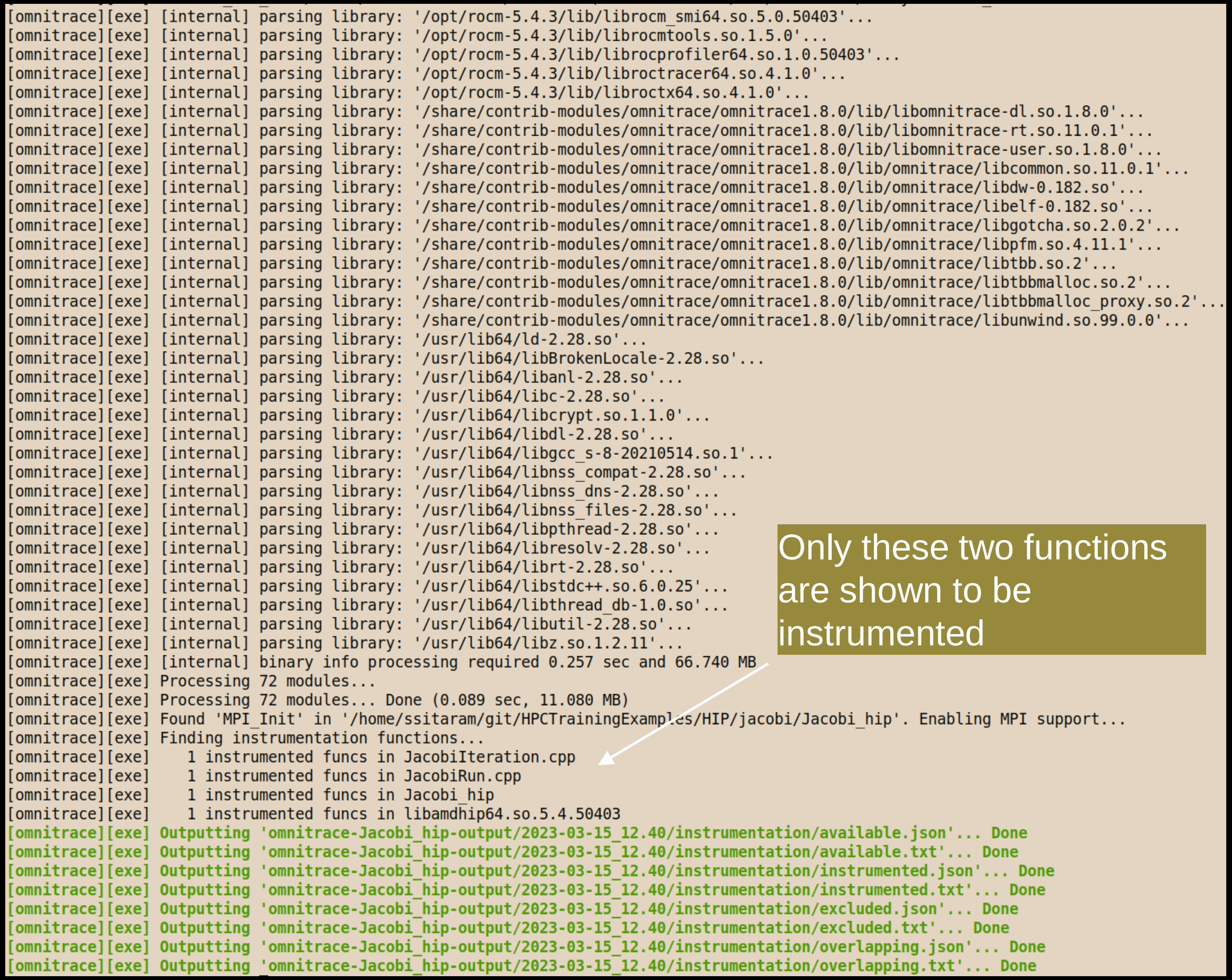
Available functions to instrument:

```
 $ mpirun -np 1 omnitrace-instrument -v 1 --simulate --
print-available functions -- ./Jacobi_hip -g 1 1
```

Custom include/exclude functions* with -I or -E, resp. For e.g:

```
 $ mpirun -np 1 omnitrace-instrument -v 1 -I
'Jacobi_t::Run' 'JacobiIteration' -- ./Jacobi_hip -g 1 1
```

Include two functions to instrument



```
[omnitrace][exe] [internal] parsing library: '/opt/rocm-5.4.3/lib/librocm_smi64.so.5.0.50403'...
[omnitrace][exe] [internal] parsing library: '/opt/rocm-5.4.3/lib/librocmtools.so.1.5.0'...
[omnitrace][exe] [internal] parsing library: '/opt/rocm-5.4.3/lib/librocprofiler64.so.1.0.50403'...
[omnitrace][exe] [internal] parsing library: '/opt/rocm-5.4.3/lib/libroctracer64.so.4.1.0'...
[omnitrace][exe] [internal] parsing library: '/opt/rocm-5.4.3/lib/libroctx64.so.4.1.0'...
[omnitrace][exe] [internal] parsing library: '/share/contrib-modules/omnitrace/omnitrace1.8.0/lib/libomnitrace-dl.so.1.8.0'...
[omnitrace][exe] [internal] parsing library: '/share/contrib-modules/omnitrace/omnitrace1.8.0/lib/libomnitrace-rt.so.11.0.1'...
[omnitrace][exe] [internal] parsing library: '/share/contrib-modules/omnitrace/omnitrace1.8.0/lib/libomnitrace-user.so.1.8.0'...
[omnitrace][exe] [internal] parsing library: '/share/contrib-modules/omnitrace/omnitrace1.8.0/lib/omnitrace/libcommon.so.11.0.1'...
[omnitrace][exe] [internal] parsing library: '/share/contrib-modules/omnitrace/omnitrace1.8.0/lib/omnitrace/libdw-0.182.so'...
[omnitrace][exe] [internal] parsing library: '/share/contrib-modules/omnitrace/omnitrace1.8.0/lib/omnitrace/libelf-0.182.so'...
[omnitrace][exe] [internal] parsing library: '/share/contrib-modules/omnitrace/omnitrace1.8.0/lib/omnitrace/libgotcha.so.2.0.2'...
[omnitrace][exe] [internal] parsing library: '/share/contrib-modules/omnitrace/omnitrace1.8.0/lib/omnitrace/libpfm.so.4.11.1'...
[omnitrace][exe] [internal] parsing library: '/share/contrib-modules/omnitrace/omnitrace1.8.0/lib/omnitrace/libtbb.so.2'...
[omnitrace][exe] [internal] parsing library: '/share/contrib-modules/omnitrace/omnitrace1.8.0/lib/omnitrace/libtbbmalloc.so.2'...
[omnitrace][exe] [internal] parsing library: '/share/contrib-modules/omnitrace/omnitrace1.8.0/lib/omnitrace/libtbbmalloc_proxy.so.2'...
[omnitrace][exe] [internal] parsing library: '/share/contrib-modules/omnitrace/omnitrace1.8.0/lib/omnitrace/libunwind.so.99.0.0'...
[omnitrace][exe] [internal] parsing library: '/usr/lib64/ld-2.28.so'...
[omnitrace][exe] [internal] parsing library: '/usr/lib64/libBrokenLocale-2.28.so'...
[omnitrace][exe] [internal] parsing library: '/usr/lib64/libanl-2.28.so'...
[omnitrace][exe] [internal] parsing library: '/usr/lib64/libc-2.28.so'...
[omnitrace][exe] [internal] parsing library: '/usr/lib64/libcrypt.so.1.1.0'...
[omnitrace][exe] [internal] parsing library: '/usr/lib64/libdl-2.28.so'...
[omnitrace][exe] [internal] parsing library: '/usr/lib64/libgcc_s-8-20210514.so.1'...
[omnitrace][exe] [internal] parsing library: '/usr/lib64/libnss_compat-2.28.so'...
[omnitrace][exe] [internal] parsing library: '/usr/lib64/libnss_dns-2.28.so'...
[omnitrace][exe] [internal] parsing library: '/usr/lib64/libnss_files-2.28.so'...
[omnitrace][exe] [internal] parsing library: '/usr/lib64/libpthread-2.28.so'...
[omnitrace][exe] [internal] parsing library: '/usr/lib64/libresolv-2.28.so'...
[omnitrace][exe] [internal] parsing library: '/usr/lib64/librt-2.28.so'...
[omnitrace][exe] [internal] parsing library: '/usr/lib64/libstdc++.so.6.0.25'...
[omnitrace][exe] [internal] parsing library: '/usr/lib64/libthread_db-1.0.so'...
[omnitrace][exe] [internal] parsing library: '/usr/lib64/libutil-2.28.so'...
[omnitrace][exe] [internal] parsing library: '/usr/lib64/libz.so.1.2.11'...
[omnitrace][exe] [internal] binary info processing required 0.257 sec and 66.740 MB
[omnitrace][exe] Processing 72 modules...
[omnitrace][exe] Processing 72 modules... Done (0.089 sec, 11.080 MB)
[omnitrace][exe] Found 'MPI_Init' in '/home/ssitaram/git/HPCTrainingExamples/HIP/jacobi/Jacobi_hip'. Enabling MPI support...
[omnitrace][exe] Finding instrumentation functions...
[omnitrace][exe]    1 instrumented funcs in JacobiIteration.cpp
[omnitrace][exe]    1 instrumented funcs in JacobiRun.cpp
[omnitrace][exe]    1 instrumented funcs in Jacobi_hip
[omnitrace][exe]    1 instrumented funcs in libamdhip64.so.5.4.50403
[omnitrace][exe] Outputting 'omnitrace-Jacobi_hip-output/2023-03-15_12.40/instrumentation/available.json'... Done
[omnitrace][exe] Outputting 'omnitrace-Jacobi_hip-output/2023-03-15_12.40/instrumentation/available.txt'... Done
[omnitrace][exe] Outputting 'omnitrace-Jacobi_hip-output/2023-03-15_12.40/instrumentation/instrumented.json'... Done
[omnitrace][exe] Outputting 'omnitrace-Jacobi_hip-output/2023-03-15_12.40/instrumentation/instrumented.txt'... Done
[omnitrace][exe] Outputting 'omnitrace-Jacobi_hip-output/2023-03-15_12.40/instrumentation/excluded.json'... Done
[omnitrace][exe] Outputting 'omnitrace-Jacobi_hip-output/2023-03-15_12.40/instrumentation/excluded.txt'... Done
[omnitrace][exe] Outputting 'omnitrace-Jacobi_hip-output/2023-03-15_12.40/instrumentation/overlapping.json'... Done
[omnitrace][exe] Outputting 'omnitrace-Jacobi_hip-output/2023-03-15_12.40/instrumentation/overlapping.txt'... Done
```

Only these two functions are shown to be instrumented

Dynamic Instrumentation

Binary Rewrite

Binary Rewrite – Jacobi Example

Binary Rewrite

```
$ omnitrace-instrument [omnitrace-options] -o <new-name-of-exec> -- <CMD> <ARGS>
```

Generating a new executable/library with instrumentation built-in:

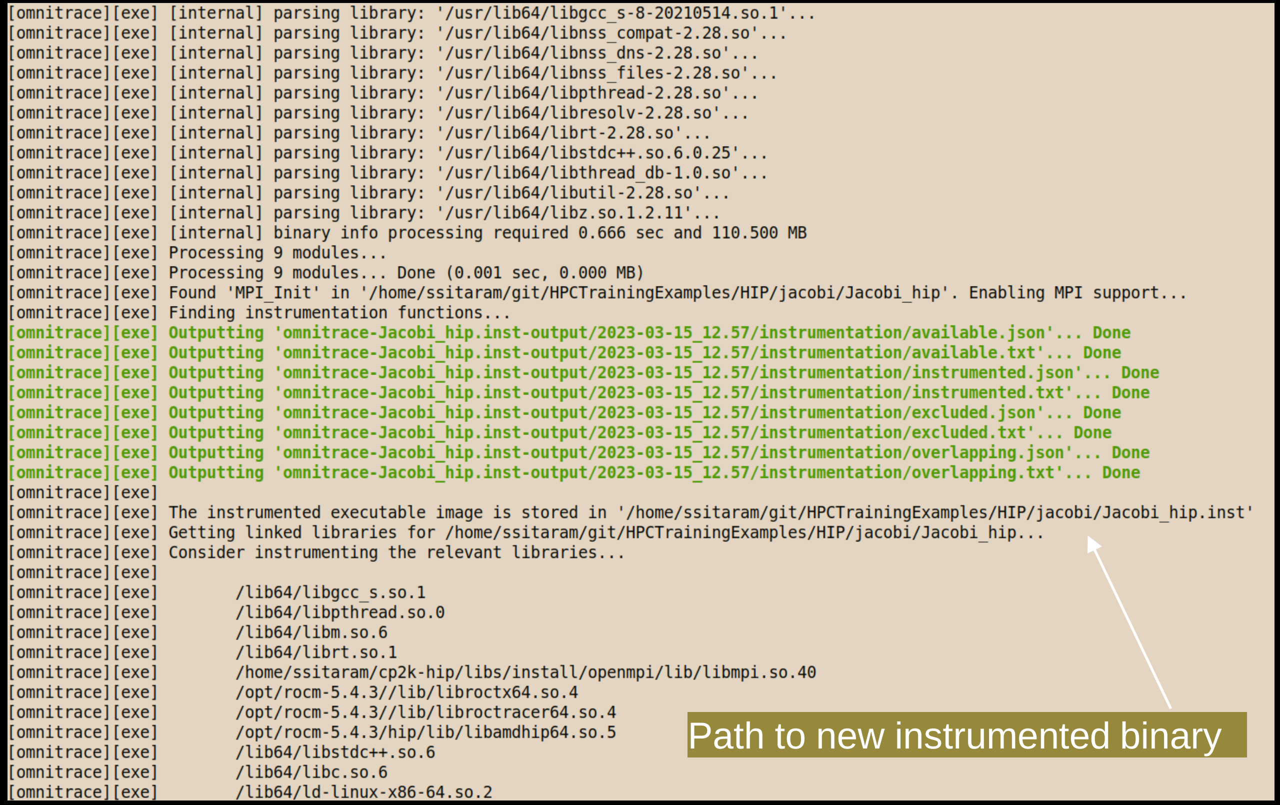
```
$ omnitrace-instrument -o Jacobi_hip.inst -- ./Jacobi_hip
```

This new binary will have instrumented functions

Subroutine Instrumentation

Default instrumentation is main function and functions of 1024 instructions and more (for CPU)

To instrument routines with 50 or more cycles, add option "-i 50" (more overhead)



```
[omnitrace][exe] [internal] parsing library: '/usr/lib64/libgcc_s-8-20210514.so.1'...
[omnitrace][exe] [internal] parsing library: '/usr/lib64/libnss_compat-2.28.so'...
[omnitrace][exe] [internal] parsing library: '/usr/lib64/libnss_dns-2.28.so'...
[omnitrace][exe] [internal] parsing library: '/usr/lib64/libnss_files-2.28.so'...
[omnitrace][exe] [internal] parsing library: '/usr/lib64/libpthread-2.28.so'...
[omnitrace][exe] [internal] parsing library: '/usr/lib64/libresolv-2.28.so'...
[omnitrace][exe] [internal] parsing library: '/usr/lib64/librt-2.28.so'...
[omnitrace][exe] [internal] parsing library: '/usr/lib64/libstdc++.so.6.0.25'...
[omnitrace][exe] [internal] parsing library: '/usr/lib64/libthread_db-1.0.so'...
[omnitrace][exe] [internal] parsing library: '/usr/lib64/libutil-2.28.so'...
[omnitrace][exe] [internal] parsing library: '/usr/lib64/libz.so.1.2.11'...
[omnitrace][exe] [internal] binary info processing required 0.666 sec and 110.500 MB
[omnitrace][exe] Processing 9 modules...
[omnitrace][exe] Processing 9 modules... Done (0.001 sec, 0.000 MB)
[omnitrace][exe] Found 'MPI_Init' in '/home/ssitaram/git/HPCTrainingExamples/HIP/jacobi/Jacobi_hip'. Enabling MPI support...
[omnitrace][exe] Finding instrumentation functions...
[omnitrace][exe] Outputting 'omnitrace-Jacobi_hip.inst-output/2023-03-15_12.57/instrumentation/available.json'... Done
[omnitrace][exe] Outputting 'omnitrace-Jacobi_hip.inst-output/2023-03-15_12.57/instrumentation/available.txt'... Done
[omnitrace][exe] Outputting 'omnitrace-Jacobi_hip.inst-output/2023-03-15_12.57/instrumentation/instrumented.json'... Done
[omnitrace][exe] Outputting 'omnitrace-Jacobi_hip.inst-output/2023-03-15_12.57/instrumentation/instrumented.txt'... Done
[omnitrace][exe] Outputting 'omnitrace-Jacobi_hip.inst-output/2023-03-15_12.57/instrumentation/excluded.json'... Done
[omnitrace][exe] Outputting 'omnitrace-Jacobi_hip.inst-output/2023-03-15_12.57/instrumentation/excluded.txt'... Done
[omnitrace][exe] Outputting 'omnitrace-Jacobi_hip.inst-output/2023-03-15_12.57/instrumentation/overlapping.json'... Done
[omnitrace][exe] Outputting 'omnitrace-Jacobi_hip.inst-output/2023-03-15_12.57/instrumentation/overlapping.txt'... Done
[omnitrace][exe]
[omnitrace][exe] The instrumented executable image is stored in '/home/ssitaram/git/HPCTrainingExamples/HIP/jacobi/Jacobi_hip.inst'
[omnitrace][exe] Getting linked libraries for /home/ssitaram/git/HPCTrainingExamples/HIP/jacobi/Jacobi_hip...
[omnitrace][exe] Consider instrumenting the relevant libraries...
[omnitrace][exe]
[omnitrace][exe]        /lib64/libgcc_s.so.1
[omnitrace][exe]        /lib64/libpthread.so.0
[omnitrace][exe]        /lib64/libm.so.6
[omnitrace][exe]        /lib64/librt.so.1
[omnitrace][exe]        /home/ssitaram/cp2k-hip/libs/install/openmpi/lib/libmpi.so.40
[omnitrace][exe]        /opt/rocm-5.4.3//lib/libroctx64.so.4
[omnitrace][exe]        /opt/rocm-5.4.3//lib/libroctracer64.so.4
[omnitrace][exe]        /opt/rocm-5.4.3/hip/lib/libamdhip64.so.5
[omnitrace][exe]        /lib64/libstdc++.so.6
[omnitrace][exe]        /lib64/libc.so.6
[omnitrace][exe]        /lib64/ld-linux-x86-64.so.2
```

Path to new instrumented binary

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Binary Rewrite – Jacobi Example

Binary Rewrite

```
$ omnitrace-instrument [omnitrace-options] -o <new-
name-of-exec> -- <CMD> <ARGS>
```

Generating a new /library with instrumentation built-in:

```
 $ omnitrace-instrument -o Jacobi_hip.inst --
./Jacobi_hip
```

Run the instrumented binary:

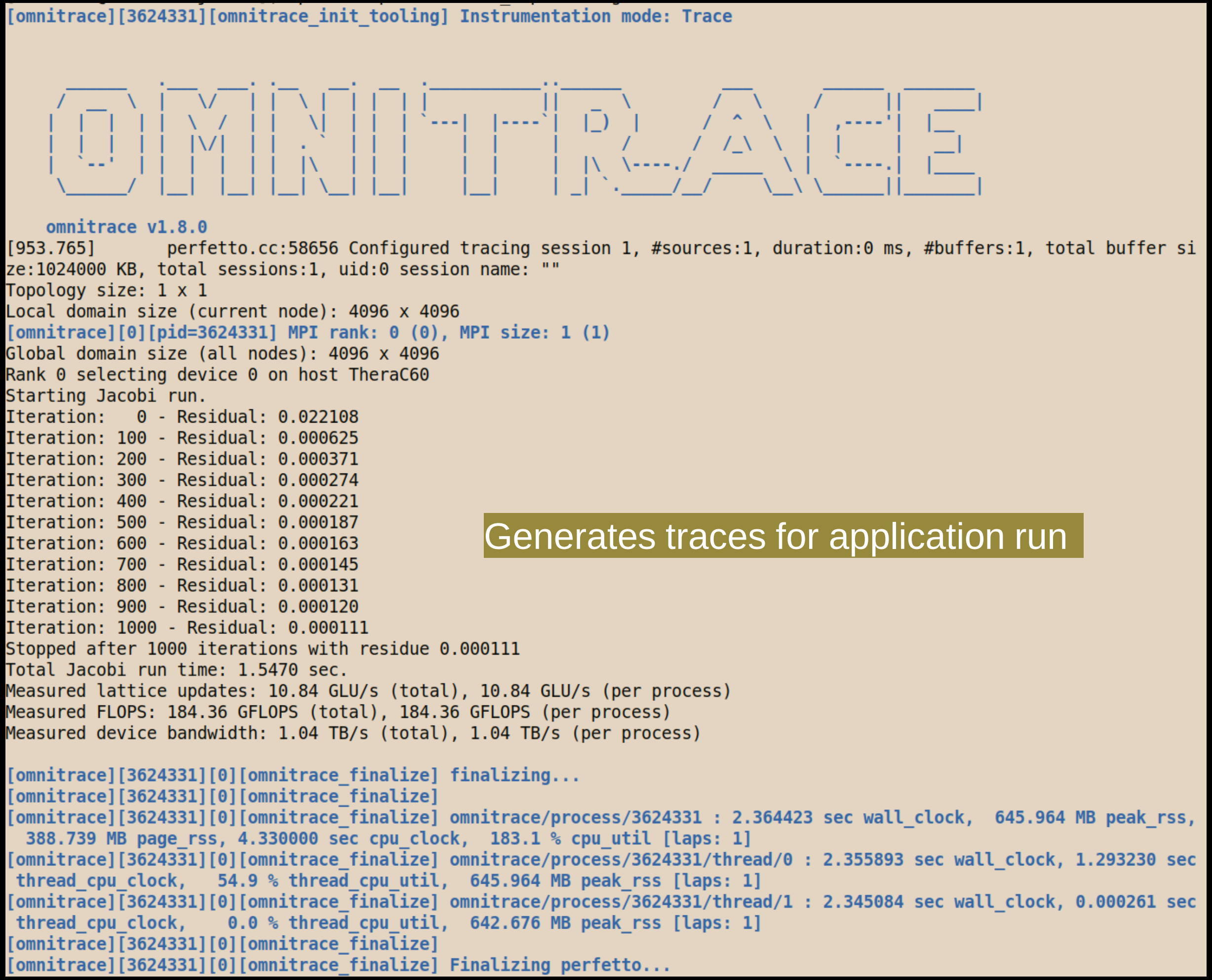
```
 $ mpirun -np 1 omnitrace-run -- ./Jacobi_hip.inst -g
1 1
```

subroutine instrumentation

Default instrumentation is main function and functions of 1024 instructions and more (for CPU)

To instrument routines with 50 or more cycles, add option `"-i 50"` (more overhead)

Binary rewrite is recommended for runs with multiple ranks as omnitrace produces separate output files for each rank

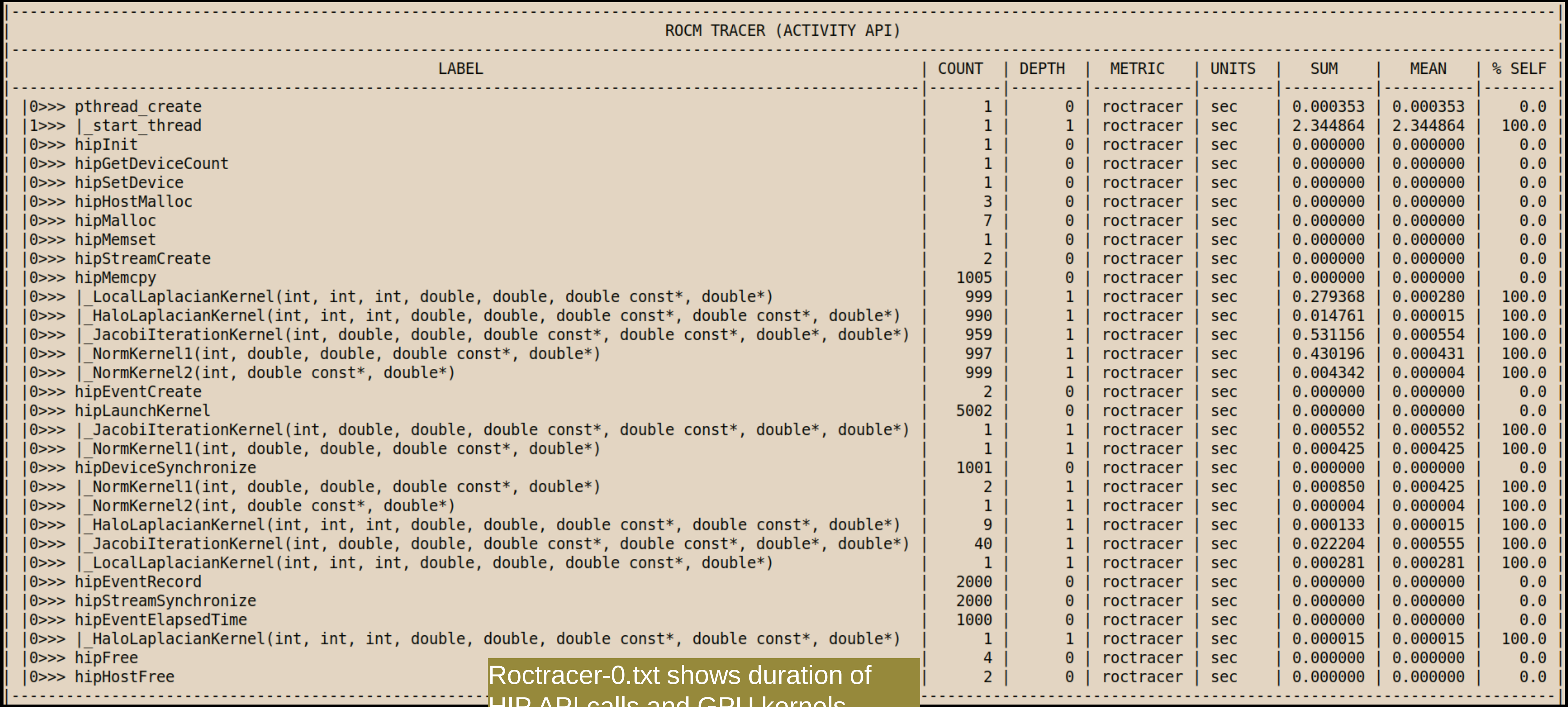


```
[omnitrace][3624331][omnitrace_init_tooling] Instrumentation mode: Trace

    omnitrace v1.8.0
[953.765]       perfetto.cc:58656 Configured tracing session 1, #sources:1, duration:0 ms, #buffers:1, total buffer si
ze:1024000 KB, total sessions:1, uid:0 session name: ""
Topology size: 1 x 1
Local domain size (current node): 4096 x 4096
[omnitrace][0][pid=3624331] MPI rank: 0 (0), MPI size: 1 (1)
Global domain size (all nodes): 4096 x 4096
Rank 0 selecting device 0 on host TheraC60
Starting Jacobi run.
Iteration:    0 - Residual: 0.022108
Iteration:  100 - Residual: 0.000625
Iteration:  200 - Residual: 0.000371
Iteration:  300 - Residual: 0.000274
Iteration:  400 - Residual: 0.000221
Iteration:  500 - Residual: 0.000187
Iteration:  600 - Residual: 0.000163
Iteration:  700 - Residual: 0.000145
Iteration:  800 - Residual: 0.000131
Iteration:  900 - Residual: 0.000120
Iteration: 1000 - Residual: 0.000111
Stopped after 1000 iterations with residue 0.000111
Total Jacobi run time: 1.5470 sec.
Measured lattice updates: 10.84 GLU/s (total), 10.84 GLU/s (per process)
Measured FLOPS: 184.36 GFLOPS (total), 184.36 GFLOPS (per process)
Measured device bandwidth: 1.04 TB/s (total), 1.04 TB/s (per process)

[omnitrace][3624331][0][omnitrace_finalize] finalizing...
[omnitrace][3624331][0][omnitrace_finalize]
[omnitrace][3624331][0][omnitrace_finalize] omnitrace/process/3624331 : 2.364423 sec wall_clock,  645.964 MB peak_rss,
  388.739 MB page_rss, 4.330000 sec cpu_clock,  183.1 % cpu_util [laps: 1]
[omnitrace][3624331][0][omnitrace_finalize] omnitrace/process/3624331/thread/0 : 2.355893 sec wall_clock, 1.293230 sec
 thread_cpu_clock,   54.9 % thread_cpu_util,  645.964 MB peak_rss [laps: 1]
[omnitrace][3624331][0][omnitrace_finalize] omnitrace/process/3624331/thread/1 : 2.345084 sec wall_clock, 0.000261 sec
 thread_cpu_clock,    0.0 % thread_cpu_util,  642.676 MB peak_rss [laps: 1]
[omnitrace][3624331][0][omnitrace_finalize]
[omnitrace][3624331][0][omnitrace_finalize] Finalizing perfetto...
```

Generates traces for application run

List of Instrumented GPU Functions

```
$ cat omnitrace-Jacobi_hip.inst-output/2023-03-15_13.57/roctracer-0.txt
```



```
|---------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
|                                                                              ROCM TRACER (ACTIVITY API)                                                                               |
|---------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
|                                         LABEL                                          | COUNT  | DEPTH  |   METRIC   | UNITS  |   SUM    |   MEAN   | % SELF |
|----------------------------------------------------------------------------------------|--------|--------|------------|--------|----------|----------|--------|
| |0>>> pthread_create                                                                   |      1 |      0 | roctracer  | sec    | 0.000353 | 0.000353 |    0.0 |
| |1>>> |_start_thread                                                                   |      1 |      1 | roctracer  | sec    | 2.344864 | 2.344864 |  100.0 |
| |0>>> hipInit                                                                          |      1 |      0 | roctracer  | sec    | 0.000000 | 0.000000 |    0.0 |
| |0>>> hipGetDeviceCount                                                                |      1 |      0 | roctracer  | sec    | 0.000000 | 0.000000 |    0.0 |
| |0>>> hipSetDevice                                                                     |      1 |      0 | roctracer  | sec    | 0.000000 | 0.000000 |    0.0 |
| |0>>> hipHostMalloc                                                                    |      3 |      0 | roctracer  | sec    | 0.000000 | 0.000000 |    0.0 |
| |0>>> hipMalloc                                                                        |      7 |      0 | roctracer  | sec    | 0.000000 | 0.000000 |    0.0 |
| |0>>> hipMemset                                                                        |      1 |      0 | roctracer  | sec    | 0.000000 | 0.000000 |    0.0 |
| |0>>> hipStreamCreate                                                                  |      2 |      0 | roctracer  | sec    | 0.000000 | 0.000000 |    0.0 |
| |0>>> hipMemcpy                                                                        |   1005 |      0 | roctracer  | sec    | 0.000000 | 0.000000 |    0.0 |
| |0>>> |_LocalLaplacianKernel(int, int, int, double, double, double const*, double*)    |    999 |      1 | roctracer  | sec    | 0.279368 | 0.000280 |  100.0 |
| |0>>> |_HaloLaplacianKernel(int, int, int, double, double, double const*, double const*, double*) |    990 |      1 | roctracer  | sec    | 0.014761 | 0.000015 |  100.0 |
| |0>>> |_JacobiIterationKernel(int, double, double, double const*, double const*, double*, double*) |    959 |      1 | roctracer  | sec    | 0.531156 | 0.000554 |  100.0 |
| |0>>> |_NormKernel1(int, double, double, double const*, double*)                       |    997 |      1 | roctracer  | sec    | 0.430196 | 0.000431 |  100.0 |
| |0>>> |_NormKernel2(int, double const*, double*)                                       |    999 |      1 | roctracer  | sec    | 0.004342 | 0.000004 |  100.0 |
| |0>>> hipEventCreate                                                                   |      2 |      0 | roctracer  | sec    | 0.000000 | 0.000000 |    0.0 |
| |0>>> hipLaunchKernel                                                                  |   5002 |      0 | roctracer  | sec    | 0.000000 | 0.000000 |    0.0 |
| |0>>> |_JacobiIterationKernel(int, double, double, double const*, double const*, double*, double*) |      1 |      1 | roctracer  | sec    | 0.000552 | 0.000552 |  100.0 |
| |0>>> |_NormKernel1(int, double, double, double const*, double*)                       |      1 |      1 | roctracer  | sec    | 0.000425 | 0.000425 |  100.0 |
| |0>>> hipDeviceSynchronize                                                             |   1001 |      0 | roctracer  | sec    | 0.000000 | 0.000000 |    0.0 |
| |0>>> |_NormKernel1(int, double, double, double const*, double*)                       |      2 |      1 | roctracer  | sec    | 0.000850 | 0.000425 |  100.0 |
| |0>>> |_NormKernel2(int, double const*, double*)                                       |      1 |      1 | roctracer  | sec    | 0.000004 | 0.000004 |  100.0 |
| |0>>> |_HaloLaplacianKernel(int, int, int, double, double, double const*, double const*, double*) |      9 |      1 | roctracer  | sec    | 0.000133 | 0.000015 |  100.0 |
| |0>>> |_JacobiIterationKernel(int, double, double, double const*, double const*, double*, double*) |     40 |      1 | roctracer  | sec    | 0.022204 | 0.000555 |  100.0 |
| |0>>> |_LocalLaplacianKernel(int, int, int, double, double, double const*, double*)    |      1 |      1 | roctracer  | sec    | 0.000281 | 0.000281 |  100.0 |
| |0>>> hipEventRecord                                                                   |   2000 |      0 | roctracer  | sec    | 0.000000 | 0.000000 |    0.0 |
| |0>>> hipStreamSynchronize                                                             |   2000 |      0 | roctracer  | sec    | 0.000000 | 0.000000 |    0.0 |
| |0>>> hipEventElapsedTime                                                              |   1000 |      0 | roctracer  | sec    | 0.000000 | 0.000000 |    0.0 |
| |0>>> |_HaloLaplacianKernel(int, int, int, double, double, double const*, double const*, double*) |      1 |      1 | roctracer  | sec    | 0.000015 | 0.000015 |  100.0 |
| |0>>> hipFree                                                                          |      4 |      0 | roctracer  | sec    | 0.000000 | 0.000000 |    0.0 |
| |0>>> hipHostFree                                                                      |      2 |      0 | roctracer  | sec    | 0.000000 | 0.000000 |    0.0 |
|---------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
```

Roctracer-0.txt shows duration of HIP API calls and GPU kernels

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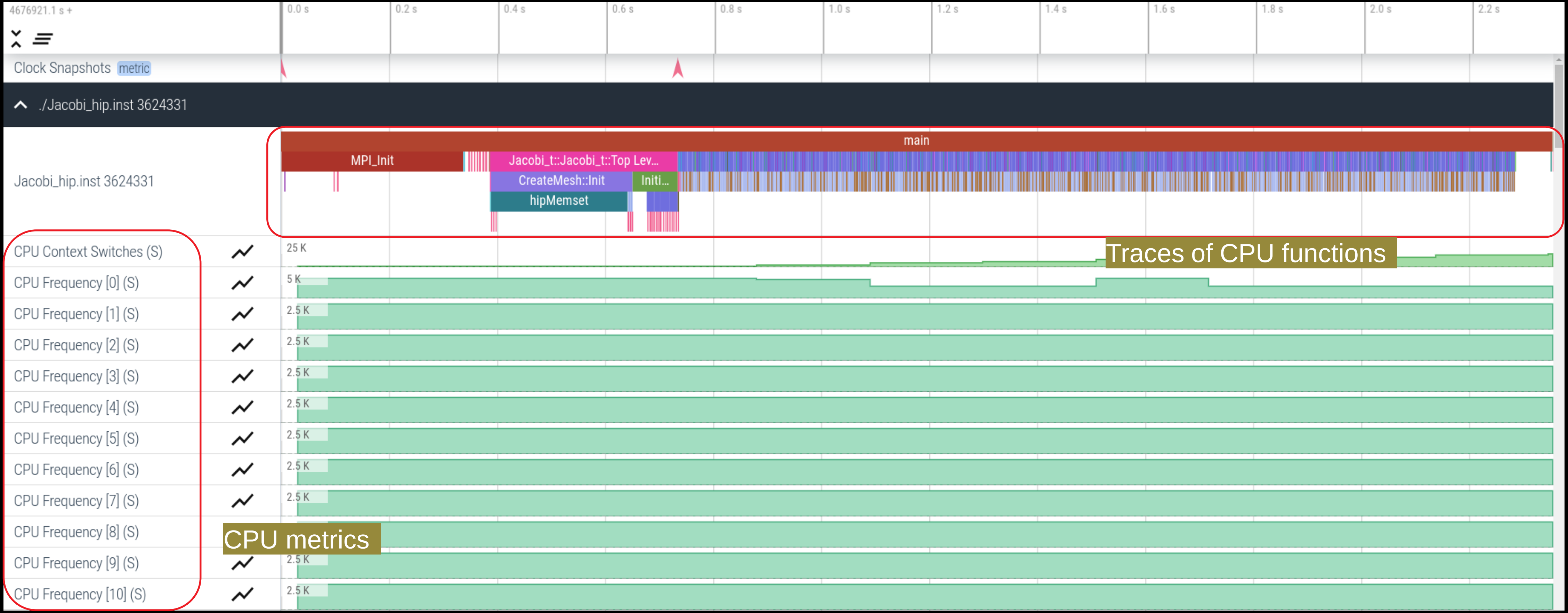
Visualizing Trace

Use Perfetto

Copy `perfetto-trace-0.proto` to your laptop, go to https://ui.perfetto.dev/, Click "Open trace file", select perfetto-trace-0.proto



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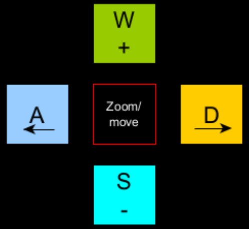
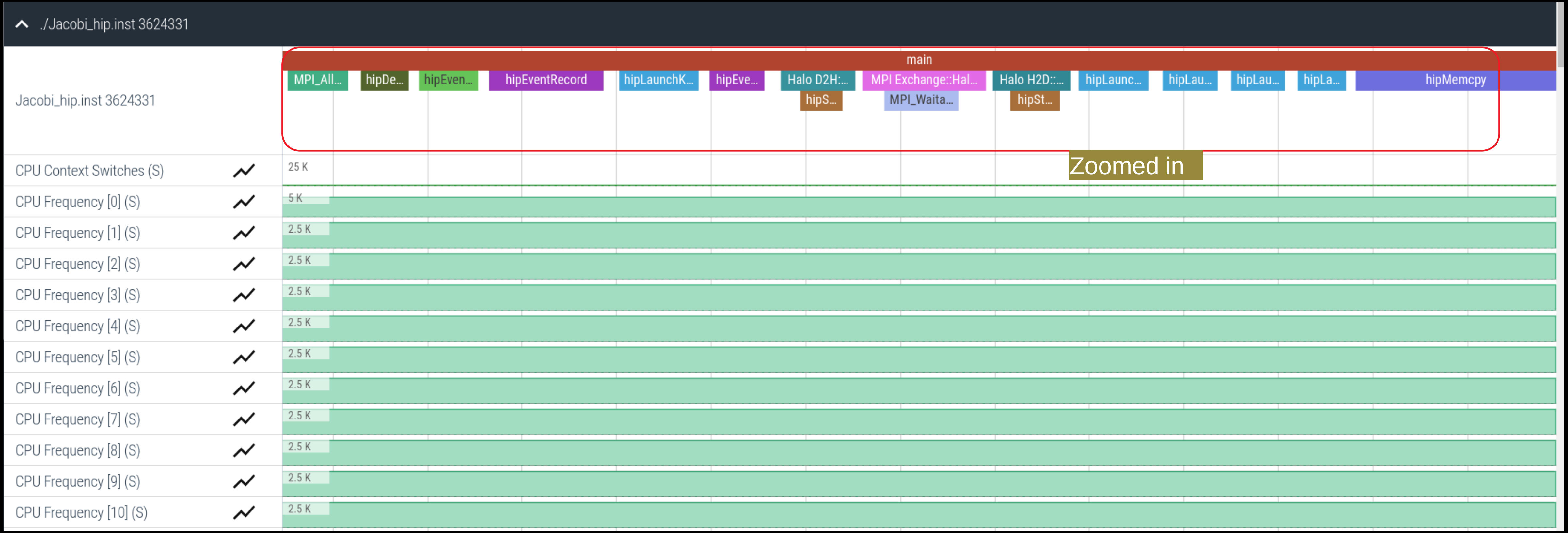
Visualizing Trace

Use Perfetto

Zoom in to investigate regions of interest

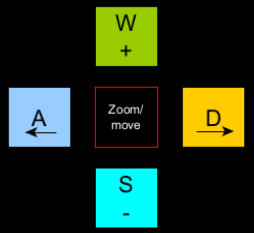


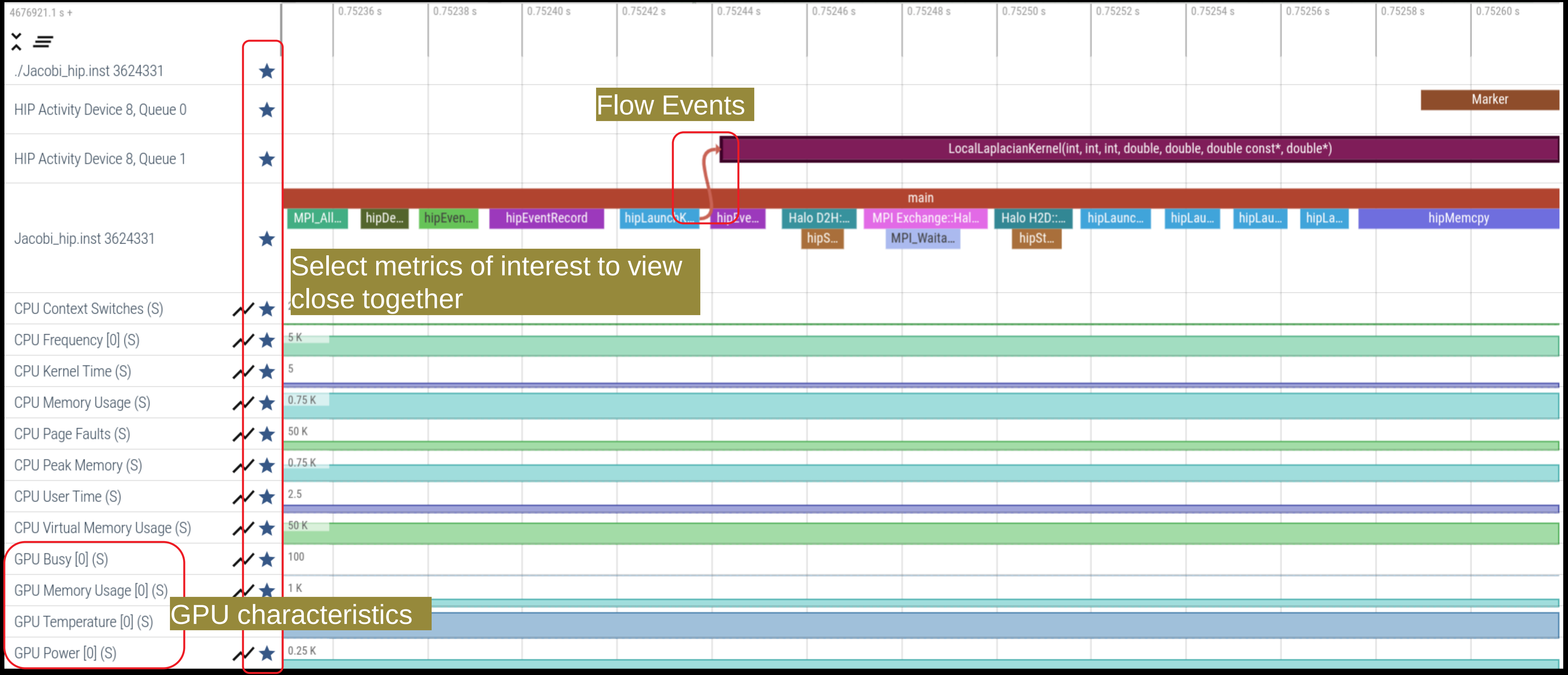


Visualizing Trace

Use Perfetto

Zoom in to investigate regions of interest





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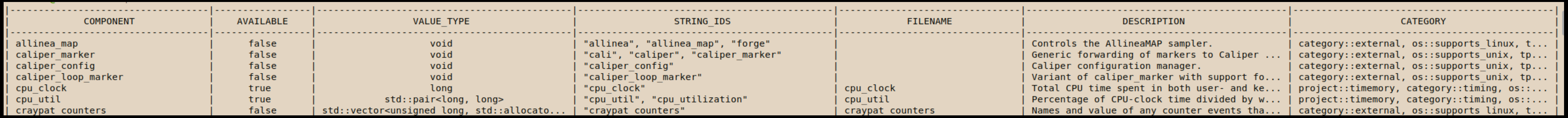
Hardware Counters

AMD

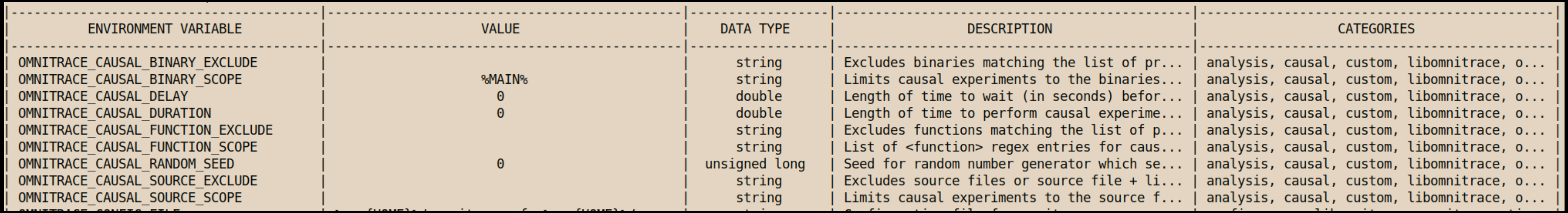
Hardware Counters – List All

```
$ mpirun –np 1 omnitrace-avail --all
```

Components, Categories

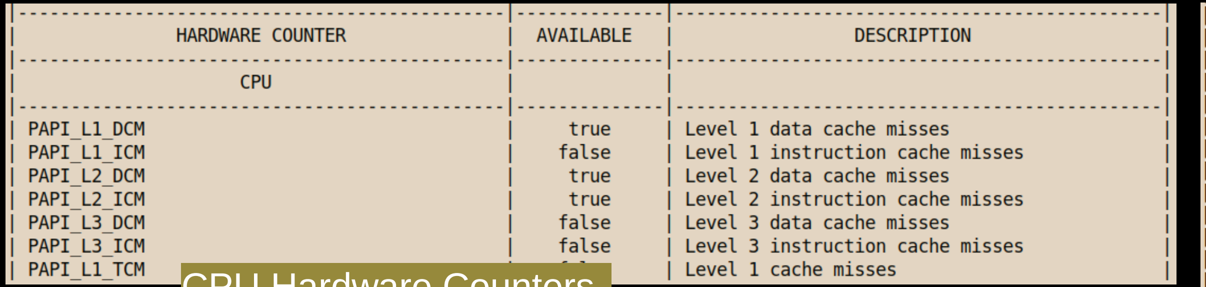


```
|-------------------------------------|-----------------|----------------------------------------------|-----------------------------------------------|---------------------------------|----------------------------------------------|-----------------------------------------------|
|              COMPONENT              |    AVAILABLE    |                  VALUE_TYPE                  |                  STRING_IDS                   |            FILENAME             |                 DESCRIPTION                  |                   CATEGORY                    |
|-------------------------------------|-----------------|----------------------------------------------|-----------------------------------------------|---------------------------------|----------------------------------------------|-----------------------------------------------|
| allinea_map                         |      false      |                     void                     | "allinea", "allinea_map", "forge"             |                                 | Controls the AllineaMAP sampler.             | category::external, os::supports_linux, t... |
| caliper_marker                      |      false      |                     void                     | "cali", "caliper", "caliper_marker"           |                                 | Generic forwarding of markers to Caliper ... | category::external, os::supports_unix, tp... |
| caliper_config                      |      false      |                     void                     | "caliper_config"                              |                                 | Caliper configuration manager.               | category::external, os::supports_unix, tp... |
| caliper_loop_marker                 |      false      |                     void                     | "caliper_loop_marker"                         |                                 | Variant of caliper_marker with support fo... | category::external, os::supports_unix, tp... |
| cpu_clock                           |      true       |                     long                     | "cpu_clock"                                   | cpu_clock                       | Total CPU time spent in both user- and ke... | project::timemory, category::timing, os::... |
| cpu_util                            |      true       |            std::pair<long, long>             | "cpu_util", "cpu_utilization"                 | cpu_util                        | Percentage of CPU-clock time divided by w... | project::timemory, category::timing, os::... |
| craypat_counters                    |      false      | std::vector<unsigned long, std::allocato...  | "craypat_counters"                            | craypat_counters                | Names and value of any counter events tha... | category::external, os::supports_linux, t... |
```



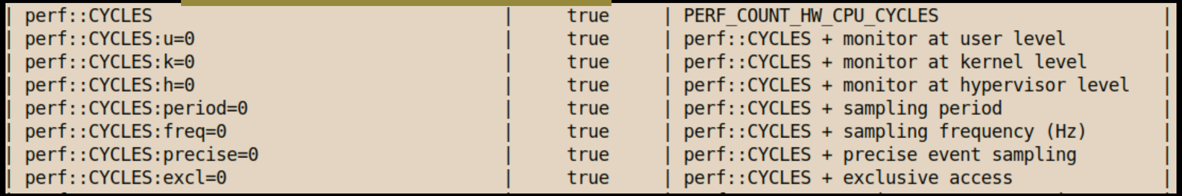
```
|----------------------------------------|-------------------------------------------------|------------------|-------------------------------------------------|-----------------------------------------------|
|          ENVIRONMENT VARIABLE          |                      VALUE                      |    DATA TYPE     |                   DESCRIPTION                   |                  CATEGORIES                   |
|----------------------------------------|-------------------------------------------------|------------------|-------------------------------------------------|-----------------------------------------------|
| OMNITRACE_CAUSAL_BINARY_EXCLUDE        |                                                 |      string      | Excludes binaries matching the list of pr...   | analysis, causal, custom, libomnitrace, o... |
| OMNITRACE_CAUSAL_BINARY_SCOPE          |                     %MAIN%                      |      string      | Limits causal experiments to the binaries...   | analysis, causal, custom, libomnitrace, o... |
| OMNITRACE_CAUSAL_DELAY                 |                        0                        |      double      | Length of time to wait (in seconds) befor...   | analysis, causal, custom, libomnitrace, o... |
| OMNITRACE_CAUSAL_DURATION              |                        0                        |      double      | Length of time to perform causal experime...   | analysis, causal, custom, libomnitrace, o... |
| OMNITRACE_CAUSAL_FUNCTION_EXCLUDE      |                                                 |      string      | Excludes functions matching the list of p...   | analysis, causal, custom, libomnitrace, o... |
| OMNITRACE_CAUSAL_FUNCTION_SCOPE        |                                                 |      string      | List of <function> regex entries for caus...   | analysis, causal, custom, libomnitrace, o... |
| OMNITRACE_CAUSAL_RANDOM_SEED           |                        0                        |  unsigned long   | Seed for random number generator which se...   | analysis, causal, custom, libomnitrace, o... |
| OMNITRACE_CAUSAL_SOURCE_EXCLUDE        |                                                 |      string      | Excludes source files or source file + li...   | analysis, causal, custom, libomnitrace, o... |
| OMNITRACE_CAUSAL_SOURCE_SCOPE          |                                                 |      string      | Limits causal experiments to the source f...   | analysis, causal, custom, libomnitrace, o... |
```

Environment Variables

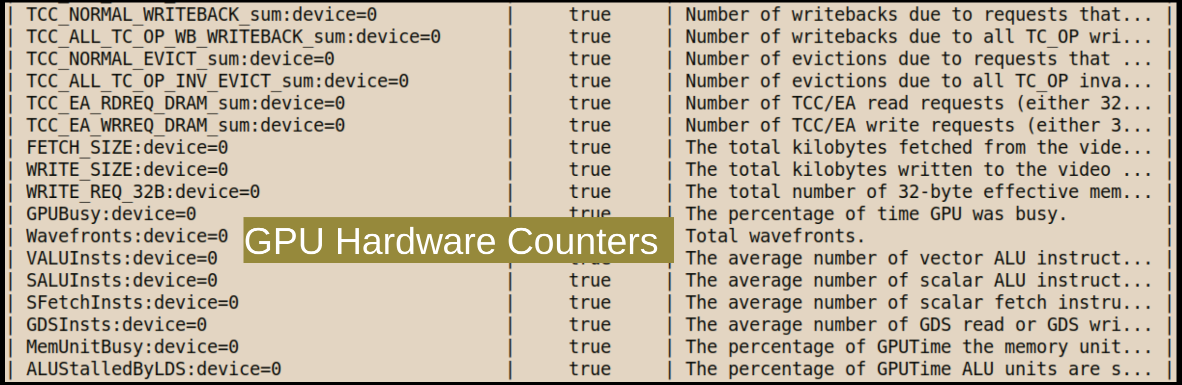


```
|----------------------------------------------|--------------|------------------------------------------------|
|               HARDWARE COUNTER               |  AVAILABLE   |                  DESCRIPTION                   |
|----------------------------------------------|--------------|------------------------------------------------|
|                     CPU                      |              |                                                |
|----------------------------------------------|--------------|------------------------------------------------|
| PAPI_L1_DCM                                  |     true     | Level 1 data cache misses                      |
| PAPI_L1_ICM                                  |    false     | Level 1 instruction cache misses               |
| PAPI_L2_DCM                                  |     true     | Level 2 data cache misses                      |
| PAPI_L2_ICM                                  |     true     | Level 2 instruction cache misses               |
| PAPI_L3_DCM                                  |    false     | Level 3 data cache misses                      |
| PAPI_L3_ICM                                  |    false     | Level 3 instruction cache misses               |
| PAPI_L1_TCM                                  |              | Level 1 cache misses                           |
```

CPU Hardware Counters



```
| perf::CYCLES                                 |     true     | PERF_COUNT_HW_CPU_CYCLES                       |
| perf::CYCLES:u=0                             |     true     | perf::CYCLES + monitor at user level           |
| perf::CYCLES:k=0                             |     true     | perf::CYCLES + monitor at kernel level         |
| perf::CYCLES:h=0                             |     true     | perf::CYCLES + monitor at hypervisor level     |
| perf::CYCLES:period=0                        |     true     | perf::CYCLES + sampling period                 |
| perf::CYCLES:freq=0                          |     true     | perf::CYCLES + sampling frequency (Hz)         |
| perf::CYCLES:precise=0                       |     true     | perf::CYCLES + precise event sampling          |
| perf::CYCLES:excl=0                          |     true     | perf::CYCLES + exclusive access                |
```



```
| TCC_NORMAL_WRITEBACK_sum:device=0            |     true     | Number of writebacks due to requests that...  |
| TCC_ALL_TC_OP_WB_WRITEBACK_sum:device=0      |     true     | Number of writebacks due to all TC_OP wri...  |
| TCC_NORMAL_EVICT_sum:device=0                |     true     | Number of evictions due to requests that ...  |
| TCC_ALL_TC_OP_INV_EVICT_sum:device=0         |     true     | Number of evictions due to all TC_OP inva...  |
| TCC_EA_RDREQ_DRAM_sum:device=0               |     true     | Number of TCC/EA read requests (either 32...  |
| TCC_EA_WRREQ_DRAM_sum:device=0               |     true     | Number of TCC/EA write requests (either 3...  |
| FETCH_SIZE:device=0                          |     true     | The total kilobytes fetched from the vide...  |
| WRITE_SIZE:device=0                          |     true     | The total kilobytes written to the video ...  |
| WRITE_REQ_32B:device=0                       |     true     | The total number of 32-byte effective mem...  |
| GPUBusy:device=0                             |     true     | The percentage of time GPU was busy.          |
| Wavefronts:device=0                          |              | Total wavefronts.                             |
| VALUInsts:device=0                           |              | The average number of vector ALU instruct...  |
| SALUInsts:device=0                           |     true     | The average number of scalar ALU instruct...  |
| SFetchInsts:device=0                         |     true     | The average number of scalar fetch instru...  |
| GDSInsts:device=0                            |     true     | The average number of GDS read or GDS wri...  |
| MemUnitBusy:device=0                         |     true     | The percentage of GPUTime the memory unit...  |
| ALUStalledByLDS:device=0                     |     true     | The percentage of GPUTime ALU units are s...  |
```

GPU Hardware Counters

A very small subset of the counters shown here

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Commonly Used GPU Counters

VALUUtilization	The percentage of ALUs active in a wave. Low VALUUtilization is likely due to high divergence or a poorly sized grid
VALUBusy	The percentage of GPUTime vector ALU instructions are processed. Can be thought of as something like compute utilization
FetchSize	The total kilobytes fetched from global memory
WriteSize	The total kilobytes written to global memory
L2CacheHit	The percentage of fetch, write, atomic, and other instructions that hit the data in L2 cache
MemUnitBusy	The percentage of GPUTime the memory unit is active. The result includes the stall time
MemUnitStalled	The percentage of GPUTime the memory unit is stalled
WriteUnitStalled	The percentage of GPUTime the write unit is stalled

Modify config file

Create a config file in $HOME:

```
$ omnitrace-avail -G $HOME/.omnitrace.cfg
```

Modify the config file $HOME/.omnitrace.cfg to add desired metrics and for concerned GPU#ID:

```
…
OMNITRACE_ROCM_EVENTS = GPUBusy:device=0,
Wavefronts:device=0, MemUnitBusy:device=0
…
```

To profile desired metrics for all participating GPUs:

```
…
OMNITRACE_ROCM_EVENTS = GPUBusy, Wavefronts,
MemUnitBusy
…
```

Full list at: https://github.com/ROCm-Developer-Tools/rocprofiler/blob/amd-master/test/tool/metrics.xml

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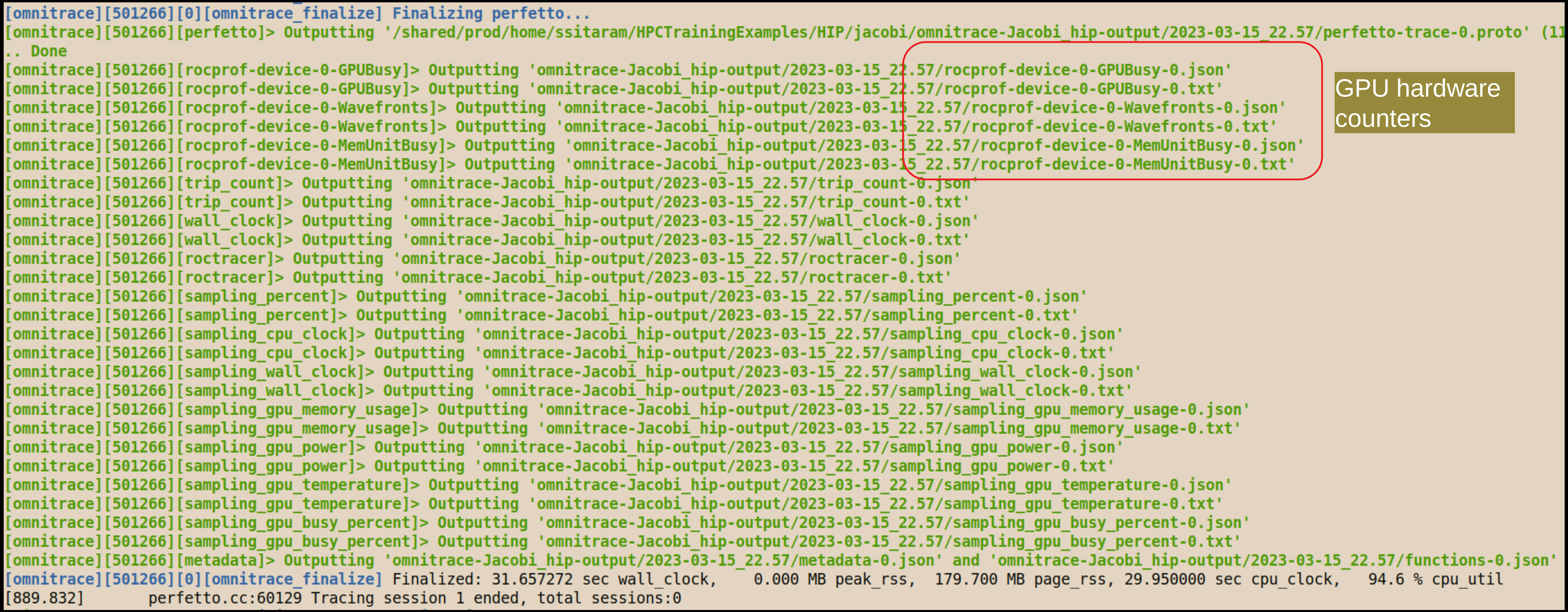
Execution with Hardware Counters

(after modifying cfg file to set up OMNITRACE_ROCM_EVENTS with GPU metrics)

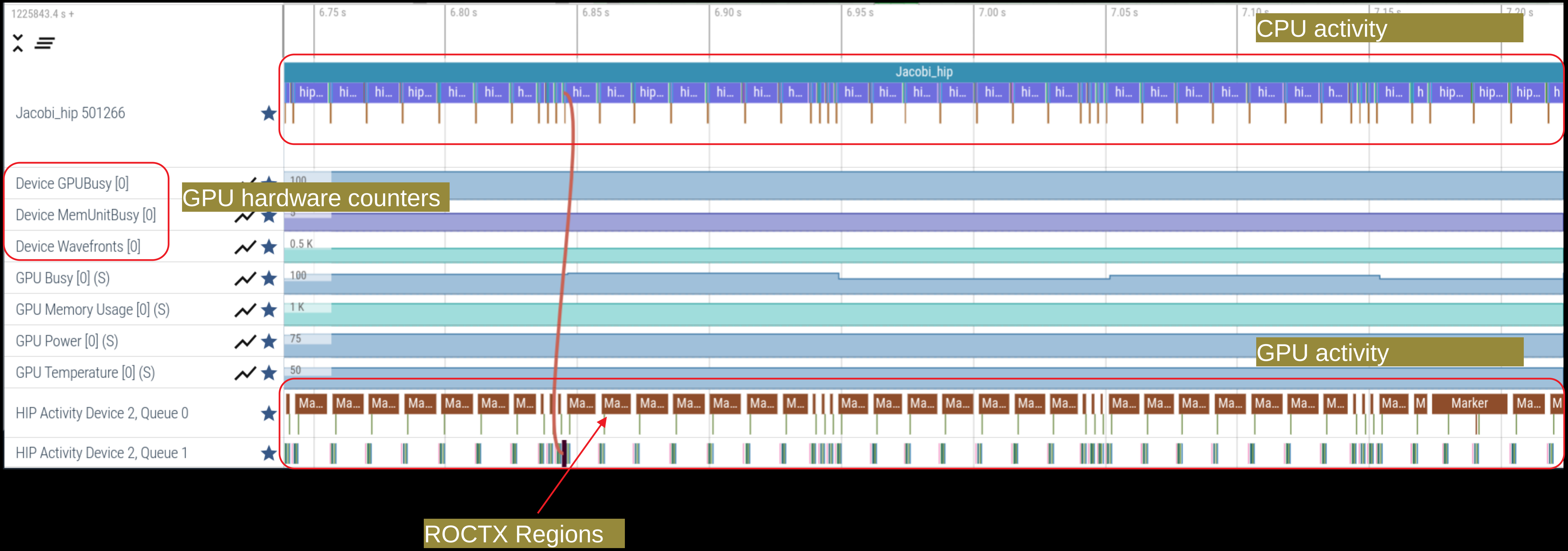
```
$ mpirun -np 1 omnitrace-run -- ./Jacobi_hip.inst -g 1 1
```



```
[omnitrace][501266][0][omnitrace_finalize] Finalizing perfetto...
[omnitrace][501266][perfetto]> Outputting '/shared/prod/home/ssitaram/HPCTrainingExamples/HIP/jacobi/omnitrace-Jacobi_hip-output/2023-03-15_22.57/perfetto-trace-0.proto' (11
.. Done
[omnitrace][501266][rocprof-device-0-GPUBusy]> Outputting 'omnitrace-Jacobi_hip-output/2023-03-15_22.57/rocprof-device-0-GPUBusy-0.json'
[omnitrace][501266][rocprof-device-0-GPUBusy]> Outputting 'omnitrace-Jacobi_hip-output/2023-03-15_22.57/rocprof-device-0-GPUBusy-0.txt'
[omnitrace][501266][rocprof-device-0-Wavefronts]> Outputting 'omnitrace-Jacobi_hip-output/2023-03-15_22.57/rocprof-device-0-Wavefronts-0.json'
[omnitrace][501266][rocprof-device-0-Wavefronts]> Outputting 'omnitrace-Jacobi_hip-output/2023-03-15_22.57/rocprof-device-0-Wavefronts-0.txt'
[omnitrace][501266][rocprof-device-0-MemUnitBusy]> Outputting 'omnitrace-Jacobi_hip-output/2023-03-15_22.57/rocprof-device-0-MemUnitBusy-0.json'
[omnitrace][501266][rocprof-device-0-MemUnitBusy]> Outputting 'omnitrace-Jacobi_hip-output/2023-03-15_22.57/rocprof-device-0-MemUnitBusy-0.txt'
[omnitrace][501266][trip_count]> Outputting 'omnitrace-Jacobi_hip-output/2023-03-15_22.57/trip_count-0.json'
[omnitrace][501266][trip_count]> Outputting 'omnitrace-Jacobi_hip-output/2023-03-15_22.57/trip_count-0.txt'
[omnitrace][501266][wall_clock]> Outputting 'omnitrace-Jacobi_hip-output/2023-03-15_22.57/wall_clock-0.json'
[omnitrace][501266][wall_clock]> Outputting 'omnitrace-Jacobi_hip-output/2023-03-15_22.57/wall_clock-0.txt'
[omnitrace][501266][roctracer]> Outputting 'omnitrace-Jacobi_hip-output/2023-03-15_22.57/roctracer-0.json'
[omnitrace][501266][roctracer]> Outputting 'omnitrace-Jacobi_hip-output/2023-03-15_22.57/roctracer-0.txt'
[omnitrace][501266][sampling_percent]> Outputting 'omnitrace-Jacobi_hip-output/2023-03-15_22.57/sampling_percent-0.json'
[omnitrace][501266][sampling_percent]> Outputting 'omnitrace-Jacobi_hip-output/2023-03-15_22.57/sampling_percent-0.txt'
[omnitrace][501266][sampling_cpu_clock]> Outputting 'omnitrace-Jacobi_hip-output/2023-03-15_22.57/sampling_cpu_clock-0.json'
[omnitrace][501266][sampling_cpu_clock]> Outputting 'omnitrace-Jacobi_hip-output/2023-03-15_22.57/sampling_cpu_clock-0.txt'
[omnitrace][501266][sampling_wall_clock]> Outputting 'omnitrace-Jacobi_hip-output/2023-03-15_22.57/sampling_wall_clock-0.json'
[omnitrace][501266][sampling_wall_clock]> Outputting 'omnitrace-Jacobi_hip-output/2023-03-15_22.57/sampling_wall_clock-0.txt'
[omnitrace][501266][sampling_gpu_memory_usage]> Outputting 'omnitrace-Jacobi_hip-output/2023-03-15_22.57/sampling_gpu_memory_usage-0.json'
[omnitrace][501266][sampling_gpu_memory_usage]> Outputting 'omnitrace-Jacobi_hip-output/2023-03-15_22.57/sampling_gpu_memory_usage-0.txt'
[omnitrace][501266][sampling_gpu_power]> Outputting 'omnitrace-Jacobi_hip-output/2023-03-15_22.57/sampling_gpu_power-0.json'
[omnitrace][501266][sampling_gpu_power]> Outputting 'omnitrace-Jacobi_hip-output/2023-03-15_22.57/sampling_gpu_power-0.txt'
[omnitrace][501266][sampling_gpu_temperature]> Outputting 'omnitrace-Jacobi_hip-output/2023-03-15_22.57/sampling_gpu_temperature-0.json'
[omnitrace][501266][sampling_gpu_temperature]> Outputting 'omnitrace-Jacobi_hip-output/2023-03-15_22.57/sampling_gpu_temperature-0.txt'
[omnitrace][501266][sampling_gpu_busy_percent]> Outputting 'omnitrace-Jacobi_hip-output/2023-03-15_22.57/sampling_gpu_busy_percent-0.json'
[omnitrace][501266][sampling_gpu_busy_percent]> Outputting 'omnitrace-Jacobi_hip-output/2023-03-15_22.57/sampling_gpu_busy_percent-0.txt'
[omnitrace][501266][metadata]> Outputting 'omnitrace-Jacobi_hip-output/2023-03-15_22.57/metadata-0.json' and 'omnitrace-Jacobi_hip-output/2023-03-15_22.57/functions-0.json'
[omnitrace][501266][0][omnitrace_finalize] Finalized: 31.657272 sec wall_clock,    0.000 MB peak_rss,  179.700 MB page_rss, 29.950000 sec cpu_clock,   94.6 % cpu_util
[889.832]       perfetto.cc:60129 Tracing session 1 ended, total sessions:0
```

GPU hardware counters

Visualization with Hardware Counters



Tracing Multiple Ranks

Profiling Multiple MPI Ranks – Jacobi Example

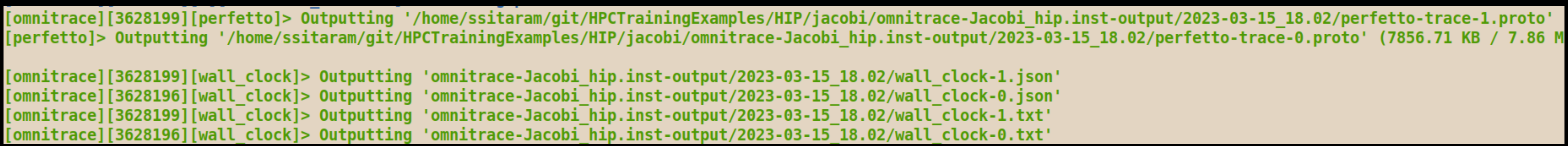
Binary Rewrite

Generating a new /library with instrumentation built-in:

```
 $ omnitrace-instrument -o Jacobi_hip.inst --
./Jacobi_hip
```

Run the instrumented binary with 2 ranks:

```
 $ mpirun -np 2 omnitrace-run --./Jacobi_hip.inst -g
2 1
```



```
[omnitrace][3628199][perfetto]> Outputting '/home/ssitaram/git/HPCTrainingExamples/HIP/jacobi/omnitrace-Jacobi_hip.inst-output/2023-03-15_18.02/perfetto-trace-1.proto'
[perfetto]> Outputting '/home/ssitaram/git/HPCTrainingExamples/HIP/jacobi/omnitrace-Jacobi_hip.inst-output/2023-03-15_18.02/perfetto-trace-0.proto' (7856.71 KB / 7.86 M

[omnitrace][3628199][wall_clock]> Outputting 'omnitrace-Jacobi_hip.inst-output/2023-03-15_18.02/wall_clock-1.json'
[omnitrace][3628196][wall_clock]> Outputting 'omnitrace-Jacobi_hip.inst-output/2023-03-15_18.02/wall_clock-0.json'
[omnitrace][3628199][wall_clock]> Outputting 'omnitrace-Jacobi_hip.inst-output/2023-03-15_18.02/wall_clock-1.txt'
[omnitrace][3628196][wall_clock]> Outputting 'omnitrace-Jacobi_hip.inst-output/2023-03-15_18.02/wall_clock-0.txt'
```

All output files are generated for each rank

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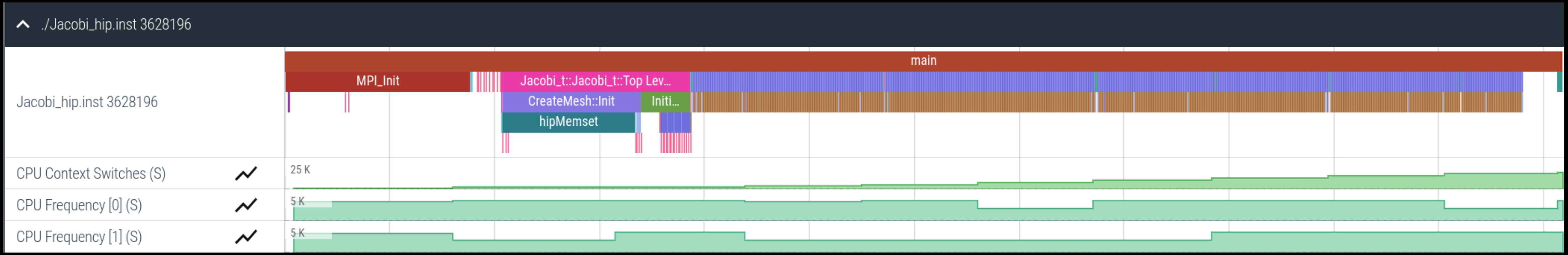
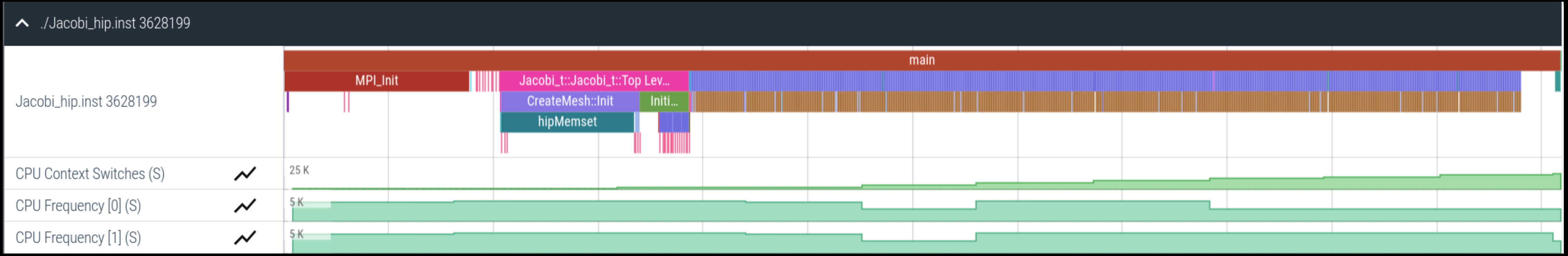
Visualizing Traces from Multiple Ranks - Separately

MPI 0



MPI 1



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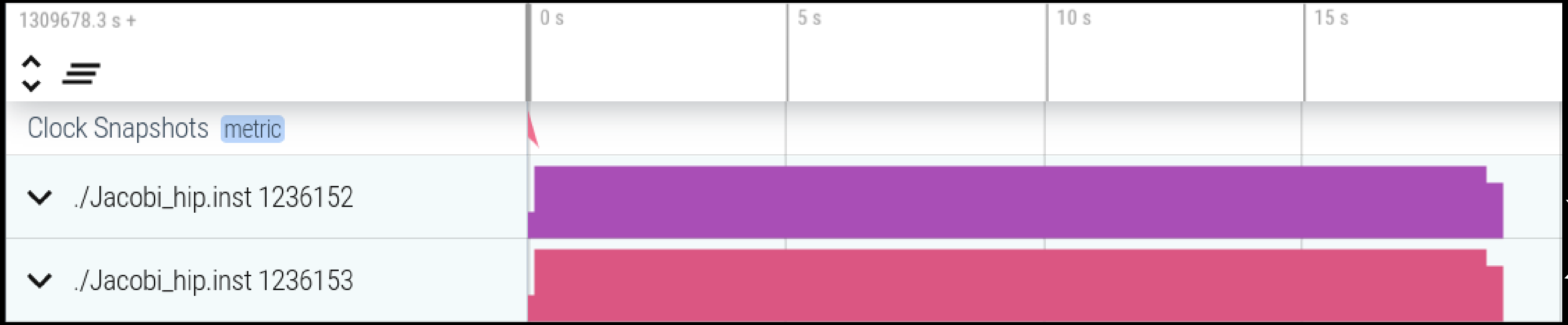
Visualizing Traces from Multiple Ranks - Combined

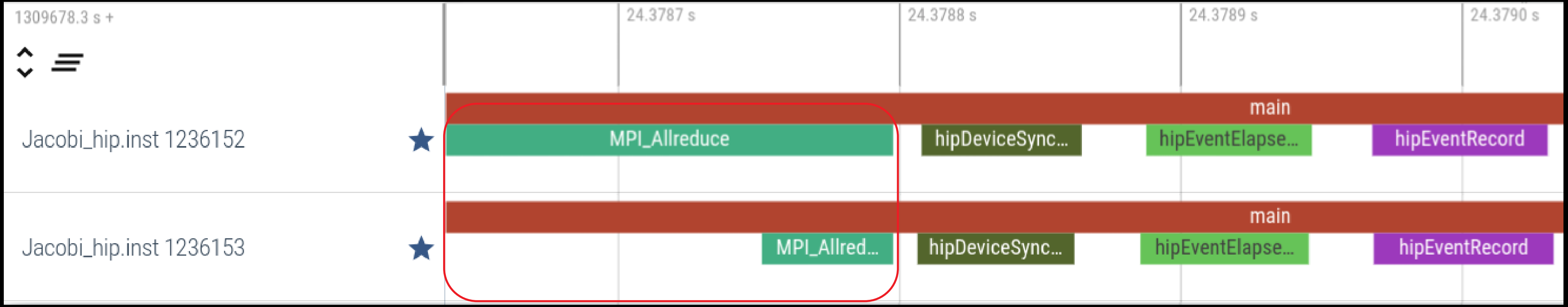
Merge Perfetto

Use the following command to merge and concatenate multiple traces:

```
$ cat perfetto-trace-0.proto perfetto-trace-1.proto > allprocesses.proto
```



Two processes seen in combined trace file



Zooming in helps understand load balance issues

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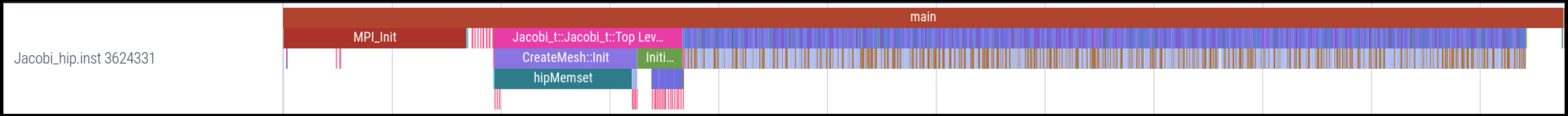
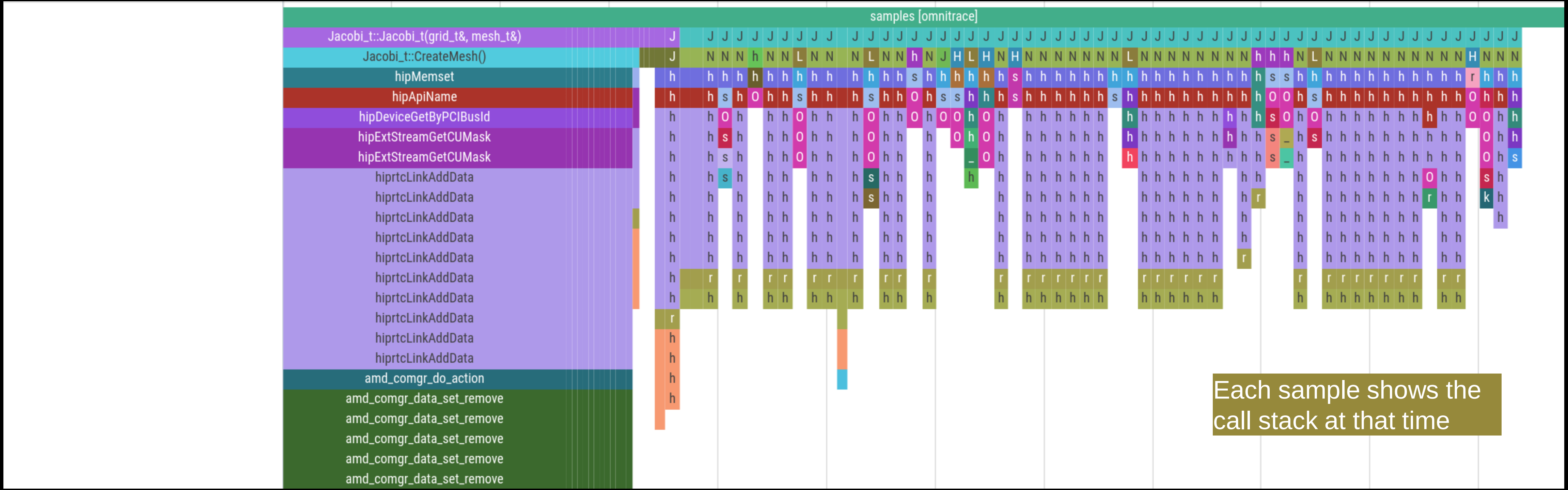
Statistical Sampling

Sampling Call-Stack (I)

`OMNITRACE_USE_SAMPLING = false`



`OMNITRACE_USE_SAMPLING = true; OMNITRACE_SAMPLING_FREQ = 100` (100 samples per second)



Each sample shows the call stack at that time

Scroll down all the way in Perfetto to see the sampling output!

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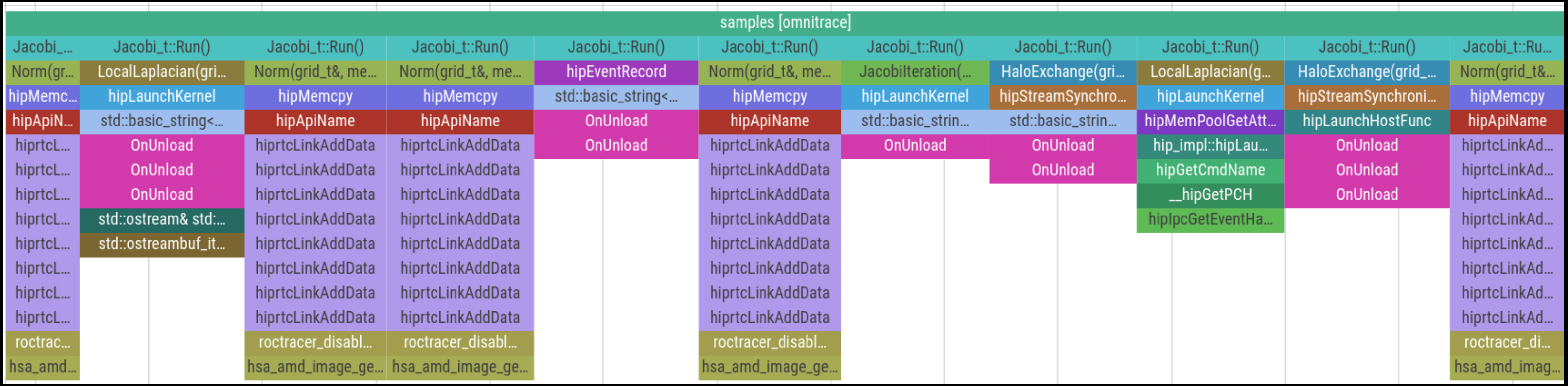
Sampling Call-Stack (II)

Zoom in call-stack sampling



Thread 0 (S) 3625610

Sampling data is annotated with (S)

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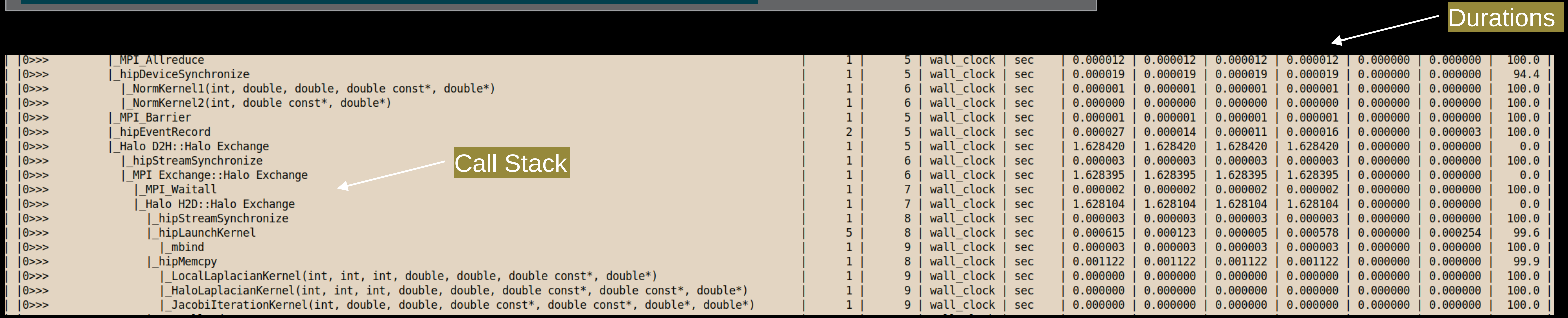
Other Features

Kernel Durations

```
$ cat omnitrace-Jacobi_hip.inst-output/2023-03-15_13.57/wall_clock-0.txt
```

If you do not see a wall_clock.txt dumped by omnitrace, try modify the config file `$HOME/.omnitrace.cfg` and enable `OMNITRACE_USE_TIMEMORY`:

```
…
OMNITRACE_USE_PERFETTO                              = true
OMNITRACE_USE_TIMEMORY                              = true
OMNITRACE_USE_SAMPLING                              = false
…
```



```
| |0>>>       |_MPI_Allreduce                                                                     |     1 |     5 | wall_clock | sec    | 0.000012 | 0.000012 | 0.000012 | 0.000012 | 0.000000 | 0.000000 |  100.0 |
| |0>>>       |_hipDeviceSynchronize                                                              |     1 |     5 | wall_clock | sec    | 0.000019 | 0.000019 | 0.000019 | 0.000019 | 0.000000 | 0.000000 |   94.4 |
| |0>>>         |_NormKernel1(int, double, double, double const*, double*)                        |     1 |     6 | wall_clock | sec    | 0.000001 | 0.000001 | 0.000001 | 0.000001 | 0.000000 | 0.000000 |  100.0 |
| |0>>>         |_NormKernel2(int, double const*, double*)                                        |     1 |     6 | wall_clock | sec    | 0.000000 | 0.000000 | 0.000000 | 0.000000 | 0.000000 | 0.000000 |  100.0 |
| |0>>>       |_MPI_Barrier                                                                       |     1 |     5 | wall_clock | sec    | 0.000001 | 0.000001 | 0.000001 | 0.000001 | 0.000000 | 0.000000 |  100.0 |
| |0>>>       |_hipEventRecord                                                                    |     2 |     5 | wall_clock | sec    | 0.000027 | 0.000014 | 0.000011 | 0.000016 | 0.000000 | 0.000003 |  100.0 |
| |0>>>       |_Halo D2H::Halo Exchange                                                           |     1 |     5 | wall_clock | sec    | 1.628420 | 1.628420 | 1.628420 | 1.628420 | 0.000000 | 0.000000 |    0.0 |
| |0>>>         |_hipStreamSynchronize                                                            |     1 |     6 | wall_clock | sec    | 0.000003 | 0.000003 | 0.000003 | 0.000003 | 0.000000 | 0.000000 |  100.0 |
| |0>>>         |_MPI Exchange::Halo Exchange                                                     |     1 |     6 | wall_clock | sec    | 1.628395 | 1.628395 | 1.628395 | 1.628395 | 0.000000 | 0.000000 |    0.0 |
| |0>>>           |_MPI_Waitall                                                                   |     1 |     7 | wall_clock | sec    | 0.000002 | 0.000002 | 0.000002 | 0.000002 | 0.000000 | 0.000000 |  100.0 |
| |0>>>           |_Halo H2D::Halo Exchange                                                       |     1 |     7 | wall_clock | sec    | 1.628104 | 1.628104 | 1.628104 | 1.628104 | 0.000000 | 0.000000 |    0.0 |
| |0>>>             |_hipStreamSynchronize                                                        |     1 |     8 | wall_clock | sec    | 0.000003 | 0.000003 | 0.000003 | 0.000003 | 0.000000 | 0.000000 |  100.0 |
| |0>>>             |_hipLaunchKernel                                                             |     5 |     8 | wall_clock | sec    | 0.000615 | 0.000123 | 0.000005 | 0.000578 | 0.000000 | 0.000254 |   99.6 |
| |0>>>               |_mbind                                                                     |     1 |     9 | wall_clock | sec    | 0.000003 | 0.000003 | 0.000003 | 0.000003 | 0.000000 | 0.000000 |  100.0 |
| |0>>>             |_hipMemcpy                                                                   |     1 |     8 | wall_clock | sec    | 0.001122 | 0.001122 | 0.001122 | 0.001122 | 0.000000 | 0.000000 |   99.9 |
| |0>>>               |_LocalLaplacianKernel(int, int, int, double, double, double const*, double*) |     1 |     9 | wall_clock | sec    | 0.000000 | 0.000000 | 0.000000 | 0.000000 | 0.000000 | 0.000000 |  100.0 |
| |0>>>               |_HaloLaplacianKernel(int, int, int, double, double, double const*, double const*, double*) |     1 |     9 | wall_clock | sec    | 0.000000 | 0.000000 | 0.000000 | 0.000000 | 0.000000 | 0.000000 |  100.0 |
| |0>>>               |_JacobiIterationKernel(int, double, double, double const*, double const*, double*, double*) |     1 |     9 | wall_clock | sec    | 0.000000 | 0.000000 | 0.000000 | 0.000000 | 0.000000 | 0.000000 |  100.0 |
```

Text file is for quick reference. JSON output is easy to script for and can be read by Hatchet, a Python package (https://hatchet.readthedocs.io/en/latest/)

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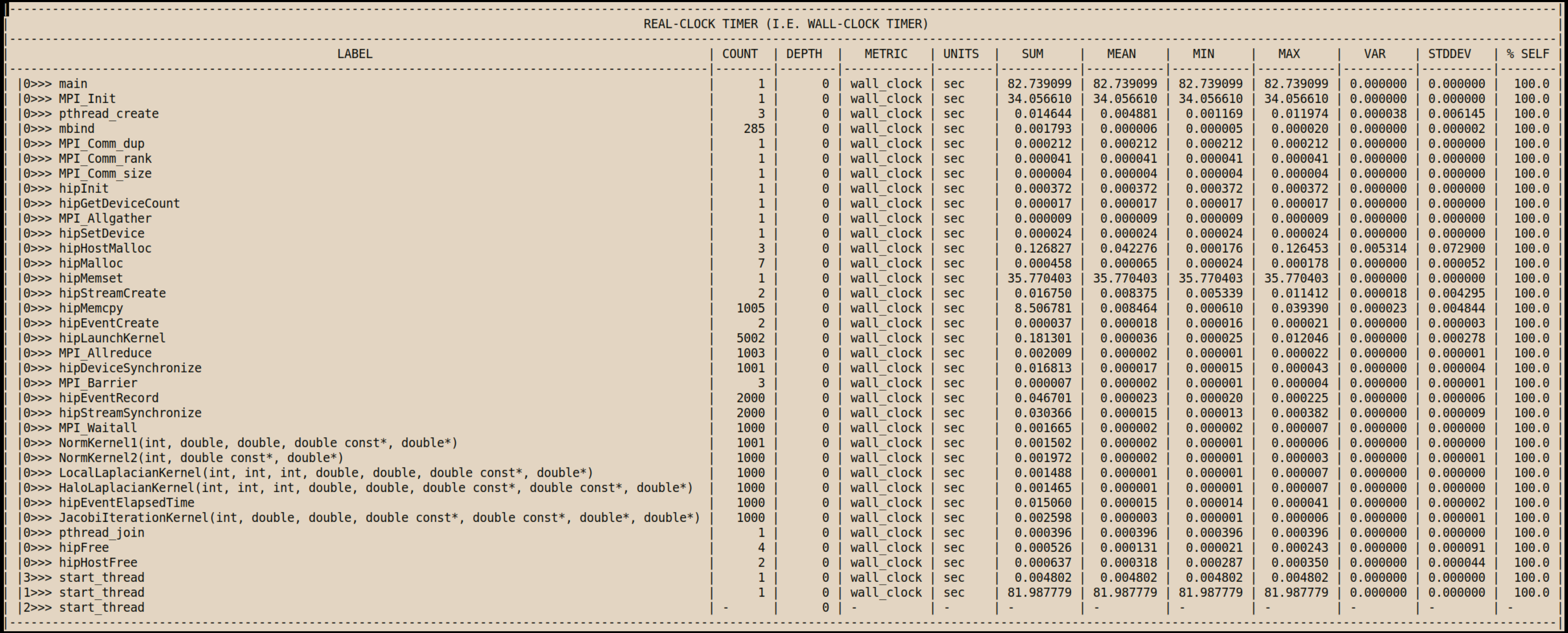
Kernel Durations (flat profile)

Edit in your omnitrace.cfg:

```
OMNITRACE_USE_TIMEMORY                              = true
OMNITRACE_FLAT_PROFILE                              = true
```

Use flat profile to see aggregate duration of kernels and functions



```
|-----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
|                                                                                 REAL-CLOCK TIMER (I.E. WALL-CLOCK TIMER)                                                                                  |
|-----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
|                                              LABEL                                               | COUNT  | DEPTH  |   METRIC   | UNITS  |    SUM    |   MEAN    |    MIN    |    MAX    |   VAR    |  STDDEV  | % SELF |
|--------------------------------------------------------------------------------------------------|--------|--------|------------|--------|-----------|-----------|-----------|-----------|----------|----------|--------|
| |0>>> main                                                                                       |      1 |      0 | wall_clock | sec    | 82.739099 | 82.739099 | 82.739099 | 82.739099 | 0.000000 | 0.000000 |  100.0 |
| |0>>> MPI_Init                                                                                   |      1 |      0 | wall_clock | sec    | 34.056610 | 34.056610 | 34.056610 | 34.056610 | 0.000000 | 0.000000 |  100.0 |
| |0>>> pthread_create                                                                             |      3 |      0 | wall_clock | sec    |  0.014644 |  0.004881 |  0.001169 |  0.011974 | 0.000038 | 0.006145 |  100.0 |
| |0>>> mbind                                                                                      |    285 |      0 | wall_clock | sec    |  0.001793 |  0.000006 |  0.000005 |  0.000020 | 0.000000 | 0.000002 |  100.0 |
| |0>>> MPI_Comm_dup                                                                               |      1 |      0 | wall_clock | sec    |  0.000212 |  0.000212 |  0.000212 |  0.000212 | 0.000000 | 0.000000 |  100.0 |
| |0>>> MPI_Comm_rank                                                                              |      1 |      0 | wall_clock | sec    |  0.000041 |  0.000041 |  0.000041 |  0.000041 | 0.000000 | 0.000000 |  100.0 |
| |0>>> MPI_Comm_size                                                                              |      1 |      0 | wall_clock | sec    |  0.000004 |  0.000004 |  0.000004 |  0.000004 | 0.000000 | 0.000000 |  100.0 |
| |0>>> hipInit                                                                                    |      1 |      0 | wall_clock | sec    |  0.000372 |  0.000372 |  0.000372 |  0.000372 | 0.000000 | 0.000000 |  100.0 |
| |0>>> hipGetDeviceCount                                                                          |      1 |      0 | wall_clock | sec    |  0.000017 |  0.000017 |  0.000017 |  0.000017 | 0.000000 | 0.000000 |  100.0 |
| |0>>> MPI_Allgather                                                                              |      1 |      0 | wall_clock | sec    |  0.000009 |  0.000009 |  0.000009 |  0.000009 | 0.000000 | 0.000000 |  100.0 |
| |0>>> hipSetDevice                                                                               |      1 |      0 | wall_clock | sec    |  0.000024 |  0.000024 |  0.000024 |  0.000024 | 0.000000 | 0.000000 |  100.0 |
| |0>>> hipHostMalloc                                                                              |      3 |      0 | wall_clock | sec    |  0.126827 |  0.042276 |  0.000176 |  0.126453 | 0.005314 | 0.072900 |  100.0 |
| |0>>> hipMalloc                                                                                  |      7 |      0 | wall_clock | sec    |  0.000458 |  0.000065 |  0.000024 |  0.000178 | 0.000000 | 0.000052 |  100.0 |
| |0>>> hipMemset                                                                                  |      1 |      0 | wall_clock | sec    | 35.770403 | 35.770403 | 35.770403 | 35.770403 | 0.000000 | 0.000000 |  100.0 |
| |0>>> hipStreamCreate                                                                            |      2 |      0 | wall_clock | sec    |  0.016750 |  0.008375 |  0.005339 |  0.011412 | 0.000018 | 0.004295 |  100.0 |
| |0>>> hipMemcpy                                                                                  |   1005 |      0 | wall_clock | sec    |  8.506781 |  0.008464 |  0.000610 |  0.039390 | 0.000023 | 0.004844 |  100.0 |
| |0>>> hipEventCreate                                                                             |      2 |      0 | wall_clock | sec    |  0.000037 |  0.000018 |  0.000016 |  0.000021 | 0.000000 | 0.000003 |  100.0 |
| |0>>> hipLaunchKernel                                                                            |   5002 |      0 | wall_clock | sec    |  0.181301 |  0.000036 |  0.000025 |  0.012046 | 0.000000 | 0.000278 |  100.0 |
| |0>>> MPI_Allreduce                                                                              |   1003 |      0 | wall_clock | sec    |  0.002009 |  0.000002 |  0.000001 |  0.000022 | 0.000000 | 0.000001 |  100.0 |
| |0>>> hipDeviceSynchronize                                                                       |   1001 |      0 | wall_clock | sec    |  0.016813 |  0.000017 |  0.000015 |  0.000043 | 0.000000 | 0.000004 |  100.0 |
| |0>>> MPI_Barrier                                                                                |      3 |      0 | wall_clock | sec    |  0.000007 |  0.000002 |  0.000001 |  0.000004 | 0.000000 | 0.000001 |  100.0 |
| |0>>> hipEventRecord                                                                             |   2000 |      0 | wall_clock | sec    |  0.046701 |  0.000023 |  0.000020 |  0.000225 | 0.000000 | 0.000006 |  100.0 |
| |0>>> hipStreamSynchronize                                                                       |   2000 |      0 | wall_clock | sec    |  0.030366 |  0.000015 |  0.000013 |  0.000382 | 0.000000 | 0.000009 |  100.0 |
| |0>>> MPI_Waitall                                                                                |   1000 |      0 | wall_clock | sec    |  0.001665 |  0.000002 |  0.000002 |  0.000007 | 0.000000 | 0.000000 |  100.0 |
| |0>>> NormKernel1(int, double, double, double const*, double*)                                   |   1001 |      0 | wall_clock | sec    |  0.001502 |  0.000002 |  0.000001 |  0.000006 | 0.000000 | 0.000000 |  100.0 |
| |0>>> NormKernel2(int, double const*, double*)                                                   |   1000 |      0 | wall_clock | sec    |  0.001972 |  0.000002 |  0.000001 |  0.000003 | 0.000000 | 0.000001 |  100.0 |
| |0>>> LocalLaplacianKernel(int, int, int, double, double, double const*, double*)                |   1000 |      0 | wall_clock | sec    |  0.001488 |  0.000001 |  0.000001 |  0.000007 | 0.000000 | 0.000000 |  100.0 |
| |0>>> HaloLaplacianKernel(int, int, int, double, double, double const*, double const*, double*)  |   1000 |      0 | wall_clock | sec    |  0.001465 |  0.000001 |  0.000001 |  0.000007 | 0.000000 | 0.000000 |  100.0 |
| |0>>> hipEventElapsedTime                                                                        |   1000 |      0 | wall_clock | sec    |  0.015060 |  0.000015 |  0.000014 |  0.000041 | 0.000000 | 0.000002 |  100.0 |
| |0>>> JacobiIterationKernel(int, double, double, double const*, double const*, double*, double*) |   1000 |      0 | wall_clock | sec    |  0.002598 |  0.000003 |  0.000001 |  0.000006 | 0.000000 | 0.000001 |  100.0 |
| |0>>> pthread_join                                                                               |      1 |      0 | wall_clock | sec    |  0.000396 |  0.000396 |  0.000396 |  0.000396 | 0.000000 | 0.000000 |  100.0 |
| |0>>> hipFree                                                                                    |      4 |      0 | wall_clock | sec    |  0.000526 |  0.000131 |  0.000021 |  0.000243 | 0.000000 | 0.000091 |  100.0 |
| |0>>> hipHostFree                                                                                |      2 |      0 | wall_clock | sec    |  0.000637 |  0.000318 |  0.000287 |  0.000350 | 0.000000 | 0.000044 |  100.0 |
| |3>>> start_thread                                                                               |      1 |      0 | wall_clock | sec    |  0.004802 |  0.004802 |  0.004802 |  0.004802 | 0.000000 | 0.000000 |  100.0 |
| |1>>> start_thread                                                                               |      1 |      0 | wall_clock | sec    | 81.987779 | 81.987779 | 81.987779 | 81.987779 | 0.000000 | 0.000000 |  100.0 |
| |2>>> start_thread                                                                               | -      |      0 | -          | -      | -         | -         | -         | -         | -        | -        | -      |
|-----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
```

User API

Omnitrace provides an API to control the instrumentation

API Call	Description
`int` **`omnitrace_user_start_trace(void)`**	Enable tracing on this thread and all subsequently created threads
`int` **`omnitrace_user_stop_trace(void)`**	Disable tracing on this thread and all subsequently created threads
`int` **`omnitrace_user_start_thread_trace(void)`**	Enable tracing on this specific thread. Does not apply to subsequently created threads
`int` **`omnitrace_user_stop_thread_trace(void)`**	Disable tracing on this specific thread. Does not apply to subsequently created threads
`int` **`omnitrace_user_push_region(void)`**	Start user defined region
`int` **`omnitrace_user_pop_region(void)`**	End user defined region, FILO (first in last out) is expected

All the API calls: https://amdresearch.github.io/omnitrace/user_api.html

OpenMP®

We use the example omnitrace/examples/openmp/

Build the code with CMake:

```
$ cmake -B build
```

Use the openmp-lu binary, which can be executed with:

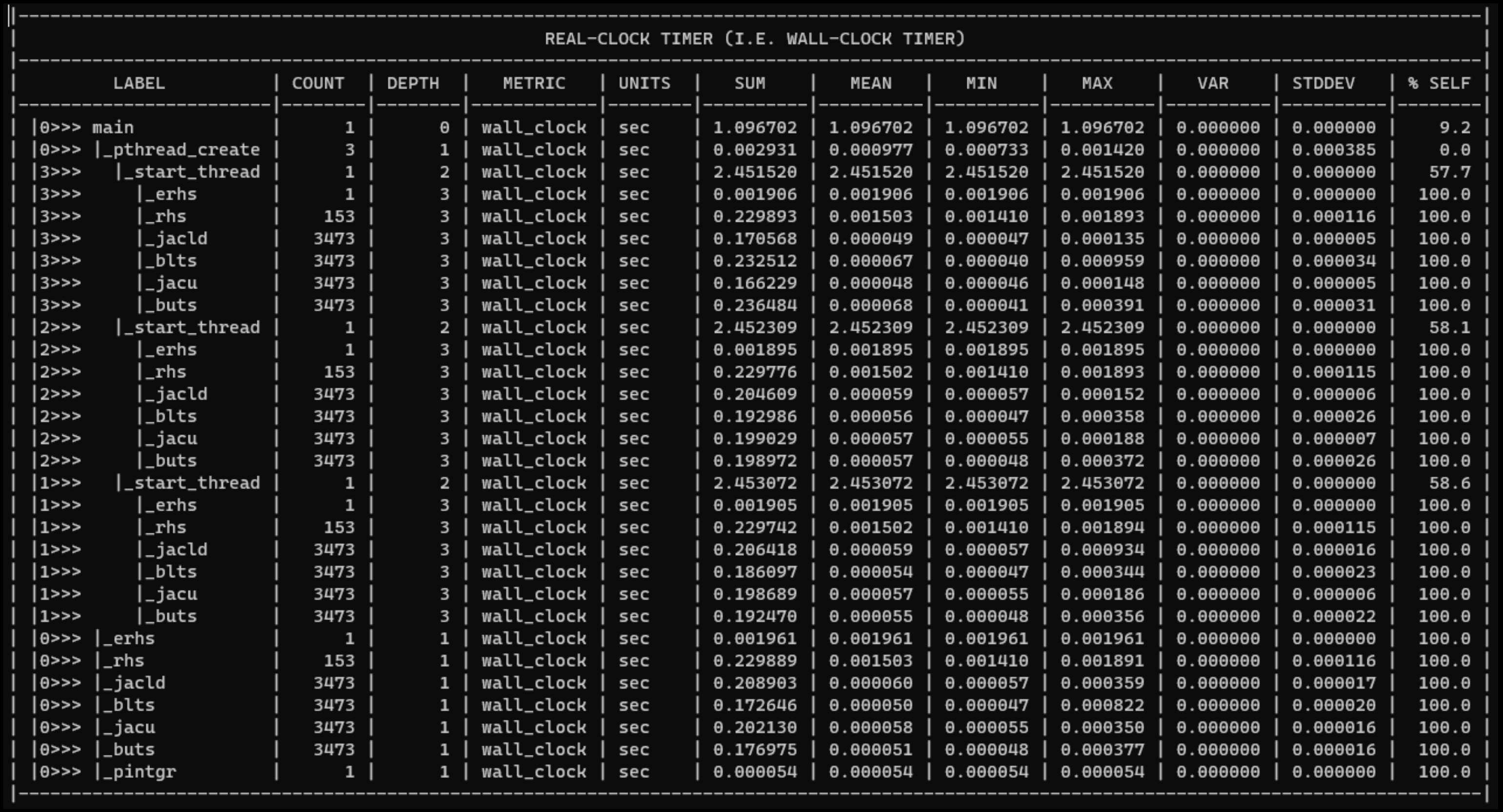
```
$ export OMP_NUM_THREADS=4
$ srun -n 1 -c 4 ./openmp-lu
```

Create a new instrumented binary:

```
$ srun -n 1 omnitrace-instrument -o openmp-lu.inst --
./openmp-lu
```

Execute the new binary:

```
$ srun -n 1 -c 4 omnitrace-run -- ./openmp-lu.inst
```



```
|---------------------------------------------------------------------------------------------------------------------------------------------|
|                                                 REAL-CLOCK TIMER (I.E. WALL-CLOCK TIMER)                                                    |
|---------------------------------------------------------------------------------------------------------------------------------------------|
|         LABEL          | COUNT  | DEPTH  |   METRIC   | UNITS  |   SUM    |   MEAN   |   MIN    |   MAX    |   VAR    |  STDDEV  | % SELF |
|------------------------|--------|--------|------------|--------|----------|----------|----------|----------|----------|----------|--------|
| |0>>> main             |      1 |      0 | wall_clock | sec    | 1.096702 | 1.096702 | 1.096702 | 1.096702 | 0.000000 | 0.000000 |    9.2 |
| |0>>> |_pthread_create |      3 |      1 | wall_clock | sec    | 0.002931 | 0.000977 | 0.000733 | 0.001420 | 0.000000 | 0.000385 |    0.0 |
| |3>>>   |_start_thread |      1 |      2 | wall_clock | sec    | 2.451520 | 2.451520 | 2.451520 | 2.451520 | 0.000000 | 0.000000 |   57.7 |
| |3>>>     |_erhs       |      1 |      3 | wall_clock | sec    | 0.001906 | 0.001906 | 0.001906 | 0.001906 | 0.000000 | 0.000000 |  100.0 |
| |3>>>     |_rhs        |    153 |      3 | wall_clock | sec    | 0.229893 | 0.001503 | 0.001410 | 0.001893 | 0.000000 | 0.000116 |  100.0 |
| |3>>>     |_jacld      |   3473 |      3 | wall_clock | sec    | 0.170568 | 0.000049 | 0.000047 | 0.000135 | 0.000000 | 0.000005 |  100.0 |
| |3>>>     |_blts       |   3473 |      3 | wall_clock | sec    | 0.232512 | 0.000067 | 0.000040 | 0.000959 | 0.000000 | 0.000034 |  100.0 |
| |3>>>     |_jacu       |   3473 |      3 | wall_clock | sec    | 0.166229 | 0.000048 | 0.000046 | 0.000148 | 0.000000 | 0.000005 |  100.0 |
| |3>>>     |_buts       |   3473 |      3 | wall_clock | sec    | 0.236484 | 0.000068 | 0.000041 | 0.000391 | 0.000000 | 0.000031 |  100.0 |
| |2>>>   |_start_thread |      1 |      2 | wall_clock | sec    | 2.452309 | 2.452309 | 2.452309 | 2.452309 | 0.000000 | 0.000000 |   58.1 |
| |2>>>     |_erhs       |      1 |      3 | wall_clock | sec    | 0.001895 | 0.001895 | 0.001895 | 0.001895 | 0.000000 | 0.000000 |  100.0 |
| |2>>>     |_rhs        |    153 |      3 | wall_clock | sec    | 0.229776 | 0.001502 | 0.001410 | 0.001893 | 0.000000 | 0.000115 |  100.0 |
| |2>>>     |_jacld      |   3473 |      3 | wall_clock | sec    | 0.204609 | 0.000059 | 0.000057 | 0.000152 | 0.000000 | 0.000006 |  100.0 |
| |2>>>     |_blts       |   3473 |      3 | wall_clock | sec    | 0.192986 | 0.000056 | 0.000047 | 0.000358 | 0.000000 | 0.000026 |  100.0 |
| |2>>>     |_jacu       |   3473 |      3 | wall_clock | sec    | 0.199029 | 0.000057 | 0.000055 | 0.000188 | 0.000000 | 0.000007 |  100.0 |
| |2>>>     |_buts       |   3473 |      3 | wall_clock | sec    | 0.198972 | 0.000057 | 0.000048 | 0.000372 | 0.000000 | 0.000026 |  100.0 |
| |1>>>   |_start_thread |      1 |      2 | wall_clock | sec    | 2.453072 | 2.453072 | 2.453072 | 2.453072 | 0.000000 | 0.000000 |   58.6 |
| |1>>>     |_erhs       |      1 |      3 | wall_clock | sec    | 0.001905 | 0.001905 | 0.001905 | 0.001905 | 0.000000 | 0.000000 |  100.0 |
| |1>>>     |_rhs        |    153 |      3 | wall_clock | sec    | 0.229742 | 0.001502 | 0.001410 | 0.001894 | 0.000000 | 0.000115 |  100.0 |
| |1>>>     |_jacld      |   3473 |      3 | wall_clock | sec    | 0.206418 | 0.000059 | 0.000057 | 0.000934 | 0.000000 | 0.000016 |  100.0 |
| |1>>>     |_blts       |   3473 |      3 | wall_clock | sec    | 0.186097 | 0.000054 | 0.000047 | 0.000344 | 0.000000 | 0.000023 |  100.0 |
| |1>>>     |_jacu       |   3473 |      3 | wall_clock | sec    | 0.198689 | 0.000057 | 0.000055 | 0.000186 | 0.000000 | 0.000006 |  100.0 |
| |1>>>     |_buts       |   3473 |      3 | wall_clock | sec    | 0.192470 | 0.000055 | 0.000048 | 0.000356 | 0.000000 | 0.000022 |  100.0 |
| |0>>> |_erhs           |      1 |      1 | wall_clock | sec    | 0.001961 | 0.001961 | 0.001961 | 0.001961 | 0.000000 | 0.000000 |  100.0 |
| |0>>> |_rhs            |    153 |      1 | wall_clock | sec    | 0.229889 | 0.001503 | 0.001410 | 0.001891 | 0.000000 | 0.000116 |  100.0 |
| |0>>> |_jacld          |   3473 |      1 | wall_clock | sec    | 0.208903 | 0.000060 | 0.000057 | 0.000359 | 0.000000 | 0.000017 |  100.0 |
| |0>>> |_blts           |   3473 |      1 | wall_clock | sec    | 0.172646 | 0.000050 | 0.000047 | 0.000822 | 0.000000 | 0.000020 |  100.0 |
| |0>>> |_jacu           |   3473 |      1 | wall_clock | sec    | 0.202130 | 0.000058 | 0.000055 | 0.000350 | 0.000000 | 0.000016 |  100.0 |
| |0>>> |_buts           |   3473 |      1 | wall_clock | sec    | 0.176975 | 0.000051 | 0.000048 | 0.000377 | 0.000000 | 0.000016 |  100.0 |
| |0>>> |_pintgr         |      1 |      1 | wall_clock | sec    | 0.000054 | 0.000054 | 0.000054 | 0.000054 | 0.000000 | 0.000000 |  100.0 |
|---------------------------------------------------------------------------------------------------------------------------------------------|
```

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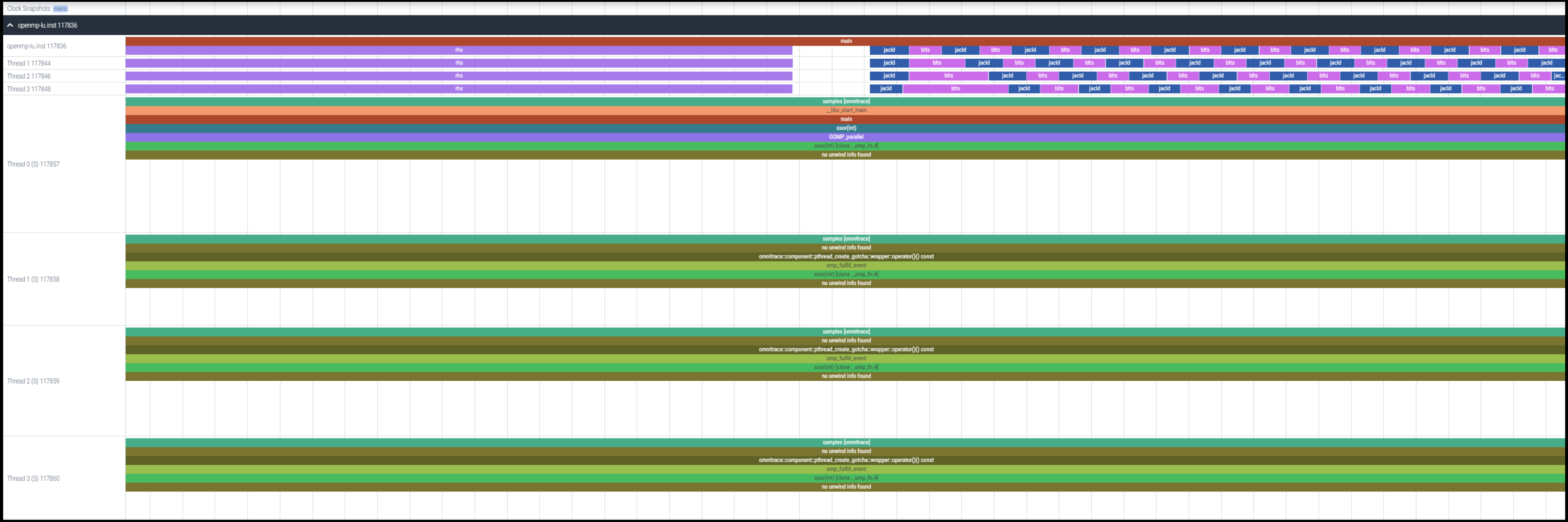
OpenMP® Visualization



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Python™

The omnitrace Python package is installed in /path/omnitrace_install/lib/pythonX.Y/site-packages/omnitrace

Setup the environment:

```
$ export PYTHONPATH=/path/omnitrace/lib/python/site-packages/:${PYTHONPATH}
```

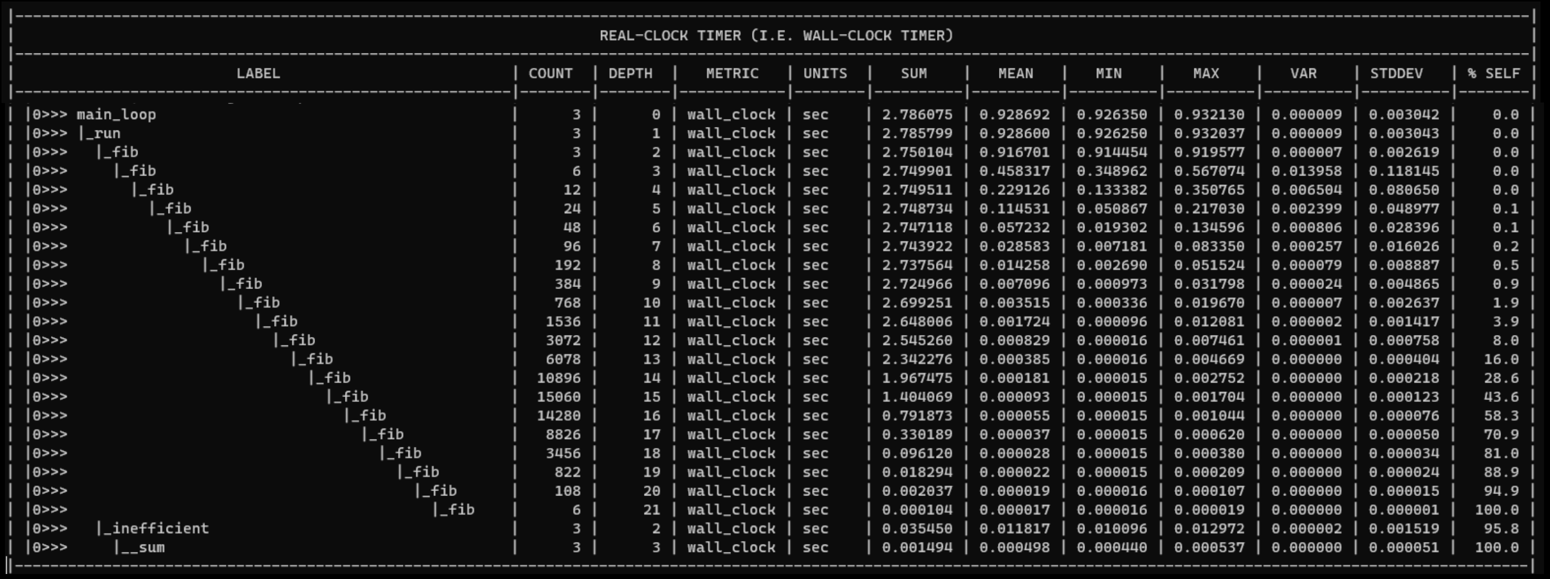
We use the Fibonacci example in omnitrace/examples/python/source.py

Execute the python program with:

```
$ omnitrace-python ./external.py
```

Profiled data is dumped in output directory:

```
$ cat omnitrace-source-output/timestamp/wall_clock.txt
```



```
|-------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
|                                                                 REAL-CLOCK TIMER (I.E. WALL-CLOCK TIMER)                                                                      |
|-------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
|                          LABEL                            | COUNT  | DEPTH  |   METRIC   | UNITS  |   SUM    |   MEAN   |   MIN    |   MAX    |   VAR    |  STDDEV  | % SELF |
|-----------------------------------------------------------|--------|--------|------------|--------|----------|----------|----------|----------|----------|----------|--------|
| |0>>> main_loop                                           |      3 |      0 | wall_clock | sec    | 2.786075 | 0.928692 | 0.926350 | 0.932130 | 0.000009 | 0.003042 |    0.0 |
| |0>>> |_run                                               |      3 |      1 | wall_clock | sec    | 2.785799 | 0.928600 | 0.926250 | 0.932037 | 0.000009 | 0.003043 |    0.0 |
| |0>>>   |_fib                                             |      3 |      2 | wall_clock | sec    | 2.750104 | 0.916701 | 0.914454 | 0.919577 | 0.000007 | 0.002619 |    0.0 |
| |0>>>     |_fib                                           |      6 |      3 | wall_clock | sec    | 2.749901 | 0.458317 | 0.348962 | 0.567074 | 0.013958 | 0.118145 |    0.0 |
| |0>>>       |_fib                                         |     12 |      4 | wall_clock | sec    | 2.749511 | 0.229126 | 0.133382 | 0.350765 | 0.006504 | 0.080650 |    0.0 |
| |0>>>         |_fib                                       |     24 |      5 | wall_clock | sec    | 2.748734 | 0.114531 | 0.050867 | 0.217030 | 0.002399 | 0.048977 |    0.1 |
| |0>>>           |_fib                                     |     48 |      6 | wall_clock | sec    | 2.747118 | 0.057232 | 0.019302 | 0.134596 | 0.000806 | 0.028396 |    0.1 |
| |0>>>             |_fib                                   |     96 |      7 | wall_clock | sec    | 2.743922 | 0.028583 | 0.007181 | 0.083350 | 0.000257 | 0.016026 |    0.2 |
| |0>>>               |_fib                                 |    192 |      8 | wall_clock | sec    | 2.737564 | 0.014258 | 0.002690 | 0.051524 | 0.000079 | 0.008887 |    0.5 |
| |0>>>                 |_fib                               |    384 |      9 | wall_clock | sec    | 2.724966 | 0.007096 | 0.000973 | 0.031798 | 0.000024 | 0.004865 |    0.9 |
| |0>>>                   |_fib                             |    768 |     10 | wall_clock | sec    | 2.699251 | 0.003515 | 0.000336 | 0.019670 | 0.000007 | 0.002637 |    1.9 |
| |0>>>                     |_fib                           |   1536 |     11 | wall_clock | sec    | 2.648006 | 0.001724 | 0.000096 | 0.012081 | 0.000002 | 0.001417 |    3.9 |
| |0>>>                       |_fib                         |   3072 |     12 | wall_clock | sec    | 2.545260 | 0.000829 | 0.000016 | 0.007461 | 0.000001 | 0.000758 |    8.0 |
| |0>>>                         |_fib                       |   6078 |     13 | wall_clock | sec    | 2.342276 | 0.000385 | 0.000016 | 0.004669 | 0.000000 | 0.000404 |   16.0 |
| |0>>>                           |_fib                     |  10896 |     14 | wall_clock | sec    | 1.967475 | 0.000181 | 0.000015 | 0.002752 | 0.000000 | 0.000218 |   28.6 |
| |0>>>                             |_fib                   |  15060 |     15 | wall_clock | sec    | 1.404069 | 0.000093 | 0.000015 | 0.001704 | 0.000000 | 0.000123 |   43.6 |
| |0>>>                               |_fib                 |  14280 |     16 | wall_clock | sec    | 0.791873 | 0.000055 | 0.000015 | 0.001044 | 0.000000 | 0.000076 |   58.3 |
| |0>>>                                 |_fib               |   8826 |     17 | wall_clock | sec    | 0.330189 | 0.000037 | 0.000015 | 0.000620 | 0.000000 | 0.000050 |   70.9 |
| |0>>>                                   |_fib             |   3456 |     18 | wall_clock | sec    | 0.096120 | 0.000028 | 0.000015 | 0.000380 | 0.000000 | 0.000034 |   81.0 |
| |0>>>                                     |_fib           |    822 |     19 | wall_clock | sec    | 0.018294 | 0.000022 | 0.000015 | 0.000209 | 0.000000 | 0.000024 |   88.9 |
| |0>>>                                       |_fib         |    108 |     20 | wall_clock | sec    | 0.002037 | 0.000019 | 0.000016 | 0.000107 | 0.000000 | 0.000015 |   94.9 |
| |0>>>                                         |_fib       |      6 |     21 | wall_clock | sec    | 0.000104 | 0.000017 | 0.000016 | 0.000019 | 0.000000 | 0.000001 |  100.0 |
| |0>>>   |_inefficient                                     |      3 |      2 | wall_clock | sec    | 0.035450 | 0.011817 | 0.010096 | 0.012972 | 0.000002 | 0.001519 |   95.8 |
| |0>>>     |__sum                                          |      3 |      3 | wall_clock | sec    | 0.001494 | 0.000498 | 0.000440 | 0.000537 | 0.000000 | 0.000051 |  100.0 |
|-------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
```

Python documentation: https://amdresearch.github.io/omnitrace/python.html

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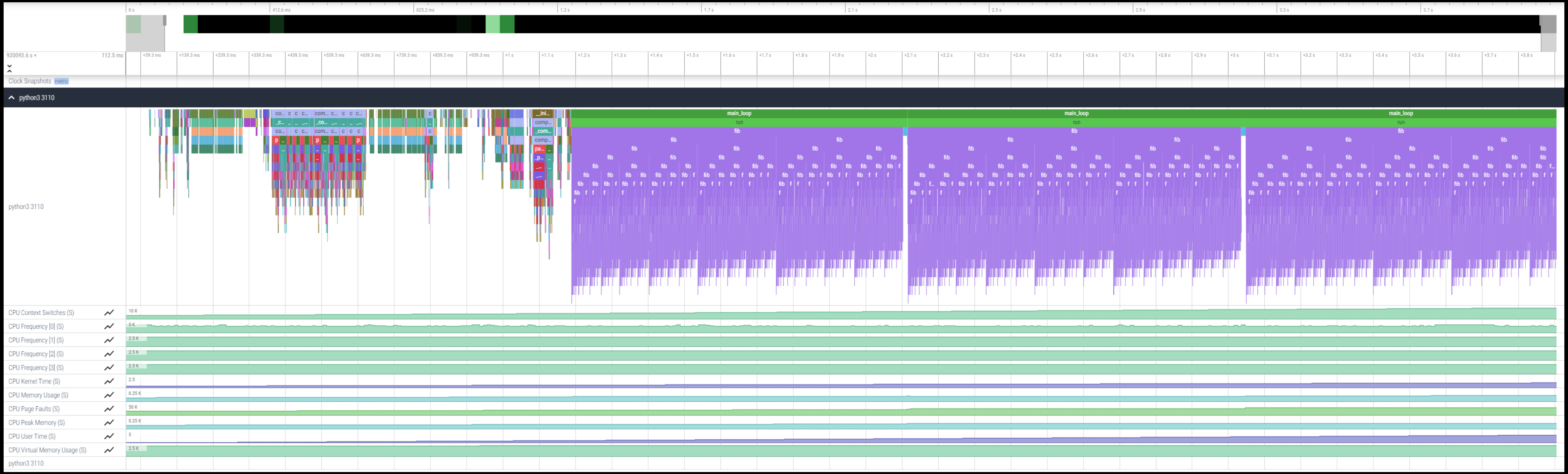
Visualizing Python™ Perfetto Tracing



Kokkos

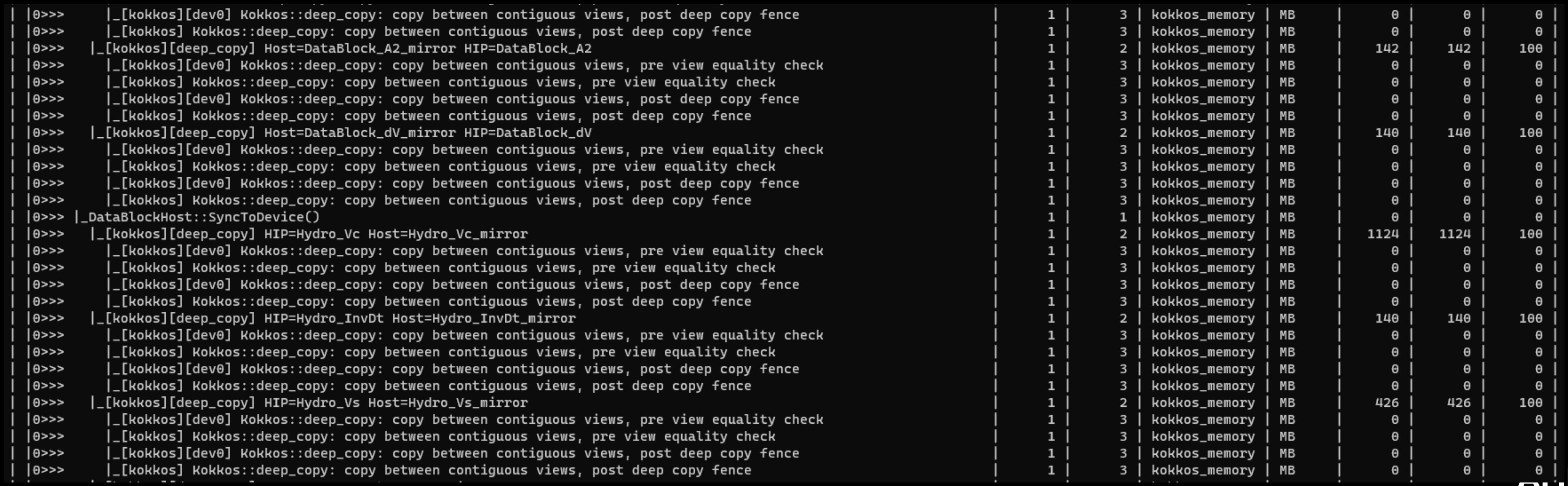
Omnitrace can instrument Kokkos applications too.

Edit the $HOME/.omnitrace.cfg file and enable omnitrace:

```
...
OMNITRACE_USE_KOKKOSP = true
...
```

Profiling with omnitrace produces *kokkos*.txt files:

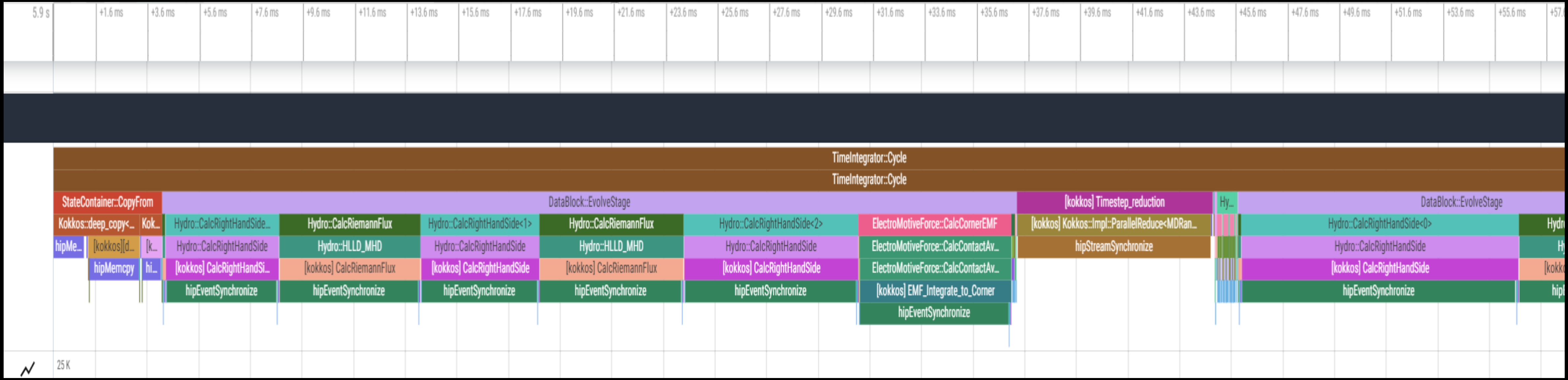
```
$ cat kokkos_memory0.txt
```



```
| |0>>>     |_[kokkos][dev0] Kokkos::deep_copy: copy between contiguous views, post deep copy fence                |       1 |       3 | kokkos_memory | MB     |     0 |     0 |     0 |
| |0>>>     |_[kokkos] Kokkos::deep_copy: copy between contiguous views, post deep copy fence                      |       1 |       3 | kokkos_memory | MB     |     0 |     0 |     0 |
| |0>>>   |_[kokkos][deep_copy] Host=DataBlock_A2_mirror HIP=DataBlock_A2                                          |       1 |       2 | kokkos_memory | MB     |   142 |   142 |   100 |
| |0>>>     |_[kokkos][dev0] Kokkos::deep_copy: copy between contiguous views, pre view equality check            |       1 |       3 | kokkos_memory | MB     |     0 |     0 |     0 |
| |0>>>     |_[kokkos] Kokkos::deep_copy: copy between contiguous views, pre view equality check                  |       1 |       3 | kokkos_memory | MB     |     0 |     0 |     0 |
| |0>>>     |_[kokkos][dev0] Kokkos::deep_copy: copy between contiguous views, post deep copy fence                |       1 |       3 | kokkos_memory | MB     |     0 |     0 |     0 |
| |0>>>     |_[kokkos] Kokkos::deep_copy: copy between contiguous views, post deep copy fence                      |       1 |       3 | kokkos_memory | MB     |     0 |     0 |     0 |
| |0>>>   |_[kokkos][deep_copy] Host=DataBlock_dV_mirror HIP=DataBlock_dV                                          |       1 |       2 | kokkos_memory | MB     |   140 |   140 |   100 |
| |0>>>     |_[kokkos][dev0] Kokkos::deep_copy: copy between contiguous views, pre view equality check            |       1 |       3 | kokkos_memory | MB     |     0 |     0 |     0 |
| |0>>>     |_[kokkos] Kokkos::deep_copy: copy between contiguous views, pre view equality check                  |       1 |       3 | kokkos_memory | MB     |     0 |     0 |     0 |
| |0>>>     |_[kokkos][dev0] Kokkos::deep_copy: copy between contiguous views, post deep copy fence                |       1 |       3 | kokkos_memory | MB     |     0 |     0 |     0 |
| |0>>>     |_[kokkos] Kokkos::deep_copy: copy between contiguous views, post deep copy fence                      |       1 |       3 | kokkos_memory | MB     |     0 |     0 |     0 |
| |0>>> |_DataBlockHost::SyncToDevice()                                                                            |       1 |       1 | kokkos_memory | MB     |     0 |     0 |     0 |
| |0>>>   |_[kokkos][deep_copy] HIP=Hydro_Vc Host=Hydro_Vc_mirror                                                  |       1 |       2 | kokkos_memory | MB     |  1124 |  1124 |   100 |
| |0>>>     |_[kokkos][dev0] Kokkos::deep_copy: copy between contiguous views, pre view equality check            |       1 |       3 | kokkos_memory | MB     |     0 |     0 |     0 |
| |0>>>     |_[kokkos] Kokkos::deep_copy: copy between contiguous views, pre view equality check                  |       1 |       3 | kokkos_memory | MB     |     0 |     0 |     0 |
| |0>>>     |_[kokkos][dev0] Kokkos::deep_copy: copy between contiguous views, post deep copy fence                |       1 |       3 | kokkos_memory | MB     |     0 |     0 |     0 |
| |0>>>     |_[kokkos] Kokkos::deep_copy: copy between contiguous views, post deep copy fence                      |       1 |       3 | kokkos_memory | MB     |     0 |     0 |     0 |
| |0>>>   |_[kokkos][deep_copy] HIP=Hydro_InvDt Host=Hydro_InvDt_mirror                                            |       1 |       2 | kokkos_memory | MB     |   140 |   140 |   100 |
| |0>>>     |_[kokkos][dev0] Kokkos::deep_copy: copy between contiguous views, pre view equality check            |       1 |       3 | kokkos_memory | MB     |     0 |     0 |     0 |
| |0>>>     |_[kokkos] Kokkos::deep_copy: copy between contiguous views, pre view equality check                  |       1 |       3 | kokkos_memory | MB     |     0 |     0 |     0 |
| |0>>>     |_[kokkos][dev0] Kokkos::deep_copy: copy between contiguous views, post deep copy fence                |       1 |       3 | kokkos_memory | MB     |     0 |     0 |     0 |
| |0>>>     |_[kokkos] Kokkos::deep_copy: copy between contiguous views, post deep copy fence                      |       1 |       3 | kokkos_memory | MB     |     0 |     0 |     0 |
| |0>>>   |_[kokkos][deep_copy] HIP=Hydro_Vs Host=Hydro_Vs_mirror                                                  |       1 |       2 | kokkos_memory | MB     |   426 |   426 |   100 |
| |0>>>     |_[kokkos][dev0] Kokkos::deep_copy: copy between contiguous views, pre view equality check            |       1 |       3 | kokkos_memory | MB     |     0 |     0 |     0 |
| |0>>>     |_[kokkos] Kokkos::deep_copy: copy between contiguous views, pre view equality check                  |       1 |       3 | kokkos_memory | MB     |     0 |     0 |     0 |
| |0>>>     |_[kokkos][dev0] Kokkos::deep_copy: copy between contiguous views, post deep copy fence                |       1 |       3 | kokkos_memory | MB     |     0 |     0 |     0 |
| |0>>>     |_[kokkos] Kokkos::deep_copy: copy between contiguous views, post deep copy fence                      |       1 |       3 | kokkos_memory | MB     |     0 |     0 |     0 |
```

Visualizing Kokkos with Perfetto Trace

- Visualize `perfetto-trace-0.proto` (with sampling enabled)

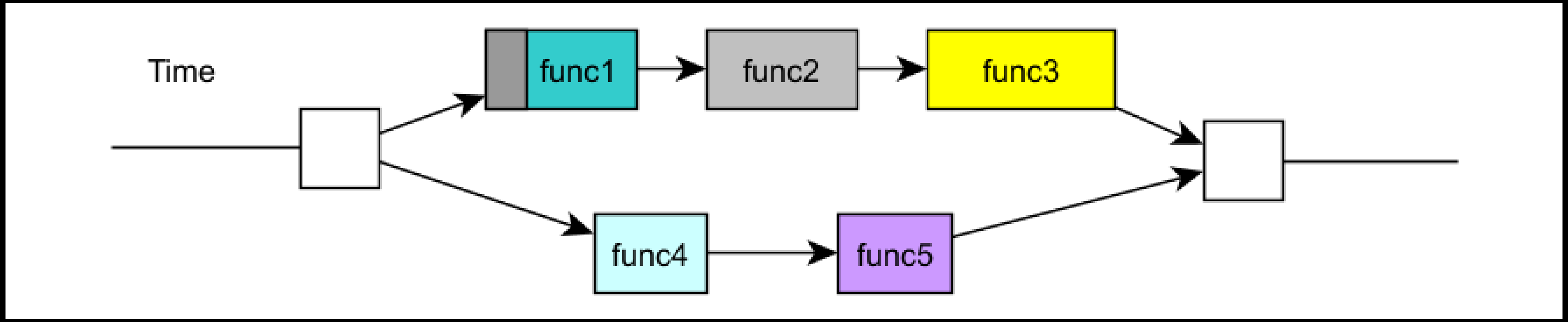


Causal Profiling

Causal Profiling

- Causal profiling requires multiple “experiments”
  - Each experiment has two independent variables:
    - Function/LOC selected for experiment
    - Virtual speed amount
  - Requires multiple runs of the application
    - For each function/LOC:
      - Baseline generation (0% virtual speedup)
      - 1+ virtual speedups > 0%
    - Speedup prediction is highly dependent on baseline
  - Progress point are required
    - Exception end to end runs
- Supports: sample space of fixed speedups, binary scope pattern, function scope pattern, source scope pattern, line scope pattern
- For now it is for CPU threads and workload, work in progress for GPU kernels
- GUI available via PyPI: omnitrace-causal-viewer
- For now you can use: https://plasma-umass.org/coz/
- We use the example: https://github.com/AMDResearch/omnitrace/tree/main/examples/causal
- Documentation: https://amdresearch.github.io/omnitrace/causal_profiling.html

Causal Profiling – Example



Causal Profiling - Recommendations

- Generate a flat profile to get familiar with the functions that take most of the time
- Insert throughput progress points in high-traffic areas
- Reduce the virtual speedup sampling space
  - Default: 0-100 in increments of 5
- Use “scoping” to restrict the experiment sampling space
  - E.g. Binary scope, source scope, function scope, line scope
- Use the function mode initially because it reduces experiment sampling space
- Use the line mode in combination with a strict function scope

Advanced options

- Source scope restricted to lines 100 and 110 of causal.cpp
  - -m line
  - -S "causal\\.cpp:(100|110)“
- Function scope, exclude functions which start with “kokkos::” or “std:enable_if”
  - -m func
  - -FE "^(Kokkos::|std::enable_if)"

Example – Causal-cpu-omni

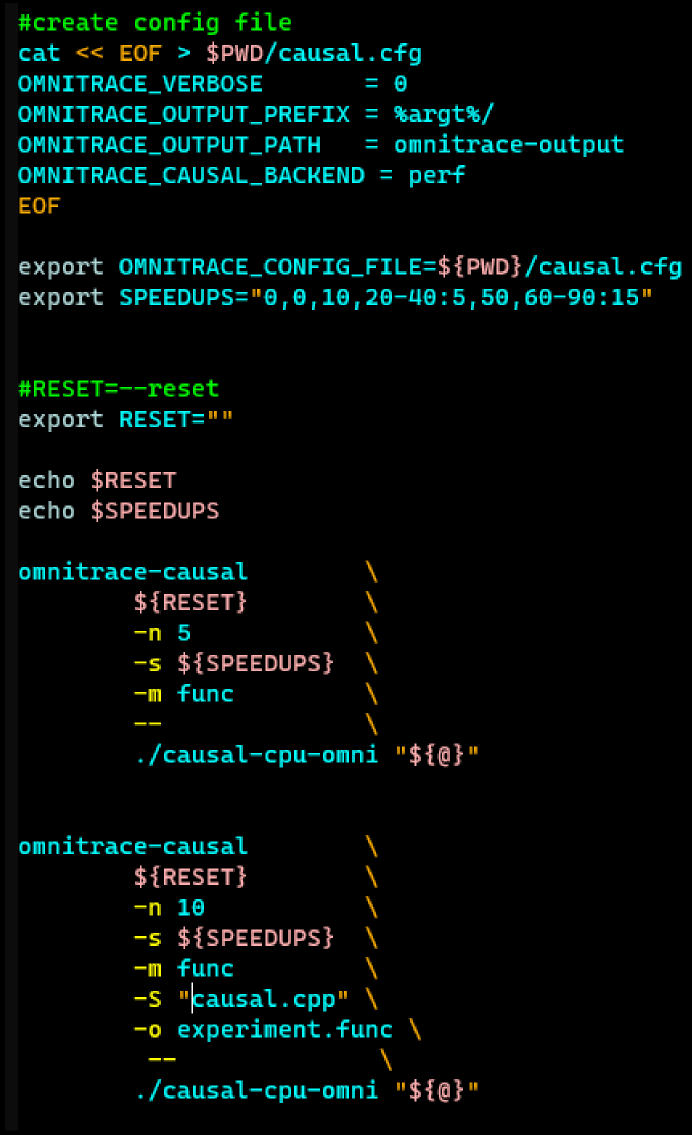
We have two functions one fast and one slow that we can control their ratio

```
srun -n 1 -c2 ./causal-cpu-omni
```

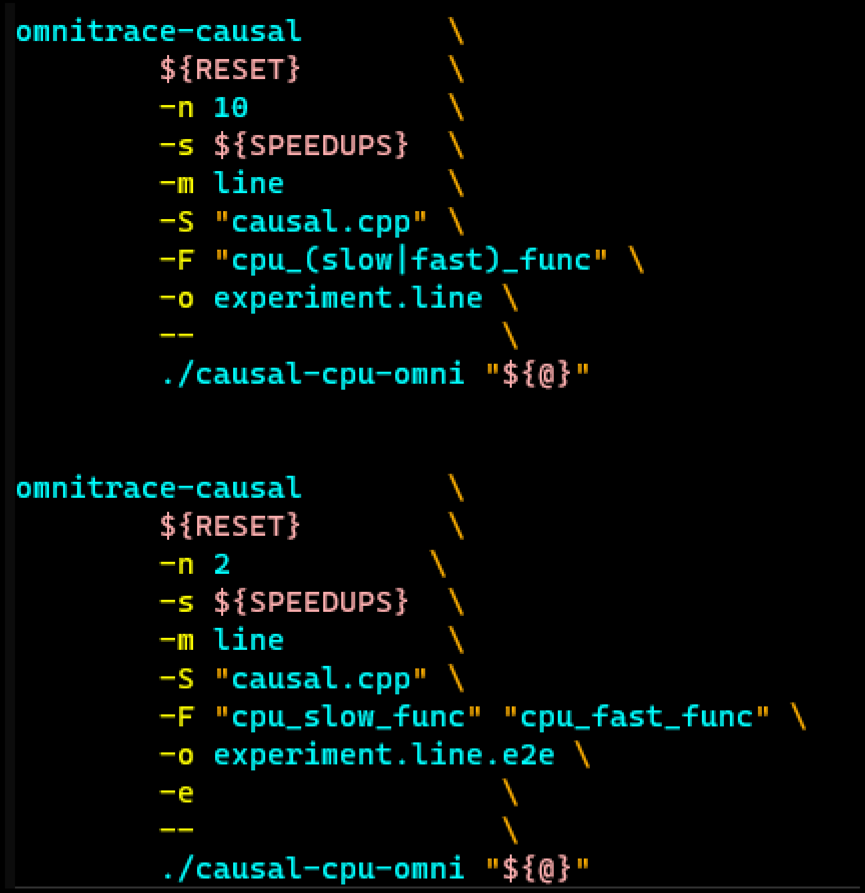
```
Fraction:  70.00, iterations: 50, random seed: 4093769362 :: slow = 200000000, fast = 140000000, expected ratio =  70.00,
sync every 1 iterations
executing iteration: 0
executing iteration: 10
executing iteration: 20
executing iteration: 30
executing iteration: 40
executing iteration: 49
slow_func() took  10000.891 ms
fast_func() took   7000.705 ms
total is         10001.183 ms
ratio is            70.001 %
rdiff is             0.001 %
```

Source code: https://github.com/AMDResearch/omnitrace/tree/main/examples/causal

Script to run various cases



```
#create config file
cat << EOF > $PWD/causal.cfg
OMNITRACE_VERBOSE        = 0
OMNITRACE_OUTPUT_PREFIX = %argt%/
OMNITRACE_OUTPUT_PATH    = omnitrace-output
OMNITRACE_CAUSAL_BACKEND = perf
EOF

export OMNITRACE_CONFIG_FILE=${PWD}/causal.cfg
export SPEEDUPS="0,0,10,20-40:5,50,60-90:15"


#RESET=--reset
export RESET=""

echo $RESET
echo $SPEEDUPS

omnitrace-causal        \
        ${RESET}        \
        -n 5            \
        -s ${SPEEDUPS}  \
        -m func         \
        --              \
        ./causal-cpu-omni "${@}"


omnitrace-causal        \
        ${RESET}        \
        -n 10           \
        -s ${SPEEDUPS}  \
        -m func         \
        -S "causal.cpp" \
        -o experiment.func \
         --              \
        ./causal-cpu-omni "${@}"
```



```
omnitrace-causal        \
        ${RESET}        \
        -n 10           \
        -s ${SPEEDUPS}  \
        -m line         \
        -S "causal.cpp" \
        -F "cpu_(slow|fast)_func" \
        -o experiment.line \
        --                 \
        ./causal-cpu-omni "${@}"


omnitrace-causal        \
        ${RESET}        \
        -n 2           \
        -s ${SPEEDUPS}  \
        -m line         \
        -S "causal.cpp" \
        -F "cpu_slow_func" "cpu_fast_func" \
        -o experiment.line.e2e \
        -e                 \
        --                 \
        ./causal-cpu-omni "${@}"
```

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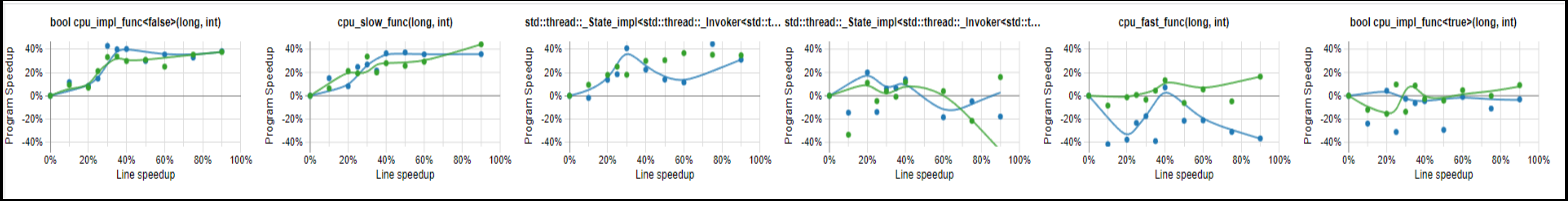
Progress points

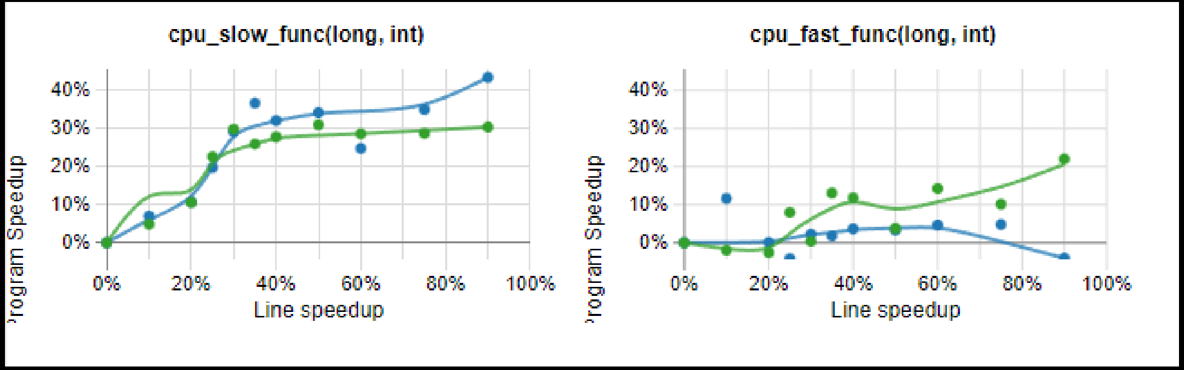
- Progress points could be MPI, Kokkos, roctracer and other calls.
- You can use the USER API, declare in your code:

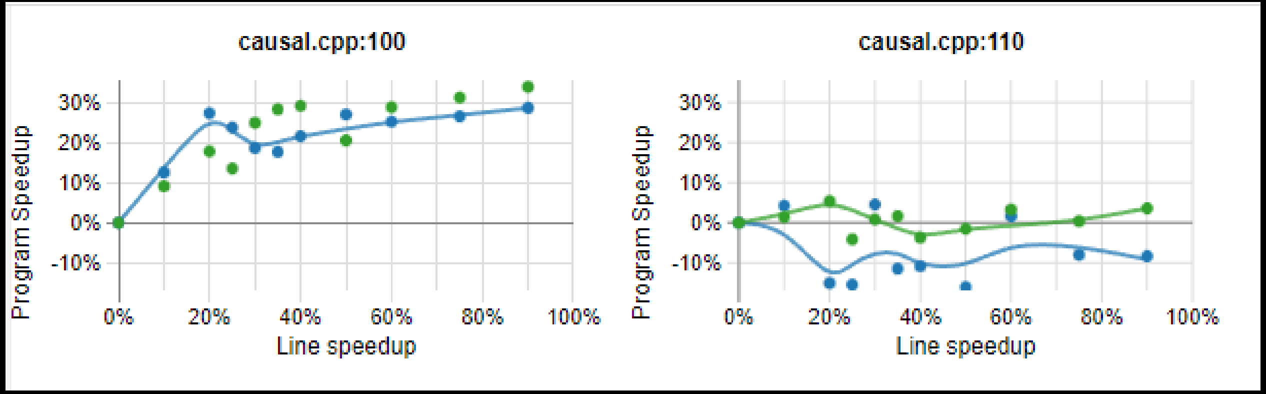
```
#   include <omnitrace/causal.h>
#   define CAUSAL_PROGRESS              OMNITRACE_CAUSAL_PROGRESS
#   define CAUSAL_PROGRESS_NAMED(LABEL) OMNITRACE_CAUSAL_PROGRESS_NAMED(LABEL)
#   define CAUSAL_BEGIN(LABEL)          OMNITRACE_CAUSAL_BEGIN(LABEL)
#   define CAUSAL_END(LABEL)            OMNITRACE_CAUSAL_END(LABEL)
```

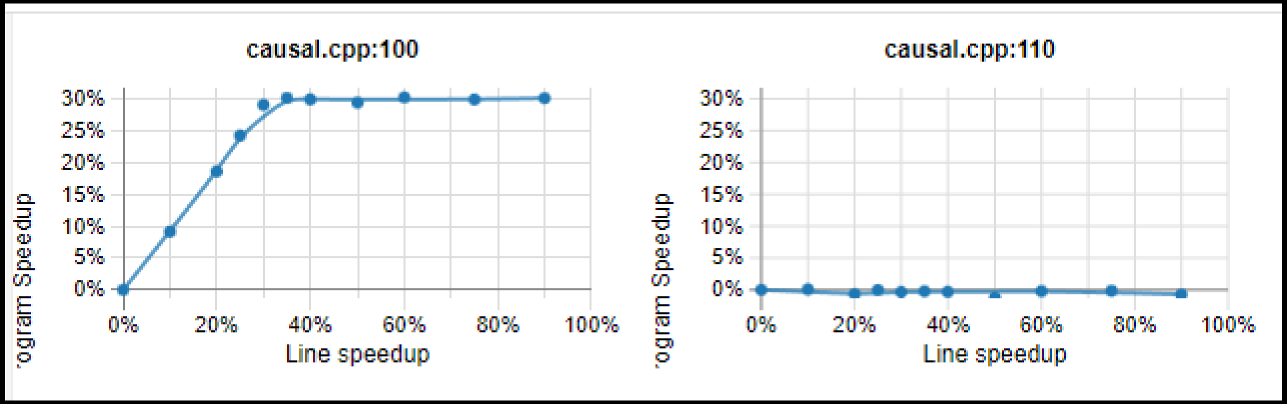
Link also with the library libomnitrace-user.

Plots









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Other Executables

- `omnitrace-sample`
  - For sampling with low overhead, use `omnitrace-sample`
  - Use `omnitrace-sample --help` to get relevant options
  - Settings in the OmniTrace config file will be used by `omnitrace-sample`
  - Example invocation to get a flat tracing profile on Host and Device (`-PTHD`), excluding all components (`-E all`) and including only `rocm-smi, roctracer, rocprofiler` and `roctx` components (`-I ...`)

```
mpirun -np 1 omnitrace-sample -PTHD -E all -I rocm-smi -I roctracer -I rocprofiler -I roctx -- ./Jacobi_hip -g 1 1
```

- `omnitrace-causal`
  - Invokes causal profiling
- `omnitrace-critical-trace`
  - Post-processing tool for critical-trace data output by omnitrace

Current documentation: https://amdresearch.github.io/omnitrace/development.html#executables

Tips & Tricks

- My Perfetto timeline seems weird how can I check the clock skew?
  - Set `OMNITRACE_VERBOSE=1` or higher for verbose mode and it will print the timestamp skew
- It takes too long to map rocm-smi samples to kernels.
  - Temporarily set OMNITRACE_USE_ROCM_SMI=OFF
- What is the best way to profile multi-process runs?
  - Use OmniTrace's binary rewrite (-o) option to instrument the binary first, run the instrumented binary with mpirun/srun
- If you are doing binary rewrite and you do not get information about kernels, set:
  - HSA_TOOLS_LIB=libomnitrace.so in the env. and set OMNITRACE_USE_ROCTRACER=ON in the cfg file
- My HIP application hangs in different points, what do I do?
  - Try to set HSA_ENABLE_INTERRUPT=0 in the environment, this changes how HIP runtime is notified when GPU kernels complete
- My Perfetto trace is too big, can I decrease it?
  - Yes, with v1.7.3 and later declare OMNITRACE_PERFETTO_ANNOTATIONS to false
- I want to remove the many rows of CPU frequency lines from the Perfetto trace
  - Declare the OMNITRACE_USE_PROCESS_SAMPLING = false

Summary

- OmniTrace is a powerful tool to understand CPU + GPU activity
  - Ideal for an initial look at how an application runs

- Leverages several other tools and combines their data into a comprehensive output file
  - Some tools used are AMD uProf, rocprof, rocm-smi, roctracer, perf, etc.

- Easy to visualize traces in Perfetto

- Includes several features:
  - Dynamic Instrumentation either at Runtime or using Binary Rewrite
  - Statistical Sampling for call-stack info
  - Process sampling, monitoring of system metrics during application run
  - Causal Profiling
  - Critical Path Tracing

Questions?

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