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Discussion 12

Profiling

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Content

- Htop
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- Perf
- Vtune
- sar

Why profiling?

- See how the program works.
- Find the bottleneck of the performance.
- Check cpu usage or memory access pattern.
- Compare different modifications
- Benchmarking

01 htop

- htop - an interactive process viewer

- You can install it by apt install htop on ubuntu.
- Then run by htop in your terminal.

- F1 Open help
- F2 Setup (Configuration)
- F9 Kill
- F10 Quit
- Please read the friendly manual for more information.
- If you are interested, try CS130 Operating System.

02 btop

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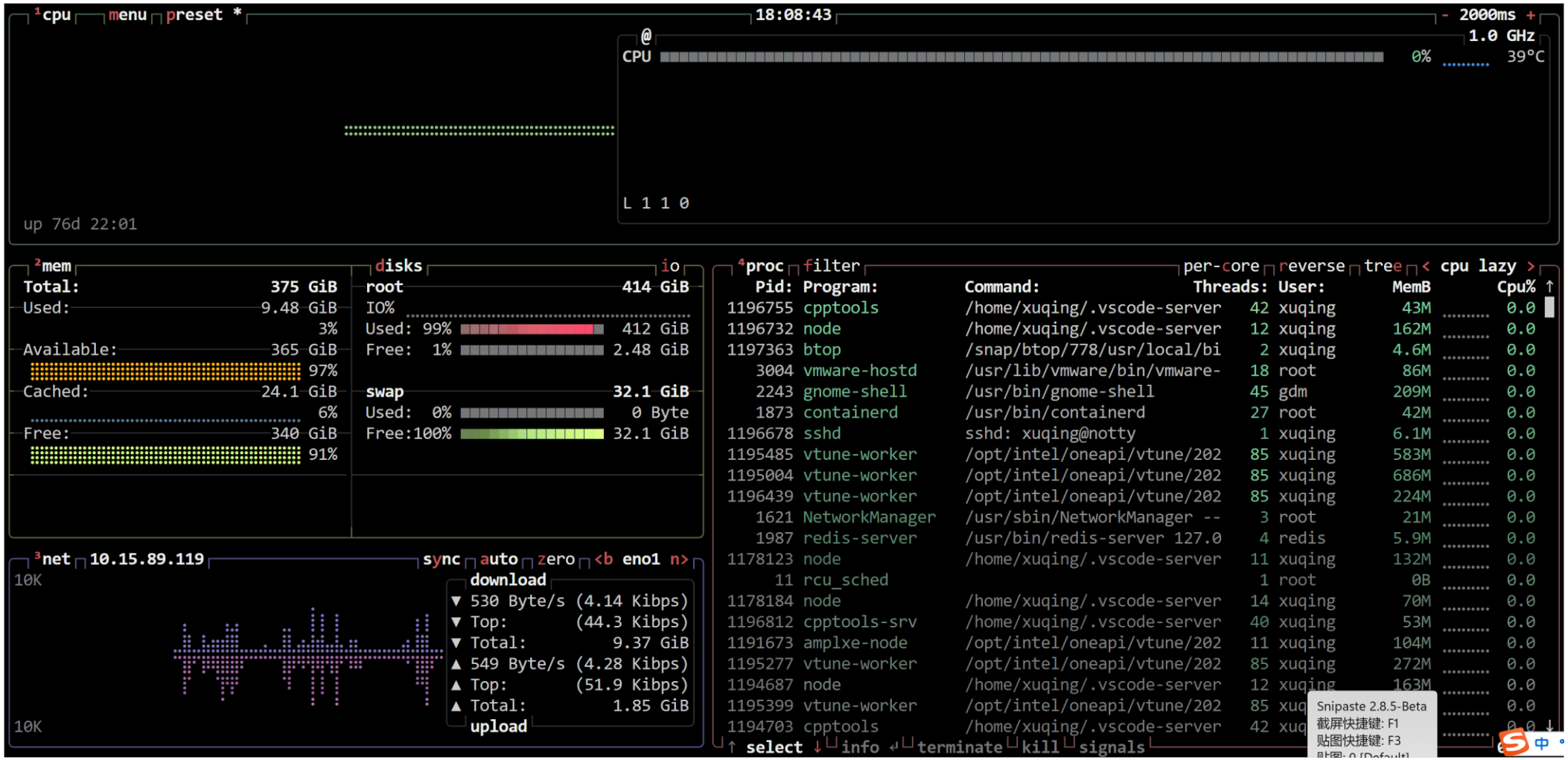
- Resource monitor that shows usage and stats for processor, memory, disks, network and processes.
- H Open help



03 perf

- perf is a Linux performance analysis tool

- Install

```
sudo apt install linux-tools-common
perf –v
```

03 perf


```
perf

 usage: perf [--version] [--help] [OPTIONS] COMMAND [ARGS]

The most commonly used perf commands are:
   annotate        Read perf.data (created by perf record) and display annotated code
   archive         Create archive with object files with build-ids found in perf.data file
   bench           General framework for benchmark suites
   buildid-cache   Manage build-id cache.
   buildid-list    List the buildids in a perf.data file
   c2c             Shared Data C2C/HITM Analyzer.
   config          Get and set variables in a configuration file.
   daemon          Run record sessions on background
   data            Data file related processing
   diff            Read perf.data files and display the differential profile
   evlist          List the event names in a perf.data file
   ftrace          simple wrapper for kernel's ftrace functionality
   inject          Filter to augment the events stream with additional information
   iostat          Show I/O performance metrics
   kallsyms        Searches running kernel for symbols
   kvm             Tool to trace/measure kvm guest os
   list            List all symbolic event types
   mem             Profile memory accesses
   record          Run a command and record its profile into perf.data
   report          Read perf.data (created by perf record) and display the profile
   script          Read perf.data (created by perf record) and display trace output
   stat            Run a command and gather performance counter statistics
   test            Runs sanity tests.
   top             System profiling tool.
   version         display the version of perf binary
   probe           Define new dynamic tracepoints

See 'perf help COMMAND' for more information on a specific command.
```

03 perf events

Events

The `perf` tool supports a list of measurable events. The tool and underlying kernel interface can measure events coming from different sources. For instance, some event are pure kernel counters, in this case they are called **software events**. Examples include: context-switches, minor-faults.

Another source of events is the processor itself and its Performance Monitoring Unit (PMU). It provides a list of events to measure micro-architectural events such as the number of cycles, instructions retired, L1 cache misses and so on. Those events are called **PMU hardware events** or **hardware events** for short. They vary with each processor type and model.

The perf_events interface also provides a small set of common hardware events monikers. On each processor, those events get mapped onto an actual events provided by the CPU, if they exists, otherwise the event cannot be used. Somewhat confusingly, these are also called **hardware events** and **hardware cache events**.

Finally, there are also **tracepoint events** which are implemented by the kernel `ftrace` infrastructure. Those are **only** available with the 2.6.3x and newer kernels.

03 perf list

- Use sudo perf list to see your supported events.
- display perf events supported by a particular module:
  - sudo perf list hw/cache/pmu/tracepoint/sw

```
perf list

List of pre-defined events (to be used in -e):

 cpu-cycles OR cycles                               [Hardware event]
 instructions                                       [Hardware event]
 cache-references                                   [Hardware event]
 cache-misses                                       [Hardware event]
 branch-instructions OR branches                    [Hardware event]
 branch-misses                                      [Hardware event]
 bus-cycles                                         [Hardware event]
 ref-cycles                                         [Hardware event]

 cpu-clock                                          [Software event]
 task-clock                                         [Software event]
 page-faults OR faults                              [Software event]
 minor-faults                                       [Software event]
 major-faults                                       [Software event]
 context-switches OR cs                             [Software event]
 cpu-migrations OR migrations                       [Software event]
 alignment-faults                                   [Software event]
 emulation-faults                                   [Software event]
 bpf-output                                         [Software event]
 cgroup-switches                                    [Software event]
 dummy                                              [Software event]

 L1-dcache-loads                                    [Hardware cache event]
 L1-dcache-load-misses                              [Hardware cache event]
 L1-dcache-stores                                   [Hardware cache event]
 L1-dcache-store-misses                             [Hardware cache event]
 L1-dcache-prefetches                               [Hardware cache event]
```

03 perf stat

- For any of the supported events, perf can keep a running count during process execution.
- In counting modes, the occurrences of events are simply aggregated and presented on standard output at the end of an application run

```
root@AEP:/home/xuqing# perf stat -h

 Usage: perf stat [<options>] [<command>]

    -a, --all-cpus        system-wide collection from all CPUs
    -A, --no-aggr         disable CPU count aggregation
    -B, --big-num         print large numbers with thousands' separators
```

03 perf stat

- perf stat -B dd if=/dev/zero of=/dev/null count=1000000

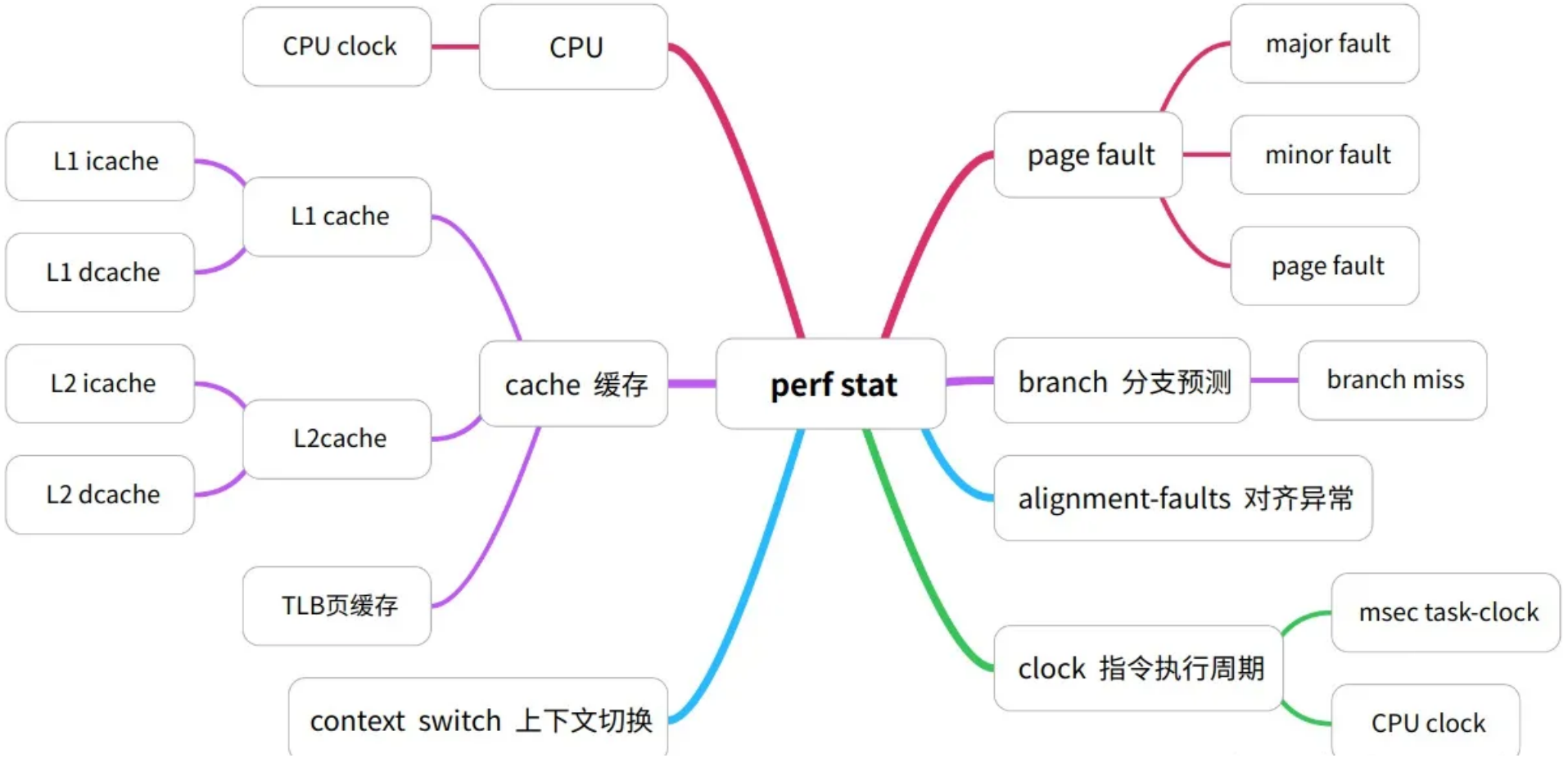
```
root@AEP:/home/xuqing# perf stat -B dd if=/dev/zero of=/dev/null count=1000000
1000000+0 records in
1000000+0 records out
512000000 bytes (512 MB, 488 MiB) copied, 1.36648 s, 375 MB/s

 Performance counter stats for 'dd if=/dev/zero of=/dev/null count=1000000':

          1,369.07 msec task-clock                #    0.998 CPUs utilized
                 3      context-switches          #    0.002 K/sec
                 0      cpu-migrations            #    0.000 K/sec
                82      page-faults               #    0.060 K/sec
     5,248,723,740      cycles                    #    3.834 GHz
    10,131,239,111      instructions              #    1.93  insn per cycle
     1,864,773,505      branches                  # 1362.069 M/sec
        26,839,770      branch-misses             #    1.44% of all branches

       1.371657112 seconds time elapsed

       0.127940000 seconds user
       1.243423000 seconds sys
```

03 perf stat

- measure one or more events per run of the perf tool
- Events are designated using their symbolic names followed by optional unit masks and modifiers.
  - perf stat -e cycles:uk dd if=/dev/zero of=/dev/null count=100000

```
root@AEP:/home/xuqing# perf stat -B -e branch-misses,cache-misses,cache-references dd if=/dev/zero of=/dev/null count=1000000
1000000+0 records in
1000000+0 records out
512000000 bytes (512 MB, 488 MiB) copied, 1.37347 s, 373 MB/s

 Performance counter stats for 'dd if=/dev/zero of=/dev/null count=1000000':

        27,691,443      branch-misses
             8,272      cache-misses              #   24.100 % of all cache refs
            34,323      cache-references

       1.376950394 seconds time elapsed

       0.116095000 seconds user
       1.261039000 seconds sys
```

03 perf stat


perf stat
CPU
CPU clock
cache 缓存
L1 cache
L1 icache
L1 dcache
L2cache
L2 icache
L2 dcache
TLB页缓存
context switch 上下文切换
page fault
major fault
minor fault
page fault
branch 分支预测
branch miss
alignment-faults 对齐异常
clock 指令执行周期
msec task-clock
CPU clock

03 perf record

The perf tool can be used to collect profiles on per-thread, per-process and per-cpu basis.

1. collect the samples : perf record.
   - generates an output file called perf.data.
   - perf record -e retired_instructions:u -c 2000 ./noploop 4
2. analyse file : perf report ; perf annotate
   - possibly on another machine

```
root@AEP:/home/xuqing# perf record -h

 Usage: perf record [<options>] [<command>]
    or: perf record [<options>] -- <command> [<options>]

    -a, --all-cpus        system-wide collection from all CPUs
    -b, --branch-any      sample any taken branches
    -B, --no-buildid      do not collect buildids in perf.data
    -c, --count <n>       event period to sample
    -C, --cpu <cpu>       list of cpus to monitor
    -d, --data            Record the sample addresses
    -D, --delay <n>       ms to wait before starting measurement after program start
    -e, --event <event>   event selector. use 'perf list' to list available events
    -F, --freq <freq or 'max'>
                          profile at this frequency
    -g                    enables call-graph recording
    -G, --cgroup <name>   monitor event in cgroup name only
```

03 perf record


```
root@AEP:/home/xuqing/bigTestcase# perf record -g ./pffast pictures/test1.jpg output.jpg 0.8 -3.0 3.0 1801 1701
0.397437
[ perf record: Woken up 1 times to write data ]
[ perf record: Captured and wrote 11.558 MB perf.data (84687 samples) ]
```

```
-rw-------  1 xuqing xuqing 3122668 5月  16 22:33 perf.data
```

report

```
Samples: 76K of event 'cycles', Event count (approx.): 51352767535
Overhead  Command  Shared Object       Symbol
  72.82%  pffast   [kernel.kallsyms]   [k] native_queued_spin_lock_slowpath
  12.36%  pffast   pffast              [.] dot_product
   7.06%  pffast   libgomp.so.1.0.0    [.] omp_get_num_procs
   1.32%  pffast   pffast              [.] gb._omp_fn.0
   0.96%  pffast   [kernel.kallsyms]   [k] function_graph_enter
   0.74%  pffast   [kernel.kallsyms]   [k] native_sched_clock
   0.49%  pffast   [kernel.kallsyms]   [k] page_counter_cancel
   0.43%  pffast   [kernel.kallsyms]   [k] prepare_ftrace_return
   0.40%  pffast   [kernel.kallsyms]   [k] ftrace_graph_caller
   0.40%  pffast   [kernel.kallsyms]   [k] trace_graph_entry
   0.29%  pffast   pffast              [.] from_stbi._omp_fn.0
   0.15%  pffast   [kernel.kallsyms]   [k] native_irq_return_iret
   0.15%  pffast   [kernel.kallsyms]   [k] clear_page_erms
   0.14%  pffast   pffast              [.] stbiw__jpg_processDU
   0.12%  pffast   [kernel.kallsyms]   [k] up_read
   0.12%  pffast   [kernel.kallsyms]   [k] _raw_spin_lock
```

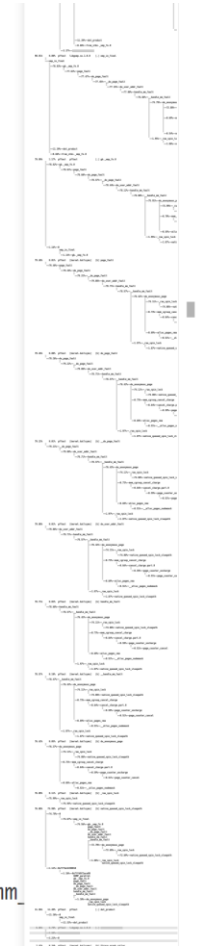
annotate

```
Samples: 76K of event 'cycles', 4000 Hz, Event count (approx.): 51352767535
native_queued_spin_lock_slowpath  /proc/kcore [Percent: local period]
Percent                 add       $0x30c00,%rax
  0.00                  add       -0x63be8680(,%rsi,8),%rax
  0.00                  mov       %rdx,(%rax)
                        mov       0x8(%rdx),%eax
                        test      %eax,%eax
                      ↓ jne       158
 77.31          14f:   pause
 17.97                 mov       0x8(%rdx),%eax
  0.00                 test      %eax,%eax
  1.99                 je        14f
  0.01          158:   mov       (%rdx),%rax
                       test      %rax,%rax
                     ↓ je        1ba
                       mov       %rax,%rsi
  0.00                 prefetchw (%rax)
                     ↓ jmp       16a
  1.49          168:   pause
  0.90          16a:   mov       (%rdi),%eax
  0.00                 test      %ax,%ax
  0.05                 jne       168
  0.01                 mov       %eax,%r8d
Press 'h' for help on key bindings
```

03 perf report

sudo perf report -f -g > res.txt

```
# Total Lost Samples: 0
#
# Samples: 84K of event 'cycles'
# Event count (approx.): 55350461031
#
# Children      Self  Command  Shared Object       Symbol
# ........  ........  .......  ..................  ..............................................
#
    94.40%     0.00%  pffast   [unknown]           [k] 0000000000000000
            |
             --94.40%--0
                       |
                       |--90.91%--omp_in_final
                       |          |
                       |          |--78.83%--gb._omp_fn.0
                       |          |          |
                       |          |           --77.63%--page_fault
                       |          |                     |
                       |          |                      --77.47%--do_page_fault
                       |          |                                |
                       |          |                                 --77.45%--__do_page_fault
                       |          |                                           |
                       |          |                                            --77.32%--do_user_addr_fault
                       |          |                                                      |
                       |          |                                                       --77.00%--handle_mm_fault
                       |          |                                                                 |
                       |          |                                                                  --76.88%--__handle_mm_
                       |          |                                                                            |
```

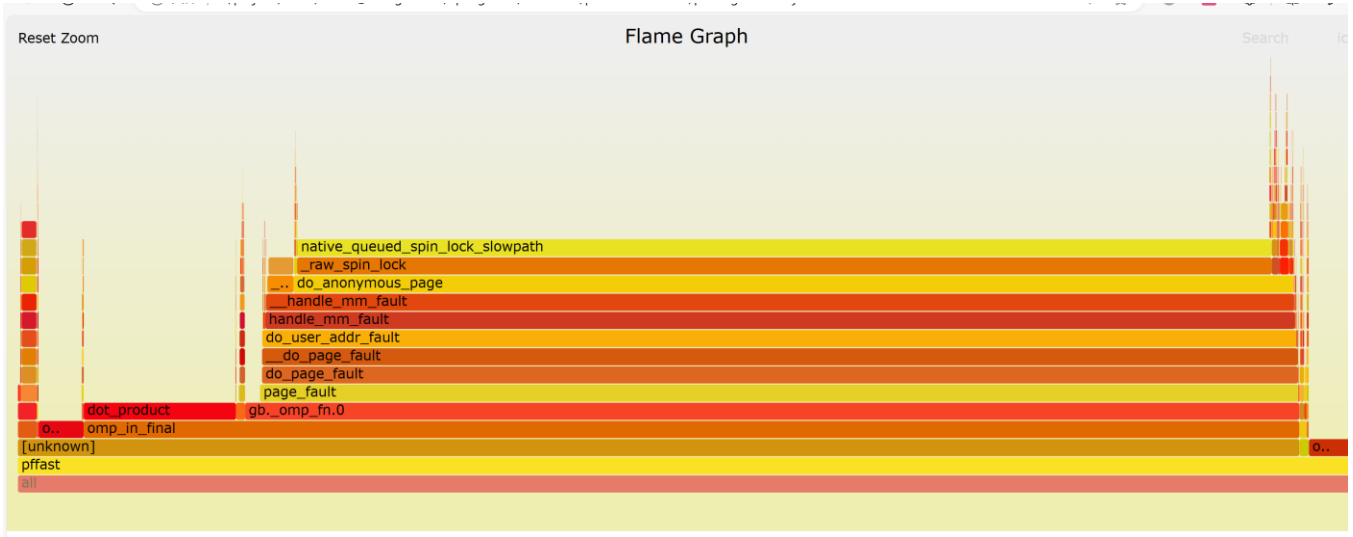


03 perf flame graph

f.wiki.kernel.org/index.php/Tutorial#Commands

- CPU Flame Graphs (brendangregg.com)
- root@AEP:/home/xuqing/FlameGraph# perf script | ./stackcollapse-perf.pl > out.perf-folded
- root@AEP:/home/xuqing/FlameGraph# ./flamegraph.pl out.perf-folded > perf.svg

- ./perf.svg



04 VTune Basics - Install

- official website
- It can only run with an Intel cpu, AMD user may use AMD Prof
- VTune is very simply and powerful

1. **Install steps**
2. **Set Environment Variables:**
3. **Verify Your Installation: vtune-self-checker.sh**

```
bin64# echo 0 > /proc/sys/kernel/yama/ptrace_scope
bin64# echo 0 > /proc/sys/kernel/perf_event_paranoid

The system is ready for the following analyses:
* Performance Snapshot
* Hotspots and Threading with user-mode sampling
* Hotspots with HW event-based sampling, HPC Performance Characterization, etc.
* Microarchitecture Exploration
* Memory Access
* Hotspots with HW event-based sampling and call stacks
* Threading with HW event-based sampling

The following analyses have failed on the system:
* GPU Compute/Media Hotspots (characterization mode)
* GPU Compute/Media Hotspots (source analysis mode)
```

04 VTune Basics – Web GUI

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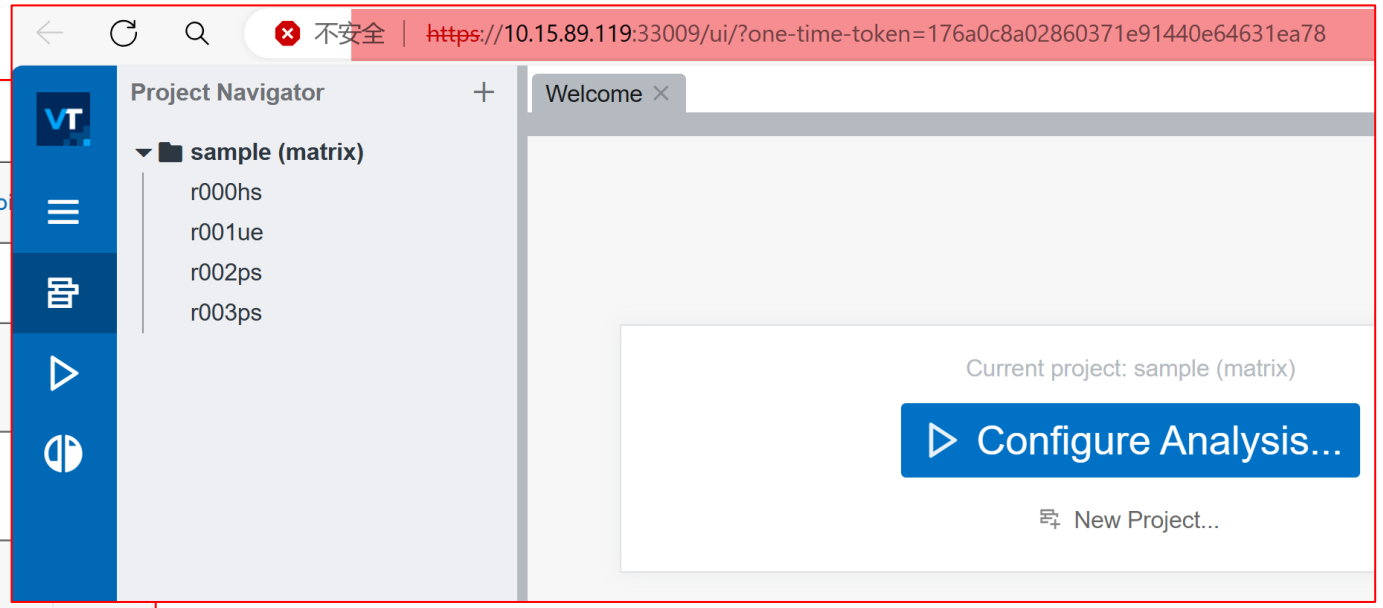
- Web Server Interface

```
^Cxuqing@AEP:/opt/intel/oneapi/vtune/latest/bin64$ vtune-backend  --allow-remote-access --enable-server-profiling
No TLS certificate was provided as a --tls-certificate command-line argument thus a self-signed certificate is generated to ena
ransport for the web server: /home/xuqing/.intel/vtune/settings/certificates/middleware.crt.
VTune Profiler GUI is accessible via https://10.15.89.119:33009/?one-time-token=176a0c8a02860371e91440e64631ea78
VTune Profiler GUI is accessible via https://172.16.78.1:33009/?one-time-token=176a0c8a02860371e91440e64631ea78
VTune Profiler GUI is accessible via https://172.16.0.1:33009/?one-time-token=176a0c8a02860371e91440e64631ea78
Warning: VTune Profiler Agent will be connected to https://10.15.89.119:33009/?one-time-token=176a0c8a02860371e91440e64631ea78
Collection has paused.
Collection has stopped.
```

		Type of Collection	Profile Applications on This Target			
			Windows	Linux	FreeBSD	Andro
Install VTune Profiler on This Host	Windows	Local	GUI |CLI	N/A	CLI*	N/A
		Remote	Use Browser	GUI |CLI	GUI |CLI	GUI |CLI
	Linux	Local	N/A	GUI |CLI	CLI*	N/A
		Remote	Use Browser (View Results Only)	GUI |CLI	GUI |CLI	GUI |CLI



04 VTune Basics - procedure

1. Prepare your target application for analysis:
   Recommendations：
   - Release mode, with maximum appropriate compiler optimization level.
   - generate debug information for your application（-O2 -g）
2. Prepare your target system for analysis:
   - Build and install the sampling drivers, if required.
     (If the drivers were not built and set up during installation , VTune Profiler provides an error message and enables driverless sampling data collection based on the Linux Perf* tool functionality, which has a limited scope of analysis options.)
3. Create a VTune Profiler project and run the performance analysis of your choice.

04 VTune Basics - example

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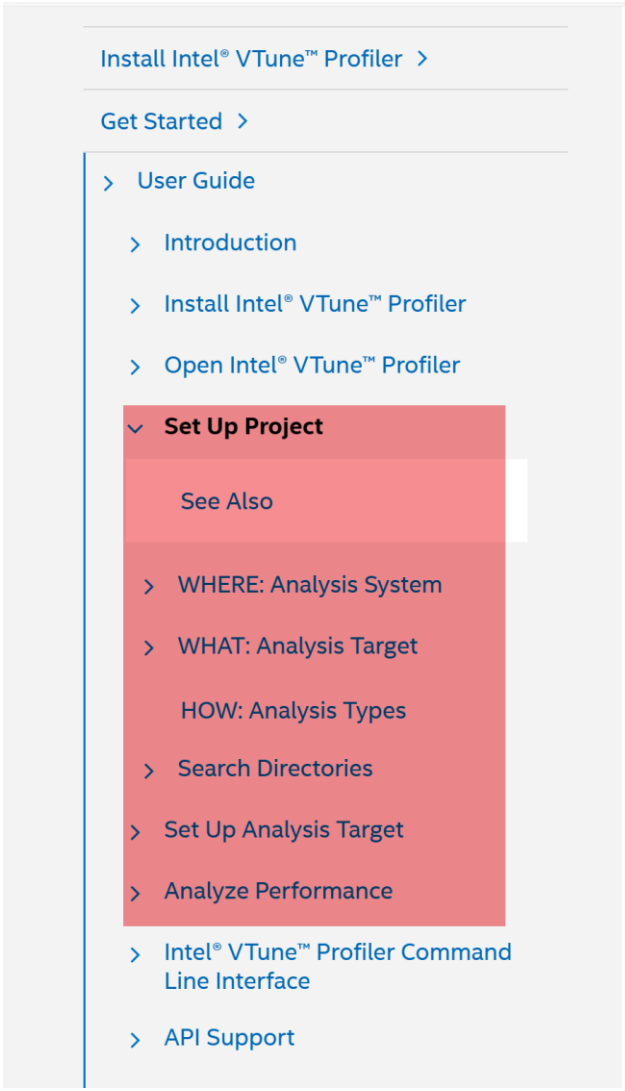
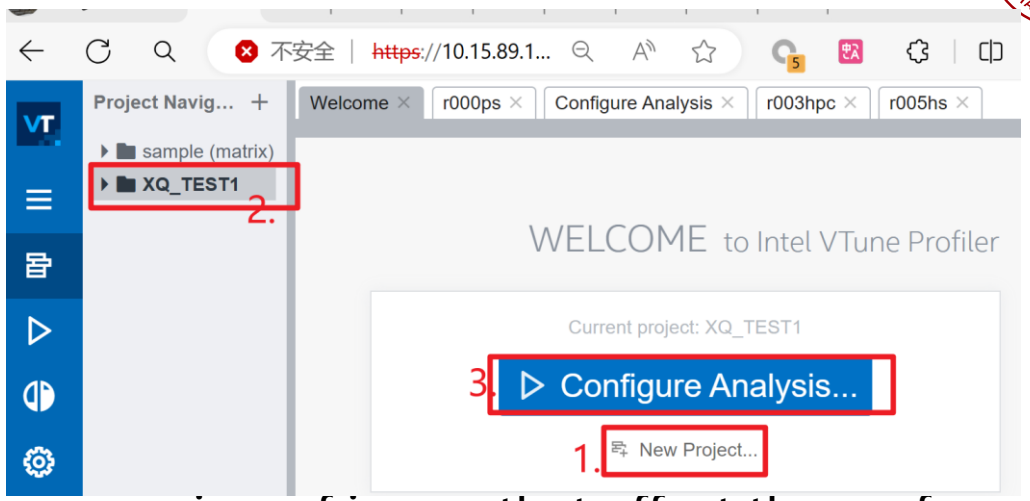
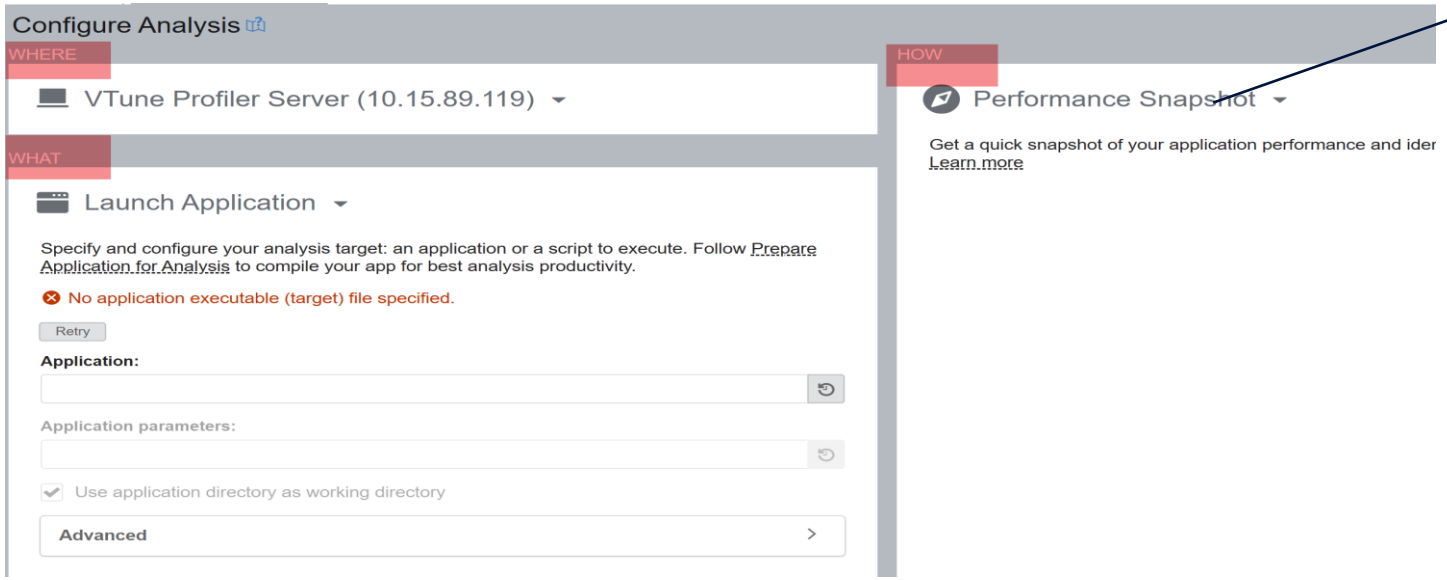


1.



an overview of issues that affect the performance of application.

2.



04 VTune Basics – performance snapshot example

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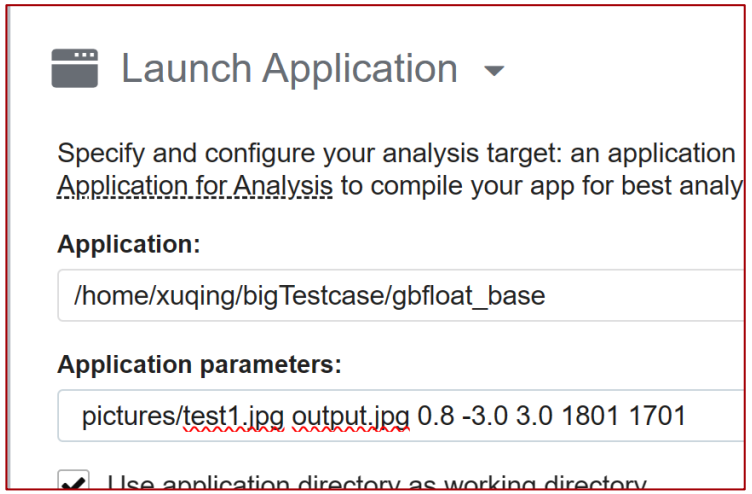
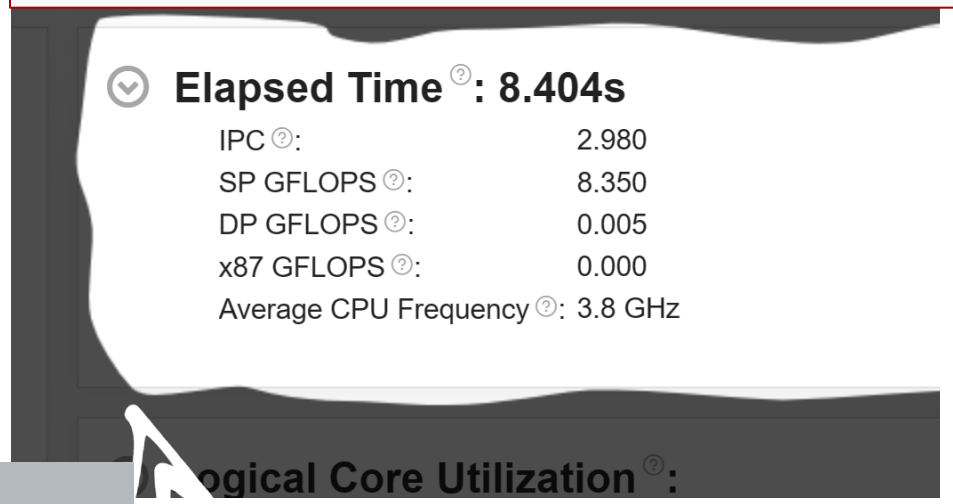
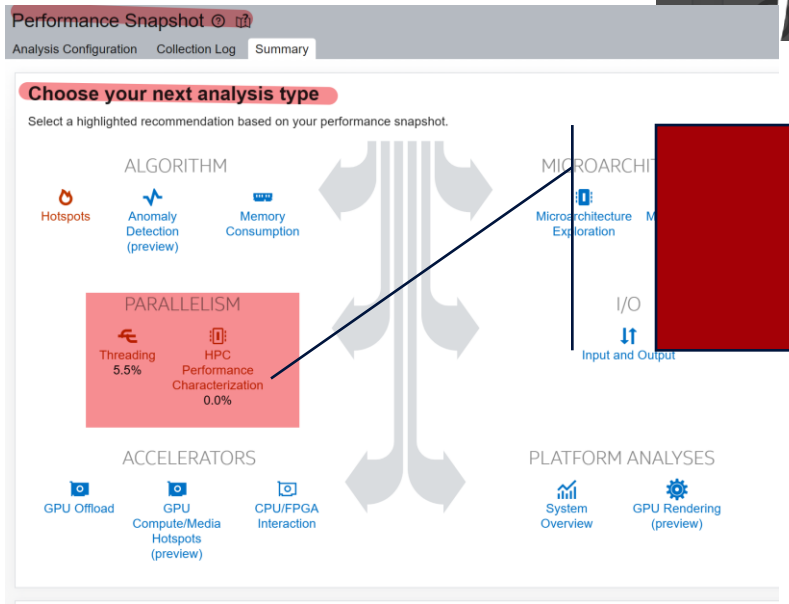



```
xuqing@AEP:~/bigTestcase$ ./gbfloat_base  pictures/te
st1.jpg output.jpg 0.8 -3.0 3.0 1801 1701
8.042599
```





next

04 VTune Basics – hpc example

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Vectorization: 0.0% of Packed FP Operations

Instruction Mix:

SP FLOPs:	17.7%	of uOps
Packed:	0.0%	from SP FP
Scalar:	100.0%	from SP FP
DP FLOPs:	0.0%	of uOps
x87 FLOPs:	0.0%	of uOps
Non-FP:	82.3%	of uOps
FP Arith/Mem Rd Instr. Ratio:	1.439	
FP Arith/Mem Wr Instr. Ratio:	123.052	

Top Loops/Functions with FPU Usage by CPU Time

This section provides information for the most time con

Can be optimized

Function	CPU Time	% of FP Ops	FP Ops: Packed	FP Ops: Scalar	Vector Instruction Set	Loop Type
[Loop@0x39d8 in gb_v._omp_fn.0]	17.210s	17.5%	0.0%	100.0%		
[Loop@0x36e0 in gb_h._omp_fn.0]	14.410s	18.6%	0.0%	100.0%		

*N/A is applied to non-summable metrics.

04 VTune Basics – hpc example

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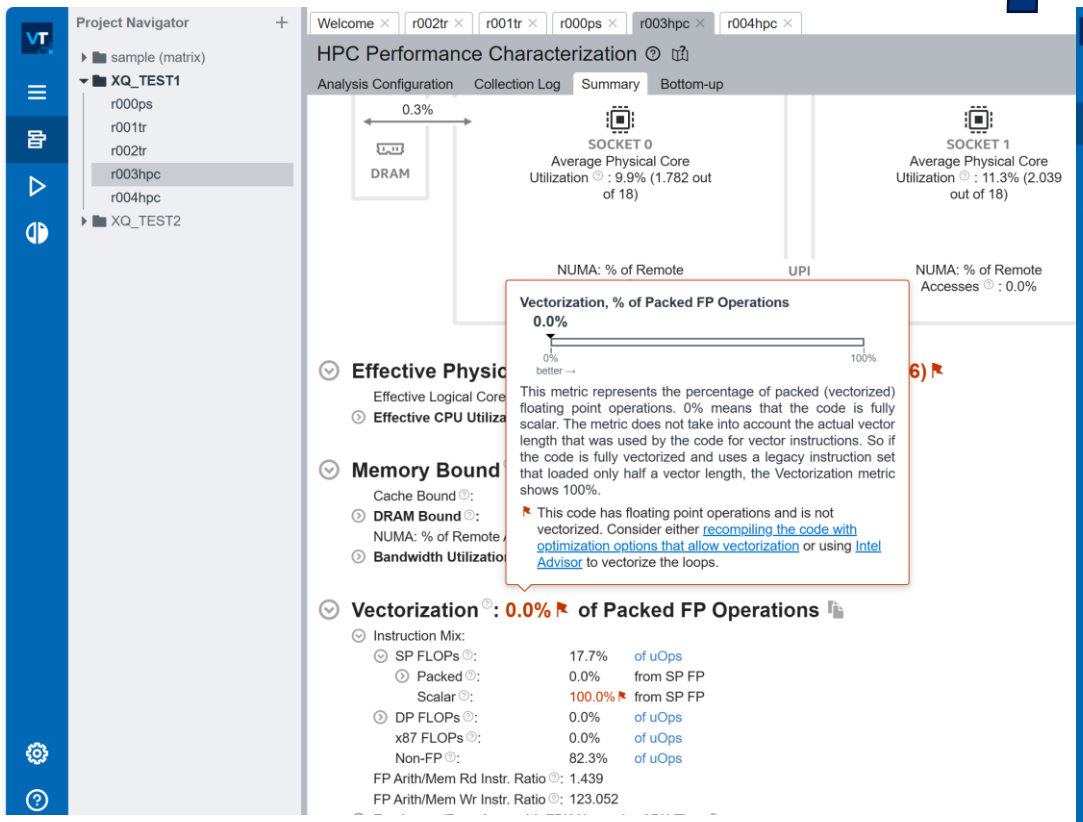

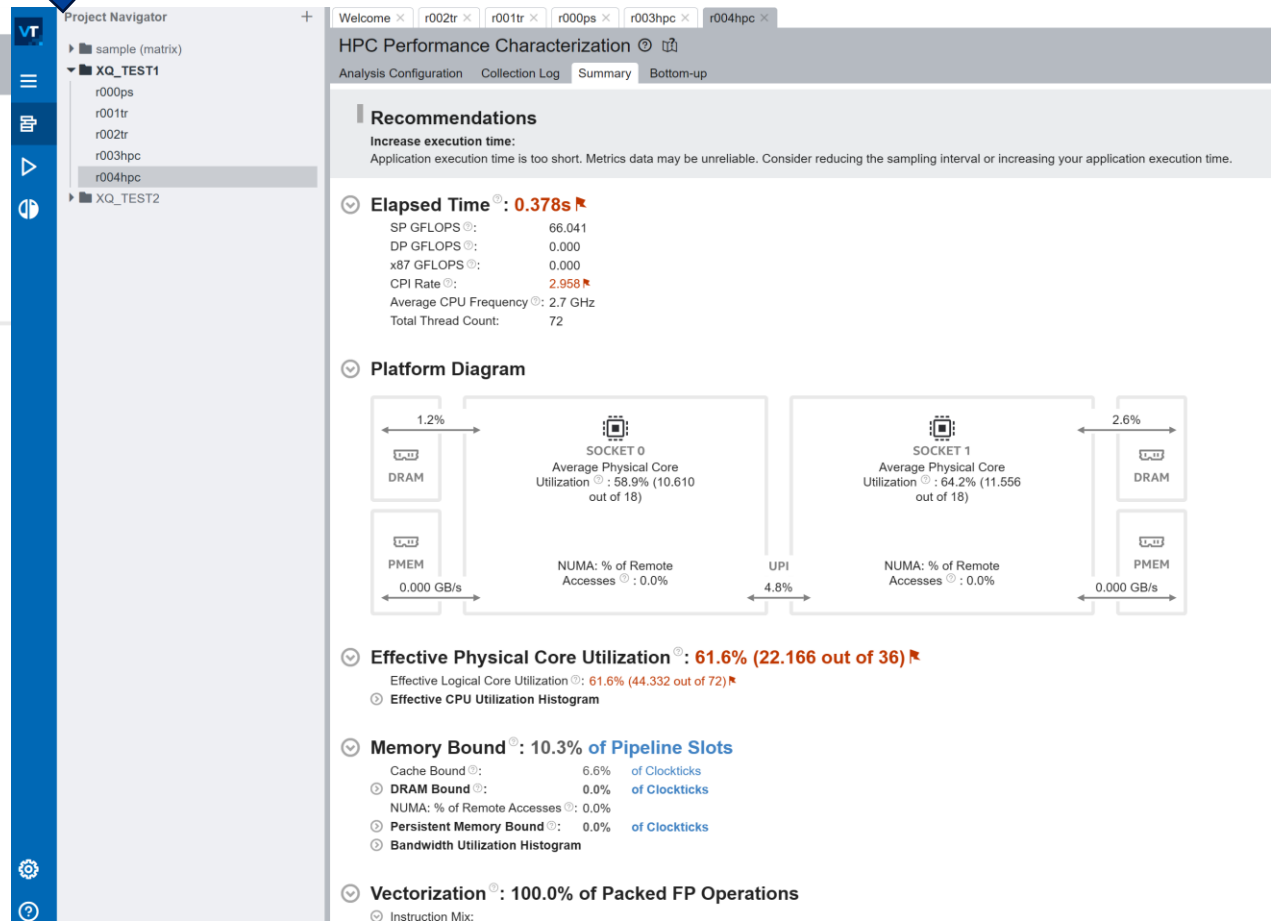

04 VTune Basics – hotspot example

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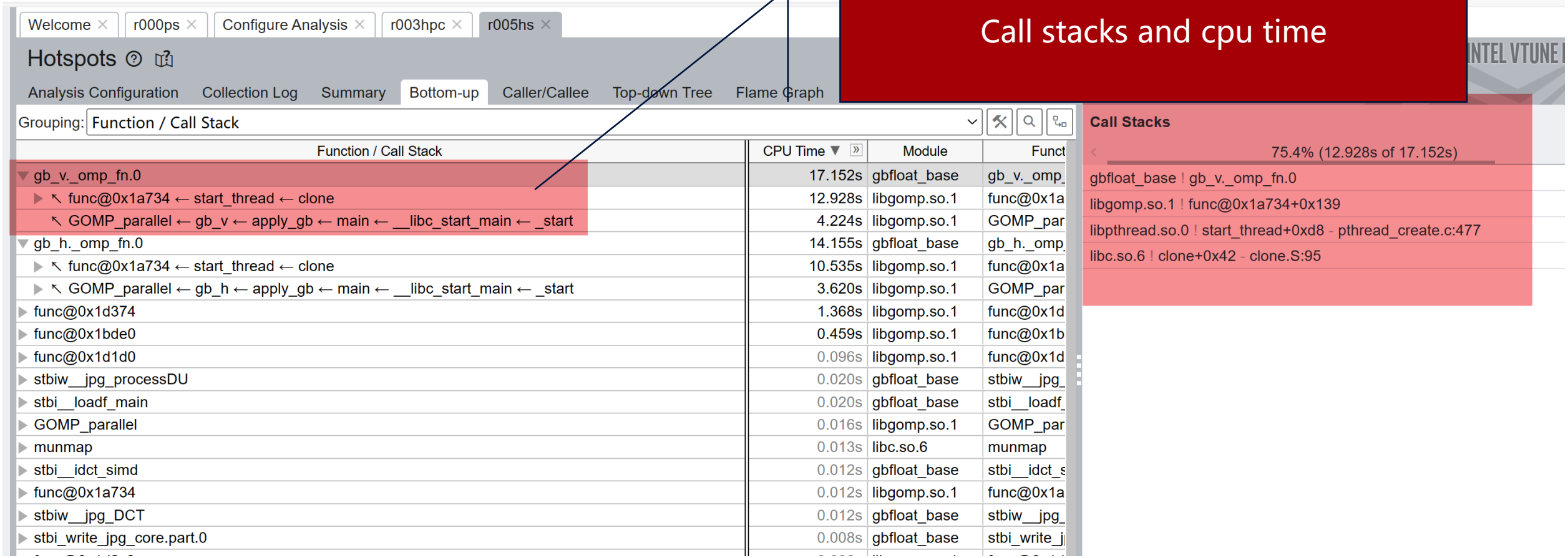
Call stacks and cpu time



04 VTune Basics – hotspot example

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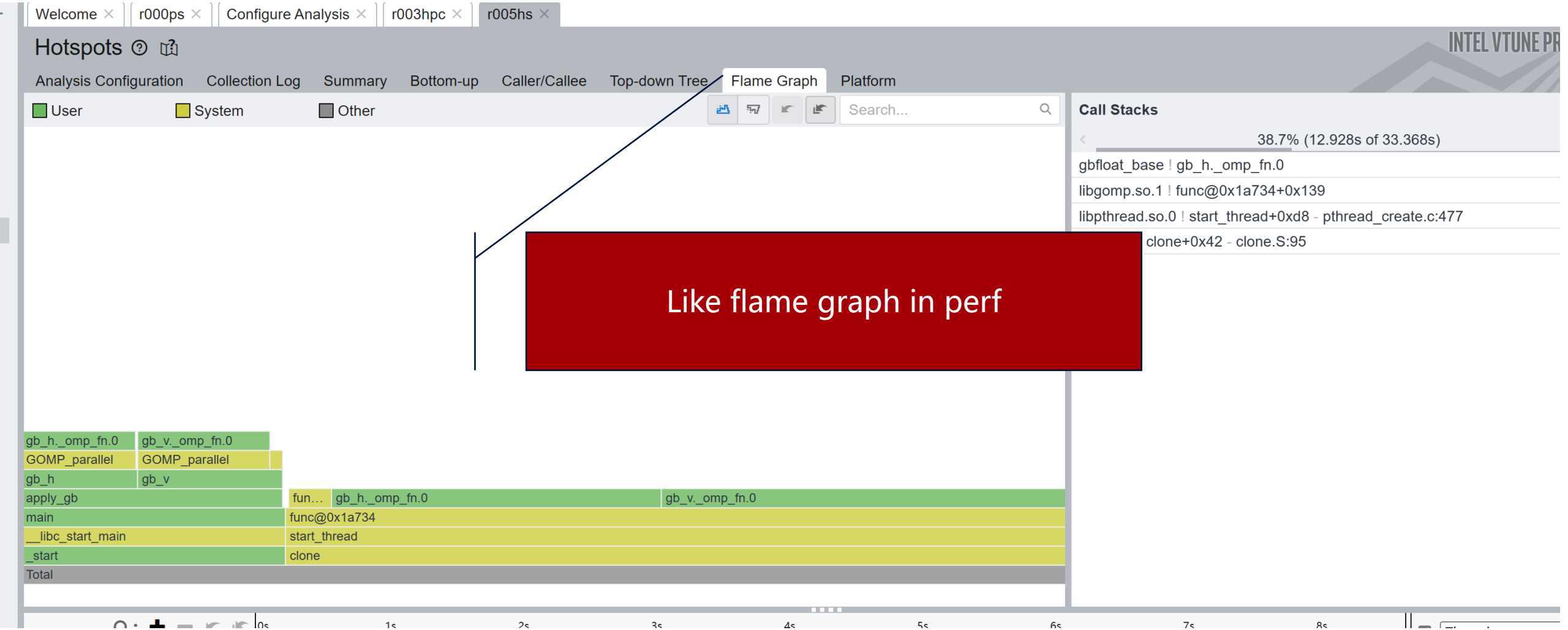

04 VTune Basics – threading example

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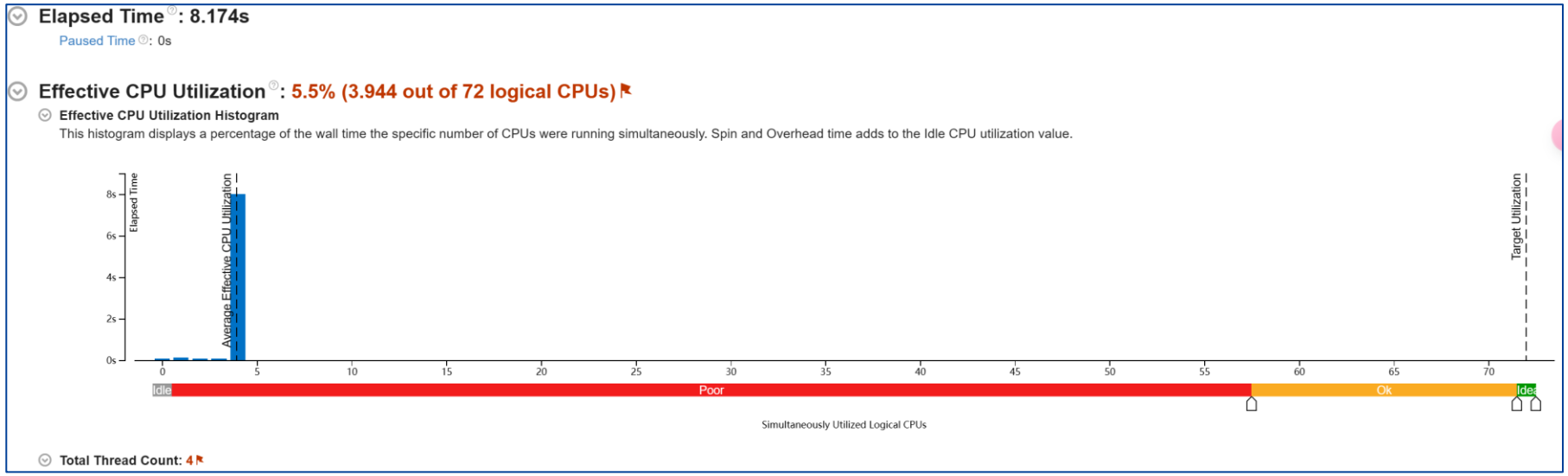
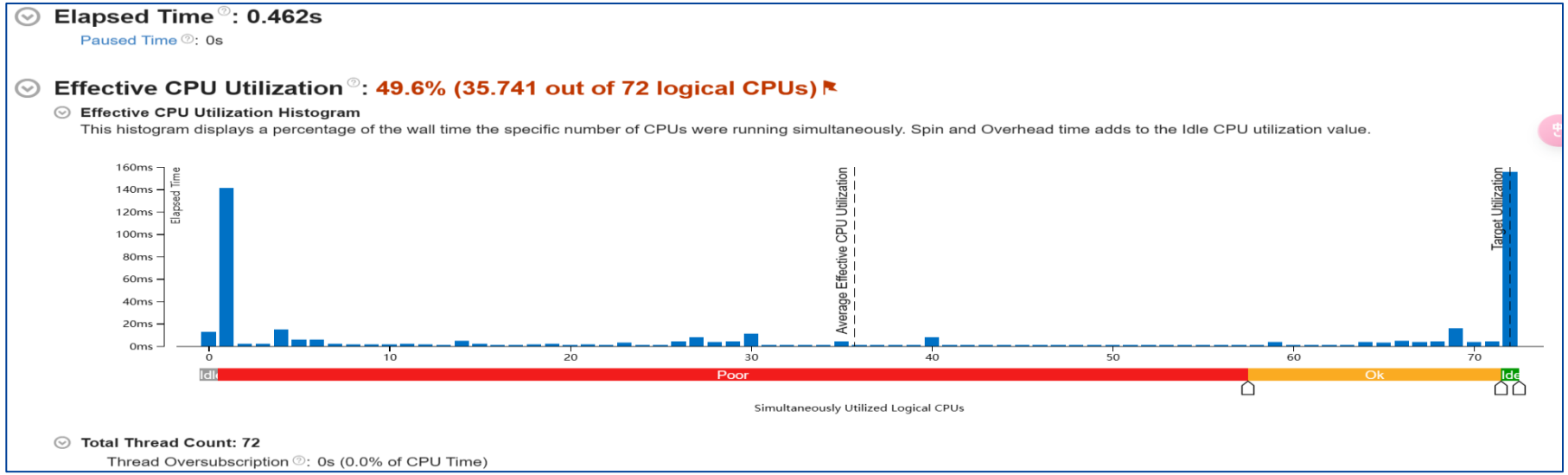
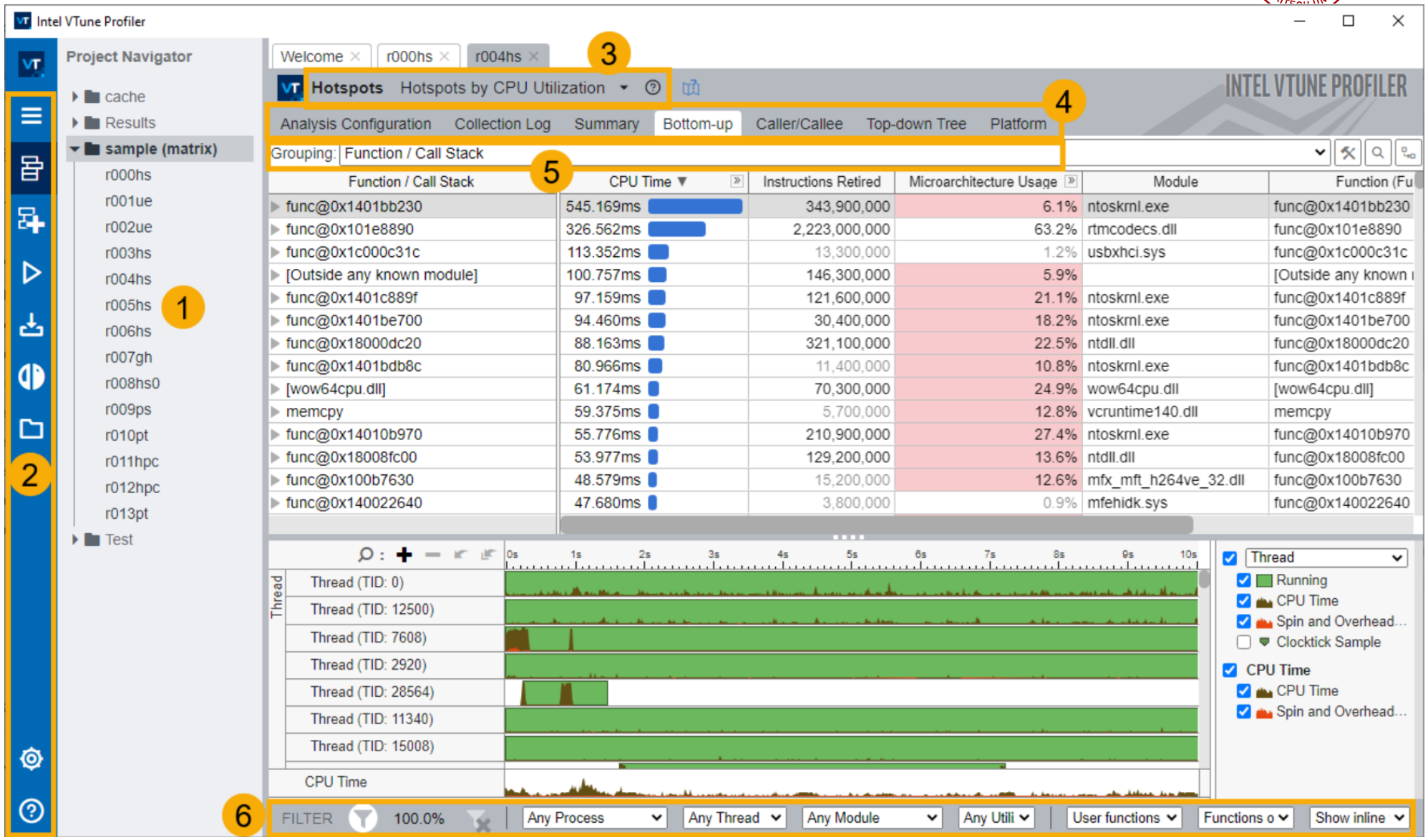




04 VTune Basics



05 sar

- sar - Collect, report, or save system activity information.
- Report selected cumulative activity counters.
- sar –help
- Usage: sar [options] [<interval> [<count>]]
  - interval == zero, displays the average statistics for the time since the system was started
  - without the count parameter, reports are generated continuously
- -o output_filename

```
xuqing@AEP:~/bigTestcase$ sar -q 1 3
Linux 5.4.0-169-generic (AEP)   2024年05月17日   _x86_64_        (72 CPU)

19时13分16秒   runq-sz  plist-sz   ldavg-1   ldavg-5  ldavg-15   blocked
19时13分17秒         2      1804      0.09      0.04      0.00         0
19时13分18秒         0      1806      0.09      0.04      0.00         0
19时13分19秒         0      1803      0.08      0.04      0.00         0
Average:             1      1804      0.09      0.04      0.00         0
```