如何使用Gcov和Linux Perf工具抓热点代码

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Gcov简介

- Gcov
  - Linux下GCC自带的C/C++代码覆盖率分析工具
  - 可以用于查找热点，有针对性地优化代码
  - 也可以查看代码覆盖情况，有针对性的为软件添加测试用例
  - 配合lcov使用，图形化显示

Gcov使用

1. **gcc -fprfile-arcs -ftest-coverage test.c -o test**

   ⟶ test test.gcno

2. **./test**

   ⟶ test.gcda

3. **gcov test.c**

   ⟶ test.c.gcov

4. **vim test.c.gcov**

Gcov使用

```c
// test.c
#include <stdio.h>
#include <stdlib.h>

void test(int count)
{
    int i;
    for (i = 1; i < count; i++)
    {
        if (i % 3 == 0)
            printf ("%d is divisible by 3\n", i);
        if (i % 11 == 0)
            printf ("%d is divisible by 11\n", i);
        if (i % 13 == 0)
            printf ("%d is divisible by 13\n", i);
    }
}

int main(int argc, char *argv[])
{
    int i = 0;
    if(argc == 2)
        i = atoi(argv[1]);
    else
        i = 10;

    printf("arg is %d\n", i);

    test(i);

    return EXIT_SUCCESS;
}
```

Gcov使用

```
molly@molly-Huawei:~/test$ gcc -fprofile-arcs -ftest-coverage test.c -o test
molly@molly-Huawei:~/test$ ls
test  test.c  test.gcno
```

Gcov使用

```
molly@molly-Huawei:~/test$ ./test
arg is 10
3 is divisible by 3
6 is divisible by 3
9 is divisible by 3
molly@molly-Huawei:~/test$ ls
test  test.c  test.gcda  test.gcno
```

```
molly@molly-Huawei:~/test$ gcov test.c
File 'test.c'
Lines executed:82.35% of 17
Creating 'test.c.gcov'

molly@molly-Huawei:~/test$ ls
test  test.c  test.c.gcov  test.gcda  test.gcno
```

Gcov使用

```
    -:    0:Source:test.c
    -:    0:Graph:test.gcno
    -:    0:Data:test.gcda
    -:    0:Runs:1
    -:    1:// test.c
    -:    2:#include <stdio.h>
    -:    3:#include <stdlib.h>
    -:    4:
    1:    5:void test(int count)
    -:    6:{
    -:    7:    int i;
   10:    8:    for (i = 1; i < count; i++)
    -:    9:    {
    9:   10:        if (i % 3 == 0)
    3:   11:            printf ("%d is divisible by 3\n", i);
    9:   12:        if (i % 11 == 0)
#####:   13:            printf ("%d is divisible by 11\n", i);
    9:   14:        if (i % 13 == 0)
#####:   15:            printf ("%d is divisible by 13\n", i);
    -:   16:    }
    1:   17:}
    -:   18:
    1:   19:int main(int argc, char *argv[])
    -:   20:{
    1:   21:    int i = 0;
    1:   22:    if(argc == 2)
#####:   23:        i = atoi(argv[1]);
    -:   24:    else
    1:   25:        i = 10;
    -:   26:
    1:   27:    printf("arg is %d\n", i);
    -:   28:
    1:   29:    test(i);
    -:   30:
    1:   31:    return EXIT_SUCCESS;
    -:   32:}
```

Lcov图形化显示

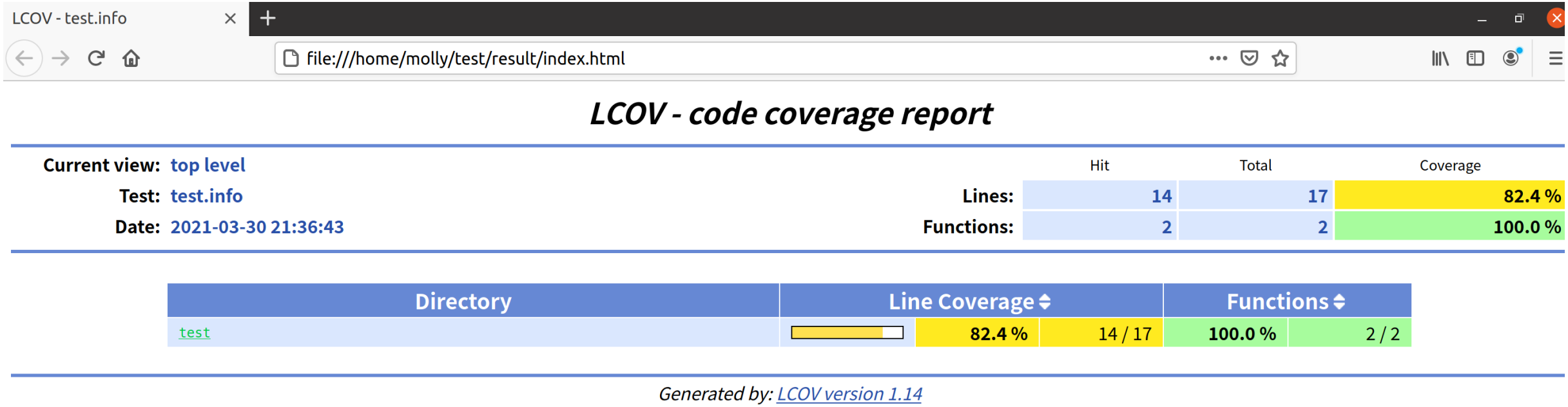
1. **lcov -d . -t 'Test Coverage' -o 'test.info' -b . -c**

   ⟶ test.info

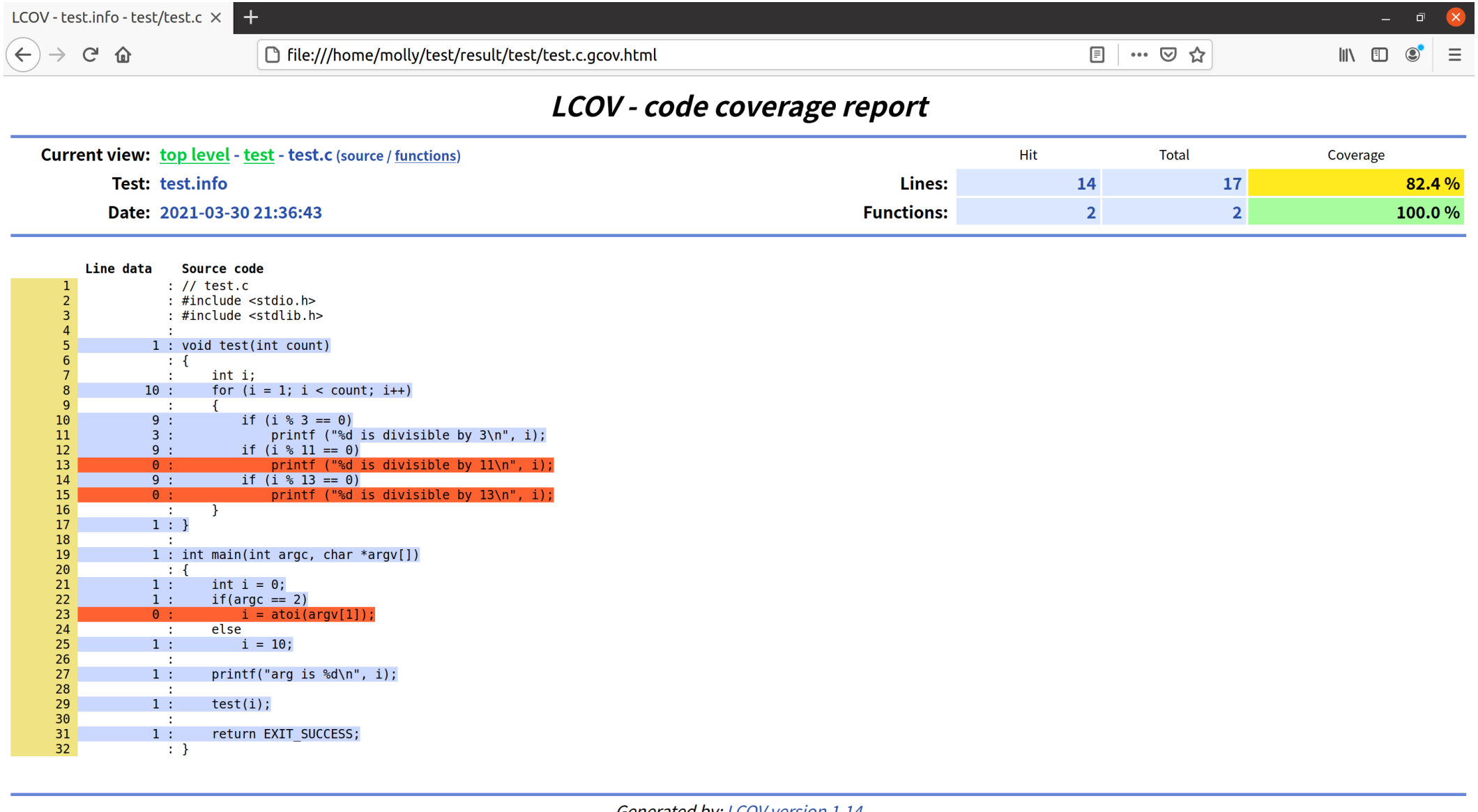
2. **genhtml -o result test.info**

   ⟶ 生成result文件夹，其中包含index.html

Lcov图形化显示


LCOV - test.info
file:///home/molly/test/result/index.html
LCOV - code coverage report
Current view: top level
Test: test.info
Date: 2021-03-30 21:36:43
Hit
Total
Coverage
Lines: 14 17 82.4 %
Functions: 2 2 100.0 %
Directory
Line Coverage
Functions
test
82.4 %
14 / 17
100.0 %
2 / 2
Generated by: LCOV version 1.14

Lcov图形化显示


LCOV - test.info - test/test.c
file:///home/molly/test/result/test/test.c.gcov.html
LCOV - code coverage report
Current view: top level - test - test.c (source / functions)
Test: test.info
Date: 2021-03-30 21:36:43
Hit
Total
Coverage
Lines: 14 17 82.4 %
Functions: 2 2 100.0 %
Line data Source code
1 : // test.c
2 : #include <stdio.h>
3 : #include <stdlib.h>
4 :
5 : 1 : void test(int count)
6 : : {
7 : : int i;
8 : 10 : for (i = 1; i < count; i++)
9 : : {
10 : 9 : if (i % 3 == 0)
11 : 3 : printf ("%d is divisible by 3\n", i);
12 : 9 : if (i % 11 == 0)
13 : 0 : printf ("%d is divisible by 11\n", i);
14 : 9 : if (i % 13 == 0)
15 : 0 : printf ("%d is divisible by 13\n", i);
16 : : }
17 : 1 : }
18 :
19 : 1 : int main(int argc, char *argv[])
20 : : {
21 : 1 : int i = 0;
22 : 1 : if(argc == 2)
23 : 0 : i = atoi(argv[1]);
24 : : else
25 : 1 : i = 10;
26 :
27 : 1 : printf("arg is %d\n", i);
28 :
29 : 1 : test(i);
30 :
31 : 1 : return EXIT_SUCCESS;
32 : : }
Generated by: LCOV version 1.14

Linux Perf 简介

- Perf
  - Linux内核自带，profiling工具，**支持CPU PMU事件和软件事件计数**
  - 用于找到程序热点，找到程序的性能瓶颈（cpu计算能力，cache利用率，内存访问，硬盘访问）

perf list [hw|sw|cache|tracepoint|pmu|...]
- **硬件：instructions, cycles, cache, branch**
- **软件：page faults, context swith**

Perf 使用

- **perf top**
  - 实时动态查看系统热点，函数热点，汇编热点
- **perf stat**
  - 统计单个应用程序整个生命周期的硬软件事件数目。
- **perf record & perf report**
  - 统计程序各模块、函数在整个生命周期中的性能数据

perf top

```
Samples: 33K of event 'cycles', 4000 Hz, Event count (approx.): 3667127735 lost: 0/0 drop
Overhead  Shared Object                     Symbol
  21.93%  [kernel]                          [k] 0xffffffff8557f7b3
  21.54%  [kernel]                          [k] 0xffffffff852bb25f
   5.26%  [kernel]                          [k] 0xffffffffc00681eb
   5.24%  [kernel]                          [k] 0xffffffffc0068204
   3.75%  [kernel]                          [k] 0xffffffffc01acabc
   1.11%  [kernel]                          [k] 0xffffffffc12f337f
   1.05%  [kernel]                          [k] 0xffffffffc0068449
   1.01%  [unknown]                         [.] 0000000000000000
   0.57%  [kernel]                          [k] 0xffffffff8530c40a
   0.40%  [kernel]                          [k] 0xffffffff8557f792
   0.37%  perf                              [.] rb_next
   0.31%  [kernel]                          [k] 0xffffffff8557fd53
   0.25%  libglib-2.0.so.0.6400.6           [.] g_hash_table_lookup
   0.25%  perf                              [.] hists__findnew_entry
   0.25%  [kernel]                          [k] 0xffffffff85600fe7
   0.25%  perf                              [.] hpp__sort_overhead
   0.23%  perf                              [.] perf_hpp__is_dynamic_entry
   0.22%  perf                              [.] hist_entry__sort
   0.18%  libc-2.31.so                      [.] _int_malloc
   0.18%  libc-2.31.so                      [.] _int_free
   0.18%  perf                              [.] output_resort
   0.18%  [kernel]                          [k] 0xffffffff85173fac
   0.17%  [kernel]                          [k] 0xffffffff8557fdbc
   0.15%  [kernel]                          [k] 0xffffffff84a6c6c9
   0.14%  [kernel]                          [k] 0xffffffff84afd152
```

perf top查看整个系统

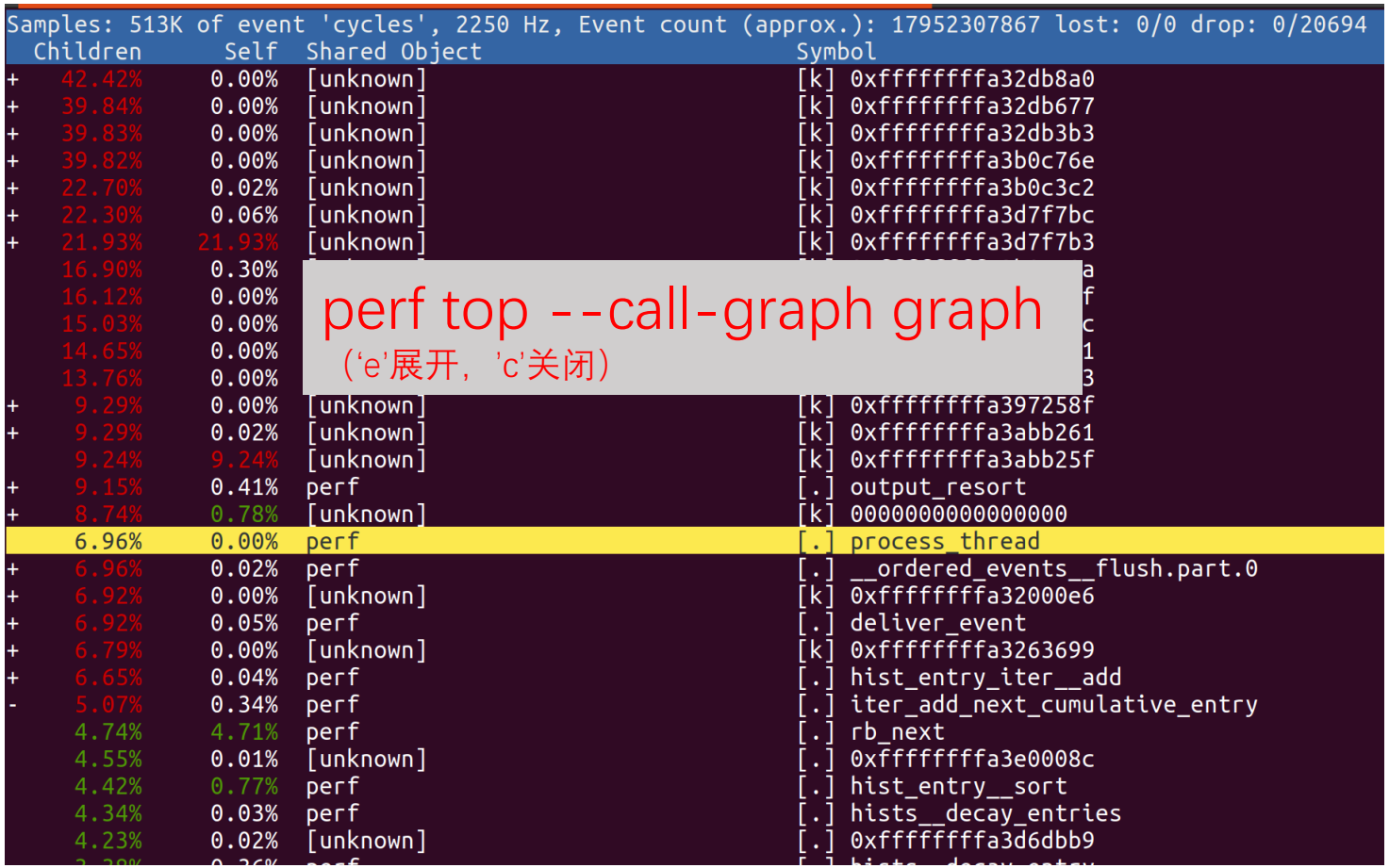
perf top

```
Samples: 6K of event 'cycles', 4000 Hz, Event count (approx.): 235309873 lost: 0/0 drop: 0/5423
Overhead  Shared Object             Symbol
   2.97%  [unknown]                 [.] 0000000000000000
   1.85%  firefox                   [.] 0x000000000000e863
   1.78%  libpthread-2.31.so        [.] __pthread_mutex_unlock
   1.40%  libpthread-2.31.so        [.] __pthread_mutex_lock
   1.29%  [kernel]                  [k] 0xffffffffa3abb25f
   0.98%  [kernel]                  [k] 0xffffffffa32fd152
   0.95%  ld-2.31.so                [.] __tls_get_addr
   0.90%  libpthread-2.31.so        [.] pthread_cond_wait@@GLIBC_2.3.2
   0.80%  [vdso]                    [.] __vdso_clock_gettime
   0.72%  firefox                   [.] 0x0000000000013266
   0.69%  libpthread-2.31.so        [.] pthread_cond_timedwait@@GLIBC_2.3.2
   0.68%  [kernel]                  [k] 0xffffffffa3d7fdbc
   0.63%  firefox                   [.] mozilla::BaseTimeDurationPlatformUtils::ToSeconds
   0.57%  ld-2.31.so                [.] _dl_update_slotinfo
   0.56%  firefox                   [.] 0x000000000000dafd
   0.51%  firefox                   [.] 0x000000000001323b
   0.50%  libc-2.31.so              [.] clock_gettime@GLIBC_2.2.5
   0.49%  [kernel]                  [k] 0xffffffffa323be75
   0.49%  [kernel]                  [k] 0xffffffffa3411db9
   0.49%  firefox                   [.] 0x0000000000013a70
   0.48%  [kernel]                  [k] 0xffffffffc024c1eb
   0.48%  libxul.so                 [.] 0x0000000000f8b520
```

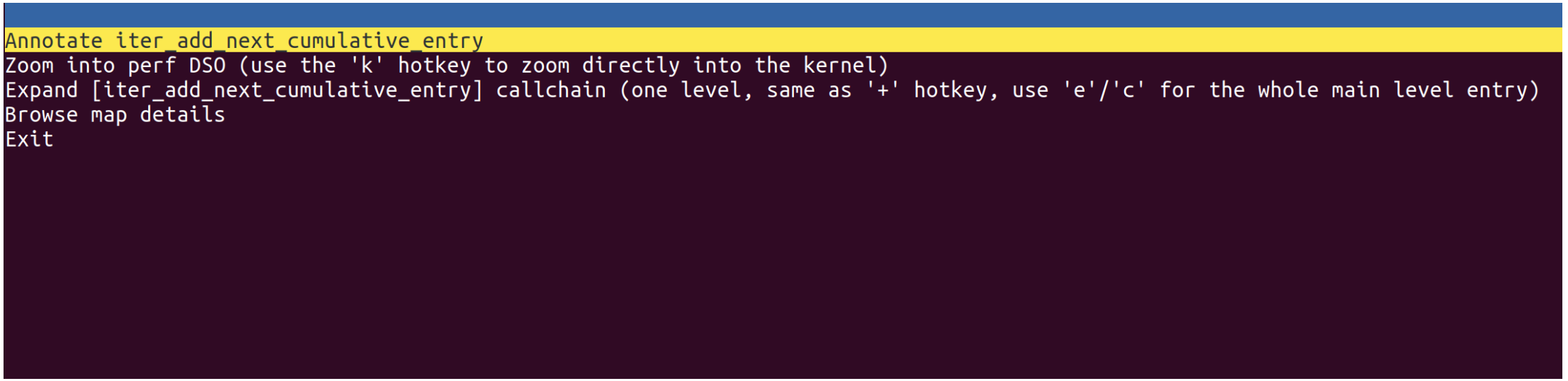
perf top –pid xxxx

查看单个应用程序

perf top

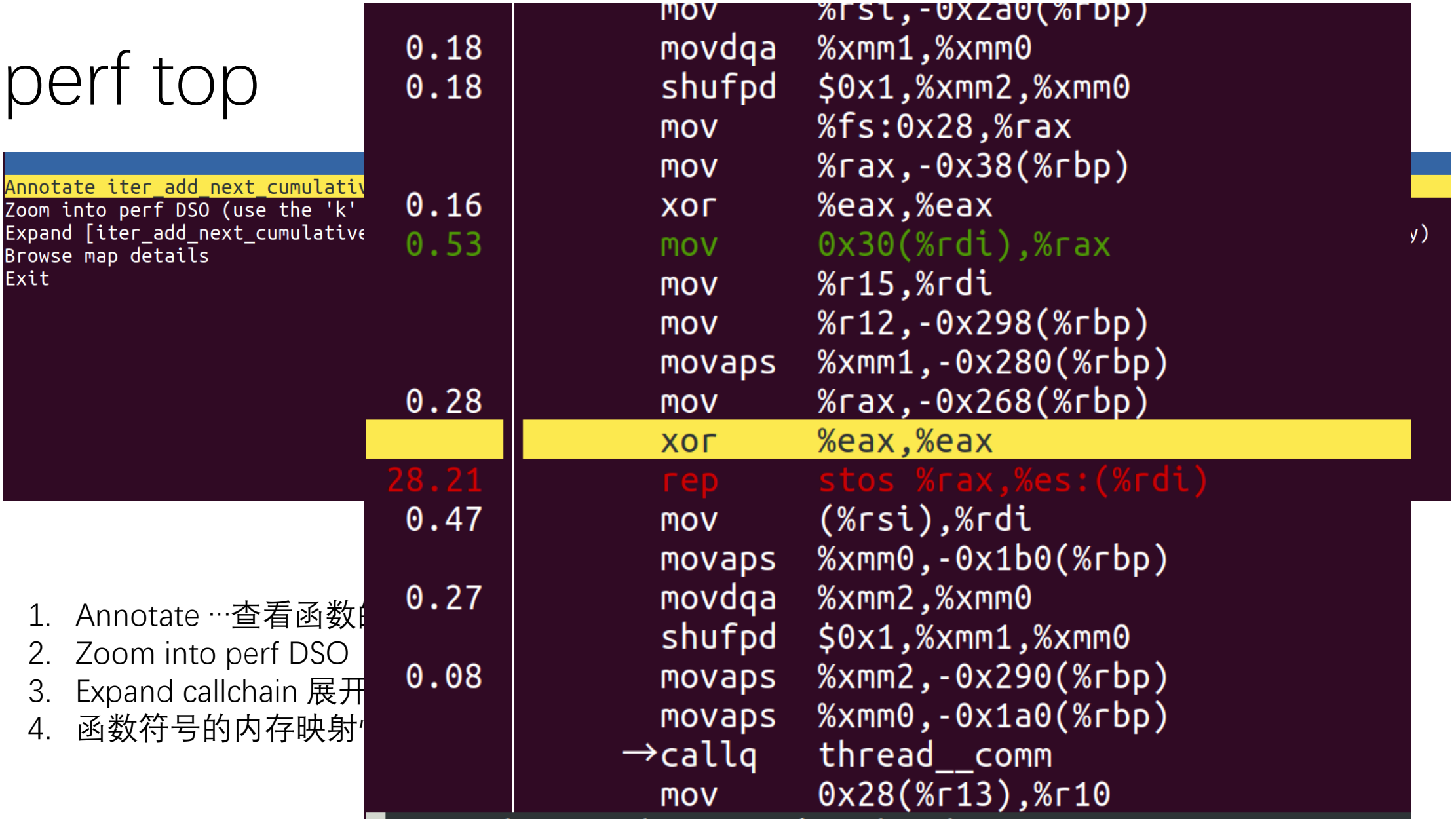

Samples: 513K of event 'cycles', 2250 Hz, Event count (approx.): 17952307867 lost: 0/0 drop: 0/20694
Children Self Shared Object Symbol
+ 42.42% 0.00% [unknown] [k] 0xffffffffa32db8a0
+ 39.84% 0.00% [unknown] [k] 0xffffffffa32db677
+ 39.83% 0.00% [unknown] [k] 0xffffffffa32db3b3
+ 39.82% 0.00% [unknown] [k] 0xffffffffa3b0c76e
+ 22.70% 0.02% [unknown] [k] 0xffffffffa3b0c3c2
+ 22.30% 0.06% [unknown] [k] 0xffffffffa3d7f7bc
+ 21.93% 21.93% [unknown] [k] 0xffffffffa3d7f7b3
16.90% 0.30%
16.12% 0.00%
15.03% 0.00%
14.65% 0.00%
13.76% 0.00%
+ 9.29% 0.00% [unknown] [k] 0xffffffffa397258f
+ 9.29% 0.02% [unknown] [k] 0xffffffffa3abb261
9.24% 9.24% [unknown] [k] 0xffffffffa3abb25f
+ 9.15% 0.41% perf [.] output_resort
+ 8.74% 0.78% [unknown] [k] 0000000000000000
6.96% 0.00% perf [.] process_thread
+ 6.96% 0.02% perf [.] __ordered_events__flush.part.0
+ 6.92% 0.00% [unknown] [k] 0xffffffffa32000e6
+ 6.92% 0.05% perf [.] deliver_event
+ 6.79% 0.00% [unknown] [k] 0xffffffffa3263699
+ 6.65% 0.04% perf [.] hist_entry_iter__add
- 5.07% 0.34% perf [.] iter_add_next_cumulative_entry
4.74% 4.71% perf [.] rb_next
4.55% 0.01% [unknown] [.] 0xffffffffa3e0008c
4.42% 0.77% perf [.] hist_entry__sort
4.34% 0.03% perf [.] hists__decay_entries
4.23% 0.02% [unknown] [.] 0xffffffffa3d6dbb9
perf top --call-graph graph
（'e'展开，'c'关闭）

perf top



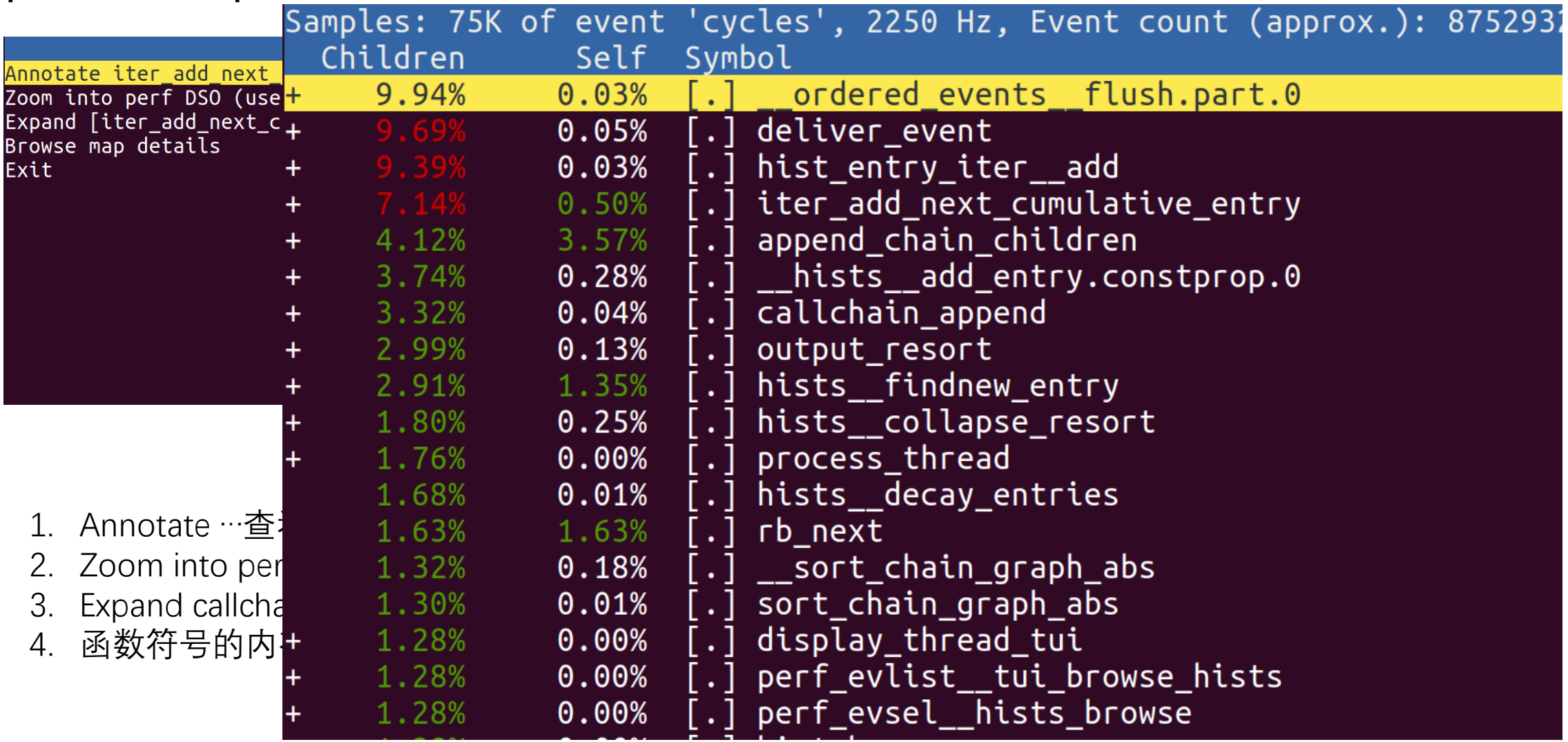
1. Annotate …查看函数的反汇编，及在汇编级的热点
2. Zoom into perf DSO 查看当前DSO的热点情况
3. Expand callchain 展开一级调用关系
4. 函数符号的内存映射情况

perf top



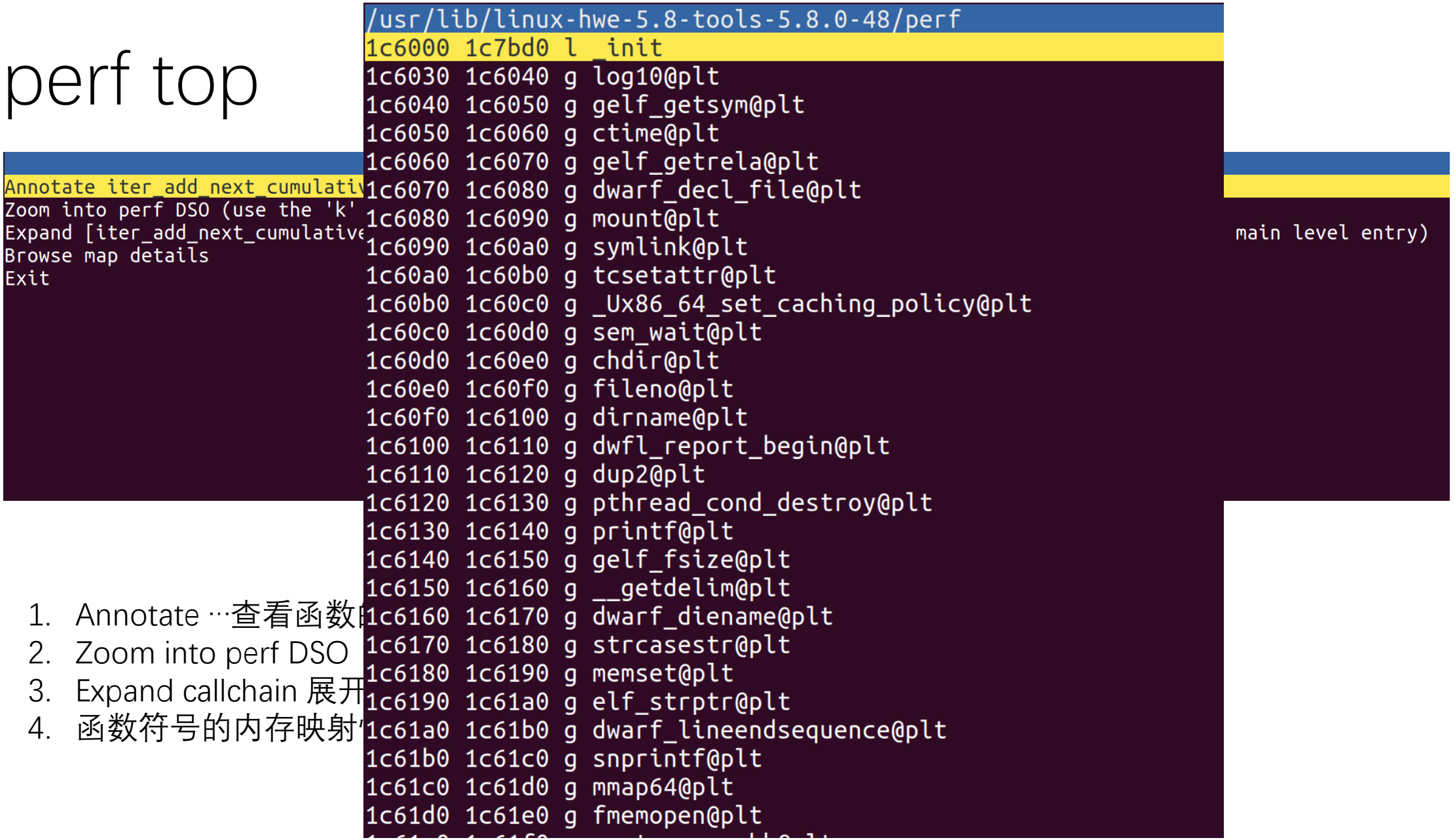
1. Annotate …查看函数
2. Zoom into perf DSO
3. Expand callchain 展开
4. 函数符号的内存映射

perf top



1. Annotate …查
2. Zoom into per
3. Expand callcha
4. 函数符号的内

perf top



1. Annotate …查看函数
2. Zoom into perf DSO
3. Expand callchain 展开
4. 函数符号的内存映射

perf stat

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

```
molly@molly-Huawei:~$ sudo perf stat dd if=/dev/zero of=/dev/null count=1000000
记录了1000000+0 的读入
记录了1000000+0 的写出
512000000字节（512 MB，488 MiB）已复制，0.333274 s，1.5 GB/s

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

            333.68 msec task-clock                #    0.999 CPUs utilized
                 2      context-switches          #    0.006 K/sec
                 0      cpu-migrations            #    0.000 K/sec
                82      page-faults               #    0.246 K/sec
     1,176,133,823      cycles                    #    3.525 GHz
     2,137,561,864      instructions              #    1.82  insn per cycle
       411,308,952      branches                  # 1232.653 M/sec
         4,740,534      branch-misses             #    1.15% of all branches

       0.333987355 seconds time elapsed

       0.120717000 seconds user
       0.213267000 seconds sys
```

-e 指定事件

```
perf stat -e cycles dd if=/dev/zero of=/dev/null count=100000
perf stat -e instructions dd if=/dev/zero of=/dev/null count=100000
```

perf record & report

1. 编译程序（加-g）

   gcc -g -O0 test.c -o test

2. perf record

   perf record –a –g ./test

   生成perf.data

3. perf report

perf record & report (例子)

```c
#include <stdio.h>

void test_little(void)
{
  int i,j;
  for(i = 0; i < 30000000; i++)
    j=i;
}

void test_mdedium(void)
{
  int i,j;
  for(i = 0; i < 60000000; i++)
    j=i;
}

void test_high(void)
{
  int i,j;
  for(i = 0; i < 90000000; i++)
    j=i;
}

void test_hi(void)
{
  int i,j;
  for(i = 0; i < 120000000; i++)
    j=i;
}
```

test.c 文件

```c
int main(void)
{
  int i, pid, result;

  for(i = 0; i<2; i++) {
    result = fork();
    if(result>0)
      printf("i=%d parent parent=%d current=%d child=%d\n", i, getppid(), getpid(), result);
    else
      printf("i=%d child parent=%d current=%d\n", i, getppid(), getpid());

    if(i==0)
    {
      test_little();
      sleep(1);
    } else {
      test_mdedium();
      sleep(1);
    }
  }

  pid = wait(NULL);
  test_high();
  printf("pid=%d wait=%d\n", getpid(), pid);
  sleep(1);
  pid = wait(NULL);
  test_hi();
  printf("pid=%d wait=%d\n", getpid(), pid);
  return 0;
}
```

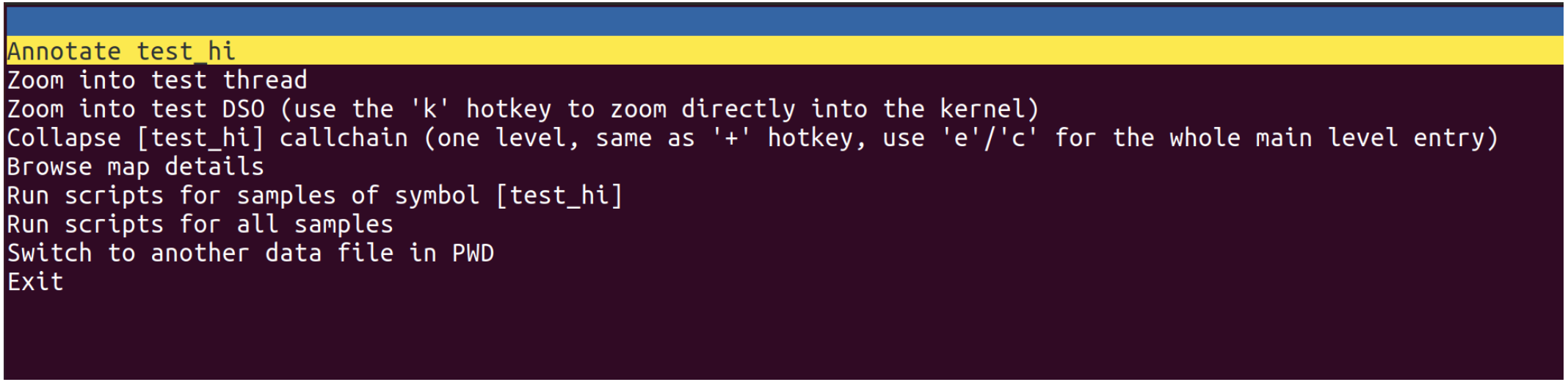
perf record & report (例子)

```
Samples: 31K of event 'cycles', Event count (approx.): 10662567324
  Children      Self  Command          Shared Object                Symbol
+   73.35%     0.00%  test             libc-2.31.so                 [.] __libc_start_main
+   73.34%     0.00%  test             test                         [.] main
+   30.22%    30.21%  test             test                         [.] test_hi
+   22.72%    22.65%  test             test                         [.] test_high
+   16.60%    16.56%  test             test                         [.] test_mdedium
+   10.96%     0.00%  swapper          [unknown]                    [k] 0xffffffffb9c000e6
+   10.96%     0.00%  swapper          [unknown]                    [k] 0xffffffffb9cdb8a0
+    9.66%     0.00%  swapper          [unknown]                    [k] 0xffffffffb9cdb677
+    9.65%     0.00%  swapper          [unknown]                    [k] 0xffffffffb9cdb3b3
+    9.65%     0.00%  swapper          [unknown]                    [k] 0xffffffffba50c76e
+    9.24%     0.00%  swapper          [unknown]                    [k] 0xffffffffb9c63699
+    8.39%     0.01%  swapper          [unknown]                    [k] 0xffffffffba50c3c2
+    8.24%     0.02%  swapper          [unknown]                    [k] 0xffffffffba77f7bc
+    8.01%     8.01%  swapper          [unknown]                    [k] 0xffffffffba77f7b3
+    3.79%     3.79%  test             test                         [.] test_little
+    3.12%     0.00%  chrome           libc-2.31.so                 [.] __libc_start_main
+    3.12%     0.01%  chrome           chrome                       [.] free
+    3.11%     0.00%  chrome           chrome                       [.] 0x00005599abd5a4ca
+    3.11%     0.00%  chrome           chrome                       [.] 0x00005599abd5c0f0
+    3.11%     0.00%  chrome           chrome                       [.] 0x00005599b0f669f7
+    3.11%     0.00%  chrome           chrome                       [.] 0x00005599abdefe00
+    3.11%     0.00%  chrome           chrome                       [.] 0x00005599abe1b09c
+    3.06%     0.00%  chrome           chrome                       [.] 0x00005599abdc8bb8
+    2.87%     0.00%  chrome           chrome                       [.] 0x00005599abe1a504
+    2.86%     0.00%  chrome           chrome                       [.] 0x00005599abe074a8
+    2.50%     0.00%  chrome           chrome                       [.] 0x00005599ad310292
+    1.72%     0.00%  swapper          [unknown]                    [k] 0xffffffffbb4c2597
```

perf record & report (例子)

```
Samples: 31K of event 'cycles', Event count (approx.): 10662567324
  Children      Self  Command          Shared Object                Symbol
+   73.35%     0.00%  test             libc-2.31.so                 [.] __libc_start_main
+   73.34%     0.00%  test             test                         [.] main
-   30.22%    30.21%  test             test                         [.] test_hi
     30.21% __libc_start_main
        main
        test_hi
+   22.72%    22.65%  test             test                         [.] test_high
+   16.60%    16.56%  test             test                         [.] test_mdedium
+   10.96%     0.00%  swapper          [unknown]                    [k] 0xffffffffb9c000e6
```

perf record & report (例子)



perf record & report (例子)

```
Samples: 31K of event 'cycles', 4000 Hz, Event count (approx.): 10662567324
test_hi  /home/molly/test/test-perf/test [Percent: local period]
Percent |
        |     Disassembly of section .text:
        |
        |     0000000000001261 <test_hi>:
        |     test_hi():
        |     for(i = 0; i < 90000000; i++)
        |     j=i;
        |     }
        |
        |     void test_hi(void)
        |     {
        |       endbr64
        |       push   %rbp
        |       mov    %rsp,%rbp
        |     int i,j;
        |
        |     for(i = 0; i < 120000000; i++)
        |       movl   $0x0,-0x8(%rbp)
        |     ↓ jmp    1b
        |     j=i;
   1.39 |  11:  mov    -0x8(%rbp),%eax
   5.76 |       mov    %eax,-0x4(%rbp)
        |     for(i = 0; i < 120000000; i++)
  30.87 |       addl   $0x1,-0x8(%rbp)
  47.67 |  1b:  cmpl   $0x7270dff,-0x8(%rbp)
  14.31 |     ↑ jle    11
        |     }
        |       nop
        |       nop
        |       pop    %rbp
        |     ←retq
```

More perf commands

- perf bench
  - perf中内置的benchmark，目前包括两套针对调度器和内存管理子系统的benchmark。
- perf mem
  - 内存存取情况
- perf timechart
  - 针对测试期间系统行为进行可视化的工具
- ……

参考资料

- gcov—a Test Coverage Program

https://gcc.gnu.org/onlinedocs/gcc/Gcov.html

- Writing Better Function Tests with GCOV

https://www.youtube.com/watch?v=U_qWLa9KnW8)

- PERF tutorial: Finding execution hot spots

http://sandsoftwaresound.net/perf/perf-tutorial-hot-spots/

- perf Examples

http://www.brendangregg.com/perf.html

- Performance profiling with perf

https://fedoramagazine.org/performance-profiling-perf/

- Rapidly Selecting Good Compiler Optimizations using Performance Counters

https://ieeexplore.ieee.org/abstract/document/4145114

- 系统级性能分析工具perf的介绍与使用

https://www.cnblogs.com/arnoldlu/p/6241297.html

THE END

THANKS FOR WATCHING