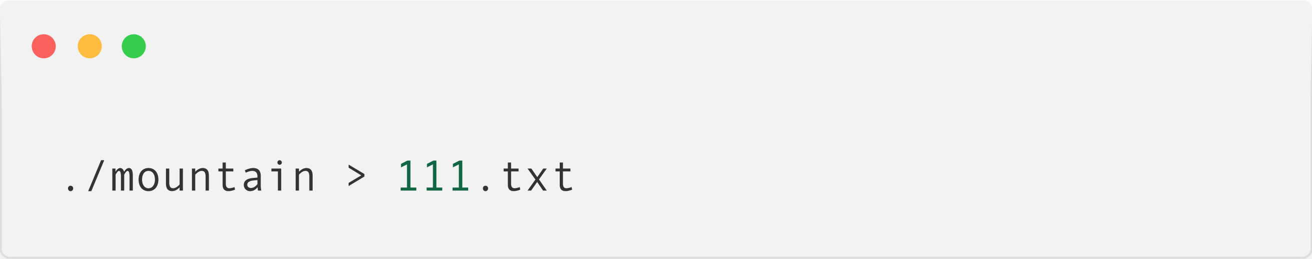
目录

绘制存储器山

建议每一个人都绘制

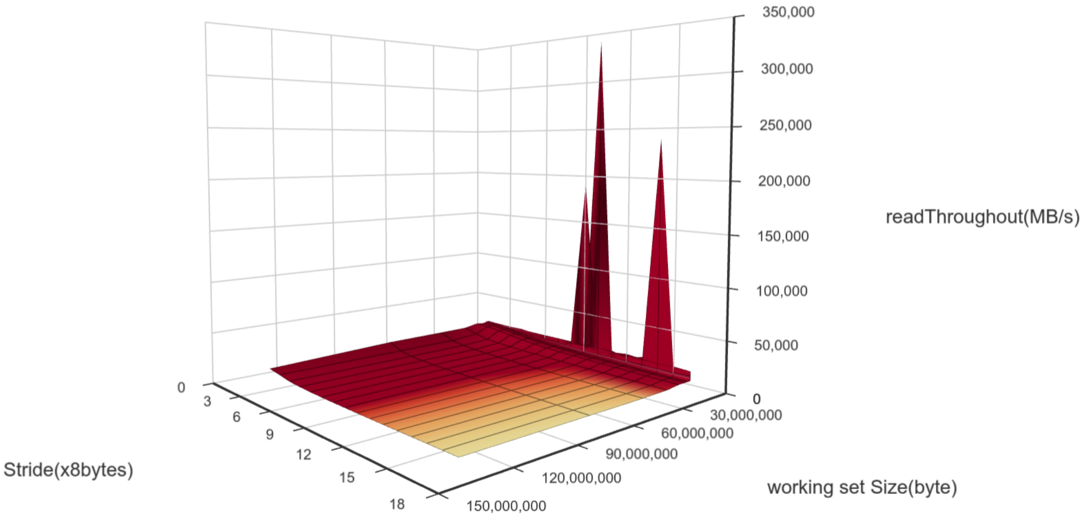
去 CMU 下载所有文件，按照readme操作



```
./mountain > 111.txt
```

得到数据111.txt,

plot.py画图，



分析

安装oprofile

```
sudo apt-get install oprofile
```

显然，我的oprofile版本高，无法使用opcontrol

```
sudo operf ./mountain
```

之后opreport -l列出所有symbols

```
❯ opreport -l
Using /home/heeler/文档/code/lab/cs-
disscussion/sixth/oprofile_data/samples/ for
samples directory.
warning: /kvm could not be found.
```

```
CPU: AMD64 generic, speed 3200 MHz (estimated)
Counted CPU_CLK_UNHALTED events (CPU Clocks
not Halted) with a unit mask of 0x00 (No unit
mask) count 100000
samples  %        image name
symbol name
138966   94.4293  mountain
test
8133      5.5265  mountain
main
12        0.0082  libc.so.6
__printf_fp_l
11        0.0075  mountain
fcyc2_full
8         0.0054  mountain
add_sample
7         0.0048  mountain
get_counter
5         0.0034  mountain
start_counter
4         0.0027  kvm
/kvm
2         0.0014  libc.so.6
__mempcpy_avx_unaligned_erms
2         0.0014  libc.so.6
__memset_avx2_unaligned_erms
2         0.0014  libc.so.6
__printf_chk
1        6.8e-04  ld-linux-x86-64.so.2
_dl_allocate_tls_storage
1        6.8e-04  ld-linux-x86-64.so.2
do_lookup_x
```

```
1         6.8e-04  ld-linux-x86-64.so.2
strcmp
1         6.8e-04  libc.so.6
_IO_file_xsputn@@GLIBC_2.2.5
1         6.8e-04  libc.so.6
__memcpy_avx_unaligned_erms
1         6.8e-04  libc.so.6
__mpn_lshift
1         6.8e-04  libc.so.6
__mpn_mul
1         6.8e-04  libc.so.6
__mpn_mul_1
1         6.8e-04  libc.so.6
__vfprintf_internal
1         6.8e-04  libc.so.6
_int_free
1         6.8e-04  libc.so.6
free
1         6.8e-04  libc.so.6
hack_digit
```

可以看到test占用了大部分时间

更为详细的版本：

```
❯ opreport -c   -% -f -g -s sample
```

```
Using /home/heeler/文档/code/lab/cs-
disscussion/sixth/oprofile_data/samples/ for
samples directory.
warning: /kvm could not be found.
CPU: AMD64 generic, speed 3200 MHz (estimated)
Counted CPU_CLK_UNHALTED events (CPU Clocks
not Halted) with a unit mask of 0x00 (No unit
mask) count 100000
samples  %        linenr info
image name               symbol name
----------------------------------------------
---------------------------------
138966   94.4293  (no location information)
/home/heeler/文档/code/lab/cs-
disscussion/sixth/mountain test
  138966   94.4293  (no location information)
  /home/heeler/文档/code/lab/cs-
disscussion/sixth/mountain test [self]
----------------------------------------------
---------------------------------
8133      5.5265  (no location information)
/home/heeler/文档/code/lab/cs-
disscussion/sixth/mountain main
  8133      5.5265  (no location information)
  /home/heeler/文档/code/lab/cs-
disscussion/sixth/mountain main [self]
----------------------------------------------
---------------------------------
12        0.0082  (no location information)
/usr/lib/x86_64-linux-gnu/libc.so.6
__printf_fp_l
```

```
  12        0.0082  (no location information)
  /usr/lib/x86_64-linux-gnu/libc.so.6
__printf_fp_l [self]
----------------------------------------------
---------------------------------
11        0.0075  (no location information)
/home/heeler/文档/code/lab/cs-
disscussion/sixth/mountain fcyc2_full
  11        0.0075  (no location information)
  /home/heeler/文档/code/lab/cs-
disscussion/sixth/mountain fcyc2_full [self]
----------------------------------------------
---------------------------------
8         0.0054  (no location information)
/home/heeler/文档/code/lab/cs-
disscussion/sixth/mountain add_sample
  8         0.0054  (no location information)
  /home/heeler/文档/code/lab/cs-
disscussion/sixth/mountain add_sample [self]
----------------------------------------------
---------------------------------
7         0.0048  (no location information)
/home/heeler/文档/code/lab/cs-
disscussion/sixth/mountain get_counter
  7         0.0048  (no location information)
  /home/heeler/文档/code/lab/cs-
disscussion/sixth/mountain get_counter [self]
----------------------------------------------
---------------------------------
5         0.0034  (no location information)
/home/heeler/文档/code/lab/cs-
disscussion/sixth/mountain start_counter
```

```
  5         0.0034  (no location information)
  /home/heeler/文档/code/lab/cs-
disscussion/sixth/mountain start_counter
[self]
----------------------------------------------
---------------------------------
4         0.0027  (no location information)
/kvm                     /kvm
  4         0.0027  (no location information)
  /kvm                     /kvm [self]
----------------------------------------------
---------------------------------
2         0.0014  (no location information)
/usr/lib/x86_64-linux-gnu/libc.so.6
__mempcpy_avx_unaligned_erms
  2         0.0014  (no location information)
  /usr/lib/x86_64-linux-gnu/libc.so.6
__mempcpy_avx_unaligned_erms [self]
----------------------------------------------
---------------------------------
2         0.0014  (no location information)
/usr/lib/x86_64-linux-gnu/libc.so.6
__memset_avx2_unaligned_erms
  2         0.0014  (no location information)
  /usr/lib/x86_64-linux-gnu/libc.so.6
__memset_avx2_unaligned_erms [self]
----------------------------------------------
---------------------------------
2         0.0014  (no location information)
/usr/lib/x86_64-linux-gnu/libc.so.6
__printf_chk
```

```
  2         0.0014  (no location information)
  /usr/lib/x86_64-linux-gnu/libc.so.6
__printf_chk [self]
----------------------------------------------
---------------------------------
1        6.8e-04  (no location information)
/usr/lib/x86_64-linux-gnu/ld-linux-x86-64.so.2
_dl_allocate_tls_storage
  1        6.8e-04  (no location information)
  /usr/lib/x86_64-linux-gnu/ld-linux-x86-
64.so.2 _dl_allocate_tls_storage [self]
----------------------------------------------
---------------------------------
1        6.8e-04  dl-lookup.c:0
/usr/lib/x86_64-linux-gnu/ld-linux-x86-64.so.2
do_lookup_x
  1        6.8e-04  dl-lookup.c:0
  /usr/lib/x86_64-linux-gnu/ld-linux-x86-
64.so.2 do_lookup_x [self]
----------------------------------------------
---------------------------------
1        6.8e-04  (no location information)
/usr/lib/x86_64-linux-gnu/ld-linux-x86-64.so.2
strcmp
  1        6.8e-04  (no location information)
  /usr/lib/x86_64-linux-gnu/ld-linux-x86-
64.so.2 strcmp [self]
----------------------------------------------
---------------------------------
1        6.8e-04  (no location information)
/usr/lib/x86_64-linux-gnu/libc.so.6
_IO_file_xsputn@@GLIBC_2.2.5
```

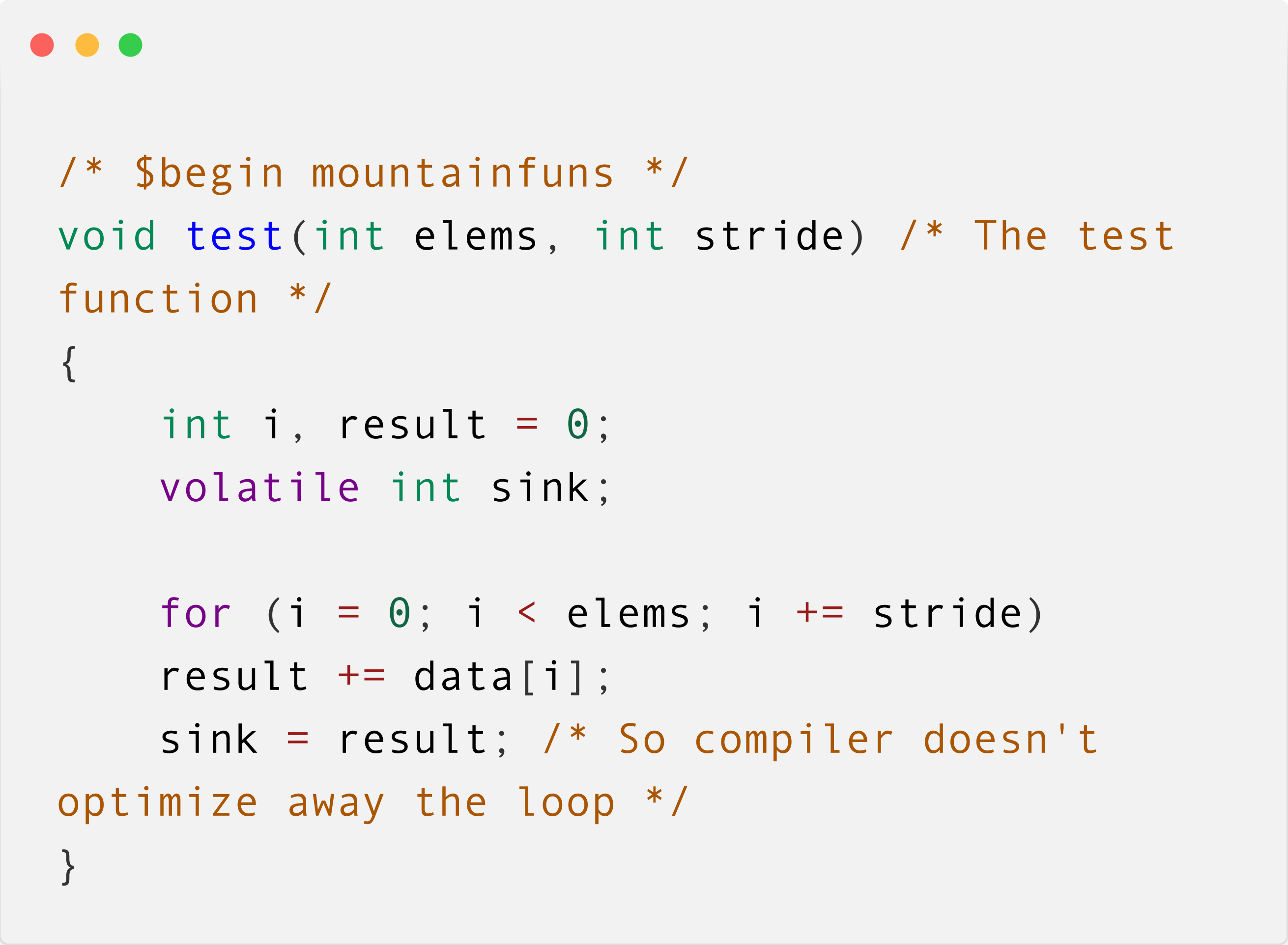
```
  1        6.8e-04  (no location information)
  /usr/lib/x86_64-linux-gnu/libc.so.6
_IO_file_xsputn@@GLIBC_2.2.5 [self]
----------------------------------------------
---------------------------------
1        6.8e-04  (no location information)
/usr/lib/x86_64-linux-gnu/libc.so.6
__memcpy_avx_unaligned_erms
  1        6.8e-04  (no location information)
  /usr/lib/x86_64-linux-gnu/libc.so.6
__memcpy_avx_unaligned_erms [self]
----------------------------------------------
---------------------------------
1        6.8e-04  (no location information)
/usr/lib/x86_64-linux-gnu/libc.so.6
__mpn_lshift
  1        6.8e-04  (no location information)
  /usr/lib/x86_64-linux-gnu/libc.so.6
__mpn_lshift [self]
----------------------------------------------
---------------------------------
1        6.8e-04  (no location information)
/usr/lib/x86_64-linux-gnu/libc.so.6 __mpn_mul
  1        6.8e-04  (no location information)
  /usr/lib/x86_64-linux-gnu/libc.so.6
__mpn_mul [self]
----------------------------------------------
---------------------------------
1        6.8e-04  (no location information)
/usr/lib/x86_64-linux-gnu/libc.so.6
__mpn_mul_1
```

```
  1        6.8e-04  (no location information)
  /usr/lib/x86_64-linux-gnu/libc.so.6
__mpn_mul_1 [self]
----------------------------------------------
---------------------------------
1        6.8e-04  (no location information)
/usr/lib/x86_64-linux-gnu/libc.so.6
__vfprintf_internal
  1        6.8e-04  (no location information)
  /usr/lib/x86_64-linux-gnu/libc.so.6
__vfprintf_internal [self]
----------------------------------------------
---------------------------------
1        6.8e-04  malloc.c:0
/usr/lib/x86_64-linux-gnu/libc.so.6 _int_free
  1        6.8e-04  malloc.c:0
/usr/lib/x86_64-linux-gnu/libc.so.6 _int_free
[self]
----------------------------------------------
---------------------------------
1        6.8e-04  (no location information)
/usr/lib/x86_64-linux-gnu/libc.so.6 free
  1        6.8e-04  (no location information)
  /usr/lib/x86_64-linux-gnu/libc.so.6 free
[self]
----------------------------------------------
---------------------------------
1        6.8e-04  printf_fp.c:0
/usr/lib/x86_64-linux-gnu/libc.so.6 hack_digit
  1        6.8e-04  printf_fp.c:0
  /usr/lib/x86_64-linux-gnu/libc.so.6
hack_digit [self]
```

```
---------------------------------------------------------------------------------
```

显然性能瓶颈在test

test在mountain.c中：



```c
/* $begin mountainfuns */
void test(int elems, int stride) /* The test function */
{
    int i, result = 0;
    volatile int sink;

    for (i = 0; i < elems; i += stride)
    result += data[i];
    sink = result; /* So compiler doesn't optimize away the loop */
}
```

可以看到最后的注释写着“因此编译器不会优化这个循环”

那么优化循环即可。

不难发现循环是取0,stride,2*stride... elems//stride *stride为索引后累加到result上

除了一般人可以想到的减少循环次数（如一次循环对result累加两次）,其实我们还可以去掉volatile，（该关键字告诉编译器不用优化），并使用register关键字来声明int

```
void test(int elems, int stride){

    register int i, result = 0;
    register int sink;
    register int stride2=stride+stride;
    for (i = 0; i < elems; i += stride2){
        result += data[i];
        result+=data[i+stride];
    }

    sink = result; /* So compiler doesn't optimize away the loop */
}
```

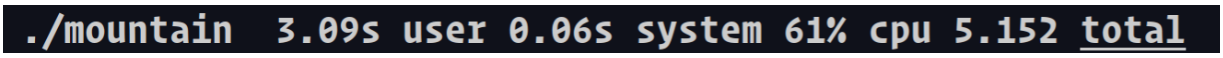
优化至只占87%

```
└─[$]> opreport -l
Using /home/heeler/文档/code/lab/cs-disscussion/sixth/oprofile_data/samples/ for samples directory.
warning: /kvm could not be found.
```

```
CPU: AMD64 generic, speed 3200 MHz (estimated)
Counted CPU_CLK_UNHALTED events (CPU Clocks
not Halted) with a unit mask of 0x00 (No unit
mask) count 100000
samples  %         image name
symbol name
11046    87.6736  mountain
test
1540     12.2232  mountain
main
3         0.0238  mountain
start_counter
2         0.0159  libc.so.6
 __printf_fp_l
2         0.0159  libc.so.6
 __vfprintf_internal
1         0.0079  kvm
 /kvm
1         0.0079  ld-linux-x86-64.so.2
do_lookup_x
1         0.0079  libc.so.6
 __mpn_divrem
1         0.0079  libc.so.6
 _int_free
1         0.0079  libc.so.6
 calloc
1         0.0079  mountain
get_counter
```

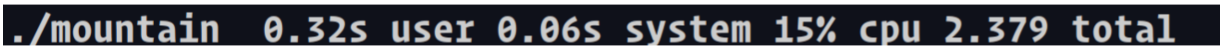
`time ./mountain`生成时间

优化前：



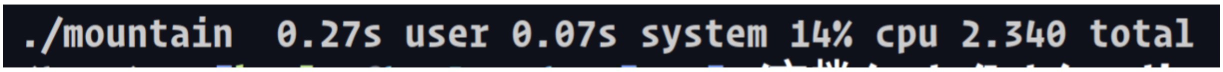
```
./mountain  3.09s user 0.06s system 61% cpu 5.152 total
```

采用上述优化后：



```
./mountain  0.32s user 0.06s system 15% cpu 2.379 total
```

实际上，我们可以大胆一点，在makefile里开启o3甚至o4优化：



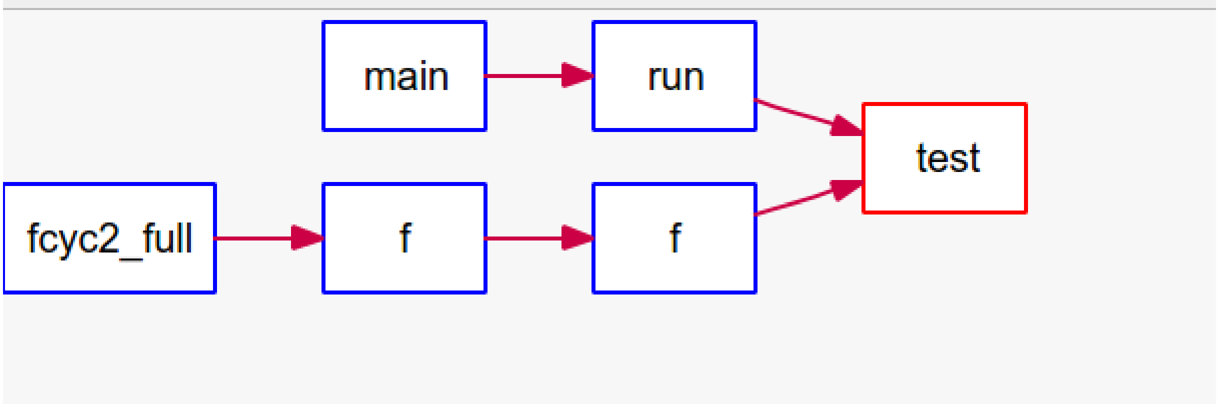
```
./mountain  0.27s user 0.07s system 14% cpu 2.340 total
```

需要指出的是，开启o3优化后性能提升并没有那么明显，实际并没有多大用。

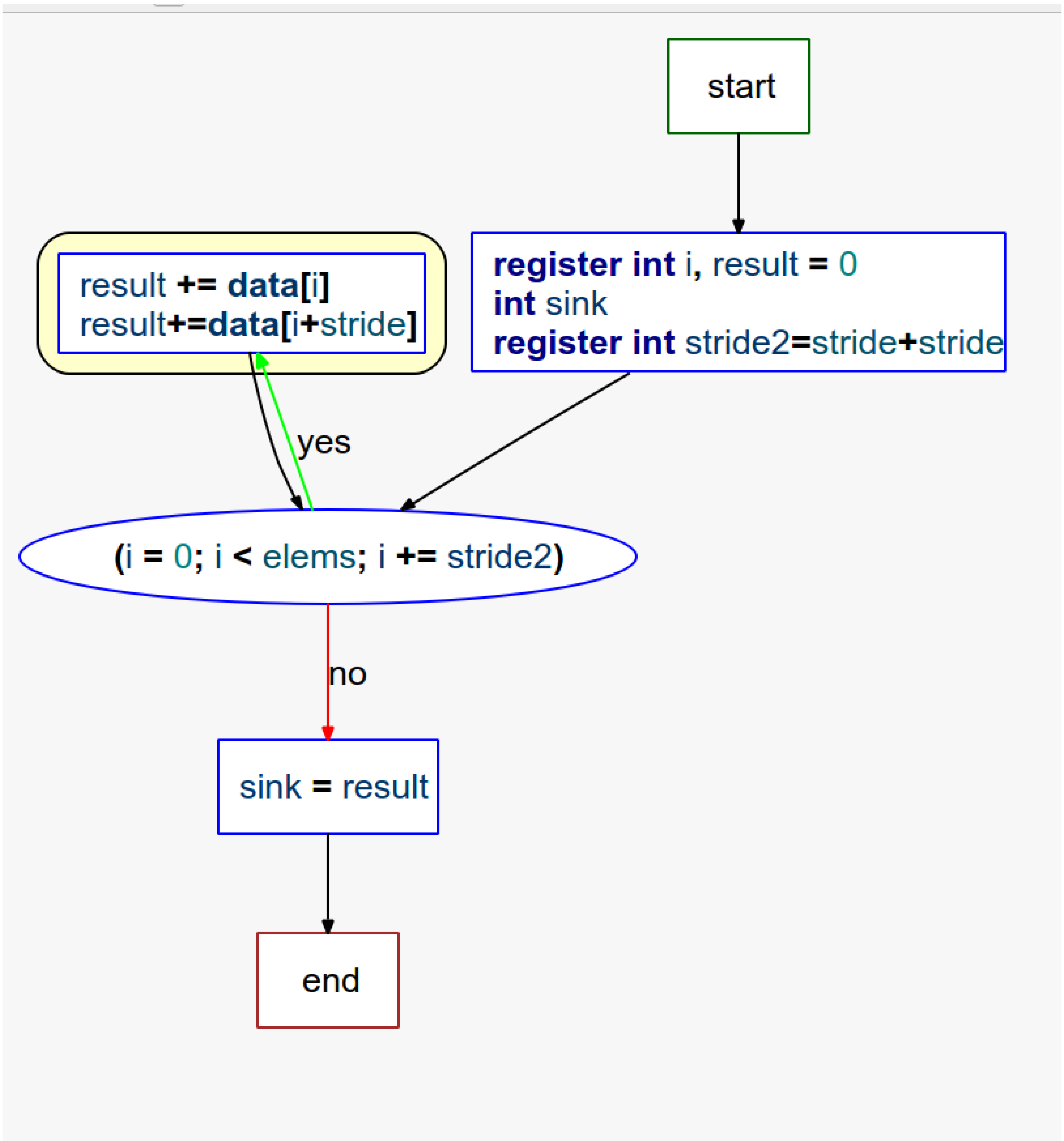
~~老子要用优化卷死你们~~

我们还能做些什么？

这是test的call graph：



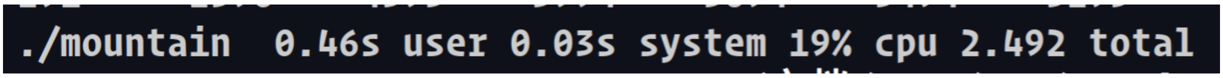
这是test的控制流图：


start
register int i, result = 0
int sink
register int stride2=stride+stride
result += data[i]
result+=data[i+stride]
yes
(i = 0; i < elems; i += stride2)
no
sink = result
end

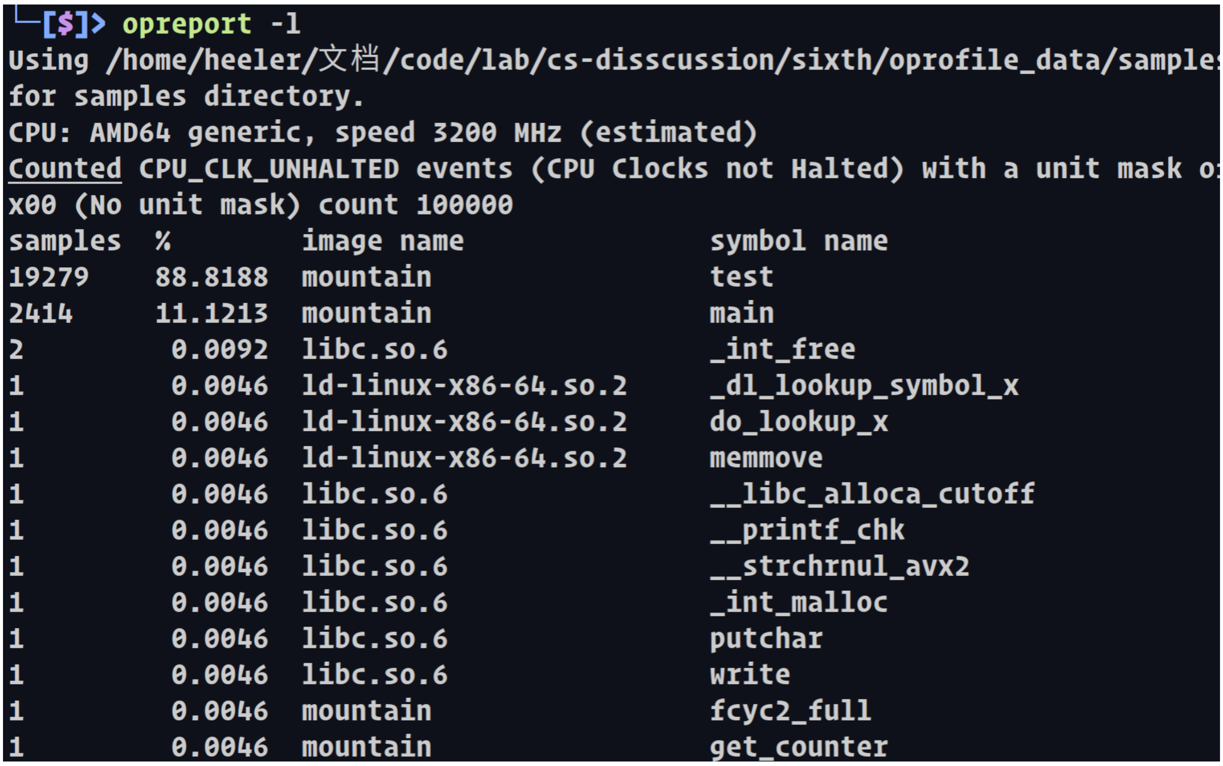
在run函数里面，我们可以看到test实际上就是一个warmup the cache的作用。

那么我也没有什么办法优化了。。。。

值得一提的是，我看到某些同学使用gpu进行并行的矩阵优化，然而并行优化仅在矩阵相乘这种无需条件判断的情况下有较大性能提升，下面是删除“并行化”代码后的结果：

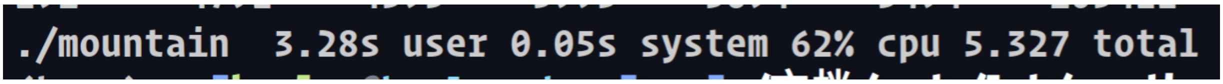


```
./mountain  0.46s user 0.03s system 19% cpu 2.492 total
```

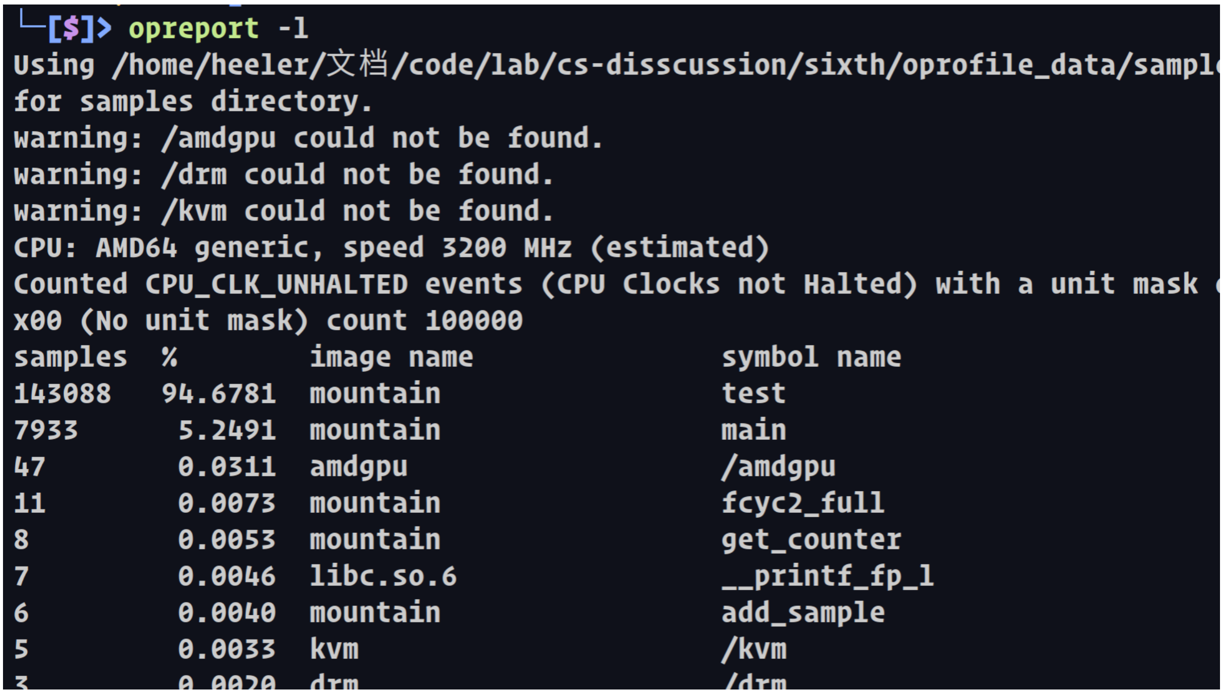


```
└─[$]> opreport -l
Using /home/heeler/文档/code/lab/cs-disscussion/sixth/oprofile_data/sample
for samples directory.
CPU: AMD64 generic, speed 3200 MHz (estimated)
Counted CPU_CLK_UNHALTED events (CPU Clocks not Halted) with a unit mask o
x00 (No unit mask) count 100000
samples  %        image name               symbol name
19279    88.8188  mountain                 test
2414     11.1213  mountain                 main
2         0.0092  libc.so.6                _int_free
1         0.0046  ld-linux-x86-64.so.2     _dl_lookup_symbol_x
1         0.0046  ld-linux-x86-64.so.2     do_lookup_x
1         0.0046  ld-linux-x86-64.so.2     memmove
1         0.0046  libc.so.6                __libc_alloca_cutoff
1         0.0046  libc.so.6                __printf_chk
1         0.0046  libc.so.6                __strchrnul_avx2
1         0.0046  libc.so.6                _int_malloc
1         0.0046  libc.so.6                putchar
1         0.0046  libc.so.6                write
1         0.0046  mountain                 fcyc2_full
1         0.0046  mountain                 get_counter
```

仅有"并行化"代码的结果：



```
./mountain  3.28s user 0.05s system 62% cpu 5.327 total
```



```
└─[$]> opreport -l
Using /home/heeler/文档/code/lab/cs-disscussion/sixth/oprofile_data/sampl
for samples directory.
warning: /amdgpu could not be found.
warning: /drm could not be found.
warning: /kvm could not be found.
CPU: AMD64 generic, speed 3200 MHz (estimated)
Counted CPU_CLK_UNHALTED events (CPU Clocks not Halted) with a unit mask o
x00 (No unit mask) count 100000
samples  %        image name               symbol name
143088   94.6781  mountain                 test
7933      5.2491  mountain                 main
47        0.0311  amdgpu                   /amdgpu
11        0.0073  mountain                 fcyc2_full
8         0.0053  mountain                 get_counter
7         0.0046  libc.so.6                __printf_fp_l
6         0.0040  mountain                 add_sample
5         0.0033  kvm                      /kvm
3         0.0020  drm                      /drm
```