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Optimizing the Spherical Geometry Program

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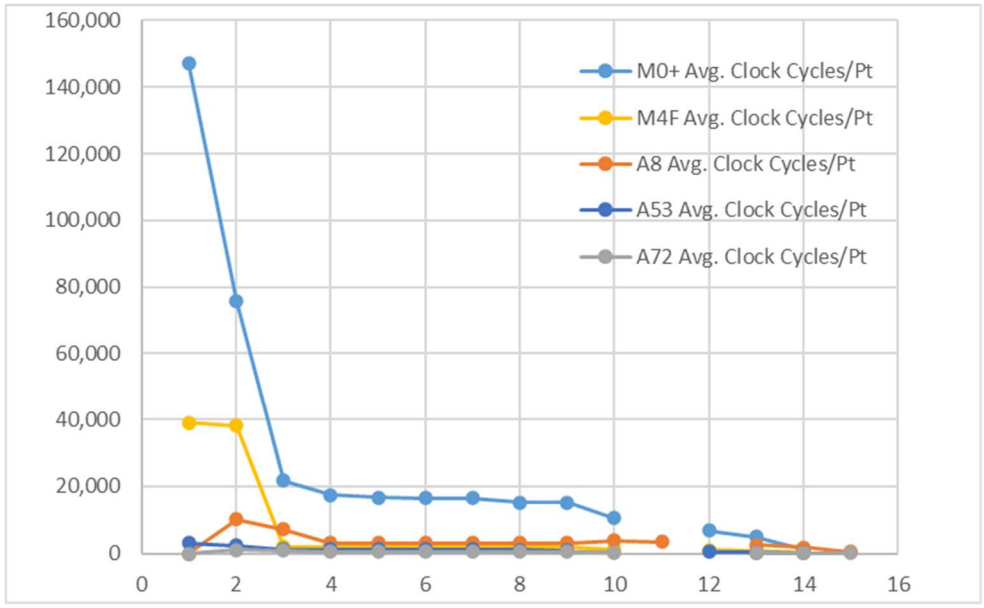
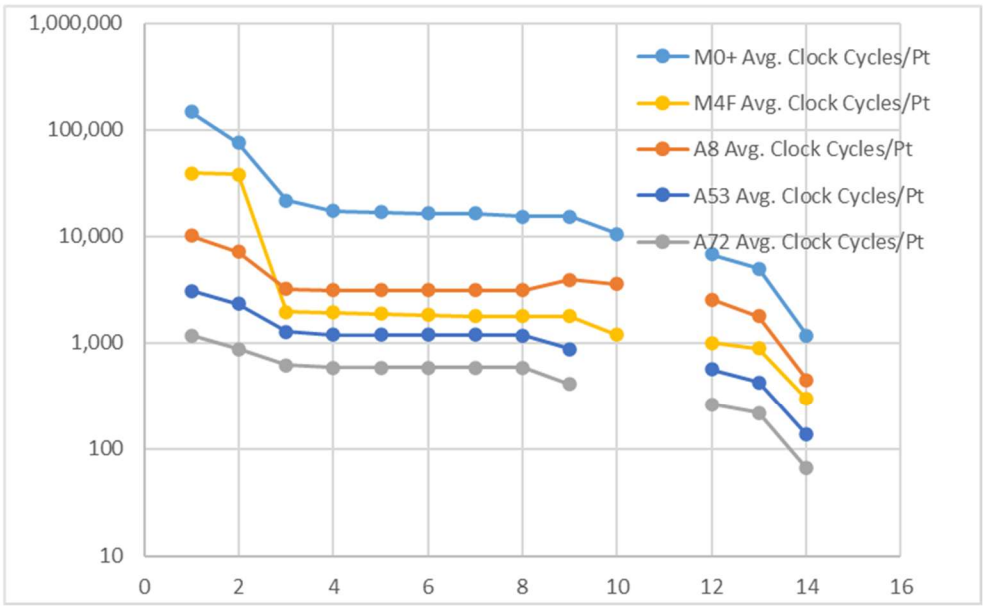
Clock Cycle Count per Point





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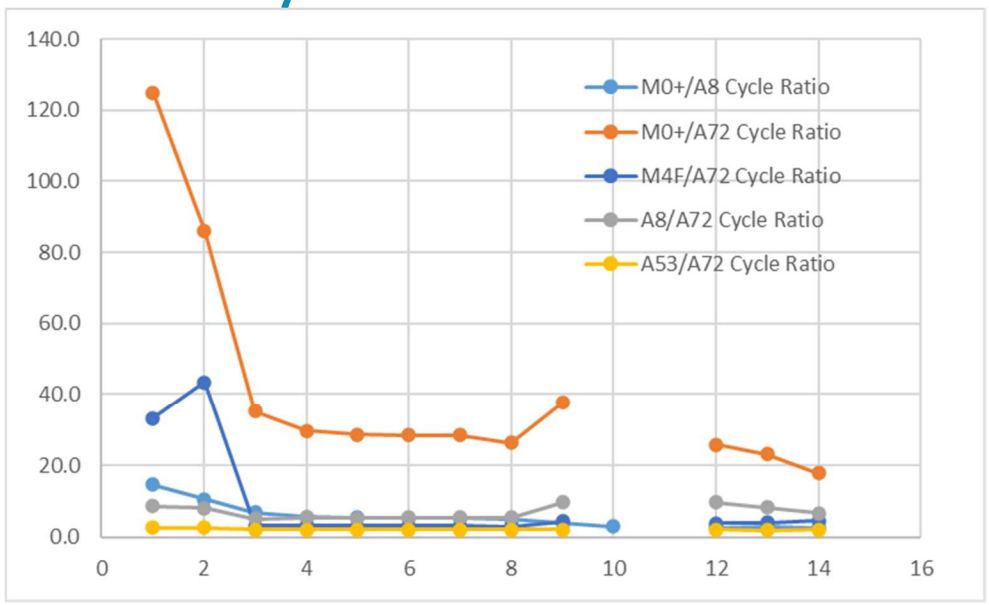
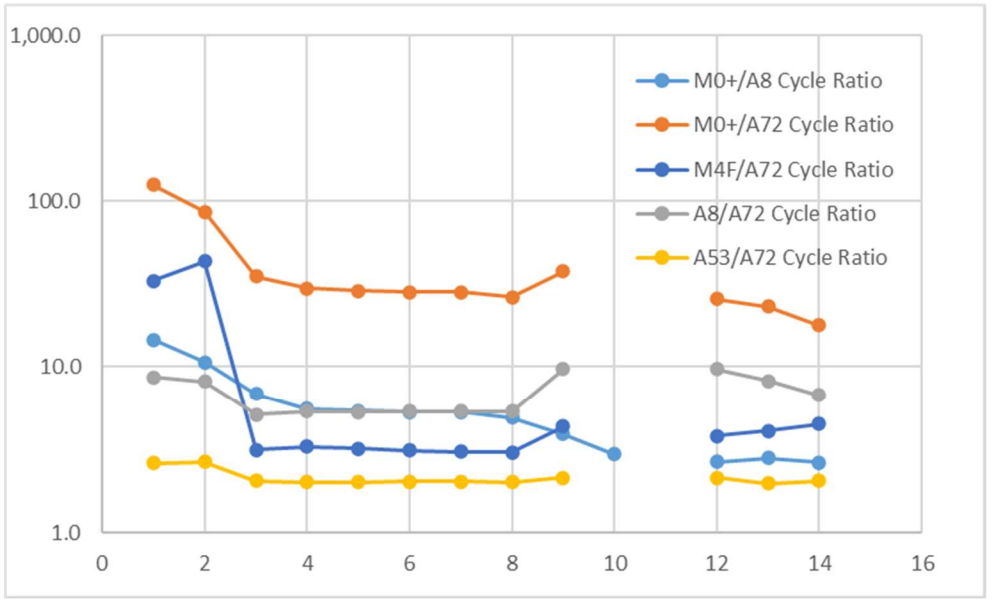
Clock Cycle Count Ratios





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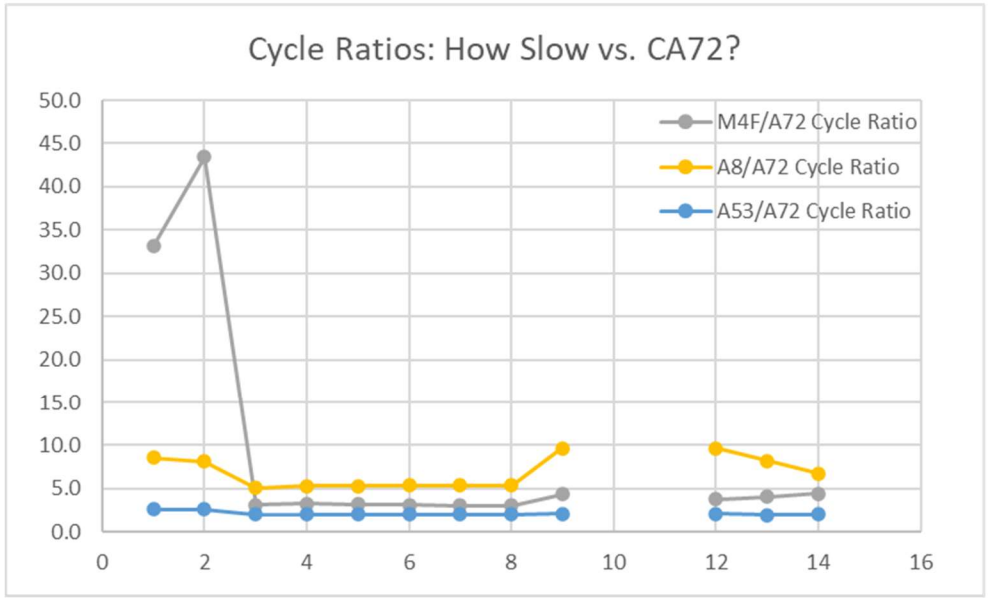
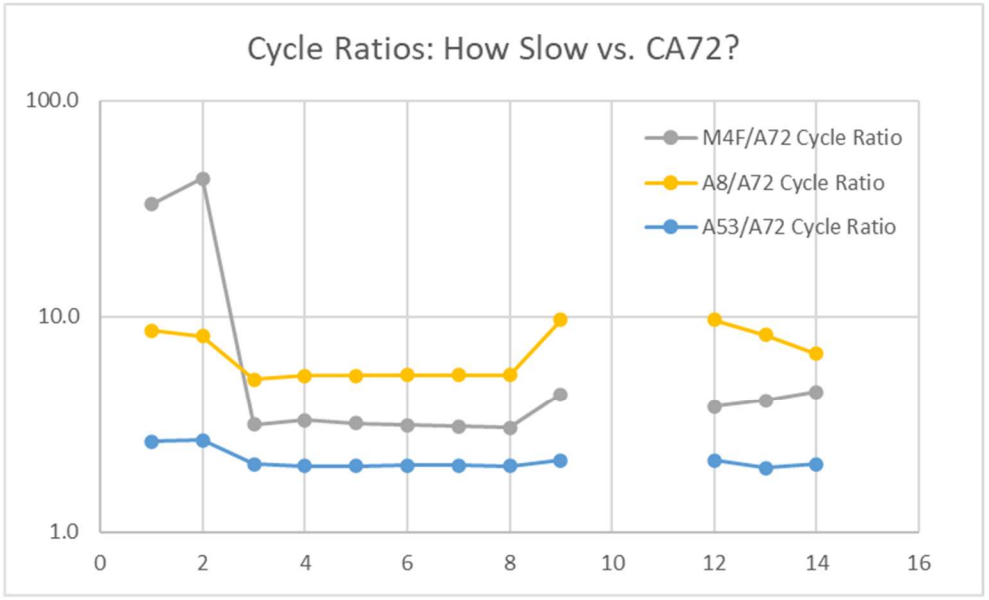
Clock Cycle Count Ratios vs. Cortex-A72 (Arm32)





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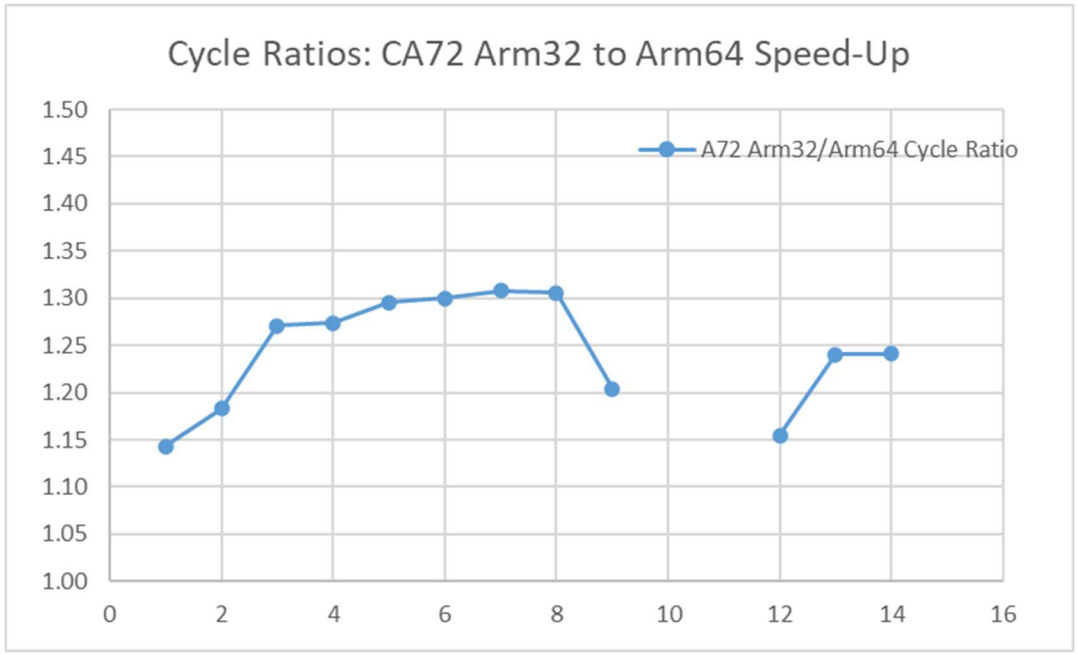
Clock Cycle Count Ratio: Cortex-A72 Arm32 to Arm64



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Analysis Process

- Build, run, update spreadsheet
  - Review spreadsheet
- Gather performance data
  - sudo perf record ./sg
  - sudo perf annotate
    - P saves to text file <symbol_name>.annotation
- Use Ghidra to analyze sg executable
  - Examine top functions

Arm64 Performance: Why so good? And why not even better?

alex@raspberrypi: ~/AES-24/Speed/Scalar/SG2

```
Samples: 2K of event 'cycles:P', Event count (approx.): 1002378189
Overhead  Command  Shared Object       Symbol
  37.97%  sg       sg                  [.] Find_Nearest_Waypoint
  21.01%  sg       sg                  [.] __cosf
   9.91%  sg       sg                  [.] strcmp
   9.25%  sg       [kernel.kallsyms]   [k] el0_svc
   8.61%  sg       [kernel.kallsyms]   [k] _raw_spin_unlock_irqrestore
   5.50%  sg       [vdso]              [.] __kernel_clock_gettime
   0.78%  sg       [kernel.kallsyms]   [k] _raw_spin_lock_irqsave
   0.52%  sg       [kernel.kallsyms]   [k] __arm64_sys_clock_gettime
   0.48%  sg       sg                  [.] __atan2f
   0.45%  sg       [kernel.kallsyms]   [k] el0_svc_common.constprop.0
   0.41%  sg       sg                  [.] __sincosf
   0.41%  sg       sg                  [.] __clock_gettime
   0.41%  sg       [kernel.kallsyms]   [k] posix_cpu_clock_get
```

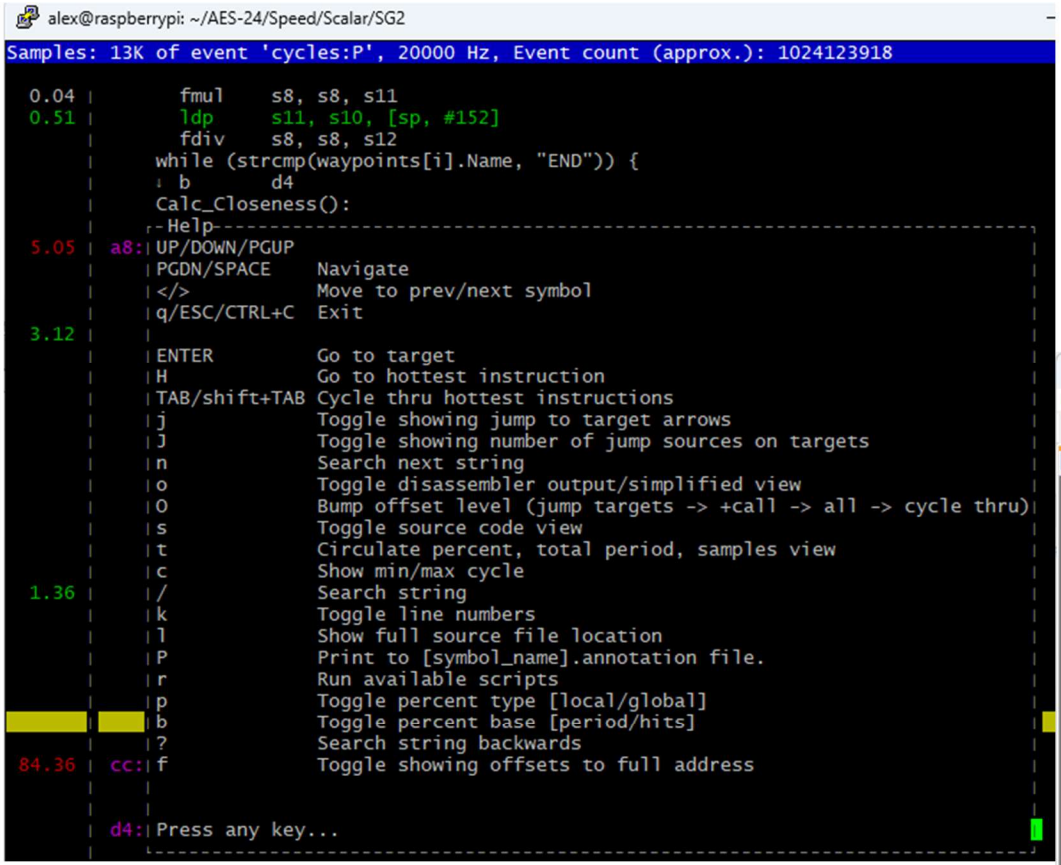
- Sanity check on results
  - Find_Nearest_Waypoint – OK, expected
  - __cosf – OK, expected
  - strcmp – OK, surprised it takes so much time
  - el0_svc – What is this? 9.25%
  - _raw_spin_unlock_irqrestore – What is this? 8.61%
  - __kernel_clock_gettime – Big! 5.50%
- P: Save this to perf.hist.N

alex@raspberrypi: ~/AES-24/Speed/Scalar/SG2

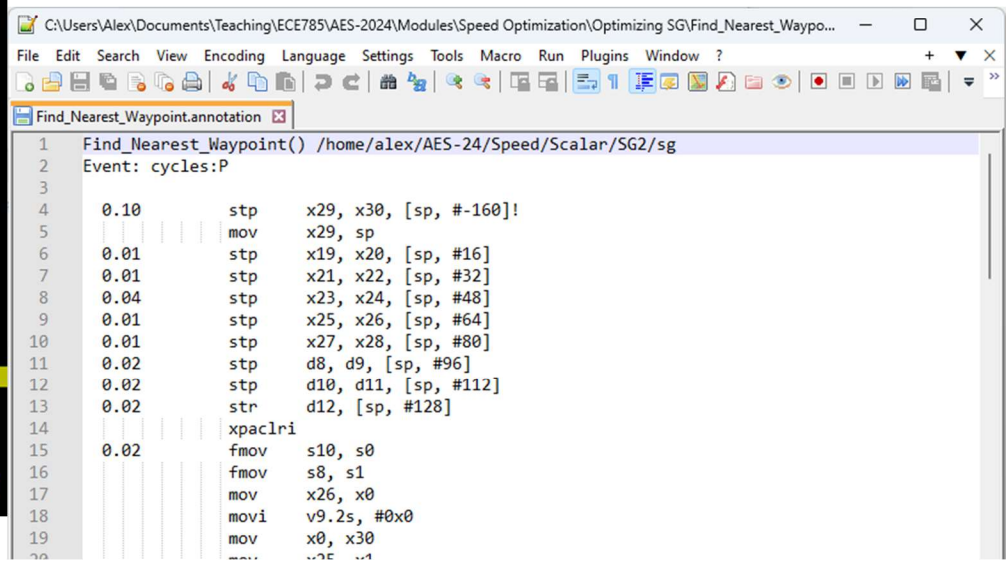
```
Samples: 13K of event 'cycles:P', Event count (approx.): 1024123918
Overhead  Command  Shared Object       Symbol
  39.42%  sg       sg                  [.] Find_Nearest_Waypoint
  22.34%  sg       sg                  [.] __cosf
  10.49%  sg       sg                  [.] strcmp
   8.33%  sg       [kernel.kallsyms]   [k] _raw_spin_unlock_irqrestor
   7.77%  sg       [kernel.kallsyms]   [k] el0_svc
   4.59%  sg       [vdso]              [.] __kernel_clock_gettime
   0.56%  sg       sg                  [.] __atan2f
   0.50%  sg       [kernel.kallsyms]   [k] __arm64_sys_clock_gettime
   0.46%  sg       [kernel.kallsyms]   [k] _raw_spin_lock_irqsave
   0.44%  sg       sg                  [.] __sincosf
   0.39%  sg       sg                  [.] __clock_gettime
   0.39%  sg       sg                  [.] __ieee754_atan2f
```

- Rerun with higher sampling frequency to get more than 2K samples:
  - sudo perf record -F 20000 ./sg
  - get 13K samples
- Repeat the sanity check
  - Similar results, so probably ok

Nice Perf Annotate Features



- h: Get this help screen
- p: Toggle percentage between local (this function) and global (entire program)
- t: Cycle percent -> period -> # samples -> …
- o, s, k: Toggle code listing
- P: Save to [symbol_name].annotation file



Try to Fill in Holes Between Samples

- Do these instructions ***really*** all complete in the same clock cycle?
- Maybe they don't but are missed by sampling
  - Program was sampled at 20 kHz, got 13,000 samples.
- Get more samples
  - Raise sampling frequency even more to 100 kHz
  - Increase program run time by raising NUM_TESTS to 1,000,000
- Now get 888,290 samples
- Eliminate possible truncation by display sample count, not percentage

Find_Nearest_Waypoint.annotation | __cosf.annotation

```
43    0.20          ldp     s11, s10, [sp, #152]
44                  fdiv    s8, s8, s12
45                ↓ b       d4
46    1.99    a8:   ldur    s0, [x19, #-4]
47                  fsub    s0, s0, s8
48                → bl      __cosf
49    1.23          ldp     s2, s1, [x19, #-12]
50                  fmul    s1, s11, s1
51                  fmul    s0, s1, s0
52                  fmadd   s0, s10, s2, s0
53    0.54          fcmpe   s9, s0
54                ↓ b.mi    194
55   33.26    cc:   add     w20, w20, #0x1
56                  add     x19, x19, #0x28
57             d4:  mov     x1, x21
58                  mov     x0, x19
59    0.08        → bl      strcmp
60    0.06        ↑ cbnz    w0, a8
61                  fmov    s0, s9
62                  sbfiz   x19, x22, #2, #32
63                  add     x19, x19, w22, sxtw
64                → bl      __acosf
65    0.03          mov     w0, #0x1800
```

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Comparison: 13k vs. 888k samples

Find_Nearest_Waypoint.annotation | __cosf.annotation

```
43   0.20          ldp    s11, s10, [sp, #152]
44                 fdiv   s8, s8, s12
45               ↓ b      d4
46   1.99    a8:   ldur   s0, [x19, #-4]
47                 fsub   s0, s0, s8
48               → bl     __cosf
49   1.23          ldp    s2, s1, [x19, #-12]
50                 fmul   s1, s11, s1
51                 fmul   s0, s1, s0
52                 fmadd  s0, s10, s2, s0
53   0.54          fcmpe  s9, s0
54               ↓ b.mi   194
55  33.26    cc:   add    w20, w20, #0x1
56                 add    x19, x19, #0x28
57         d4:     mov    x1, x21          New!
58                 mov    x0, x19
59   0.08        → bl     strcmp
60   0.06        ↑ cbnz   w0, a8
61                 fmov   s0, s9           New!
62                 sbfiz  x19, x22, #2, #32
63                 add    x19, x19, w22, sxtw
64               → bl     __acosf
65   0.03          mov    w0, #0x1800
```

Find_Nearest_Waypoint.annotation

```
43      765056          ldp    s11, s10, [sp, #152]
44                      fdiv   s8, s8, s12
45                    ↓ b      d4
46   248473989    a8:   ldur   s0, [x19, #-4]
47                      fsub   s0, s0, s8
48                    → bl     __cosf
49   141652362          ldp    s2, s1, [x19, #-12]
50                      fmul   s1, s11, s1
51                      fmul   s0, s1, s0
52                      fmadd  s0, s10, s2, s0
53    68382855          fcmpe  s9, s0
54                    ↓ b.mi   194
55  4021122350    cc:   add    w20, w20, #0x1
56                      add    x19, x19, #0x28
57       13359    d4:   mov    x1, x21
58                      mov    x0, x19
59     4093965        → bl     strcmp
60     3981251        ↑ cbnz   w0, a8
61     1299935          fmov   s0, s9
62                      sbfiz  x19, x22, #2, #32
63                      add    x19, x19, w22, sxtw
64                    → bl     __acosf
65     2891705          mov    w0, #0x1800
```

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Latest Profile

alex@raspberrypi: ~/AES-24/Speed/Scalar/SG2

```
Samples: 888K of event 'cycles:P', Event count (approx.): 11898345696
Overhead  Command  Shared Object       Symbol
  38.73%  sg       sg                  [.] Find_Nearest_Waypoint
  22.84%  sg       sg                  [.] __cosf
  10.56%  sg       [kernel.kallsyms]   [k] _raw_spin_unlock_irqrestore
  10.43%  sg       sg                  [.] strcmp
   7.27%  sg       [kernel.kallsyms]   [k] el0_svc
   3.43%  sg       [vdso]              [.] __kernel_clock_gettime
   0.76%  sg       [kernel.kallsyms]   [k] _raw_spin_lock_irqsave
   0.64%  sg       sg                  [.] __atan2f
   0.56%  sg       [kernel.kallsyms]   [k] __arm64_sys_clock_gettime
   0.40%  sg       sg                  [.] __ieee754_atan2f
   0.37%  sg       [kernel.kallsyms]   [k] posix_cpu_clock_get
   0.36%  sg       [kernel.kallsyms]   [k] invoke_syscall
   0.34%  sg       [kernel.kallsyms]   [k] put_timespec64
   0.32%  sg       [kernel.kallsyms]   [k] el0_svc_common.constprop.0
   0.29%  sg       [kernel.kallsyms]   [k] do_el0_svc
   0.29%  sg       sg                  [.] __sincosf
   0.27%  sg       sg                  [.] __atanf
   0.27%  sg       [kernel.kallsyms]   [k] __arch_copy_to_user
```

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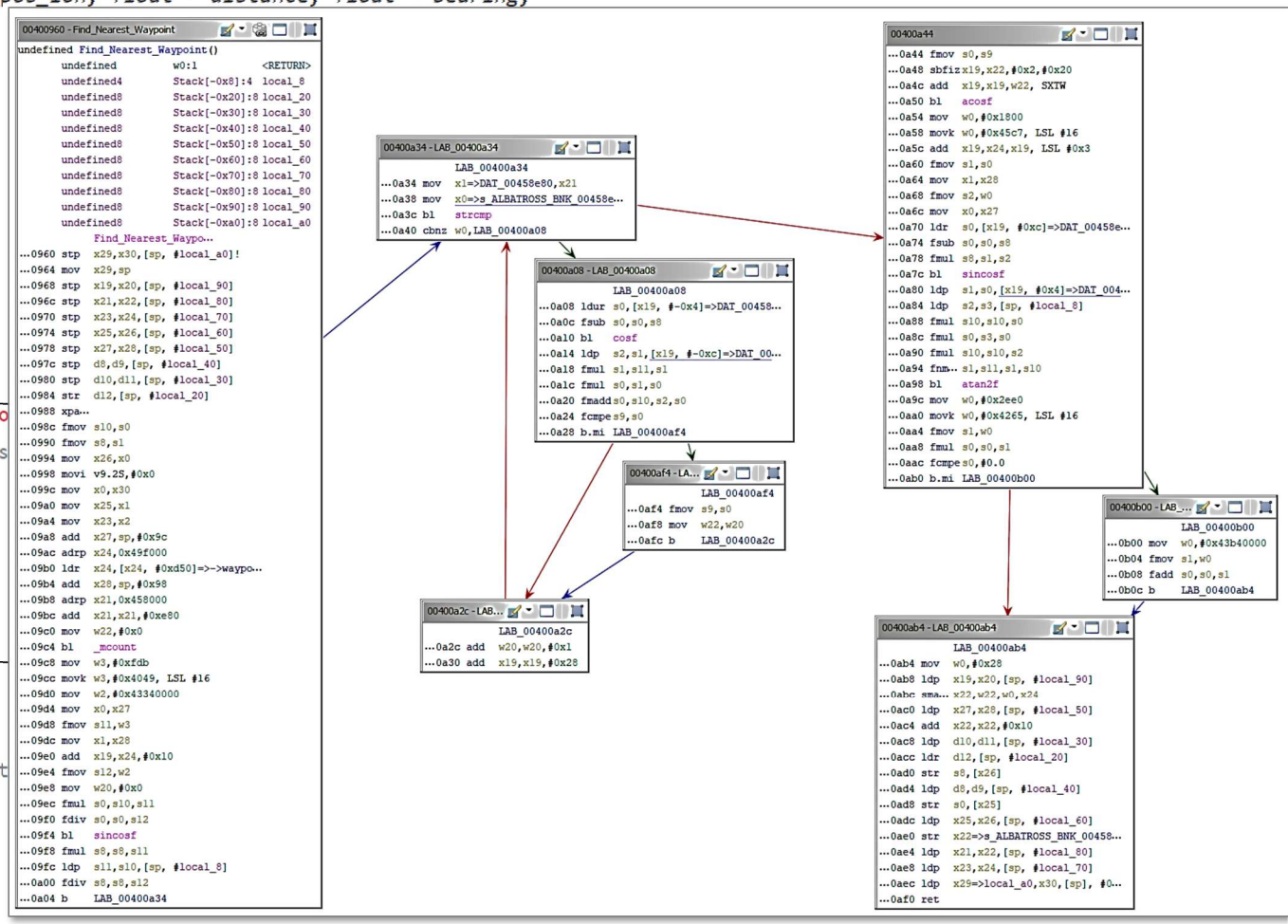
Find_Nearest_Waypoint: 38.7% of Program's Time

```
void Find_Nearest_Waypoint(float cur_pos_lat, float cur_pos_lon, float * distance, float * bearing,
                           char  * * name) {
  // cur_pos_lat and cur_pos_lon are in degrees
  // distance is in kilometers
  // bearing is in degrees

  int i=0, closest_i=0;
  PT_T ref;
  float d, b, c, max_c=0, closest_d=1E10;

  while (strcmp(waypoints[i].Name, "END")) {
    c = Calc_Closeness(&ref, &(waypoints[i]) );
    if (c>max_c) {
      max_c = c;
      closest_i = i;
    }
    i++;
  }

  // Finish calcuations for the closest point
  b = Calc_Bearing(&ref, &(waypoints[closest_i]) );

  // return information to calling function about closest
  *distance = d;
  *bearing = b;
  *name = (char * ) (waypoints[closest_i].Name);
}
```

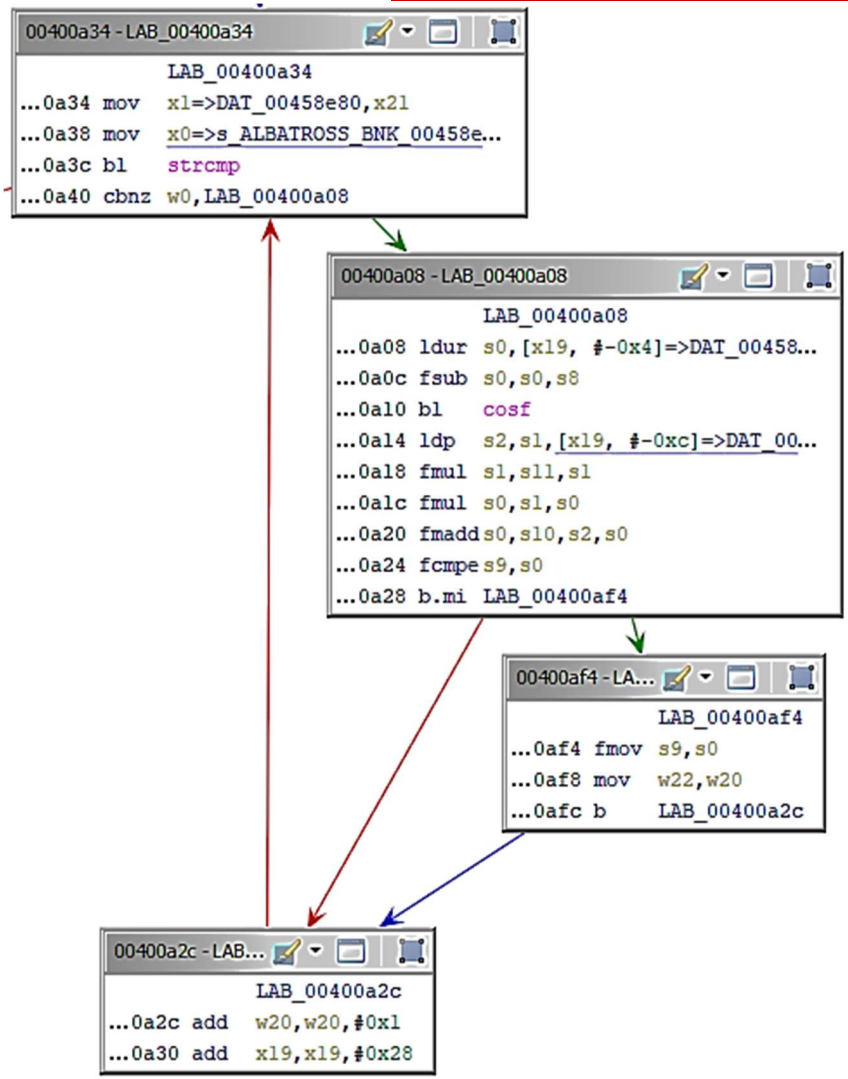
```
float Calc_Closeness( PT_T * p1,  co
  // calculates closeness (decreases

  return p1->SinLat * p2->SinLat +
    p1->CosLat * p2->CosLat*
    cosf(p2->Lon - p1->Lon);
}
```



Find_Nearest_Waypoint Loop

```
while (strcmp(waypoints[i].Name, "END")) {
  c = Calc_Closeness(&ref, &(waypoints[i]) );
    return p1->SinLat * p2->SinLat +
      p1->CosLat * p2->CosLat*
      cosf(p2->Lon - p1->Lon);
  if (c>max_c) {
    max_c = c;
    closest_i = i;
  }
  i++;
}
```

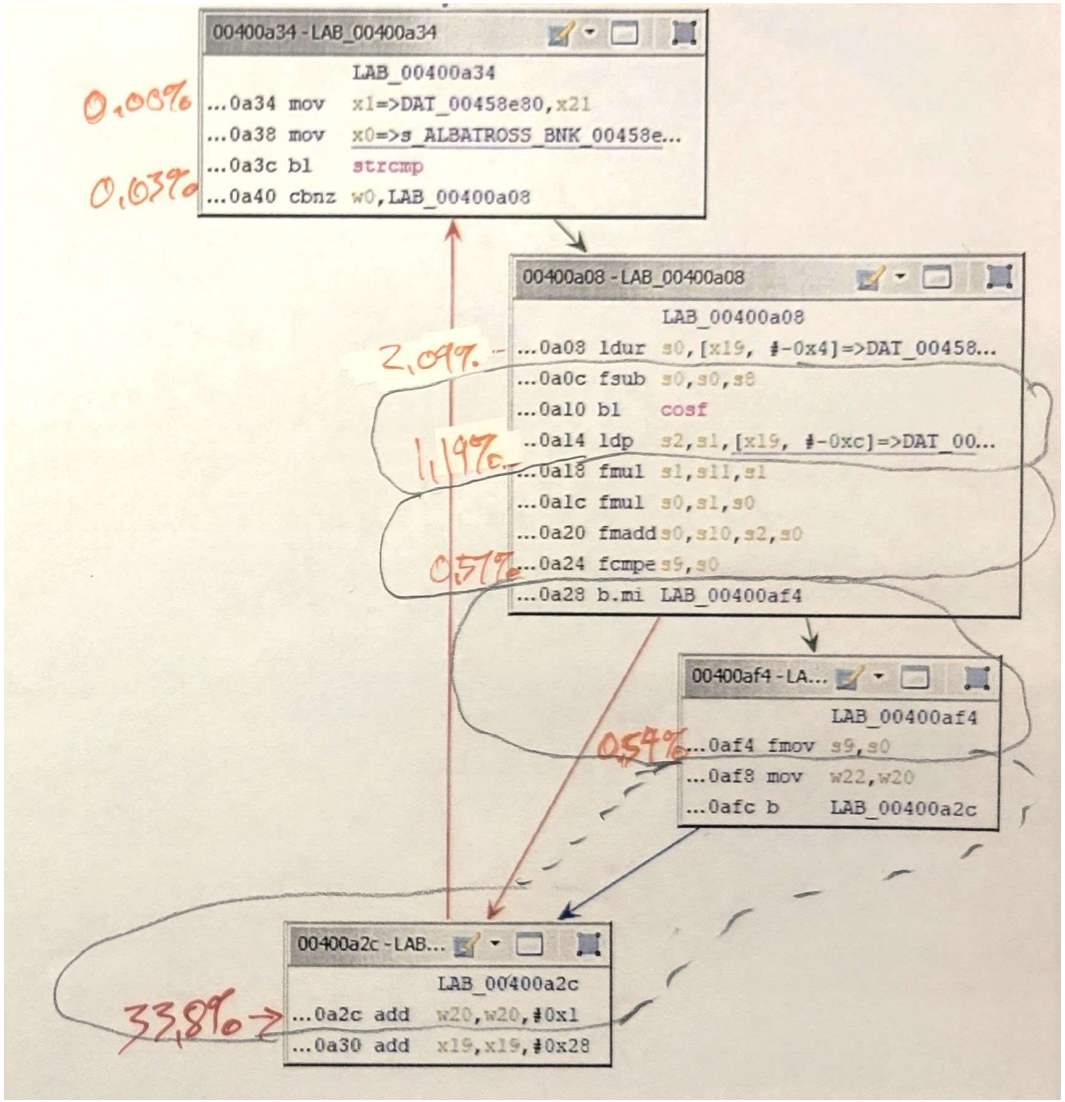
- What is going on here? Mark up hot instructions from annotation information



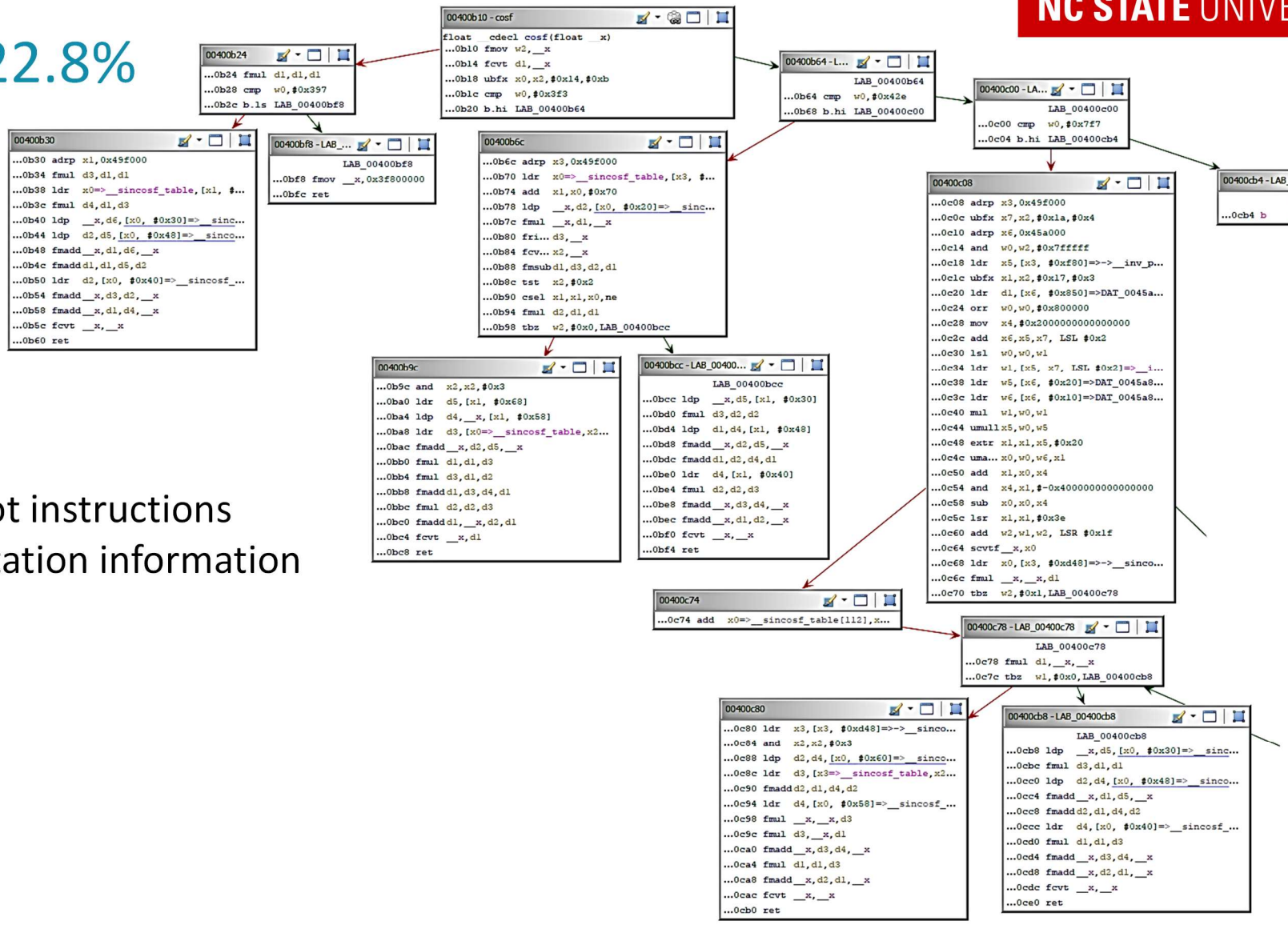
Find_Nearest_Waypoint Loop

```
while (strcmp(waypoints[i].Name, "END")) {
  c = Calc_Closeness(&ref, &(waypoints[i]) );
    return p1->SinLat * p2->SinLat +
      p1->CosLat * p2->CosLat*
      cosf(p2->Lon - p1->Lon);
  if (c>max_c) {
    max_c = c;
    closest_i = i;
  }
  i++;
}
```

- What is going on here? Mark up hot instructions from annotation information

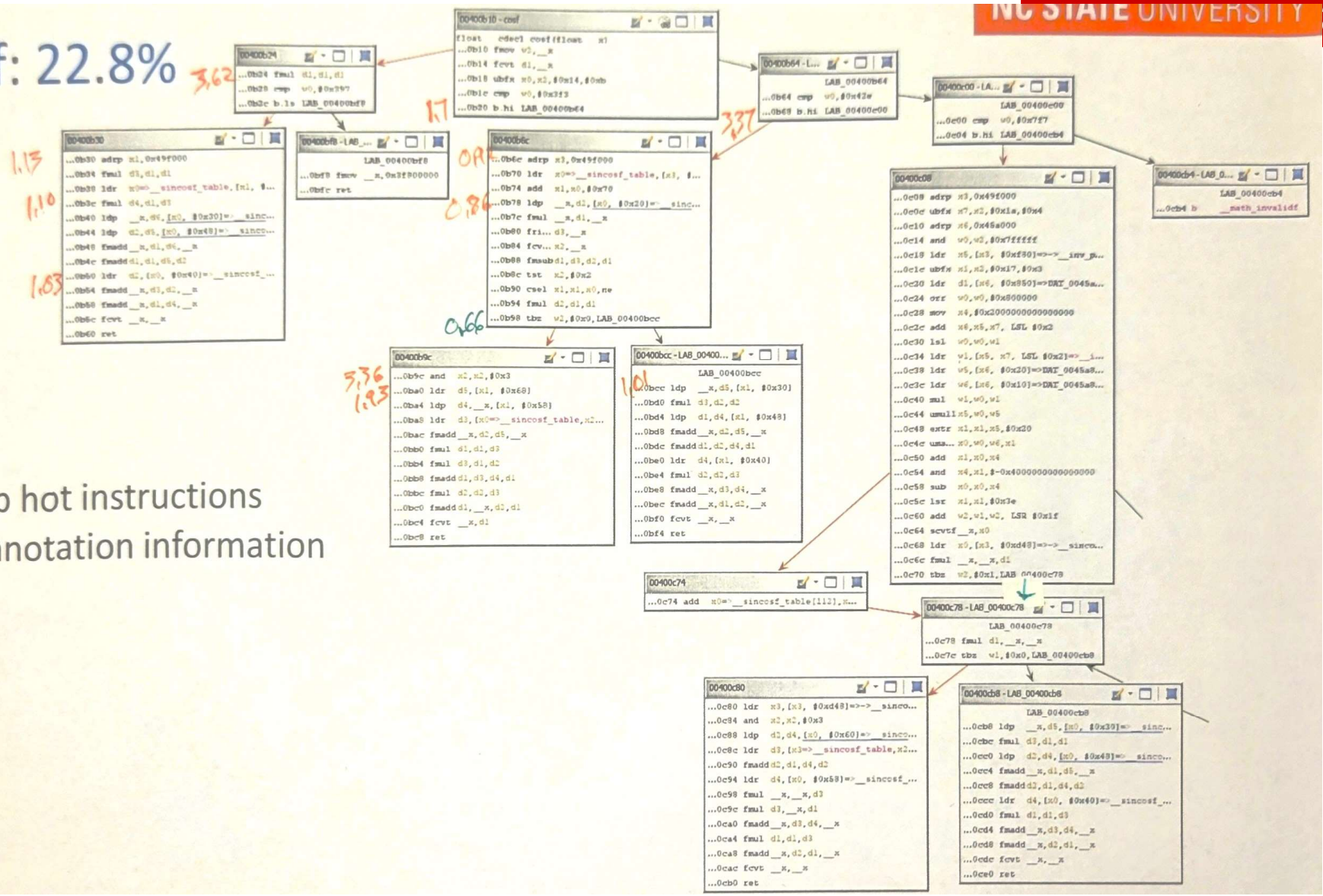


__cosf: 22.8%



- Mark up hot instructions from annotation information

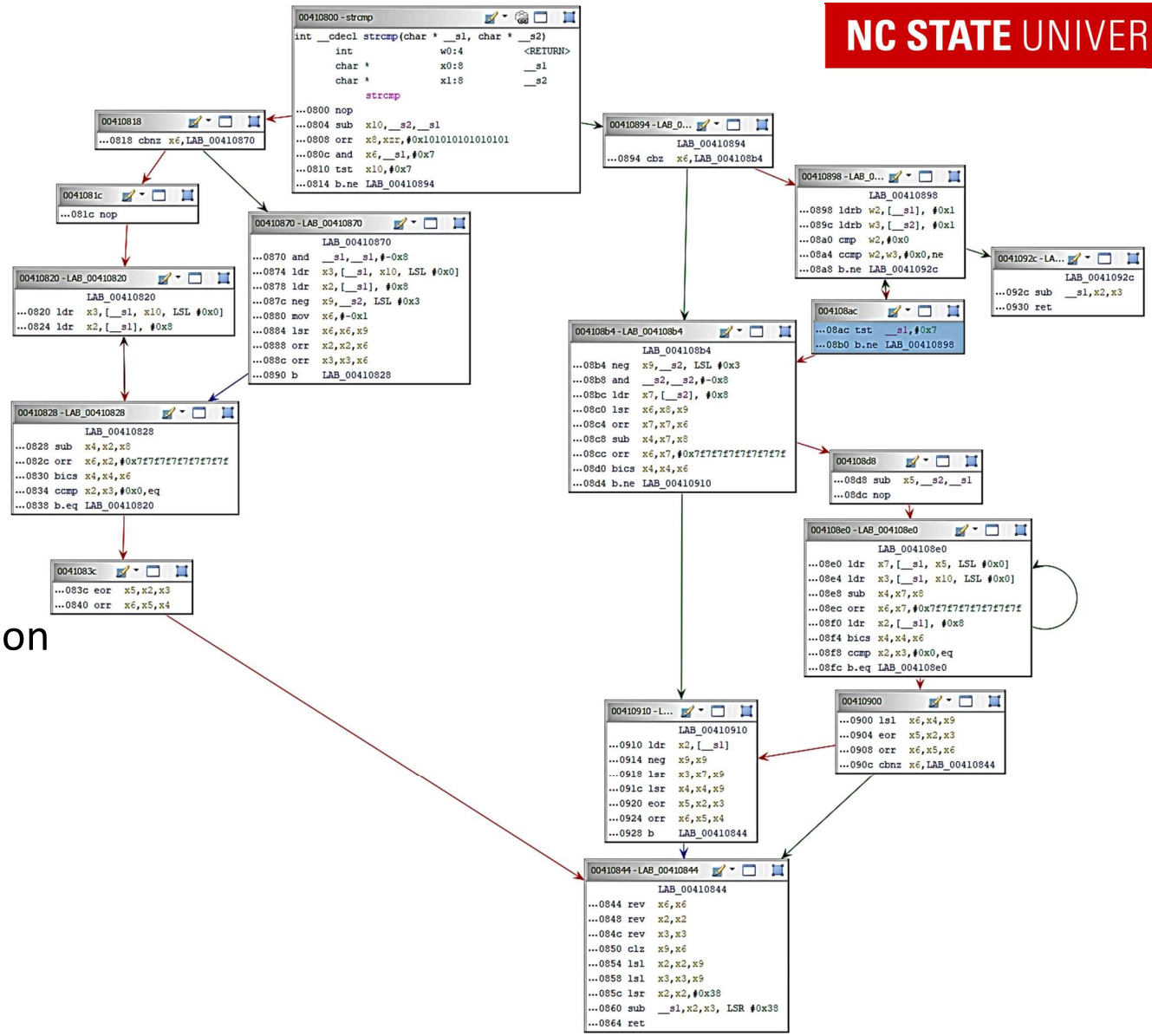
__cosf: 22.8%



- Mark up hot instructions from annotation information

strcmp: 10.4%

- Mark up hot instructions from annotation information



strcmp: 10.5%

- Mark up hot instructions from annotation information