Benchmarking:
You're Doing It Wrong

DEVNEXUS™

Aysylu Greenberg

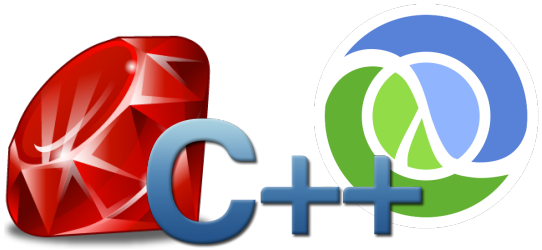
@aysylu22

Google

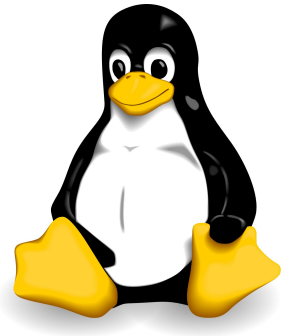
Loom

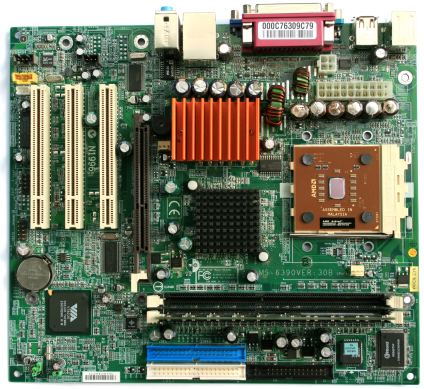

BENCHMARKING
YOU'RE DOING IT WRONG
imgflip.com

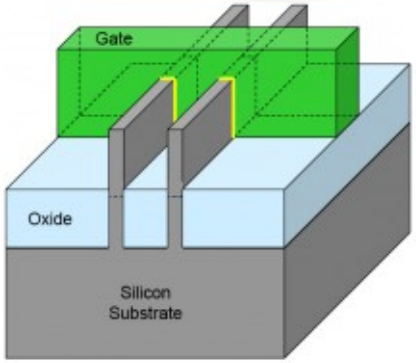
To Write Good Benchmarks…



Need to be Full Stack







Benchmark = How Fast?

your process vs goal

your process vs best practices

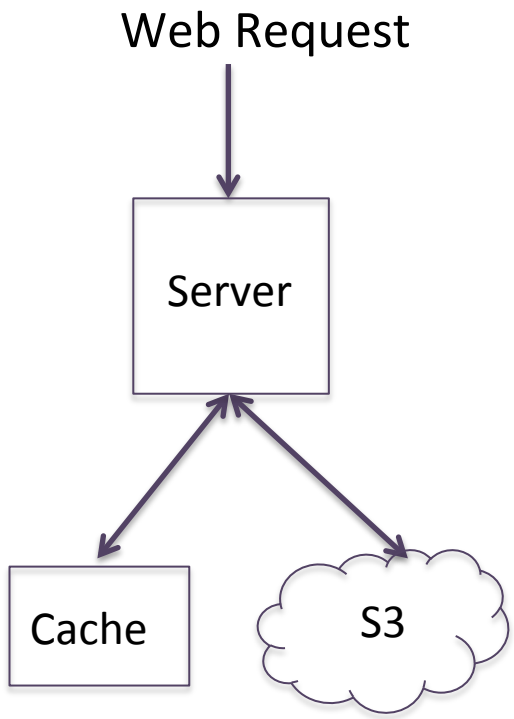
Today

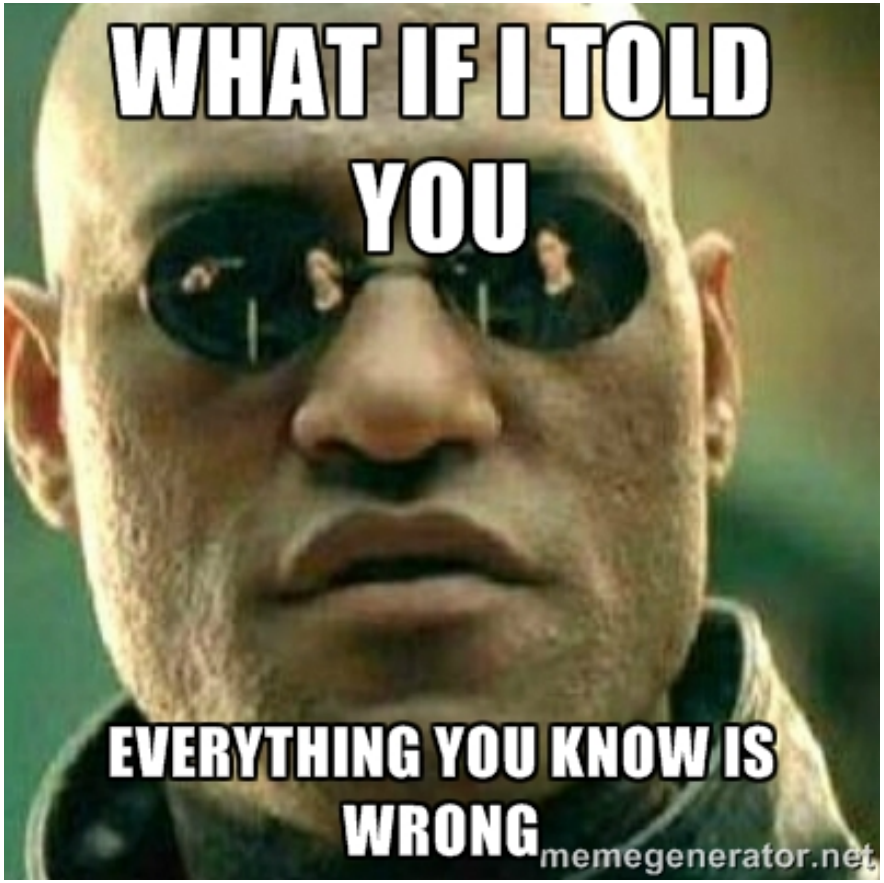
- How Not to Write Benchmarks
- Benchmark Setup & Results:
  - You're wrong about machines
  - You're wrong about stats
  - You're wrong about what matters
- Becoming Less Wrong

HOW NOT TO WRITE BENCHMARKS

Website Serving Images

- Access 1 image 1000 times
- Latency measured for each access
- Start measuring immediately
- 3 runs
- Find mean
- Dev environment



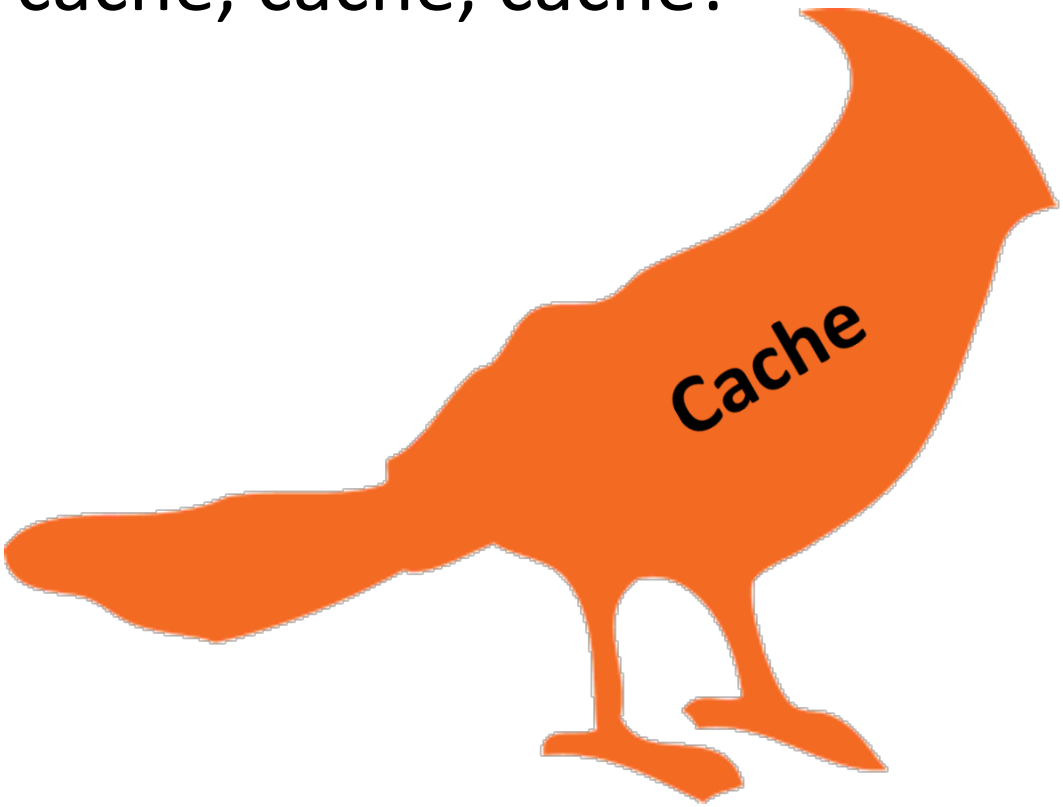


WHAT'S WRONG WITH THIS BENCHMARK?

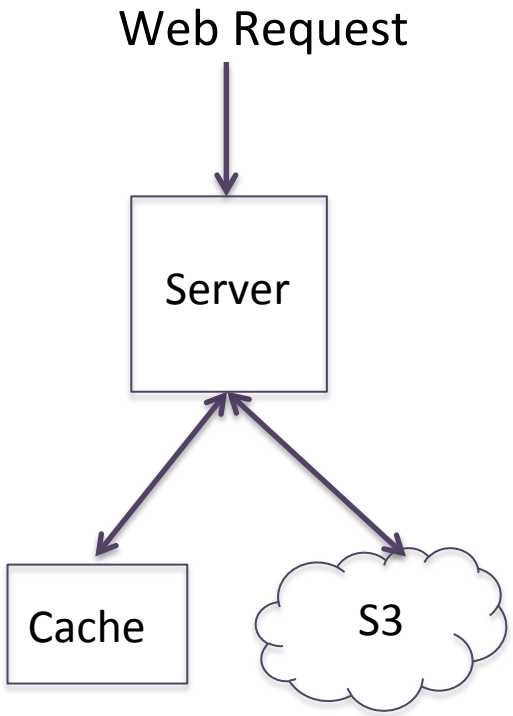
YOU'RE WRONG ABOUT THE MACHINE

Wrong About the Machine

- Cache, cache, cache, cache!



It’s Caches All The Way Down



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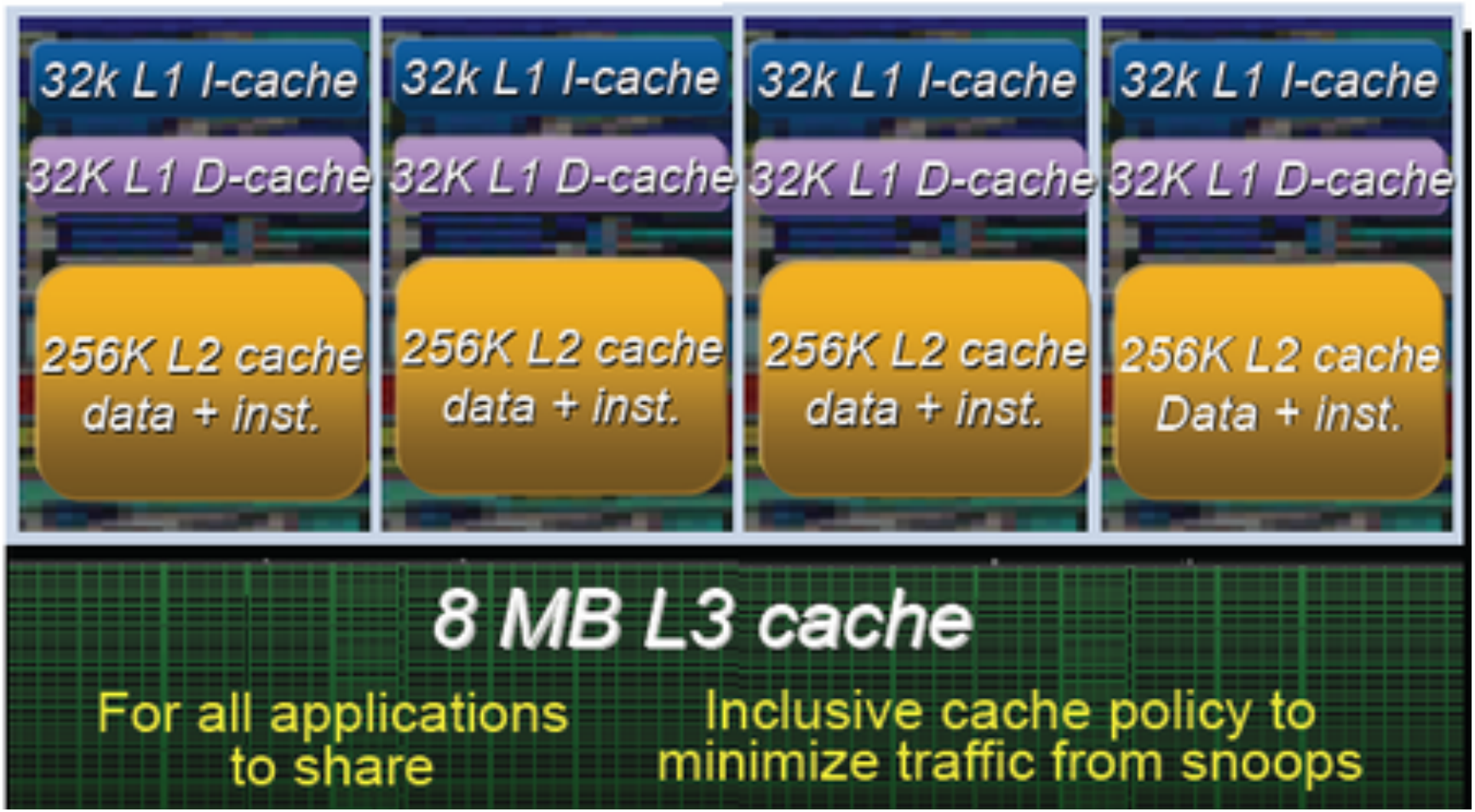
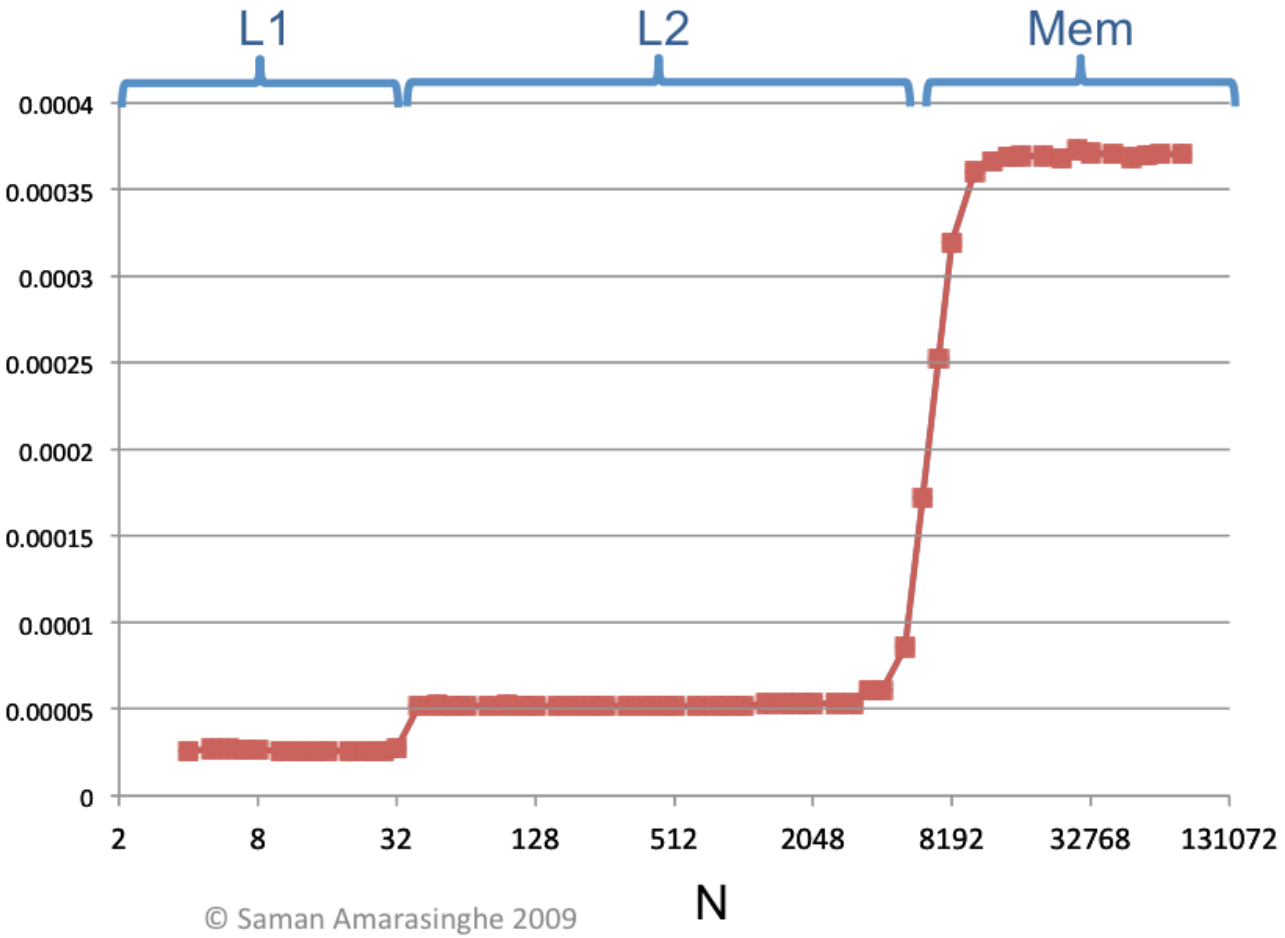


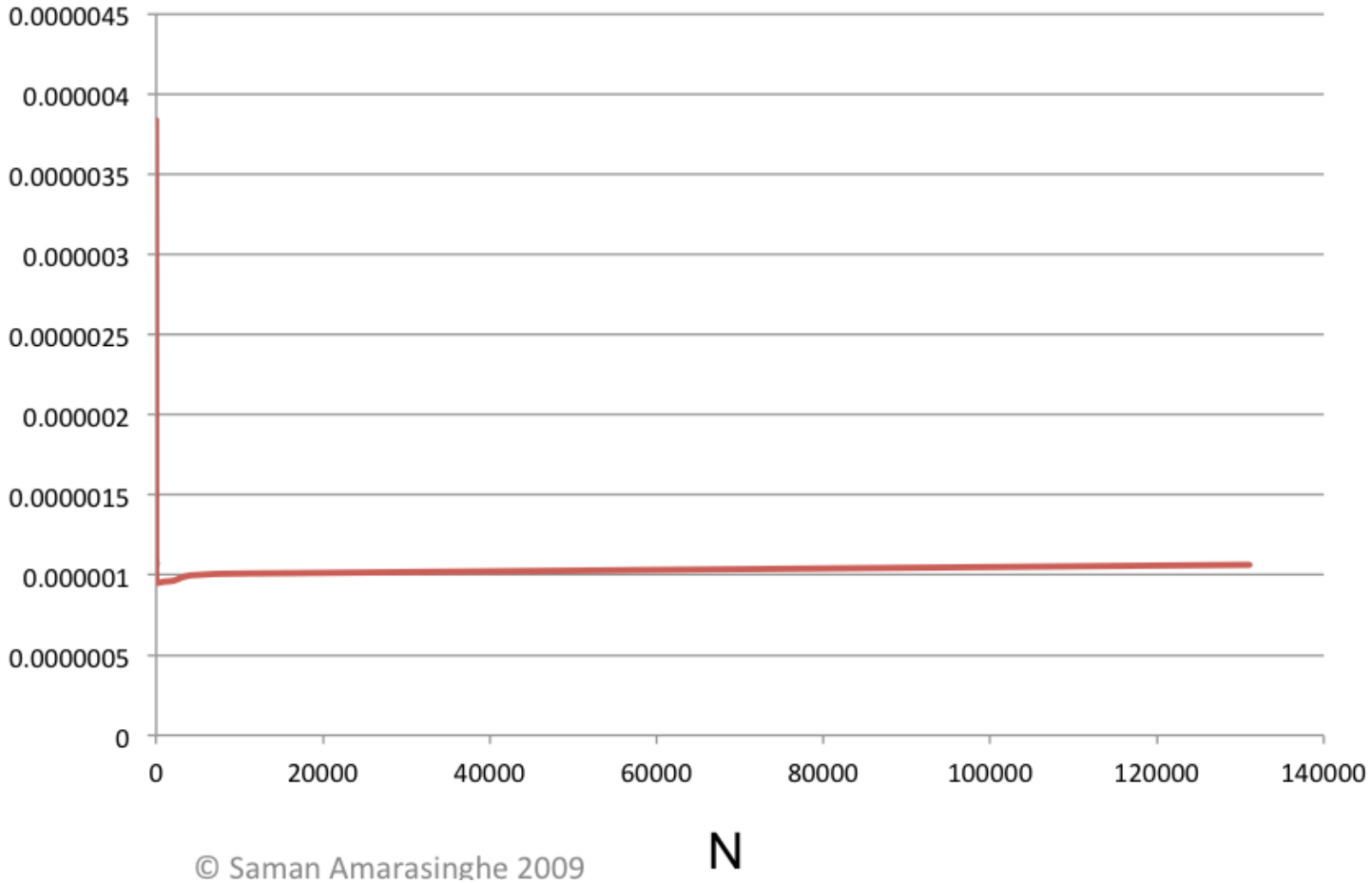
Prefetching: Program

```
for(rep=0; rep < REP; rep++)
    for(a=0; a <  N ; a++)
        A[a] = A[a] +  1;
```

Prefetching: Disabled

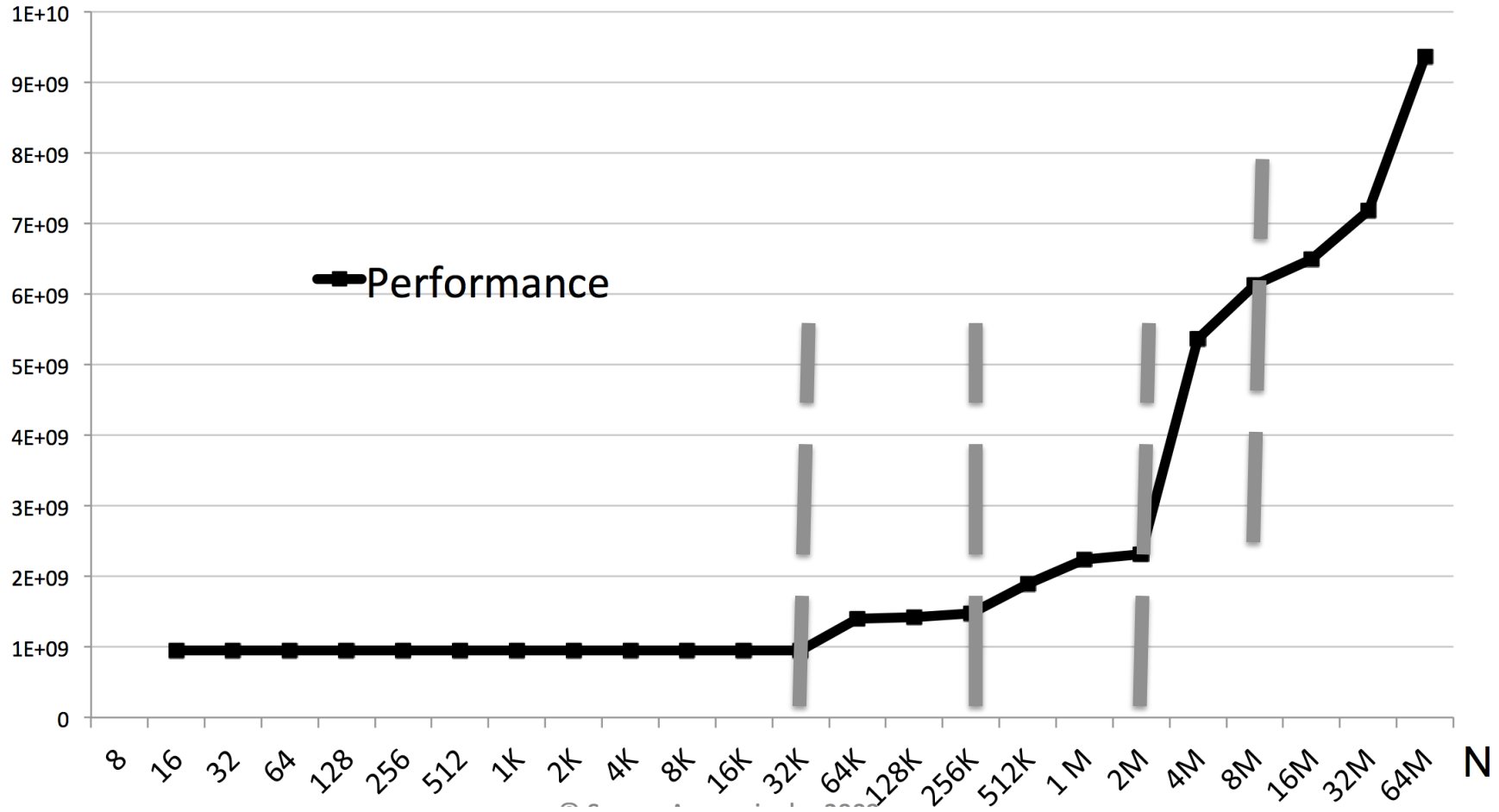


Prefetching: Enabled



Caches in Benchmarks

Prof. Saman Amarasinghe, MIT 2009



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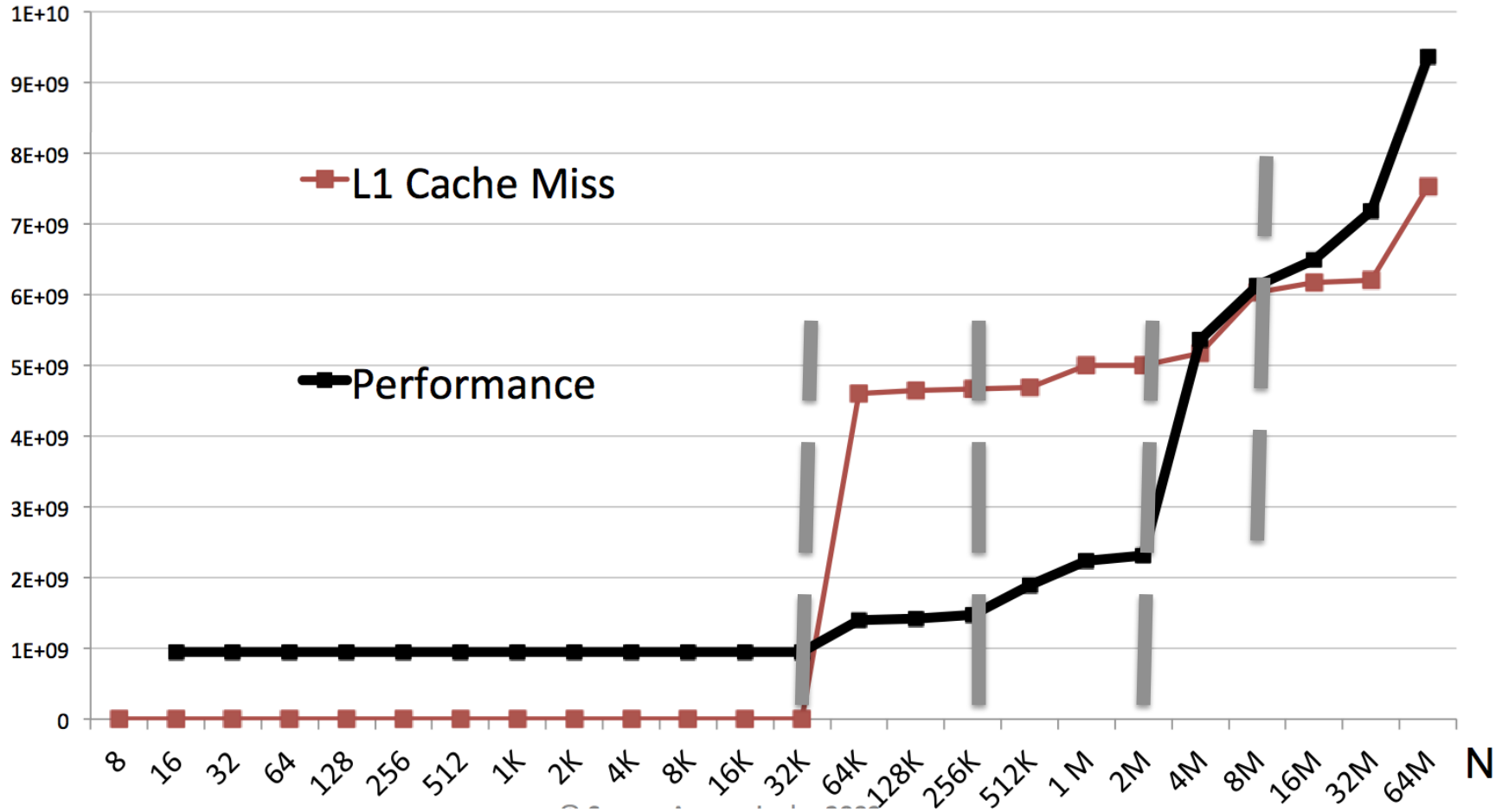

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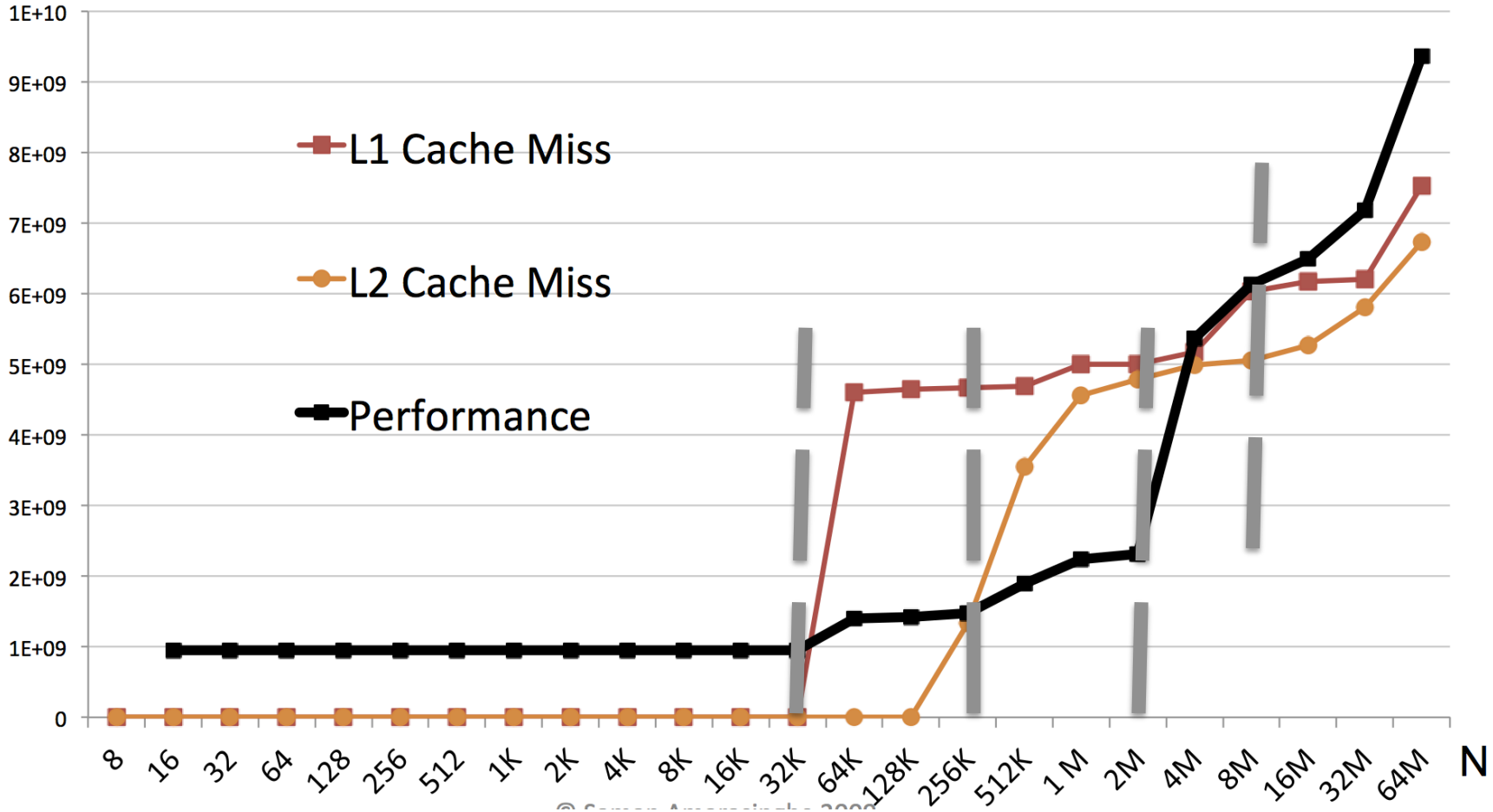

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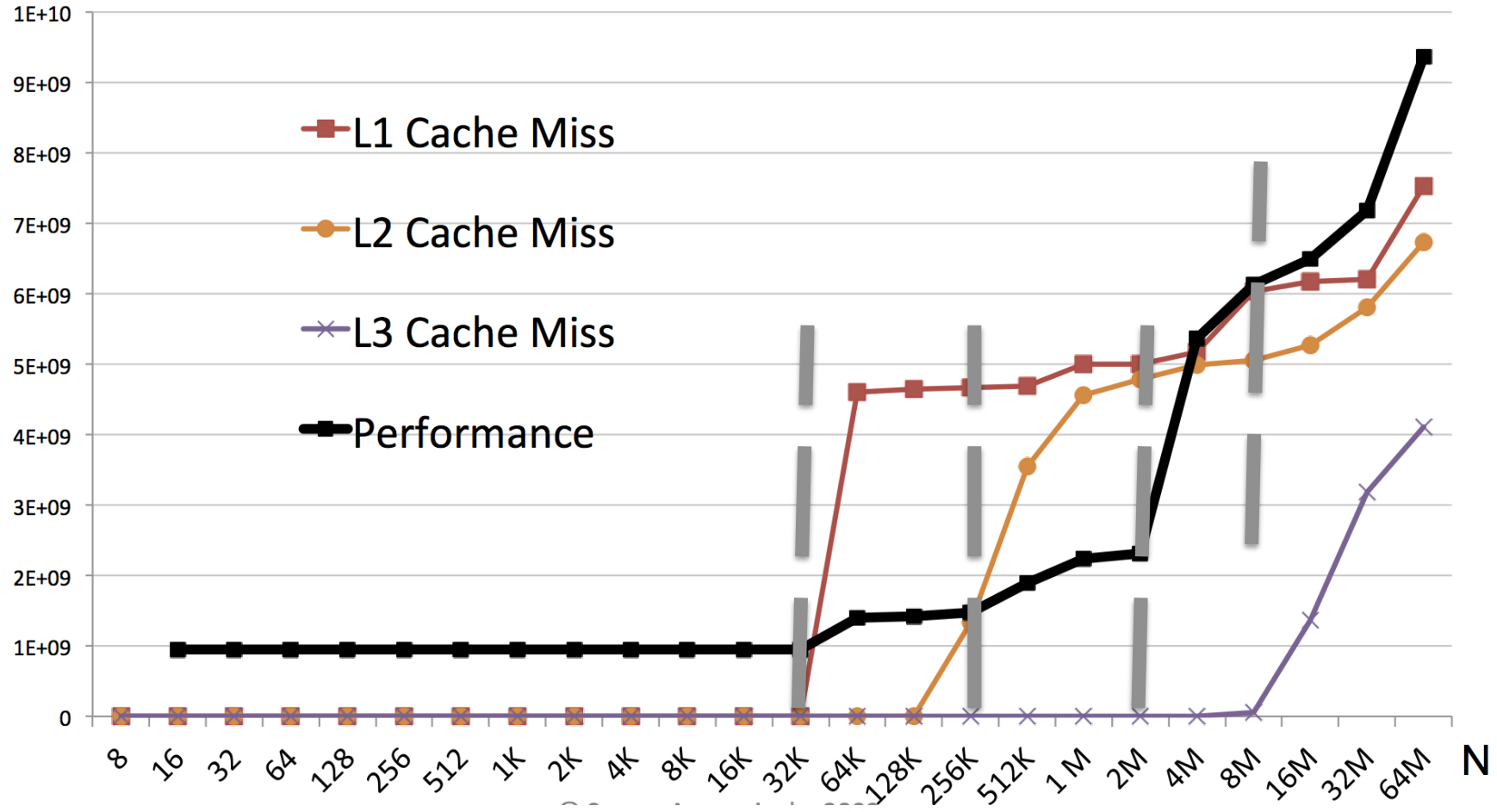

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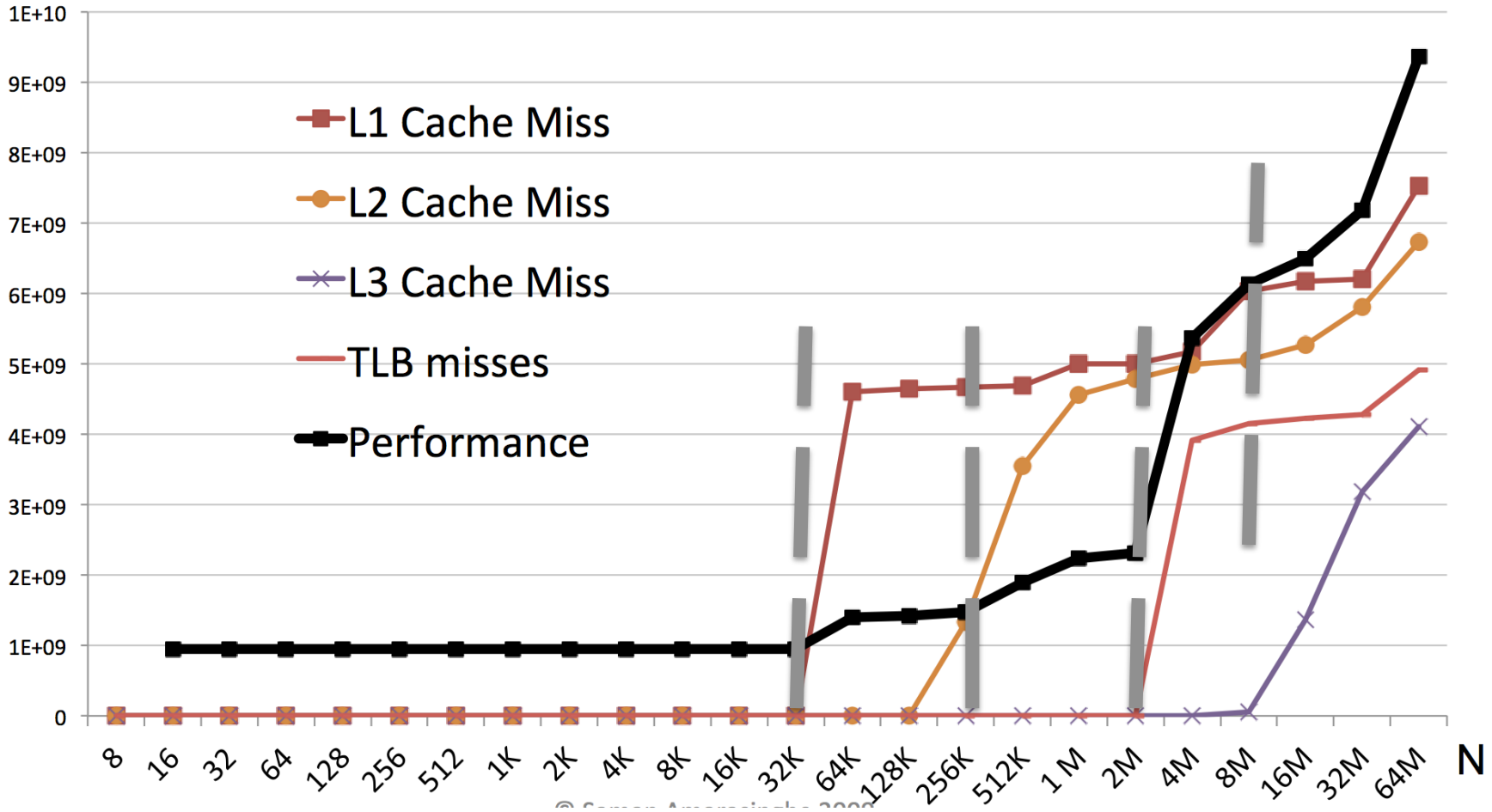

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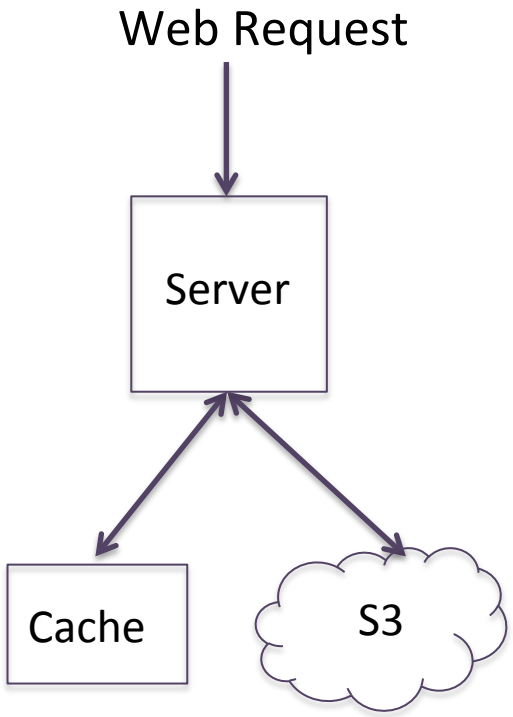

Wrong About the Machine

- Cache, cache, cache, cache!
- Warmup & timing

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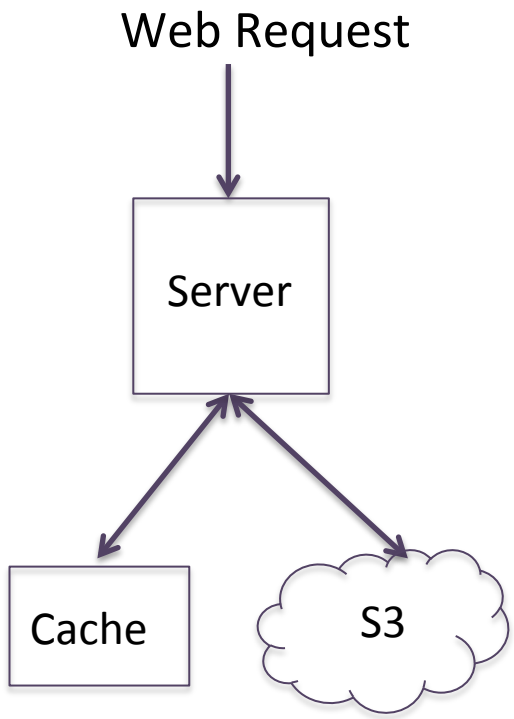
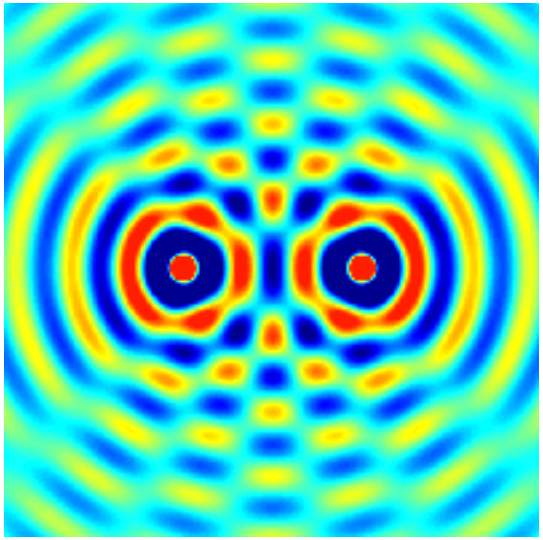
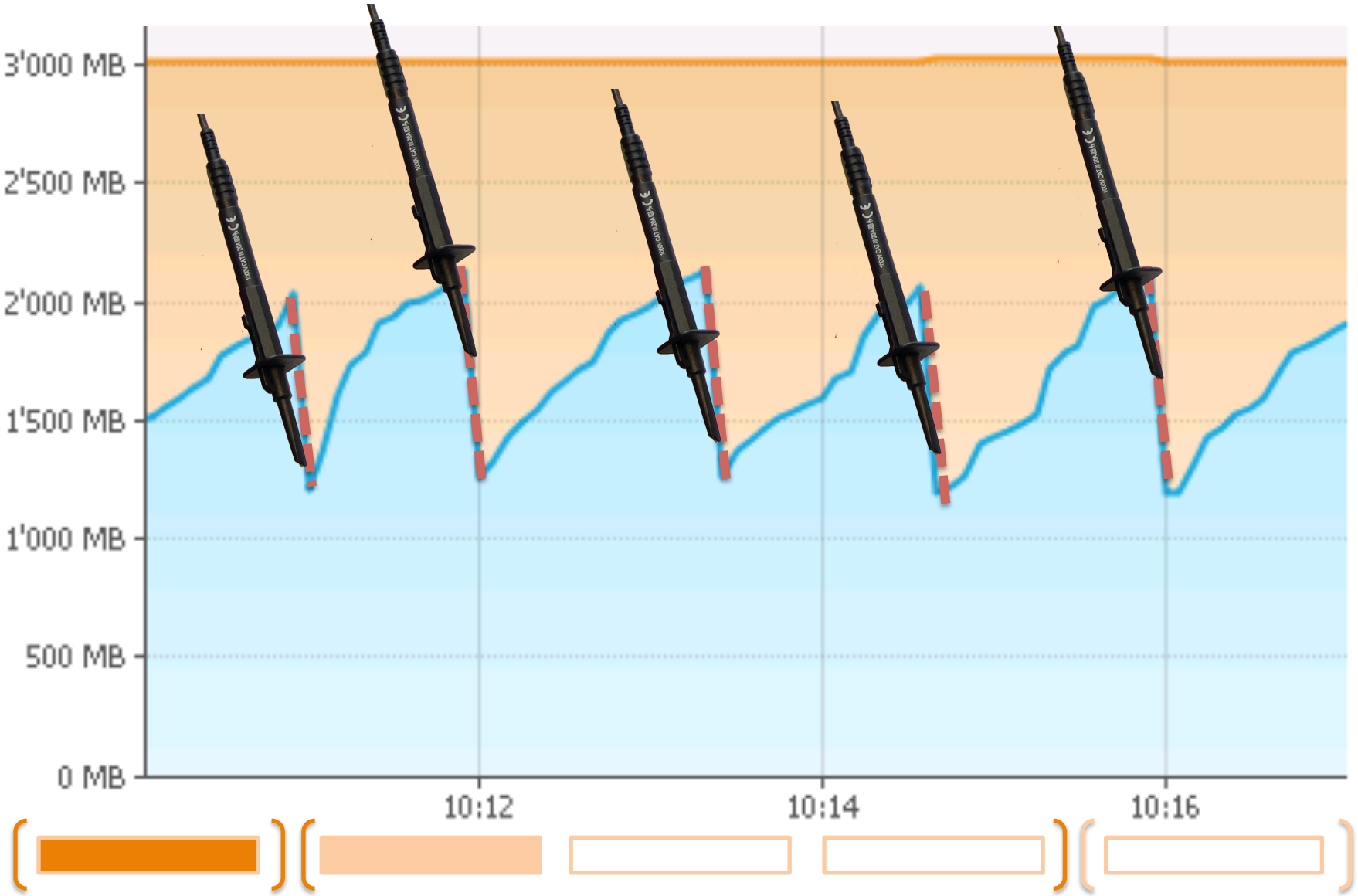


Wrong About the Machine

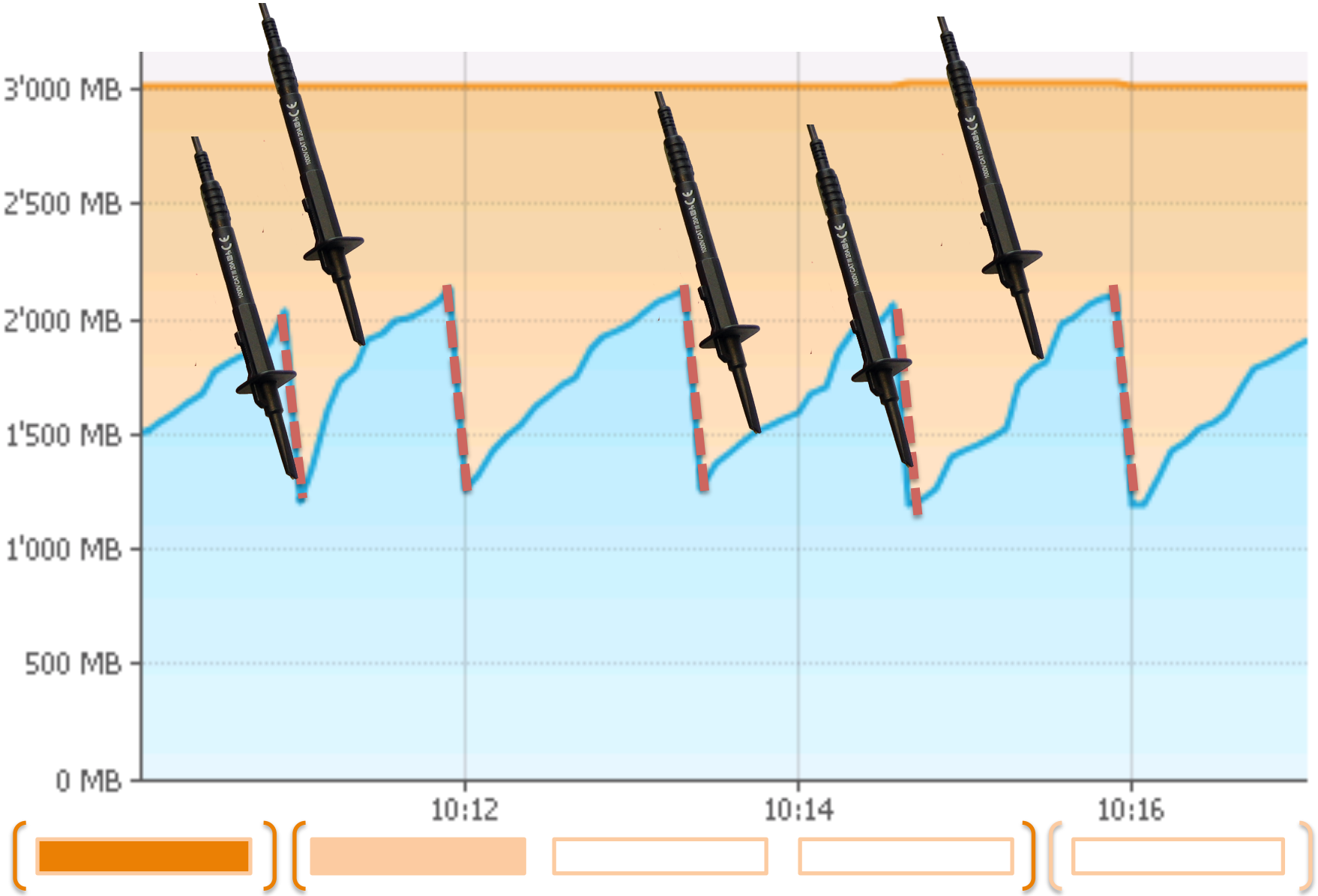
- Cache, cache, cache, cache!
- Warmup & timing
- Periodic interference



Periodic Interference



Periodic Interference



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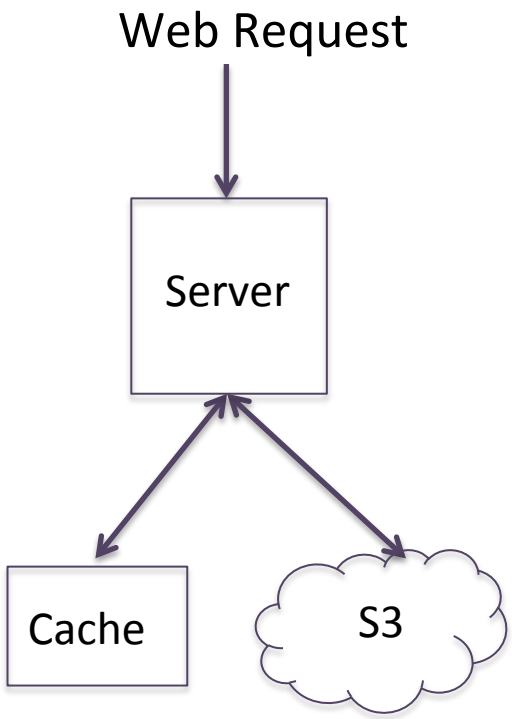

Wrong About the Machine

- Cache, cache, cache, cache!
- Warmup & timing
- Periodic interference
- Test != Prod

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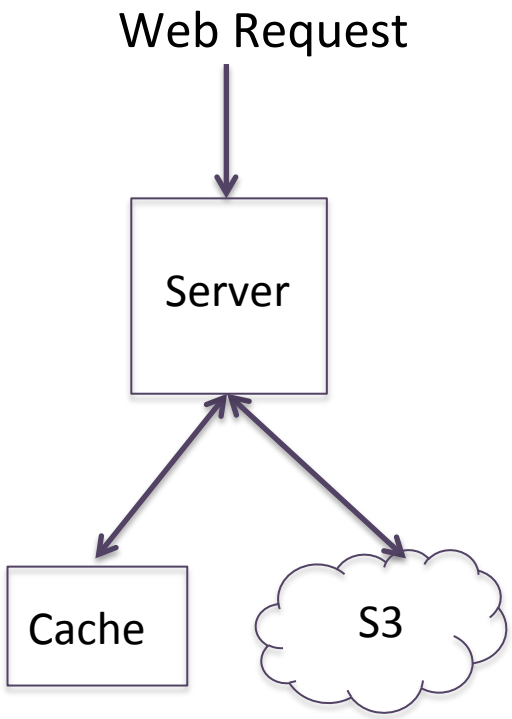
  - Find mean
- ✗ Dev environment



Wrong About the Machine

- Cache, cache, cache, cache!
- Warmup & timing
- Periodic interference
- Test != Prod
- Power mode changes

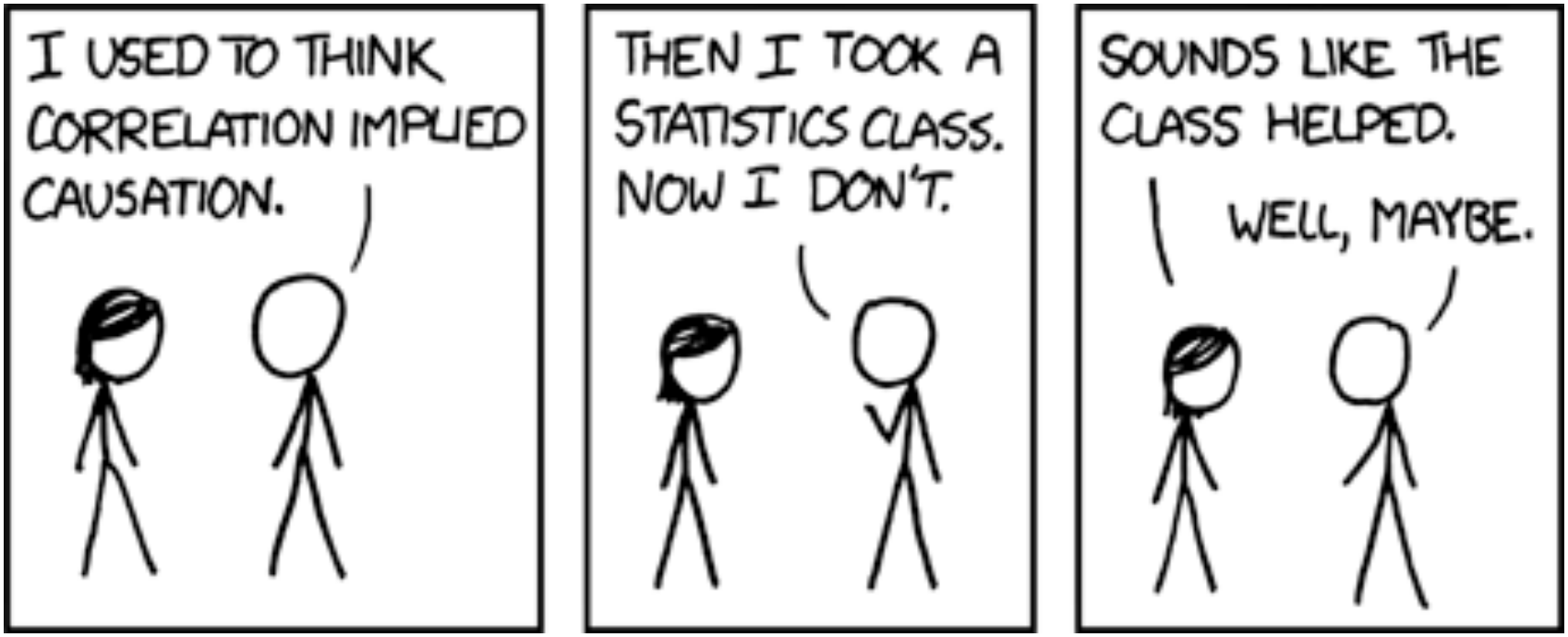
Power Modes

$ cat /sys/devices/system/cpu/*/cpufreq/scaling_governor

“ondemand” OR “performance”

Current CPU frequencies:

$ grep "MHz" /proc/cpuinfo

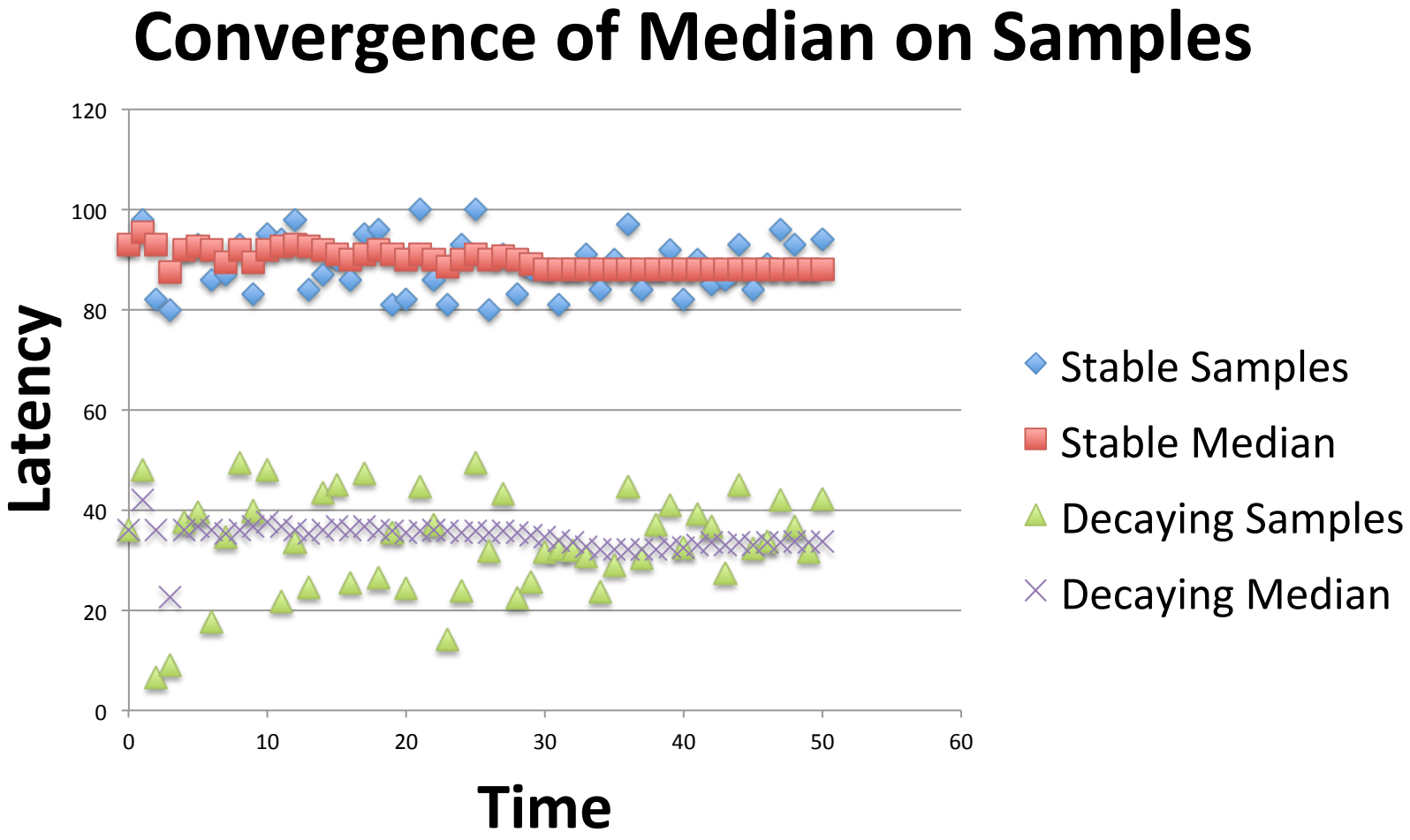


YOU'RE WRONG ABOUT THE STATS

Wrong About Stats

- Too few samples

Wrong About Stats



Website Serving Images

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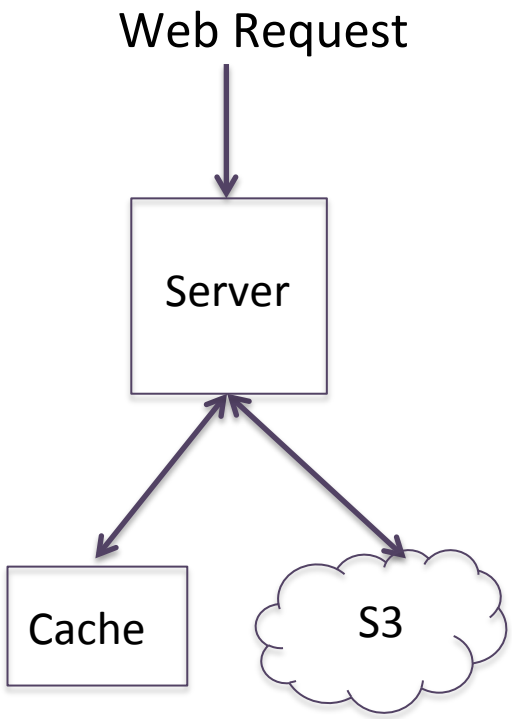
- Find mean
- ~~Dev machine~~



Wrong About Stats

- Too few samples
- Gaussian (not)

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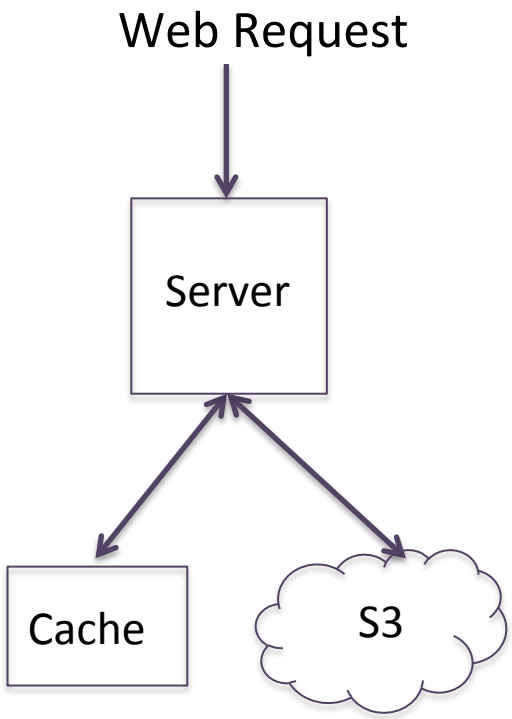
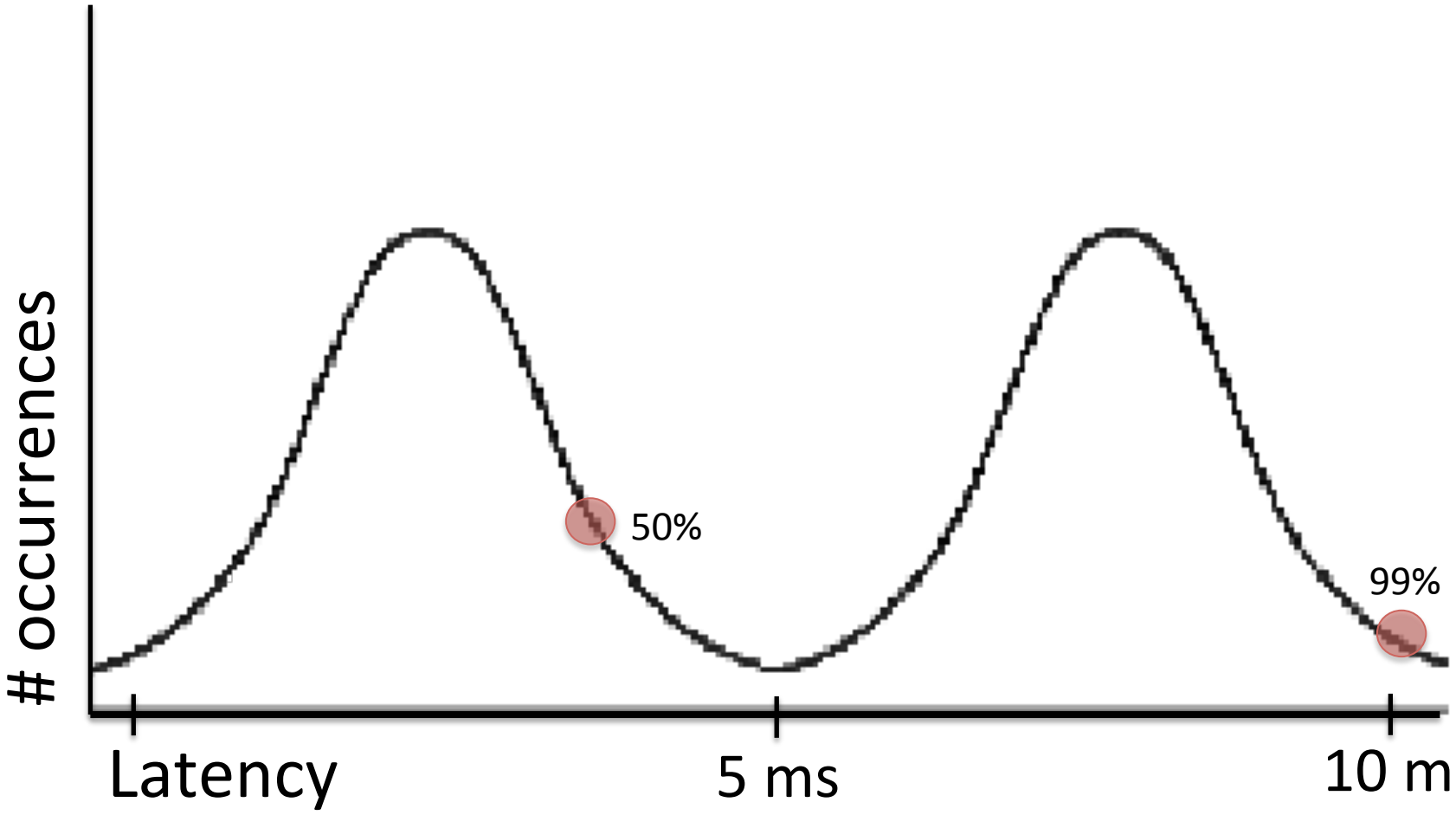


Wrong About Stats

- Too few samples
- Gaussian (not)
- Multimodal distribution

Multimodal Distribution



Multimodal Distribution

Using Kernel Density Estimates to investigate Multimodality

By B. W. SILVERMAN

University of Bath, U.K.

[Received August 1980]

SUMMARY

A technique for using kernel density estimates to investigate the number of modes in a population is described and discussed. The amount of smoothing is chosen automatically in a natural way.

Keywords: DENSITY ESTIMATE; MODE; BOOTSTRAP; TOTAL POSITIVITY; CHONDRITES; BUMP HUNTING

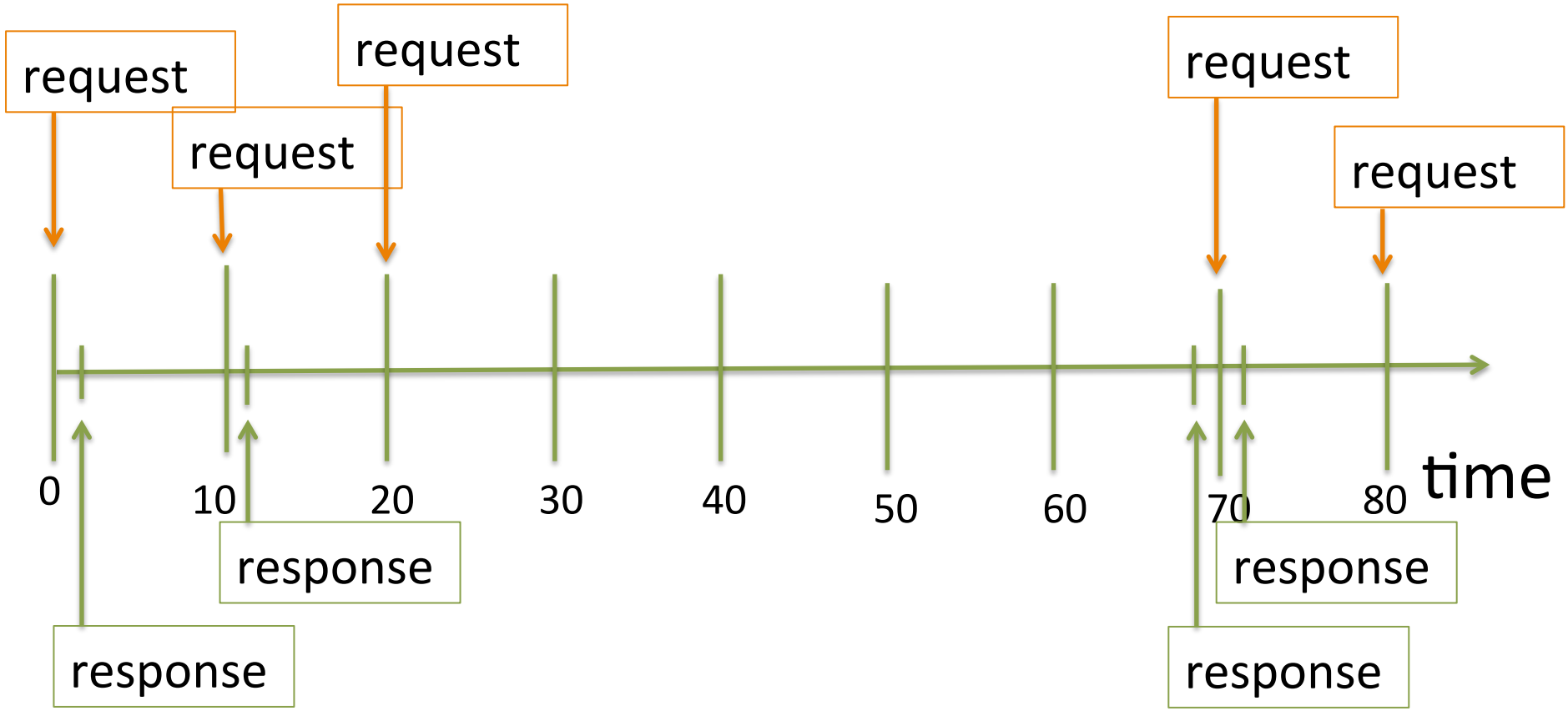
1. INTRODUCTION

INVESTIGATION of the number of modes or maxima in a density or its derivative has been considered by several authors, for example Cox (1966) and Good and Gaskins (1980). Most

Wrong About Stats

- Too few samples
- Gaussian (not)
- Multimodal distribution
- Outliers

Coordinated Omission



Wrong About Stats

- Too few samples
- Gaussian (not)
- Multimodal distribution
- Outliers

YOU'RE WRONG ABOUT WHAT MATTERS

Wrong About What Matters

- Premature optimization

"Programmers waste enormous amounts of time thinking about … the speed of noncritical parts of their programs … Forget about small efficiencies …97% of the time: **premature optimization is the root of all evil**. Yet we should not pass up our opportunities in that critical 3%."

-- Donald Knuth

Wrong About What Matters

- Premature optimization
- Unrepresentative workloads

Wrong About What Matters

- Premature optimization
- Unrepresentative workloads
- Memory pressure

Wrong About What Matters

- Premature optimization
- Unrepresentative workloads
- Memory pressure
- Hidden components

Wrong About What Matters

- Premature optimization
- Unrepresentative workloads
- Memory pressure
- Hidden components
- Reproducibility of measurements

BECOMING LESS WRONG

User Actions Matter

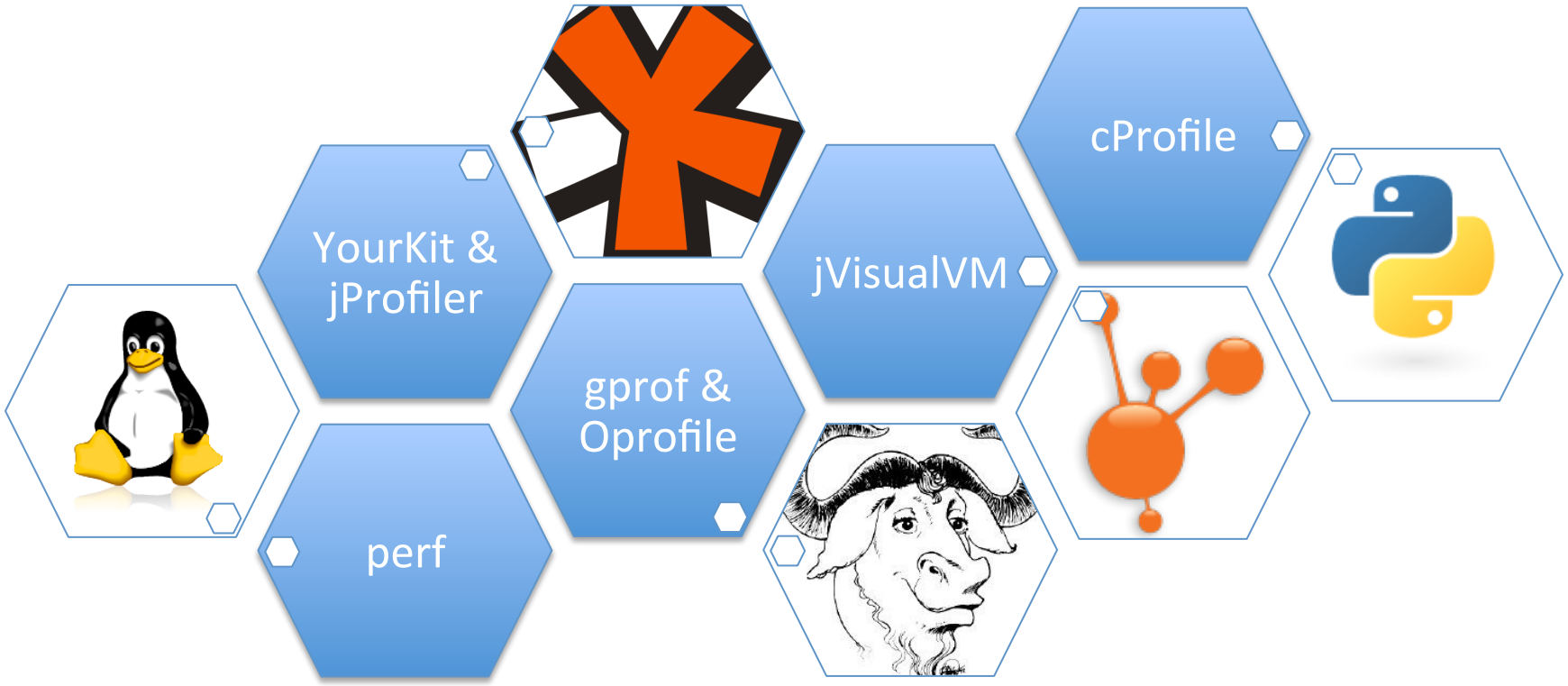
X > Y for workload Z

with trade offs A, B, and C

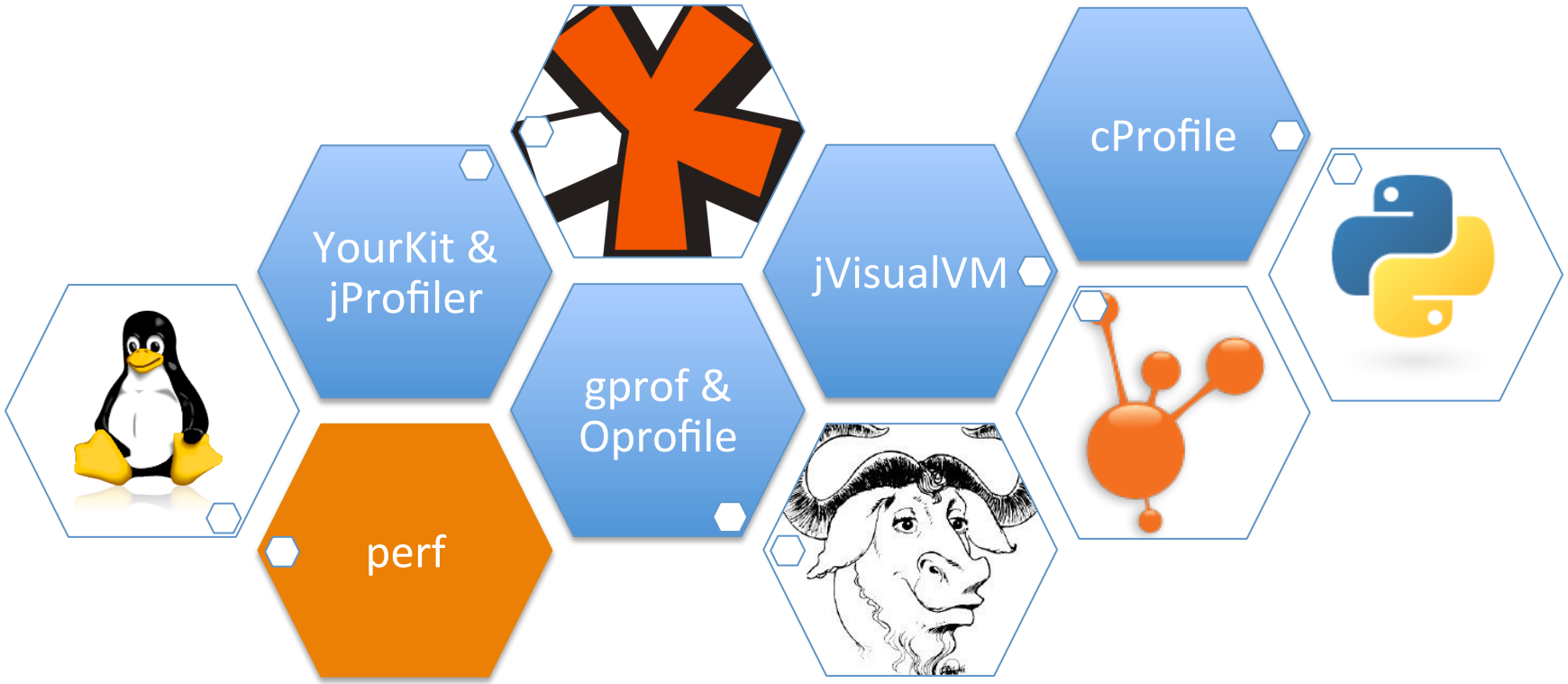
- http://www.toomuchcode.org/

Profiling

Profiling


YourKit &
jProfiler
jVisualVM
cProfile
gprof &
Oprofile
perf

Profiling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perf

Various basic CPU statistics, system wide, for 10 seconds

perf stat -e cycles,instructions,cache-misses -a sleep 10

Count system calls for the entire system, for 5 seconds

perf stat -e 'syscalls:sys_enter_*' -a sleep 5

Sample CPU stack traces, once every 10,000 Level 1 data cache misses, for 5 seconds

perf record -e L1-dcache-load-misses -c 10000 -ag -- sleep 5

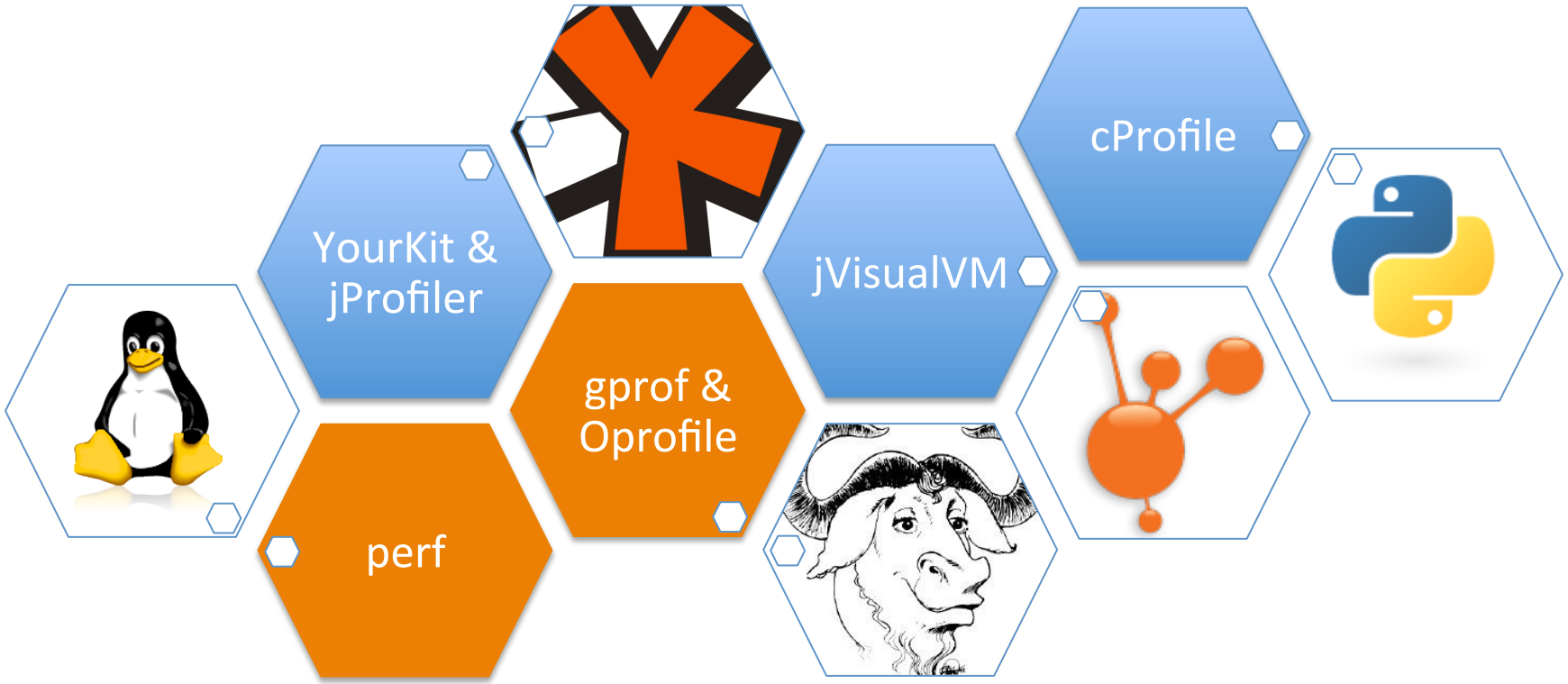
http://www.brendangregg.com/perf.html

perf

```
# perf stat gzip file1

 Performance counter stats for 'gzip file1':

       1920.159821 task-clock                #    0.991 CPUs utilized
                13 context-switches          #    0.007 K/sec
                 0 CPU-migrations            #    0.000 K/sec
               258 page-faults               #    0.134 K/sec
     5,649,595,479 cycles                    #    2.942 GHz                      [83.43%]
     1,808,339,931 stalled-cycles-frontend   #   32.01% frontend cycles idle     [83.54%]
     1,171,884,577 stalled-cycles-backend    #   20.74% backend  cycles idle     [66.77%]
     8,625,207,199 instructions              #    1.53  insns per cycle
                                             #    0.21  stalled cycles per insn [83.51%]
     1,488,797,176 branches                  #  775.351 M/sec                    [82.58%]
        53,395,139 branch-misses             #    3.59% of all branches          [83.78%]

       1.936842598 seconds time elapsed
```

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

Profiling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gprof: Where Does It Spend Its Time?

- Compile with profiling

```
$ gcc -Wall -pg test_gprof.c test_gprof_new.c -o test_gprof
```

- Execute the code

```
$ ./test_gprof
```

- Run the gprof

```
$  gprof test_gprof gmon.out > analysis.txt
```

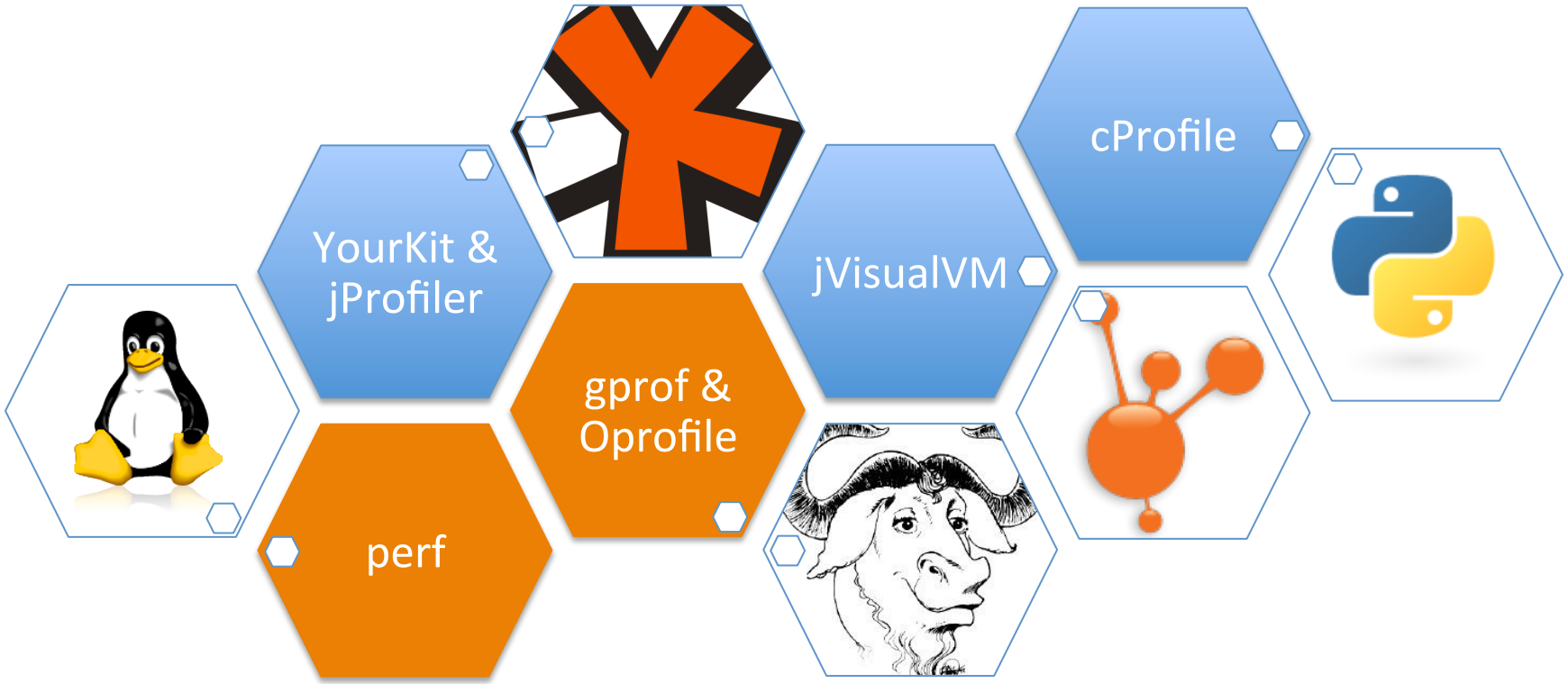
http://www.thegeekstuff.com/2012/08/gprof-tutorial/

gprof: Where Does It Spend Its Time?

```
%    cumulative self              self   total
time seconds    seconds calls s/call s/call name
33.86 15.52     15.52    1    15.52  15.52  func2
33.82 31.02     15.50    1    15.50  15.50  new_func1
33.29 46.27     15.26    1    15.26  30.75  func1
0.07  46.30     0.03                       main
```

http://www.thegeekstuff.com/2012/08/gprof-tutorial/

Profiling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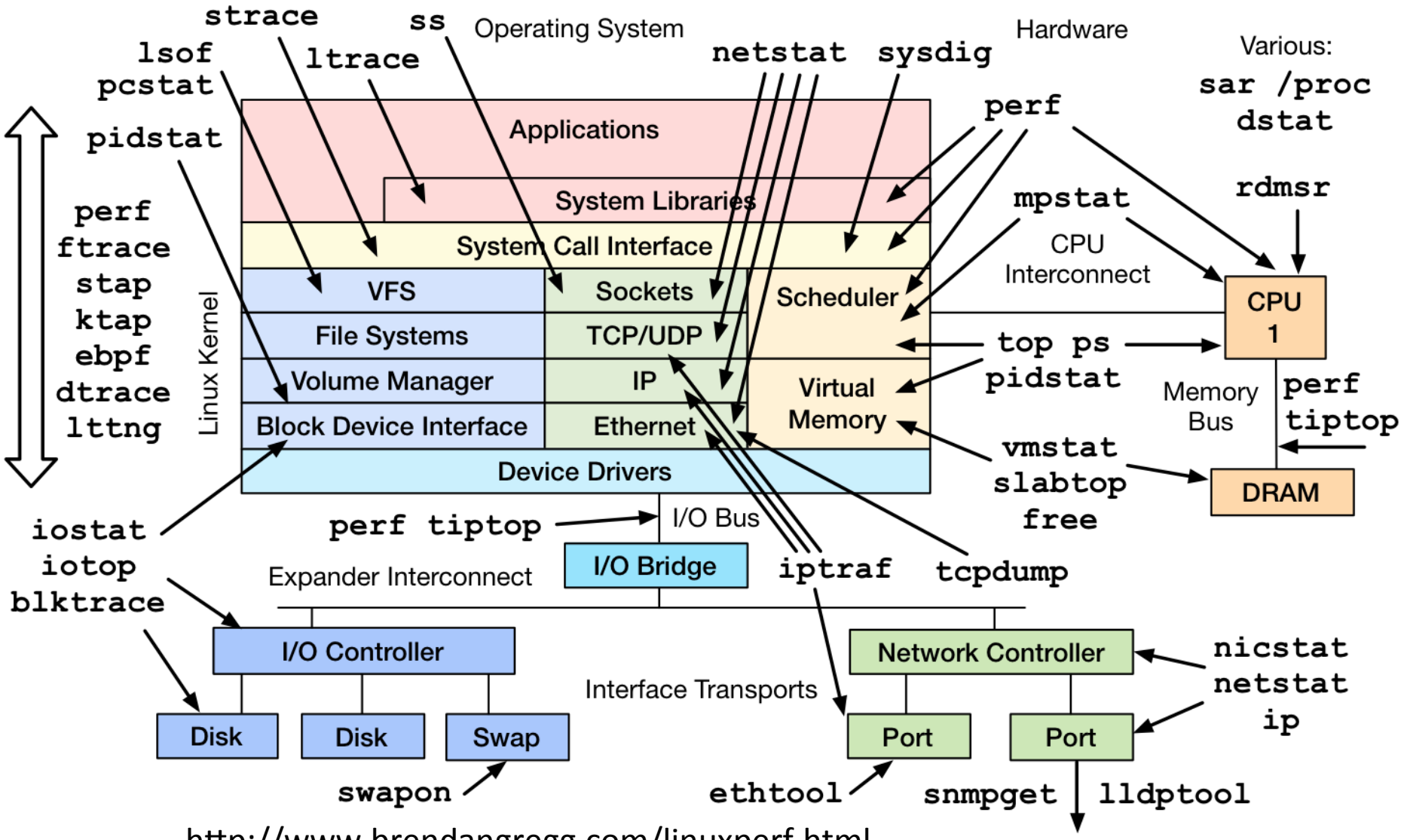
Linux Performance Observability Tools



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

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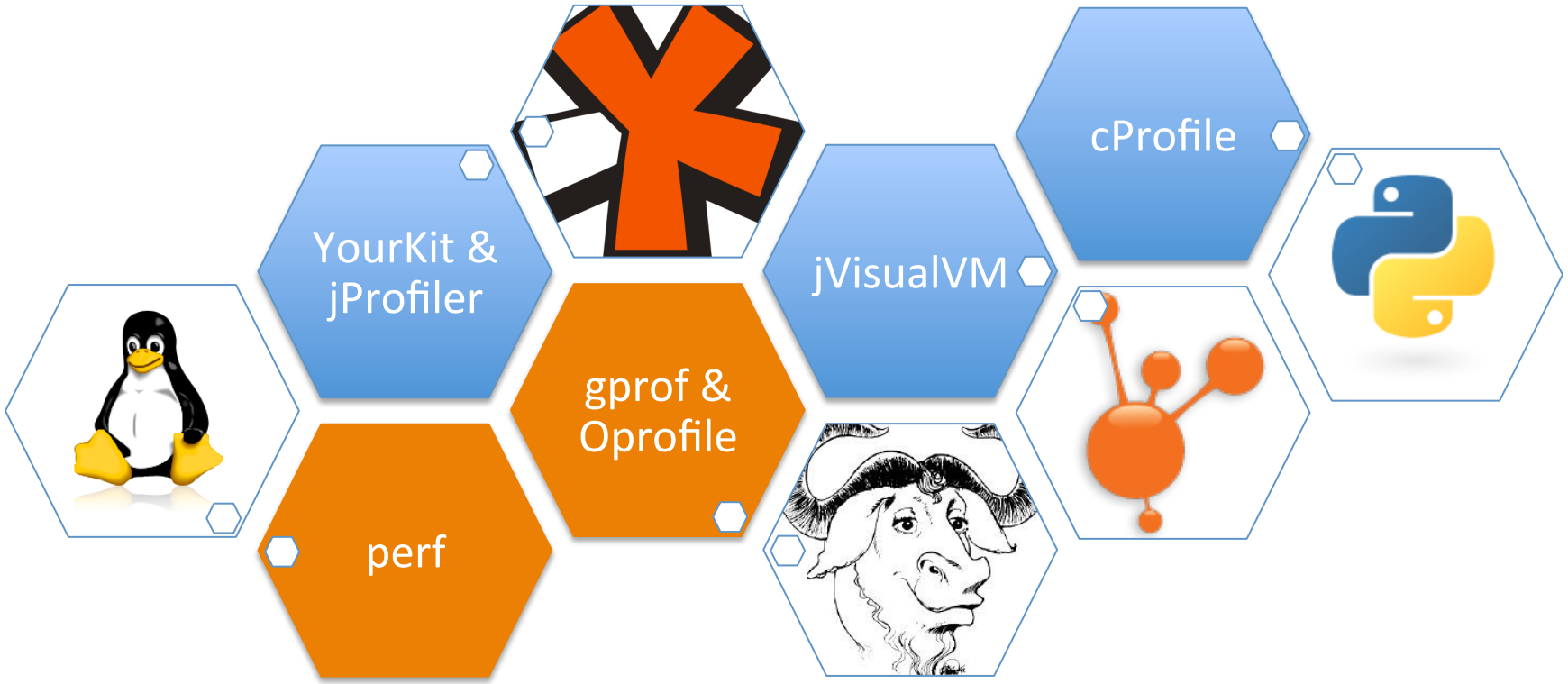
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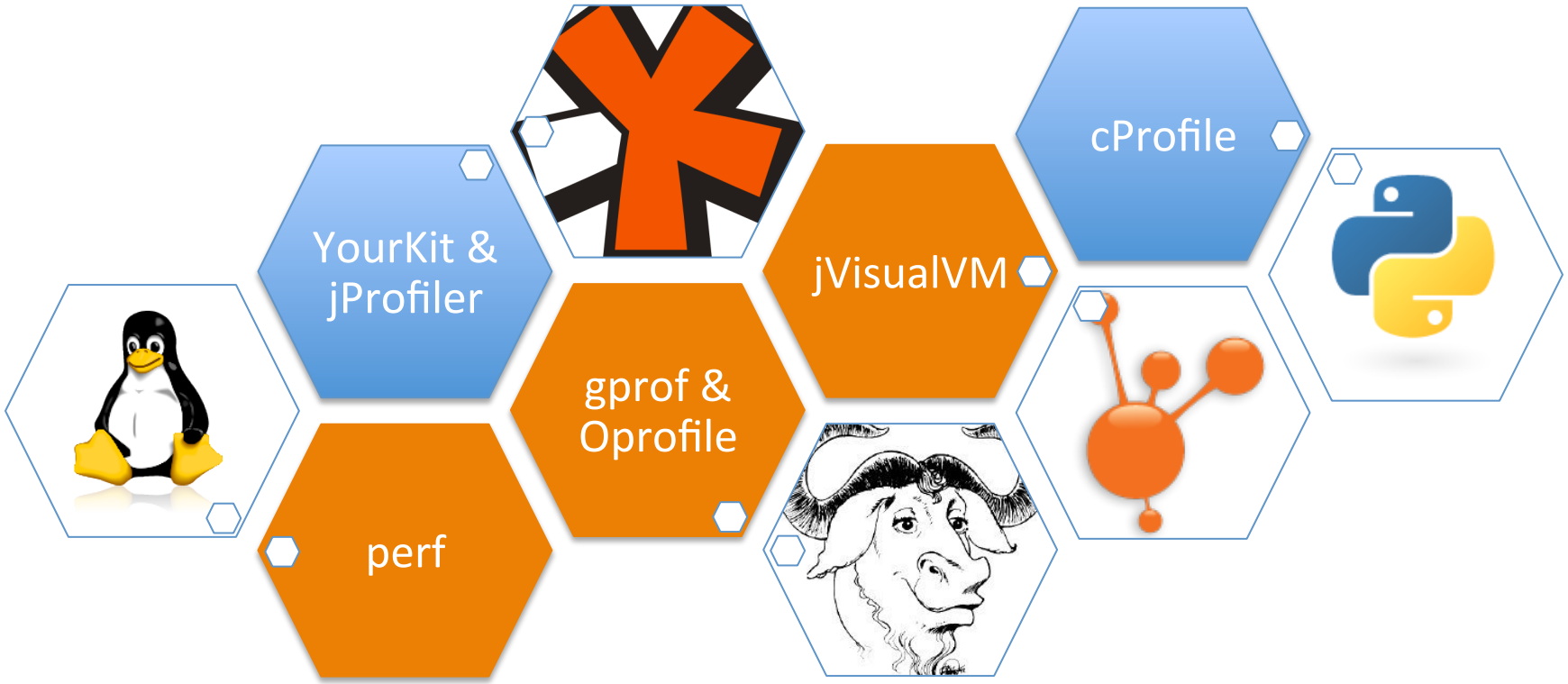
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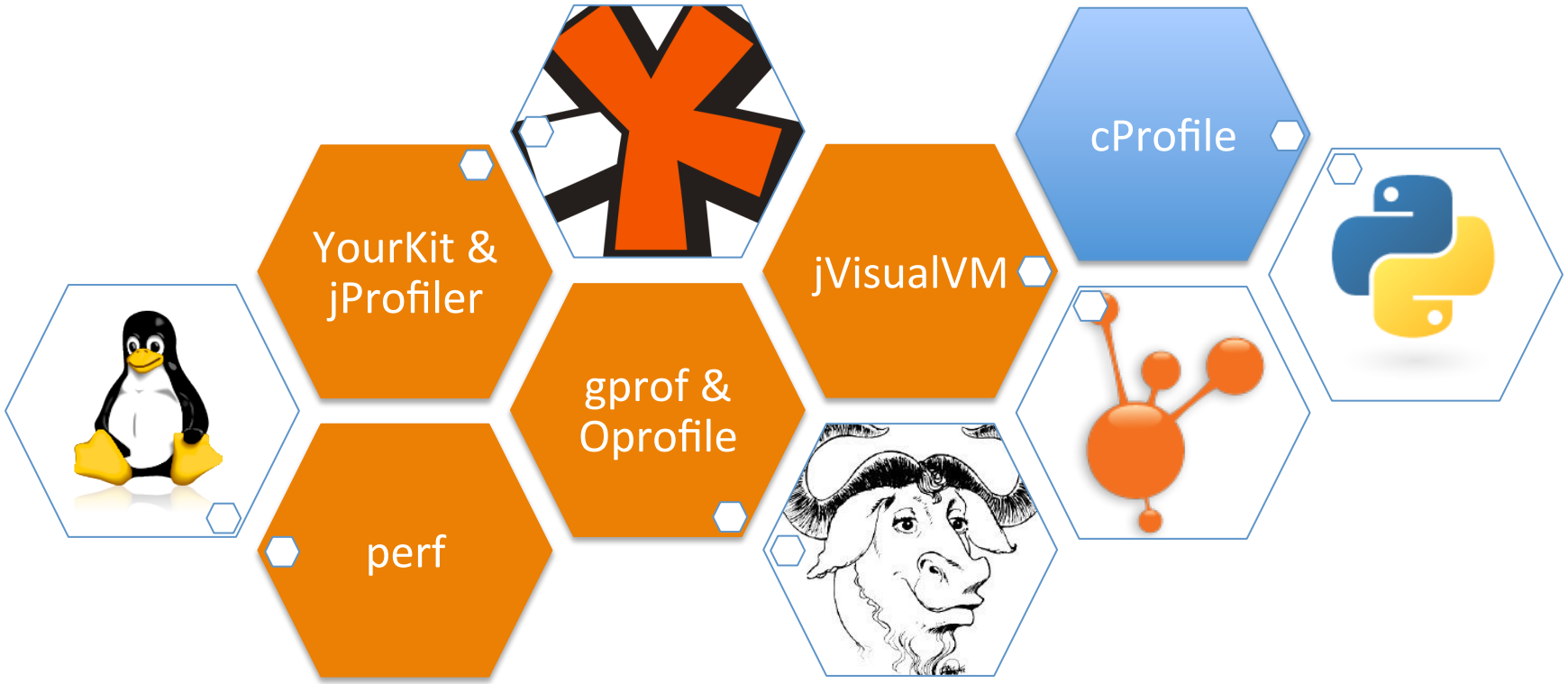
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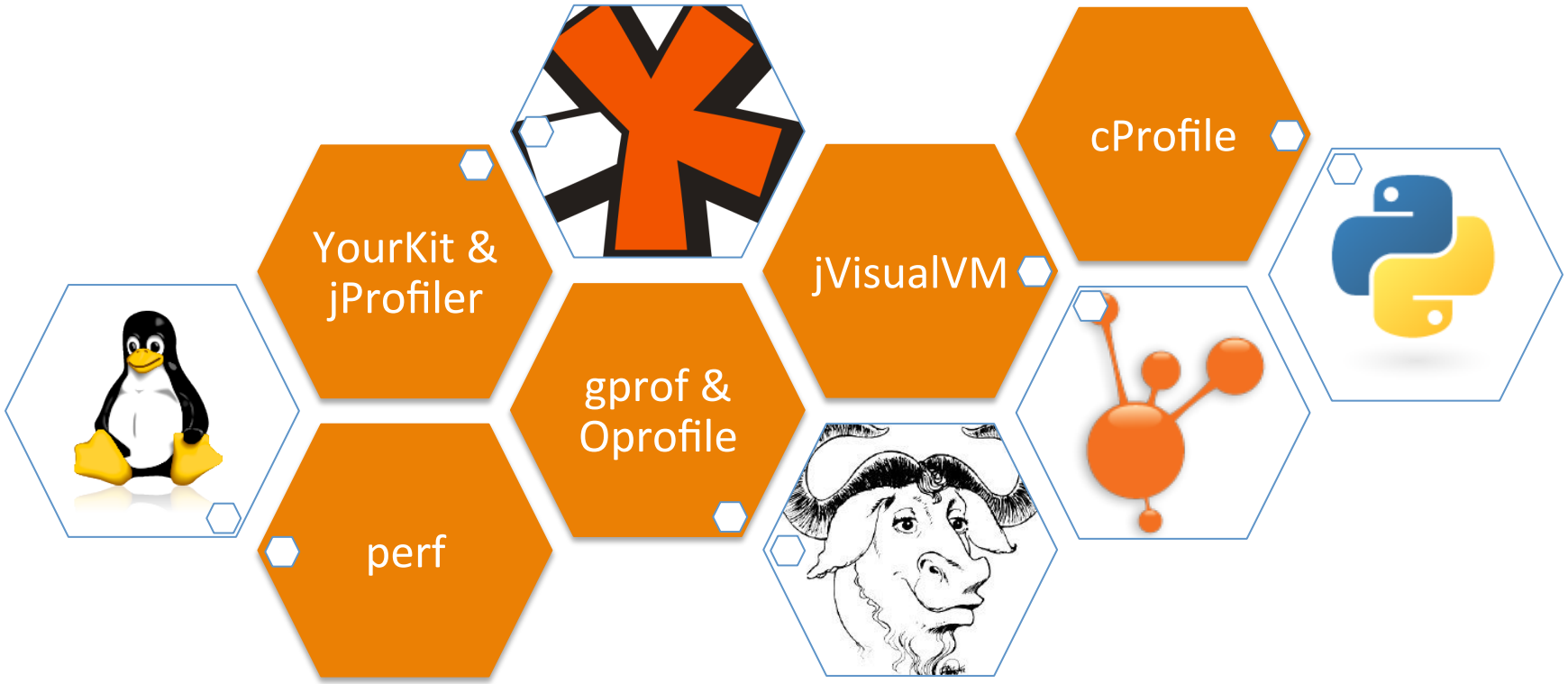
perf

Profiling


YourKit &
jProfiler
gprof &
Oprofile
jVisualVM
cProfile
perf

Profiling

Code instrumentation

Aggregate over logs

Traces

Microbenchmarking: Blessing & Curse

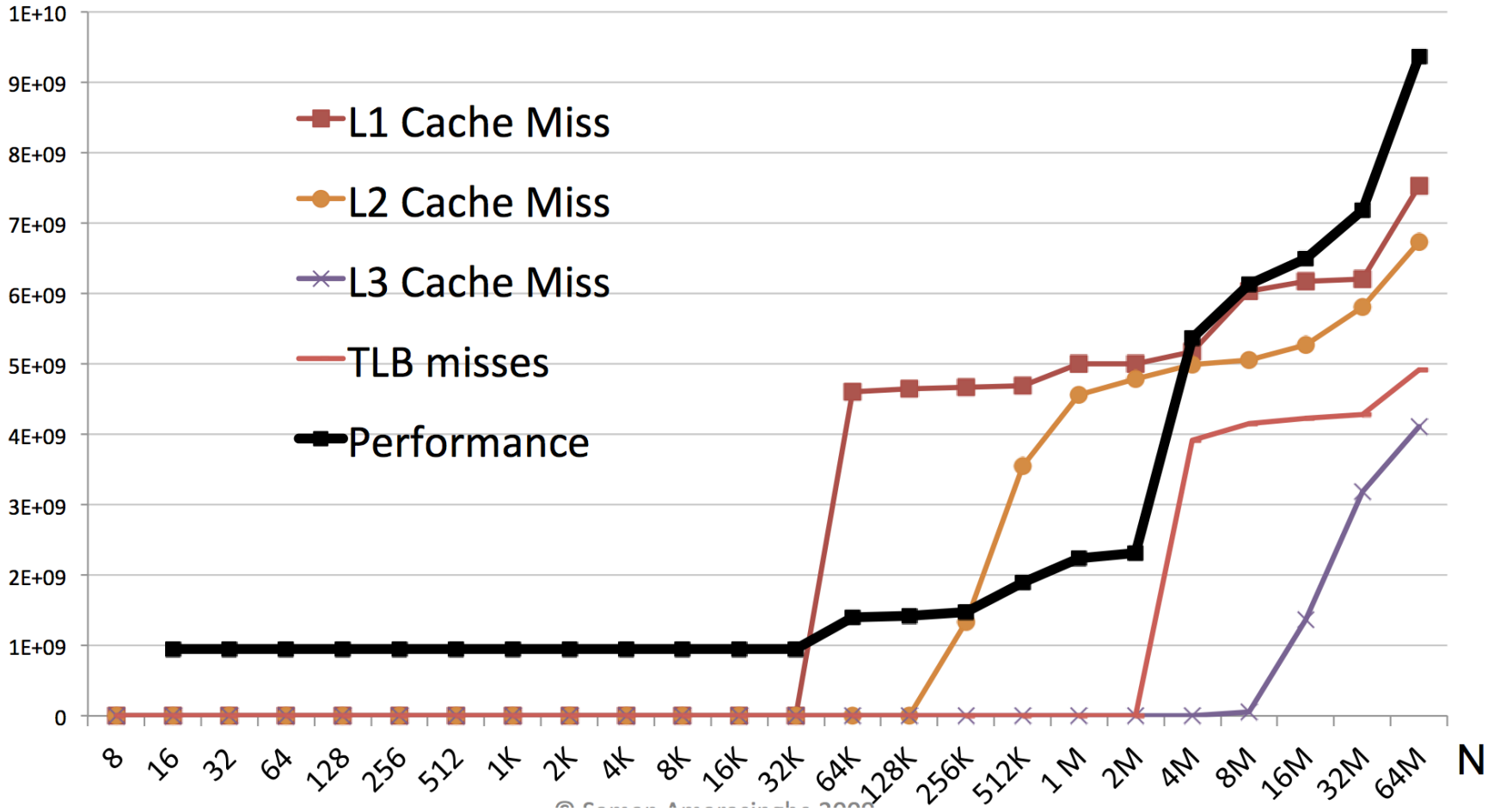
+ Quick & cheap
+ Answers narrow ?s well
– Often misleading results
– Not representative of the program

Microbenchmarking: Blessing & Curse

- Choose your N wisely

Choose Your N Wisely

Prof. Saman Amarasinghe, MIT 2009



Microbenchmarking: Blessing & Curse

- Choose your N wisely
- Measure side effects

Microbenchmarking: Blessing & Curse

- Choose your N wisely
- Measure side effects
- Beware of clock resolution

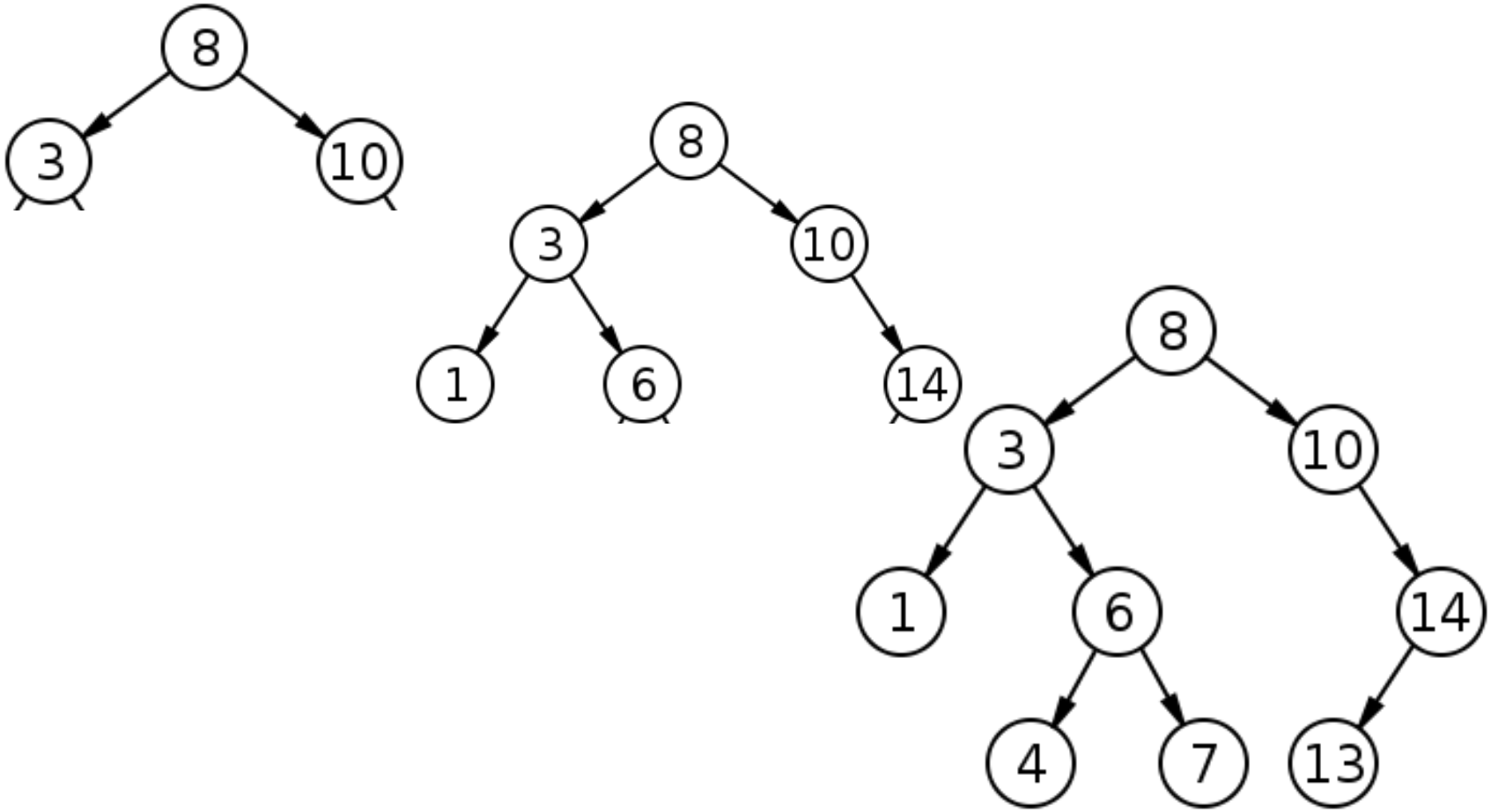
Microbenchmarking: Blessing & Curse

- Choose your N wisely
- Measure side effects
- Beware of clock resolution
- Dead Code Elimination

Microbenchmarking: Blessing & Curse

- Choose your N wisely
- Measure side effects
- Beware of clock resolution
- Dead Code Elimination
- Constant work per iteration

Non-Constant Work Per Iteration



What Should a Benchmark Do?

Measures behavior of system

Represents realistic workload

Runs for sufficiently long time

Compares in the same context

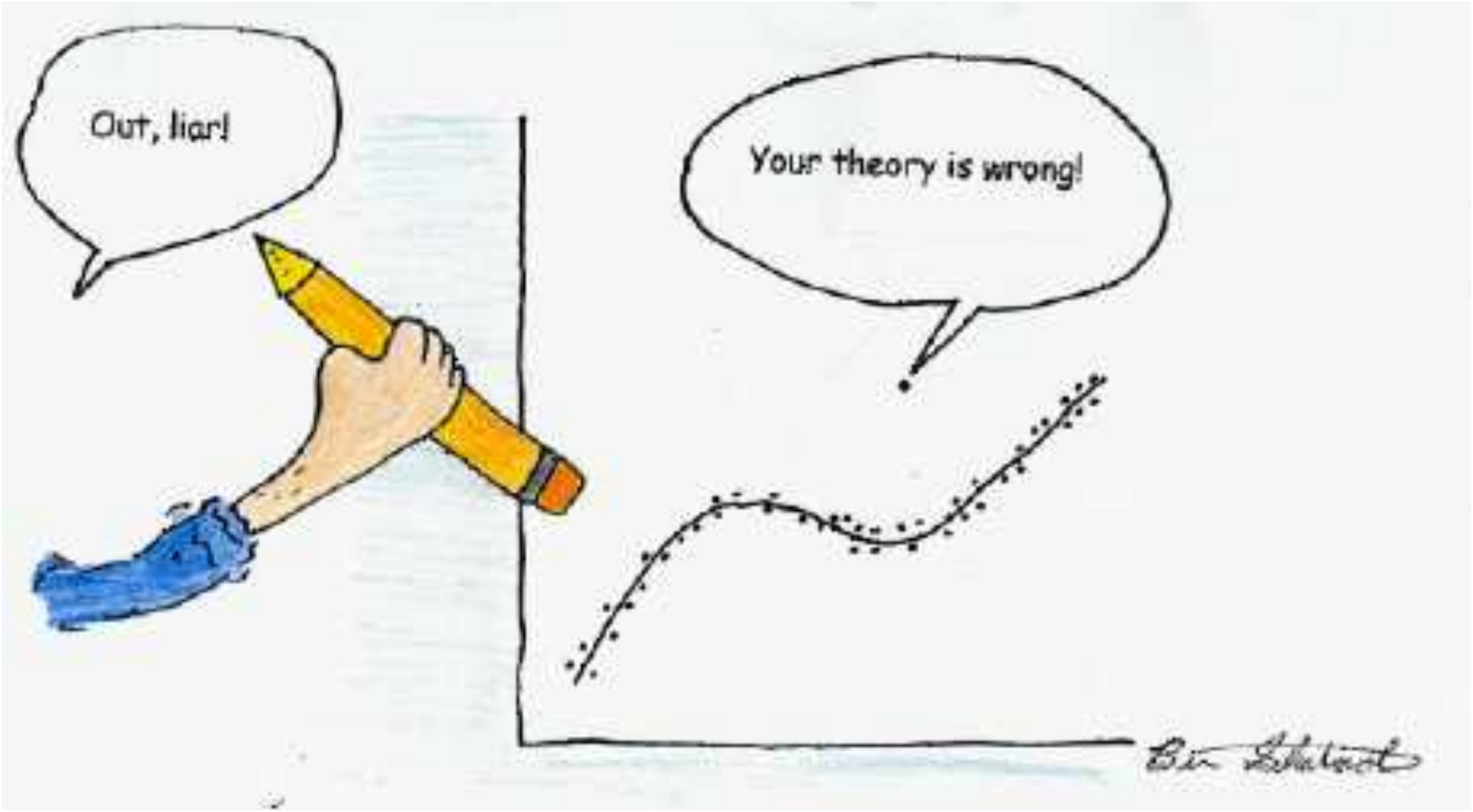
Predictable and reproducible results

Follow-up Material

- *How NOT to Measure Latency* by Gil Tene
  - http://www.infoq.com/presentations/latency-pitfalls
- *Taming the Long Latency Tail* on highscalability.com
  - http://highscalability.com/blog/2012/3/12/google-taming-the-long-latency-tail-when-more-machines-equal.html
- *Performance Analysis Methodology* by Brendan Gregg
  - http://www.brendangregg.com/methodology.html
- *Silverman's Mode Detection Method* by Matt Adereth
  - http://adereth.github.io/blog/2014/10/12/silvermans-mode-detection-method-explained/
- *How Not To Measure System Performance* by James Bornholt
  - https://homes.cs.washington.edu/~bornholt/post/performance-evaluation.html
- *Trust No One, Not Even Performance Counters* by Paul Khuong
  - *http://www.pvk.ca/Blog/2014/10/19/performance-optimisation-~-writing-an-essay/#trust-no-one*

Takeaway #1: Cache

Takeaway #2: Outliers



Takeaway #3: Workload

DEVNEXUS™

Benchmarking:
You're Doing It Wrong

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Google