Lecture 20 — Performance Case Studies

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Case Study: Firefox Quantum

Some Firefox Perf Improvements, per Mike Conley

- don't animate out-of-view elements
- move db init off main thread
- keep better profiling data
- parallel painting for macOS
- lazily instantiate Search Service
- halve size of the blocklist
- refactor to reduce main-thread IO
- don't hold all frames of animated GIFs/APNGs in memory
- eliminate unnecessary hash table
- use more modern compiler

`https://mikeconley.ca/blog/2018/02/14/firefox-performance-update-1/`

We've seen this before:

- do less work (or do it sooner/later);
- use threads (move work off main thread);
- measure performance;

Which of the updates fall into which categories?

Some Firefox Perf Improvements, per Mike Conley

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How?

- do less work (or do it sooner/later);
- use threads (move work off main thread);
- measure performance;

Tab Warming

https://mikeconley.ca/blog/2018/01/11/making-tab-switching-faster-in-firefox-with-tab-warming/.

"Maybe this is my Canadian-ness showing, but I like to think of it almost like coming in from shoveling snow off of the driveway, and somebody inside has *already made hot chocolate for you*, because they knew you'd probably be cold." — Mike Conley

How Can Tab Warming Work?

Before: Firefox requests paint of newly-active tab, and then waits for the result before switching.

Idea: reduce user-visible latency by predicting an imminent tab switch.

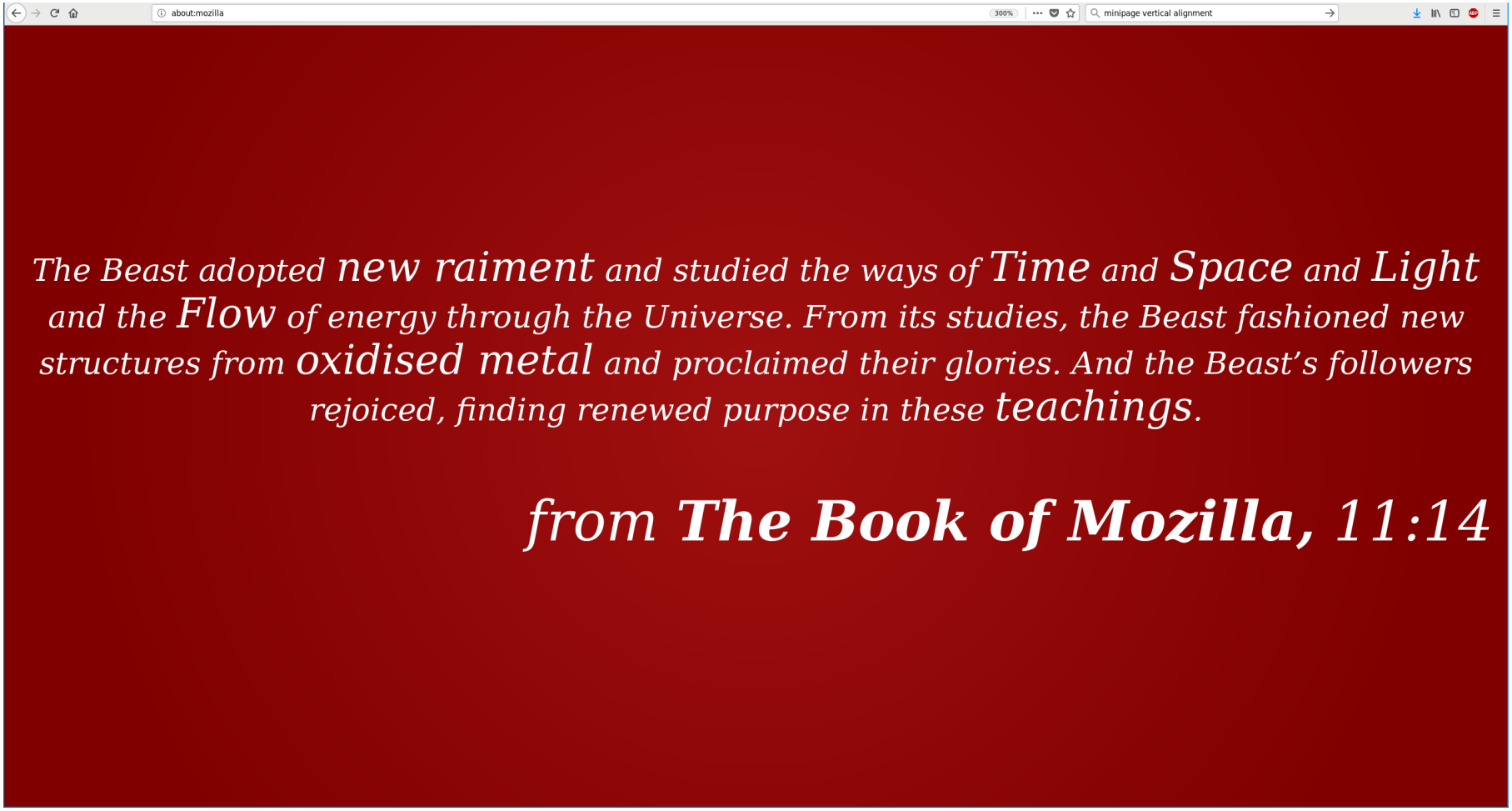
Q: How can we predict the future?

Q': How can we predict which tab will be switched to?

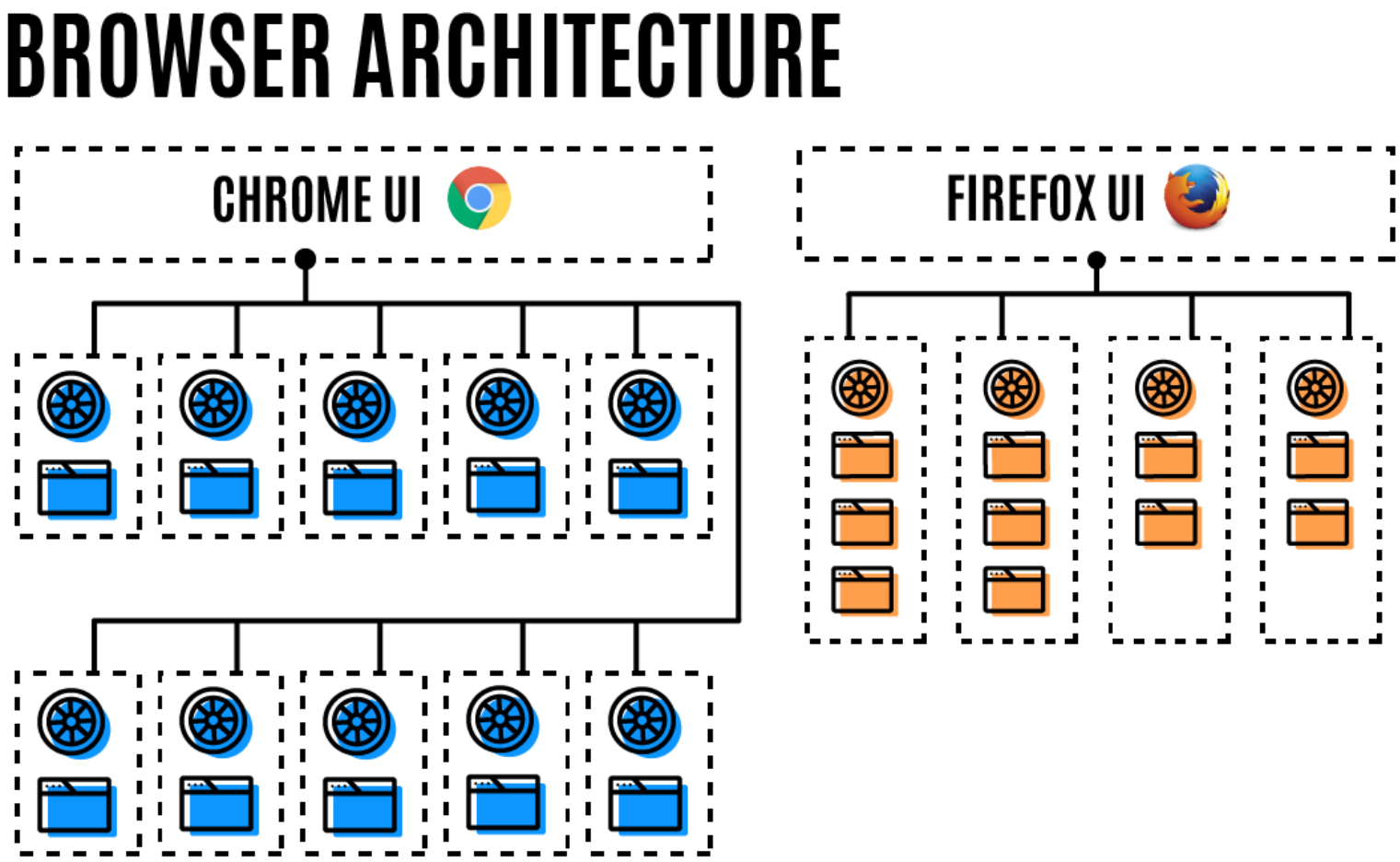
A: When the user has a mouse, then the mouse cursor will hover over the next tab.

> *Assuming a sufficiently long delay between hover and click, the tab switch should be perceived as instantaneous. If the delay was non-zero but still not long enough, we will have nonetheless shaved that time off in eventually presenting the tab to you.*
> *And in the event that we were wrong, and you weren't interested in seeing the tab, we eventually throw the uploaded layers away.*

Blog post does not report performance numbers.


about:mozilla
300%
minipage vertical alignment
The Beast adopted new raiment and studied the ways of Time and Space and Light and the Flow of energy through the Universe. From its studies, the Beast fashioned new structures from oxidised metal and proclaimed their glories. And the Beast's followers rejoiced, finding renewed purpose in these teachings.
from The Book of Mozilla, 11:14

Electrolysis (2017): multiple OS-level processes.
(Think about threading models).



Chrome vs Firefox

Chrome: 1-process-per-tab.
Firefox: 4 shared content processes.

Firefox uses less memory (has less render state).

Electrolysis challenges:
internal architecture, and add-ons.

Electrolysis vs Flow

Two different Firefox projects:

Electrolysis = split across processes
Quantum Flow = leverage multithreading
(using Rust's "fearless concurrency"),
plus other improvements.

Steps:

1. Measure slowness & prioritize
2. Gather help
3. Fix all (well, some of) the things!

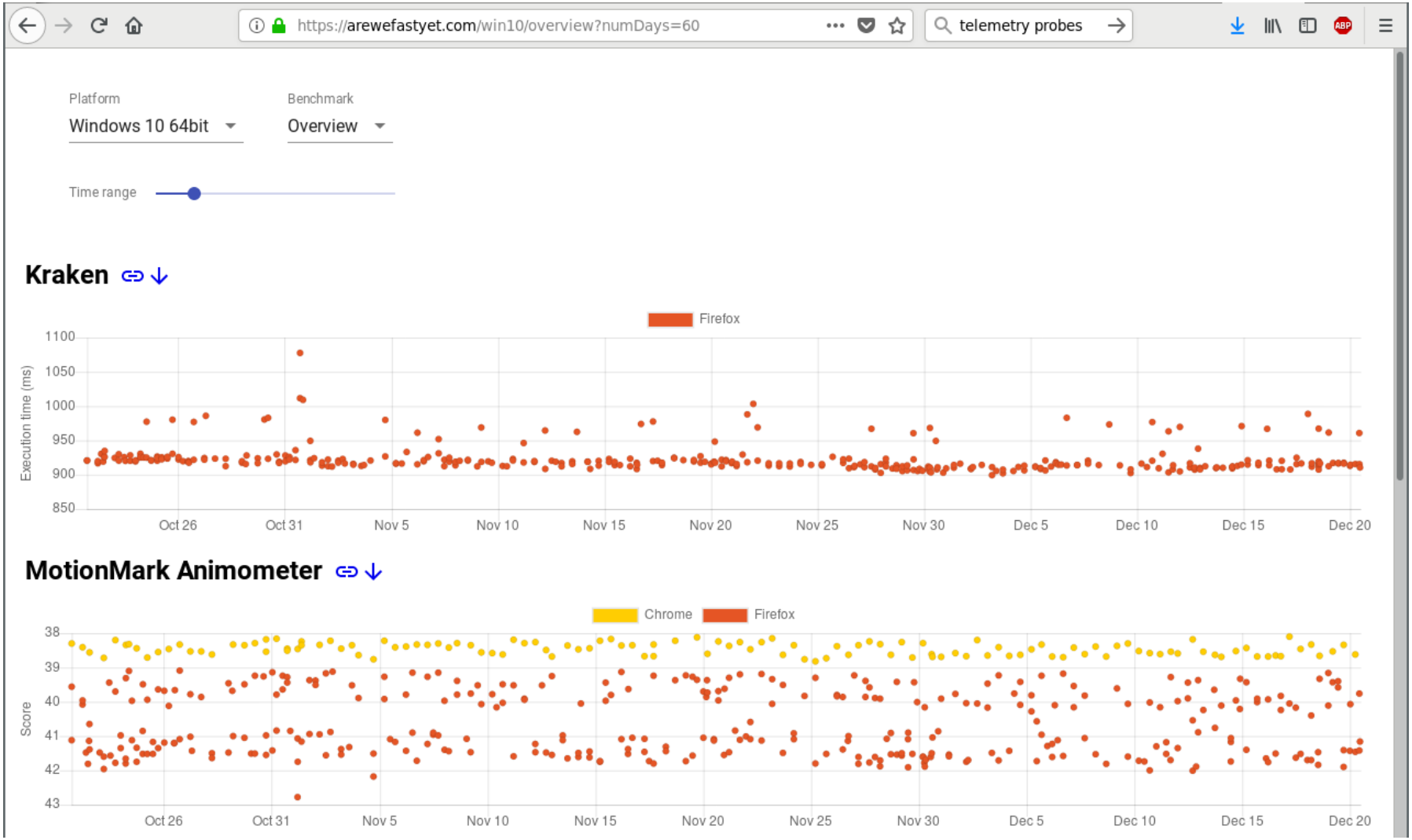
In 6 months:

prioritized 895 bugs, fixed 369.

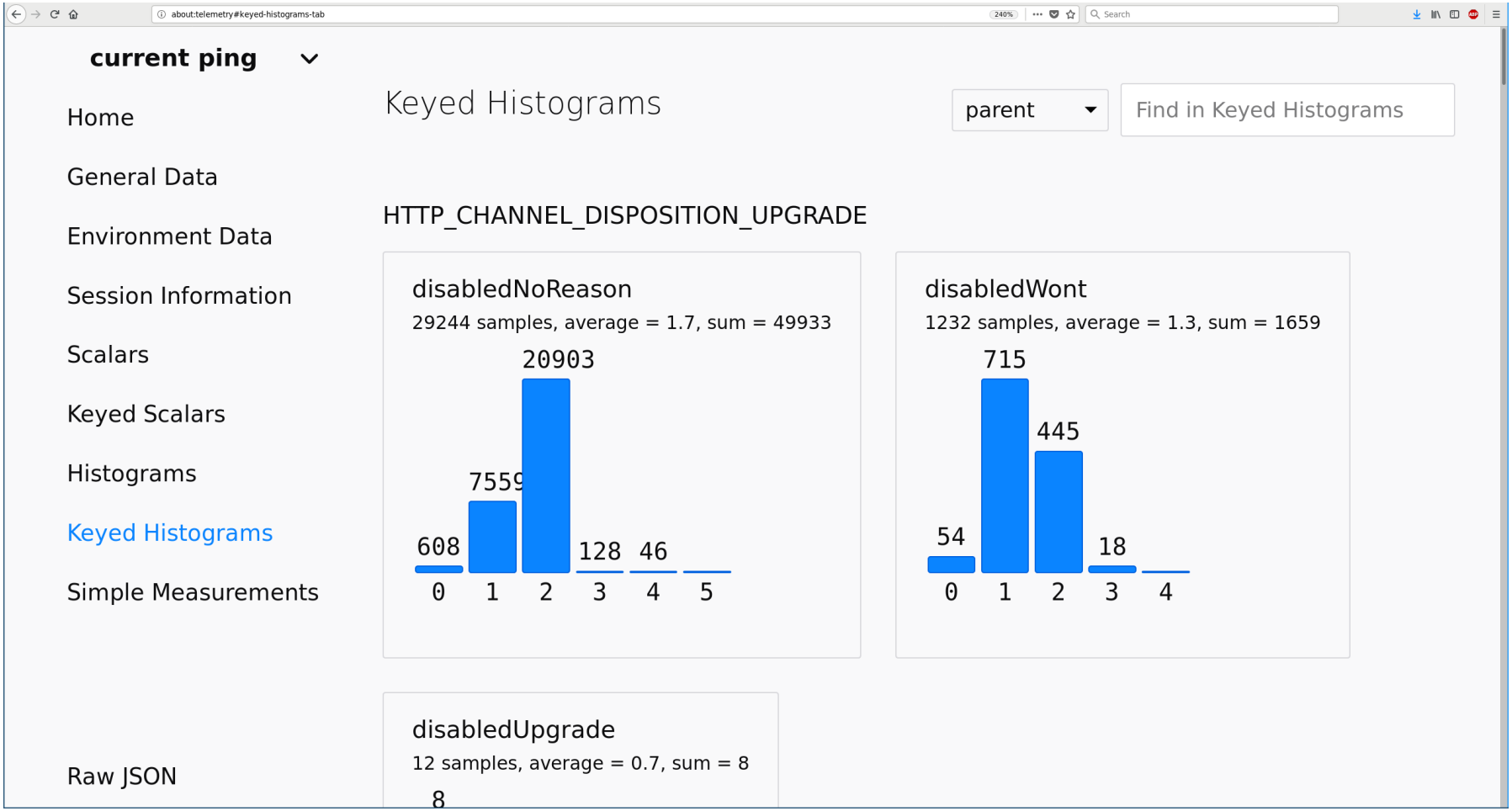
Key tool:

“Quantum Flow Engineering Newsletter”.

arewefastyet dot com



about:telemetry



About Telemetry

Idea: Ask questions first, act second.

Collect data about Firefox usage, then start hacking.

100s of GBs of anonymous metrics/day,
publicly available.

Analogous to CPU profiling, but massively distributed.

- collected much less often than CPU profiling data, but at much broader scope.

`https://telemetry.mozilla.org/`

Example Telemetry Questions

- Is Firefox the user's default browser? (69% yes)
- Does e10s make startup faster? (no, slower)
- Which plugins tend to freeze the browser on load? (Silverlight and Flash)

Can also see evolution of data over time.

Devs can propose new probes;
reviewed for data privacy plus normal code review.

Firefox sends pings:

- “main ping” every 24 hours;
- upon shutdown;
- upon environment change;
- upon abnormal shutdown.

Presumably compressed JSON to Mozilla servers.

```
{
  type: <string>, // "main", "activation", "optout", ...
  id: <UUID>, // a UUID that identifies this ping
  creationDate: <ISO date>, // the date the ping was generated
  version: <number>, // the version of the ping format

  application: {
    architecture: <string>, // build architecture, e.g. x86
    buildId: <string>, // "20141126041045"
    // etc
  },

  clientId: <UUID>, // optional
  environment: { ... }, // optional, not all pings contain
  payload: { ... }, // actual payload data for this ping type
}
```

Ping contents

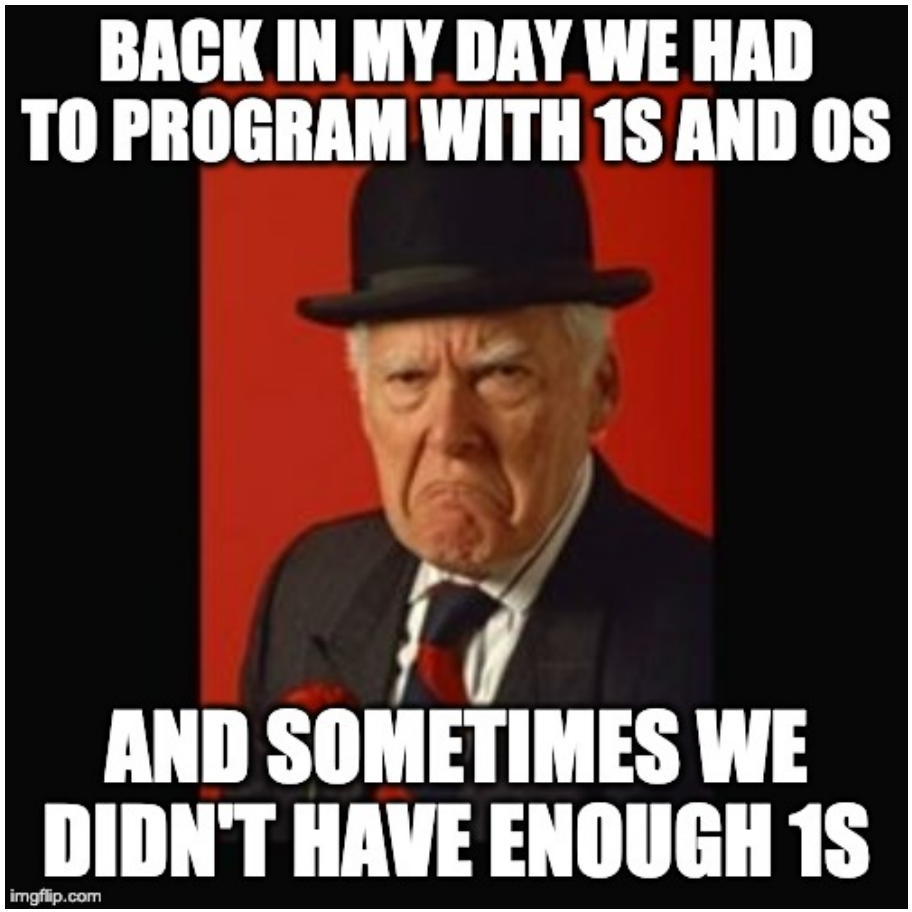
1. Scalars (counts, booleans, strings)
2. Histograms = bucketed data (like grade distributions)

Both scalars and histograms can be keyed,
e.g. how often searches happen for which search engines.

Part II

Lower Level = Faster?

OK Boomer


BACK IN MY DAY WE HAD
TO PROGRAM WITH 1S AND 0S
AND SOMETIMES WE
DIDN'T HAVE ENOUGH 1S
imgflip.com

C is low level, which is good for learning what's really going on.

Writing compact, readable code in C is hard.
Common C sights:

- #define macros
- void*

C++11 has made major strides towards readability and efficiency (it provides light-weight abstractions).

Outline

Goal

Sort a bunch of integers.

In C, usually use qsort from `stdlib.h`.

```
void qsort (void* base, size_t num, size_t size,
            int (*comparator) (const void*, const void*));
```

- A fairly ugly definition (as usual, for generic C functions)

How ugly? `qsort` usage

```c
#include <stdlib.h>

int compare(const void* a, const void* b)
{
    return (*((int*)a) - *((int*)b));
}

int main(int argc, char* argv[])
{
    int array[] = {4, 3, 5, 2, 1};
    qsort(array, 5, sizeof(int), compare);
}
```

- This looks like a nightmare, and is more likely to have bugs.

C++ has a sort with a much nicer interface[1]...

```
template <class RandomAccessIterator>
void sort (
    RandomAccessIterator first,
    RandomAccessIterator last
);

template <class RandomAccessIterator, class Compare>
void sort (
    RandomAccessIterator first,
    RandomAccessIterator last,
    Compare comp
);
```

[1] ...nicer to use, after you get over templates (they're useful, I swear).

C++ sort Usage

```
#include <vector>
#include <algorithm>

int main(int argc, char* argv[])
{
    std::vector<int> v = {4, 3, 5, 2, 1};
    std::sort(v.begin(), v.end());
}
```

Note: Your compare function can be a function or a functor.
By default, `sort` uses `operator<` on the objects being sorted.

- Which is less error prone?
- Which is faster?

The C++ version is twice as fast. Why?

- The C version just operates on memory—it has no clue about the data.
- We're throwing away useful information about what's being sorted.
- A C function-pointer call prevents inlining of the compare function.

OK. What if we write our own sort in C, specialized for the data?

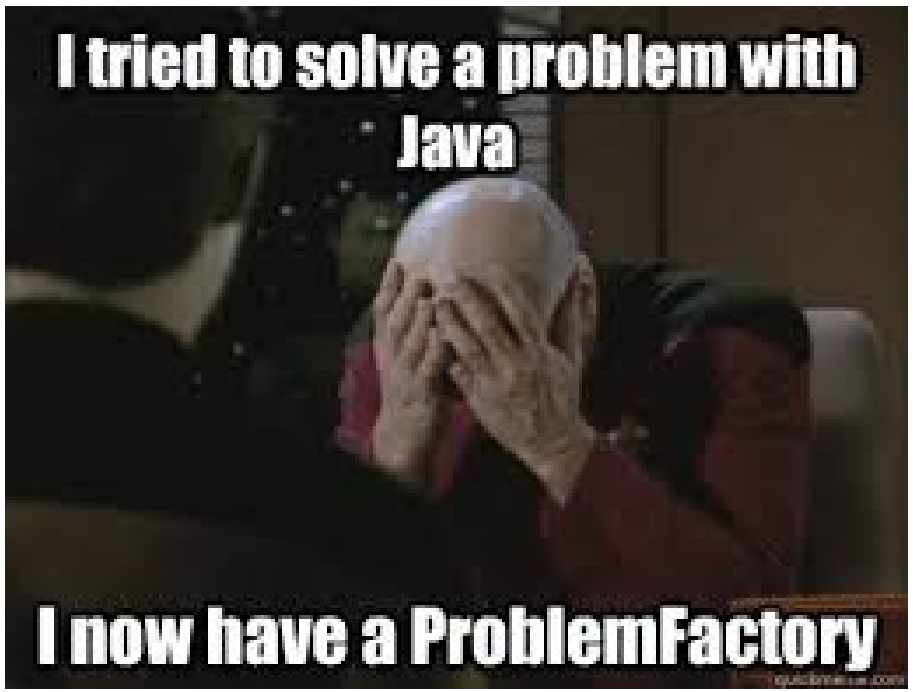
Custom Sort

- The C++ version is still faster (although it's close).
- However, this is quickly going to become a maintainability nightmare.
  - Would you rather read a custom sort or 1 line?
  - What (who) do you trust more?

Abstractions don’t always make your program slower.

They allow speedups and are much easier to maintain and read.

Let's throw Java-style programming (or at least collections) into the mix and see what happens.



Outline

Vectors vs. Lists: Problem

1. Generate N random integers and insert them into (sorted) sequence.

Example: 3 4 2 1

- 3
- 3 4
- 2 3 4
- 1 2 3 4

2. Remove N elements one at a time by going to a random position and removing the element.

Example: 2 0 1 0

- 1 2 4
- 2 4
- 2
-

For which N is it better to use a list than a vector (or array)?

Complexity

- Vector
  - Inserting
    - $\mathrm{O}(\log \mathrm{n})$ for binary search
    - $\mathrm{O}(\mathrm{n})$ for insertion (on average, move half the elements)
  - Removing
    - $\mathrm{O}(1)$ for accessing
    - $\mathrm{O}(\mathrm{n})$ for deletion (on average, move half the elements)
- List
  - Inserting
    - $\mathrm{O}(\mathrm{n})$ for linear search
    - $\mathrm{O}(1)$ for insertion
  - Removing
    - $\mathrm{O}(\mathrm{n})$ for accessing
    - $\mathrm{O}(1)$ for deletion

Therefore, based on their complexity, lists should be better.

Vectors dominate lists, performance wise. Why?

- Binary search vs. linear search complexity dominates.
- Lists use far more memory.
  On 64 bit machines:
  - Vector: 4 bytes per element.
  - List: At least 20 bytes per element.
- Memory access is slow, and results arrive in blocks:
  - Lists' elements are all over memory, hence many cache misses.
  - A cache miss for a vector will bring a lot more usable data.

Performance Tips: Bullets

- Don't store unnecessary data in your program.
- Keep your data as compact as possible.
- Access memory in a predictable manner.
- Use vectors instead of lists by default.
- Programming abstractly can save a lot of time.