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RiSE Research in Software Engineering

JSMeter: Characterizing the Behavior of JavaScript Web Applications

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Why Measure JavaScript?

- Standardized, de facto language for the web
  - Support in every browser, much existing code
- Browser and JavaScript performance is important
  - Are current JavaScript benchmarks representative?
  - Limited understanding of JavaScript behavior in real sites
- Who cares?
  - Users, web application developers, JavaScript engine developers

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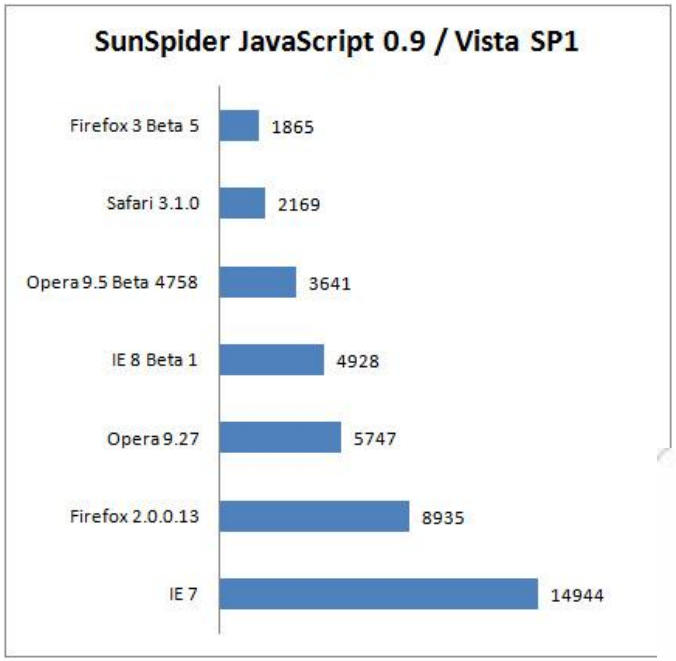
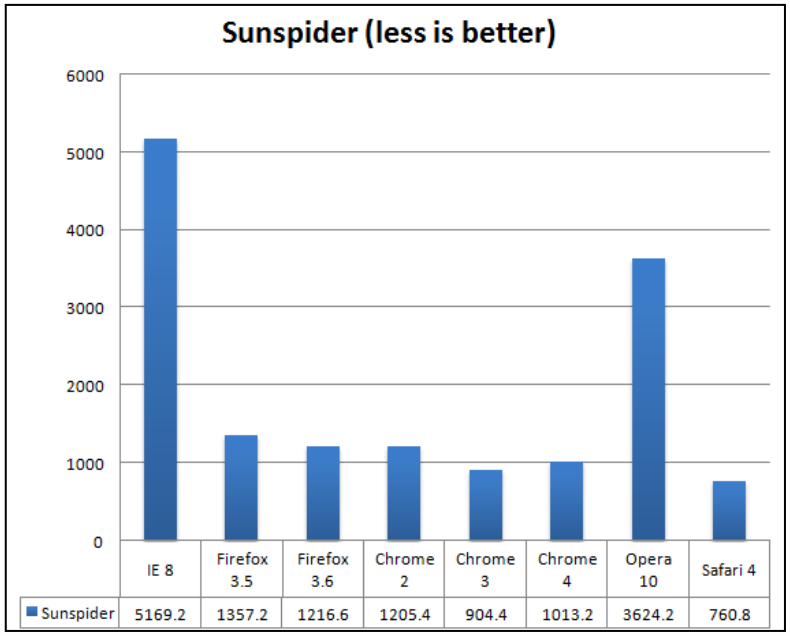
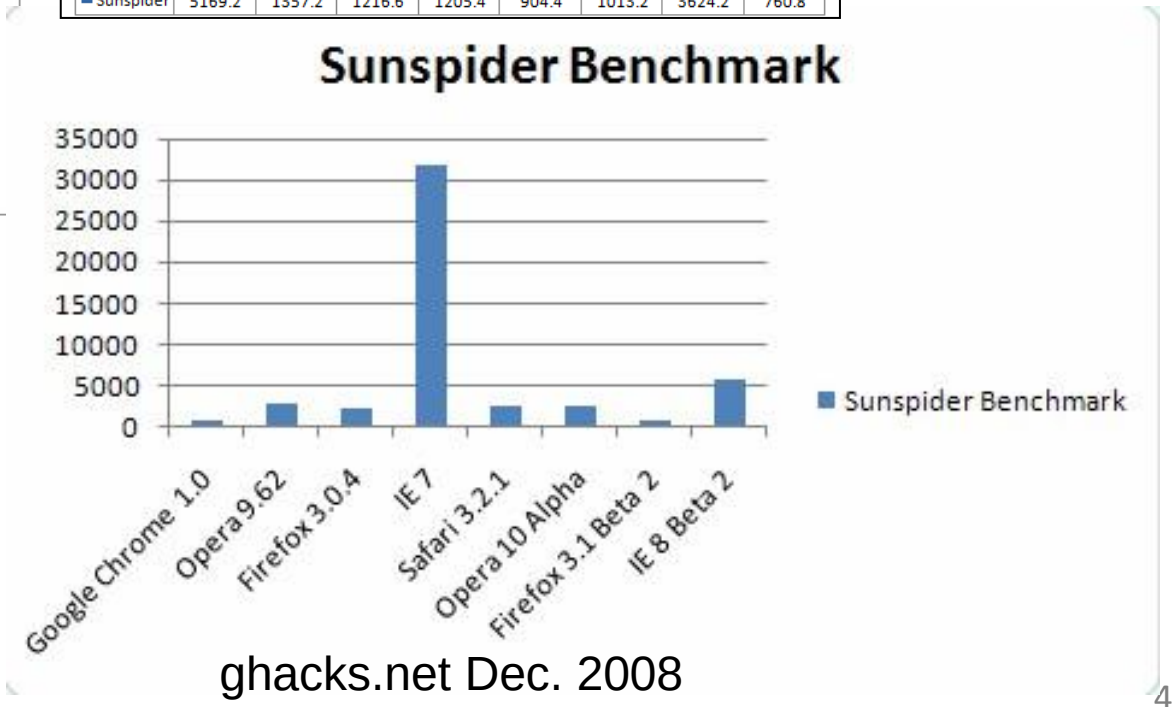


ZDNet 29 May 2008



Browser Wars!



ghacks.net Dec. 2008

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Artificial Benchmarks versus Real World Sites

7 V8 programs:

- richards
- deltablue
- crypto
- raytrace

8 SunSpider programs:

- 3-draytrace
- access-nbody
- bitops-nsieve
- controlflow

JSMeter

11 real sites:

bing Google Gmail Windows Live Hotmail amazon.com ebay

Goals of JSMeter Project

- Instrument JavaScript execution and measure behavior
- Compare behavior of JavaScript benchmarks against real sites
- Consider how benchmarks can mislead design decisions

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How We Measured JavaScript

\ie\jscript*.cpp

Source-level instrumentation

custom jscript.dll

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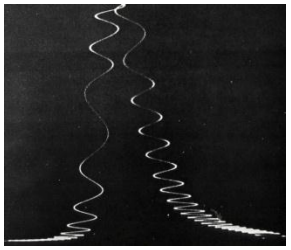
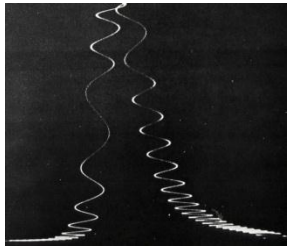
ebay

CNN

website visits

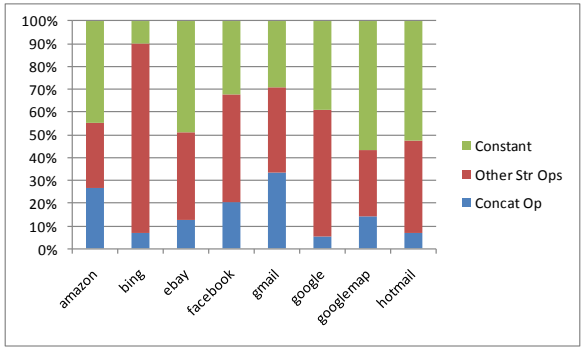


custom trace files



custom trace files

Offline analyzers



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Visiting the Real Sites

- Getting past page load performance
- Attempted to use each site in “normal” way:

amazon	Search a book, add to shopping cart, sign in, and sign out
bing	Type in a search query and also look for images and news
bingmap	Search for a direction from one city to another
cnn	Read front page news
ebay	Search for a notebook, bid, sing in, and sign out
economist	Read front page news, view comments
facebook	Log in, visit a friend pages, browse through photos and comments
gmail	Sign in, check inbox, delete a mail, and sign out
google	Type in a search query and also look for images and news
googlemap	Search for a direction from one city to another
hotmail	Sign in, check inbox, delete a mail, and sign out

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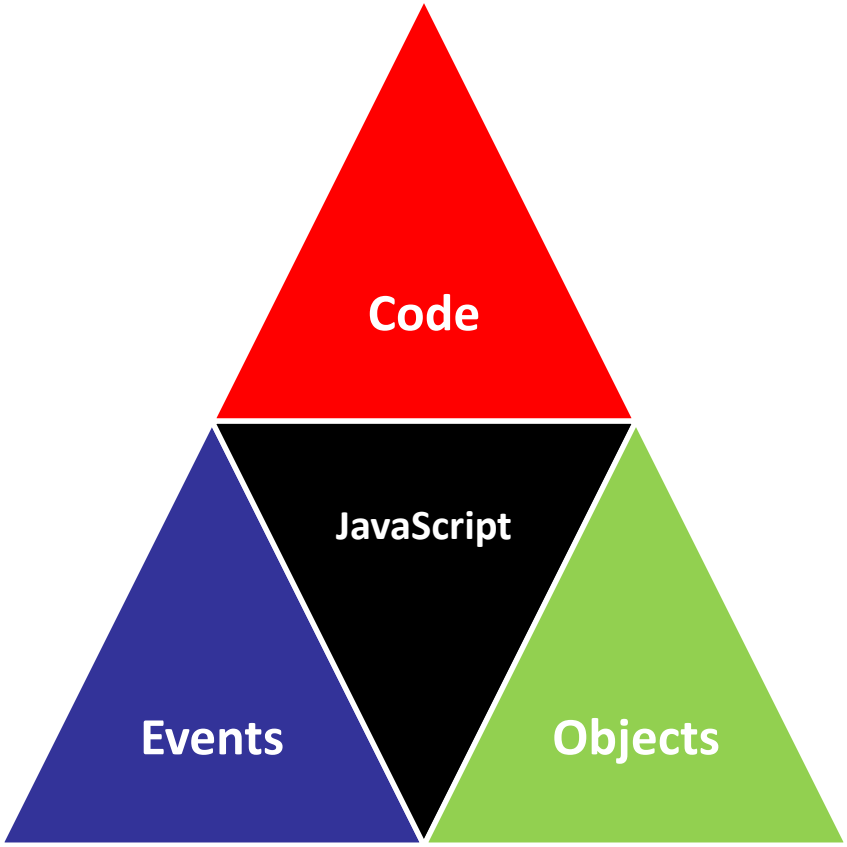
Understanding JavaScript Behavior



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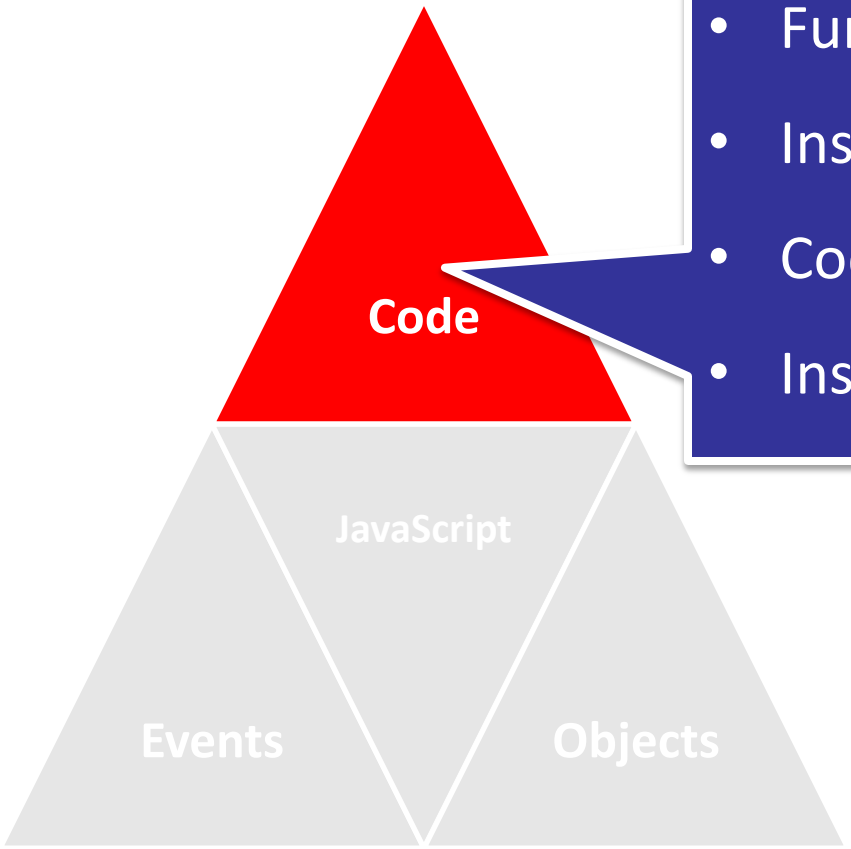
Code Behavior



- Function size
- Instructions/call
- Code locality
- Instruction mix

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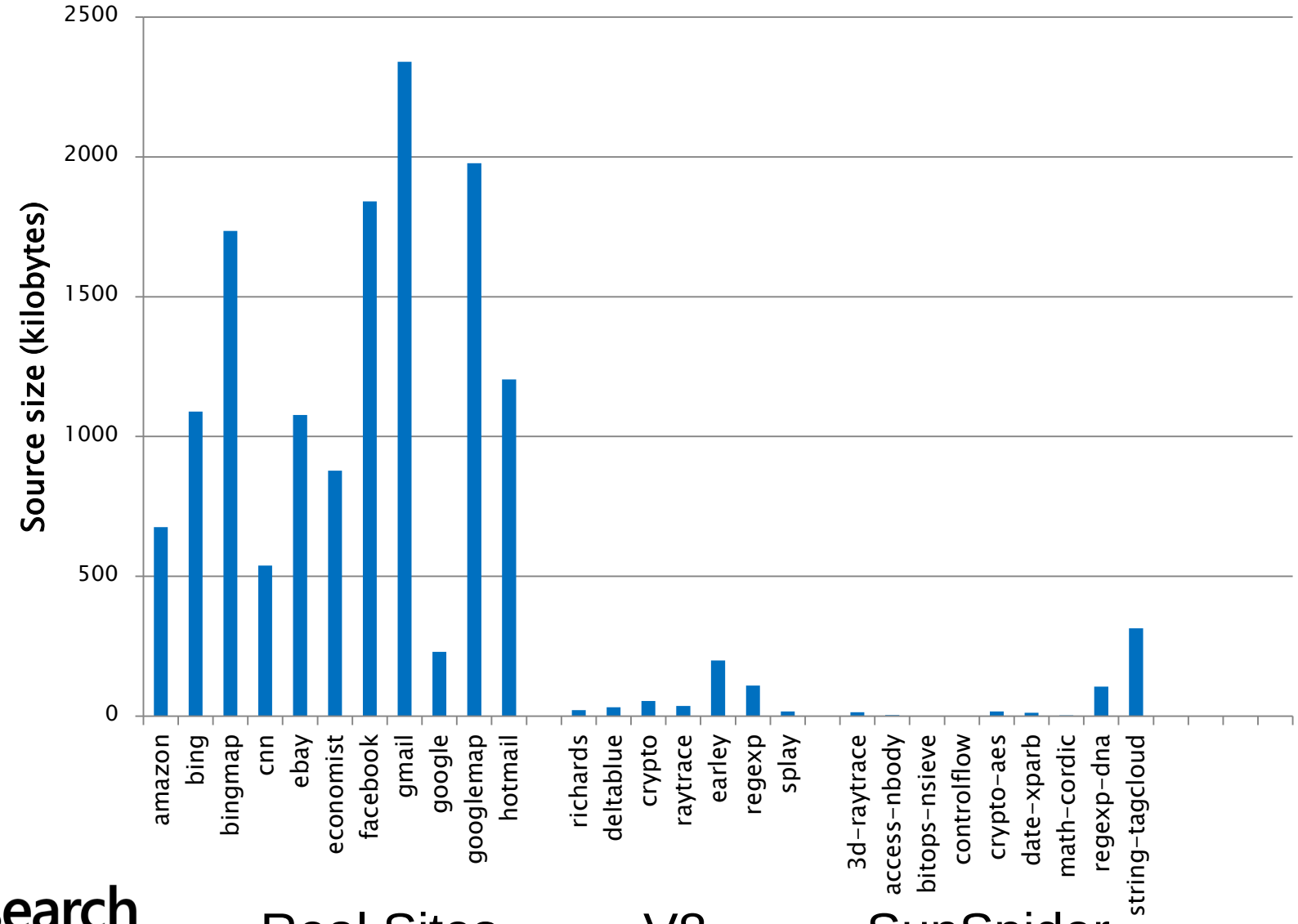
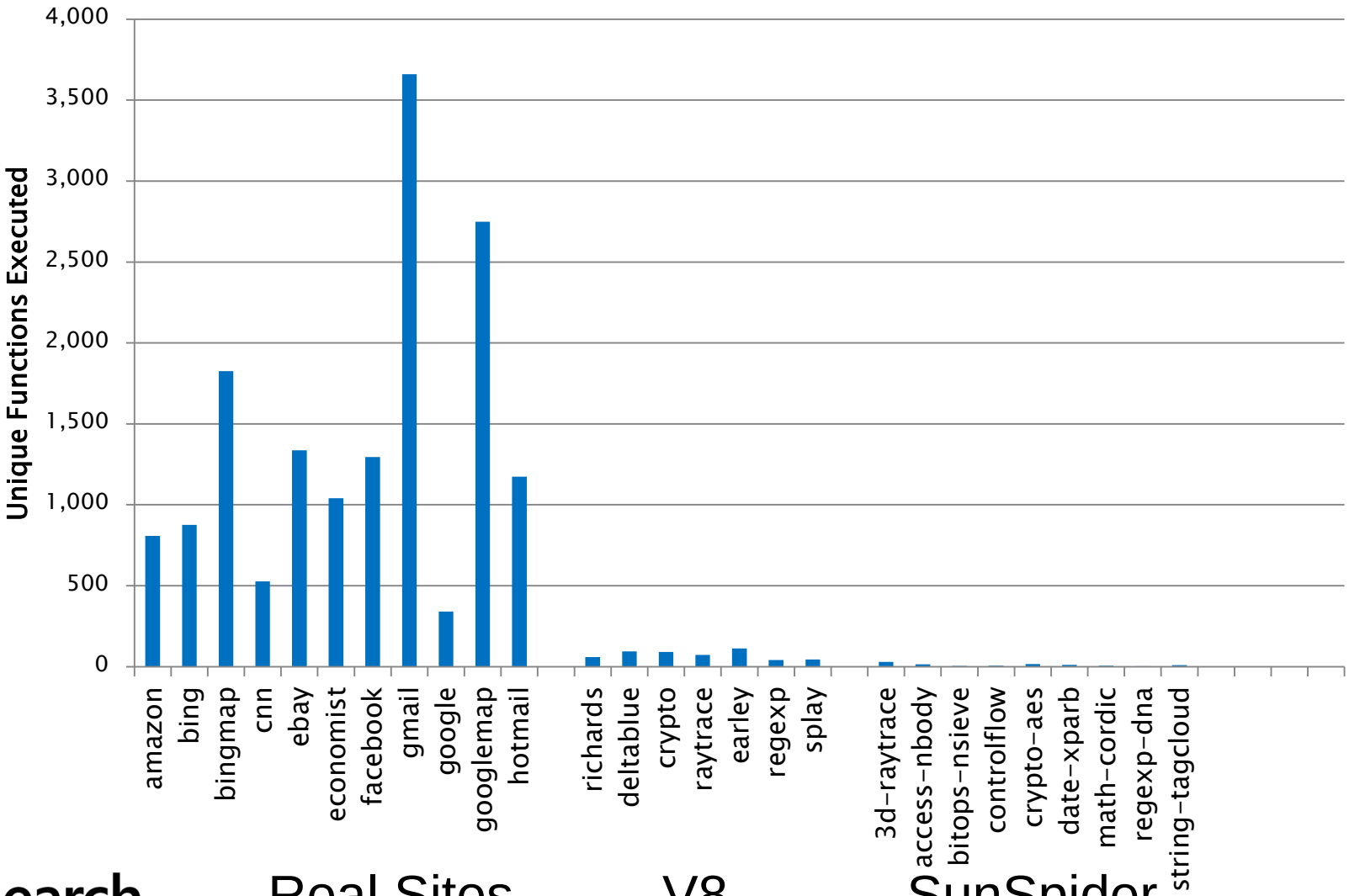
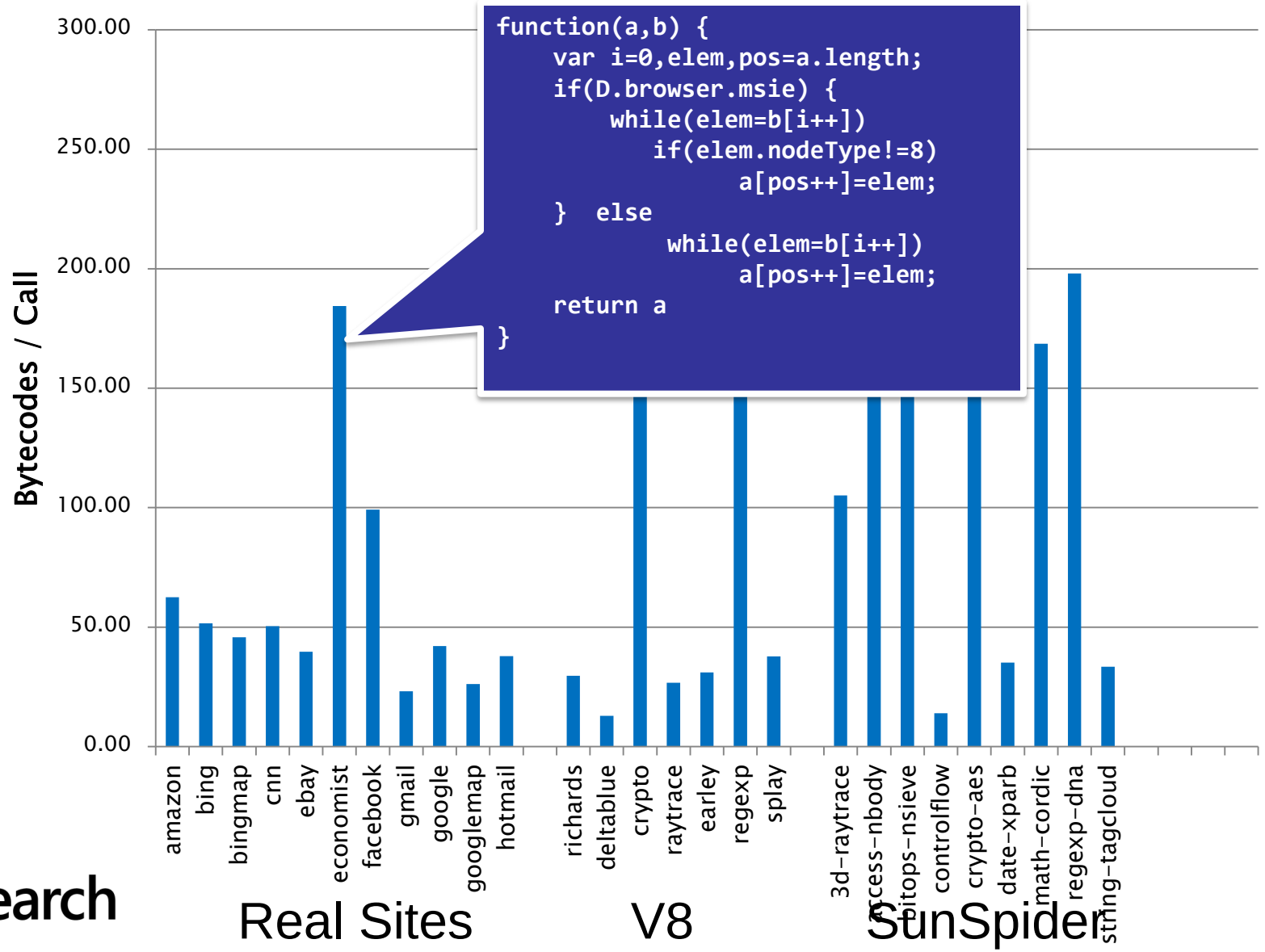
Total Bytes of JavaScript Source



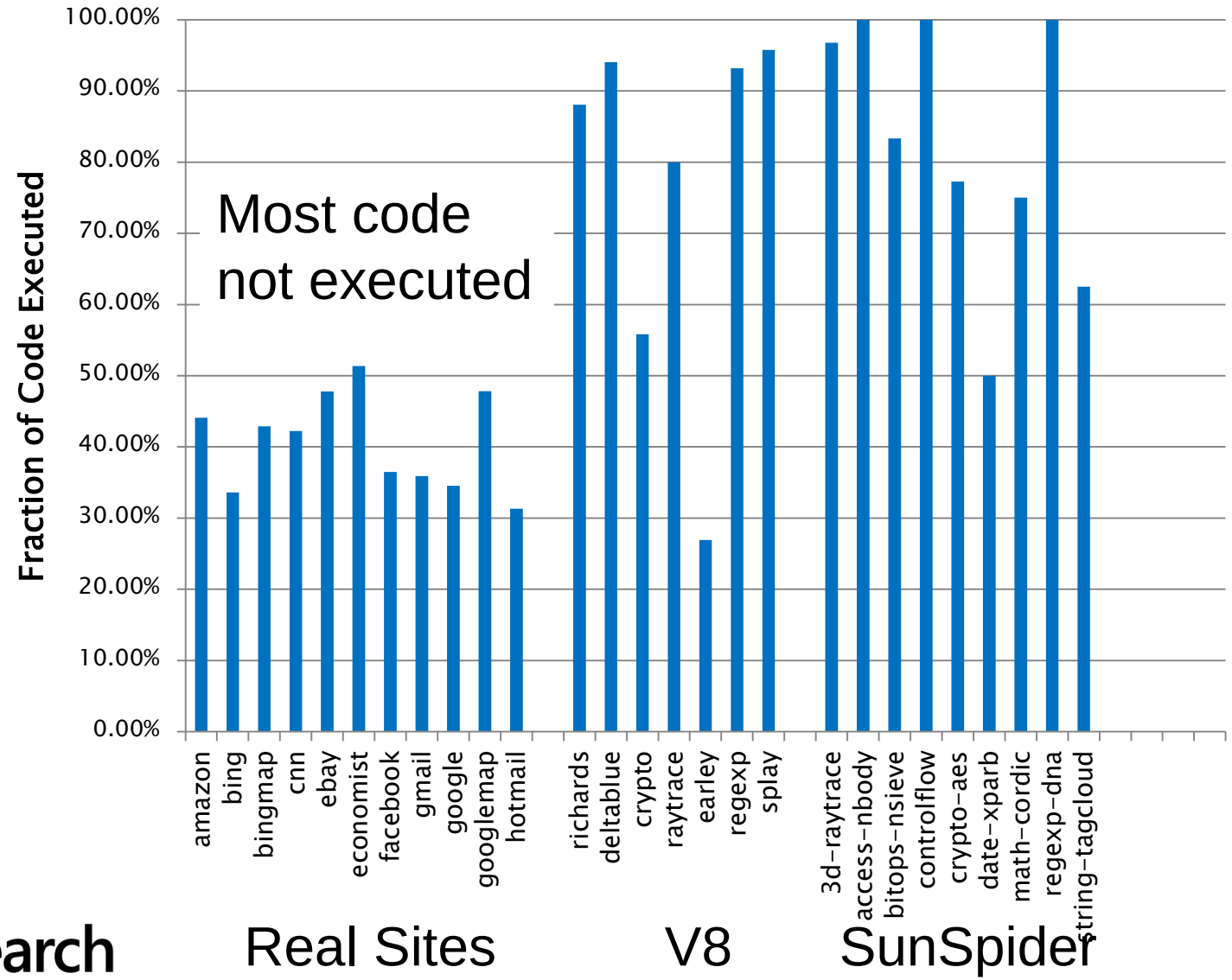
Static Unique Functions Executed



Bytecodes / Call



Fraction of Code Executed



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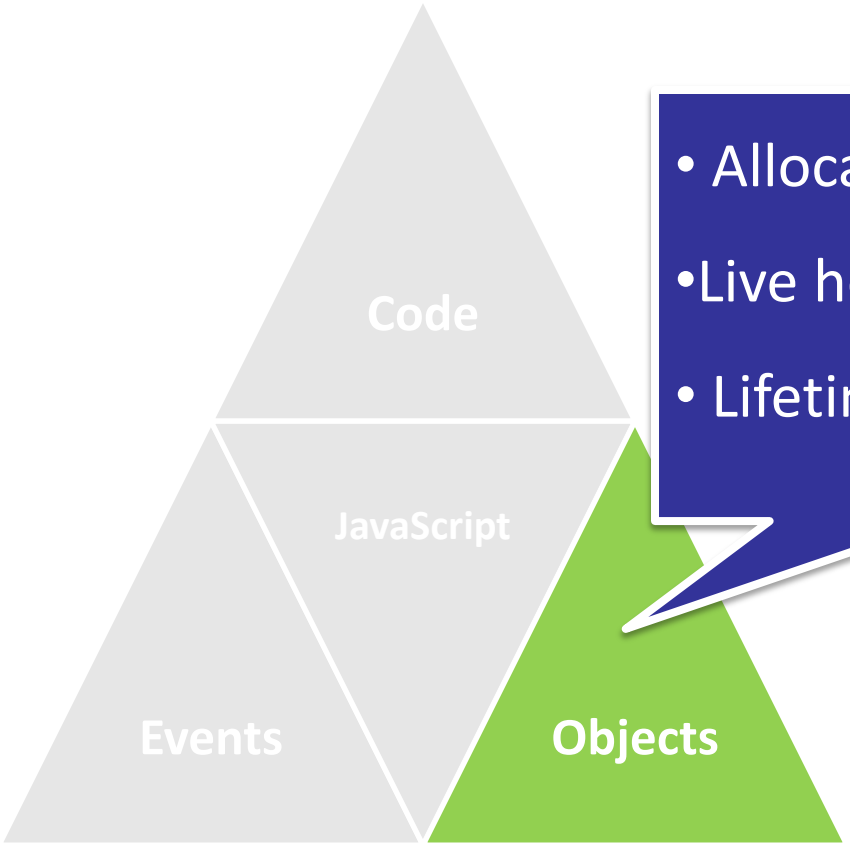
Object Allocation Behavior



- Allocation by types
- Live heap composition
- Lifetime distribution

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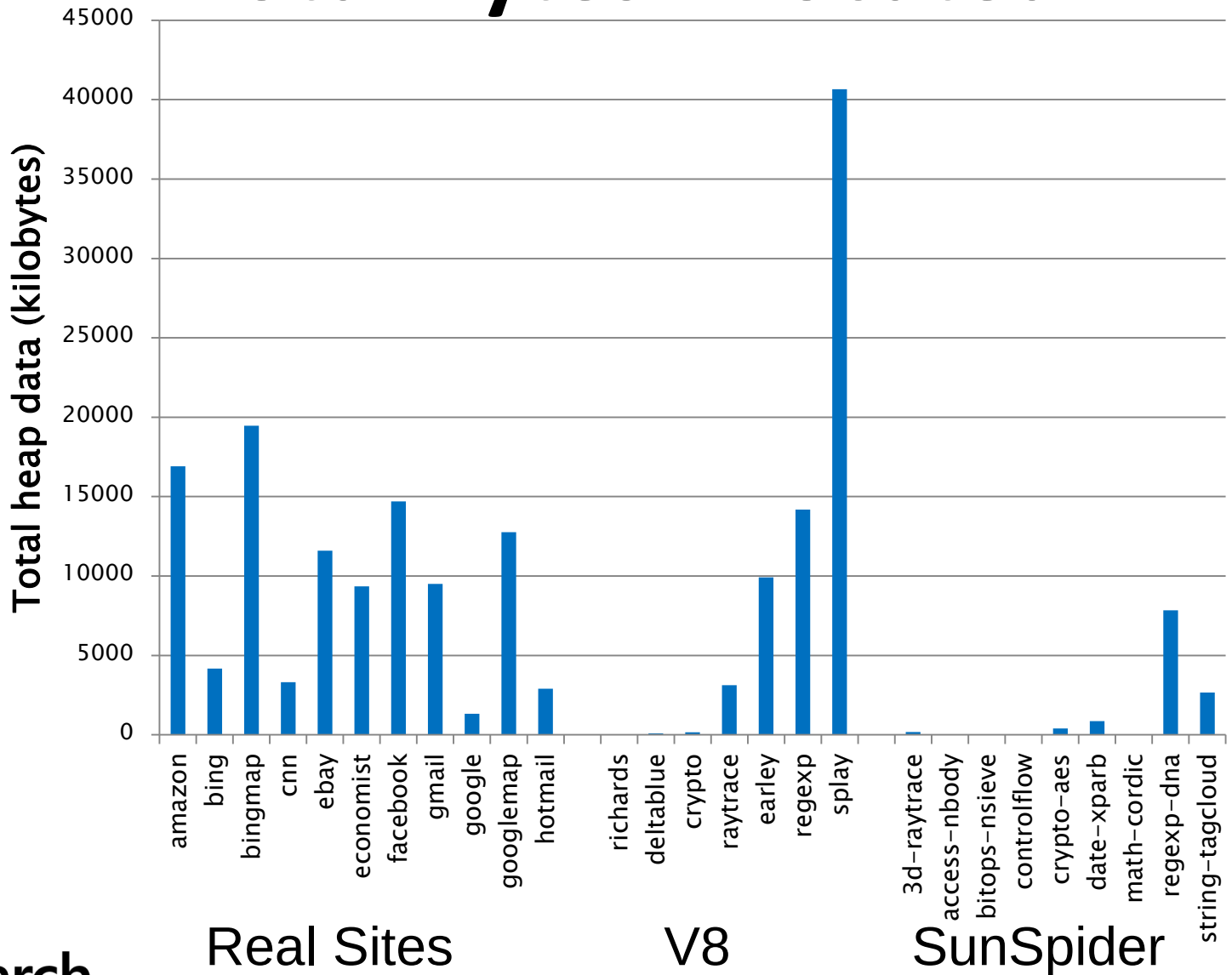
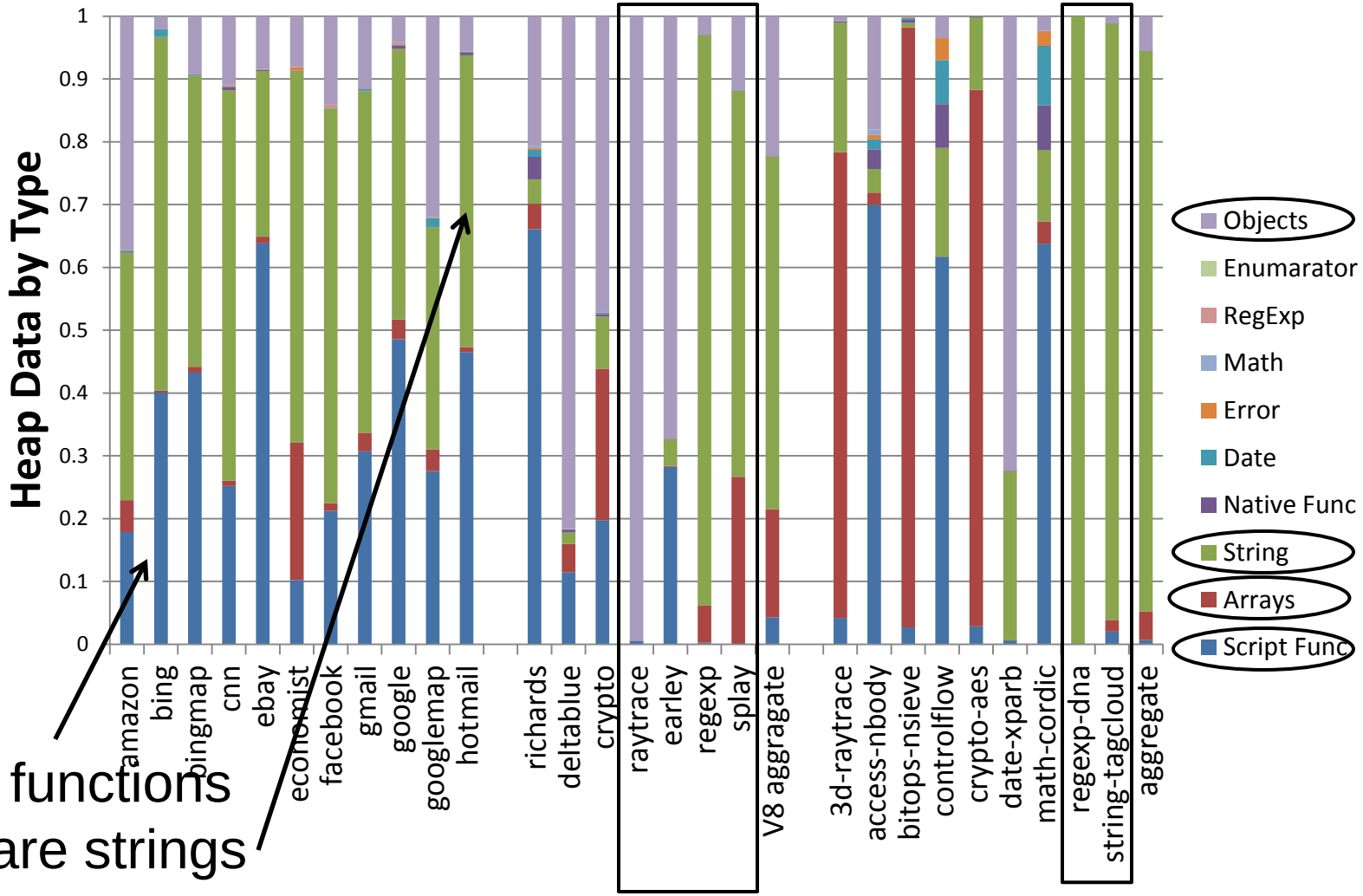
Total Bytes Allocated



Heap Data by Type

Few benchmarks allocate much data



Many functions

Rest are strings

Real Sites

V8

SunSpider

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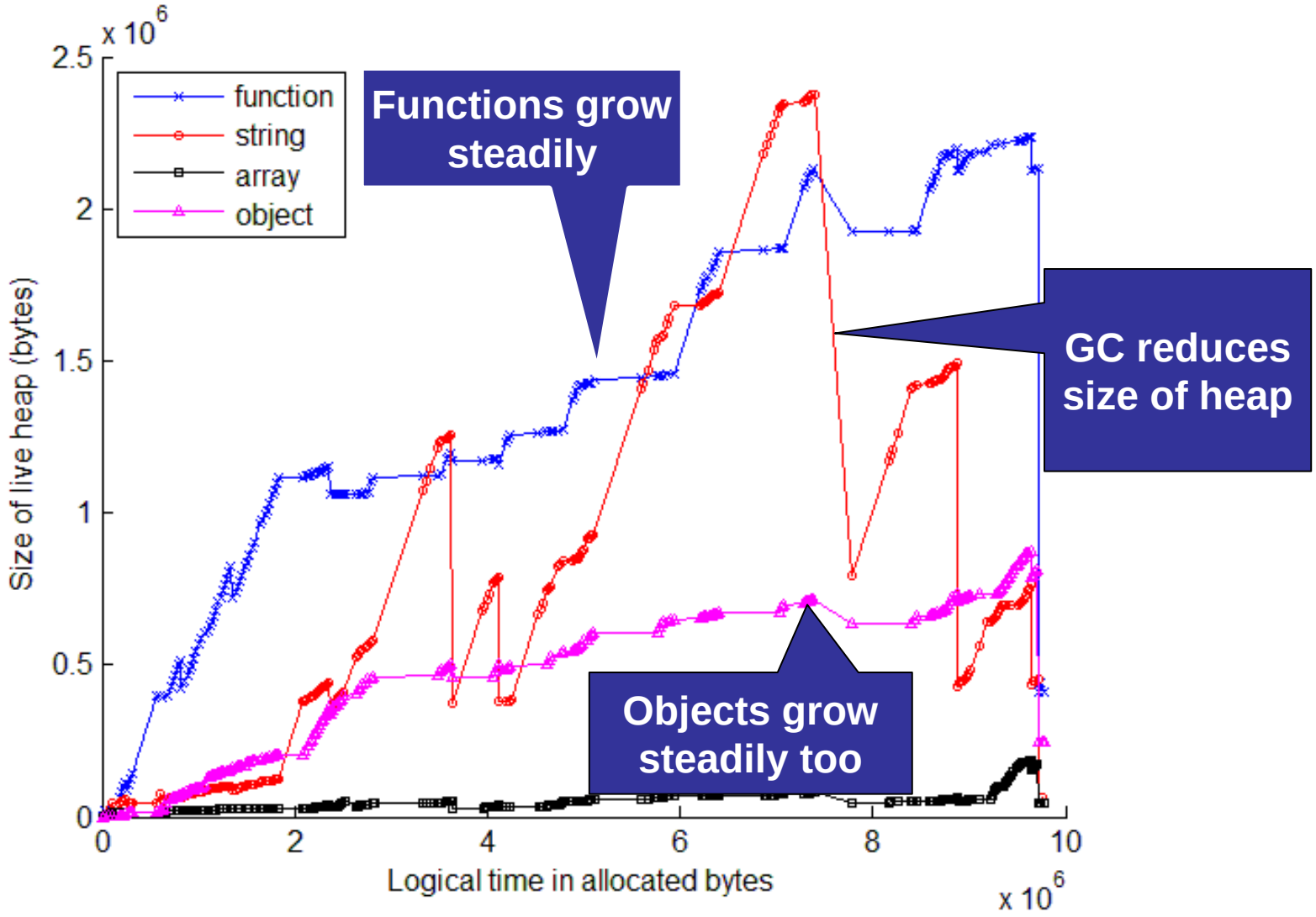
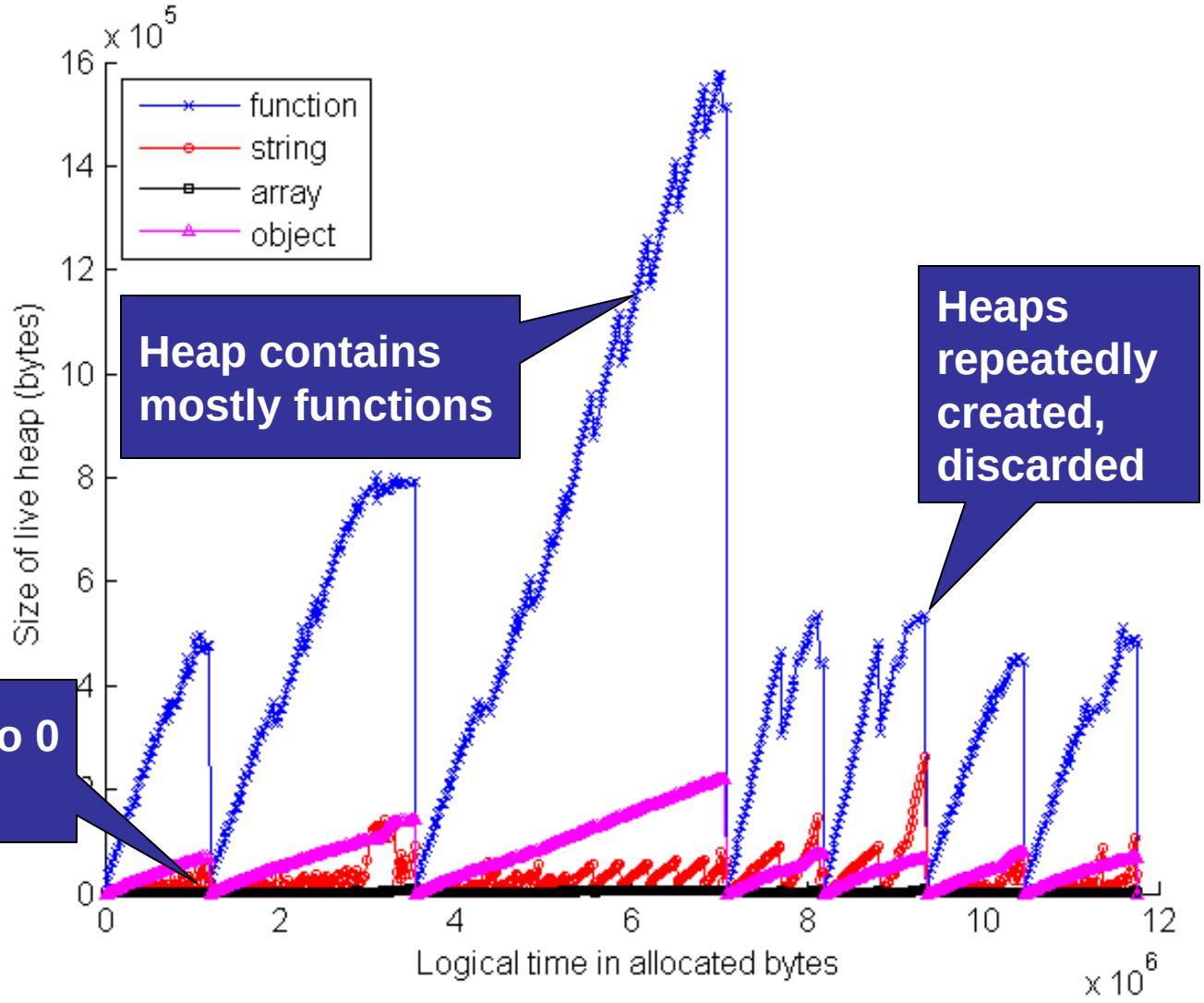
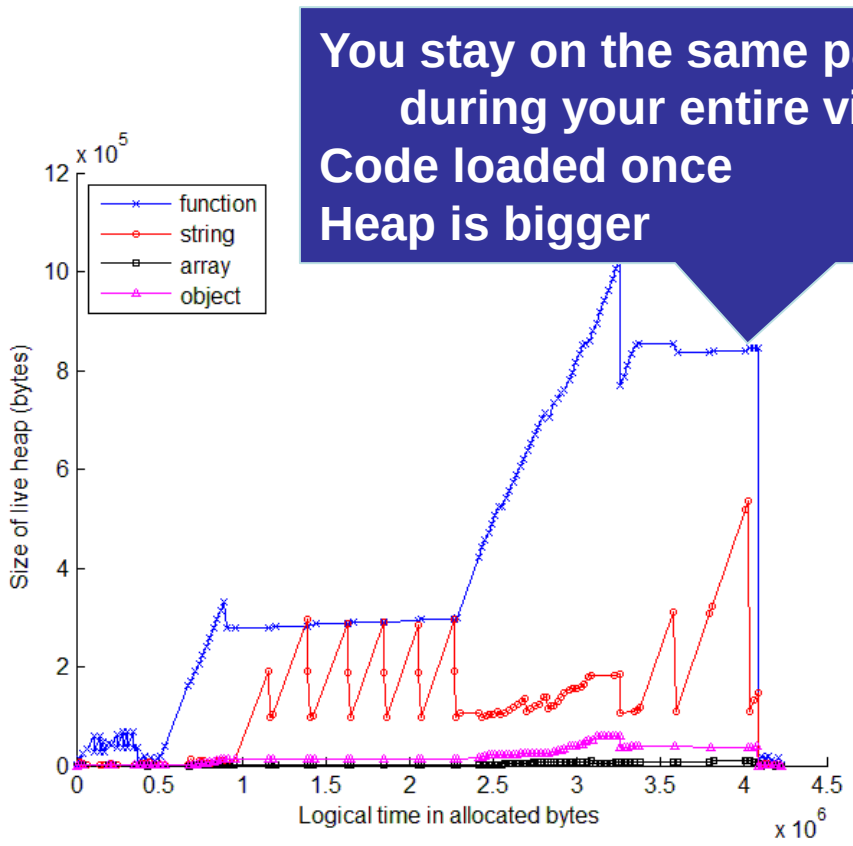
Live Heap Over Time (gmail)



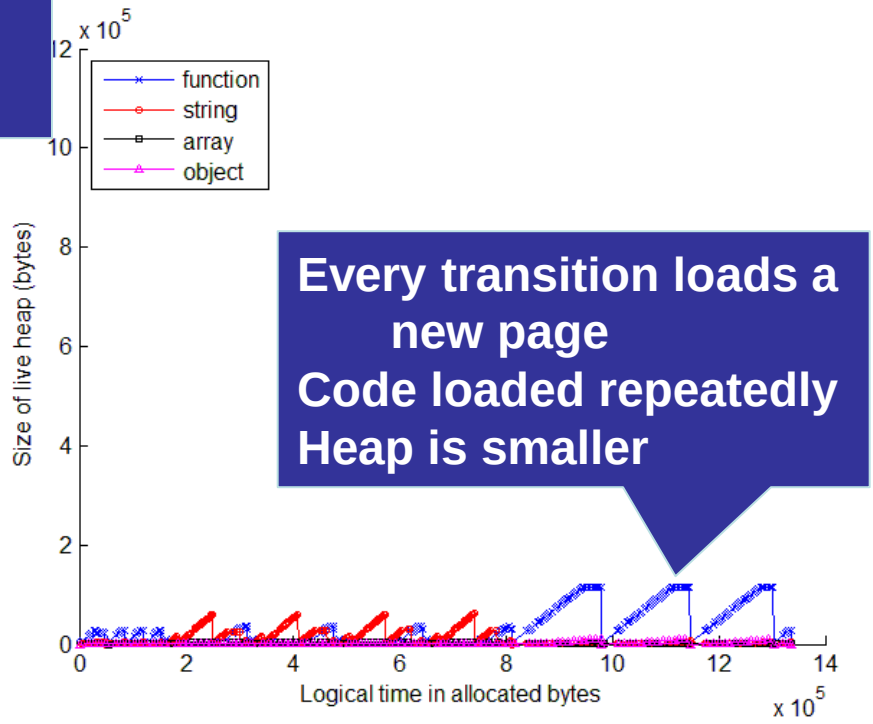
Live Heap over Time (ebay)



2 Search Websites, 2 Architectures



Bing



Google

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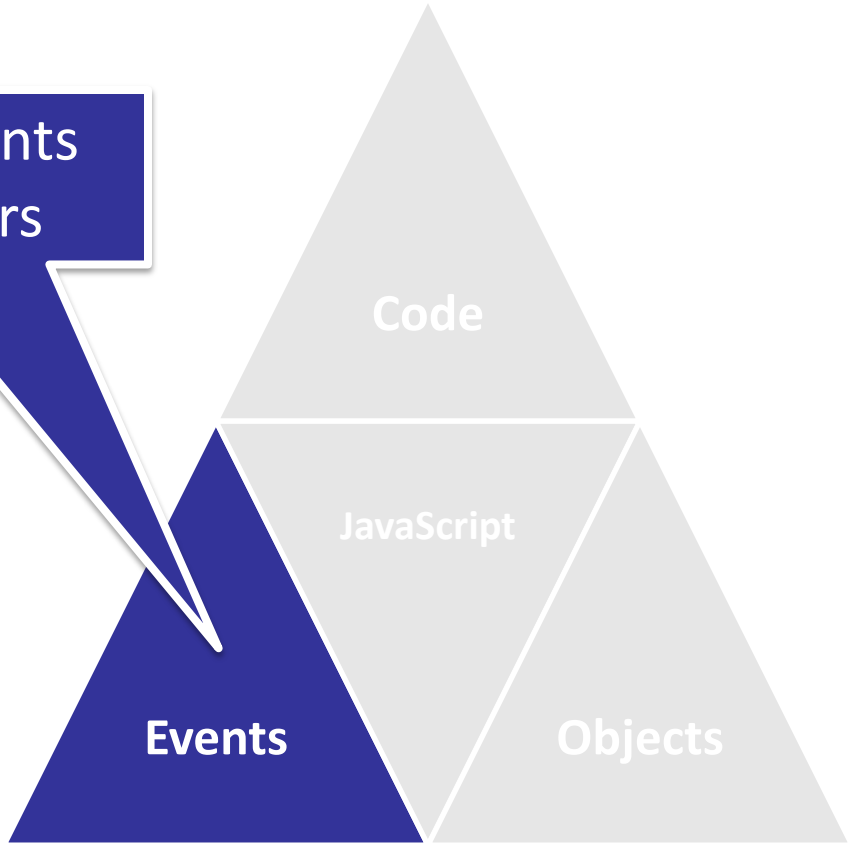
Event Handlers in JavaScript

- Number of events
- Sizes of handlers



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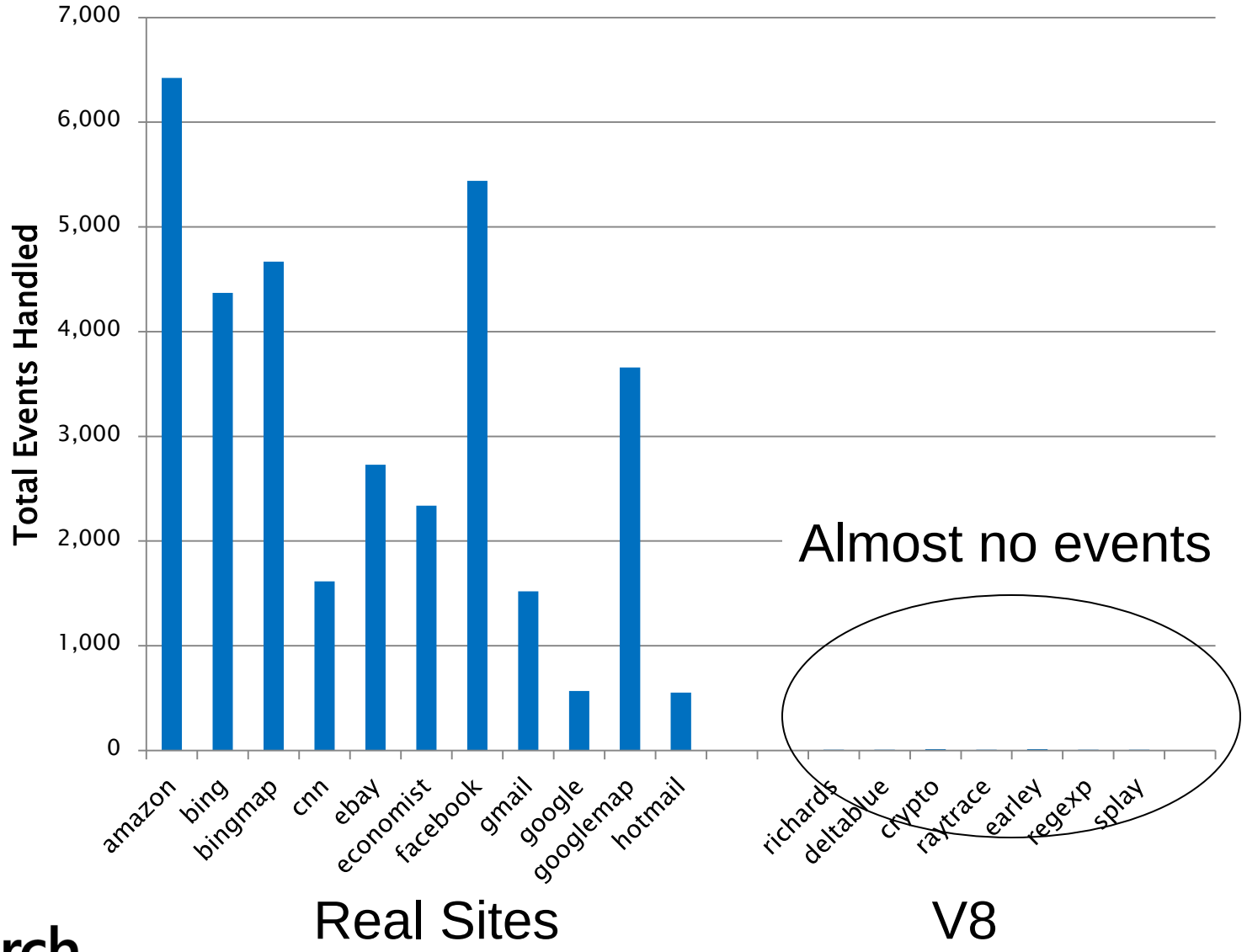
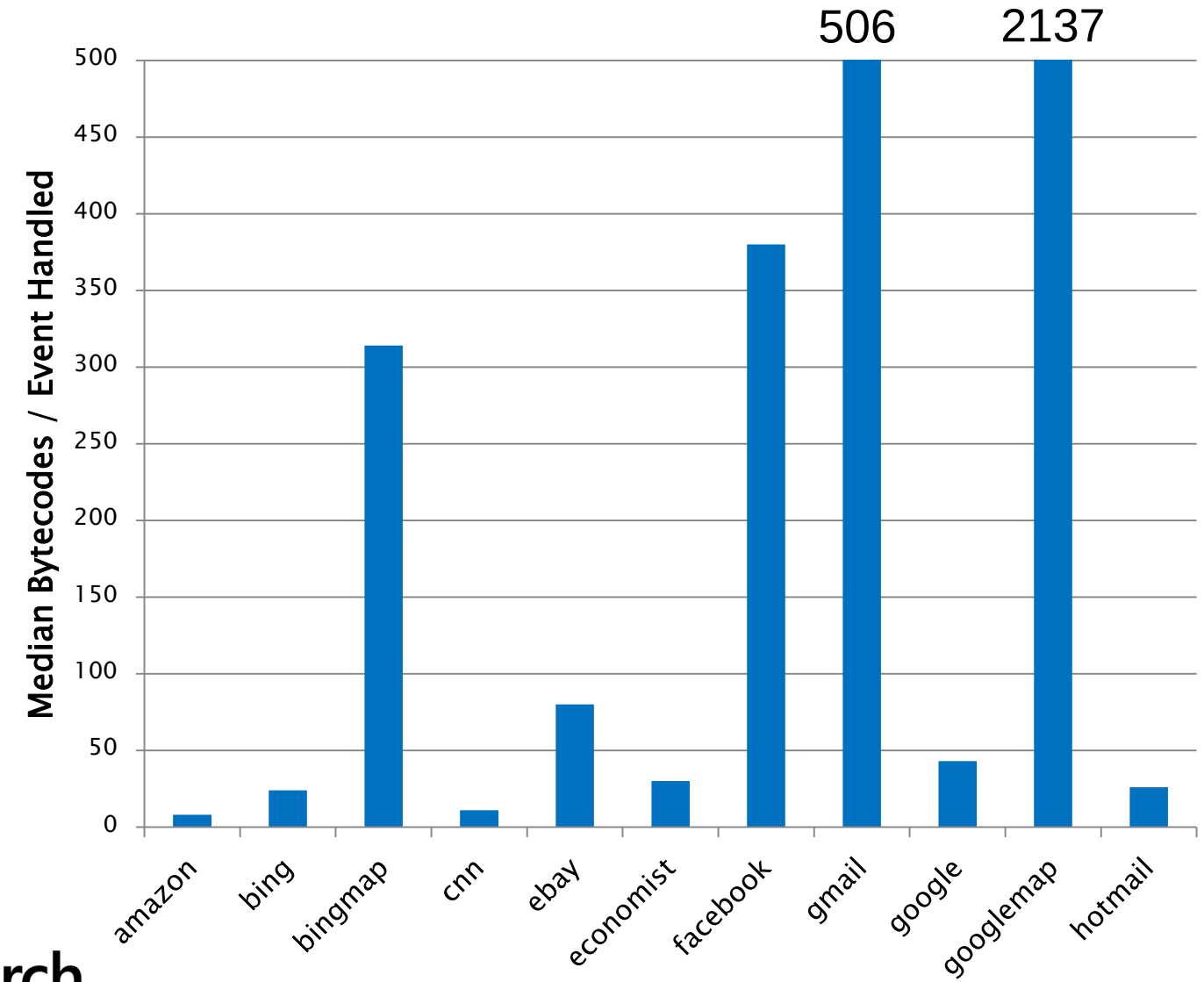
Event-driven Programming Model

- Single-threaded, non-preemptive event handlers
- Example handlers: onabort, onclick, etc.
- Very different from batch processing of benchmarks
- Handler responsiveness critical to user experience

Total Events Handled



Median Bytecodes / Event Handled



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Sure, this is all good, but…

- Everyone knows benchmarks are unrepresentative
- How much difference does it make, anyway?
- Wouldn't any benchmarks have similar issues?

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Cold-code Experiment

- Observation
  - Real web apps have lots of code (much of it cold)
  - Benchmarks do not
- Question: What happens if the benchmarks have more code?
  - We added extra, unused to code to 7 SunSpider benchmarks
  - We measured the impact on the benchmark performance

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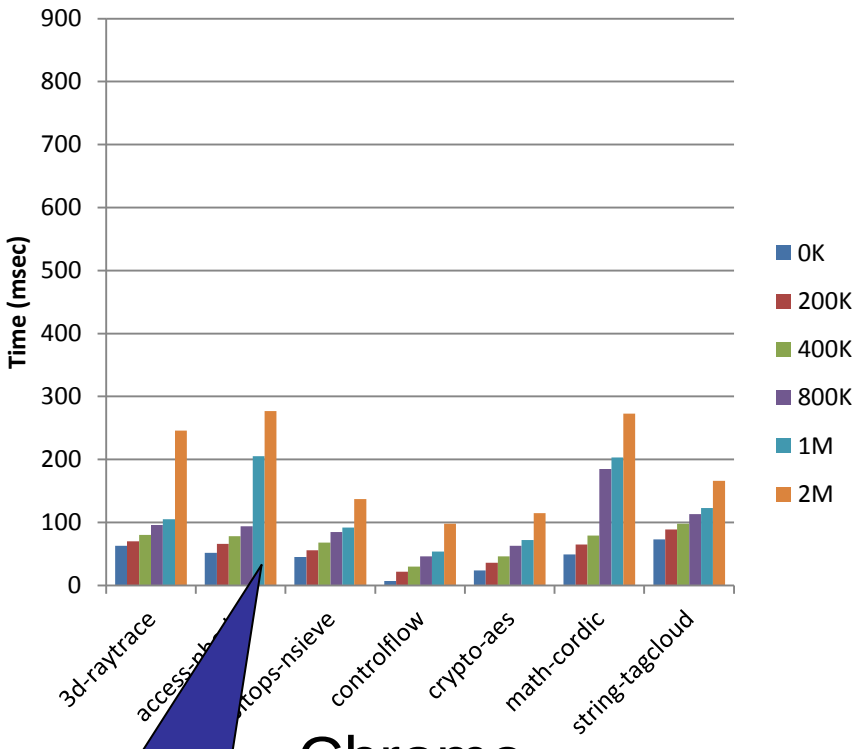
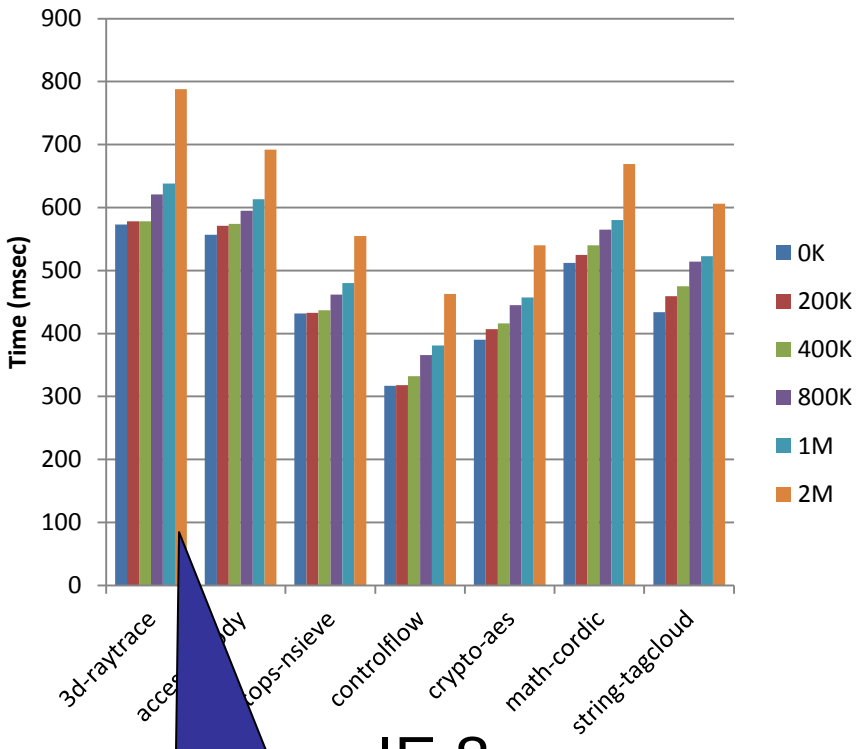
Performance Impact of Cold Code



Chrome

Cold code makes SunSpider on Chrome up to 4.5x slower



IE 8

Cold code has non-uniform impact on execution time

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Impact of Benchmarks

- What gets emphasis
  - Making tight loops fast
  - Optimizing small amounts of code
- Important issues ignored
  - Garbage collection (especially of strings)
  - Managing large amounts of code
  - Optimizing event handling
  - Considering JavaScript context between page loads

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Conclusions

- JSMeter is an instrumentation framework
  - Used to measure and compare JavaScript applications
  - High-level views of behavior promote understanding
- Benchmarks differ **significantly** from real sites
  - Misleads designers, skews implementations
- Next steps
  - Develop and promote better benchmarks
  - Design and evaluate better JavaScript runtimes
  - Promote better performance tools for JavaScript developers

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Additional Resources

- **Project**: http://research.microsoft.com/en-us/projects/jsmeter/
- **Video**: Project JSMeter: JavaScript Performance Analysis in the Real World" - MSDN Channel 9 interview with Erik Meier, Ben Livshits, and Ben Zorn
- **Paper:**
  - "JSMeter: Comparing the Behavior of JavaScript Benchmarks with Real Web Applications", Paruj Ratanaworabhan, Benjamin Livshits and Benjamin G. Zorn, USENIX 2010 Conference on Web Application Development (WebApps'10), June 2010.
- **Additional measurements:**
  - "JSMeter: Characterizing Real-World Behavior of JavaScript Programs", Paruj Ratanaworabhan, Benjamin Livshits, David Simmons, and Benjamin Zorn, MSR-TR-2009-173, December 2009 (49 pages), November 2009.

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Additional Slides

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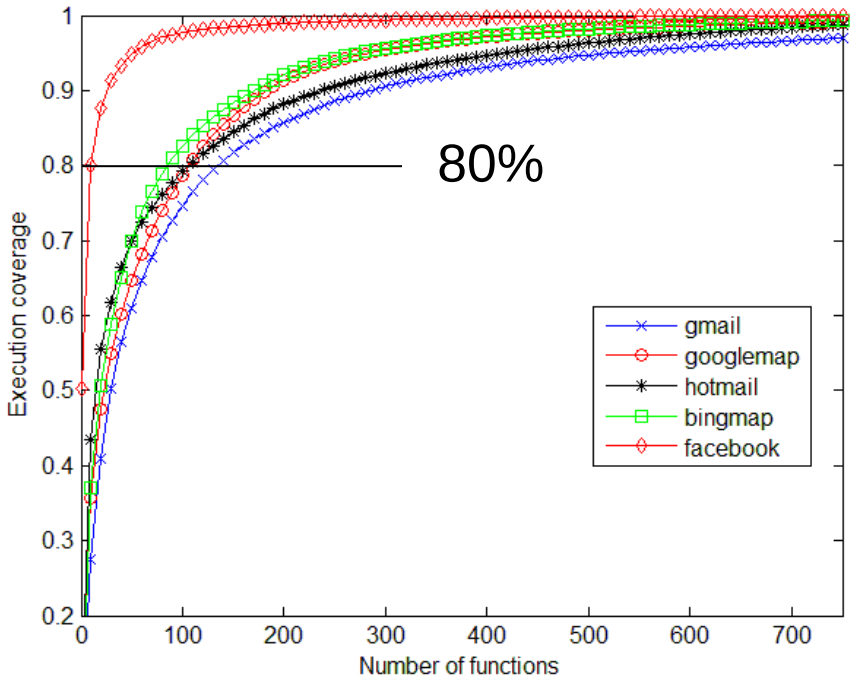
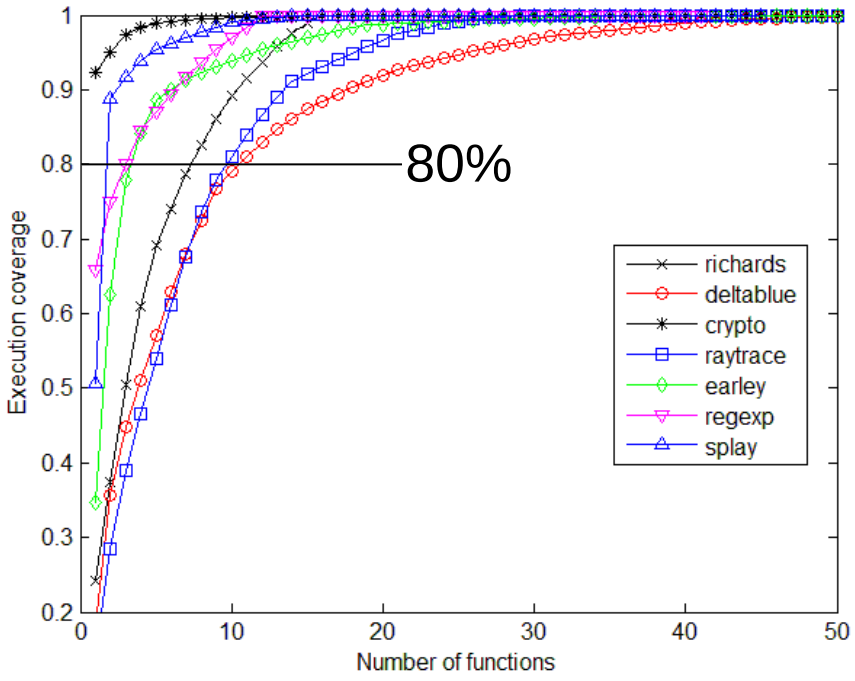
Hot Function Distribution

80% of time in 100+ functions



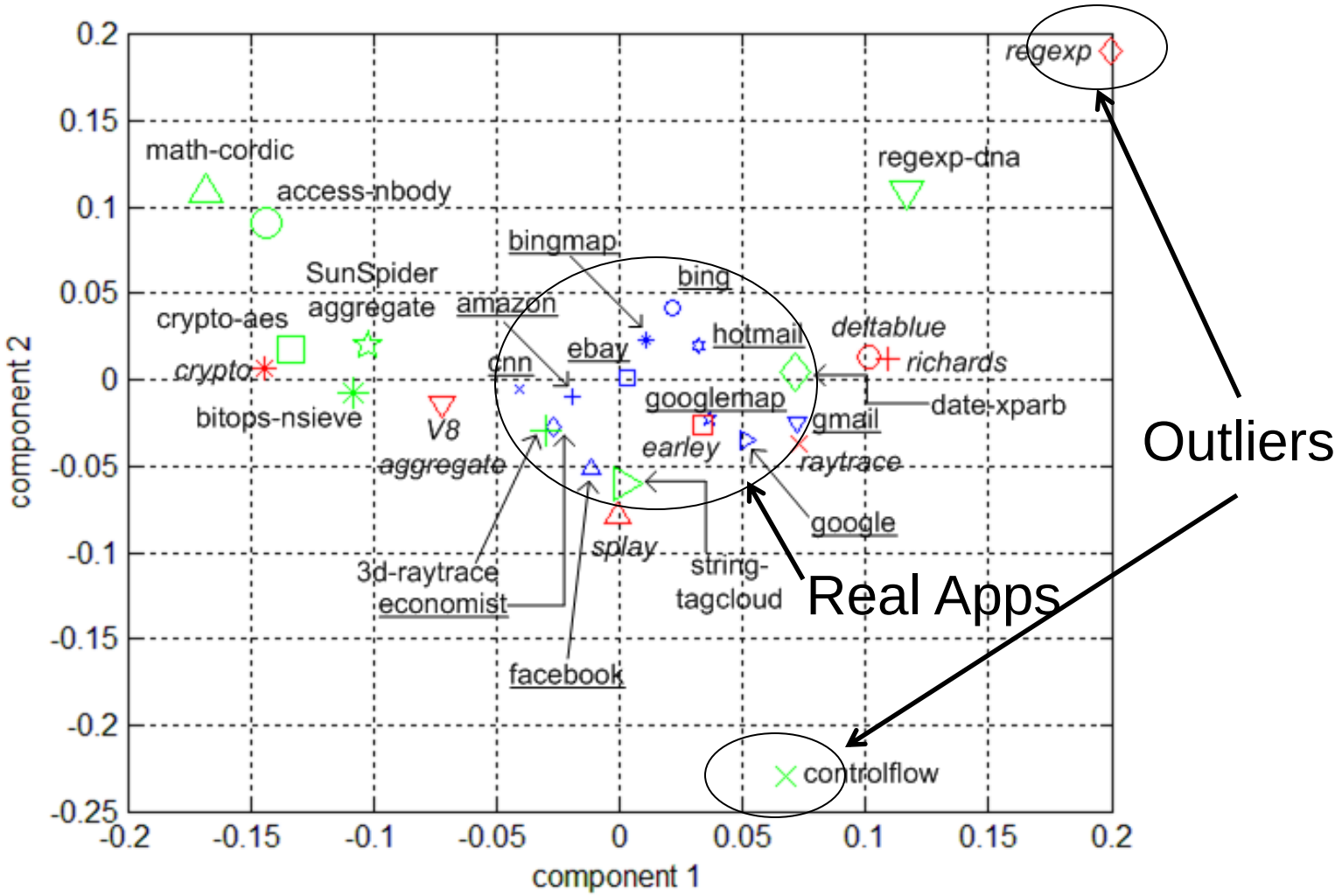
Real Sites

80% of time in < 10 functions



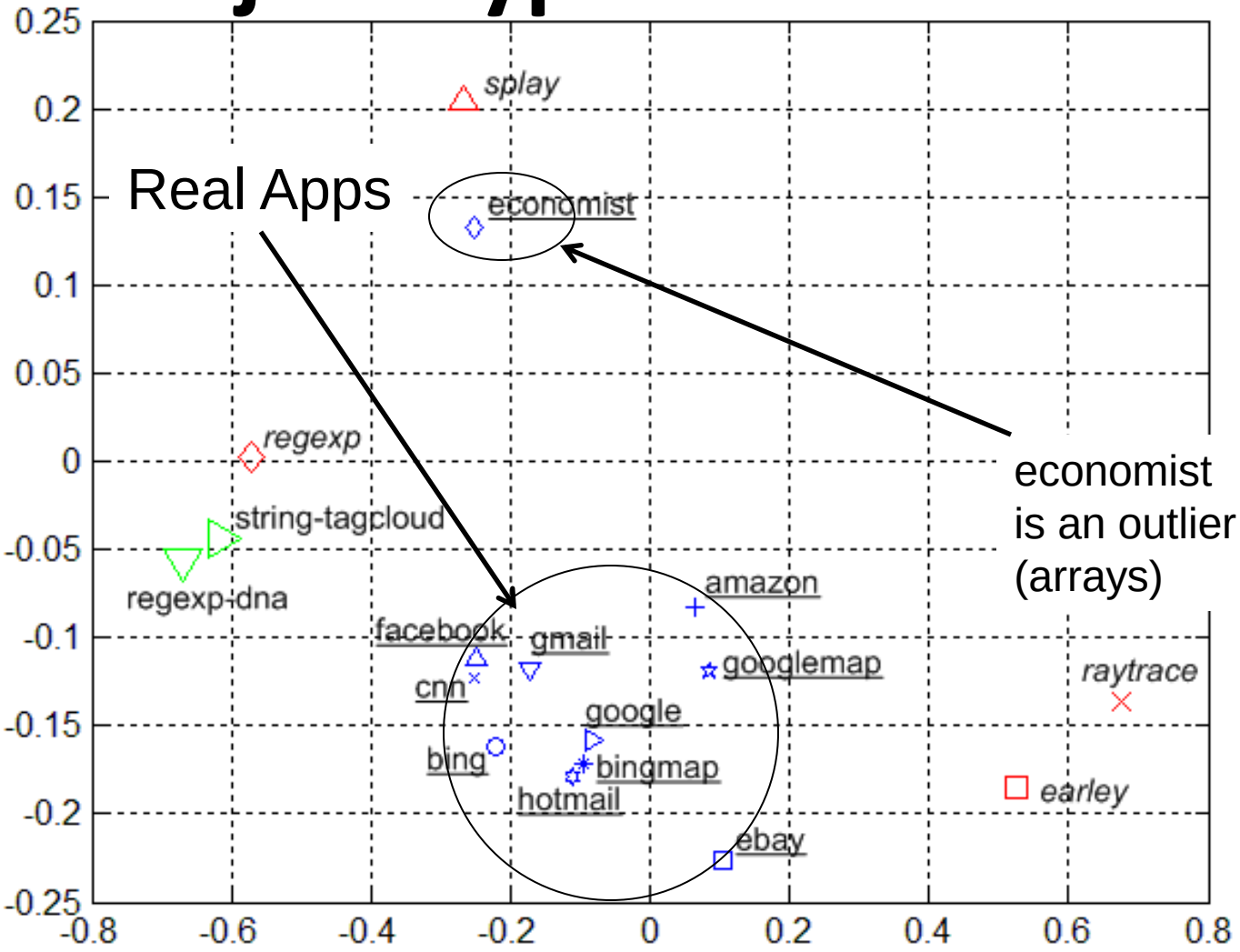
V8 Benchmarks

Opcode Distribution



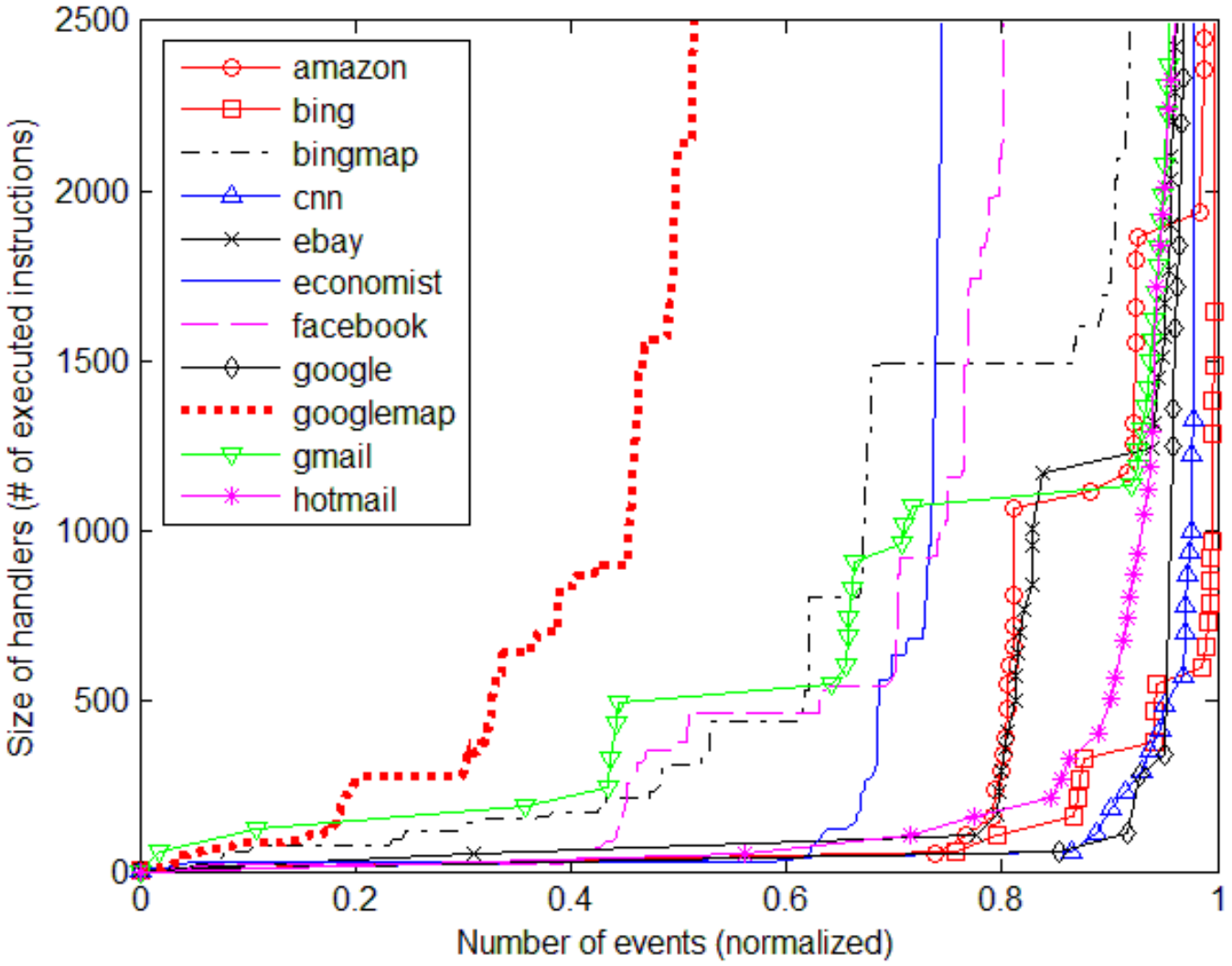
Green = SunSpider | Blue= Real Web Apps | Red = V8

Object Type Distribution



Green = SunSpider | Blue= Real Web Apps | Red = V8

Distribution of Time in Handlers



Related Work

- JavaScript
  - Richards, Lebresne, Burg, and Vitek (PLDI'10)
  - Draw similar conclusions
- Java
  - Doufour et al. (OOPSLA'03), Dieckmann and U. Hölzle (ECOOP'99)
- Other languages
  - C++: Calder et al. (JPL'95)
  - Interpreted languages: Romer et al. (ASPLOS'96)