JavaScript Profiling and Optimization on V8

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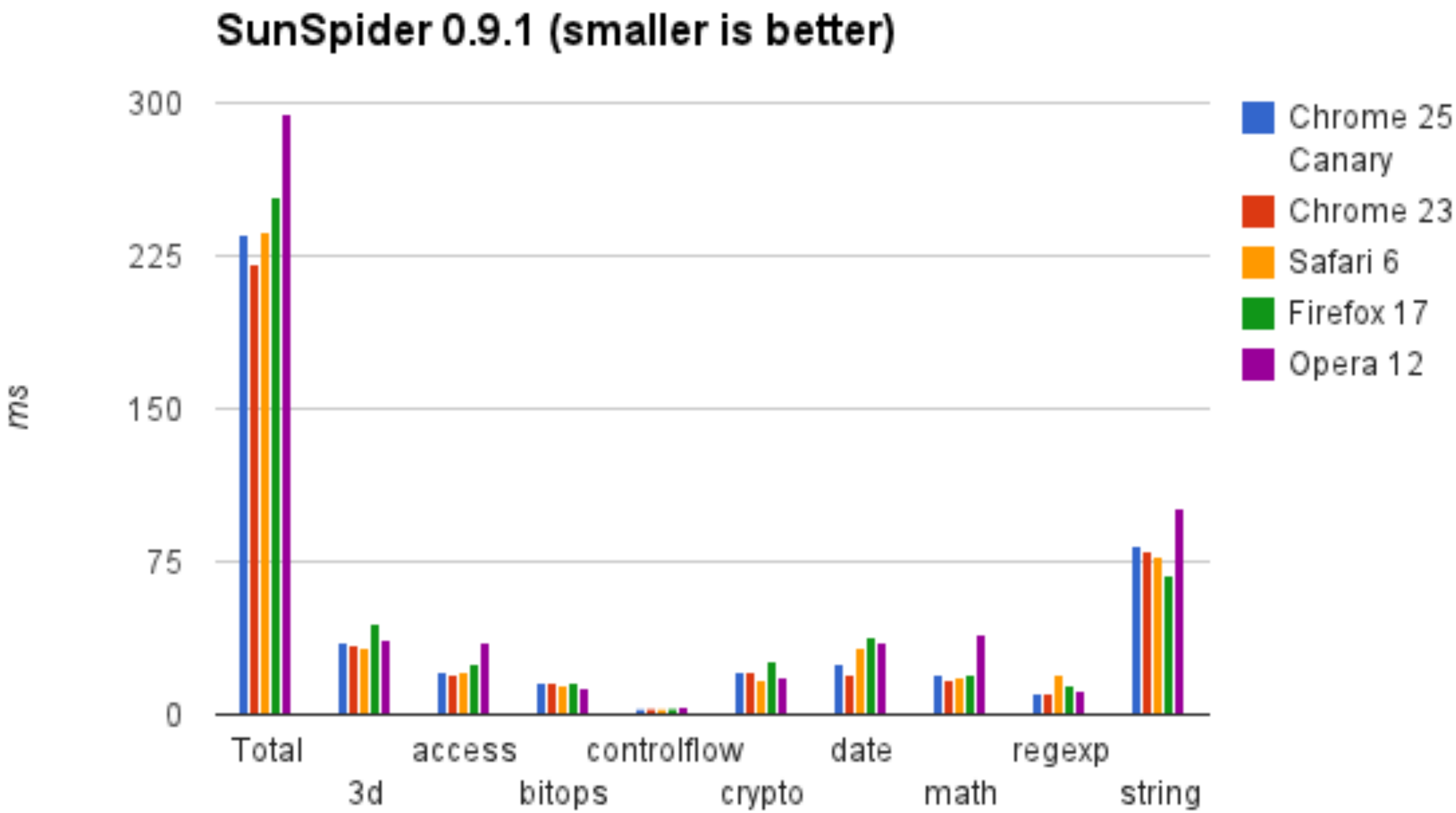
About JavaScript

- ECMAScript
- Used in Adobe Flash, Mac OS Dashboard widgets, Yahoo! widgets, browser bookmarklets, etc.
- Client-side scripting, DOM manipulation, Ajax


SunSpider 0.9.1 (smaller is better)
300
225
150
75
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ms
Total
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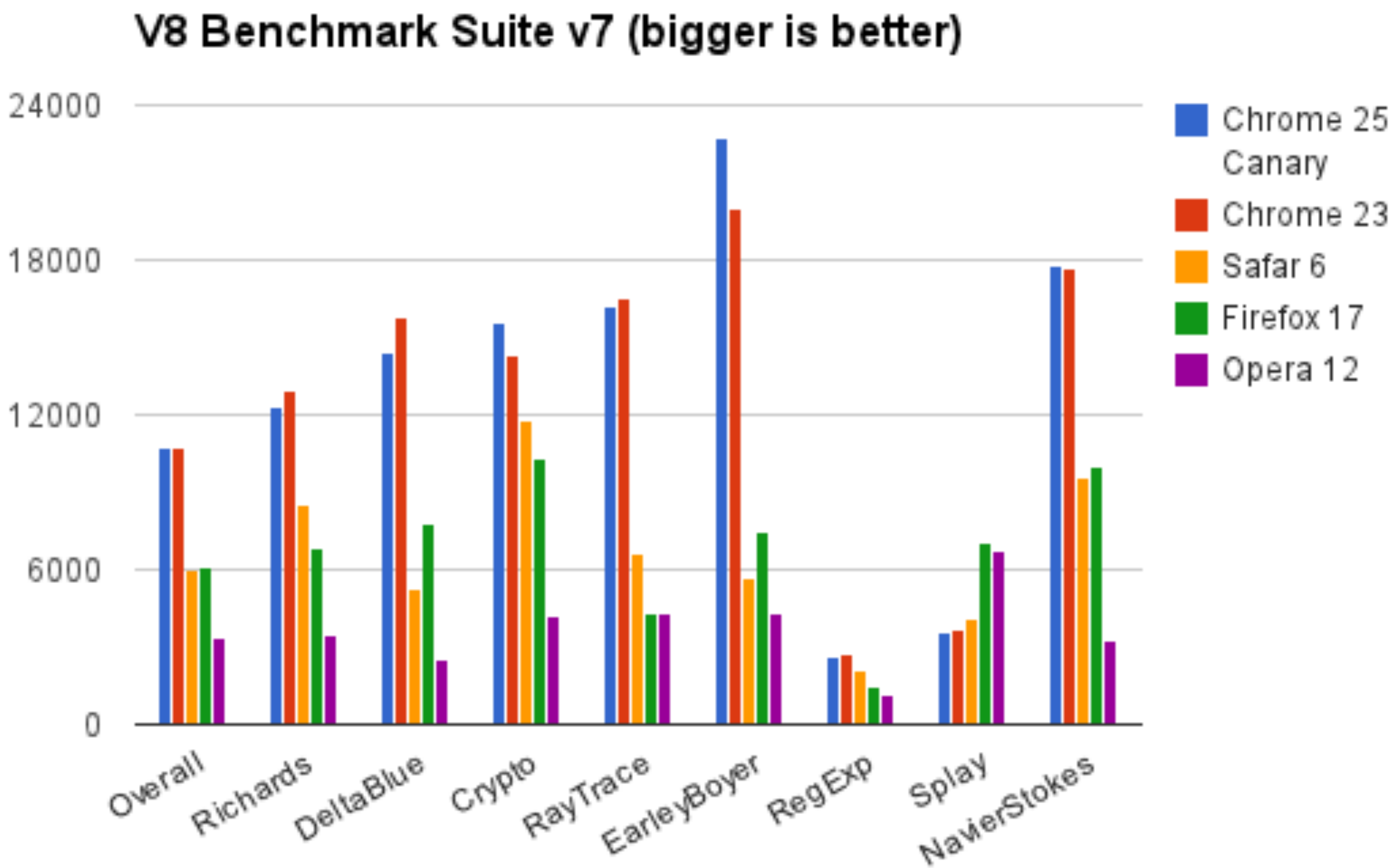
crypto
date
math
regexp
string
Chrome 25 Canary
Chrome 23
Safari 6
Firefox 17
Opera 12


V8 Benchmark Suite v7 (bigger is better)
24000
18000
12000
6000
0
Overall
Richards
DeltaBlue
Crypto
RayTrace
EarleyBoyer
RegExp
Splay
NavierStokes
Chrome 25 Canary
Chrome 23
Safar 6
Firefox 17
Opera 12

V8

- Open source JS engine by Google
- Written in C++ and used in Chrome
- Implements ECMAScript (ECMA-262, 5E)
- Can run standalone or embedded in any C++ applications
- Designed to be fast and efficient, like a V8 engine should be

What makes V8 so fast?

- Fast property access
- Dynamic machine code
- Efficient garbage collection

Fast Property Access

- JS is a dynamic language
- Hidden class vs. dictionary lookup
- High degree of structure-sharing

Fast Property Access

- JS is a dynamic language
- Hidden class vs. dictionary lookup
- High degree of structure-sharing

Hidden Class

- Created dynamically behind the scene
- Changed when a new property is added

```
function Point(x, y) {
  this.x = x;
  this.y = y;
}
```

*example borrowed from https://developers.google.com/v8/design

```
function Point(x, y) {
  this.x = x;
  this.y = y;
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```

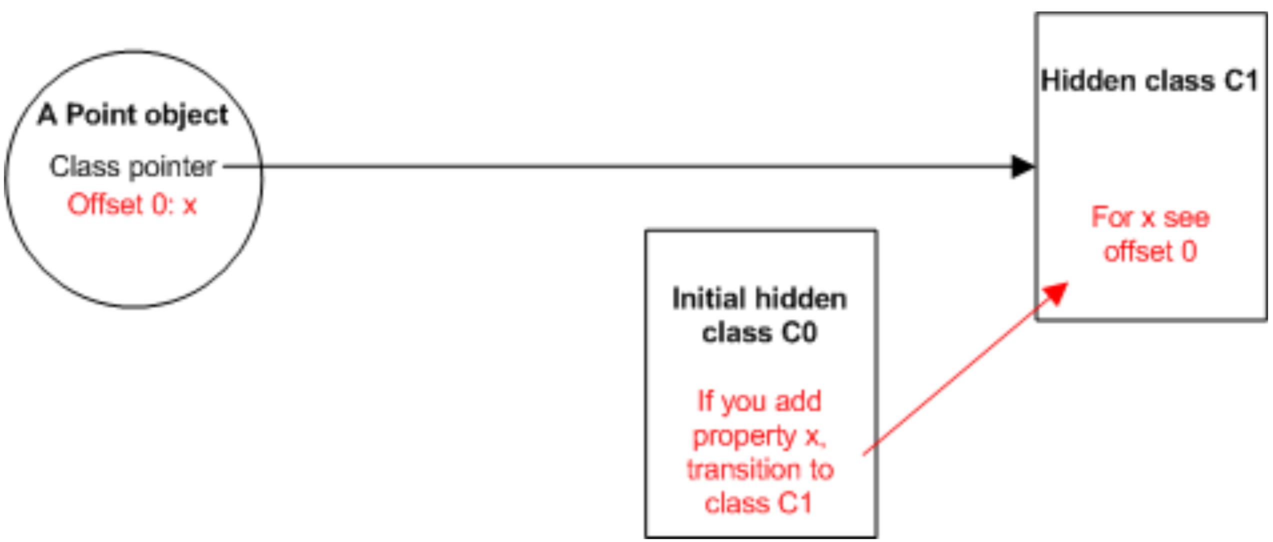

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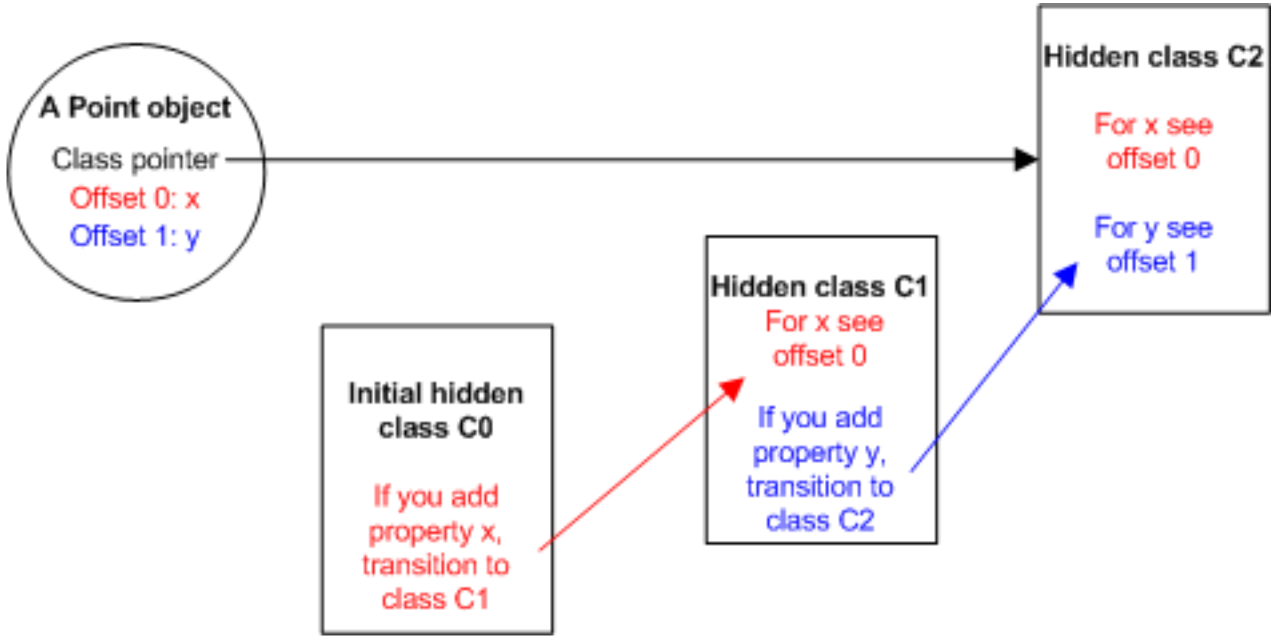

Advantages of using hidden class

- No dictionary lookup for property access

- Enable V8 to use inline caching

Inline Cache (IC)

- Caches type-dependent code
- Needs to validate type assumptions
- Changed at runtime

Dynamic Machine Code

- Directly compiled into machine code
- No intermediate byte code or interpreter
- Inline caching for correct prediction on hidden classes

Efficient Garbage Collection

- Stops program execution
- Processes only part of the object heap
- Accurate objects and pointers locating in memory to avoid memory leaks

V8 Compilation Process

1. Base compiler

2. Runtime profiler

3. Optimizing compiler

4. Deoptimization support

1. Base Compiler

- A full compiler to generate machine code upon execution
- No assumption about types at compilation time
- Uses ICs to retrieve types at runtime
- Fast, but not optimized

2. Runtime Profiler

- Sampling every milliseconds
- In preparation for the optimization

3. Optimizing Compiler

- SSA form
- Loop-invariant code motion
- Common subexpression elimination
- Linear-scan register allocation
- Function inlining

4. Deoptimization Support

- What if overly optimistic?
- An opportunity to 'bail-out'
- Easily observed with the profiler

JavaScript is Slow

Problem:

Compute the 25,000th prime

Algorithm:

For x = 1 to infinity: if x not divisible by any member of an initially empty list of primes, add x to the list until we have 25,000

[2012 Google I/O]

The Contenders

c++

```
class Primes {
     public:
      int getPrimeCount() const { return
     prime_count; }
      int getPrime(int i) const { return primes[i]; }
      void addPrime(int i) { primes[prime_count++] =
     i; }

      bool isDivisibe(int i, int by) { return (i %
     by) == 0; }

      bool isPrimeDivisible(int candidate) {
        for (int i = 1; i < prime_count; ++i) {
          if (isDivisibe(candidate, primes[i]))
     return true;
        }
        return false;
      }

     private:
      volatile int prime_count;
      volatile int primes[25000];
     };int main() {
      Primes p;
      int c = 1;
      while (p.getPrimeCount() < 25000) {
        if (!p.isPrimeDivisible(c)) {
          p.addPrime(c);
        }
        c++;
      }
      printf("%d\n",
     p.getPrime(p.getPrimeCount()-1));
```

JavaScript

```
function Primes() {
  this.prime_count = 0;
  this.primes = new Array(25000);
  this.getPrimeCount = function() { return
this.prime_count; }
  this.getPrime = function(i) { return this.primes[i]; }
  this.addPrime = function(i) {
    this.primes[this.prime_count++] = i;
  }

  this.isPrimeDivisible = function(candidate) {
    for (var i = 1; i <= this.prime_count; ++i) {
      if ((candidate % this.primes[i]) == 0) return true;
    }
    return false;
  }
};function main() {
  p = new Primes();
  var c = 1;
  while (p.getPrimeCount() < 25000) {
    if (!p.isPrimeDivisible(c)) {
      p.addPrime(c);
    }
    c++;
  }
  print(p.getPrime(p.getPrimeCount()-1));
}

main();
```

```cpp
class Primes {
  public:
   int getPrimeCount() const { return prime_count; }
   int getPrime(int i) const { return primes[i]; }
   void addPrime(int i) { primes[prime_count++] = i; }

   bool isDivisibe(int i, int by) { return (i % by) == 0; }

   bool isPrimeDivisible(int candidate) {
     for (int i = 1; i < prime_count; ++i) {
       if (isDivisibe(candidate, primes[i])) return true;
     }
     return false;
   }
  private:
   volatile int prime_count;
   volatile int primes[25000];
 };int main() {
   Primes p;
   int c = 1;
   while (p.getPrimeCount() < 25000) {
     if (!p.isPrimeDivisible(c)) {
       p.addPrime(c);
     }
     c++;
   }
   printf("%d\n", p.getPrime(p.getPrimeCount()-1));
 }
```

```
function Primes() {
    this.prime_count = 0;
    this.primes = new Array(25000);
    this.getPrimeCount = function() { return
  this.prime_count; }
    this.getPrime = function(i) { return this.primes[i]; }
    this.addPrime = function(i) {
      this.primes[this.prime_count++] = i;
    }

    this.isPrimeDivisible = function(candidate) {
      for (var i = 1; i <= this.prime_count; ++i) {
        if ((candidate % this.primes[i]) == 0) return true;
      }
      return false;
    }
  };function main() {
    p = new Primes();
    var c = 1;
    while (p.getPrimeCount() < 25000) {
      if (!p.isPrimeDivisible(c)) {
        p.addPrime(c);
      }
      c++;
    }
    print(p.getPrime(p.getPrimeCount()-1));
  }main();
```

The Results

```
% g++ primes.cc -o primes
   % time ./primes287107

   real  0m2.955s
   user  0m2.952s
   sys   0m0.001s
```

C++

```
% time d8 primes.js287107

real     0m15.584s
user     0m15.612s
sys      0m0.073s
```

JavaScript

C++ is about 5x faster than JavaScript

Inline Caches

Candidate % this.primes[i]

No calls in this code

Inline Caches

Candidate % this.primes[i]

this.primes[i]

->call LoadIC_Initialize

-> call 0x311286e0

-> move eax, [edi+0fx]

Logging What Gets Optimized

Command:

./out/ia32.release/d8 --trace-opt samples/
primes.js

Log name of optimized functions to stdout:

addPrime, IsPrimDivisible, main...

Profiling the JavaScripts

./out/ia32.release/d8 samples/primes.js --prof
287107

./tools/mac-tick-processor v8.log

Profiling the JavaScripts

```
Statistical profiling result from v8.log, (10868 ticks, 81 unaccounted, 0 excluded).
 [JavaScript]:
   ticks  total  nonlib   name
   1254   11.5%   11.5%  LazyCompile: *main samples/primes.js:18
    959    8.8%    8.8%  LazyCompile: MOD native runtime.js:238
    643    5.9%    5.9%  Stub: CEntryStub
    468    4.3%    4.3%  KeyedLoadIC: A keyed load IC from the snapshot
    388    3.6%    3.6%  Stub: BinaryOpStub_MOD_Alloc_SMI+Oddball
      1    0.0%    0.0%  LazyCompile: ~Primes.isPrimeDivisible samples/primes.js:10
 [C++]:
   ticks  total  nonlib   name
   3274   30.1%   30.1%  _atanhl$fenv_access_off
   1301   12.0%   12.0%  v8::internal::Runtime_NumberMod
    979    9.0%    9.0%  v8::internal::Heap::NumberFromDouble
```

Something is Wrong with the Code

```
this.isPrimeDivisible = function(candidate) {
      for (var i = 1; i <= this.prime_count; ++i) {
        if ((candidate % this.primes[i]) == 0)
  return true;
      }
      return false;
    }
```

Profiling Again

/out/ia32.release/d8 samples/primes.js --prof

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./tools/mac-tick-processor v8.log

Profiling Again

```
[JavaScript]:
 ticks  total  nonlib   name
 1426   99.4%   99.4%  LazyCompile: *main samples/primes-2.js:18
    5    0.3%    0.3%  LazyCompile: *Primes.isPrimeDivisible samples/primes-2.js:10

[C++]:
 ticks  total  nonlib   name
    1    0.1%    0.1%  v8::internal::StaticVisitorBase::GetVisitorId
    1    0.1%    0.1%  v8::internal::Runtime_FunctionSetName
    1    0.1%    0.1%  v8::internal::Map::LookupDescriptor
    1    0.1%    0.1%  v8::internal::LAllocator::TraceAlloc
```

Runtime

```
time v8 primes-2.js
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real   0m1.829s
user   0m1.827s
sys    0m0.010s
```

Optimize Your Algorithm

```
this.isPrimeDivisible = function(candidate) {
    for (var i = 1; i < this.prime_count; ++i) {
   var current_prime = this.primes[i];
      if (current_prime * current_prime > candidate)
  {
        return false;
      }
   if ((candidate % current_prime) == 0) return
  true;
    }
    return false;
  }
```

Optimize Your Algorithm

time v8 primes-3.js

287107

real 0m0.044s

user 0m0.038s

sys 0m0.004s

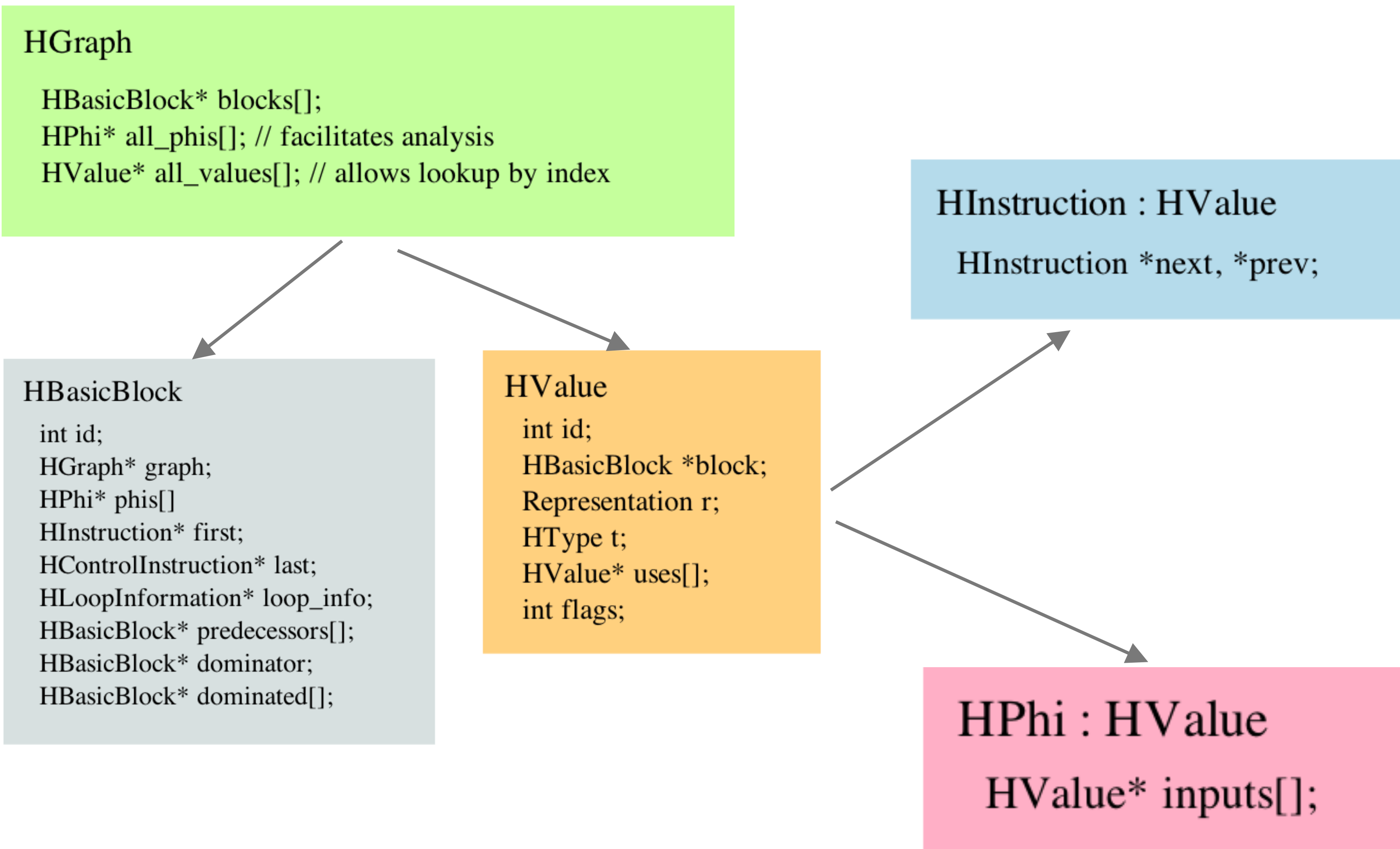
Crankshaft

Hydrogen-SSA in Crankshaft [Wingolog]

1. To permit inlining. Inlining is truly the mother of all optimizations, in that it permits more optimizations to occur.

2. To facilitate loop-invariant code motion and common subexpression elimination.

SSA Data Structures



Optimization Proposal

- More sophisticated algorithms in determining the 'hot code': frequency alone might not be the best way to define 'hot'
  - Use counter instead of sampling every millisecond

- Phi node insertion optimization

Conclusion

- Chrome with V8 engine outperforms other browsers in most benchmarks, especially V8 benchmarks

- Hidden classes introduces inline caching and type assumption

- Use run-time profiling to optimize hot code, and do nothing if the profiler decided it's not hot