Bringing SIMD to the web via Dart

John McCutchan

Biography

- inotify
  - Linux kernel system for monitoring file systems for changes
- Port Bullet Physics to the PS3
  - SPUs are fun
- Optimizer for PS3 and PS Vita
  - Make games run faster
- PS4 CPU/GPU Expert
  - Hardware architecture and algorithms

Biography

- The Web
  - Dart
  - WebGL
  - HTML5

1. **Structure**
   a. Tool visible type system
   b. Class based, object oriented
   c. Lexical *this*
   d. ; required

2. **Performance**
   a. Dart is designed to run fast by being less permissive
   b. New VM opens up new possibilities
      i. SIMD

Why can Dart run fast?

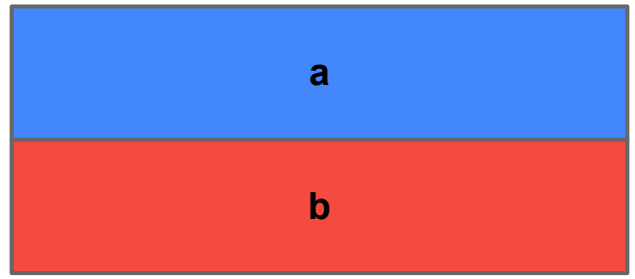
Some of the reasons...

Static Object Shape

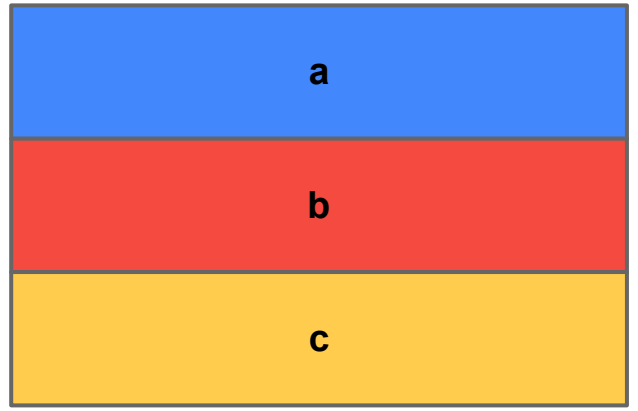
```
function MyClass() {
  this.a = 1;
  this.b = "hey";
}
```

```
foo = new MyClass();
...
foo.c = 3.14159;
```

Shape of MyClass



Shape of foo

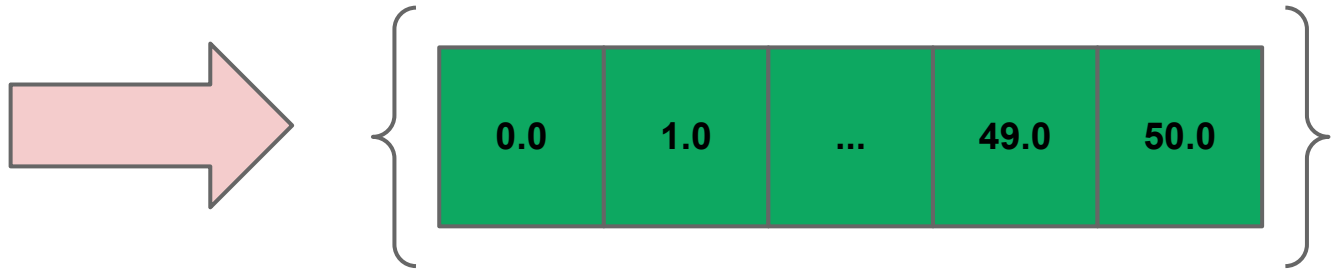


Object Shape Change

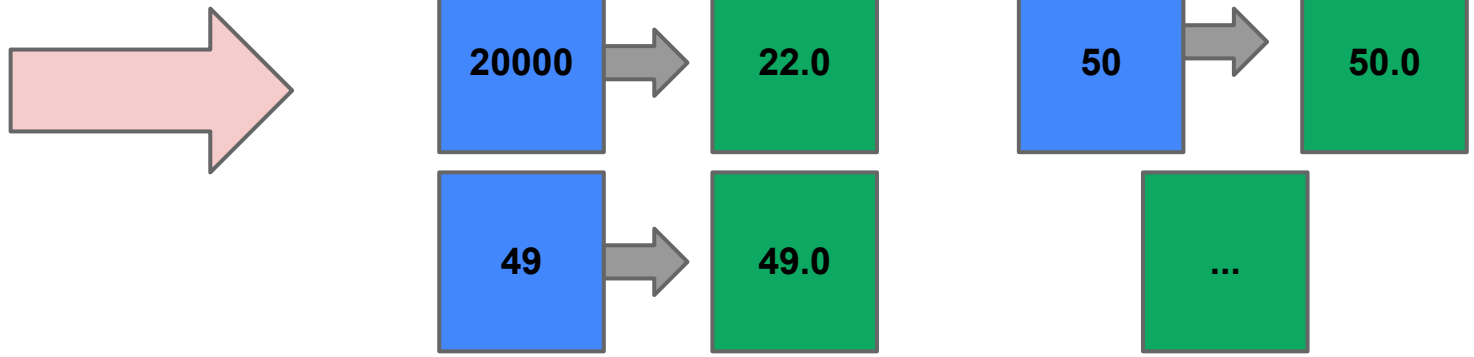
Previous optimizations invalid.

Hole Free Arrays

```
bigData = [];
bigData[0] = 0.0;
bigData[1] = 1.0;
...
bigData[50] = 50.0;
```




```
bigData[20000] = 22.0;
```



Distinction between growable and fixed sized arrays

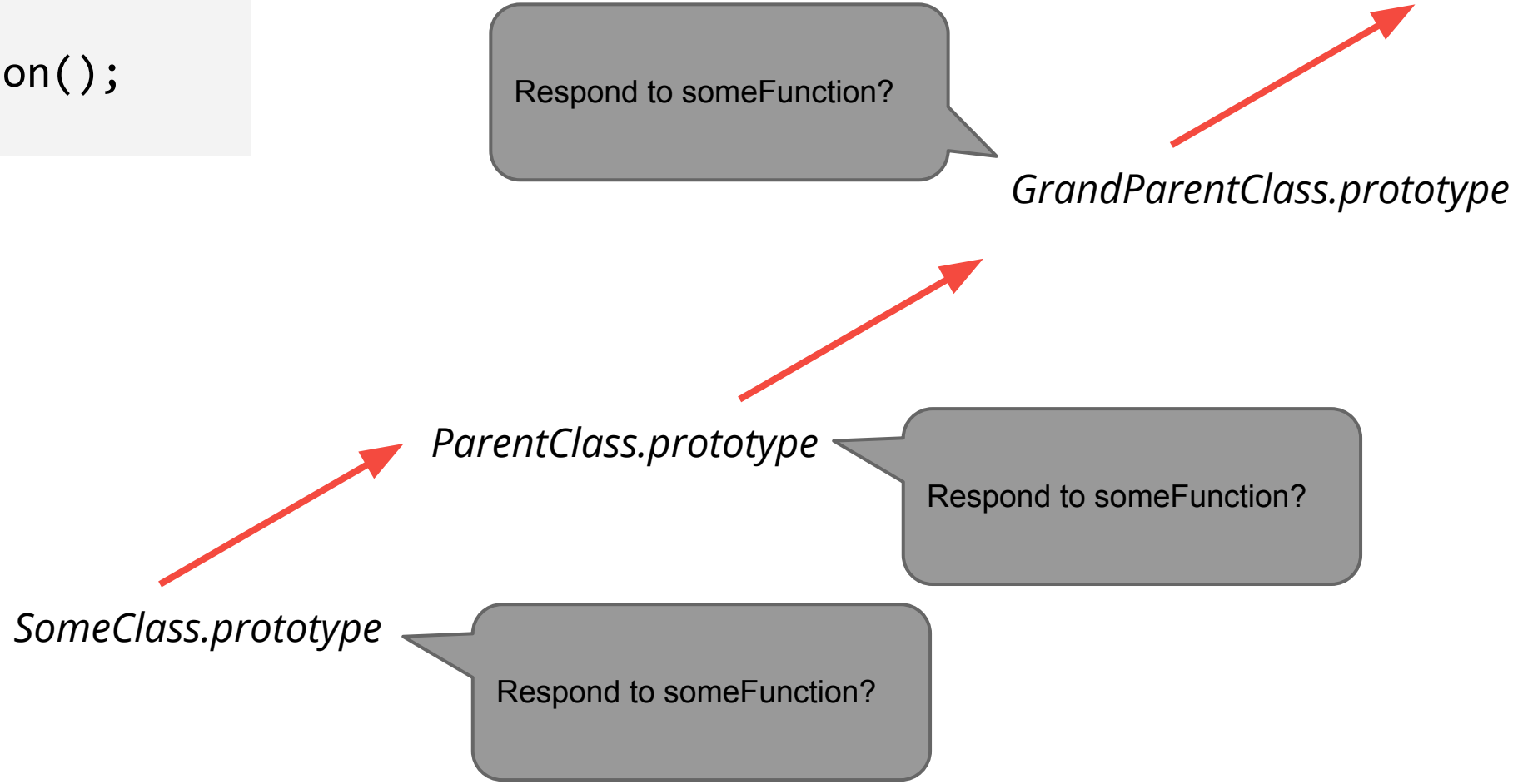
```
var growable = new List<double>(); // length == 0

var fixed = new List<double>(200);
```

```
for (int i = 0; i < fixed.length; i++) {
   // Safely query length only once
 // Bounds check hoisted out of loop
}
```

```
for (int i = 0; i < growable.length; i++) {
   // May have to query length many times
 // Bounds check inside the loop
}
```

No prototype chain

```
foo = new SomeClass();

foo.someFunction();
```



Distinction between integer and double numbers

- JavaScript only has double
  - Double arithmetic slower than Integer arithmetic
    - For mobile processors difference is greater

- Dart has both double and integer
  - Gives choice to developer

	Double	Integer	Double slowdown
Multiply	6	2	3x
Addition	4	1	4x
Load	2	2	N/A
Store	2	2	N/A

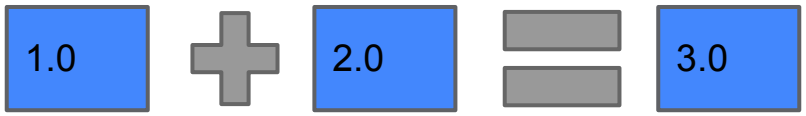
http://infocenter.arm.com/help/index.jsp - Cortex A9 CPU

What is SIMD?

... and why does it matter?

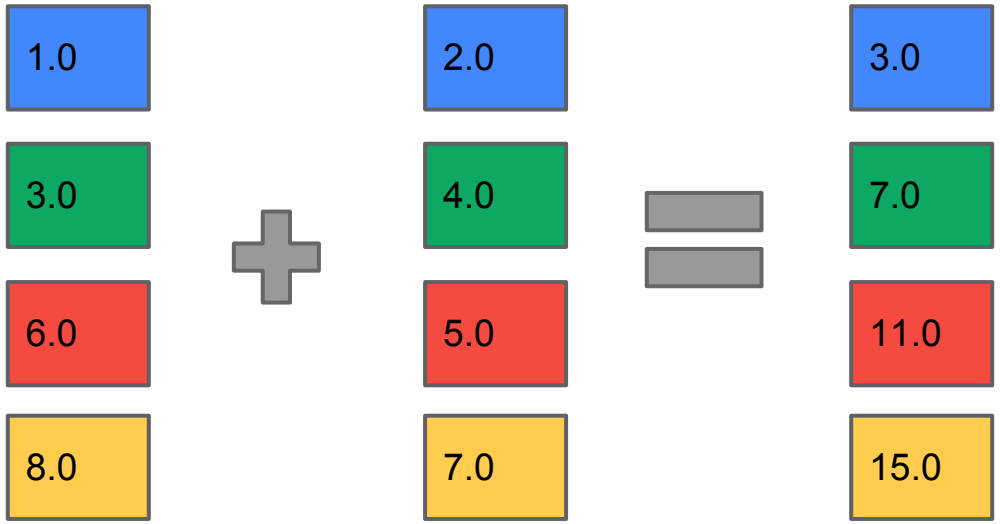
What is SIMD?

Single Instruction Single Data (SISD)



What is SIMD?

Single Instruction Multiple Data (SIMD)



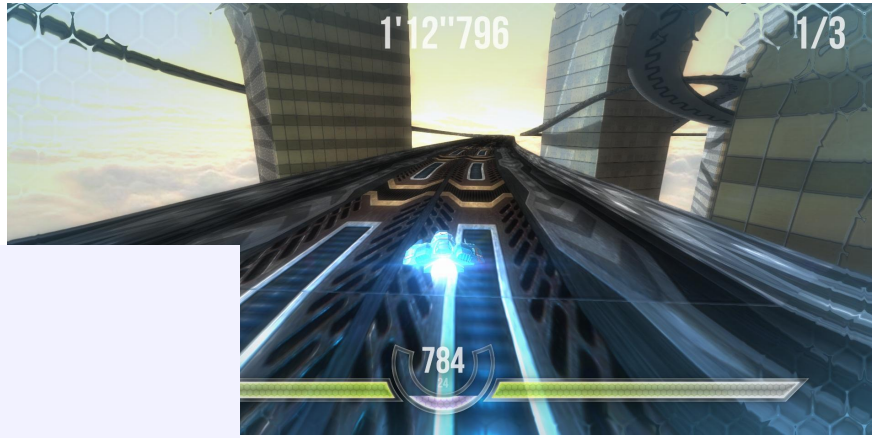
Vector Processor

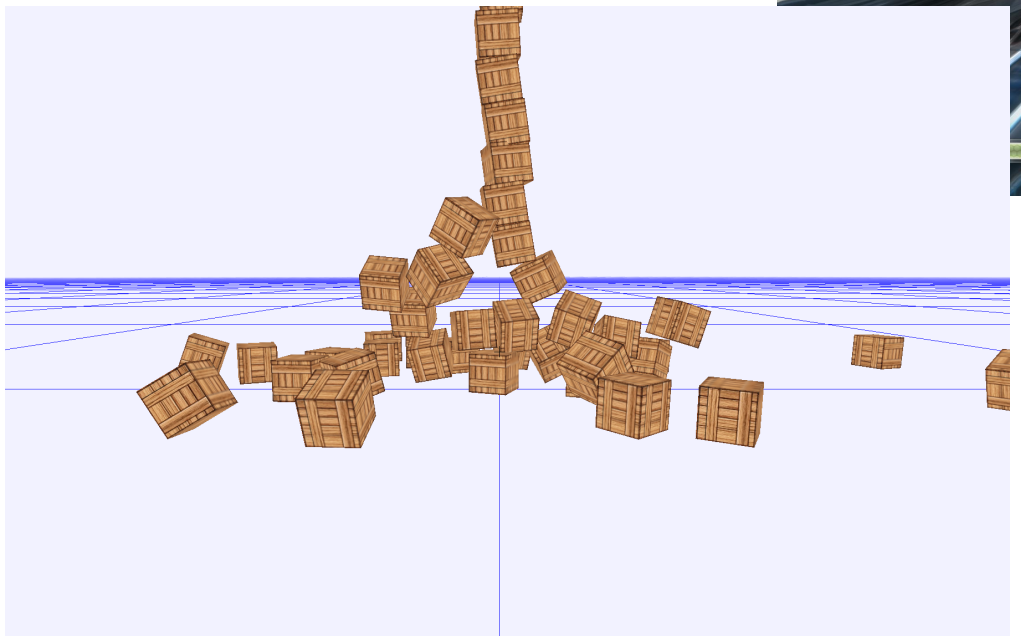
Why does SIMD matter?

- SIMD can provide substantial speedup to:
  - 3D Graphics
  - 3D Physics
  - Image Processing
  - Signal Processing
  - Numerical Processing

Why does SIMD matter to the web?

- SIMD can provide substantial speedup to:
  - WebGL
  - Canvas
  - Animation
  - Games
  - Physics



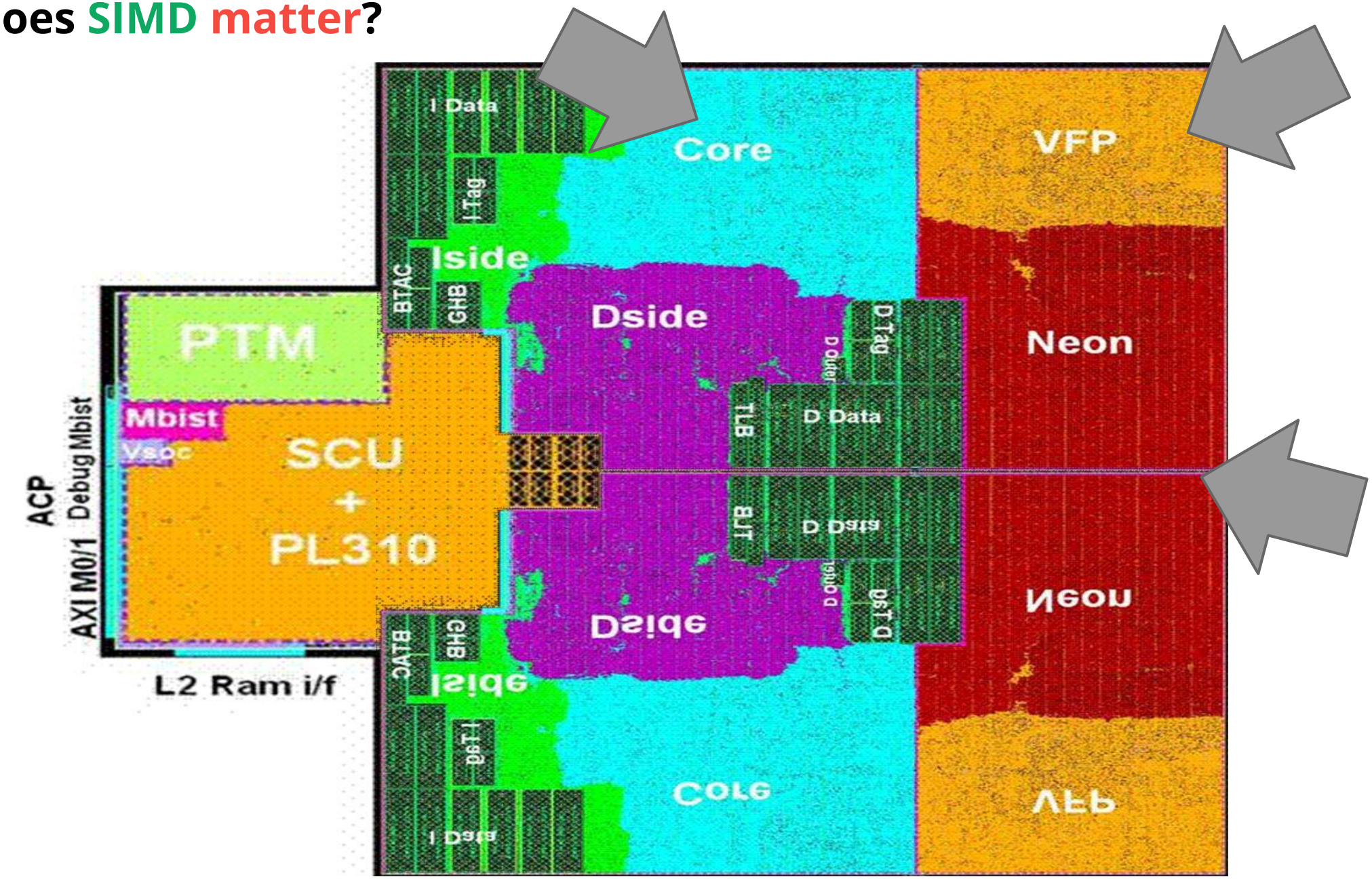


Why does SIMD matter to the web?

Console Games 1998

Web Games 2013

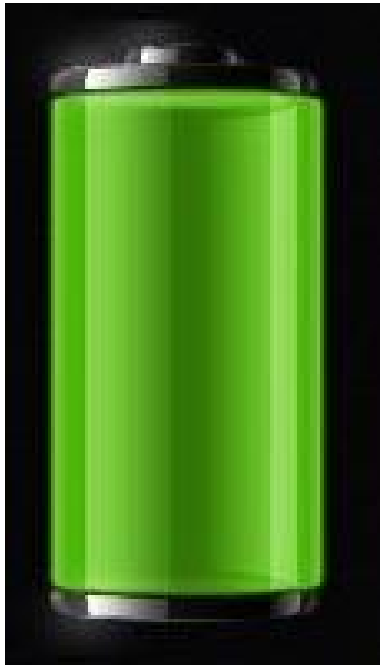
Why does SIMD matter?



Why does SIMD matter?

- SIMD requires fewer instructions to be executed
  - Fewer instructions means longer battery life

VS



Why does SIMD matter?

- Mozilla is attempting to automatically use SIMD in IonMonkey VM
  - Gaussian Blur sped up
    - https://bugzilla.mozilla.org/show_bug.cgi?id=832718
  - Based on pattern recognition
    - Programs must be written to patterns detectable by VM
  - "Automatic Vectorization"
    - Open research topic

SIMD in Dart

SIMD in Dart

- New types
  - Float32x4
  - Float32x4List
  - Uint32x4

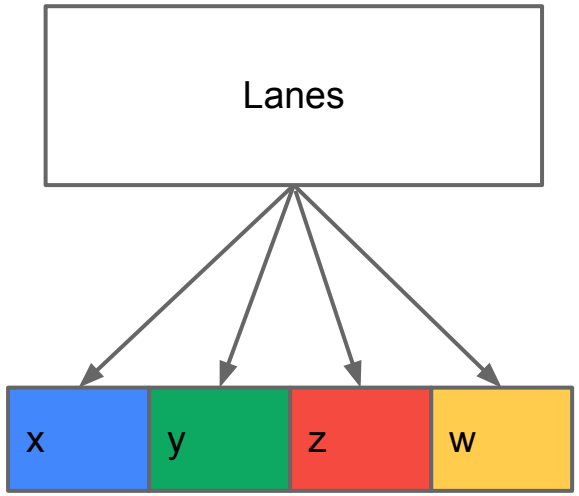
4 IEEE-754 32-bit Floating Point Numbers
List of Float32x4
4 Unsigned 32-bit Integer Numbers

- Composable operations
  - Arithmetic
  - Logical
  - Comparisons
  - Reordering (shuffling)

SIMD in Dart

Float32x4

- +
- -
- /
- *
- sqrt (square root)
- reciprocal
- rsqrt (reciprocal square root)
- min
- max
- clamp
- abs (absolute value)



Constructing

```
var a = new Float32x4(1.0, 2.0, 3.0, 4.0);
```


```
var b = new Float32x4.zero();
```

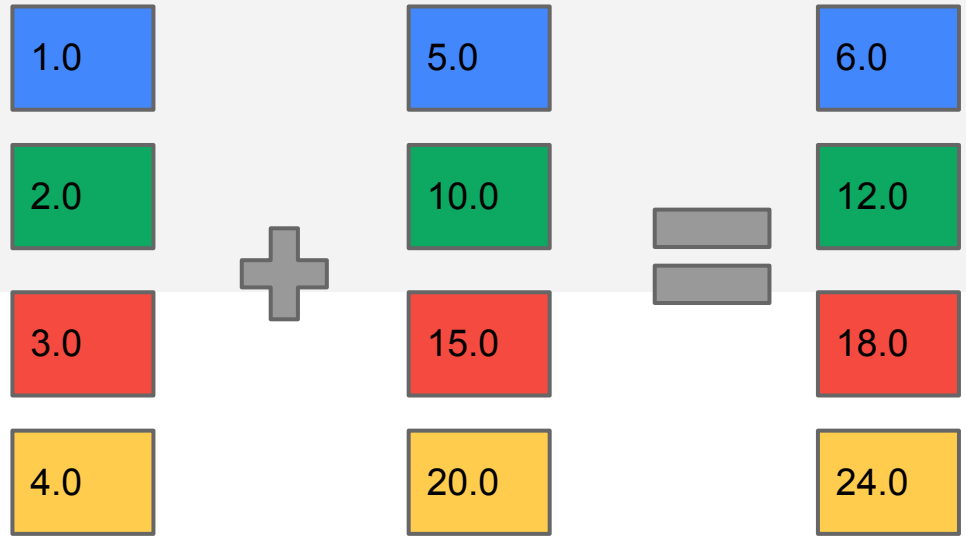
Accessing and Modifying Individual Elements

```
var a = new Float32x4(1.0, 2.0, 3.0, 4.0);
```


```
var b = a.x; // 1.0

var c = a.withX(5.0);
```

Arithmetic

```
var a = new Float32x4(1.0, 2.0, 3.0, 4.0);

var b = new Float32x4(5.0, 10.0, 15.0, 20.0);

var c = a + b;
```



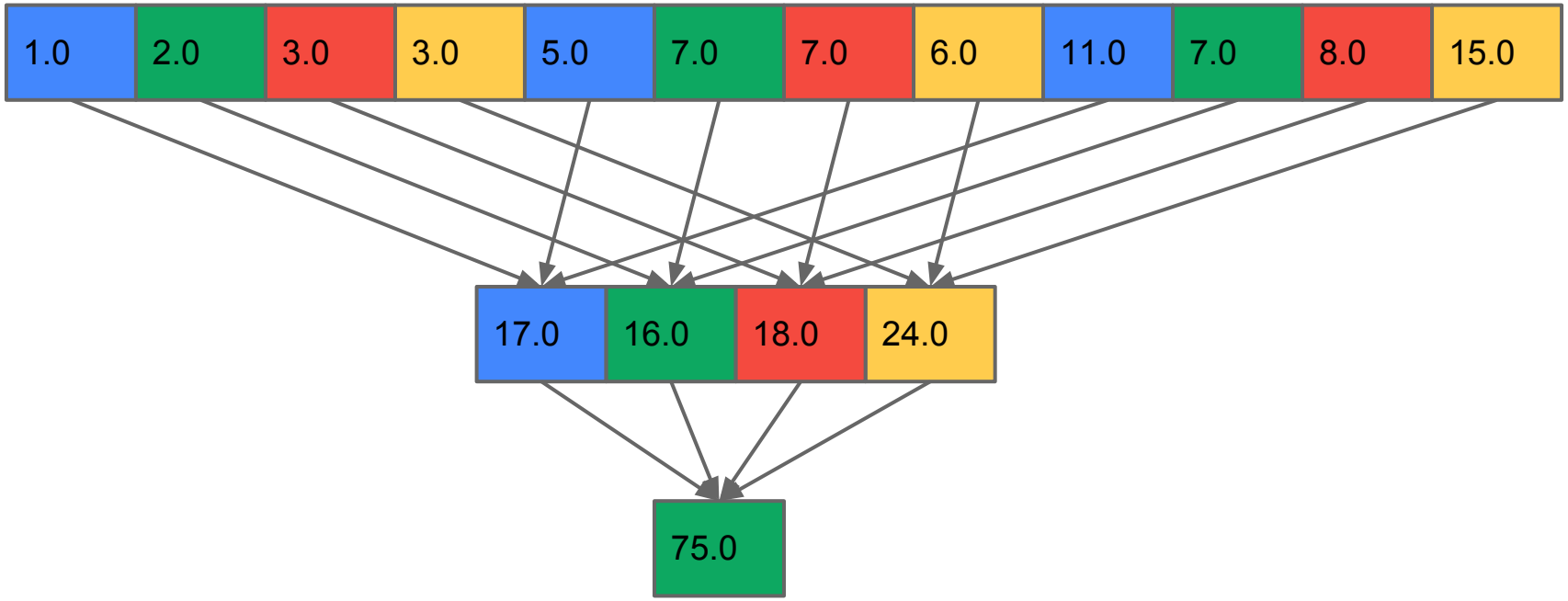
Example

```
double average(Float32List list) {
  var n = list.length;
  var sum = 0.0;
  for (int i = 0; i < n; i++) {
    sum += list[i];
  }
  return sum / n;
}
```

Example

```
double average(Float32x4List list) {
  var n = list.length;
  var sum = new Float32x4.zero();
  for (int i = 0; i < n; i++) {
    sum += list[i];
  }
  var total = sum.x + sum.y + sum.z + sum.w;
  return total / (n * 4);
}
```

Example



SIMD in Dart

75% fewer loads

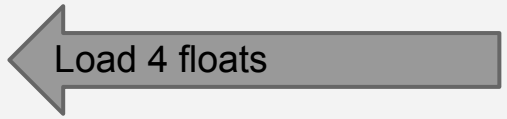
75% fewer adds

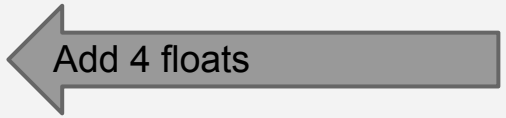
75% fewer stores

The inner loop

```
sum += list[i];
```

```
  ;; Load list[i]
0x4ccddcc d1ff        sar edi, 1
0x4ccddce 0f104c3807 movups xmm1,[eax+edi*0x1+0x7]
0x4ccddd3 03ff        add edi,edi
  ;; sum +=
0x4ccddde 0f59ca      addps xmm2,xmm1
```





Shuffling

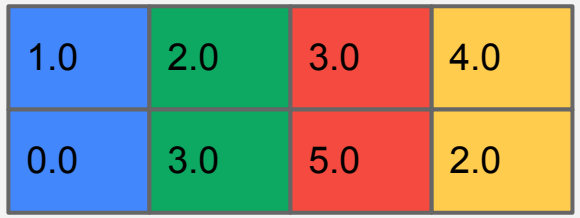
```
var a = new Float32x4(1.0, 2.0, 3.0, 4.0);

var b = a.xxyy;

var c = a.wwww;

var d = a.wzyx;
```

Branching

```
double max(double a, double b) {
  if (a > b) {
    return a;
  } else {
    return b;
  }
}

max(4.0, 5.0) -> 5.0
```

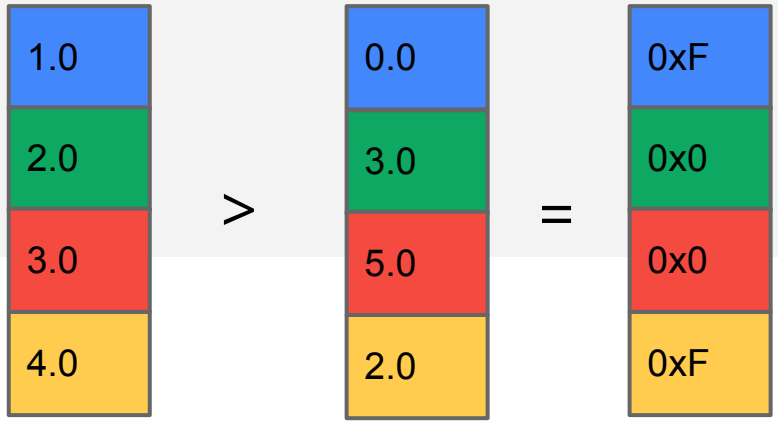
Branching

```
Float32x4 max(Float32x4 a, Float32x4 b) {
  if (a > b) {
    return a;
  } else {
    return b;
  }
}
```



Branching

```
Float32x4 max(Float32x4 a, Float32x4 b) {
  Uint3x4 greaterThan = a.greaterThan(b);
  return greaterThan.select(b, a);
}
```



Branching

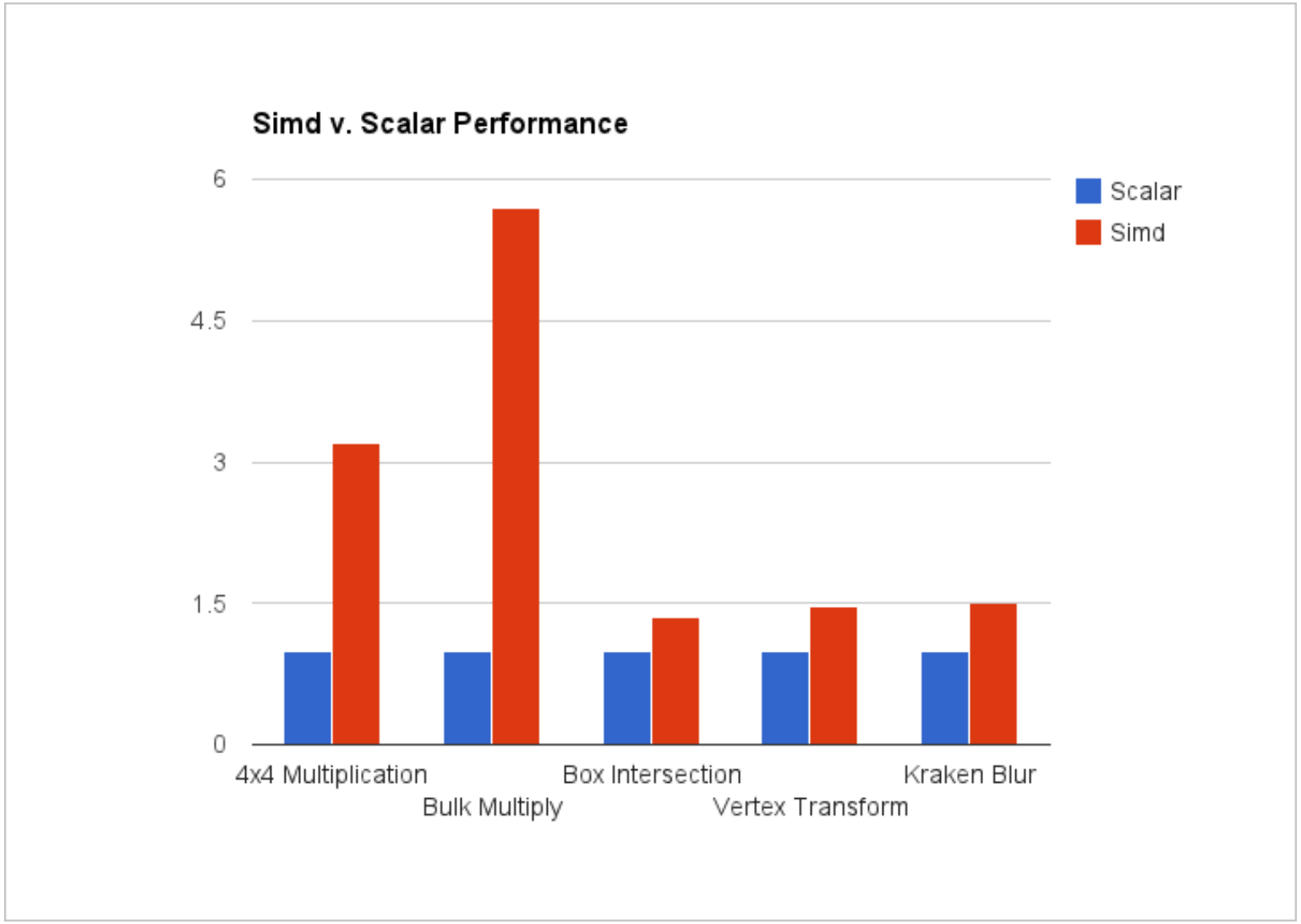
```
Float32x4 max(Float32x4 a, Float32x4 b) {
  Uint3x4 greaterThan = a.greaterThan(b);
  return greaterThan.select(a, b);
}
```

How does the VM optimize for SIMD?

1. Unboxing
   a. Boxed -> allocated in memory
   b. Unboxed -> in CPU memory (in registers)

2. Replacing method calls with inlined machine instructions
   a. Allows values to remain unboxed (in registers)
   b. Avoids method call overhead

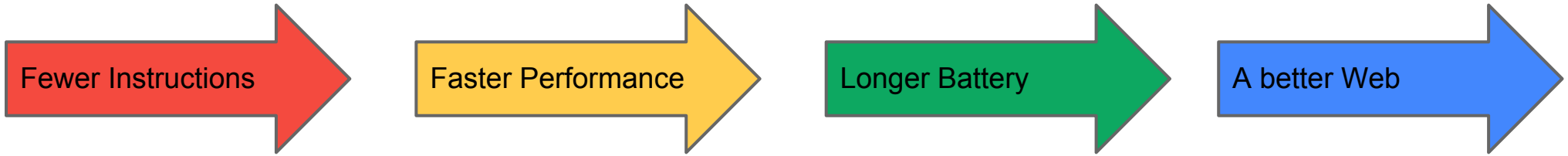
More Benchmarks



Wrap up

Wrap Up

- Dart SIMD has landed*
  - Try it out!
  - Use your **entire** CPU



Dart VM stretches the performance envelop.
Dart VM makes new, magical experiences possible.

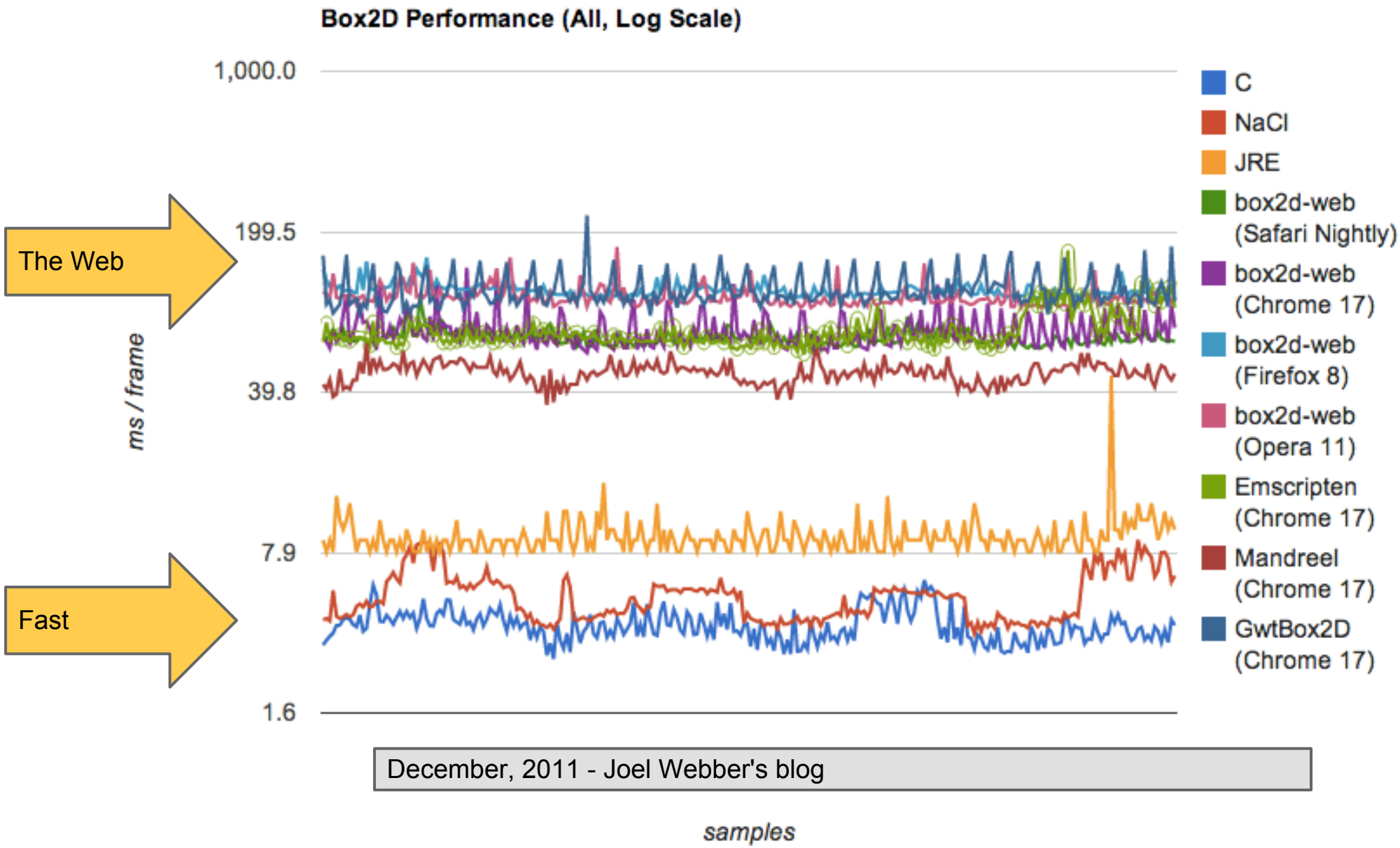
Why does SIMD matter to the web?

Wrap Up

- The web needs SIMD if we want this:

Wait, what exactly is "fast"?

... and when will web programs be "fast"?


Box2D Performance (All, Log Scale)
1,000.0
199.5
39.8
7.9
1.6
ms / frame
samples
C
NaCl
JRE
box2d-web (Safari Nightly)
box2d-web (Chrome 17)
box2d-web (Firefox 8)
box2d-web (Opera 11)
Emscripten (Chrome 17)
Mandreel (Chrome 17)
GwtBox2D (Chrome 17)
The Web
Fast
December, 2011 - Joel Webber's blog

Questions!

www.johnmccutchan.com

www.dartgamedevs.org

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Wrap Up

- SIMD References
  - Wikipedia
    - http://en.wikipedia.org/wiki/SIMD
  - Intel's site
    - http://software.intel.com/en-us/articles/using-intel-streaming-simd-extensions-and-intel-integrated-performance-primitives-to-accelerate-algorithms
    - http://software.intel.com/en-us/articles/optimizing-the-rendering-pipeline-of-animated-models-using-the-intel-streaming-simd-extensions
  - ARM's site
    - http://blogs.arm.com/software-enablement/161-coding-for-neon-part-1-load-and-stores/
  - www.gamasutra.com
  - www.gamedev.net

What is SIMD?