CrowdCL

Web-Based Volunteer Computing with WebCL

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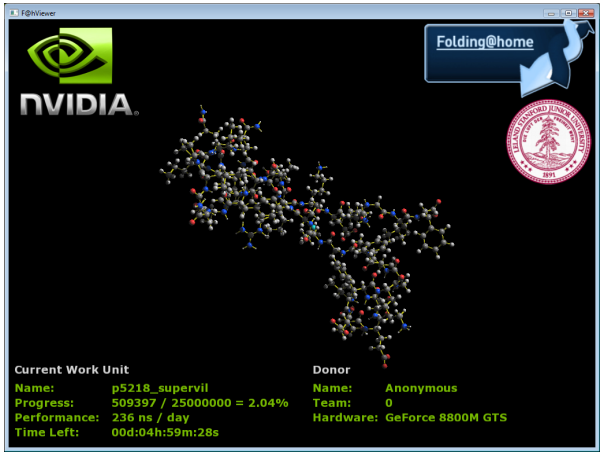
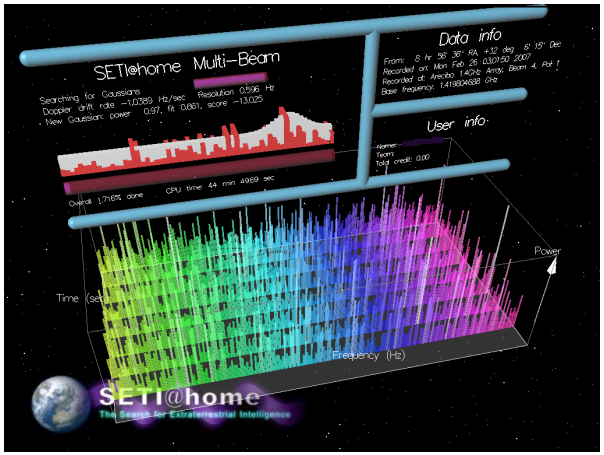
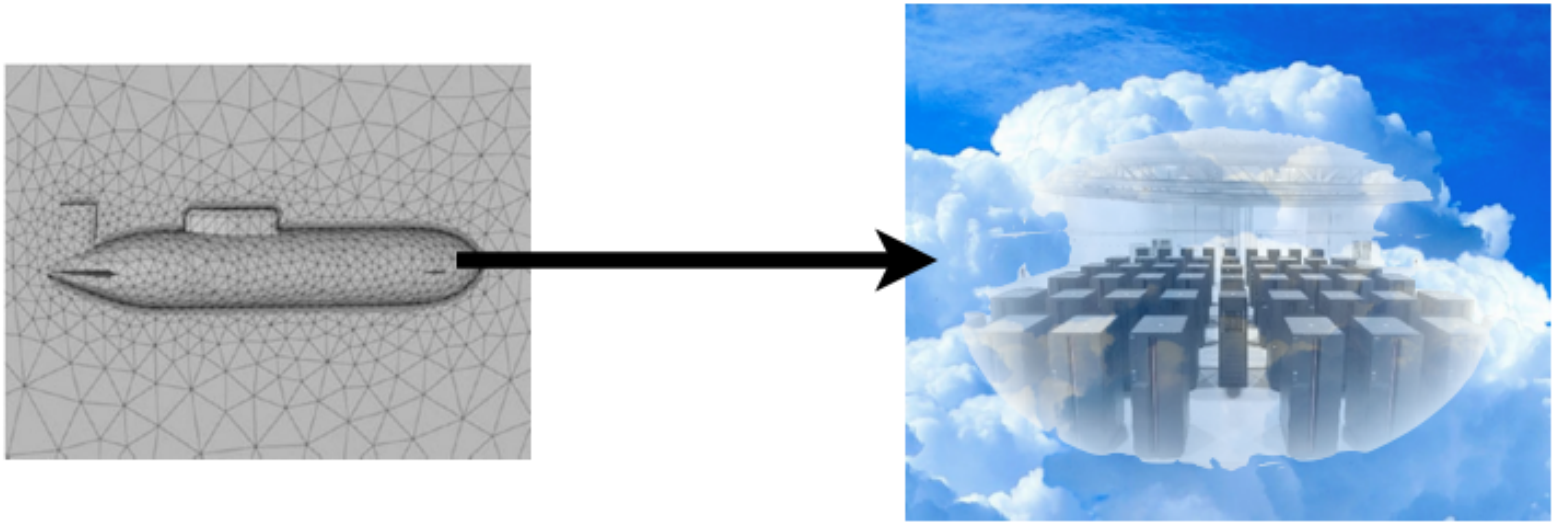
Volunteer Computing

- “Donation" of CPU cycles to scientific problems
- Folding@home
  - 300,000 contributors... right now.
  - 5 PetaFLOPS sustained
- SETI@home
  - 3 million participants
- PrimeGrid, GPUGRID, NFS@Home, NSA@Home (j/k)

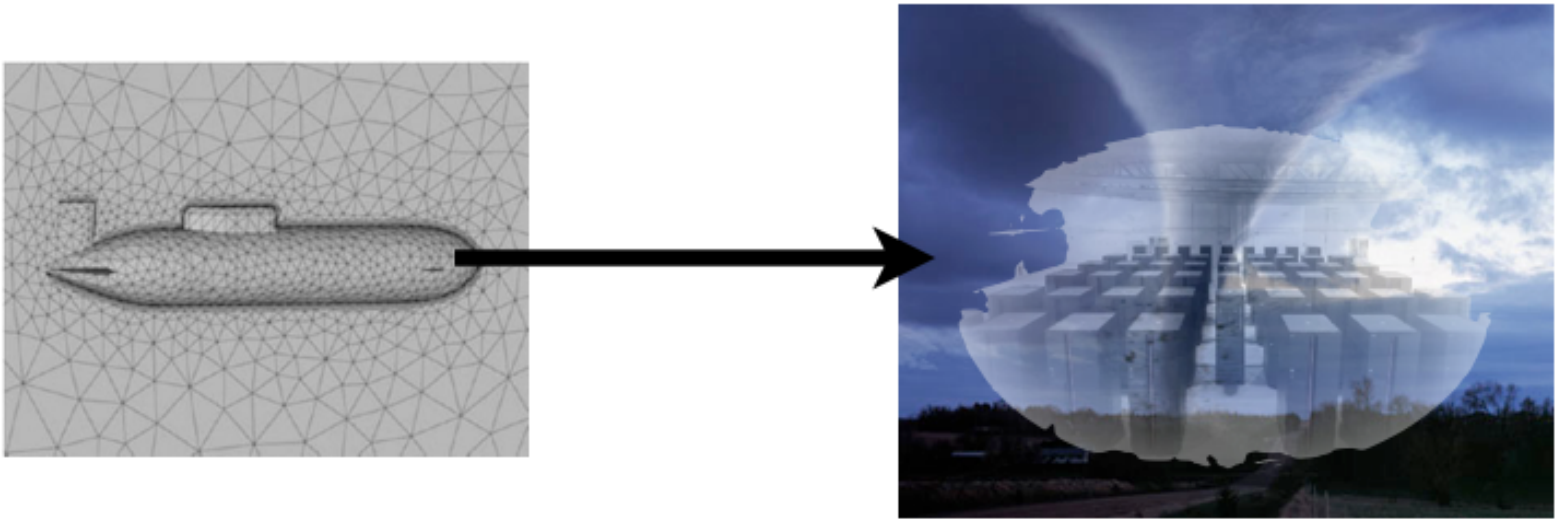




High Throughput Science



High Throughput Science



High Throughput Science

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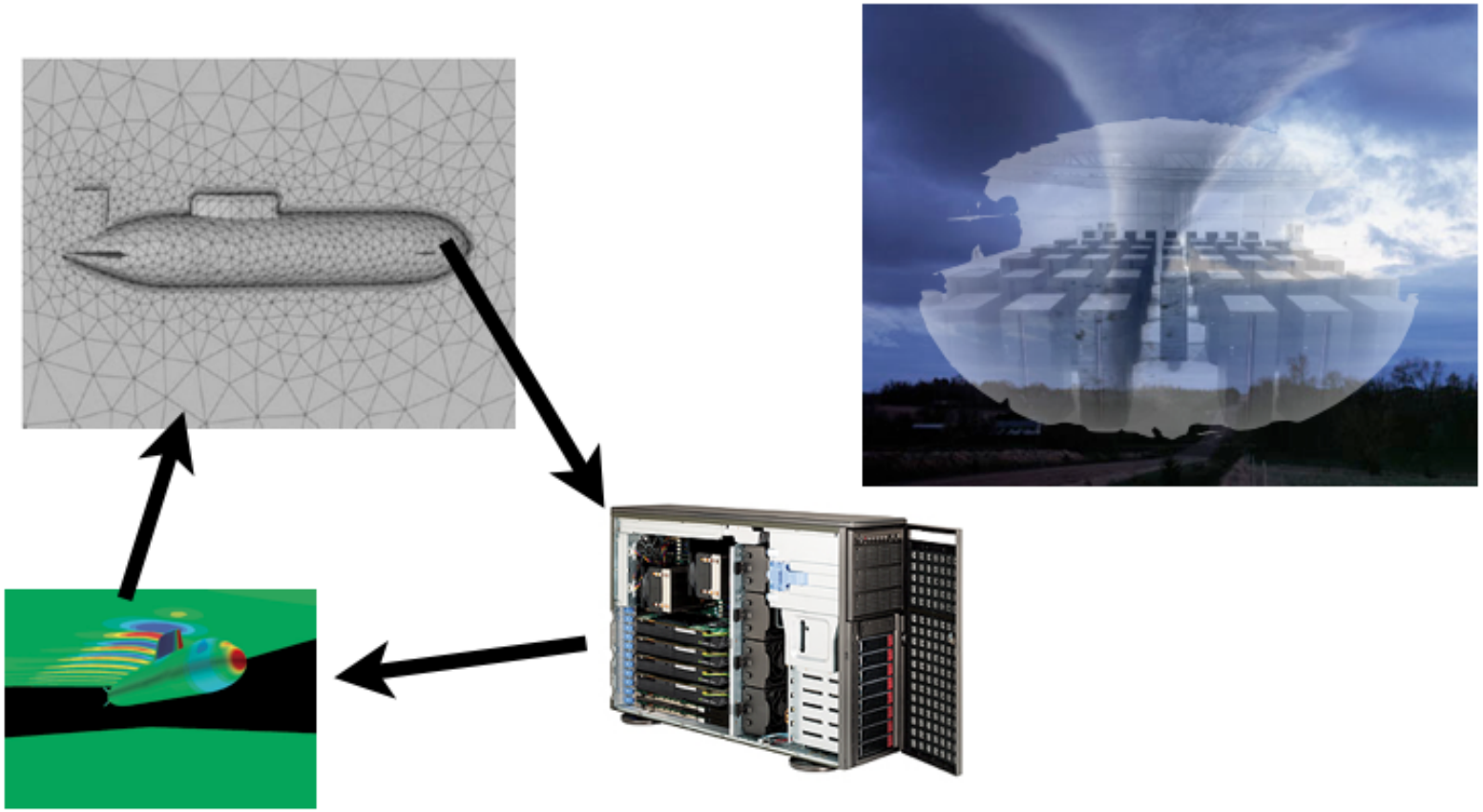


Goals

- Bring volunteer computing to the web browser
  - “Volunteer"
  - Reduce downloading/installing friction.
  - Web-browser as a high-performance distributed computing platform.
- Develop robust library for GPU computing in Javascript.
  - Enable GPU development and metaprogramming on the web.

“Windows and Linux present a near-infinite combination of hardware, software, and drivers that would not be encountered in a local setting. This means that a significant amount of time is spent dealing with incompatibilities when the clients are developed, and every time a new version of the operating system is shipped such as Windows 7, or the latest version of a Linux distribution."

– Beberg et al. *Folding@home: Lessons From Eight Years of Volunteer Distributed Computing*

WebCL

- Experimental cross-platform JS binding for OpenCL
- Available for Firefox, WebKit, and Node.js

- API is verbose, procedural, and difficult to use

Contributions

- **KernelContext, KernelUtils**
  - PyCUDA inspired abstraction layer for WebCL
- **CrowdCL**
  - Framework for developing and deploying high performance, web-based volunteer computing projects.

- Application to existing crowd-generated data project.
- Comparison with existing cross-platform solutions

KernelContext

- Abstraction layer for WebCL inspired by PyCUDA
  - Minimizes WebCL/OpenCL boilerplate
  - OpenCL kernels are first-class citizens
  - Lazy evaluation utilizes the OpenCL command queue.

KernelContext

```
1 var ctx = new KernelContext;
2 var source_str = "__kernel void FN_NAME(...) {...}"
3 var kernel = ctx.compile(source_str, 'FN_NAME');
4
5 var data = new Uint32Array(10);
6 var d_data = ctx.toGPU(data);
7 kernel({local: 32, global: 32}, d_data);
8 ctx.fromGPU(d_data, data);
```

KernelUtils

- Dynamically generate kernels following common patterns

- `mapKernel, reduceKernel`
  - Generate a re-usable map or reduce kernel
  - “Templated" on map/reduce operation
  - Hides complexity – job size, multiple launches, etc.
- `map, reduce`
  - Generate and launch a single-use map or reduce kernel

KernelUtils

```
1 var ctx = new KernelContext;
2 var util = new KernelUtils(ctx);
3
4 var a1 = new Uint32Array(10);
5 var result = util.map('x', 'x[i] + 1', a1);
6
7 var a2 = new Uint32Array(100000);
8 var result = util.map('x', 'x[i] * 0.43', a2);
```

KernelUtils

```
1  var ctx = new KernelContext;
2  var util = new KernelUtils(ctx);
3
4  var a1 = new Uint32Array(10);
5  var sum1 = util.reduce('a + b', a1);
6  var max1 = util.reduce('(a > b) ? a : b', a1);
7
8  var a2 = new Uint32Array(100000);
9  var prd2 = util.reduce('a * b', a2);
10 var min2 = util.reduce('(a < b) ? a : b', a2);
```

KernelUtils

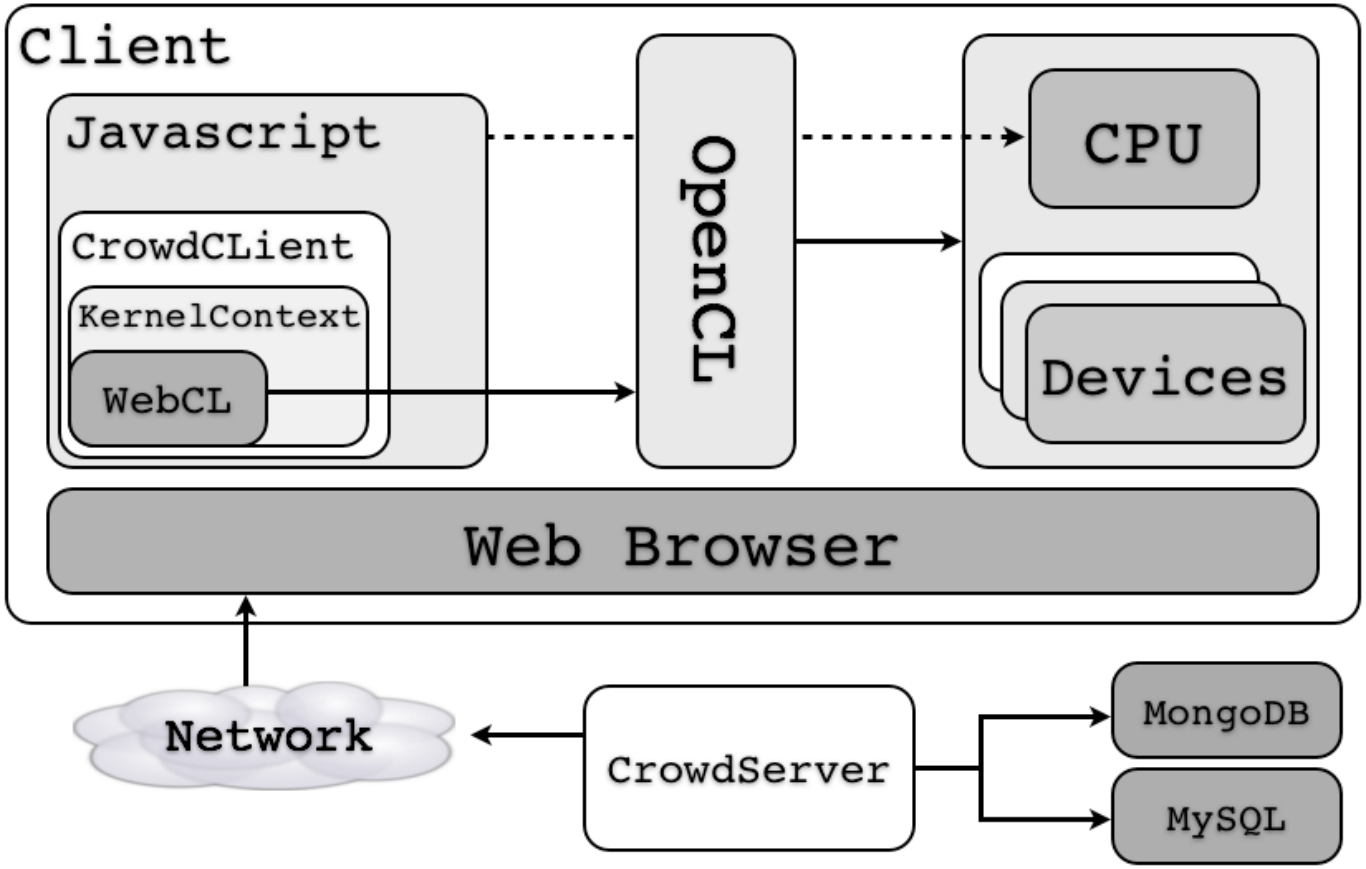
```
1 var sum_kernel = util.reduceKernel(Uint32Array, 'a +
     b');
2 var max_kernel = util.reduceKernel(Uint32Array, '(a
    > b) ? a : b');
3
4 var a1 = new Float32Array(100000);
5 var d_a1 = ctx.toGPU(a1);
6
7 var sum2 = sum_kernel(d_a1);
8 var max2 = max_kernel(d_a1);
```

CrowdCL

- Built on `KernelContext` to provide a re-usable framework for volunteer computing applications

- `CrowdCLient`
  - Client library – generate results via WebCL
- `CrowdServer`
  - Server library – collect results, aggregate data

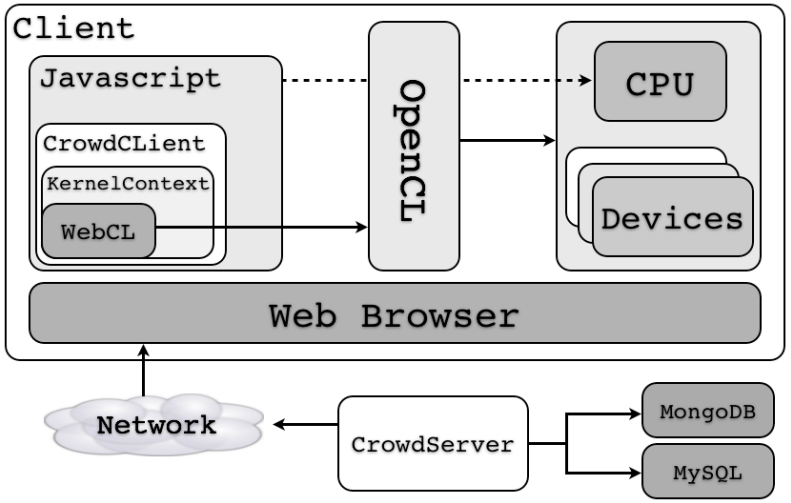
CrowdCL Architecture



CrowdCLient

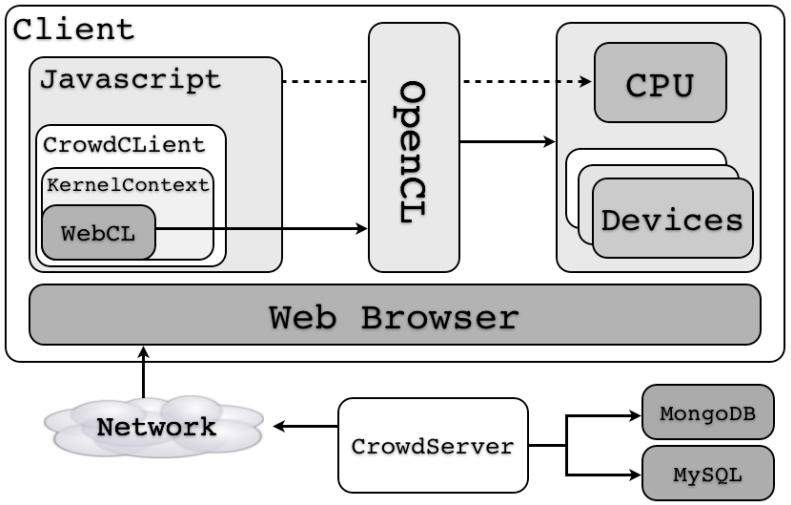
- Execute code in the background of a web page
- Send batched results to `CrowdServer`

- Acts like a Thread class:
  - Define a `run` method that generates results for a problem
  - API to `pause`, `resume`, and `sleep` execution.



CrowdServer

- RESTful Node.js application to aggregate `CrowdCLient` results
- Supports both MongoDB and MySQL to store data



Thomson Problem

- Thomson problem: nonlinear optimization problem, useful in many problems in biology, math, physics, and computer science
- Lowest energy configurations of N repelling charges on a sphere
  - Force (gradient) and energy require $\mathcal{O}(N^2)$ computation.
  - Number of local minima grows exponentially with N

Thomson Problem

Let $\omega_N = x_1, \ldots, x_N$ with $\|x_i\| = 1$ and

$$E_s(\omega_N) = \sum_{\substack{x,y \in \omega_N \\ x \neq y}} \frac{1}{\|x - y\|^s}$$

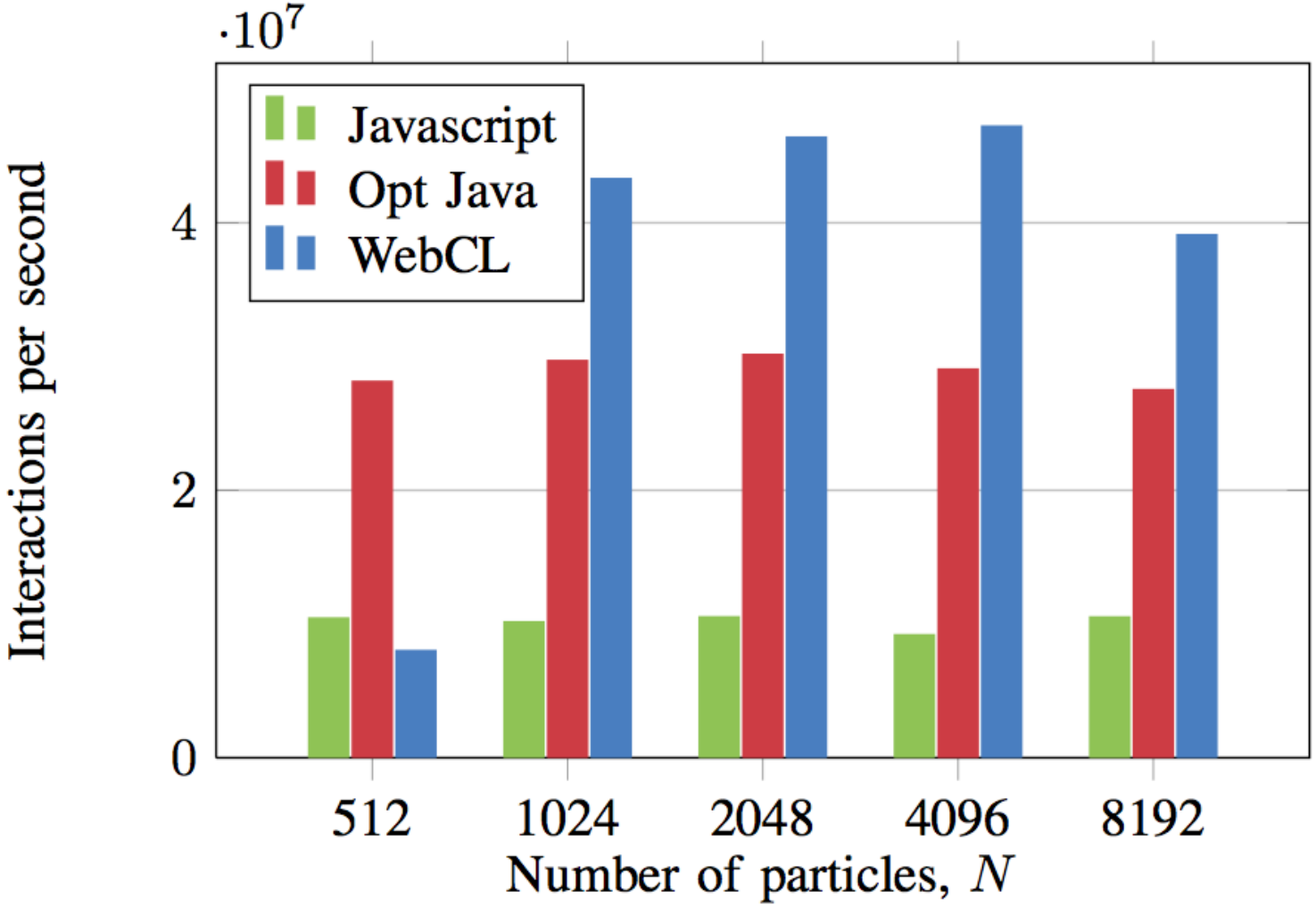
Gradient descent:

- Compute the gradient (force on each point $x \in \omega_N$)

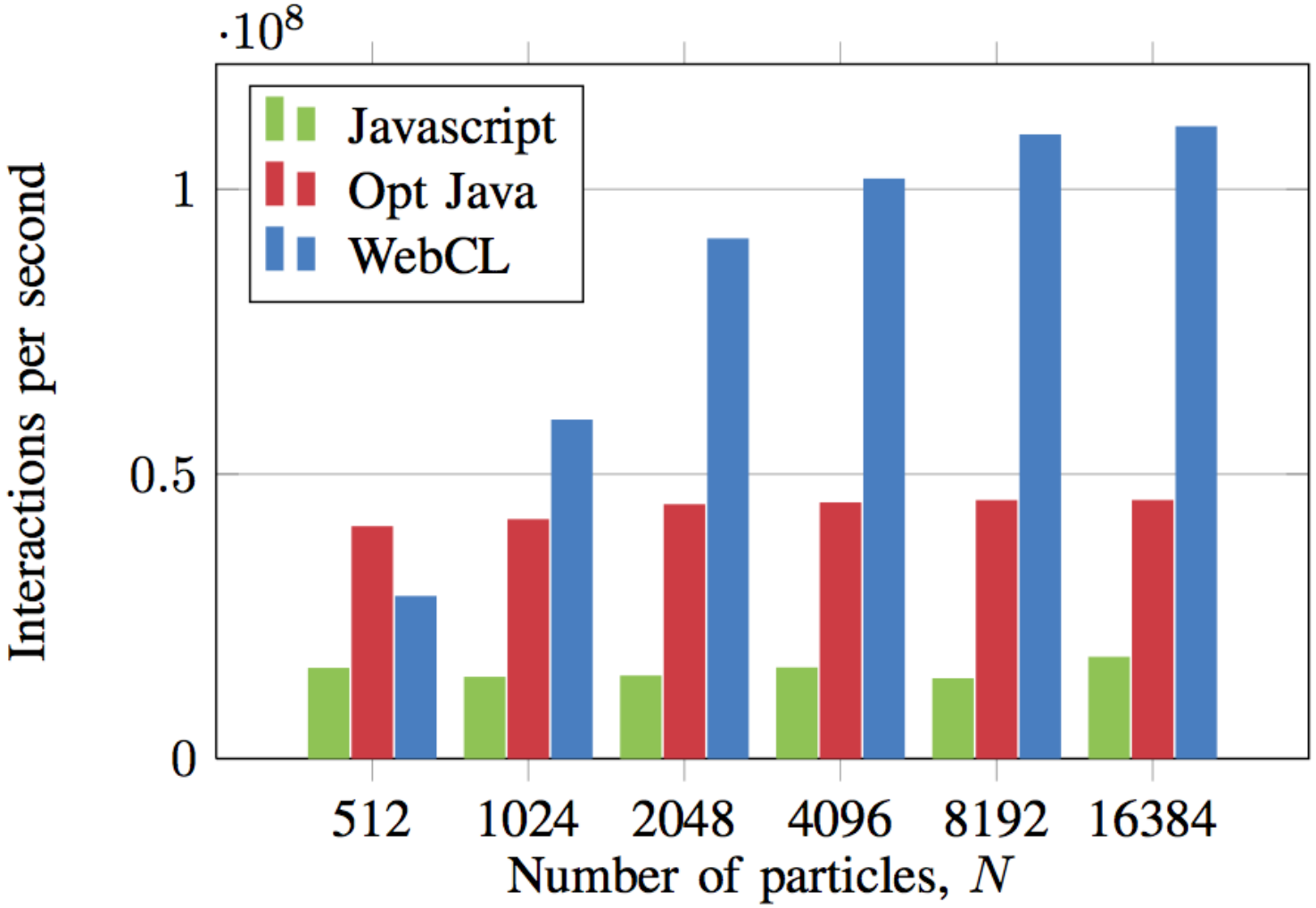
$$G(\omega_N)[x] = \sum_{\substack{y \in \omega_N \\ y \neq x}} \frac{x - y}{|x - y|^3}$$

- Compute a (heuristic) step-length
  - $ds := f(\omega_N, G(\omega_N))$
- Update all points in ω_N and renormalize
  - $x := x + ds \cdot G(\omega_N)[x]$
  - $x := \frac{x}{\|x\|}$

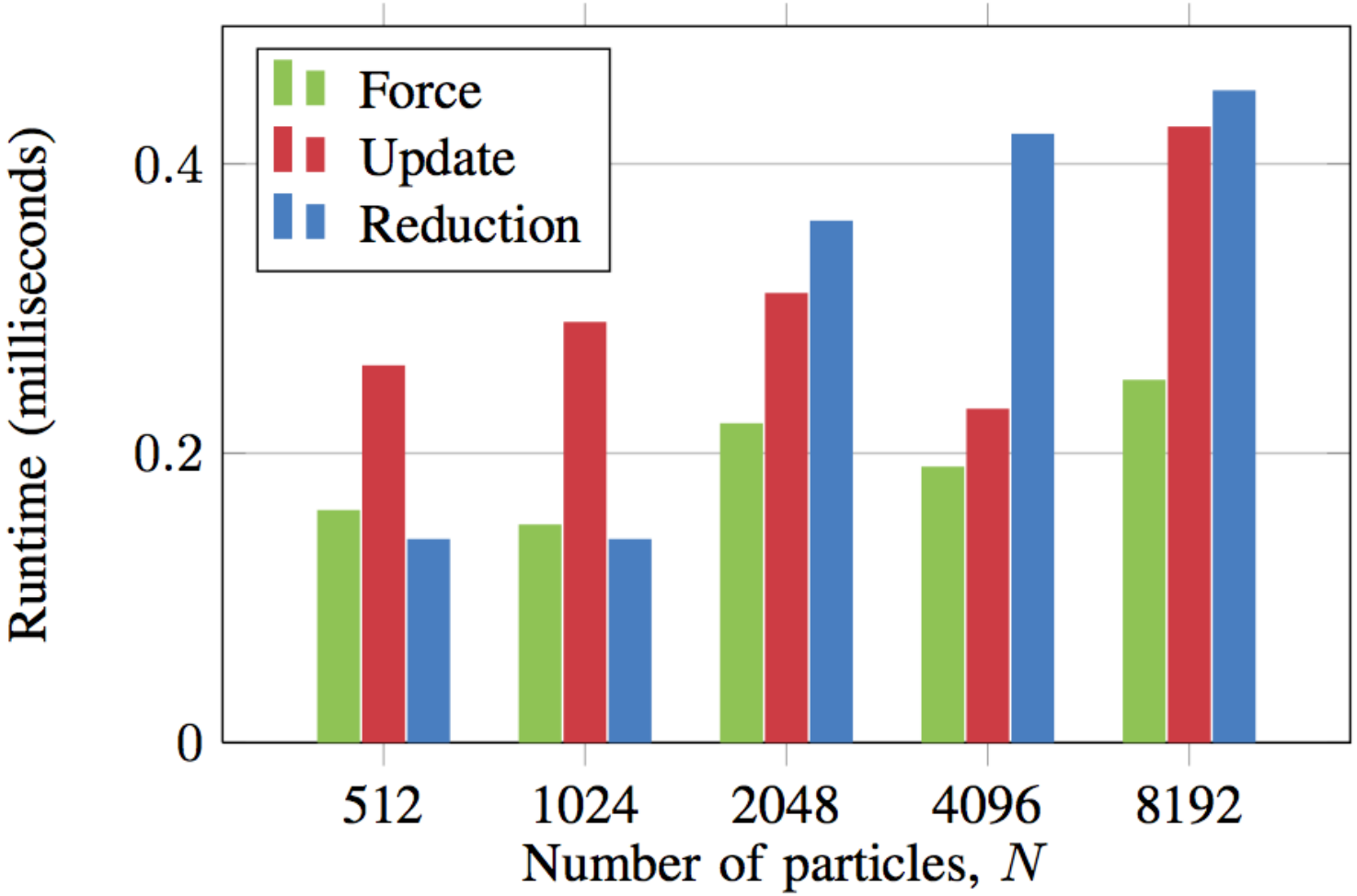
NVIDIA 320M


$\cdot 10^7$
Javascript
Opt Java
WebCL
Interactions per second
0
2
4
512
1024
2048
4096
8192
Number of particles, N

NVIDIA Tesla K20



Kernel Performance (NVIDIA 320M)



- WebCL only available on Firefox 19 + plugin
- Nice, big security issues for general deployment

Thank you

- https://github.com/tmacwill/webcl-kernelcontext
- https://github.com/tmacwill/crowdcl