Parallel Programming for the Web

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JavaScript* – What You Need To Know

- It is not Java*
- Blend of many programming paradigms
  - Object oriented with prototypes
  - Higher-order functions and first class function objects
  - Dynamically typed and interpreted
- Safety and security built in
  - Requirement for web programming
  - Managed runtime
  - No pointers, no overflows, …
- Designed for portability
  - Fully abstracts hardware capabilities

Concurrency in JavaScript*

- Cooperative multi-tasking
  - Scripts compete with the browser for computing resources
  - Event driven execution model
- Concurrent programming mindset
  - Asynchronous call-backs for latency hiding
- Fully deterministic
  - Run-to-completion semantics
  - No concurrent side effects
- **No support for concurrent execution**
  - Single threaded evaluation of JavaScript

Yet Another Parallel Programming API?

Pthreads
Rust
Chapel
NESL
Cilk
Multilisp
DpH
TBB
OpenCL
OpenACC
UPC
SaC
CUDA
Manticore
XIO
Parlog

Design Considerations

Language Design with the Web in Mind

1. Ease of use
   - Build on developer's existing knowledge
   - Allow for mash-up of sequential and parallel code

> "Meant to be a scripting language […] for the designer, the amateur programmer, the beginner programmer"
>
> Brendan Eich, CTO Mozilla

Language Design with the Web in Mind

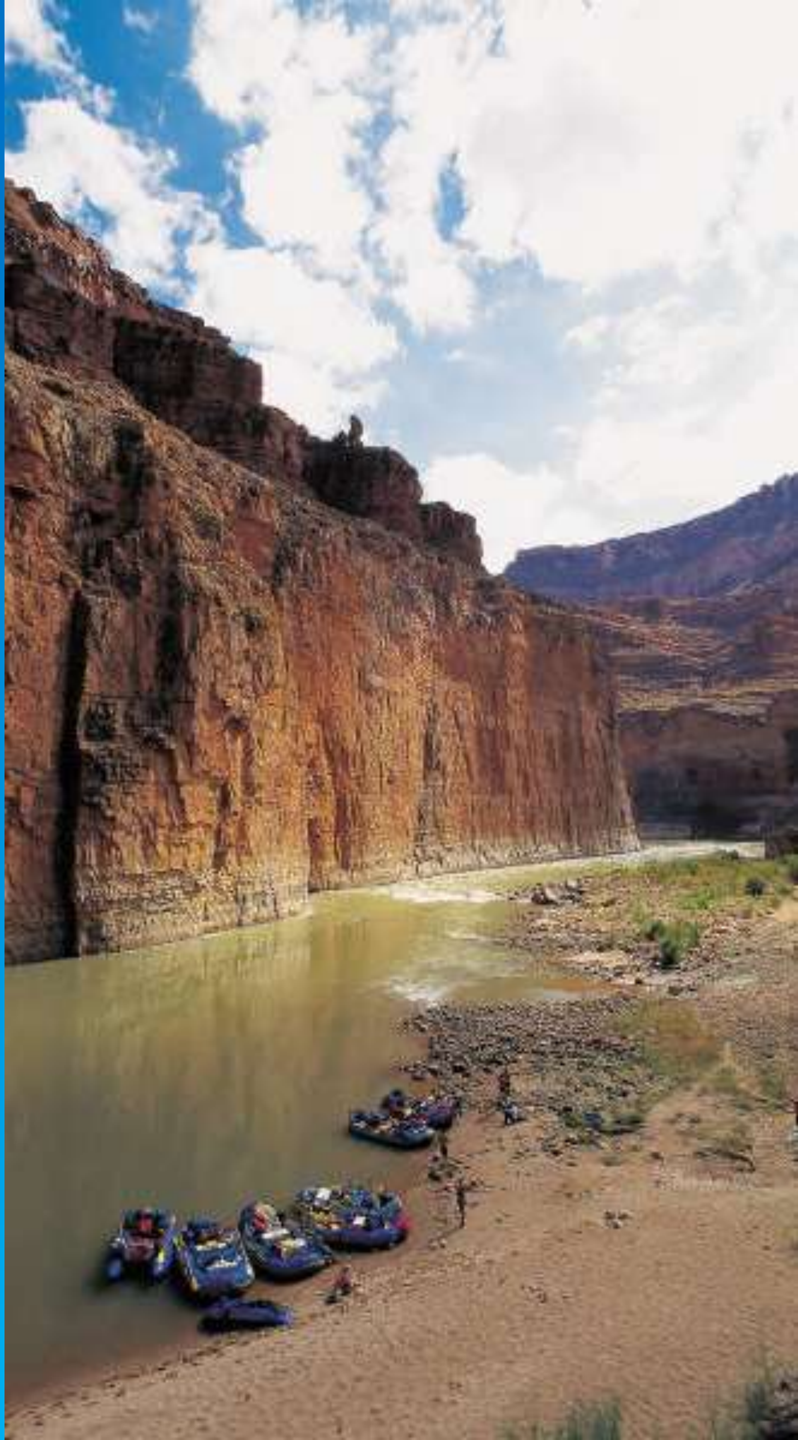
1. Ease of use
   - Build on developer’s existing knowledge
   - Allow for mash-up of sequential and parallel code
2. Platform independent
   - Support all kinds of platforms, parallel or not
   - Perform well on different parallel architectures (multi-core, GPUs, …)
3. Suitable for the Open Web
   - Meet existing safety and security promises
   - Needs to be reasonably easy to implement in JavaScript JIT engines

Challenge: meet these criteria and get good performance

Design Choices

- Performance portability
  - ⇒ Use High-Level Parallel Patterns
- Deterministic execution model
  - ⇒ No side effects: shared state is immutable
  - ⇒ Require commutative and associative operators
  - ⇒ No magic: floating point anomalies may still occur
- Support mash-up coding
  - ⇒ All code still written purely in JavaScript
  - ⇒ Looks like JavaScript*, behaves like JavaScript*
- Maintain JavaScript*'s Safety and Security
  - ⇒ Use fully managed runtime

River Trail API



Three Pillar Approach

- Data structure: `ParallelArray`
  - Immutable, dense and homogeneous
- Six Methods: `map`, `combine`, `reduce`, `scan`, `filter`, `scatter`
  - Provide the basic skeletons for parallel computing
  - Typically creates a freshly minted ParallelArray
- Elemental functions (kernel functions)
  - Written purely in JavaScript
  - Side effect free

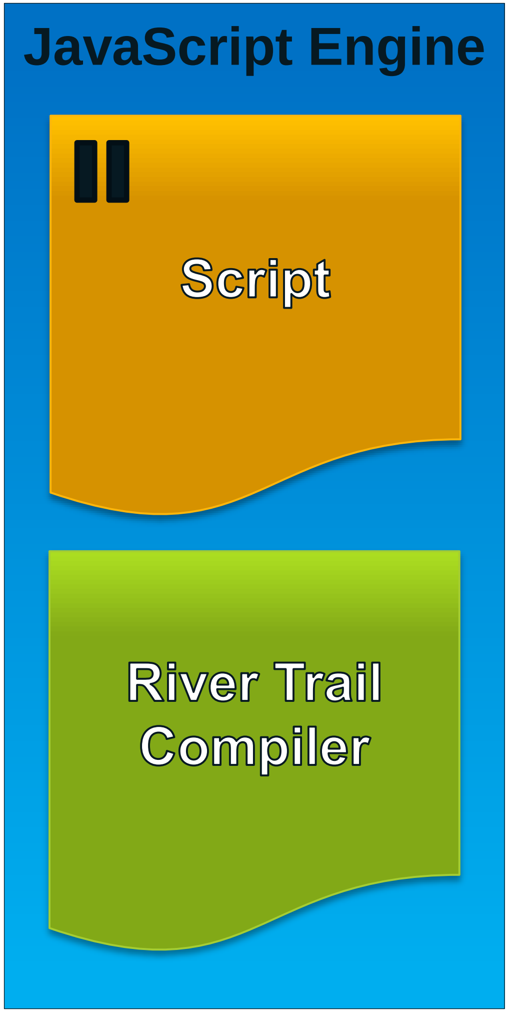
```
pa = new ParallelArray([1, 2, 3, 4]);

pa.map(function (v) { return v+1; })
```

An Example: Grayscale Conversion

```
pixelData.map(toGrayScale)
         .map(function toRGBA(color) {
                 return [color,color,color,255];
              }
)
```

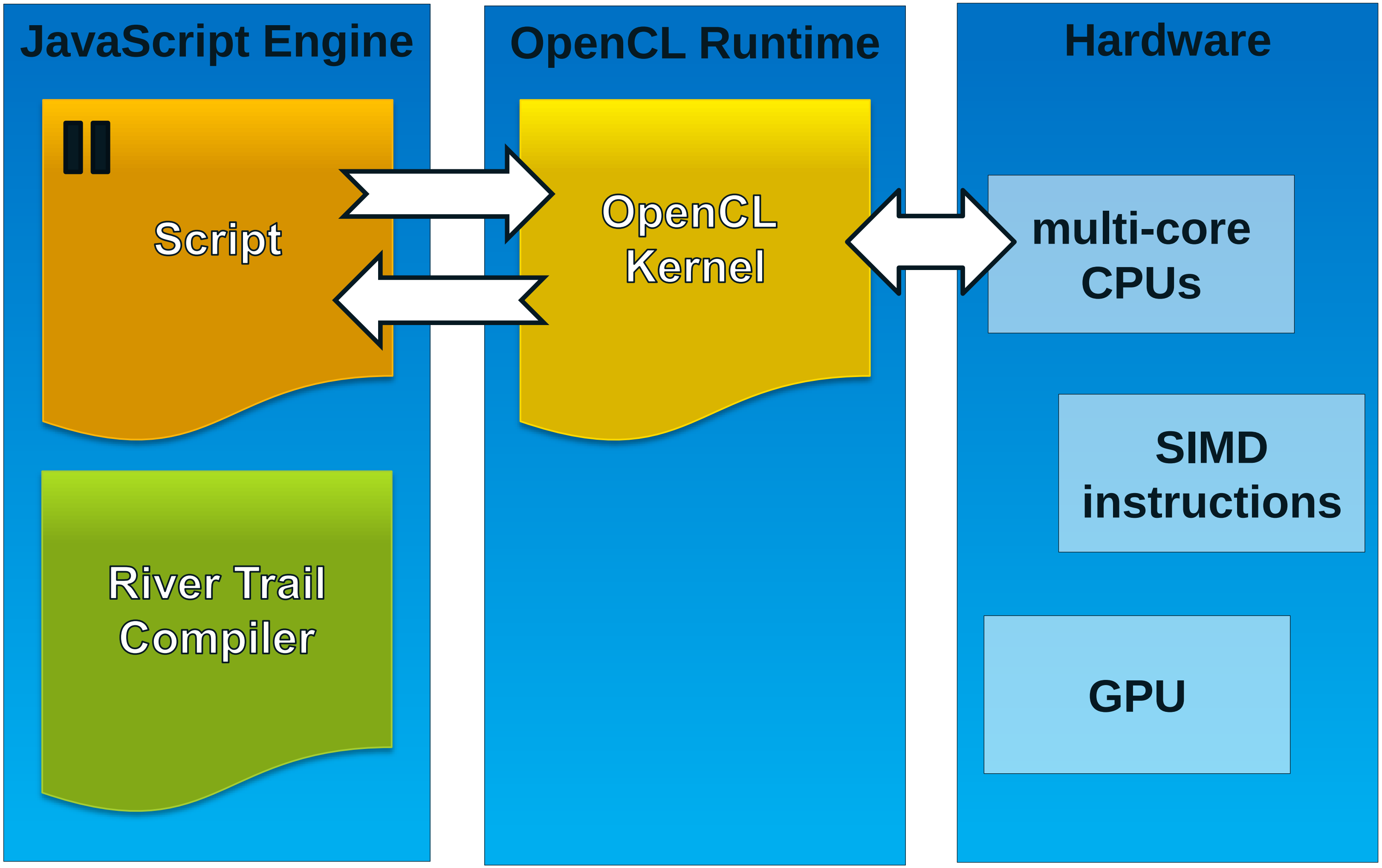
Prototype Implementation

Compiling River Trail (Prototype)

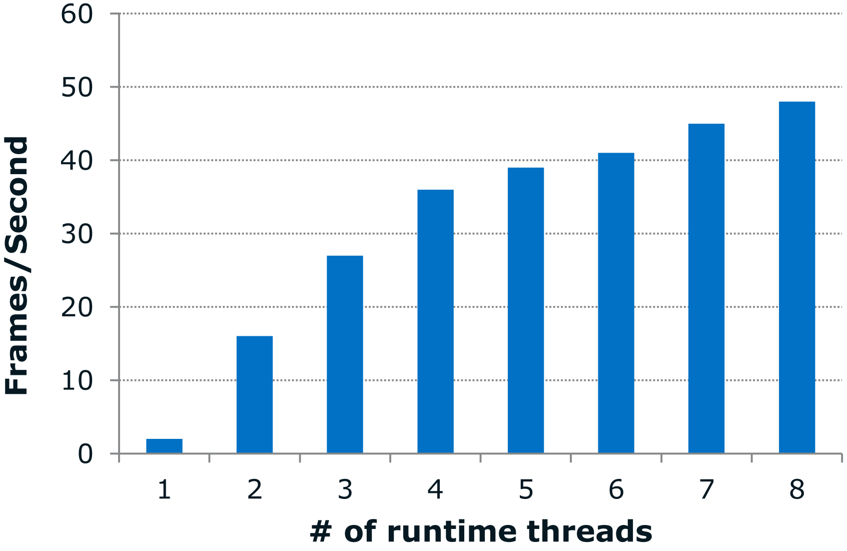


- Type inference
  - Infers array types and shapes
  - Checks for side effects
- Representation analysis
  - Computes bounds on local variables
  - Updates type information of known Integer numbers
- Static memory allocation
- Bounds check elimination
- Code generation
  - Emits OpenCL code

Compiling River Trail (Prototype)



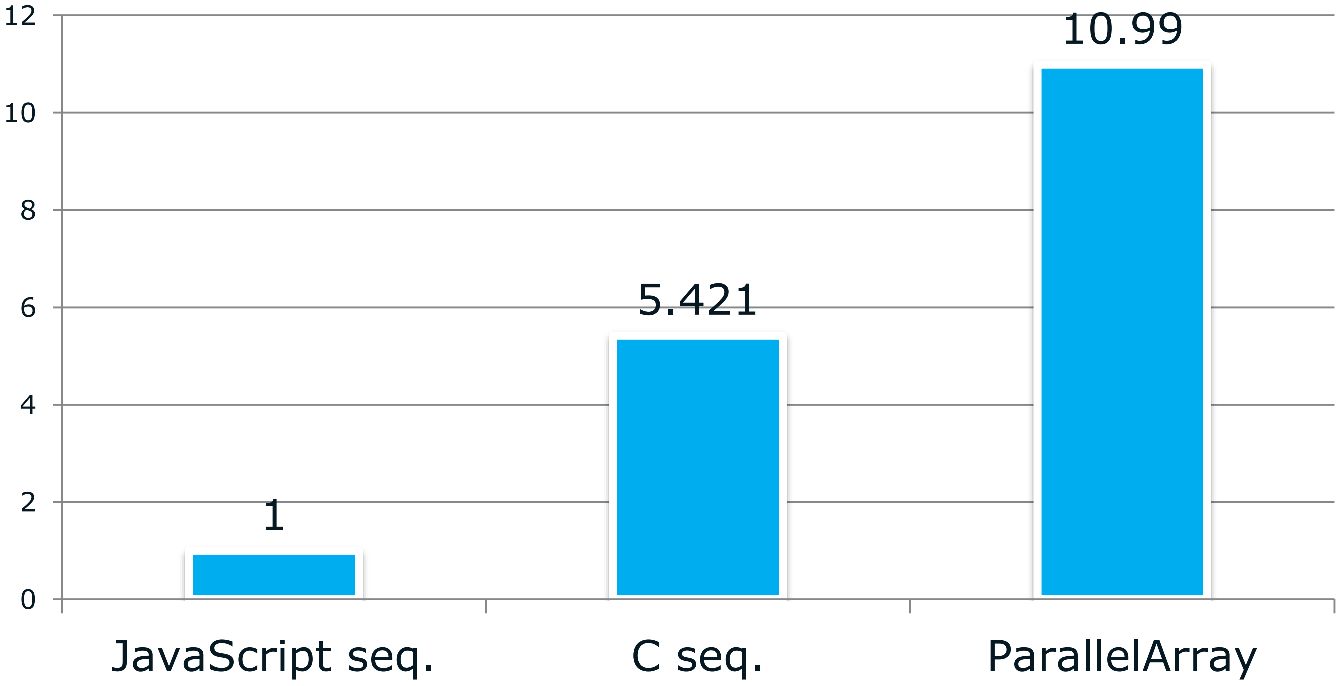
Performance Results: Particle Physics



Particle model ($O(n^2)$) computed using River Trail on a 2nd Generation Core i7 with 4 cores

http://github.com/RiverTrail/RiverTrail/wiki

Performance Results: Matrix Matrix Multiply



O(n^3) dense matrix matrix multiplication on 1000 x 1000 element matrices; dual-core 2nd Generation Core i5 with HyperThreading enabled and 4GB RAM; JavaScript* benchmarks use Firefox 8

Status Quo

- Open source Firefox prototype available on GitHub
  - Pre-built binary extension for Firefox 12
  - Sequential library fall back for other browsers
- ECMAScript proposal of the full API published
  - Removes many limitations of the prototype
- First sequential implementation for SpiderMonkey
  - Lives in Mozilla’s IonMonkey branch
  - Intended as API testing vehicle

http://github.com/RiverTrail/RiverTrail/wiki

http://wiki.ecmascript.org/doku.php?id=strawman:data_parallelism

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