

Using algorithmic skeletons in EcmaScript to parallelize computation in browsers through Web Workers

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Abstract. With the growing tendency of browsers being used for CPU intensive applications (such as 3D games) it is important to take advantage of multiple cores to reduce user perceived latency. This paper presents a JavaScript library based on algorithmic skeletons that allows users to take advantage of parallel processing in browsers while maintaining a familiar coding style.

Keywords: browsers, ecmaScript, parallelization, algorithmic skeletons

1 Introduction

In 1965 Gordon Moore proposed the popularly known “Moore’s law” [1], which predicts that the number of transistors in integrated circuits will double every two years. As a consequence, programs that use a single processor/core will automatically become faster without the need to modify them with that purpose in mind.

In the year 2010 it was predicted that this tendency would be slowly reaching its end, mostly due to reasons related to heat dissipation. This is the cause why newer computer have a greater number of processors instead of processors with more computing power.

To be able to maximize the performance of these computers, it is paramount that systems professionals can create programs that process data in parallel, through different mechanisms, such as threads or processes executing simultaneously in different processors. In the case of application executed on a single device (e.g. browsers and web pages, applications for mobile devices, desktop apps, server applications) a lot of languages and platforms provide a simple way for programmers to abstract the complexity and coordination required for this type of processing. For example, the .NET platform has the Task Parallel Library (TPL) and Parallel LINQ (PLINQ) [2] libraries that use algorithmic skeletons modelled with high order functions so developers can perform complex operations through a simple API.

On a different note, one of the tendencies that is beginning to take off is the use of EcmaScript [3] (also known as Javascript) to create applications that were previously only considered viable in a native environment, such as video games. This has been possible thanks to components like asm.js [4] and WebGL [5] together with the constant evolution of browsers and JavaScript runtime engines. In this context, one of the plans of the committee that develops the language is to provide an API to simplify the processing of data in parallel for version 7 (ES7) of the language, with the goal of keeping up with native applications. Initiatives such as ParallelJS [7] and River trail [6] or the possibility of taking advantage of SIMD instructions [8] (single instruction multiple data) are some of the options to implement this.

The goal of this paper is to provide an alternative for parallel code execution in EcmaScript, through a library that exposes high order functions to model algorithmic skeletons such as map, filter and reduce. This library will take advantage of Web Workers [9] (the mechanism proposed by browsers for parallelism at the time of writing) to allow the simultaneous execution of code in multiple processors.

2 Serialization and Transference

Let's consider an array of N elements on which a particular transformation is to be performed through the `map` function. If the transformation is executed using a single thread (no parallelism) and the average time to process each element is t then the total time (T_{ser}) for the operation can be approximated as:

$$T_{ser} = \sum_{i=0}^N t = Nt . \quad (1)$$

When trying to parallelize this operation using K threads the ideal goal is to reach a total time (T_{par}) that is:

$$T_{par} = \frac{T_{ser}}{K} . \quad (2)$$

Nevertheless, there are additional time consuming tasks other than the main computation that need to be considered when performing the operation in parallel in programs where not all memory is shared. These are:

- Serializing/deserializing the elements to transfer.
- Transferring the elements back and forth between the UI thread and the workers.
- Transferring to each worker the functions for the transformation.

If we consider T_{ft} as the function transfer time, T_{et} as the elements transfer time, and T_s as the serialization/deserialization time it is clear that:

$$T_{sync} = T_{ft} + T_{et} + T_s . \quad (3)$$

$$T_{par} \approx \frac{T_{ser}}{K} + T_{sync} . \quad (4)$$

Based on the previous equations it can be deduced that the more T_{sync} can be reduced, the closer to the ideal scenario the computation will be.

In our case we are trying to transfer objects between a browser's JavaScript UI thread and Web Workers so we are constrained by the means of that environment. The Worker interface is the following [9]:

Web Worker interface

```
[Constructor(DOMString scriptURL)]
interface Worker : EventTarget {
    void terminate();

    void postMessage(any message, optional sequence<Transferable> transfer);
    [TreatNonCallableAsNull] attribute Function? onmessage;
};
Worker implements AbstractWorker;
```

(Example extracted from the W3C Web Workers specification)

As the aforementioned interface states one can either send just a message or send a message with a sequence of transferable objects. From section 2.7.5 of the HTML Standard [10]: *“Some objects support being copied and closed in one operation. This is called transferring the object, and is used in particular to transfer ownership of unsharable or expensive resources across worker boundaries.”*

2.1 Elements

Considering the definition of a **Transferable** the latter seems like a good alternative to minimize both T_{et} and T_s . Even more so when one considers that otherwise objects are copied using structured cloning(explained in section 2.7.6 of that same standard).

To verify our hypothesis, we put together two benchmarks¹ that aim to verify the difference between invoking `postMessage` with and without structured cloning for a **SharedTypedArray**. Both transfer a **SharedTypedArray** back and forth between the UI thread and a worker; the only difference between the two is that one has 100000 (a hundred thousand) elements in the **SharedTypedArray** and the other one 1000000 (a million). The results are in Tab. 2. As it can be seen from the results, increasing the amount of elements by 10x does not change the amount of operations that can be performed when using **Transferable** objects, it scales. On the other hand, the amount of operations that can be performed with structured cloning greatly decreases.

For that reason only works with **SharedTypedArrays** and **TypedArrays**.

¹ All benchmarks in this document use the environment described in Tab. 1.

Computer	Mac Book Air
Processor	Intel Core i5
Clock Frequency	1.8 GHz
System Memory	4 GB
Operating System	OS X Yosemite 10.10.3
Browser version	Firefox Nightly 40.0a1 (2015-04-26)

Table 1. Benchmarks environment.

Elements	Cloning [ops/sec]	Transferring [ops/sec]
1E5	1000	9000
1E6	100	16000

Table 2. Difference between transferring and cloning shared buffers.

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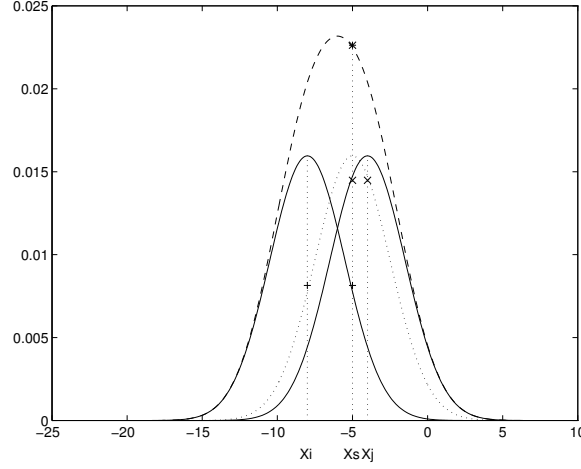


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Example of a Computer Program

```
program Inflation (Output)
{Assuming annual inflation rates of 7%, 8%, and 10%,...
 years};
const
  MaxYears = 10;
var
  Year: 0..MaxYears;
  Factor1, Factor2, Factor3: Real;
begin
  Year := 0;
  Factor1 := 1.0; Factor2 := 1.0; Factor3 := 1.0;
  WriteLn('Year 7% 8% 10%'); WriteLn;
  repeat
    Year := Year + 1;
    Factor1 := Factor1 * 1.07;
    Factor2 := Factor2 * 1.08;
    Factor3 := Factor3 * 1.10;
    WriteLn(Year:5,Factor1:7:3,Factor2:7:3,Factor3:7:3)
  until Year = MaxYears
end.
```

(Example from Jensen K., Wirth N. (1991) Pascal user manual and report. Springer, New York)

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