Automatic pipeline parallelism for event-loops

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Abstract

The popularity of Javascript recently exploded. Most implementations of Javascript present an event-loop design. Node.js is an example. We believe this design is more efficient to build web applications than the classical thread approach [2]. An event-loop uses a single-core execution, and a global memory. It relieves the developer from the synchronization burden, but limits the implementation to a single machine. When the desired throughput augments, latency increases. Physics currently prevents us from building CPU with faster clocks. Eventually, the only solution to keep a reasonable latency is to use multiple machines. A particularly efficient design to leverage this parallelism is to slice an application into stages to form a parallel pipeline [3]. However, slicing an application into stages is a costly operation when done manually. Every stage must be balanced to fit on a machine so as to avoid bottlenecks leading to wasted resources. Moreover, for important changes in the application, the slicing is reconsidered to keep the balance.

We argue that an event-loop is similar to a parallel pipeline executing on a single-core. We propose to automatically isolate stages in the application logic. The resulting application can be distributed over a network of machines. We believe this work will later allow to automatically balance stages to maximize throughput with the available resources.

An event loop invokes handlers to react on events. Handlers end without return, they asynchronously trigger the next handlers. The call stacks of two handlers are disjoints. Thus, it is possible to parallelize their execution, as long as causality is preserved. Every event handlers becomes a stage in the pipeline.

In a mono-thread execution model like Node.js, the memory is global. But the atomic execution of handlers removes the need for synchronization and isolation [1]. The memory holds both the communications between the handlers, and their state. To parallelize the handlers, we isolate the state of each handler to reproduce exclusivity ; and we identify their communications to reproduce a one way flow of messages.

We built a first incomplete compiler as a proof of concept. After successful results with custom applications, we are building a complete compiler to transform real applications.

Références

[1] A Adya, J Howell et M Theimer. “Cooperative Task Management Without Manual Stack Management.” In : *USENIX Annual Technical Conference* (2002).

[2] Kai Lei, Yining Ma et Zhi Tan. “Performance Comparison and Evaluation of Web Development Technologies in PHP, Python, and Node.js”. In : *2014 IEEE 17th International Conference on Computational Science and Engineering*. IEEE, déc. 2014, p. 661–668. doi : 10.1109/CSE.2014.142.

[3] M Welsh, SD Gribble, EA Brewer et D Culler. *A design framework for highly concurrent systems*. 2000.

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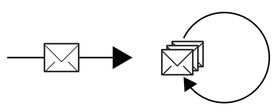
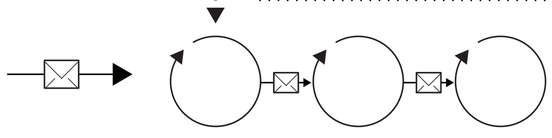
event-loop



+ linearly scalable
+ no synchronization
- limited to a single core

manual slicing

need to balance stages
at each code modification



+ linearly scalable
- costly evolution

pipeline parallelism

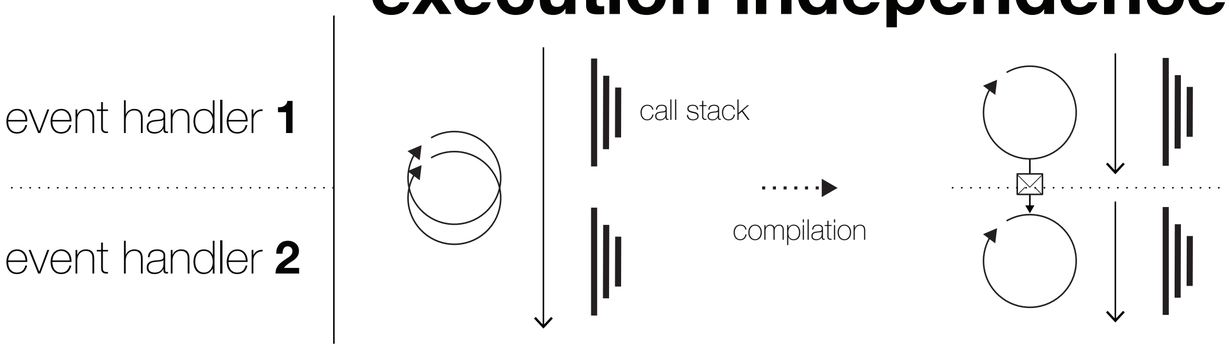
problematic

an event-loop is limited, and switching to pipeline parallelism is costly.

proposition

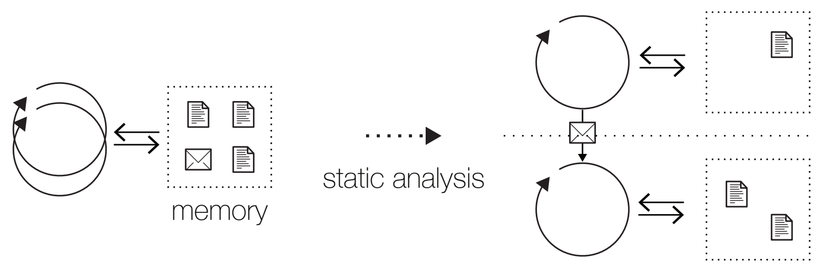
We propose to automate the slicing process at compile time

event-loop assures
execution independence



&

static analysis provides
memory independence



compilation example

source[5]

```
var app = require('express')(),
    fs = require('fs'),
    count = 0;

app.get('/', function handler(req, res){
  fs.readFile(__filename, function reply(err, data){
    count += 1;
    var code = ('' + data)
                    .replace(/\n/g, '<br>')
                    .replace(/ /g, ' ');
    res.send(err
           || 'downloaded ' + count +
              ' times<br><br><code>' +
              code + '</code>');
  });
});

app.listen(8080);
console.log('>> listening 8080');
```

target[5]

```
flx source.js {}
>> handler-1000 [res]
  var app = require('express')(),
      fs = require('fs'),
      count = 0;
  app.get('/', >> handler-1000);
  app.listen(8080);
  console.log('>> listening 8080');
```

req, res

```
flx handler-1000 {fs}
-> reply-1001 [res]
  function handler(req, res) {
    fs.readFile(__filename, -> reply-1001);
  }
```

res, err, data

```
flx reply-1001 {count}
-> null
  function reply(err, data) {
    count += 1;
    var code = ('' + data)
                    .replace(/\n/g, '<br>')
                    .replace(/ /g, ' ');
    res.send(err
          || 'downloaded ' + count +
             ' times<br><br><code>' +
             code + '</code>');
  }
```


[1] A Adya, J Howell and M Theimer. “Cooperative Task Management Without Manual Stack Management.” In : USENIX Annual Technical Conference (2002).

[2] JR von Behren, J Condit and EA Brewer. “Why Events Are a Bad Idea (for High-Concurrency Servers).” In : HotOS (2003).

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[5] flx-example: https://github.com/etnbrd/flx-example/tree/1.0. Accessed: 2014-08-22.

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