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Hiphop.js: a language to orchestrate web applications

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CCS CONCEPTS
• Software and its engineering → Domain specific languages;
  Orchestration languages;

KEYWORDS
Web Programming, Reactive Programming, Orchestration

ACM Reference Format:

1 INTRODUCTION
We are interested in web orchestration, which is the problem of appropriately handling the asynchronous events appearing in program executions. It is known as one of the major difficulties of web programming (see callback hell [9, 11]).

High-level approaches to orchestrate web applications have been developed in academia or industry. The Functional Reactive Programming (FRP) concept [4] has been carried up to the web by Flapjax [5, 10], which adopts a dataflow programming style: when a variable is modified, any expression that references it is implicitly reevaluated. Others techniques targeting GUI updates [1, 6, 8, 12] consist in associating a state with a set of graphical elements and automatically updating the graphics on changes. In JavaScript Promises and async/await constructions [7] make it possible to chain asynchronous actions in a specific sequential order. Working at a more abstract level, these solutions avoid using callbacks.

Our goal is to go further with yet another solution based on a new language called Hiphop.js. It is a JavaScript extension of Esterel [2] based on three reactive control mechanisms: explicit concurrency, synchronisation using synchronous signals, which makes the handling of concurrent issues much easier, and preemption, i.e. the explicit cancellation of an ongoing orchestration subactivity. Hiphop.js suitably extends the core Esterel notions to deal with web paradigms such as application structure dynamicity. Hiphop.js follows a previous Scheme-based prototype [3], but takes different approaches w.r.t. the interaction with the host language.

This paper gives an informal introduction to Hiphop.js through a small example that compares the programming of a simple event-aware program in both JavaScript and Hiphop.js.

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2 SPECIFICATION OF THE EXAMPLE
We study the timer application of the 7 GUIs project 1 where the timer’s duration is represented by a slider, the current elapsed time is displayed both by a gauge and as a number, and a Reset button resets the timer.

When running the timer the gauge and numeric field are constantly updated until the duration is reached. From then on, setting a bigger duration immediately restarts the timer from the current elapsed time. At any time, pressing Reset resets the elapsed time to 0 and restarts the timer.

3 IMPLEMENTATION
We compare the JavaScript and Hiphop.js timer implementations, the latter introducing the Hiphop.js programming style and constructions.

The plain HTML GUI is common to JavaScript and Hiphop.js:

```
<div>Elapsed time: <meter id="meter"></meter></div>
<div><span id="elapsed"></span></div>
Duration: <input id="range" type="range" max="100"
onchange="setD(this.value)"/>
<button onclick="resetE()">Reset</button>
```

3.1 JavaScript implementation
The JavaScript code is as follows:

```javascript
var D=0, E=0, id=-1;
window.onload = function() {
  $('meter').value=E; $('meter').max=D;
  $('elapsed').innerHTML=E; $('range').value=D;
}
function tick() {
  if (E<D) {
    E +=0.1; $('meter').value=E;
    $('elapsed').innerHTML=E;
  }
  if (E==D) { clearTimeout(id); id=-1; }
}
function startIntervalIfNeeded() {
  if (id == -1 && E<D) id=setInterval(tick, 100);
}
function resetE() {
  E=0; $('meter').value=E; clearTimeout(id); id=-1
  startIntervalIfNeeded();
}
function setD(value) {
  D=value; $('meter').max=D;
}
```

1https://github.com/eugenkiss/7guis/wiki/time
3.2 Hiphop.js implementation

Let us first ignore the Reset button with a BasicTimer:

```javascript
MODULE BasicTimer {
  IN duration(0);
  OUT elapsed;
  EMIT elapsed(0);
  LOOP {
    IF (VAL(elapsed) < VAL(duration)) {
      RUN(TimeoutMod(100));
      EMIT elapsed(PREVAL(elapsed) + 0.1);
    } ELSE {
      PAUSE;
    }
  }
}
```

All Hiphop.js keywords are capitalized. `MODULE` defines a module, here the whole Hiphop.js program. `IN` and `OUT` declare the program interface. A Hiphop.js program is executed as a succession of atomic reactions, each handling input signals and possibly generating output signals.

Contrary to JavaScript scattered callbacks, in Hiphop.js there is a unique temporal code, which is based on classical sequencing and looping, signal emission, and temporal statements. Each statement has a temporal duration in terms of reactions. `EMIT` emits a signal and terminates immediately, i.e., passes control in sequence in the very same reaction. `LOOP` immediately starts its body and restarts it immediately when it terminates. `PAUSE` pauses for one reaction.

Let us now explain how `BasicTimer` executes. At initial reaction, `LOOP` starts its body that emits the `elapsed` signal with value 0. The `IF` test is then evaluated. If the value of `elapsed` is less than that of `duration`, the `TimeoutMod` module is run. As presented in Section 7 this will terminate the reaction, and after 1/100 will resume with the `elapsed` emission. Otherwise, the reaction terminates.

Adding Reset is achieved by another temporal statement called `LOOPEACH` placed around the unmodified `BasicTimer` module:

```javascript
MODULE Timer {
  IN duration(0), reset;
  OUT elapsed;
  LOOPEACH(NOW(reset)) {
    RUN(BasicTimer);
  }
}
```

`LOOPEACH` immediately starts the `BasicTimer`. From then on, whenever Reset is pressed, this timer is killed whichever state it was in, and a new timer is immediately restarted afresh. The advantage of temporal programming to modularly describe behavior becomes obvious: no internal state manipulation of `BasicTimer` needs to be performed by the user.

4 EXTENSION OF THE SPECIFICATION

The differences between Hiphop.js and JavaScript are more visible as the orchestration problem gets more complex. Let us add a new functionality to the previous specification: the timer can be suspended when it is running. In that case, the elapsed time is no longer incremented until the timer is resumed. The duration slider and Reset button remain active during suspension. In the GUI, we add a Suspend button that toggles the timer between the normal and suspended mode. The Suspend button turns to orange during suspension.

5 EXTENDED IMPLEMENTATION

The GUI is extended with a Suspend button:

```html
<button id="susp" onclick="susp()">Suspd</button>
```

5.1 New JavaScript implementation

Events triggered by the Suspend button are handled by:

```javascript
function susp() {
  if (isSusp) {
    isSusp = false;
    $('susp').style.backgroundColor="transparent";
    startIntervalIfNeeded();
  } else {
    isSusp = true;
    $('susp').style.backgroundColor="orange";
    clearTimeout(id); id = -1;
  }
}
```

A new global variable `isSusp` is used to keep the current state of the suspension. The previous code needs adaptations:

```javascript
function resetE() {
  if (isSusp) {
    isSusp = false;
    $('susp').style.backgroundColor="transparent";
    E=0; $('meter').value=E;
    clearTimeout(id); id=-1;
    startIntervalIfNeeded();
  }
}
```

```javascript
function setD(value) {
  D=value; $('meter').max=D;
  if (!isSusp) startIntervalIfNeeded();
}
```

The orchestration becomes more complex to understand; the whole program has been modified in a non-local way by adding `isSusp`, patching existing functions, and adding another function.

5.2 New Hiphop.js implementation

The new Hiphop.js `SuspendableTimer` is as follows:

```javascript
MODULE SuspendableTimer {
  IN duration(0), reset, suspend;
  OUT elapsed, suspendColor;
  LOOPEACH(NOW(reset)) {
    RUN(BasicTimer);
  }
}
```

`SuspendableTimer` immediately starts the `BasicTimer`. From then on, whenever Reset is pressed, this timer is killed whichever state it was in, and a new timer is immediately restarted afresh. The advantage of temporal programming to modularly describe behavior becomes obvious: no internal state manipulation of `BasicTimer` needs to be performed by the user.
EXEC

The input signals duration
This section explains the link between Hiphop.js and JavaScript. Let
us call stm the reactive machine compiled from SuspendableTimer
and describe its API. When Reset button is pressed, the GUI calls
the resetE JavaScript function in Hiphop.js, we make this function
send the reset signal and trigger a reaction:

function resetE() {
    stm.input("reset"); stm.react();
}

The input signals duration and suspend are respectively handled
by functions setD and SUSP in the same way.
Conversely, to transform signal output by Hiphop.js into JavaScript
actions, we associate Hiphop.js event listeners with output signals.
For instance, the following code updates the gauge and numeric
field:

```
stm.addEventListener("elapsed", evt => {
    $("meter").value = evt.signalValue;
    $("elapsed").innerHTML = evt.signalValue;
});
```

The other outputs are handled in the same way.

7 CONTROLLING ASYNCHRONOUS ACTIONS
The EXEC Hiphop.js statement is used to launch and control extern-
al actions whose execution spans several Hiphop.js reactions: a
XMLHttpRequest, a setTimeout call, etc.
Here is the source code of the parametric TimeoutMod timer
submodule, parameterized by a number of milliseconds:

```
function TimeoutMod (nms) {
    return MODULE {
        let id;
        EXEC id = setTimeout(DONEREACT, nms)
        ONKILL clearTimeout(id)
        ONSUSP clearTimeout(id)
        ONRES id = setTimeout(DONEREACT, nms);
    }
}
```

The Hiphop.js “EXEC start-expr” statement executes the JavaScript
expression start-expr. Then, it pauses at each reaction, terminating
only when the action has completed. When EXEC starts, a JavaScript
function is automatically created, it is referred to as DONEREACT in
Hiphop.js. Its call will trigger both the termination of EXEC and
a new reaction. An EXEC statement also specifies three optional
side-effecting expressions: the ONKILL expression is automatically
evaluated when the EXEC statement is killed, for example here by
the “LOOPEACH(NOW(reset))” enclosing statement. The ONSUSP
expression is automatically evaluated when EXEC gets suspended,
and the ONRES statement when it gets resumed.

8 CONCLUSION
Callback-based orchestration of web applications in JavaScript is
known to be quite difficult and hazardous. Better solutions have
already been studied in academic and industrial contexts. In our
opinion, they are not yet fully satisfactory since they are either too
invasive (dataflow programming style), too specific (targeting only
the GUI updates), or still limited (promises and async/await t.).

The Hiphop.js language extends JavaScript with a reactor orches-
tration solution. Our approach has been to port Esterel concepts
and techniques to the web, basing orchestration of web applications
on dedicated temporal statements.
In our opinion, Hiphop.js has two important virtues. First, it
deals with events orchestration in a very behavioral and modular
way, promoting straight code reuse over deep modification of ex-
isting code. Second, being smoothly embedded into JavaScript and
interfaced with standard code, it does not impose a drastic technical
change to users.

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