JavaScript as an Embedded DSL

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Why?

- Challenges in developing a large code base in JavaScript include:
  - Lack of static typing
  - “Inversion of Control” in asynchronous callback-driven programming
  - Impedance mismatch between client and server languages

Approaches

- Compile a new language to JavaScript: e.g. Links, WebDSL, Dart, ...
- Compile an existing language to JavaScript: e.g. Java/GWT, Scala/GWT, ...
- Our approach: embedding JavaScript in Scala

Main Benefit:

Deep Linguistic Reuse

Lightweight Modular Staging

- Embedding DSLs as libraries
- Staging
  - Rep[T] vs T

```
def prog1(b: Boolean, x: Rep[Int]) = if (b) x else x+1
def prog2(b: Rep[Boolean], x: Rep[Int]) = if (b) x else x+1

prog1(true, x) //-> x
prog2(b, x)    //-> If(b, x, Plus(x, Const(1)))
```

Tiark Rompf, Martin Odersky: Commun. ACM 55(6): 121-130 (2012)

DSL Program and Generated Code

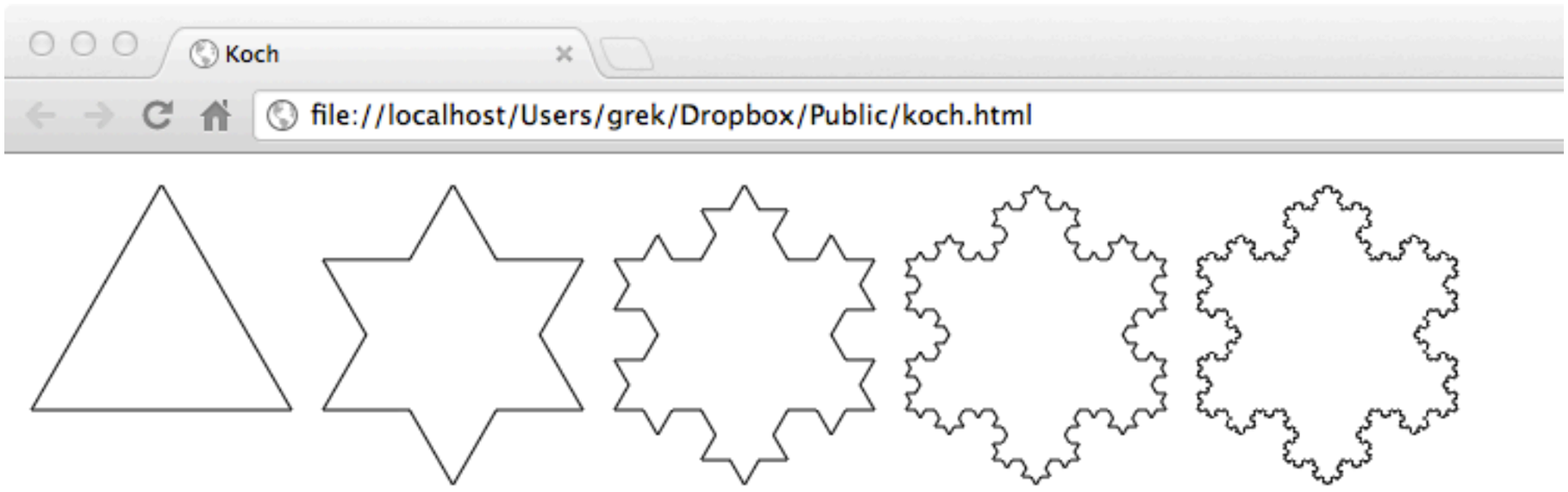
Scala

```
def test(n: Rep[Int]): Rep[Array[Int]] =
  for (i <- range(0, n); j <- range(0, n)) yield i*j
```

JS

```
function test(x0) {
  var x6 = []
  for(var x1=0;x1<x0;x1++){
    var x4 = []
    for(var x2=0;x2<x0;x2++){
      var x3 = x1 * x2
      x4[x2]=x3
    }
    x6.splice.apply(x6, [x6.length,0].concat(x4))
  }
  return x6
}
```

Koch Snowflake Example



Koch Snowflake Example

```
def snowflake = fun { (c: Rep[Context], n: Rep[Int], x: Rep[Int], y: Rep[Int], len: Rep[Int]) =>
  def leg: Rep[Int => Unit] = fun { n =>
    c.save();
    if (n == 0) {
      c.lineTo(len, 0);
    } else {
      c.scale(1.0/3,1.0/3);
      leg(n-1);
      c.rotate(60*deg);
      leg(n-1);
      c.rotate(-120*deg);
      leg(n-1);
      c.rotate(60*deg);
      leg(n-1);
    }
    c.restore();
    c.translate(len, 0);
  }

  c.save();
  c.translate(x,y);
  c.moveTo(0,0);
  leg(n);
  c.rotate(-120*deg);
  leg(n);
  c.rotate(-120*deg);
  leg(n);
  c.closePath();
  c.restore();
}
```

Scala

```
function snowflake(c, n, x, y, len) {
  function leg(n) {
    c.save();
    if (n == 0) {
      c.lineTo(len, 0);
    } else {
      c.scale(1/3,1/3);
      leg(n-1);
      c.rotate(60*deg);
      leg(n-1);
      c.rotate(-120*deg);
      leg(n-1);
      c.rotate(60*deg);
      leg(n-1);
    }
    c.restore();
    c.translate(len, 0);
  }

  c.save();
  c.translate(x,y);
  c.moveTo(0,0);
  leg(n);
  c.rotate(-120*deg);
  leg(n);
  c.rotate(-120*deg);
  leg(n);
  c.closePath();
  c.restore();
}
```

JS

Dynamic API

```
//c: JSDynamic
def leg: Rep[Int => Unit] = fun { n =>
  c.save();
  if (n == 0) {
    c.lineTo(len, 0);
  } else {
    c.scale(1.0/3,1.0/3);
    leg(n-1);
    c.rotate(60*deg);
    leg(n-1);
    c.rotate(-120*deg);
    leg(n-1);
    c.rotate(60*deg);
    leg(n-1);
  }
  c.restore();
  c.translate(len, 0);
}
```

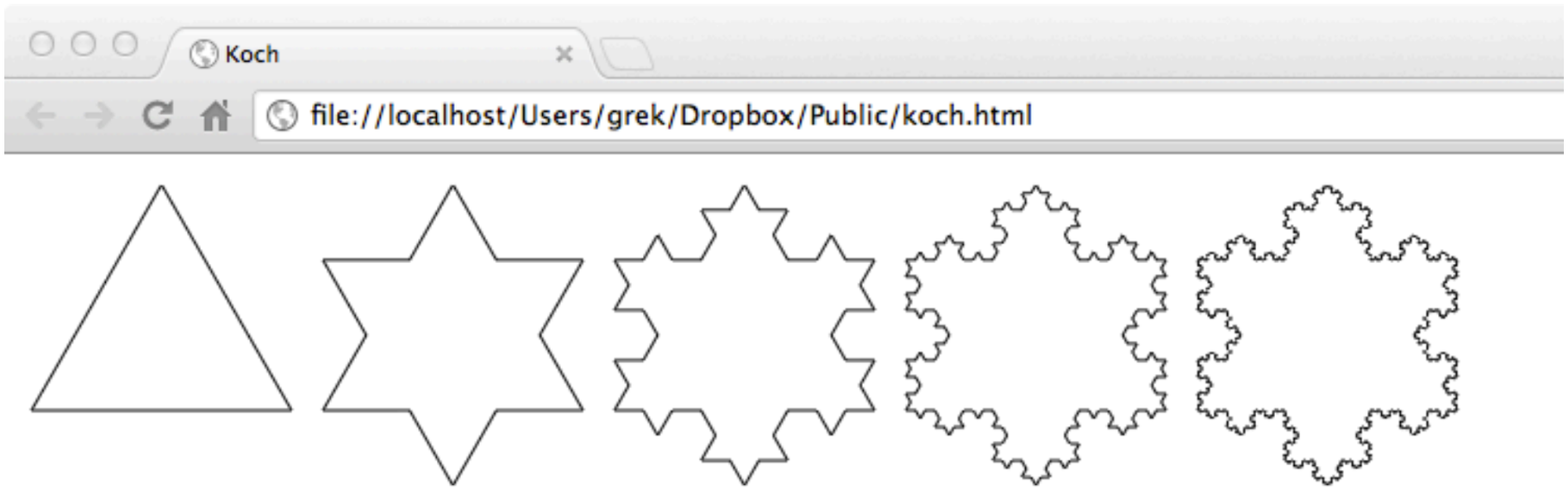
Typed API

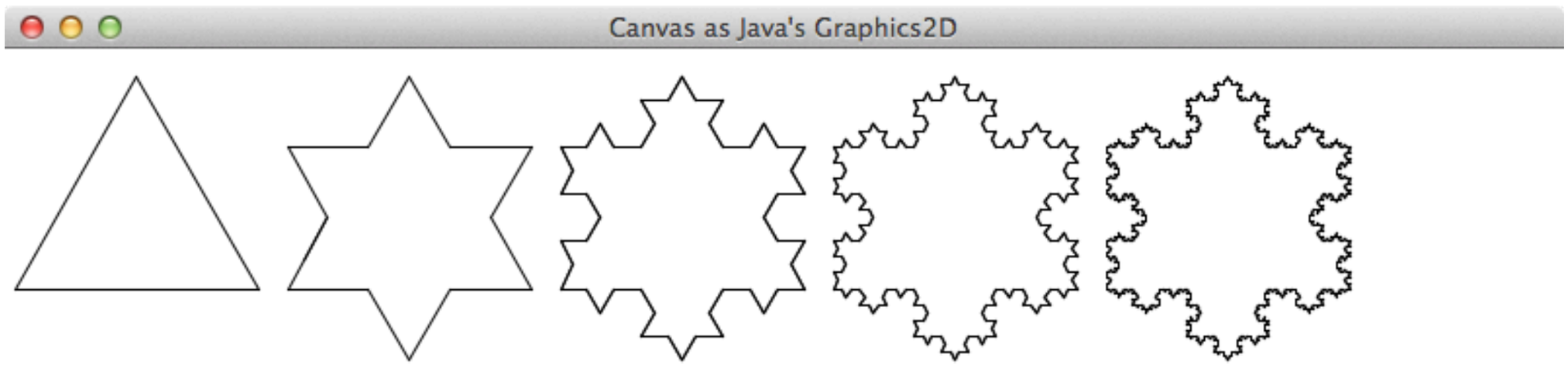
```
//c: Rep[Context]
def leg: Rep[Int => Unit] = fun { n =>
  c.save();
  if (n == 0) {
    c.lineTo(len, 0);
  } else {
    c.scale(1.0/3,1.0/3);
    leg(n-1);
    c.rotate(60*deg);
    leg(n-1);
    c.rotate(-120*deg);
    leg(n-1);
    c.rotate(60*deg);
    leg(n-1);
  }
  c.restore();
  c.translate(len, 0);
}
```

```
trait Context
trait ContextOps {
  def save(): Rep[Unit]

  def lineTo(x: Rep[Int], y:
Rep[Int]): Rep[Unit]

  def scale(x1: Rep[Double], x2:
Rep[Double]): Rep[Unit]

  def rotate(x: Rep[Double]):
Rep[Unit]

//...
}
```

```
implicit def repToContextOps(x: Rep[Context]): ContextOps =
  repProxy[Context,ContextOps](x)
```

Koch Snowflake Example





Rep[T] = T

```
trait Context
trait ContextOps {
  def save(): Rep[Unit]

  def lineTo(x: Rep[Int], y: Rep[Int]): Rep[Unit]

  def scale(x1: Rep[Double], x2: Rep[Double]): Rep[Unit]

  def rotate(x: Rep[Double]): Rep[Unit]

//...
}
```

Rep[T] = T

```
trait Context
trait ContextOps {
  def save(): Unit

  def lineTo(x: Int, y: Int): Unit

  def scale(x1: Double, x2: Double): Unit

  def rotate(x: Double): Unit

//...
}
```

Validation

```
val commentForm: Form[Comment] = Form(
  mapping(
    "firstname" -> nonEmptyText,
    "lastname" -> nonEmptyText,
    "company" -> optional(text),
    "email" -> email,
    "phone" -> optional(text verifying jsPattern("""[0-9.+]+""", "c.phone", "e.phone")),
    "message" -> nonEmptyText.verifying(jsConstraint("c.nice", "e.nice") { new { def eval(c: JS) = { import c._;
              (msg: Rep[String]) => {
                val words = msg.split(" ")
                def countWords(regex: String) =
                  words.filter(regex.r.test(_)).length
                val hateCount = countWords("[Hh]ate|[Ss]uck")
                val loveCount = countWords("[Ll]ove|[Rr]ock")
                hateCount < loveCount
              }
    }}})
  )(Comment.apply)(Comment.unapply)
)
```

Validation

```
val commentForm: Form[Comment] = Form(
  mapping(
    "firstname" -> nonEmptyText,
    "lastname" -> nonEmptyText,
    "company" -> optional(text),
    "email" -> email,
    "phone" -> optional(text verifying jsPattern("""[0-9.+]+""", "c.phone", "e.phone")),
    "message" -> nonEmptyText.verifying(jsConstraint("c.nice", "e.nice") { new { def eval(c: JS) = { import c._;
              (msg: Rep[String]) => {
                val words = msg.split(" ")
                def countWords(regex: String) =
                  words.filter(regex.r.test(_)).length
                val hateCount = countWords("[Hh]ate|[Ss]uck")
                val loveCount = countWords("[Ll]ove|[Rr]ock")
                hateCount < loveCount
              }
    }}})
  )(Comment.apply)(Comment.unapply)
)
```

Show it!

Typed Object Literals

```scala
def fetchTweets(username: Rep[String]) =
(ajax.get {
  new JSLiteral {
    val url = "http://api.twitter.com/1/statuses/user_timeline.json"
    val `type` = "GET"
    val dataType = "jsonp"
    val data = new JSLiteral {
      val screen_name = username
      val include_rts = true
      val count = 5
      val include_entities = true
    }
  }
}).as[TwitterResponse]

type TwitterResponse =
  Array[JSLiteral {val text: String}]
```

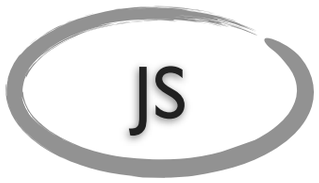
Scala

```json
{
  url: "http://api.twitter.com/1/statuses/user_timeline.json/",
  type: "GET",
  dataType: "jsonp",
  data: {
    screen_name : username,
    include_rts : true,
    count : 5,
    include_entities : true
  }
}
```

JSON

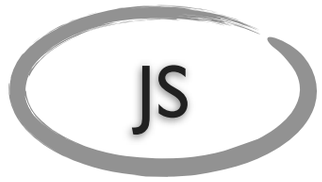
Puzzle

```
var xs = [1, 2, 3]
var i = 0
var msg = null
function f1() {
  if (i < xs.length) {
    window.setTimeout(f2, xs[i]*1000)
    msg = xs[i]
    i++
  } else {
    console.log("done")
  }
}
function f2() {
  console.log(msg)
  f1()
}
f1()
```



What does this code do?

Puzzle




```
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    msg = xs[i]
    i++
  } else {
    console.log("done")
  }
}
function f2() {
  console.log(msg)
  f1()
}
f1()
```

Puzzle

JS

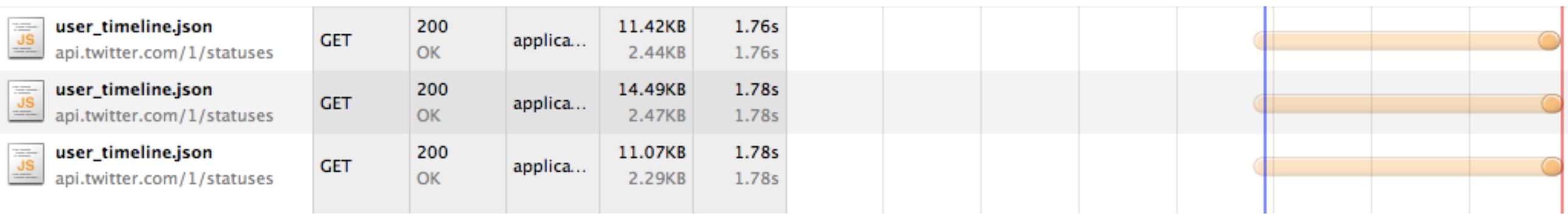
```
var xs = [1, 2, 3]
var i = 0
var msg = null
function f1() {
  if (i < xs.length) {
    window.setTimeout(f2, xs[i]*1000)
    msg = xs[i]
    i++
  } else {
    console.log("done")
  }
}
function f2() {
  console.log(msg)
  f1()
}
f1()
```

Scala

```
val xs = array(1, 2, 3)
for (x <- xs.suspendable) {
  sleep(x * 1000)
  console.log(String.valueOf(x))
}
console.log("done")
```

Twitter Example

```
val users = array("gkossakowski", "odersky", "adriaanm")
for (user <- users.parSuspendable) {
  console.log("fetching " + user)
  val tweets = fetchTweets(user)
  console.log("finished fetching " + user)
  for (t <- tweets)
    console.log("fetched " + t.text)
}
console.log("done")
```



Timeline of Twitter API AJAX requests

Under the Hood

- We've used the CPS plugin of the host language in our DSL to build a non-trivial abstraction
- CPS transforming the code generator enables us to generate code that is in CPS
- Staging allows us to strip out most of the abstractions at staging time so they don't leak into generated JavaScript code

Under the Hood

The only equation in this talk

```
Rep[A => B] • Rep[B => C] == Rep[(A => B) • (B => C)]
```

CPS is about composing functions
Function composition distributes over staging

See the paper for implementation details
on our abstraction for asynchronous programming

Conclusion

Deep Linguistic Reuse FTW!

- Type-Safe by re-using host type system
- DSL can be evaluated in Scala, enabling sharing code between client and server
- Intuitive abstractions for objects
- DSL as a thin layer on top of JavaScript, on top of which abstractions can be built

http://github.com/js-scala