Specifying JavaScript in ML

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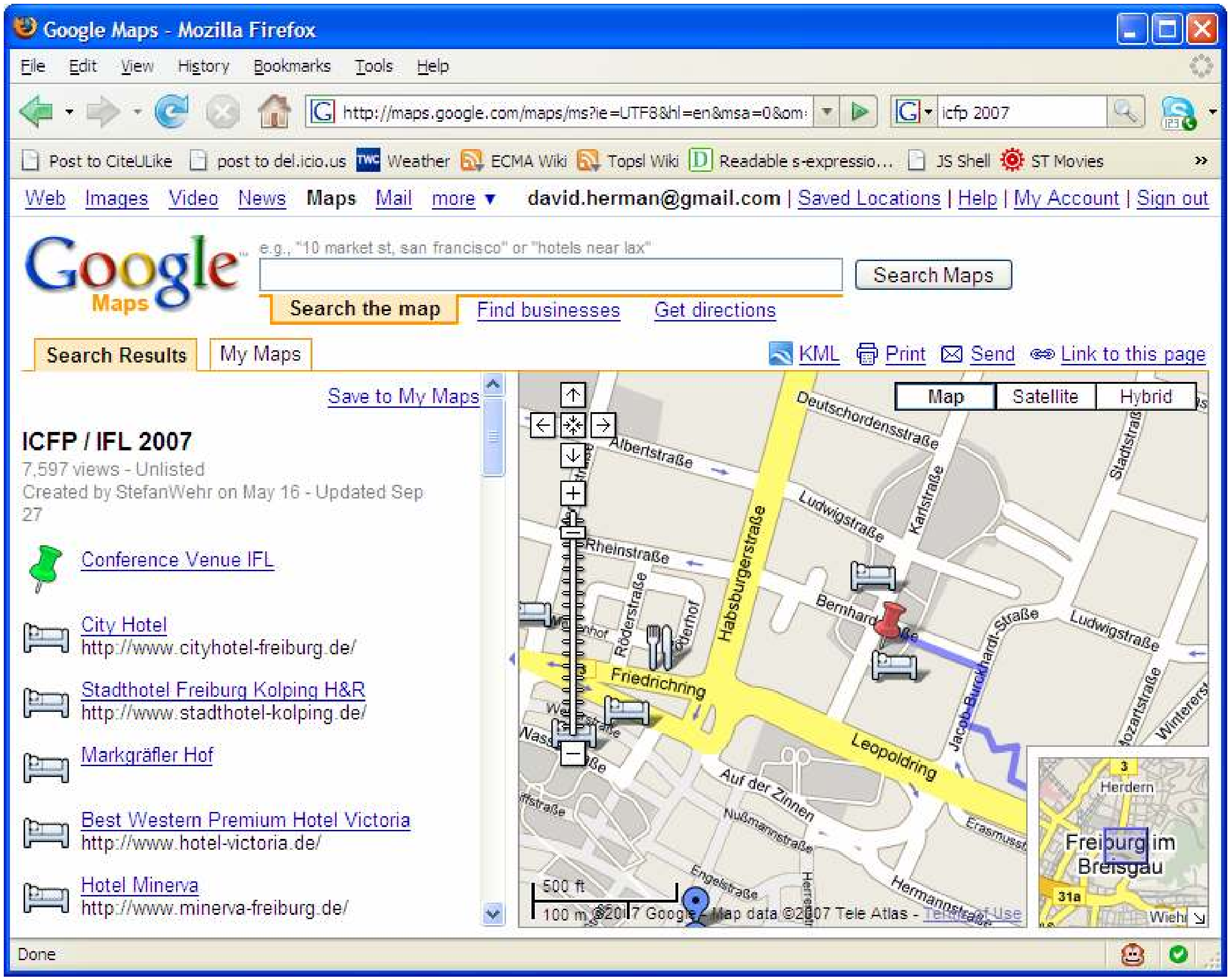
JavaScript: the "j" in Ajax



JavaScript is not Java-Lite.

JavaScript is almost nothing like Java!

- Multi-paradigm
- Functional! Lexically-scoped!
- Prototypes, no classes (until now…)
- Dynamically typed (until now…)

Outline

I. How we got here
II. Specifying JavaScript with ML
III. The evolution of JavaScript
IV. Status report

I. Testimonial: coming to ML

Standardized JavaScript

- Many implementations exist (multiple browsers, JVM, Flash, …)
- Highly competitive market
- First standardized at Ecma Int'l in '97

Existing JavaScript specifications

Grammar production:

ConditionalExpression →
  LogicalORExpression **?** *AssignmentExpression* **:** *AssignmentExpression*

Evaluation:

1. Evaluate *LogicalORExpression*.
2. Call GetValue(Result(1)).
3. Call ToBoolean(Result(2)).
4. If Result(3) is **false**, go to step 8.
5. Evaluate the first *AssignmentExpression*.
6. Call GetValue(Result(5)).
7. Return Result(6).
8. Evaluate the second *AssignmentExpression*.
9. Call GetValue(Result(8)).
10. Return Result(9).

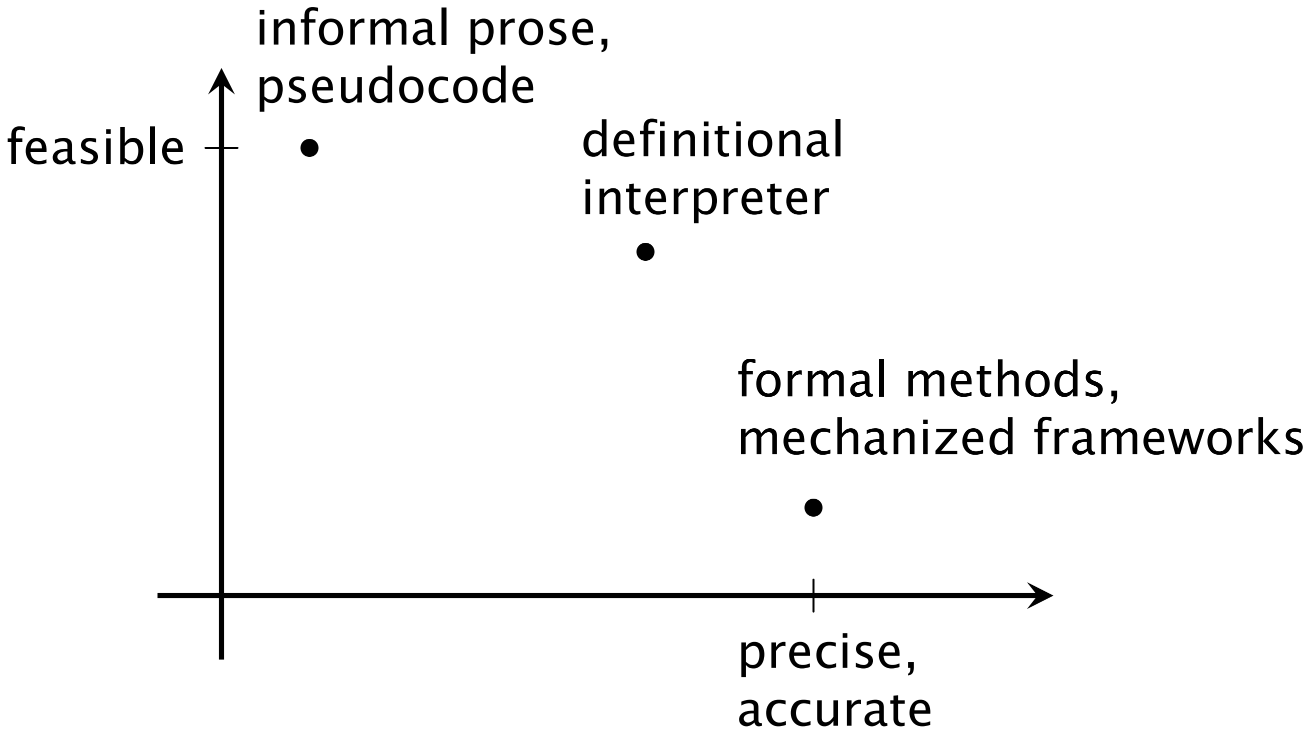
Any bugs in there?
Who knows?

Existing JavaScript specifications

From: Brendan Eich
Date: 12/2/2005
To: Dave Herman
Subject: Specifying JavaScript semantics

...In my view, we TG1'ers desperately need a machine-checkable specification... Others in TG1 may agree in principle, but are not wild about taking too much time to develop a checkable spec. So we are looking for help...

Meeting in the middle



One interpreter, several artifacts

- Read—literate source
- Run, test—executable
- Prove theorems—source code (maybe)

An executable spec in SML/NJ

- First-level sanity checks
- Tests: JS2 standard library,
  JS2 → Flash VM compiler
- Biggest benefit: Mozilla/Adobe regression test suites for JavaScript 1.x

II. Specifying JavaScript with SML

Interpreter style

- No gratuitous optimization
- No gratuitous mutation (duh!)
- Modularize language feature encodings ("keep the monster in a box")
- Big-step, impure, direct style

```
eval : EXPR * ENV -> VAL
```

Exploiting ML: algebraic datatypes

```
datatype EXPR =
    UnaryExpr of (UNOP * EXPR)
  | BinaryExpr of (BINOP * EXPR * EXPR)
  | TernaryExpr of (EXPR * EXPR * EXPR)
  | LiteralExpr of LITERAL
  | CallExpr of { func: EXPR,
                  actuals: EXPR list }
  | ...
and STMT =
    ExprStmt of EXPR
  | ForStmt of FOR_STMT
  | WhileStmt of WHILE_STMT
  | IfStmt of { cnd: EXPR,
                thn: STMT,
                els: STMT }
  | ...
```

Exploiting ML: refs

```
datatype VAL =
    Object of OBJ
  | Null
  | Undef
and OBJ =
    Obj of { ident: int,
             tag: VAL_TAG,
             proto: VAL,
             props: PROP_BINDINGS }
and VAL_TAG =
    ObjectTag of FIELD_TYPE list
  | ArrayTag of TYPE_EXPR list
  | FunctionTag of FUNC_TYPE
  | ClassTag of NAME

withtype PROP = { ty: TYPE_EXPR,
                  attrs: ATTRS,
                  state: VAL }
and PROP_BINDINGS = (NAME * PROP) list ref
```

Exploiting ML: exceptions

- Non-local jumps in JS: `return`, `throw`, tail calls
- Tail calls via modified trampoline:

```
exception TailCallException of (unit -> VAL)
```

- Non-tail function call protocol:

[[*expr*]]
```
handle TailCallException thunk => thunk()
```

Exploiting (S)ML(/NJ): `callcc`

- JavaScript *generators* (coroutines)
- `yield` instead of `return`: suspend current procedure activation as an object

```
function nats() {
    var i = 0;
    while (true) { yield i; i++; }
}
var gen = nats();
print(gen.next()); // 0
print(gen.next()); // 1
print(gen.next()); // 2
```

Exploiting (S)ML(/NJ): `callcc`

- `yield` captures a (delimited) continuation
- Alternatives: threads, delimited continuations, CPS
- Benefit of `callcc`: localizing the encoding

Exploiting ML: modules

```
datatype OBJ = Obj of { ... props: PROP_BINDINGS ... }
withtype PROP = { ty: TYPE_EXPR,
                  attrs: ATTRS,
                  state: VAL }
     and PROP_BINDINGS = (NAME * PROP) list ref
```

Exploiting ML: modules

```
datatype OBJ = Obj of { ... props: PROP_BINDINGS ... }
withtype PROP = { ty: TYPE_EXPR,
                  attrs: ATTRS,
                  state: VAL }
     and PROP_BINDINGS = (PROP NameMap.map) ref

structure NameMap = BinaryMapFn (NameKey);
(* structure NameMap = SplayMapFn (NameKey); *)
(* structure NameMap = ListMapFn (NameKey); *)
```

Limitations of code

- Underspecification: `sort` must be *n log*(*n*)
- Overspecification: `type(x)` reveals concrete implementation of interface
- Conclusion: *prose is still necessary*

Frustrations with SML

- Non-nested `withtype` declarations
- Deciphering type inference errors
- No recursive modules

III. The evolution of JavaScript

Typed functional programming for the web

JavaScript 1.x/ECMAScript Edition 3

- Dynamically typed
- *Mostly* well-behaved scoping
- Prototypes inspired by Self
- Objects: (string × value) table

JavaScript 2.0/ECMAScript Edition 4

- "Opt-in" static typing
- *Improved* lexical scoping
- Prototypes *and* classes
- Objects: ((key × string) × value) table
- Generous syntactic sugar
- Advanced control constructs (generators)

Gradual typing

- Conservative extension of dynamically typed JavaScript 1.x
- Optional type annotations
- Optional static type checker
- Careful interface between typed and untyped code

Type system

- Nominal types (Java, C#)
- Structural types

```
type thunk = function():int;
function foo(f:thunk):[int] { ... }
var obj : { m:function(thunk):[int] } = { m:foo };
```

- Type "dynamic":

```
var image : * = read(filename);
switch type (image) { ... }
```

- Parameterized types

IV. Status report

Status report

- Feature freeze, coding and writing
- ~25 KLOC mostly pure SML, ~12 KLOC JS2 standard libraries
- SML/NJ, proof-of-concept ports to SML.NET and MLton
- Release: 2008 (tentatively)

Steal this source code

- Read, run, test ✓
- Prove theorems?
- Industry-scale case study for research
  - Experimental language extensions
  - Development tools, IDE's
  - Inference, migration tools
  - …what else? Have at it: www.ecmascript.org/download.php

Thank you!

http://www.ecmascript.org