A Certified JavaScript Interpreter

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JavaScript Compared to Other Languages.

1. The "assembly language of the Internet";
2. A *scripting* language;
3. A precise norm of the language: ECMAScript 3;
4. A lot of features mimicking other languages's features:
   - Functional languages;
   - Imperative languages;
   - Prototype oriented languages.

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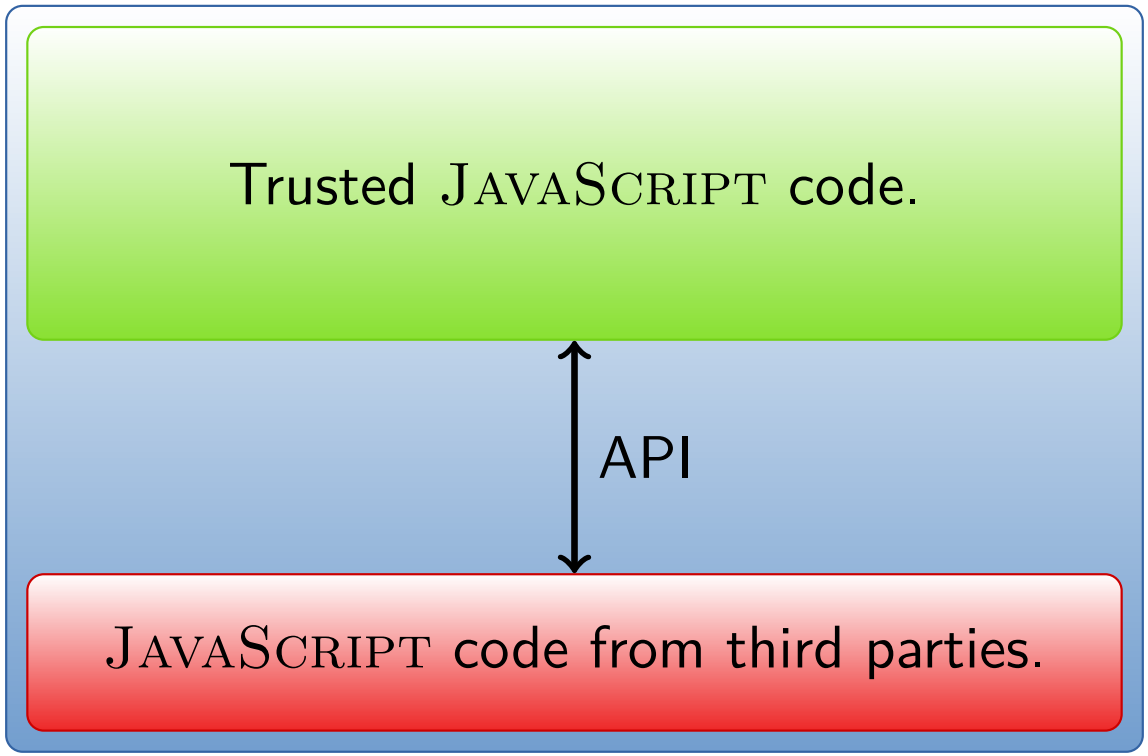
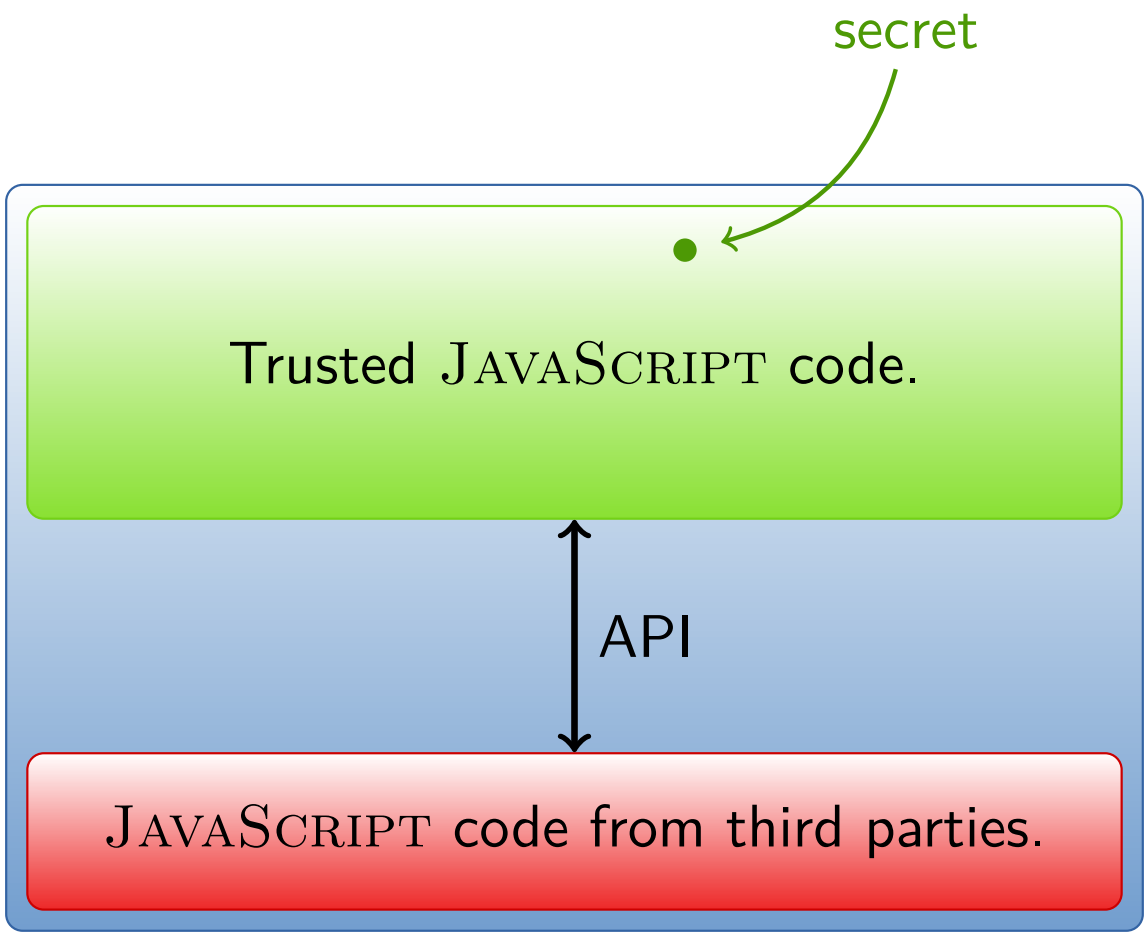

Trusted JavaScript code.
API
JavaScript code from third parties.
Web page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JavaScript's `var`. Counter-intuitive behaviour.

```
1 v = 5 ;
2 f = function() { x = v ; v = 4 ; var v ; y = v } ;
3 f () ; z = v
```

Dynamic scopes. Difficult to analyse.

```
1 function f(o) { with(o) { x = 0 } } ;
2 f({x : 1}) ; // x is undefined.
3 f({})        // x is defined.
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2. The `eval` function;
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- Contains a lot of *locations*.
- Each locations contains some fields, associated to a *value*.
- Some special locations: `null`, l_g, `Object.prototype`, etc.
- Each writes are performed on the *same* heap!

Scope chain

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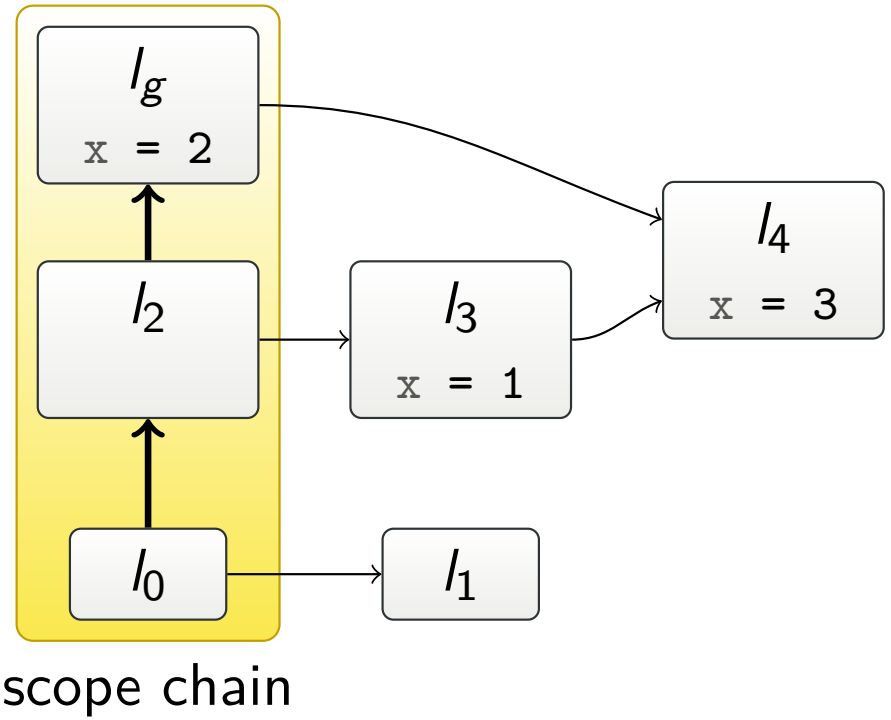

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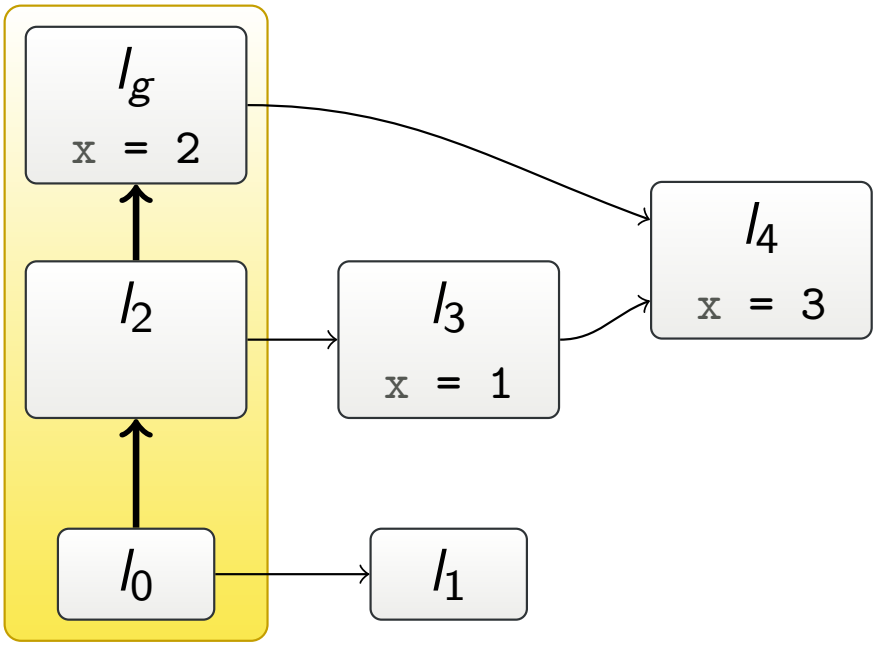

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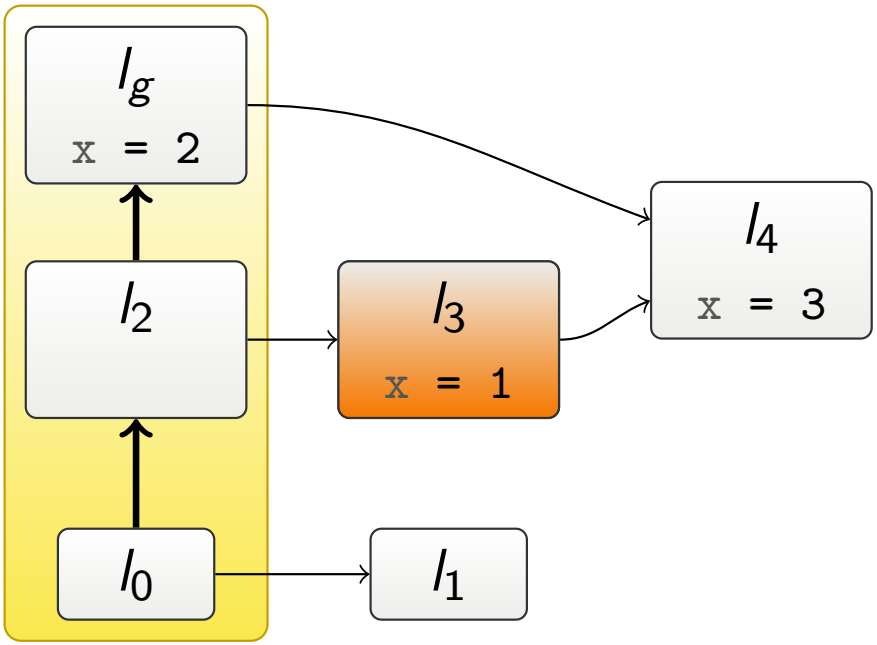

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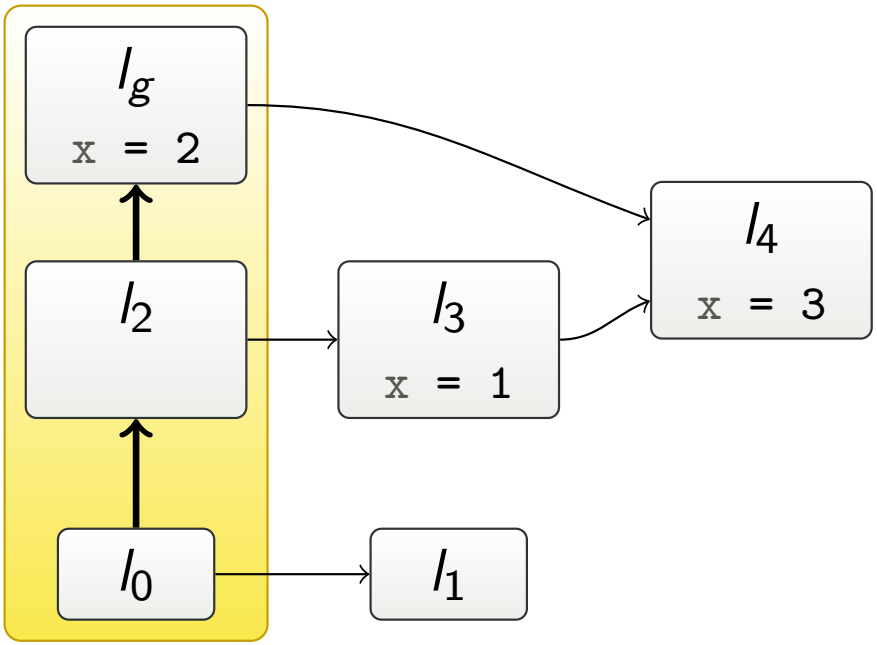

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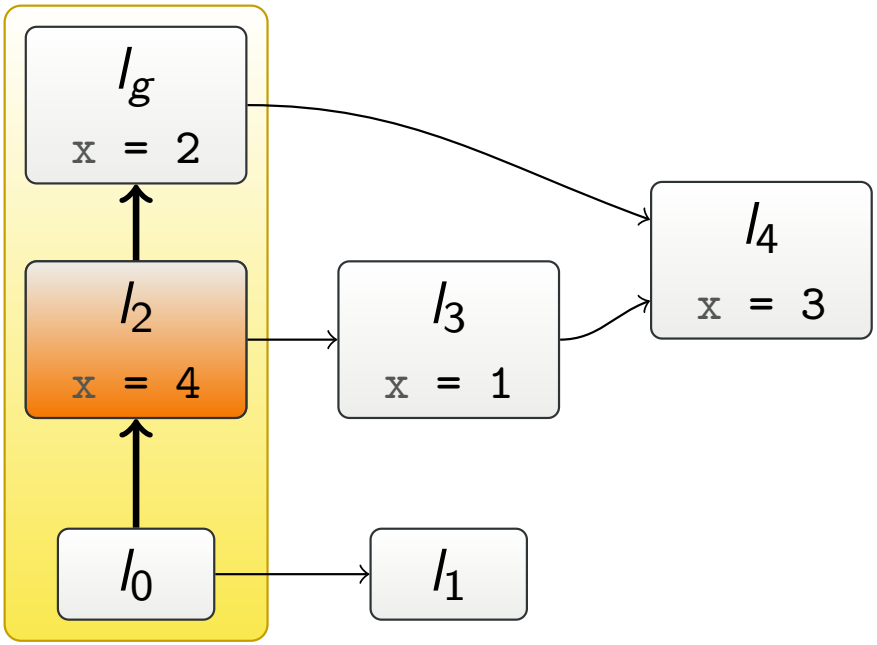

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- A Coq formalisation of JavaScript's semantic.
- Based on a small step semantic made by Sergio Maffeis.
- It uses the Flocq formalisation for IEEE floats.
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```
H,l,v=va -> H,l,@PutValue(v,va) [E-Asgn]

Type(l1*m)=Reference
---------------------------------------- [R-PutValue-val]
H,l,@PutValue(l1*m,va) -> H,l,l1.@Put(m,va)
```

```
1  Inductive red : heap → scope → expr →
2                  heap → result → Prop :=
3                                    ⋮

4    | red_assign : ∀l f v h0 h1 h2 h3 s e1 e2 r2,
5      red h0 s e1 h1 (Ref l f) →
6      red h1 s e2 h2 r2 →
7      getval h2 r2 v →
8      h3 = update h2 l f v →
9      red h0 s (exp_assign e1 e2) h3 v
```

File name	Size (Kio) Definitions	Proofs	Description
`JsSyntax.v`	4.5	0	Syntax of JavaScript
`JsSyntaxAux.v`	1.5	7.5	Basic properties on objects defined in `JsSyntax.v`
`JsSemantic.v`	21.5	0	Reduction rules for JavaScript
`JsSemanticAux.v`	0.5	15.5	Basic properties on objects defined in `JsSemantic.v`
`JsWf.v`	4.5	0	Definition of inductive principles over heaps conserved through execution
`JsWfAux.v`	0	6.5	Basic properties on objects defined in `JsWf.v`
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Trusted base	30.5	0	

For every predicate in the semantic, the interpreter defines an equivalent function.

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                        ⋮
```

```
Fixpoint run (max_step : nat) (h0 : heap) (s : scope)
             (e : expr) : out :=
  match max_step with
    | O ⇒out_bottom
    | S max_step' ⇒

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Rule expressed in the semantic

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5    h3 = update h2 l f v →
6    red h0 s (exp_assign e1 e2) h3 v
```
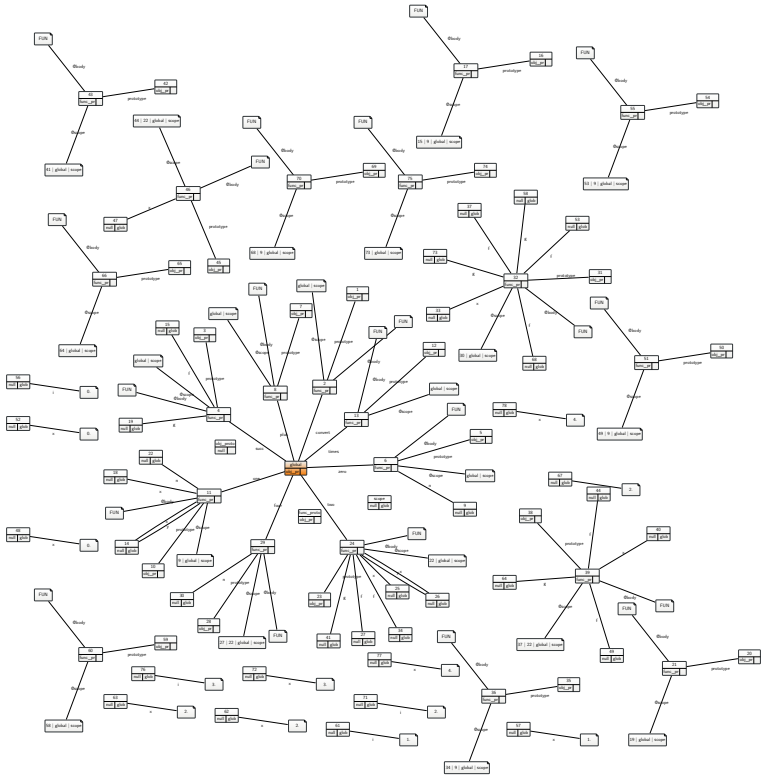

Rule expressed in the interpreter

```
1  | exp_assign e1 e2 ⇒
2    if_success (run' h0 s e1) (fun h1 r1 ⇒
3      if_is_ref h1 r1 (fun l f ⇒
4        if_success_value (run' h1 s e2) (fun h2 v ⇒
5          out_return (update h2 l f v) v)))
```

It Now Works...



...But is it correct?

```
1  Theorem run_correct : ∀m h s e h' v,
2    run m h s e = out_return h' (ret_res v) →
3    ok_heap h →
4    ok_scope h s →
5    red h s e h' v.
```

- For each sub-function, prove that it's correct according to its corresponding predicate.
- For each case of the proof, prove the correctness of intermediary heaps and scope chains. This can be done as in the safety proof.
- Combine all these lemmas to get the final result.

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```
1   (* assign *)
2   forwards [(?&?) | (r1&h1&eq1)]: elim_if_success R; tryfalse.
3   rewrite eq1 in R. simpl in R.
4   forwards [(eqw&v'&eqv') | (l&f&eq')]: elim_if_is_ref R.
5   lets (h'0&eqw'): eqw. forwards*: wrong_not_ret eqw'.
6   rewrite eq' in R. simpl in R.
7   forwards [(?&?) | [(v0&h2&eq2&eqv0) | (v0&h2&b&eq2&eqv0)]]:
        elim_if_success_value R; tryfalse.
8   rewrite eq2 in R. simpls. rewrite eqv0 in R. simpls. forwards*:
        wrong_not_ret R.
9   rewrite eq2 in R. simpls. rewrite eqv0 in R. simpls.
10  inverts* R.
11  forwards* R1: run_correct eq1.
12  forwards* (OK1&OKL1&OKr1): sub_safety R1.
13  inverts* OKr1; tryfalse.
14  inverts H0.
15  forwards* R2: run_correct eq2.
16  forwards* (OK2&OKL2&OKr2): sub_safety R2.
17  apply* red_assign.
18  apply* getvalue_comp_correct.
```

Deconstruction of the interpreter's definition

Proof of correctness of intermediate results

Construction of the derivation's proof

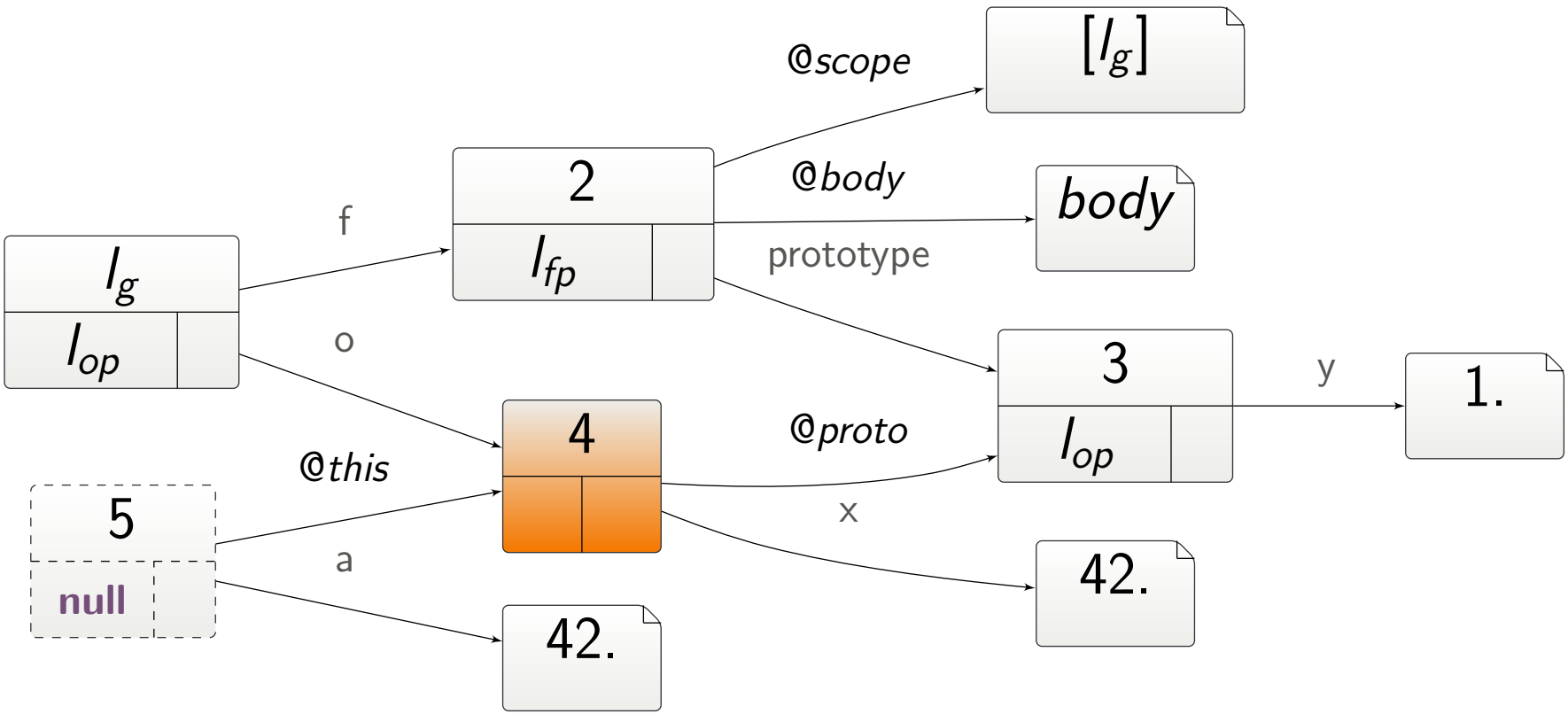
What Has Been Done So Far.

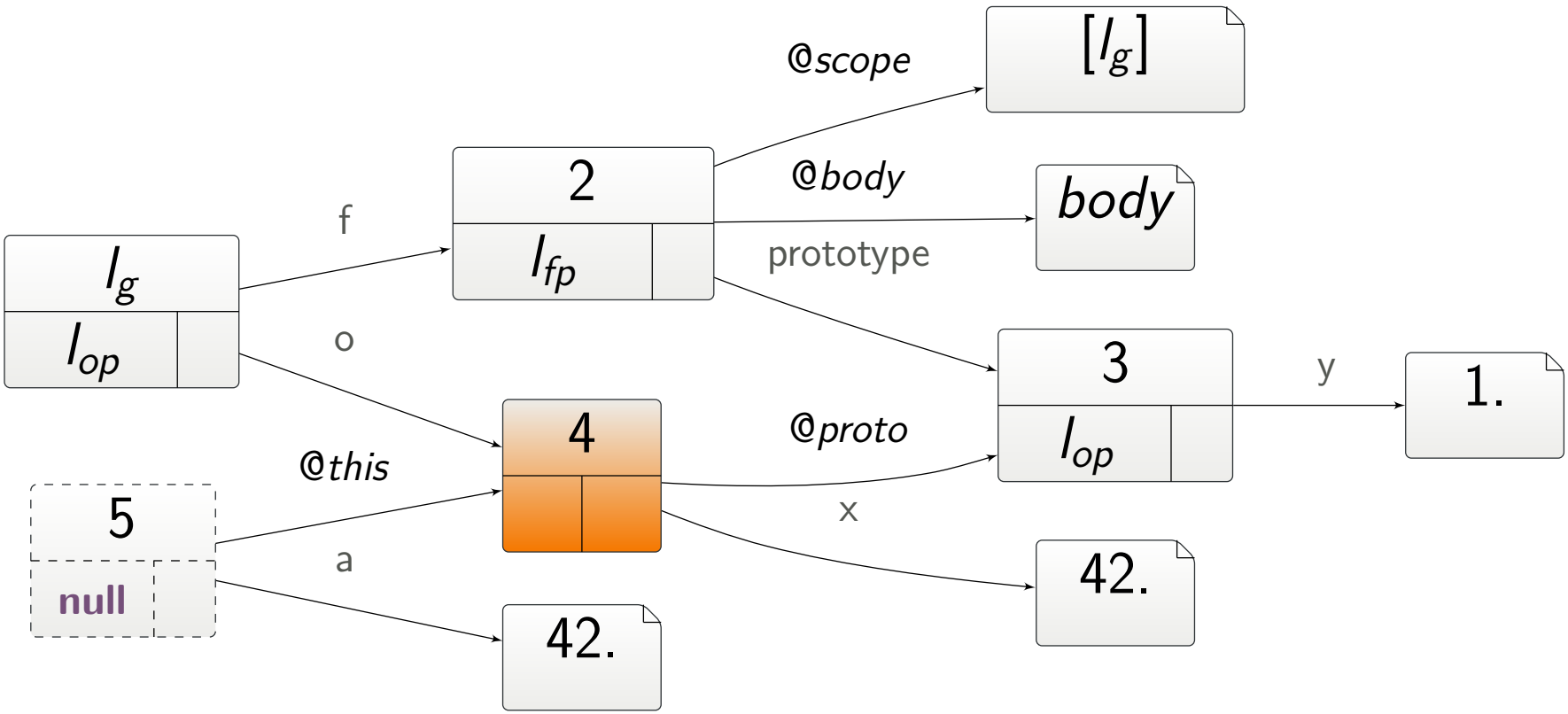
- A formalisation of JavaScript's semantic in Coq.
- Some properties about execution objects proven as being invariant.
- A JavaScript interpreter, proven correct.

Future Work.

- Extending the formalised semantic:
  - Support of exceptions and errors.
  - Support of other objects.
- A proof of completeness of the interpreter.
  - Some equivalence properties over heaps are needed.
- Proven analyses of JavaScript program.

Demo


@scope
$[l_g]$
2
l_{fp}
@body
body
prototype
f
l_g
l_{op}
o
3
l_{op}
y
1.
4
@proto
@this
5
null
a
x
42.
42.



Any questions?