

Experimental New Directions for JavaScript

Andreas Rossberg, V8/Google

Motivation

Broad need for (more) **scalable** JavaScript

- Usability, esp. **maintainability**
- Performance, esp. **predictability**

ES6 opens up new opportunities

Types desperately needed (but tricky)



An Experiment

Embrace Harmony

Shun bad legacy

Grow types

In a VM!

Two Parts (Working titles)

“**SaneScript**” – a cleaner subset of JavaScript

- Focus on **removing** features
- Transition path to...

“**SoundScript**” – a gradual type system for JavaScript

- Based on TypeScript, but **sound & effective**
- Does not depend on, but benefits from, SaneScript

Both fully **interoperate** with good old JavaScript

Plan

- **Implement** in V8, prototype in Traceur
- Test in the field, iterate
- Need **feedback!** Collaboration welcome
- Ideally, develop into ES **proposals** eventually

“SaneScript”

In an insane world, it was the sanest choice.

— Sarah Connor

Motivation

Guide programmers on well-lit path

- **Safer** semantics
- **Predictable** performance
- Aim for the 95% use cases

“Sane” Mode

- Opt-in: “use sanity” (TBD)
- Implies **strict** mode
- Freely **interoperable** with “insane” code
- Can still be run as “insane” code (with caveats)

Subsetting the Language

- **Static** restrictions (early errors)
- **Dynamic** restrictions (exceptions)
- **Per-object** restrictions (“sane objects”)

Subsetting Compatibility

- Sane code not hitting any of the restrictions would have **same meaning** outside the mode
- That is, “correct” sane code can run **unchanged** on VMs not recognising the opt-in

Sane Scoping

- No more `var`
- No undeclared variables
- No use before declaration (**static dead zone**),
except mutually recursive function declarations

`let` is the new `var`. Proper scoping FTW.

Sane Objects

- Accessing missing properties **throws** (on both reads & writes)
- Objects created in sane mode are **non-extensible**
- No freezing of non-configurable properties

If you want maps, you take maps.

Sane Classes

- Class objects and their prototypes are **frozen**
- Instances are created **sealed**
- Methods require proper instances

Fast and safe method & field access FTW.

Sane Arrays

- No holes, no accessors, no reconfiguration
- Length always in sync
- No out-of-bounds access, except extension at the end

Fast arrays FTW. Maps are the new sparse arrays.



Sane Functions

- No arguments object
- Calling with too few arguments throws

Optional and rest arguments FTW.

Sane Coercions

- Nothing implicit besides ToBoolean (almost?)
- == and != require compatible typeof

No more WAT, no more WTF.



Plan

- Implement in Q1/2

“SoundScript”



That’s sound advice at any time.

— Jean-Luc Picard

Motivation

- Everybody keeps inventing type systems for JS
 - Both user-facing and internal
- We strongly support **standardisation!**
- But inside a VM **new requirements** arise
- ...and **new opportunities!**
- Needs investigation

Design Goals

- Based on **TypeScript** (familiarity, reuse)
- **Gradual** (interop with untyped code)
- **Sound** (reliability, non-local optimisations)
- **Precise** (aggressive optimisations)
- **Effective** (feasible inside VM)
- **Modular** (lazy compilation, caching)

Sound Gradual Typing

- When it claims $E:T$, then, in fact, $E:T$
- But type `any` means “dynamically typed”
- Type `any` induces `runtime type checks` if necessary
- Protects invariants of statically typed code
- Disallow higher-order casts that’d require wrapping (expensive; observable in JavaScript!)

Runtime Type Checking

- Objects and functions carry (more) **runtime type information**
- Operations at type `any` may need to check
 - `get`, `set`, `call`, ...
- Should not be a common case
- Much cheaper when done by VM!

Structural à la TypeScript

```
interface T extends U {  
  a : number,  
  m(x : string) : number,  
  (x : boolean) : T,  
  new(x : string) : U  
}
```

$$(x : T) \Rightarrow U \quad := \quad \{(x : T) : U\}$$

Functions & Methods

- Can annotate type of this:
`function(this : T, x : U) { }`
- **Function** types are **contravariant** (soundness!)
- **Method** types are different, **covariant** in this
(tied to concise method syntax)
- Method extraction only allowed when `this : any`

Nominal Classes

- Class C introduces **nominal instance type** C
- ...and **nominal class type** typeof C
- Both are **subtypes** of respective structural types
- “Interfaces” remain structural

Why Nominal?

- Sound **private state**
- Sound **binary methods**
- Sound **first-class classes**
- More **efficient** code
- More efficient **compilation** (it's runtime, too!)

Nominal Typing, Example

```
class D extends C {  
  public a : T  
  constructor(x : T) {}  
  m(x : T) : U {}  
  static s(x : T) : U  
}
```

- $D < C$
- $D < \{a:T, m(x:T):U, \text{constructor: typeof } D, \dots C's\dots\}$
- $\text{typeof } D < \{\text{new}(x:T):D, s(x:T):U, \dots C's\dots\}$

Subtyping

- Nominal type are subtypes of structural
- Vice versa also allowed (semi-structural types)
- No (depth) subtyping on **mutable** properties
- But on **immutable** properties
 - various requests for immutable data
- Invariant generics (at least for now)

Generics

- **Sound** (for realz)
- Runtime **type passing** (i.e., unerased)
- But no first-class instantiation
(that is, $f\langle T \rangle$ is not a value)
- Rationale: would change operational semantics

Going More Gradual

- Choice between T or `any` not gradual enough
- Enter `any<T>` — restricts uses as if T , but provides no more guarantees than `any`
- Essentially, TypeScript's interpretation of T
- Mainly for typing intrinsics, programmers shouldn't need it often

Type Inference

- **Bidirectional** type checking
- No inference across function boundaries
- Don't break lazy compilation!

Lazy Compilation

- Keep supporting function granularity jit
- Mayhaps require “deferred early errors”
- Consider eager type-checking later (cost?)

Numerous Challenges

- Would like “**non-nullable**” as default, feasible?
- Would like a proper **integer** type, how?
- How much **immutability** can we require in typed code?
- Full ES6: **symbols**, how avoid dependent types?
- Full ES6: **first-class classes**, how deal with generativity?
- **Control-flow** dependent typing, how much?
- **Reflection**, what API?
- **Syntax**, what to do about incompatibilities?
- **Performance**, how keep cost of type checking low?
- **Blame** tracking, do we need any in the absence of wrapping?
- **Object.observe** breaks all optimisation ideas
- ...



Plan

- Implement in Q2-4 (?)

Types in VM: Challenges

- Type system must respect **open world** assumption
 - additional definitions can be added at any time
- Type checking must be **efficient** enough
 - preference for nominal typing
- Must not break **lazy compilation** of functions
 - precludes non-local type inference
 - necessitates “deferred early error” semantics

Types in VM: Opportunities

- More **optimisations!**
 - aggressive ones require soundness
- Affordable **runtime type checks**
 - easier debugging
 - enabler for soundness
- **Predictable** performance
 - Reduced warm-up time
 - No opt/deopt cycles of death
- **Ahead-of-time** compilation/optimisation

Summary

- Both new **challenges** and new **opportunities** putting types into a VM
- Standardising an unsound type system would be a big lost opportunity
- This is an **experiment**
- All public, we would like **your feedback!**

Encore

Optional Types

- All types are “**non-nullable**” by default
 - preferably exclude both null and undefined, but the latter might be very hard to reconcile with existing APIs
- Type **?T** as short-hand for `T | undefined | null`

First-Class Classes

- Requires proper **class types**: `class C extends T {...}`
- Essentially, **F-bounded existential** type
- **Generative**: functions returning a class create a new class (i.e., existential type) with each call
- **Implicitly opened** when bound to a variable
- Classes as parameters behave dually (universal type)
- do-expressions will introduce “**avoidance problem**”