Better Inferred Types for JavaScript

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### Types Prevent Crashes

Statically typed languages guarantee that some run-time errors cannot occur. For example, if the user submits 0 to Figure 1, an integer gets treated as an object. A type system would eliminate this possible error.

```javascript
var y, z;
y = input('1 or 0?');
if (y == 1) {
  z = {}; // z is an object
  z.s1 = 5;
  z.s2 = 7;
  z.s3 = 9;
} else {
  z = 2; // z is an int
}

// type error if int
write(z.s1 + z.s2 + z.s3);
```

**Figure 1:** Possible type-error in JavaScript

### JavaScript Lacks Types

JavaScript is a dynamically typed language, so variable types are checked at run-time. For example, the type of variable `z` in Figure 2 is determined to be either object or int during the program’s execution.

```javascript
var y, z;
y = input('1 or 0?');
if (y == 1) {
  z = {}; // runtime object
  z.s1 = 5;
  z.s2 = 7;
  z.s3 = 9;
} else {
  z = 2; // runtime int
}

write(z.s1 + z.s2 + z.s3);
```

**Figure 2:** Dynamically typed variable in JavaScript

### Added vs. Inferred Types

There are two approaches to the benefits of static types to a dynamically typed language:

**Explicit** types are annotations added by the programmer, identical to a static type system. They require more work from the compiler, but require a completely new language specification.

**Inferred** types are calculated by the compiler. They require no extra work by the programmer and operate on the same base language, but are less powerful than explicit types. For example, in Figure 3, the compiler can infer the type of `y` to be String.

Our work focuses on inferred types, but both techniques are active areas of research.

```
var y, z;
y = input('1 or 0?');
if (typeof z == 'object') {
  write(z.s1 + z.s2 + z.s3);
} else {
  write(z);
}
```

**Figure 3:** Inferred String Type

### Costs of Inferred Types

Unfortunately, due to undecidability, inferred type systems often can’t assign a single type to a variable. For example, an inferred type system would determine `z`’s possible type in Figure 4 to be both object and int.

```
var y, z;
y = input('1 or 0?');
if (y == 1) {
  z = {}; // z could be object...
  z.s1 = 5;
  z.s2 = 7;
  z.s3 = 9;
} else {
  z = 2; // and could be int...
}
// so z could be
// either object or int
if (typeof z == "object") {
  write(z.s1 + z.s2 + z.s3);
} else {
  write(z);
}
```

**Figure 4:** Imprecise inferred types

### Our Improvement

Our work takes advantage of information in conditional checks to make an inferred type system more precise [1]. For example, in Figure 5, our work precisely determines the type of `z` to be object in the true branches and int in the false branches.

```
var y, z;
y = input('1 or 0?');
if (y == 1) {
  z = {}; // and could be int...
  z.s1 = 5;
  z.s2 = 7;
  z.s3 = 9;
} else {
  z = 2; // and could be int...
}
// so z could be
// either object or int
if (typeof z == "object") {
  write(z.s1 + z.s2 + z.s3);
} else {
  write(z);
}
```

**Figure 5:** Precise inferred types

### Impact

Since our inferred types are more accurate, we present fewer possible errors to the programmer. For example, a naive type inference algorithm reports possible errors in Figure 6, while our system certifies it as error-free.

```
var y, z;
y = input('1 or 0?');
if (y == 1) {
  z = {}; // inferred warnings
  z.s1 = 5;
  z.s2 = 7;
  z.s3 = 9;
} else {
  z = 2;
}
```

**Figure 6:** Unnecessary warnings due to imprecise types

### Acknowledgements & References

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