

Project Report - Limited Static Type Checking for JavaScript

Huascar A. Sanchez Tim Disney

April 5, 2010

Abstract

Implementations of static type checkers are available. However, many only work for a subset of JavaScript. In this report we explore an alternative that can parse full JavaScript code. We call this alternative JScheck. JScheck is a static type checker for prototype-based objects in JavaScript.

We study the type checking problem given the definitions studied in class. A set of changes were made to the HJS parsing library to recognize type annotations in JavaScript code. Then, we implemented the major components of JScheck: a type extractor and a type checker. Both components complement each other. The type extractor is responsible for finding all the JavaScript object types that have been defined. The Type Checker is responsible for finding all functions that have been type annotated. The result of these functions' invocation indicates if the JavaScript is well-typed. The main rationale is to prevent the occurrence of errors during program execution.

1 Introduction

In the construction of software it is generally cheaper to catch programming errors earlier in the development cycle. One common method to catch errors is static type checking which can check the type consistency of the program before it is even run. If the code has any type violations the type checker will find them and alert the programmer.

For example, in strongly typed languages like Java it is impossible to invoke a method which has not been defined for a class (unless reflection is used). The compiler will immediately complain and prevent the program from compiling. However, in languages like JavaScript, this kind of error will not be discovered until runtime.

Adding static type checking to a dynamic language like JavaScript is a challenge, especially since objects can be modified at runtime. Given this challenge, we have implemented a static type checker, called JScheck, for user-defined objects in JavaScript. The scope of JScheck is limited to properties on an object's prototype. In other words, we are completely ignoring type checking of the built

in types such as strings and numbers. The whole idea, as Luca Cardelli said [6], is to prevent the occurrence of errors during program execution.

The rest of this paper is divided as follows. Section (2) gives an overview of how user-defined types work in JavaScript, section (3) will discuss the design and implementation choices that were made through the development of JSCheck, related work will be discussed in (5), and future work and conclusions in Sections (6) and (7).

2 Types in JavaScript

User-defined types in JavaScript can be written in a variety of styles and forms. The form that we considered in the scope of this project is object creation using constructor functions and prototype modification.

Snippet 1 Checking Types in JavaScript

```
function Dog(){
    // ..
}

Dog.prototype.getName = function(){
    //..
}

Dog.prototype.bark = function(){
    //..
}

var mydog = new Dog();
```

For example, in Snippet 1 we defined a `Dog` type which has two methods, `getName` and `bark` which are added to the `Dog` prototype. New “instances” of the `Dog` type can be created with the `new` keyword.

There are other ways of creating objects including using object literal notation and assigning methods directly to fields of an existing object. Due to time constraints, we opted to not include them in the scope of JSCheck.

To enable JSCheck to check the usages of an object we added the comment type annotation to the JavaScript language as seen in Snippet 2. In this example the `fido` parameter has been annotated with the `Dog` type in the `/// comment. JSCheck will then check that all usages of the fido parameter conforms to the definition of the Dog type.`

Snippet 2 Type Checking

```
/// @type Dog fido
function useDog(fido) {
    fido.bark();
}

var mydog = new Dog();
useDog(mydog);
```

3 Implementation

JSCheck is implemented in Haskell. We were originally considering defining a subset of JavaScript to ease the burden of creating a parser for JavaScript. However we found a Haskell library called HJS [2] which implements a full parser for JavaScript (ECMAScript 3rd edition plus some additions from JavaScript 1.5). We needed to make a few modifications to HJS in order to pick up the type annotations. This greatly simplified much of the implementation effort of JSCheck.

Figure 1 shows in general terms how JSCheck works. JSCheck takes in a JavaScript source file and runs it through a modified version of the HJS parser. This produces an abstract syntax tree (AST) which is then fed into a type extractor function which finds all the JavaScript object types that have been defined. The output of this function is a list of types (type name and all associated fields) which is given to a type checker function along with the original AST. The checker function finds all functions that have been annotated with our special type comments and checks all usages of typed parameters against the extracted types. The final output will be a boolean which represents if the code is well-typed or not.

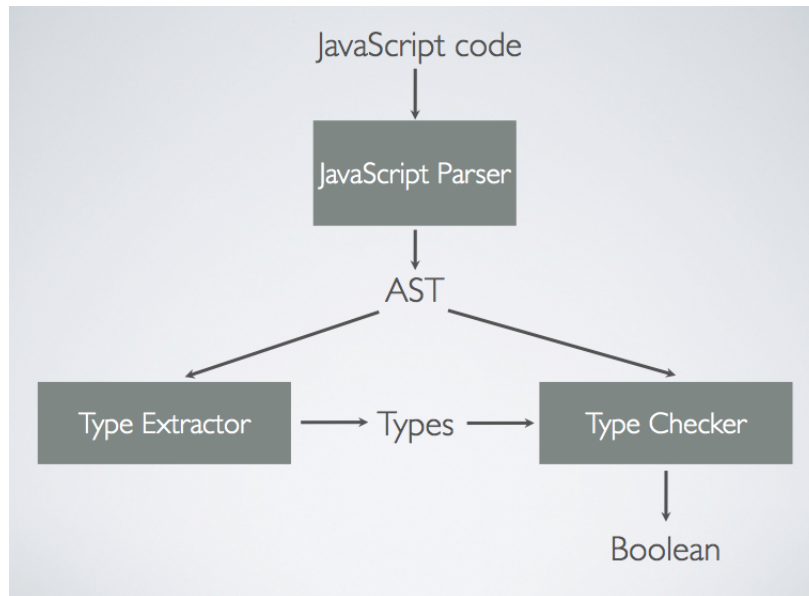


Figure 1: Type Checking - the JSCheck way

Because of the dynamic nature of JavaScript our implementation is both unsound and incomplete. It is unsound because methods could be added to the object at runtime. So, even though the checker may find a usage of an unknown field, that field might actually be defined. It is incomplete because fields could also be removed from an object at runtime. The JavaScript program could be accessing non-existent fields even though the checker thought they were there.

4 Testing JScheck

JScheck went through an exhaustive testing, i.e., functional and unit testing. To illustrate the type of code that can be reviewed by JScheck, we created a demo page, which is found online at <http://www.hsanchez.net/demo.html>. In this page, there is some JavaScript code (See code 3) that will get executed every time you refresh the browser. This demo code was run through JScheck which confirmed, at compile time, that this code is well-typed.

Snippet 3 JavaScript code to be type-checked

```
function Guitar(name, color) {
    this.name = name;
    this.color = color;
    this.strings = ['E', 'A', 'D', 'G', 'B', 'e'];
    this.price = 0;
    this.currency = "USD"
}

Guitar.prototype.print = function() {
    var cPrice    = this.price;
    var cCurrency = this.currency;
    return '<br />' + 'This guitar is ' +
        this.color +
        ', it has ' + this.strings.length + ' strings' +
        ' and it costs ' + cPrice + ' ' + cCurrency;
}

Guitar.prototype.tune = function(newStrings) {
    this.strings = newStrings;
}

var myChords = new Array();
myChords[0] = "DM7";
myChords[1] = "DM9";
myChords[2] = "DM4";
Guitar.prototype.play = function() {
    var randomnumber=Math.floor(Math.random()*3)
    return myChords[randomnumber] + " chord was played.";
}

Guitar.prototype.update = function (newPrice, newCurrency) {
    this.price    = newPrice;
    this.currency = newCurrency;
}

Guitar.prototype.paint = function (newColor) {
    this.color    = newColor;
}

/** @type Guitar guitar
function describe(guitar) {
    return guitar.print();
}

/** @type Guitar guitar
function playTune(guitar){
    return guitar.play();
}
```

The above JavaScript code, contained in a file called `demo.js`, was tested by running a function similar to the one in 4. This function takes our `demo.js` file as an input, and then it parses it. The result of this parsing is an AST. This AST is then fed to the checker and extractor functions. The result of these functions' invocation will tell us whether the code in the `demo.js` is well-typed.

Snippet 4 Type Checking of `Demo.js`

```
check_demo_file = do
  s <- readFile "testfiles/demo.js"
  parse_fail s (\p -> if check_now p (runExtractor p)
    then assertFailure "should have failed the type check"
    else assertBool "passed correctly" True)
```

5 Related Work

Other work has been done to add various forms of static type checking to dynamic languages like JavaScript. Anderson *et al.* [3, 4] had a series of papers on adding type inference and type checking to a JavaScript subset called *JS₀*. Austin and Sadowski [5] implemented type checking for another subset of JavaScript called Featherweight JavaScript. While the techniques used by both these groups can catch many more type errors than JSCheck, they also only work for a JavaScript subset while JSCheck can parse full JavaScript code.

There has also been work done adding static typing to other dynamic languages. Furr *et al.* [7] created a tool called DRuby that adds static type inference to the Ruby language. They also do not use a language subset and can check real Ruby code.

Google has a tool for checking JavaScript called the Closure compiler [1] (not to be confused with Clojure the programming language). While this tool is mainly focused on minifying (the process of removing whitespace from JavaScript files to reduce file size) and optimizing JavaScript, it can also do some type checking. It uses type annotations in comments which is similar to what JSCheck uses.

6 Future Work

There are several areas where JSCheck could be expanded. The messages that are displayed to the user are currently very primitive. JSCheck will only display “True” if the input code is well-typed or “False” if it is ill-typed. For this to be a truly useful tool it would be highly desirable to display the line numbers where type errors were found.

JSCheck could also be extended to understand more forms of object creation. Currently only constructor function and prototype modification are supported but many other forms are in common use.

Other future work could include extending the type consistency checks for other elements of the language, such as usages of built in types such as strings and numbers.

7 Conclusion

Type errors are a frustrating part of developing software in dynamic languages. We have developed a static type checker for prototype based objects in JavaScript which can help ease that pain. By using JSCheck and adding a few type annotations a developer is able to catch many type errors before ever running the program.

All source code for JSCheck is publicly available and can be found online at <http://github.com/disnet/jscheck>.

References

- [1] Google Closure Compiler. <http://code.google.com/closure/compiler/>.
- [2] Hjs Haskell Library. http://www.haskell.org/haskellwiki/Libraries_and_tools/HJS, accessed March 2010.
- [3] C. Anderson, S. Drossopoulou, and P. Giannini. Towards Type Inference for Javascript. In *19th European Conference on Object-Oriented Programming (ECOOP 2005), Glasgow, Scotland*, pages 428–452, June 2005.
- [4] C. Anderson and P. Giannini. Type Checking for Javascript. *Electronic Notes in Theoretical Computer Science*, 138(2):37 – 58, 2005. Proceedings of the Second Workshop on Object Oriented Developments (WOOD 2004).
- [5] T. H. Austin and C. Sadowski. Structural Typechecking for Featherweight Javascript. Paper from course project, 2009.
- [6] L. Cardelli. Type systems. *ACM Comput. Surv.*, 28(1):263–264, 1996.
- [7] M. Furr, J. Hoon (David) An, J. S. Foster, and M. Hicks. Static Type Inference for Ruby. In *SAC '09: Proceedings of the 2009 ACM symposium on Applied Computing*, pages 1859–1866, New York, NY, USA, 2009. ACM.