

First-class Functions

Compiler Construction '12 Final Report

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1. Introduction

After implementing the so-called "toolc"-compiler, which compiles a very basic computer language, we now would like to extend it with first class functions. This means that we allow function declarations to be assigned to variables, to be passed as parameters to functions or to be returned from functions. The most difficult part consists in correctly attaching the non-local variables, which are internally used, to the first class function (Closure). The problem is often referred as the funarg problem.

2. Example

Here is an example that summarizes the challenges of implementing first-class functions:

```
1 object firstClassExampleStarter{
2   def main() : Unit = {
3     println(new firstClassExample().go());
4   }
5 }
6
7 class firstClassExample {
8   var x : Int;
9
10  def getFunc() : (Int) => Int = {
11    var y : Int;
12    var func : (Int) => Int;
13
14    y = 7;
15    func = (z: Int) => {
16      x = x-z;
17      y = y+z;
18      return x+y;
19    };
20    return func;
21  }
22
23  def go() : Int = {
24    var func1 : (Int) => Int;
```

```
25    var func2 : (Int) => Int;
26
27    x = 44;
28    func1 = getFunc();
29    func2 = getFunc();
30    println(func1(2)); // will print x+y=42+9=51
31    println(func2(6)); // will print x+y=36+13=49
32    println(func1(1)); // will print x+y=35+10=45
33    return 0;
34  }
35 }
```

Short description of the code example:

(10) function declaration that returns a first-class function

(12+28+29) variable declarations, which take functional literals as values

(15) assigning a functional literal to a variable

(16+17) new assignment of a non-local variable

(30) invocation of the first-class function func1. We notice that y, which normally would be out of scope at this point in code, can still be accessed and is initially equal to 7. X, on the other hand, is not out of scope, it is equal to 44.

(31) invocation of the first-class function func2. We notice that y hasn't change and is initially equal to 7 again, whereas x is in the beginning of func2 invocation equal to 42.

(32) second invocation of func1. We notice that y is initially equal to 9, that is the same value as the value it had when the first invocation of func1 terminated on line 30.

3. Implementation

This is a very important section, you explain to us how you made it work.

3.1 Theoretical Background

3.1.1 Funarg Problem

”Funarg Problem refers to the difficulty in implementing first-class functions (functions as first-class objects) in implementations with stack-based memory allocation.” (Wikipedia ”Funarg Problem”, Jan 2013) For this, let us consider `y` from the example of the previous chapter. As we already mentioned that `y` would normally be out of scope when invoking `func1` at line 30. But since it is used in a first-class function, it becomes a free variable (contrary to bound variables) and can still be accessed even if the context of the variable is closed. In order to make this possible, one has to introduce closures, which binds the functional literals to their free variables. One way of implementing this is described by the Lambda Lifting.

If you are using theoretical concepts, explain them first in this subsection. Even if they come from the course (eg. lattices), try to explain the essential points *in your own words*. Cite any reference work you used like this [?]. This should convince us that you know the theory behind what you coded.

3.2 Implementation Details

Describe all non-obvious tricks you used. Tell us what you thought was hard and why. If it took you time to figure out the solution to a problem, it probably means it wasn’t easy and you should definitely describe the solution in details here. If you used what you think is a cool algorithm for some problem, tell us. Do not however spend time describing trivial things (we what a tree traversal is, for instance).

After reading this section, we should be convinced that you knew what you were doing when you wrote your extension, and that you put some extra consideration for the harder parts.

4. Possible Extensions

If you did not finish what you had planned, explain here what’s missing.

In any case, describe how you could further extend your compiler in the direction you chose. This section should convince us that you understand the challenges of writing a good compiler for high-level programming languages.