Operational Semantics Exercises
CS 4610 — Spring 2017

This Review Set asks you to prepare written answers to questions on operational semantics. Each of the questions has a short answer. You may discuss this Review Set with other students and work on the problems together.

1 Definitions and Background

1. Define the following terms and give examples where appropriate.
   (a) Environment:

   (b) Store:

   (c) Call-by-value:

   (d) Call-by-reference:

2. Briefly describe the purpose of operational semantics.

3. What are the constituent parts of the context in a Cool operation semantics rule? Why is each portion of the context necessary?

4. How are side-effects modeled by operational semantics?

5. How is evaluation order enforced by the Cool operational semantics?

2 Operational Semantics

1. Consider these six operational semantics rules:

$$(1)\ \frac{so, E, S \vdash e_1 : Bool(false), S_1}{so, E, S \vdash \text{while } e_1 \text{ loop } e_2 \text{ pool } : void, S_1} \qquad (4)\ \frac{\begin{array}{c} E(id) = l_{id} \\ S(l_{id}) = v \end{array}}{so, E, S \vdash id : v, S}$$

$$(2)\ \frac{\begin{array}{l} so, E, S \vdash e_1 : Bool(true), S_1 \\ so, E, S_1 \vdash e_2 : v, S_2 \\ so, e, S_2 \vdash \text{while } e_1 \text{ loop } e_2 \text{ pool } : void, S_3 \end{array}}{so, E, S \vdash \text{while } e_1 \text{ loop } e_2 \text{ pool } : void, S_3} \qquad (5)\ \frac{\begin{array}{c} so, E, S \vdash e : v, S_1 \\ E(id) = l_{id} \\ S_2 = S_1[v/l_{id}] \end{array}}{so, E, S \vdash id \leftarrow e : v, S_2}$$

$$(3)\ \frac{\begin{array}{c} so, E, S \vdash e_1 : v_1, S_1 \\ l_{new} = newloc(S_1) \\ so, E[l_{new}/id], S_1[v_1/l_{new}] \vdash e_2 : v_2, S_2 \end{array}}{so, E, S \vdash \text{let } id : T \leftarrow e_1 \text{ in } e_2 : v_2, S_2}$$

$$(6)\ \frac{\begin{array}{c} so, E, S \vdash e_1 : Int(n_1), S_1 \\ so, E, S_1 \vdash e_2 : Int(n_2), S_2 \\ v = \begin{cases} Bool(true) & \text{if } n_1 < n_2 \\ Bool(false) & \text{if } n_1 \geq n_2 \end{cases} \end{array}}{so, E, S \vdash e_1 < e_2 : v, S_2}$$

Use these rules to construct a derivation for the following piece of code:

```
let x : Int <- 2 in
while 1 < x loop
 x <- x - 1
pool
```

You may assume reasonable axioms, e.g. it is always true that $so, E, S \vdash 2 - 1 : Int(1), S$. Start your derivation using the `let` rule (3) as follows:

$$\frac{\dfrac{}{so, E, S \vdash 2 : Int(2), S} \qquad \dfrac{\dots}{so, E[l_{new}/x], S[Int(2)/l_{new}] \vdash \text{while } 1 < x \text{ loop } x \leftarrow x - 1 \text{ pool } : void, S_{final}}(2)}{so, E, S \vdash \text{let } x : Int \leftarrow 2 \text{ in while } 1 < x \text{ loop } x \leftarrow x - 1 \text{ pool } : void, S_{final}}(3)$$

Note that you only need to expand hypotheses that need to be proved (i.e. those containing $\vdash$).

2. Suppose we wanted to add arrays to Cool, using the following syntax:

`let a:T[`e_1`] in` e_2	Create an array a with size e_1 of Ts, usable in e_2
`a[`e_1`] <-` e_2	Assign e_2 to element e_1 in a
`a[e]`	Get element e of a

Write the operational semantics for these three syntactic constructs. You may find it helpful to think of an array of type $T[n]$ as an object with n attributes of type T.

3. The operational semantics for Cool's `while` expression show that result of evaluating such an expression is always `void`.

   However, we could have used the following alternative semantics:

   - If the loop body executes at least once, the result of the `while` expression is the result from the *last* iteration of the loop body.
   - If the loop body never executes (i.e., the condition is false the first time it is evaluated), then the result of the `while` expression is `void`.

   For example, consider the following expression:

   ```
   while (x < 10) loop x <- x+1 pool
   ```

   The result of this expression would be 10 if, initially, $\texttt{x} < 10$ or `void` if $\texttt{x} \geq 10$.

   Write new operational rules for the `while` construct that formalize these alternative semantics.