

Homework 2: Operational Semantics for WHILE

CS 252: Advanced Programming Languages
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1 Introduction

For this assignment, you will implement the semantics for a small imperative language, named WHILE.

The language for WHILE is given in Figure 1. Unlike the Bool* language we discussed previously, WHILE supports *mutable references*. The state of these references is maintained in a *store*, a mapping of references to values. (“Store” can be thought of as a synonym for heap.) Once we have mutable references, other language constructs become more useful, such as sequencing operations ($e_1; e_2$).

2 Small-step semantics

The small-step semantics for WHILE are given in Figure 3. For the sake of brevity, these rules use *evaluation contexts* (C), which specify which *redex* will be evaluated next. The evaluation rules then apply to the “hole” (\bullet) in this context.

Most of these rules are fairly straightforward, but there are a couple of points to note with the [SS-WHILE] rule. First of all, this is the only rule that makes a more complex expression when it has finished.

Secondly, note the final value of this expression once the while loop completes. It will *always* be **false** when it completes. We could have created a special value, such as **null**, or we could have made the while loop a statement that returns no value. Both choices, however, would complicate our language needlessly.

3 YOUR ASSIGNMENT

Part 1: Rewrite the operational semantic rules for WHILE in \LaTeX to remove the contexts ($C[\dots]$) and to use evaluation order rules instead. Submit both your \LaTeX source and the generated PDF file.

Extend your semantics with features to handle boolean values. Specifically, add support for:

- **and**
- **or**
- **not**

The exact behavior of these new features is up to you, but should seem reasonable to most programmers.

Part 2: Once you have your semantics defined, download `WhileInterp.hs` and implement the `evaluate` function, as well as any additional functions you need. Your implementation must be consistent with your operational semantics. Also, you may not change any type signatures provided in the file.

Finally, implement the interpreter to match your semantics.

Zip all files together into `hw2.zip` and submit to Canvas.

| | |
|--|-------------------------|
| $e ::=$ | <i>Expressions</i> |
| x | variables/addresses |
| v | values |
| $x := e$ | assignment |
| $e; e$ | sequential expressions |
| $e \text{ op } e$ | binary operations |
| if e then e else e | conditional expressions |
| while (e) e | while expressions |
| $v ::=$ | <i>Values</i> |
| i | integer values |
| b | boolean values |
| $op ::=$ | <i>Binary operators</i> |
| $+ \mid - \mid * \mid / \mid > \mid >= \mid < \mid <=$ | |

Figure 1: The WHILE language

Runtime Syntax:

$$\begin{array}{ll}
C \in \text{Context} & ::= C; e \mid C \text{ op } e \mid v \text{ op } C \mid x := C \mid \text{if } C \text{ then } e_1 \text{ else } e_2 \mid \bullet \\
\sigma \in \text{Store} & = \text{variable} \rightarrow v
\end{array}$$

Evaluation Rules:

$e, \sigma \rightarrow e', \sigma'$

| | |
|--------------|---|
| [SS-VAR] | $\frac{x \in \text{domain}(\sigma) \quad \sigma(x) = v}{C[x], \sigma \rightarrow C[v], \sigma}$ |
| [SS-ASSIGN] | $\overline{C[x := v], \sigma \rightarrow C[v], \sigma[x := v]}$ |
| [SS-OP] | $\frac{v = v_1 \text{ op } v_2}{C[v_1 \text{ op } v_2], \sigma \rightarrow C[v], \sigma}$ |
| [SS-SEQ] | $\overline{C[v; e], \sigma \rightarrow C[e], \sigma}$ |
| [SS-IFTRUE] | $\overline{C[\text{if true then } e_1 \text{ else } e_2], \sigma \rightarrow C[e_1], \sigma}$ |
| [SS-IFFALSE] | $\overline{C[\text{if false then } e_1 \text{ else } e_2], \sigma \rightarrow C[e_2], \sigma}$ |
| [SS-WHILE] | $\overline{C[\text{while } (e_1) \text{ } e_2], \sigma \rightarrow C[\text{if } e_1 \text{ then } e_2; \text{while } (e_1) \text{ } e_2 \text{ else false}], \sigma}$ |

Figure 2: Small-step semantics for WHILE