

Homework 4

CSC 7101, Spring 2009

Due: 22 April 2009

1. Translate our operational semantics rules into Prolog clauses. Represent syntactic constructs using functors. E.g., the if-statement could be represented as `ifThenElse(B, C0, C1)`. Represent the three different evaluation functions, `<. , .>->.`, as predicates. Assume that appropriate predicates for arithmetic, comparisons, boolean operations are built in.

Assume that a state is represented as a list of pairs of a variable and a value, and that bindings at the beginning of the list shadow later bindings. E.g., the axioms for numeric constants and variables could be written as follows:

```
evalArithExp(const(N), Sigma, N).
evalArithExp(var(X), Sigma, Val) :- get(Sigma, X, Val).
```

where `get(Sigma, X, Val)` computes the result of $\sigma(X)$ in `Val` and is defined as follows:

```
get([], X, undefined).
get([[X,V]|T], X, V).
get([_H|T], X, V) :- get(T, X, V).
```

You don't need to test and run your Prolog program. Writing it on paper is good enough.

2. Develop semantic rules for our operational semantics system for the following (simplified) loop construct adopted from Ada:

loop S_1 ; exit when B ; S_2 end

In the above statement, S_1 and S_2 are statements and B is a boolean expression. The semantics of 'exit when B ' is the same as 'if (B) break;' in C.

3. Consider the following statement:

$\langle letstmt \rangle ::= \boxed{let} \boxed{int} \langle id \rangle \boxed{:=} \langle intexp \rangle \boxed{in} \langle stmtseq \rangle \boxed{end}$

When executing this statement, we first evaluate the integer expression $\langle intexp \rangle$. We then *bind* the variable $\langle id \rangle$ to the value of this expression, and then evaluate the statement sequence $\langle stmtseq \rangle$.

Semantic constraints: The let-statement shadows any outer declaration of the variable $\langle id \rangle$. I.e., any occurrence of $\langle id \rangle$ in $\langle stmtseq \rangle$ refers to the variable from the let-statement. The scope of this variable is only $\langle stmtseq \rangle$. I.e., any occurrence of $\langle id \rangle$ in $\langle intexp \rangle$, in a post-condition of the let-statement, or in a statement following the let-statement refers to some outer declaration of $\langle id \rangle$. There are no restrictions on the use of variable $\langle id \rangle$ in $\langle stmtseq \rangle$. In particular, it is possible to assign a new value to $\langle id \rangle$. The let-statement is evaluated strictly. I.e., if $\langle intexp \rangle$ does not terminate (assuming that there can be function calls in $\langle intexp \rangle$), then the let-statement does not terminate.

Define the operational semantics of the let-statement. Justify your proposal (informally). If you cannot formally define the semantics according to all the semantic constraints above, define it as good as you can and explain in English what's missing.

4. Consider Dijkstra's guarded loop:

$$\langle c \rangle ::= \text{do } \langle be \rangle_1 \rightarrow \langle c \rangle_1 \ [\] \ \langle be \rangle_2 \rightarrow \langle c \rangle_2 \ [\] \ \langle be \rangle_3 \rightarrow \langle c \rangle_3 \ \text{od}$$

where `do` and `od` are keywords, $\langle be \rangle_i$ are boolean expressions and $\langle c \rangle_i$ are commands. (Dijkstra's guarded loop has arbitrarily many clauses; we'll restrict ourselves to exactly three for simplicity.)

The guarded loop is a generalization of the while loop with multiple conditions ($\langle be \rangle_1 \dots \langle be \rangle_3$) and multiple loop bodies ($\langle c \rangle_1 \dots \langle c \rangle_3$). The boolean expressions are *guards* for the commands that follow them. A command $\langle c \rangle_i$ can only be executed if its guard $\langle be \rangle_i$ is true.

Informally, each loop iteration of the guarded loop is executed as follows. All the boolean expressions (guards) are evaluated. If none of the guards $\langle be \rangle_i$ is true, none of the commands $\langle c \rangle_i$ is executed and the loop terminates. If one guard is true, the corresponding command is executed. If more than one guard is true, **one** of the commands whose guard is true is chosen **nondeterministically** (at random) to be executed. After execution of the selected command, execution proceeds to the next loop iteration.

The special case in which two of the guards are always **false** is equivalent to the while loop.

Define the operational semantics of this command. Do not assume a certain deterministic evaluation order. Explain your semantic rules.

5. Suppose we change the intuitive operational model of the language whose semantics we have been defining as follows: Whenever the value of a variable is 'used' its value reduces by 1. In other words, expression evaluation has side effects. Thus executing an assignment command like ' $x := y + z$ ' not only assigns a value to x , it also reduces the values of y and z by 1 each.

What changes would you have to make to the operational semantics of the language? Specify all the required changes. If you need to make any assumptions, state these assumptions clearly.