University of Massachusetts Lowell — Comp 3010: Organization of Programming Languages

Assignment 2

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Make sure that the remaining pages of this assignment do not contain any identifying information.

1 Small-Step Semantics (25 points)

Let us define the calculator language below that performs arithmetic and boolean operations. It has three different syntactic classes: (1) arithmetic expressions a (2) boolean expressions b, and (3) final values v. The following questions require you define small-step semantics. That is, first you need to define the configuration. Then, you need to write inference rules that show one configuration small-steps to another configuration.

$$
\begin{array}{lcl}
n & \in & \mathbb{Z} \\
a & ::= & n \mid a_1 + a_2 \mid a_1 \times a_2 \\
b & ::= & \textbf{true} \mid \textbf{false} \mid a = a \mid a \neq a \\
 & & \mid a \leq a \mid a > a \mid \neg b \mid b \&\& b \\
v & ::= & n \mid \textbf{true} \mid \textbf{false}
\end{array}
$$

(a) Write small-step semantics for the syntactic class of arithmetic expressions generated by a.

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(a) Small-step semantics for arithmetic expressions generated by athe rules for arithmetic expressions:

$$a ::= n \mid a_1 + a_2 \mid a_1 \times a_2$$

We define small-step reduction rules for arithmetic expressions:

1.Addition: If the left-hand side of the addition is not a value, reduce it:

$$\frac{a_1 \to a_1'}{a_1 + a_2 \to a_1' + a_2}$$

If the right-hand side is not a value:

$$\frac{a_2 \to a_2'}{n + a_2 \to n + a_2'}$$

When both sides are values:

$$n_1 + n_2 \to n_1 + n_2$$

2. Multiplication: If the left-hand side of the multiplication is not a value, reduce it:

$$\frac{a_1 \to a_1'}{a_1 \times a_2 \to a_1' \times a_2}$$

If the right-hand side is not a value:

$$\frac{a_2 \to a_2'}{n \times a_2 \to n \times a_2}$$

When both sides are values:

$$n_1 \times n_2 \to n_1 \times n_2$$

3. For all integer literals:

$$n \to n(where\ x \in Z)$$

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(b) Write small-step semantics for the syntactic class of boolean expressions generated by b.

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Boolean expressions are generated by the following grammar:

$$b ::= \textbf{\textit{true}} \mid \textbf{\textit{false}} \mid a = a \mid a \neq a \mid a \leq a \mid a \rangle a \mid \neg b \mid b \wedge b$$

The small-step semantics for boolean expressions are defined as:

1. Equality check:

$$\frac{a_1 \to a_1'}{a_1 = a_2 \to a_1' = a_2}$$

$$\frac{a_2 \to a_2'}{n = a_2 \to n = a_2'}$$

$$n_1 = n_2 \to \textbf{\textit{true}} \quad \textbf{\textit{if}}\ n_1 = n_2$$

$$n_1 = n_2 \to \textbf{\textit{false}} \quad \textbf{\textit{if}}\ n_1 \neq n_2$$

2. Inequality check:

$$\frac{a_1 \to a_1'}{a_1 \neq a_2 \to a_1' \neq a_2}$$

$$n_1 \neq n_2 \to \textbf{\textit{true}} \quad \textbf{\textit{if}}\ n_1 \neq n_2$$

$$n_1 \neq n_2 \to \textbf{\textit{false}} \quad \textbf{\textit{if}}\ n_1 = n_2$$

3. Relational operators ($\langle$, $\rangle$):

$$\frac{a_1 \to a_1'}{a_1 \leq a_2 \to a_1' \leq a_2}$$

$$n_1 \leq n_2 \to \textbf{\textit{true}} \quad \textbf{\textit{if}}\ n_1 \leq n_2$$

$$n_1 \leq n_2 \to \textbf{\textit{false}} \quad \textbf{\textit{if}}\ n_1 \rangle n_2$$

4. Negation:

$$\frac{b \to b'}{\neg b \to \neg b'}$$

$$\neg \textbf{\textit{true}} \to \textbf{\textit{false}}$$

$$\neg \textbf{\textit{false}} \to \textbf{\textit{true}}$$

5. Boolean conjunction (AND):

$$\frac{b_1 \to b_1'}{b_1 \wedge b_2 \to b_1' \wedge b_2}$$

$$\textbf{\textit{true}} \wedge b_2 \to b_2$$

$$\textbf{\textit{false}} \wedge b_2 \to \textbf{\textit{false}}$$

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