University of Massachusetts Lowell
Comp 3010: Organization of Programming Languages
Assignment 1

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Small-Step Semantics Evaluation

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1.Small-Step Semantics Warm-up

From the given boolean language, we evaluate the term as follows:

$$t ::= \text{true} \mid \text{false} \mid \text{if } t \text{ then } t \text{ else } t$$

1.a) Single-Step Evaluation:

For the term:

$$\text{if true then if false then false else false else true}$$

The single-step evaluation is:

$$\text{if true then if false then false else false else true} \xrightarrow{\text{IfTrue}} \text{if false then false else false}$$

1.b) Final Result of Evaluation:

Evaluating the next step:

$$\text{if true then if false then false else false else true} \xrightarrow{\text{IfTrue}} \text{if false then false else false} \xrightarrow{\text{IfFalse}} \text{false}$$

Thus the final result is as follows:

$$\text{if true then if false then false else false else true} \implies \text{false}$$

1.c) All Intermediate Steps for evaluation:

The complete evaluation with all intermediate steps is:

$$\text{if true then if false then false else false else true} \xrightarrow{\text{IfTrue}} \text{if false then false else false} \xrightarrow{\text{IfFalse}} \text{false}$$

In total, it takes **2 steps** to evaluate to the value **false**.

Boolean and Arithmetic Language Evaluation

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2 Boolean Arithmetic Language

2.a) Validity of the Term $1 + \text{true}$

The term $1 + \text{true}$ is not a valid term of the boolean and arithmetic language. In this language, addition is defined only for integer terms. Since true is a boolean value, the expression is invalid.

2.b) Small-Step Rules for Term Addition

There are three small-step rules for term addition in the boolean and arithmetic language:

1. Addition of Two Numbers (AddNum):

$$n_1 + n_2 \xrightarrow{\text{AddNum}} n_1 + n_2 = n$$

2. Evaluating the Left Operand (EvalLeft):

$$t_1 + t_2 \xrightarrow{\text{EvalLeft}} t_1' + t_2 \quad \text{if } t_1 \to t_1'$$

3. Evaluating the Right Operand (EvalRight):

$$n + t_2 \xrightarrow{\text{EvalRight}} n + t_2' \quad \text{if } t_2 \to t_2'$$

2.c) Evaluating the Term $1 + 2 + 3$

To evaluate the term $1 + 2 + 3$, we follow these steps:

1. Start with the term:

$$1 + 2 + 3$$

2. Apply the EvalLeft rule:

$$1 + 2 + 3 \xrightarrow{\text{EvalLeft}} (1 + 2) + 3$$

3. Evaluate $1 + 2$ using AddNum:

$$(1 + 2) + 3 \xrightarrow{\text{AddNum}} 3 + 3$$

4. Finally, apply AddNum again:

$$3 + 3 \xrightarrow{\text{AddNum}} 6$$

Putting it all together, the complete evaluation sequence is:

$$1 + 2 + 3 \xrightarrow{\text{EvalLeft}} (1 + 2) + 3 \xrightarrow{\text{AddNum}} 3 + 3 \xrightarrow{\text{AddNum}} 6$$