Language Syntax, Semantics, Errors, Nondeterminism

CS 536: Science of Programming, Fall 2019

Due Wed 9/25, 11:59 pm

Problems [50 points]

Lecture 5: Language Syntax/Operational Semantics

1. [8 points] Translate the program below into our programming language.

```
x = 1; j = 0; while (j++ <= m) x++; x += y;
```

2. [8 = 2*4 points] Let $S \equiv$ **if** x>0 **then** x:=x+2*y; y:=3*y **fi**.
   a. Evaluate $\langle S, \{x = 2, y = 6\}\rangle$ to completion, using step-by-step operational (i.e., $\rightarrow$) semantics.
   b. Evaluate $\langle S, \{x = -2, y = 8\}\rangle$ to completion, using step-by-step operational semantics.

3. [10 points] Let W be the program below and let $\sigma_0 = \{i = 1, x = 1, n = 5\}$.

   $W \equiv$ **while** i ≠ n **do** S **od** where $S \equiv$ i := i+1; x := x+i*i

   Evaluate $\langle W, \sigma_0\rangle$ to completion. You can use $\rightarrow^n$ to emphasize how each iteration changes the state, but be sure to include six configurations (which ones are your choice), including the initial $\langle W, \sigma_0\rangle$ and final $\langle E,$ *(you fill in)* $\rangle$.

Lecture 6: Denotational Semantics, Runtime Errs, Sequential Nondeterminism pt. 1

4. [6 = 2*3 points] What are the denotational semantics of the configurations in Problems 2a and 2b? (I.e., $M(S, \ldots) = \ldots$?)

5. [3 points] Let W be the loop in Problem 3. What is the set of σ such that $\langle W, \sigma\rangle \rightarrow^* \langle E, \perp\rangle$?

6. [6 = 2*3 points] Let S be deterministic.
   a. If $\perp \in M(S, \sigma)$, can we conclude anything about $\langle S; T, \sigma\rangle$ where T is any other statement? Give a brief justification.
   b. If $\langle S, \sigma\rangle \rightarrow^* \langle E, \tau\rangle$ and $\tau \not\models$ T, can we conclude anything more specific about τ? Give a brief justification. (Recall T means true.)

Lecture 7: Sequential Nondeterminism pt. 2

7. [3 points] Let S be nondeterministic. Suppose S always terminates when run in σ (i.e., $\perp \notin M(S, \sigma)$). Is it possible nonetheless for there to be a predicate φ where $M(S, \sigma) \not\models \varphi$ and $M(S, \sigma) \not\models \neg\varphi$ simultaneously? Give a brief explanation.

8. [6 = 2*3 points] Let W be the incomplete program **do** $\mathtt{x} \geq 0 \rightarrow \ldots \square\ \mathtt{x} \ldots \rightarrow \ldots$ **od**. Complete W by completing the guarded commands such that both a and b below are possible (and say what W is).
   a. $\perp_d \in M(W, \{\mathtt{x} = 0\})$. Sketch an operational execution path where this happens. (I.e., $\langle W, \{\mathtt{x} = 0\}\rangle \rightarrow^*$ *some configuration* $\rightarrow^*$ *some configuration* and so on.
   b. $\{\mathtt{x} = \alpha\} \in M(W, \{\mathtt{x} = 0\})$. Sketch an operational execution path where this happens and say what value α has.

