

Hand in your assignment in class. Please type in your solution, or write *very neatly*.

1. Redefine the small step evaluation relation for expressions presented in class to force the evaluation from right to left (instead of left to right). Indicate which rules need to be changed and write the new rules.
2. Redefine the small step evaluation of expressions such that, if one of the operands is zero, then it yields a result of zero without evaluating the other operand. Indicate which rules need to be changed and write the new rules.
3. Suppose we replace the following rule in the evaluation of expressions:

$$\frac{\langle e_2, s \rangle \rightarrow \langle e'_2, s' \rangle}{\langle n + e_2, s \rangle \rightarrow \langle n + e'_2, s' \rangle} \text{ (rplus)}$$

with a new axiom:

$$\overline{\langle e_1 + e_2, s \rangle \rightarrow \langle e_2 + e_1, s \rangle} \text{ (new)}$$

- (a) Write a counterexample showing that the execution is no longer deterministic. Show the evaluation steps that lead to different results.
 - (b) Add a side condition to the new axiom (or rewrite the axiom) to ensure that the execution is deterministic and yields the same result as the original semantics.
4. Consider the language of arithmetic expressions with variable updates discussed in class. Prove that the execution is deterministic, i.e., if expression e , states s_0, s, s' , and integers n, n' are such that $\langle e, s_0 \rangle \rightarrow^* \langle n, s \rangle$ and $\langle e, s_0 \rangle \rightarrow^* \langle n', s' \rangle$, then $s = s'$ and $n = n'$.

Note: make sure you clearly indicate the property you are trying to prove, and where and how you use the induction hypothesis.