Programming Language Qualifying Exam
Spring 2010

Answer all five of the following problems.

1. **Languages and Compilation**

   (a) A modern compiler often can compile either to native code or to a byte code. Explain what the difference is between these two approaches, and give an advantage for each.

   (b) Explain the difference between the functional programming paradigm and the imperative programming paradigm. Give an example of a language in each category.

   (c) Most languages being released today are garbage collected. Explain garbage collection, give an advantage of using garbage collected languages, and give one example of a situation in which a garbage collected language would **not** be appropriate.

2. **Abstraction**

   (a) What is an abstract data-type? What kinds of problems can result if data-types are not abstract?

   (b) If you examine the code generated by a compiler, you may find many places where abstraction is not followed. Why is this acceptable?

3. **Grammars**

   Consider the following grammar:

$$\begin{array}{rcl} S & \rightarrow & E\ x \\ & | & a\ b \\ E & \rightarrow & y\ S \\ & | & a\ b \end{array}$$

   (a) Construct the Characteristic Finite State Machine for the above grammar.

   (b) Convert the above grammar to an LL grammar (or explain why it is already LL).

   (c) Is the above grammar ambiguous? Give a proof with your answer.

4. **Weakest Precondition**

   (a) Give the definition of *weakest precondition*.

   (b) Give an example P, Q, and S such that $WLP(S, Q) = P$, but not $WP(S, Q) = P$.

   (c) Suppose $WP(S, Q) = P$. Suppose also we have $x \notin P$, and when we ran S from x, we got a state in Q. Explain how this could happen.

5. **Loop Verification**

   (a) To verify a loop, you need to solve five equations. List each equation and give a one sentence description of its role in the verification.

   (b) We want a program that, given an array $A[0..N]$, sets the integer a to be the average of the elements of the array.

      i. Write a specification for your program by giving a precondition Q, postcondition R, and loop invariant P.

      ii. Write the program, and formally verify it.