Programming Language Qualifying Exam
Fall 2010

Answer all five of the following problems.

1. **Languages and Compilation**

   (a) Compare and contrast the following: interpreter, compiler, interactive compiler, just in time compiler.

   (b) Functional languages are especially well suited for parallel computation. Why is that?

   (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.

   (d) What is the difference between the call-by-name, call-by-value, and call-by-reference parameter passing styles? Give an example of each.

2. **Abstraction**

   Abstraction is an extremely important aspect of computer science.

   (a) Explain what abstraction is.

   (b) Give a language construct that supports it.

   (c) Explain the difference between abstraction and abstract data type.

   (d) If you read the output of a compiler, you will often see that the code makes no attempt to use abstraction. Why is this acceptable?

3. **Grammars**

   Consider the following grammar:

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

   (a) Give the First and Follow sets for the non-terminals.

   (b) Construct the Characteristic Finite State Machine.

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

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

4. **Weakest Precondition**

   (a) Give the definition of *weakest precondition*. How is that different from *weakest liberal precondition*?

   (b) Compute $WP(S, Q)$, for $S \equiv$ `if x > 10 then y:=-x else y:=x` and $Q \equiv y < 0$.

   (c) Give example programs S_1 and S_2, and predicates P and Q, such that $WP(S_1, Q) = P$, $WP(S_2, Q) = P$ but $WP(S_1; S_2, Q) \neq P$.

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 a **sorted** array $A[0..N]$, sets the integer i to be the value such that $A[i] = x$, for some given x, using binary search.

      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.