Programming Language Qualifying Exam
Fall 2012

Answer the following five problems.

1. Languages and Compilation

   (a) (4pts) Explain the difference between interpreted, compiled, and byte-code languages. Give an example of each.

   (b) (4pts) Your company needs to create some software for a 1024-core machine. One of your teams wants to use mutable data structures, and the other wants to use immutable data structures. What kinds of tradeoffs would you expect to see with either of those choices?

   (c) (4pts) Explain the tradeoffs between using a statically typed vs. a dynamically typed language.

   (d) (4pts) The call by reference parameter passing style is very common. Define call by reference, show a small example in the programming language of your choice, and give a reason for its popularity. Does it have any disadvantages?

   (e) (4pts) Closures are going to be introduced in Java 8. What is a closure, and why are people interested in having them in a language?

2. Abstraction

   (a) (5pts) What is an abstract data-type?

   (b) (5pts) In an object oriented language, we use objects and private fields to facilitate abstraction. Suppose you are working in a language that does not have objects. What techniques could you use to still be able to provide abstraction?

3. Grammars

   Consider the following grammar:

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

   (a) (5pts) Construct the Characteristic Finite State Machine for the above grammar. You must show the LR tables (i.e., Action and Go To tables) for credit.

   (b) (5pts) Convert the above grammar to an LL grammar (or explain why it is already LL).

   (c) (5pts) What advantage results from a grammar being LL?

   (d) (5pts) Is the above grammar ambiguous? Give a proof with your answer.

4. Weakest Precondition

   (a) (5 pts) Define *weakest precondition* and *weakest liberal precondition.*

   (b) (5 pts) In English, explain what $WP(S,T) = F$ indicates. (Note, we say explain, not simply translate.)

   (c) (10 pts) Consider the following program S. Let the postcondition $R \equiv x = y$. Determine formally the conditions under which this program returns the correct answer.

```
x := x + y;
y := y - x;
if x > y then x := x + 1
         else y := y + 1
fi
```

5. Loop Verification

   (a) (5 pts) In order to verify the correct operation of a loop, you need to check five formulas. What are they?

   (b) (10 pts) Fix any bugs that exist in the following program (if there are any), and formally prove the result. The postcondition is $m = max(A[0], A[1], \cdots, A[n-1])$. So, if $a = [1, 9, 3, 7]$ then on termination we should have $m = 9$.

   You will need to determine the loop invariant.

```
i := 0 ;
m := 0 ;
do i < |A| ->
   if A[i]>m then m:=A[i]
             else skip
od
```