Programming Language Qualifying Exam
Spring 2006

Answer the following 5 problems.

1. Function Call Stack

   - Describe a typical stack frame. What are the components, and what do they do?
   - What is tail recursion, and what is its benefit?

2. Memory Management

   - What is a garbage collector?
   - Write a small program fragment in your favorite (garbage collected) language in which data is allocated and then made available for collection.
   - Give one advantage and one disadvantage of using a garbage collector.

3. Abstraction

   Suppose you are the manager for a software team. The project they are working on requires a queue, but the library code only has lists. You get two proposals on how to fix this.

   Proposal A Copy the `List` class, and rename it as `Queue`. Add two methods, `enqueue` and `dequeue`. To make unit testing easier, leave in the original `List` methods, such as `insert`.

   Proposal B Create a new class called `Queue`. Use a private member variable of type `List` internally to store the data, and then provide `enqueue` and `dequeue` methods.

   Which of these methods is the best way to do it, and why? (You will **NOT** get credit if you do not justify your answer.)

4. Program Verification

   - What is a weakest precondition?
   - The following program is supposed to take a sorted array A of length $n > 2$, (i.e., $\forall 0 \leq i \leq n-2 \ : \ A[i] < A[i+1]$). After running, the variable x will contain the index of the array containing the value of y, it it exists. (This is a standard binary search algorithm.) If y is not in A, then the value of x is allowed to be undefined.

```
a := -1;
b := n;
x := (a + b)/2;
while (a+1 < b and A[x] != y) {
   if A[x] < y
     then a := x
     else b := x
}
```

Formally prove or disprove correctness and termination of this program. Do **NOT** assume that the value y is contained in A.

5. Parsing

   (a) Consider the following grammar. By convention, the upper-case symbols represent non-terminals, and the lower-case symbols represent terminals.

$$\begin{array}{lcl} S & \rightarrow & E\ \$ \\ E & \rightarrow & E\ x\ E \\ & | & E\ x\ E\ x\ E \\ E & \rightarrow & v \end{array}$$

      i. Give the Characteristic Finite State Machine (CFSM) for the above grammar.

      ii. Is the grammar ambiguous? How can you prove it?

      iii. Is the grammar LL? Why or why not?