CSI3120: Programming Language Concepts
Fall 2014
Assignment 2
Due Date: October 23, 2014, at 23:59

Question 1

Here is a description of the classical puzzle entitled the Cannibal and Missionary problem: three cannibals and three missionaries are standing on a river bank. A boat capable of carrying up to two people across the river is at their disposal. The cannibals and the missionaries would like to cross the river in order to stand together again but on the opposite bank. There is one difficulty, however, there should never be fewer missionaries than cannibals standing on either bank of the river at any given time (until they disembark, the missionaries on the boat are safe even if outnumbered).

You can solve this puzzle for fun if you want, but this is not the point of the question. In this question, I ask you to generate two grammars: one to represent the river banks configuration in a generalized version of the problem and another one to represent the river banks configuration in the actual version of the problem and answer some questions about these grammars. In more detail,

(a) Write a grammar for the generalized version of the Cannibal and Missionary problem in which the total number of cannibals does not need to equal the total number of missionaries and neither the number of cannibals nor the number of missionaries need to equal three. On the other hand, you can assume that on each river bank, all the missionaries will always be listed prior to all the cannibals.

(b) Show the bottom up and the top down derivations of the following configuration using your grammar, where *m* stands for a missionary, and *c*, for a cannibal:

m m c c river m m m m c c

How many steps are involved? Draw the parse tree resulting from these derivations.

(c) Consider writing a grammar for the actual Cannibal and Missionaries problem (in which you must have exactly three cannibals and three missionaries, though you can keep the restriction regarding the order in which the missionaries and cannibals are listed on each

river bank). Can you write the same type of solution as you did in (a)? Is the problem easier or harder? In what way?

(d) Do write the grammar for the actual Cannibals and Missionaries problem (i.e., don't just consider doing it like in step (c)!).

Question 2

Consider the following grammar:

$S \rightarrow a\ B \mid A\ B$

$B \rightarrow b\ A \mid b$

$A \rightarrow a\ B \mid a$

(a) What language does it generate?

(b) Explain why it is ambiguous. You may need to illustrate your point with an example.

(c) Re-write it in a way that eliminates the ambiguity. Explain the choices that you have made in doing so.

Question 3

Using the rules of Axiomatic Semantics, prove formally that the following theorem is true. The pre- and post-conditions are highlighted:

```
{ x <=  -10 ; y < 3}
x = y * x;
If ( x < 0 )
   { y = x * y  ;
     x = x * x }
{ x >= 0 ; y <= 0 }
```

Question 4

Find the post-condition and the rule invariant of the following program fragment (**Note:** div represents the integer division operator):

```
{M > 0 and N >= 0 }
a = M; b = N; k = 1;
while ( b > 0 ) {
        if (b == 2 * ( b  div 2) )
         {   a = a*a;
             b = b/2
         }
        else
         {    b = b–1;
              k := k*a;
         }
  { ? ? }
```

Question 5

Consider the following grammar :

$S \rightarrow m\ G \mid m\ K\ p$

$G \rightarrow n\ G \mid n$

$K \rightarrow n\ K\ r \mid m\ n$

(a) Build the Cannonical LR(0) collection for the extended grammar S'.

(b) From your answer in (a) build the parsing table for that grammar

(c) Show each step of the LR(0) parse of the following sentence:

m n n m n r r p