Midterm : CS 2104 : Programming Language Concepts

September 20, 10 - 11 AM

Instructions to Candidates

- Answer **ALL** questions. This exam has two questions.
- All answers **MUST** come with the correct explanations. There is no credit for guessing. A correct answer without the correct explanation will receive no marks.
- Answers must be written in the space provided in this booklet; **otherwise they will not be graded**.
- This is an **OPEN BOOK** examination. You are allowed to bring in any books/lecture notes etc., but not a laptop.
- You can ask for extra sheets for rough work.
- **PLEASE WRITE YOUR MATRICULATION NUMBER BELOW**.

MATRICULATION NO.:

(This portion is reserved for the examiner's use only)

Question		Marks
Question A	14	
Question B	11	
TOTAL	25	

Section A: Language Syntax and Semantics
$(2 + 3 + 4 + 2 + 3) = 14$ marks

1. The programming language IMP was discussed in class. Consider the IMP program :

   `while (a = a) do a := 1`

   Assume a is a variable which is initialized to 0. Then, starting from this initial state how many states in total are reached by execution of this program ? Explain your answer.

2. Show that the following BNF grammar is ambiguous.

$$S \to SS \mid a \mid b$$

Then construct an *equivalent* BNF grammar (which has the same language) which is unambiguous.
[1 + 2] = 3 marks

3. Consider the following BNF grammar of algebraic expressions with a single identifier a

$$S \to S + S \mid S - S \mid S * S \mid S/S \mid (S) \mid a$$

How many parse trees are there for each of the following:
(i) `a + a * a` (ii) `a + a * a / a` (iii) `a + a + a + a` (iv) `(a + (a + a)) + a`
Explain your answer in each case. Try to explain without drawing all the parse trees.

4. Consider the following IMP program where `n` $\geq$ `0` initially. Find a loop invariant for the loop in the program. The stronger your loop invariant, the more useful it is (*e.g.* `true` is a loop invariant for all loops, but it is not very useful).

```
j := 0;
x := 1;
while j < n do
    j := j + 1; x := 2 * x
```

5. Note that `n` is never modified in the program fragment of question A.4. Now by using the method proving via Hoare triples show that the property `x = ` 2^n holds at the end of the while loop.

Section B: Imperative and Object-oriented Programming
$(3 + 6 + 2) = 11$ marks

1. Consider the following class definitions taken from an object oriented programming language.

```
Class  Shape{
Protected :
  float   width;

Public :
  float  align;
Private:
    int  data;
}
```

```
Class  Text{
   protected:
       char  str;
       Int len;
}
```

```
Class Circle:Shape{
  private:
     float  rad
}
```

   Among the fields width, align,data,str,len,rad which are visible to an instance of the Circle class and why ?

2. Explain what are the three numbers printed in case the parameter Y is transmitted by (i) name (ii) value (iii) reference (iv) value result.

```
program Main();
   var Y : integer;
   procedure Proc(X: integer);
        begin X := X + 1; write(X, Y) end
   begin
        Y := 1; P(Y); write(Y)
   end
end
```

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3. Consider an array A

```
A : array[1..M,1..N] of integer
```

In class, we discussed the formula for computing the address of array element A[i,j] using the address of A[0,0]. This was done assuming that the array layout is in row-major order *i.e.* the first row appears first followed by the second row and so on. What will be the formula for the address of A[i,j] (in terms of the address of A[0,0]) if the array layout is in column major order. Explain with pictures. You may assume that any integer occupies 4 bytes of memory.