HONG KONG UNIVERSITY OF SCIENCE & TECHNOLOGY

COMP3031 (Principles of Programming Languages)

Fall 2016

FINAL EXAMINATION

08:30AM - 11:30AM
Dec 8, 2016 Thursday
LG5 Multi-function Room

Name	
Student ID **Solution**	**ITSC Account**

1. *About the exam:*
   a. *This is a closed-book, closed-note examination.*
   b. *You CANNOT use any electronic devices including calculators during the examination. Please TURN OFF all of your electronic devices (e.g., mobile phone) and put them into your bag.*
   c. *You CANNOT leave during the last 15 minutes of the examination.*
2. *About this paper:*
   a. *This paper contains 12 pages, including this title page.*
   b. *The total number of points is 100, distributed to seven problems.*
3. *About your answers:*
   a. *Write your answers in the designated space following each question.*
   b. *Make sure your final answers are clearly recognizable.*
   c. *Attempt all questions.*

Problem	1	2	3	4	5	6	7	Total
Marks								

Problem 1. SML Programming (20 points)

Given the following SML datatypes:

```
datatype node = Nd of int * int list; (*node ID and list of children*)
datatype tree = Tr of node list;
```

Example:

```
val t =
Tr [Nd(0, [3,5]), Nd(2, [0,1]), Nd(1, [6]), Nd(3, [4]), Nd(4, []),
Nd(5, []), Nd(6, [])];
```

In this tree t, we can see that the node labeled `2` is the root, with nodes labeled 0 and 1 as children. **Assume all node labels are unique.**

a) Write a function `depth` to calculate the depth of a node, i.e., the number of edges to traverse from the root to this node. If the node does not exist in the tree, return ~1.

```
val depth = fn : int * tree -> int
```

Examples:

```
- depth(0, t);
val it = 1 : int
- depth(2, t);
val it = 0 : int
- depth(1, t);
val it = 1 : int
- depth(3, t);
val it = 2 : int
- depth(4, t);
val it = 3 : int
- depth(7, t);
val it = ~1 : int
```

```
Sol:

fun exists (_, Tr []) = false |
      exists (nid, Tr (Nd(id, nlist) :: T)) =
      if nid = id then true else exists (nid, Tr T);

fun exist (_, []) = false |
    exist (nid, h::t) = if nid = h then true else exist (nid, t);

fun calc (_, Tr [], _) = 0 |
    calc (nid, Tr (Nd(id, nlist) :: T), Tr L) =
      if exist (nid, nlist) then 1 + calc (id, Tr L, Tr L)
      else calc (nid, Tr T, Tr L);

fun depth (nid, Tr L) =
      if exists (nid, Tr L) then calc (nid, Tr L, Tr L) else ~1;
```

Grading criteria:

Base case for root node – 2pts; recursion on branches – 4pts; function to correctly check whether a node exists – 2pts; path function 2pts;

b) Write a function `path` to detect whether there exists a path from a node labeled `n1` to a node labeled `n2`.

```
val path = fn : int * int * tree -> bool
```

Examples:

```
- path(0, 2, t);
val it = false : bool
- path(2, 0, t);
val it = true : bool
- path(0, 4, t);
val it = true : bool
- path(2, 4, t);
val it = true : bool
- path(0, 6, t);
val it = false : bool
- path(1, 0, t);
val it = false : bool
- path(6, 7, t);
val it = false : bool
- path(8, 7, t);
val it = false : bool
```

```
Sol 1:

fun search (n1, n2, Tr [], Tr _) = false |
    search (n1, n2, Tr (Nd(id, nlist)::T), Tr L) =
if exist (n2, nlist)
then
      if n1 = id then true
      else search(n1, id, Tr L, Tr L)
else search (n1, n2, Tr T, Tr L);

fun path (n1, n2, Tr L) =
if exists (n1, Tr L) then
      if n2 = n1 then true
      else search (n1, n2, Tr L, Tr L)
else false;
```

```
Sol 2:

fun children (nid, Tr []) = [] |
    children (nid, Tr (Nd(id, nlist) :: T)) =
if nid = id then nlist else children (nid, Tr T);

fun search (nid, [], _) = false |
    search (nid, _, Tr []) = false |
    search (nid, h::t, Tr L) =
      if exist (nid, h::t) then true
      else
            let val nnl = children (h, Tr L)
            in search (nid, nnl, Tr L) orelse search (nid, t, Tr L)
            end;

fun path (n1, n2, Tr L) =
      if n1 = n2 then exist (n1, L)
      else
      let val nlist = children (n1, Tr L)
      in search (n2, nlist, Tr L) end;
```

Grading criteria:

Searching a node in the children list – 3pts; base case for searching the node – 2pts; recursion to a child's children list – 3pts; recursion to a child's siblings – 2pts.

Solution that gets n2's ancestors and then searches n1 in the ancestors is similarly graded.

Problem 2. Prolog Programming (20 points)

Given a knowledge base of facts in the form of `edge(X, Y),` where X, Y are the labels of two tree nodes. Each fact represents a directed edge in a binary tree and each node label is unique:

```
edge(a,b).
edge(a,c).
edge(b,d).
edge(b,p).
edge(c,e).
edge(c,f).
```

a) Define a predicate `hop(X,Y,H)` in which X, Y are the labels of two tree nodes, and H is the length of the path from node X to node Y. The code skeleton is given. You only need to fill in the missing predicates, one predicate per blank.

Examples:

```
    ?- hop(a,b,X).
```

```
X = 1.
?- hop(b,a,X).
false.
?- hop(a,f,X).
X = 2.
?- hop(a,X,1).
X = b ;
X = c ;
false.
```

```
hop(X,Y,1):-    ________edge(X,Y)____________ . (2pts)


hop(X,Y,H):-    ________edge(X,Z)____________ , (2pts)

                ________hop(Z,Y,H1)____________ , (3pts)

                ________H is H1 + 1____________ .  (3pts)
```

Grading Criteria:
(1) If order is incorrect, we will subtract the points by 1 or 2.

b) Define a predicate `lca(X,Y,A)` such that for a given pair of nodes X and Y, A is the lowest common ancestor of the two nodes. A common ancestor means there is a path from A to X as well as a path from A to Y. The lowest common ancestor means except A, there is no other common ancestor of X and Y on the path A->X and path A->Y. The code skeleton is given. You only need to fill in the missing predicates, one predicate per blank.

Examples:

```
?- lca(b,b,X).
X = a.
?- lca(b,d,X).
X = b.
?- lca(e,f,X).
X = c.
?- lca(d,p,X).
X = b.
?- lca(e,X,a).
X = a ;
X = b ;
X = d ;
X = p ;
false.
```

```
ancestor(A, B) :- edge(A, B).

ancestor(A, B) :- _____edge(C, B)____________, (2pts)

                  _____ancestor(A, C)_________. (2pts)


lca(A, B, A) :- ancestor(A,B).


lca(A, B, B) :- _____ancestor(B, A)_________. (2pts)


lca(A, B, X) :- _____ancestor(X, A)________, (2pts)


                _____ancestor(X, B)______, (2pts)

                not((ancestor(X,Y),
                    ancestor(Y,A),
                    ancestor(Y,B)
                  )),

                not((ancestor(A,B),
                     ancestor(B,A)
                   )).
```

Grading criteria: If only the order of parameters is incorrect, subtract 1 point each predicate.

Problem 3. Cuts and Negation in Prolog (10 points)

Given the following Prolog database, write *all* the answers to each of the query a) – e):

```
teach(frank, physics).
teach(fred, history).
teach(fred, english).
enroll(anne, english).
enroll(alice, english).
enroll(alice, physics).
```

a)
```
?- enroll(X, Y), !, teach(fred, Y).
```

X = anne,
Y = english. (2pts)

b)
```
?- enroll(X, Y), \+teach(fred, Y), !.
```

X = alice,
Y = physics. (2pts)

c)
```
?- enroll(X, Y), !, \+teach(fred, Y).
```

false. (2pts)

d)
```
?- \+enroll(_, X), teach(_, X), !.
```

false. (2pts)

e)
```
?- teach(_, X), \+enroll(_, X), !.
```

X = history. (2pts)

Problem 4. Prolog Search Tree (10 points)

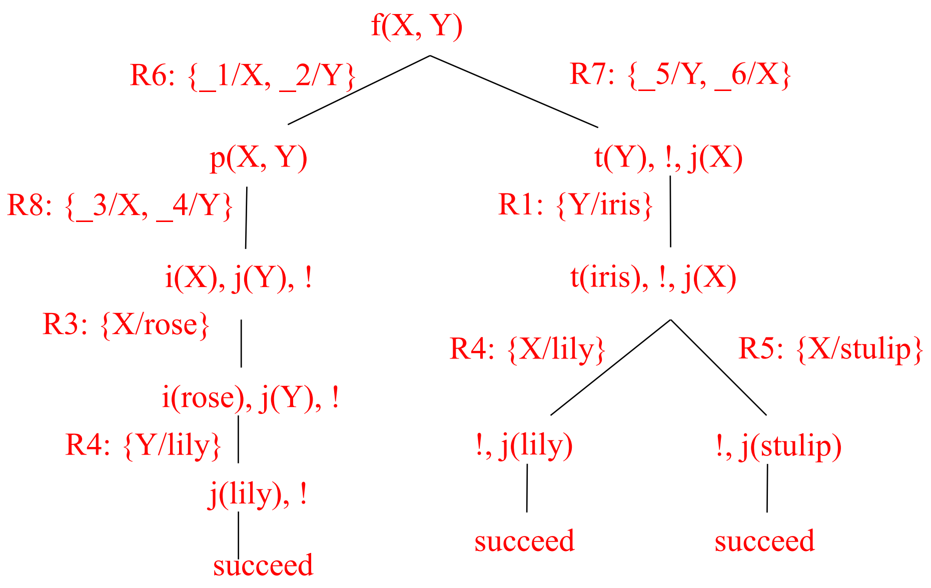
Consider the following program:

```
/*R1*/ t(iris).
/*R2*/ t(aloe).
/*R3*/ i(rose).
/*R4*/ j(lily).
/*R5*/ j(tulip).
/*R6*/ f(X,Y) :- p(X,Y).
/*R7*/ f(X,Y) :- t(Y), !, j(X).
/*R8*/ p(X,Y) :- i(X), j(Y), !.
```

Draw the complete Prolog search tree for the query `f(X,Y)`, giving **all** answers. At each **tree edge**, whenever applicable, **i)** indicate the rule number Ri, i=1,..,8, of the rule being applied, and **ii)** the unification(s) being made. At each **tree node** indicate the goal to be satisfied. At each leaf node indicate "succeed" or "fail". The initial step has been done for you.

```
                        f(X, Y)
      R6: {_1/X, _2/Y}/
                     p(X, Y)
```

Sol:



Grading criteria:
First branch – 4pts, second branch – 3pts, third branch – 3pts.
Extra branch – 2pts reduction (if one branch generates more than one extra answer, only one is counted).

Problem 5. Flex and Bison (20 points)

Given the following grammar for bit expressions:

```
<S> ::= <S> and <S1> | <S> or <S1> | <S> xor <S1>
<S1> ::= ( <S> ) | <NUM>
<NUM> ::= 0 | 1
```

Complete the following Flex and Bison files to evaluate the bit expressions. Some examples:

Input : 1 or 0
Output : 1
Input : 1 and 0
Output : 0
Input : 1 xor 0
Output : 1
Input : 1 xor 1
Output : 0
Input : 1 xor 0 and 1
Output : 1
Input : 1 xor (0 or 1)
Output : 0

Flex file “logic.lex”:

```
%option noyywrap
%{
#define YYSTYPE int
#include "logic.tab.h"
#include <stdio.h>
#include <stdlib.h>
%}
num    0|1
lb     [(]
rb     [)]
ws  [ \t]+
%%
{num} {____yylval = atoi(yytext)_______; return NUM;}
{lb}   return LB;
{rb}   return RB;
"and"  __return AND______________;
"xor"  __return XOR______________;
"or"   __return OR_______________;
{ws}
"\n"   return *yytext;
%%
```

Bison file "logic.y":

```
%{
#include <stdio.h>
#include <stdlib.h>
int yylex(void);
int yyerror(const char*);
%}

%token      NUM AND OR XOR LB RB


%%
/* Fill in the blanks in the grammar rules and actions*/
input: input line
      | line
      ;
line: '\n'
      | expr '\n' { printf("res : %d\n", $1);};
expr:
      expr AND exprh    {___$$ = $1 && $3;_________}
      | expr OR exprh   {___$$ = $1 || $3;________}
      | expr XOR exprh {___$$ = ($1+$3) % 2;________}
      | exprh           {___$$ = $1;_______________}
      ;
exprh:
      NUM               {___$$ = $1;_______________}
      | LB expr RB      {___$$ = $2;_______________}
      ;
%%
int main() { return yyparse();}
int yyerror(const char* s) {
printf("error \n");
return 0;
}
```

Grading criterion: 2pts each blank. Correct logic, 1pt,no syntax error, 1pt.

Problem 6. Parameter Passing Methods (10 Points)

The following program is in an imaginary D language, which has a syntax similar to the C language, but can apply static or dynamic scoping as well as various parameter passing methods as we specify. Determine the output of the following D program with each specified scoping and parameter passing method:

```
int i, j;
i = j = 1;
void calc(int x, int y)
{
      int i = 5;
      y = y + (x++);
      x = i + y;
      printf("%d ", i + j);
}
int main(int argc, char **argv)
{
      calc(i, j);
      int j = 6;
      calc(i, j);
      printf("%d ", i + j);
}
```

Static scoping, call by value:

6 6 7 (3pts)

Grading criteria: partial points – one correct figure 1pt

Static scoping, call by reference:

8 8 35 (2pts)

Grading criteria: partial points – one correct figure 0.5pt

Static scoping, call by value-result:

6 8 35 (2pts)

Grading criteria: partial points – one correct figure 0.5pt

Dynamic scoping, call by name:

20 30 13 (3pts)

Grading criteria: partial points – one correct figure 1pt

Problem 7. Activation Records (10 points)

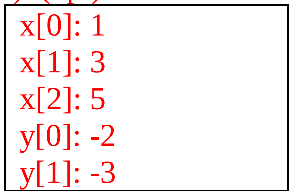
Recall that the C language by default uses static scoping on variable names and passing-by-value for parameter passing in procedure calls. Complete the activation records, including the variables and their values if known, the parameters and their values if known, and the control links for the following C program at the specified point in time:

(i) right before calling main;
(ii) right before calling conv;
(iii) right before exiting the call of conv;
(iv) right before exiting main;

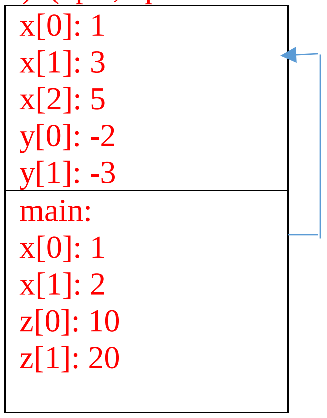
```
#include <stdio.h>

int x[3] = {1,3,5};
int y[2] = {-2,-3};

void conv(int a[], int len, int b[]){
      int i,j,temp;
      for(i=0;i<4 - len;i++){
            temp = 0;
            for(j=i;j<i+len;j++){
                  temp += a[j-i] * x[j];
            }
            b[i] = y[i] + temp;
      }
      return;
}

int main(int argc, char const *argv[])
{
      int x[2] = {1,2},z[2] = {10,20};
      conv(x,2,z);
      printf("z[0] : %d, z[1] : %d\n", z[0],z[1]);
      return 0;
}
```

Activation Records:

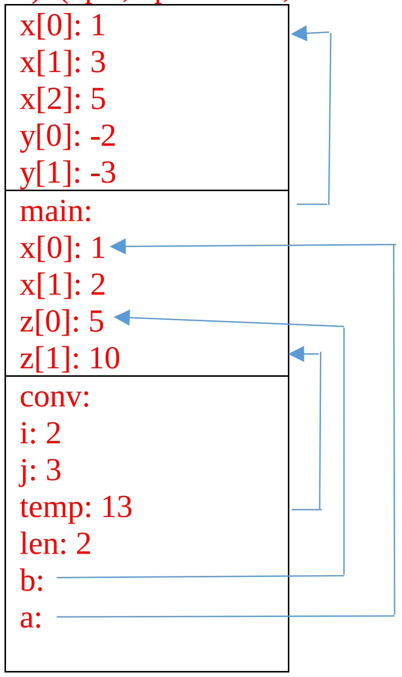
i) (1pt)



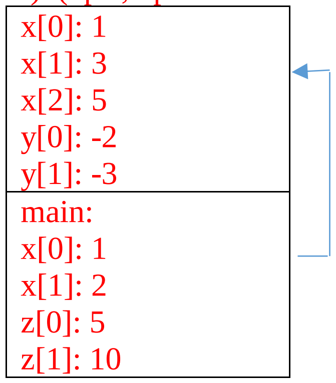
ii) (3pts, 1pt for each blank, 1pt for control link)



iii) (4pts, 2pts for 2nd, 3rd blank, 2pts for the control link)



iv) (2pts, 1pt for all blanks, 1pt for control link)


x[0]: 1
x[1]: 3
x[2]: 5
y[0]: -2
y[1]: -3
main:
x[0]: 1
x[1]: 2
z[0]: 5
z[1]: 10