Concepts of Programming Languages, CSCI 305, Fall 2021
Exam 2, Oct. 29

The exam will have two parts, a non-programming portion and a programming portion. You may not use notes, book, etc. for the non-programming portion. You can use the text, your notes and the web, but not other people, for the programming portion.

Multiple Choice

1. Which of the following is least likely to be considered a procedural language? (4 pts.)
    a. Prolog
    b. Python
    c. JavaScript
    d. C#
    e. Pascal

2. Which of the following is NOT typically a static semantic error? (4 pts.)
    a. Undeclared identifier
    b. Subroutine call providing the wrong number of arguments
    c. Subroutine call providing the wrong type of arguments
    d. Non-void functions not explicitly returning a value
    e. Out of bound array subscripts

3. Which of the following best describes what is meant by a “lexeme”. (4 pts.)
    a. A syntactic category
    b. A pattern of characters
    c. A string of characters that is a lowest-level syntactic unit
    d. Basic building block of a program
    e. All of the above

4. What best describes why the following context-free grammar is ambiguous.

expr → id (4 pts.)
expr → number
expr → - expr
expr → (expr)
expr → expr op expr
op → + | - | * | /

a. More than one production is defined for the variable 'expr'
b. An expression in the language has more than one parse tree
c. An expression in the language has both a right-most and a left-most derivation
d. The 'op' variable can be replaced by 4 different operators.
e. This grammar is not ambiguous

5. Which is the least likely to be a task of a parser? (4 pts.)
 1. Detect syntax errors
 2. Collect characters into logical groupings
 3. Create a parse tree
 4. Produce diagnostic messages and recover
 5. Build symbol table

New Material

6. Create a grammar for a language which would be able to generate the strings such as the following.

   - a + -sin(b + c) * (- (b - a))

   Your language should allow bracketing (left and right parentheses), leading unary signs (+, -), the binary operations of addition, subtraction, division and multiplication (+, -, * /), and simple function calls which are passed a single argument.

   The order of precedence for your language should be:

   function calls (highest)
   unary + and –
   binary + and –
   binary * and / (lowest)

   Note that this is non-standard. The expression a + b * c would be evaluated (a+b) * c, rather than the usual a + (b * c).

   Your grammar should use right associativity. The expression a + b + c would be evaluated a+(b+c), rather than the usual (a+b)+c. (10 pts.)

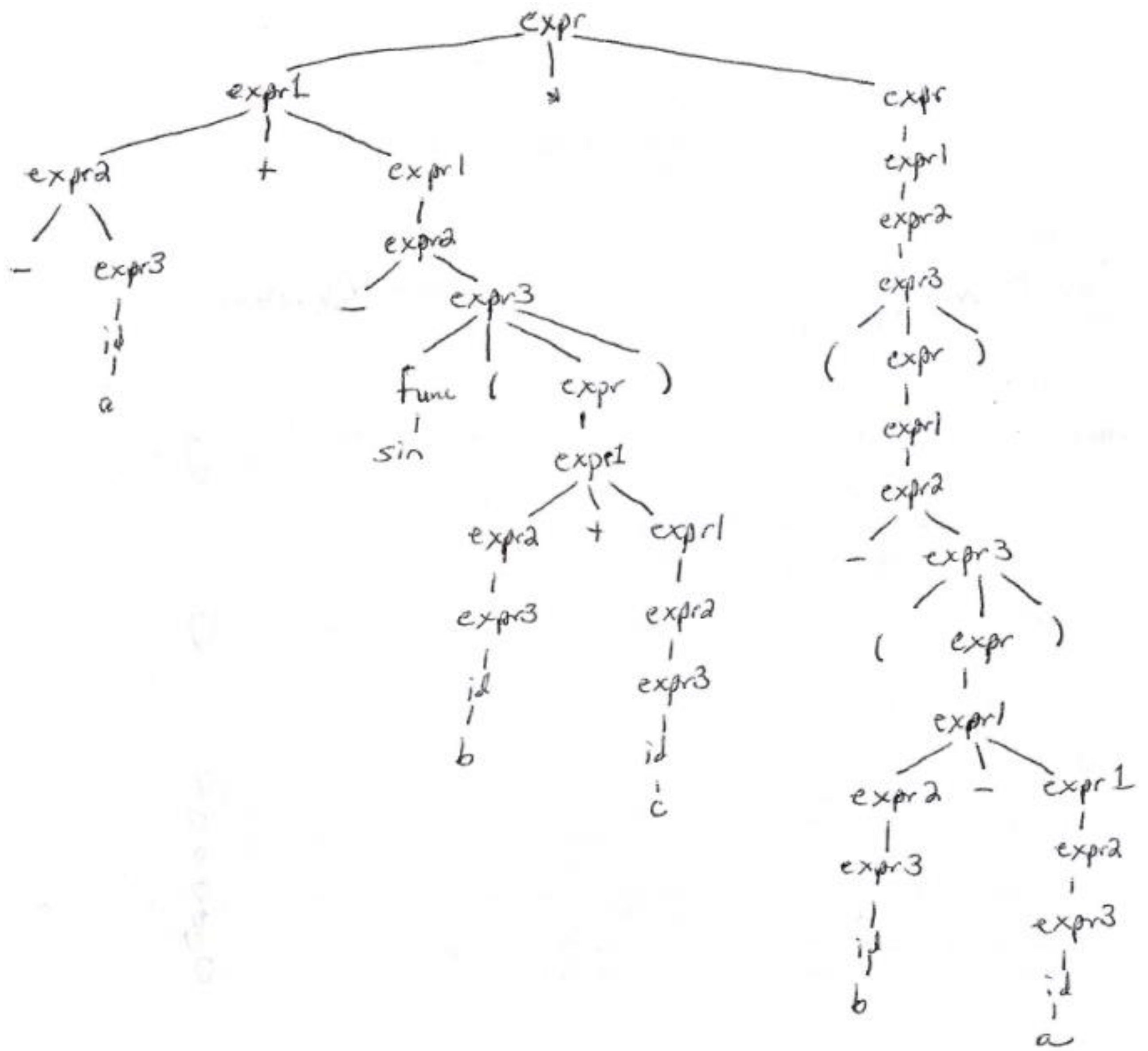
   expr → expr1 * expr | expr1 / expr | expr1
   expr1 → expr2 + expr1 | expr2 – expr1 | expr2
   expr2 → + expr3 | - expr3 | expr3
   expr3 → func (expr) | (expr) | id

   func → sin | …
   id → a | b | c | …

   To verify your work, feel free to use your grammar to create a parse tree for the string:

   - a + -sin(b + c) * (- (b - a))

   (This is optional and doing it won't add points to your overall score.)


expr
expr1
*
expr
expr2
+
expr1
expr1
-
expr3
expr2
expr2
id
-
expr3
expr3
a
func
(
expr
)
(
expr
)
sin
expr1
expr1
expr1
expr2
expr2
+
expr1
-
expr3
expr3
expr2
(
expr
)
id
expr3
expr1
b
id
expr2
-
expr1
c
expr3
expr2
id
expr3
b
id
a

7. Consider the following grammar. If this grammar is not in LL(1), fix the rules, so that it recognizes the same language, but an LL(1) parser can be used. (10 pts.)

expr → id := expr
expr → (expr) term_tail factor_tail
expr → id term_tail factor_tail
term_tail → + term term_tail
term_tail → ε
term → (expr)
term → id
factor_tail → * factor factor_tail
factor_tail → ε
factor → (expr)
factor → id

expr → id **expr_rest**
expr_rest → := expr
expr_rest → term_tail factor_tail

expr → (expr) term_tail factor_tail

term_tail → + term term_tail
term_tail → ε
term → (expr)
term → id
factor_tail → * factor factor_tail
factor_tail → ε
factor → (expr)
factor → id

8. Consider the grammar defined by:

   Variables - {rexp, rexp’, rterm, rterm’, rfactor, rfactor’, rprimary}
   Terminals - {+, • , *, a, b, $}
   Start symbol - rexp

   Productions:

   1. rexp $\rightarrow$ rterm rexp’
   2. rexp’ $\rightarrow$ + rterm rexp’
   3. rexp’ $\rightarrow$ ε
   4. rterm $\rightarrow$ rfactor rterm’
   5. rterm’ $\rightarrow$ • rfactor rterm’
   6. rterm’ $\rightarrow$ ε
   7. rfactor $\rightarrow$ rprimary rfactor’
   8. rfactor’ $\rightarrow$ * rfactor’
   9. rfactor’ $\rightarrow$ ε
   10. rprimary $\rightarrow$ a
   11. rprimary $\rightarrow$ b

   with the parsing table:

	a	**b**	+	•	*	**$**
rexp	1	1				
rexp’			2			3
rterm	4	4				
rterm’			6	5		6
rfactor	7	7				
rfactor’			9	9	8	9
rprimary	10	11				

   Hand-execute table-driven recursive descent parsing (pseudo code is given on the next page) on the following string, showing all pushes and pops to the stack.

   (10 pts.)

   b* + a $

```
terminal = 1 . . number_of_terminals
non_terminal = number_of_terminals + 1 . . number_of_symbols
symbol = 1 . . number_of_symbols
production = 1 . . number_of_productions

parse_tab : array [non_terminal, terminal] of record
    action : (predict, error)
    prod : production
prod_tab : array [production] of list of symbol
–– these two tables are created by a parser generator tool

parse_stack : stack of symbol

parse_stack.push(start_symbol)
loop
    expected_sym : symbol := parse_stack.pop()
    if expected_sym ∈ terminal
        match(expected_sym)                         –– as in Figure 2.17
        if expected_sym = $$ then return            –– success!
    else
        if parse_tab[expected_sym, input_token].action = error
            parse_error
        else
            prediction : production := parse_tab[expected_sym, input_token].prod
            foreach sym : symbol in reverse prod_tab[prediction]
                parse_stack.push(sym)
```

b * + a $

~~a~~
~~rprimary~~
~~rfactor'~~
~~rfactor~~
~~rterm'~~
~~+~~
~~rterm~~
~~rexp'~~
~~*~~
~~rfactor'~~
~~b~~
~~rprimary~~
~~rfactor'~~
~~rfactor~~
~~rterm'~~
~~rterm~~
~~rexp'~~
~~rexp~~

9. Consider the grammar defined by:

    Variables - {G, S, M, A, E, B}
    Terminals - {a, b, $$}
    Start symbol - G

    Productions:

    1. G $\rightarrow$ S $
    2. S $\rightarrow$ AM
    3. M $\rightarrow$ S
    4. M $\rightarrow$ ε
    5. A $\rightarrow$ aE
    6. A $\rightarrow$ bAA
    7. E $\rightarrow$ aB
    8. E $\rightarrow$ bA
    9. E $\rightarrow$ ε
    10. B $\rightarrow$ bE
    11. B $\rightarrow$ aBB

Give the EPS, FIRST and FOLLOW predict sets. (15 pts)

	EPS	**FIRST**	**FOLLOW**
G	false	{a,b}	{ }
S	false	{a,b}	{$}
A	false	{a,b}	{a, b, $}
M	true	{a,b}	{$}
E	true	{a,b}	{a, b, $}
B	false	{a,b}	{a, b, $}
$	false	{$}	Leave blank
a	false	{a}	Leave blank
b	false	{b}	Leave blank

10. Consider the following Prolog program that takes a list and puts the reverse of the list in the second variable. For example,

?-reverse([a, b, c, d],X).
X = [d, c, b, a].

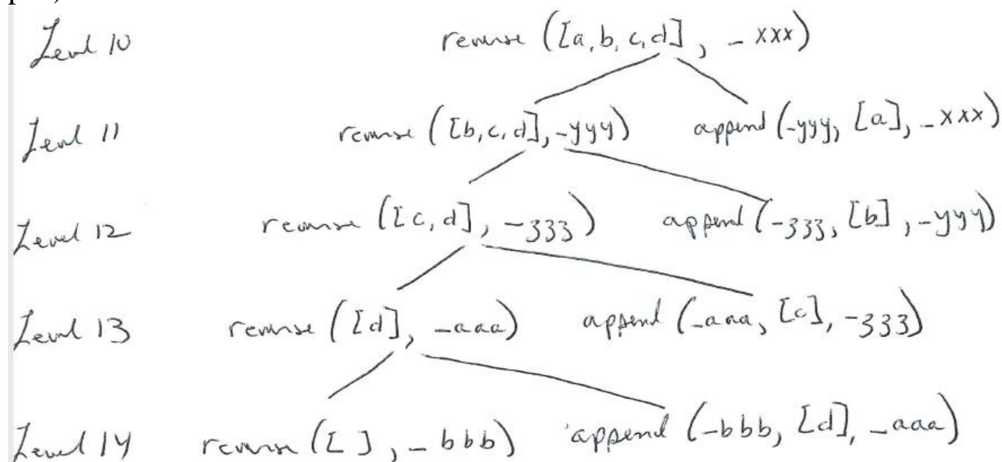
Prolog program:

```
reverse([],[]).
reverse([H|T],Ans):- reverse(T,SubAns), append(SubAns,[H], Ans).
```

(Note that append is a set of tuples of the form (X,Y, Z), where Z consists of the elements of X followed by the elements of. Y.
Example: ([a],[b],[a, b]) is in the relation append.)

Trace how this program would execute, given the query
?- reverse([a, b, c, d],X).

By trace, give the "calls", "exits", "redo", "fail", along with the levels and goals which would occur in resolving this query. Assume that the first call is at level 10. (10 pts.)



Call: (10) reverse([a, b, c, d], _16070) ? creep
Call: (11) reverse([b, c, d], _17316) ? creep
Call: (12) reverse([c, d], _18072) ? creep
Call: (13) reverse([d], _18828) ? creep
Call: (14) reverse([], _19584) ? creep
Exit: (14) reverse([], []) ? creep
Call: (14) lists:append([], [d], _18828) ? creep
Exit: (14) lists:append([], [d], [d]) ? creep
Exit: (13) reverse([d], [d]) ? creep

```
   Call: (13) lists:append([d], [c], _18072) ? creep
   Exit: (13) lists:append([d], [c], [d, c]) ? creep
   Exit: (12) reverse([c, d], [d, c]) ? creep
   Call: (12) lists:append([d, c], [b], _17316) ? creep
   Exit: (12) lists:append([d, c], [b], [d, c, b]) ? creep
   Exit: (11) reverse([b, c, d], [d, c, b]) ? creep
   Call: (11) lists:append([d, c, b], [a], _16070) ? creep
   Exit: (11) lists:append([d, c, b], [a], [d, c, b, a]) ? creep
   Exit: (10) reverse([a, b, c, d], [d, c, b, a]) ? creep
X = [d, c, b, a].
```

Old Material

11. Consider three different systems, or three components of the same system:
    - Code that needs to be very robust because system errors could cause loss of life or severe financial loss
    - Real-time code that needs to be very fast, where delayed execution could case failure, and
    - Code that needs to be easily modified as users with different needs are constantly being added.

    Discuss the pros and cons of interpreted, compiled, and some combination of interpretation/compilation. Tell what type of system you would recommend for the 3 systems above and why. (15 pts.)

    Answer is an essay that includes at least the points below:
    Advantages of compiled languages:
    - More efficient execution (faster execution) than interpreted languages because interpreter isn't needed
    - More robust and safe due to static typing (in dynamically typed languages errors can be hard to identify due to the large number of possible variable types)
    - Easier to understand code, so more robust and safe, due to static scoping

    Advantages of interpreted languages:
    - More flexible due to dynamic typing
    - Easier to debug since are working directly with the source code, not with an executable
    - Making a change only requires an edit, it isn't necessary to recompile
    - Programmer doesn't need to manage memory since typically includes automatic memory management

    Advantages of both (compilation for a virtual machine and the interpreting):
    - Get advantages of interpreting but is executes more efficiently

Robust code – use a complied language, or a language with a virtual machine. I'd recommend Ada, C# or Java since they have support for assertions. C++ also good.

Real time code – use a complied language. I'd recommend C because it gives the programmer greater control.

Modifiable, user-friendly code – I'd recommend an interpreted language such as JavaScript (for a web app) or Python. Also C# or Java.

Extra Credit

The programming language FORTRAN was created around

a. 1957
b. 1977
c. 1987
d. 1997
e. 2007 (1 pt.)

The programming language MATLAB first appeared around

a. 1960
b. 1970
c. 1980
d. 1990
e. 2000 (1 pt.)

The programming language Lua first appeared around

a. 1963
b. 1973
c. 1983
d. 1993
e. 2003 (1 pt.)

The programming language F# first appeared around

a. 1975
b. 1985
c. 1995
d. 2005
e. 2015 (1 pt.)

The programming language Go first appeared around

a. 1979
b. 1989
c. 1999
d. 2009
e. 2019 (1 pt.)

Concepts of Programming Languages, CSCI 305, Fall 2021
Exam 2, Computer Portion, Oct. 29

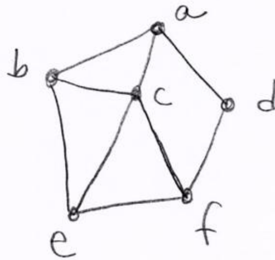
Programming Portion

Turn in the first portion of the exam before beginning this portion. To complete this portion of the exam you may use your notes, any previous assignments, the text and/or the Internet. You may not communicate with anyone other than me during this exam.

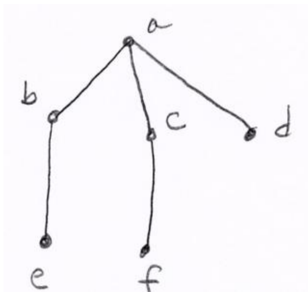
When you are done, email your answers to me:

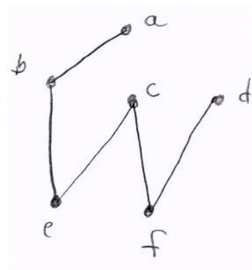
12. Jake plans to write a spanning tree function in Prolog and has decided that he needs some helper functions.

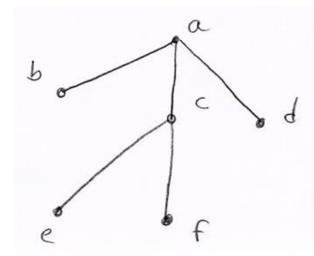
    Recall that a spanning tree of a graph, is a graph which contains all of the vertices in the original graph, however, it is also a tree. For example, the following graph



    has several spanning trees.







    Jake wants the following functions.

    a. The helper function 'subsetOf' takes two lists and returns true if all of the elements in the first list are contained in the second list.

       For example:
       ?- subsetOf([1,2,3],[1,2,3,4]).
       true.

?- subsetOf([1,2,3],[5,6,1,2]).
false.

?- subsetOf([],[a,b,c]).
true.

?- subsetOf([a,b,c],[]).
false.

Define subsetOf in prolog using Horn clauses.

The above examples return true or false directly. Your program may return values (true/false or 1/0) in a variable if you prefer.

Feel free to use the built-in prolog function ‘member’, which takes an element and a list, and returns true if the element is in the list. Do not use any other built-in functions.

For example,
?- member(3, [a, b, c, 1, 2, 3, 4]).
true.

Hint: your prolog “programs” are likely to be very short.

(5 pts.)

```
subsetOf([],_).
subsetOf([H|T], _):- member(H,_), subsetOf(T, _).
```

b. The helper function 'sameElements' takes two lists and returns true if the lists contain the same elements, ignoring repetition.

For example:
?- sameElements([a, b, c, a, a, a],[c, b, b, b, a]).
true .

?- sameElements([],[]).
true .

?- sameElements([a,b,c], [b, a, a, a]).
false.

Define sameElements in prolog using Horn clauses. (5 pts.)

```
sameElements(X, Y):- subsetOf(X, Y); subsetOf(Y, X).
```