# CSE 401/M501 18au Midterm Exam 11/2/18

## Sample Solution

**Question 1.** (14 points) Regular expressions. We would like to process strings that represent file paths in a hypothetical file system. A file path consists of a drive specification, zero or more directories separated by backslashes, and a filename with a required file extension. The drive specification consists of a single uppercase letter followed by a colon and a backslash. Directory names and file names start with a single lowercase letter, and may be followed by any number of lowercase letters, numbers, or underscores. File extensions are exactly the same, but may not contain underscores. The file name is separated from the final directory name (if any) by a backslash, and the file name is separated from the file extension by a dot.

Some examples of valid file paths:

```
C:\folder\file.txt
A:\abc\temp_25\d.b4
Z:\midterm_solutions.docx
D:\marketing3.pptx
```

Some invalid file paths:

| | |
|---|---|
| `B:\18au\scanner.pdf` | (names cannot start with numbers) |
| `M:\data.a_file` | (extensions cannot contain underscores) |
| `E:\\backups` | (directories names cannot be empty and file extensions are required) |
| `Z:\docs\README.txt` | (must use lower-case letters only) |

As with homework problems, you must restrict yourself to the basic regular expression operations covered in class and on homework assignments: r s, r | s, r*, r+, r?, character classes like [a-cxy] and [^aeiou], abbreviations name=regexp, and parenthesized regular expressions. No additional operations that might be found in the "regexp" packages in various Unix programs, scanner generators like JFlex, or language libraries are allowed.

Write your ….

answers on ….

the next page.

**Remove this page from the exam and do not include it when you hand in your exam. It will not be scanned or graded.**

**Sample Solution**

**Question 1.** Write your answers here. Hint: it may be useful to work on the regular expression and the DFA parts simultaneously.

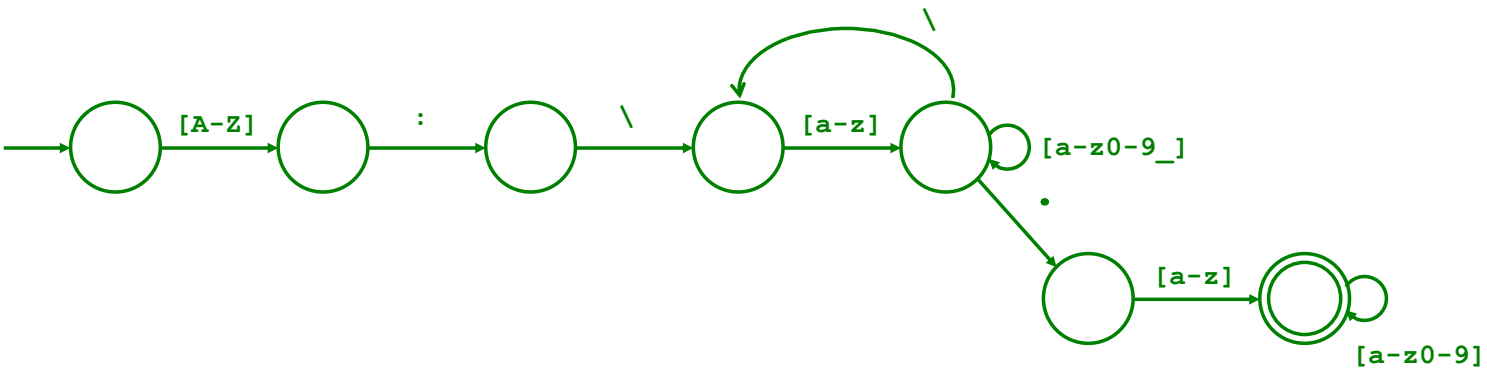
(a) (7 points) Give a regular expression (possibly with subexpressions if it makes things clearer) that generates all valid file paths according to the above rules.

*name* = `[a-z][a-z0-9_]*`

*extension* = `[a-z][a-z0-9]*`

*filepath* = `[A-Z]:\` ( *name* `\` )* *name* **.** *extension*

(b) (7 points) Draw a DFA that accepts all valid file paths according to the above rules.



**Sample Solution**

**Question 2.** (8 points) Tokens 'R Us. We've been having so much fun testing the MiniJava scanner that we decided to see what would happen if we used it to process the following Bash shell script:

```
# comment
while [ $# -gt 0 ]
do
  echo $*
  shift
done
```

Below, list in order the tokens that would be returned by a scanner for MiniJava as it reads this input. If there is a *lexical* error in the input, indicate where that error is encountered by writing a short explanation of the error in between the valid tokens that appear before and after the error(s) (something brief like "illegal character @" where a "@" was found in the file would be fine). The token list should include additional tokens found after any error(s) in the input. You may use any reasonable token names (e.g., LPAREN, ID(x), etc.) as long as your meaning is clear.

A copy of the MiniJava grammar is attached as the last page of the test. You may remove it for reference while you answer this question. You should assume the scanner implements MiniJava syntax as defined in that grammar, with no extensions or changes to the language.

**Illegal character '#'**

**ID(comment) WHILE LBRACKET**

**Illegal character '$'**

**Illegal character '#'**

**MINUS ID(gt) INT(0) RBRACKET ID(do) ID(echo)**

**Illegal character '$'**

**TIMES ID(shift) ID(done)**

**Note: Several answers indicated illegal characters as if they were tokens (i.e., ILLEGAL('#') ). A scanner should report illegal characters in the input but must not include them as tokens that would then need to be processed by a parser.**

**Sample Solution**

**Question 3.** (10 points, 2 each) Ambiguity I. The following grammar is ambiguous:

*A* ::= *B* `b` *C*
*B* ::= `b` | ε
*C* ::= `b` | ε

To demonstrate this ambiguity we can use pairs of derivations. Here are five different pairs. For each pair of derivations, circle OK if the pair correctly proves that the grammar is ambiguous. Circle WRONG if the pair does *not* give a correct proof. You do not need to explain your answers.

(Note: Whitespace in the grammar rules and derivations is used only for clarity. It is not part of the grammar or of the language generated by it.)

(a) OK (WRONG) **(Mix of left/rightmost derivations; also b b b has unique leftmost and unique rightmost derivations)**

```
A => B b C => b b C => b b b
A => B b C => B b b => b b b
```

(b) (OK) WRONG **(Two different leftmost derivations of `b b`)**

```
A => B b C => b b C => b b
A => B b C => b C   => b b
```

(c) OK (WRONG) **(Different derivations: one leftmost, one rightmost)**

```
A => B b C => b b C => b b
A => B b C => B b b => b b
```

(d) OK (WRONG) **(Two different strings, not two derivations of same string)**

```
A => B b C => b b C => b b
A => B b C => b b C => b b b
```

(e) (OK) WRONG **(Two different rightmost derivations of `b b`)**

```
A => B b C => B b   => b b
A => B b C => B b b => b b
```

**Sample Solution**

**Question 4. (8 points)** Ambiguity II. The following grammar is ambiguous. (As before, whitespace is used only for clarity; it is not part of the grammar or the language generated by it.)

*P* ::= `!` *Q* | *Q* `&&` *Q* | *Q*
*Q* ::= *P* | `id`

Give a grammar that generates exactly the same language as the one generated by this grammar but that is not ambiguous. You may resolve the ambiguities however you want – there is no requirement for any particular operator precedence or associativity in the resulting grammar.

**This solution disambiguates `!` and `&&` by putting them in different productions, and also forces the binary operator `&&` to be left-associative:**

***P* ::= *P* `&&` *Q* | *Q***
***Q* ::= `!` *Q* | `id`**

**Other unambiguous grammars that generated all of the strings produced by the original grammar also received full credit, regardless of how they fixed the problem.**

# CSE 401/M501 18au Midterm Exam 11/2/18

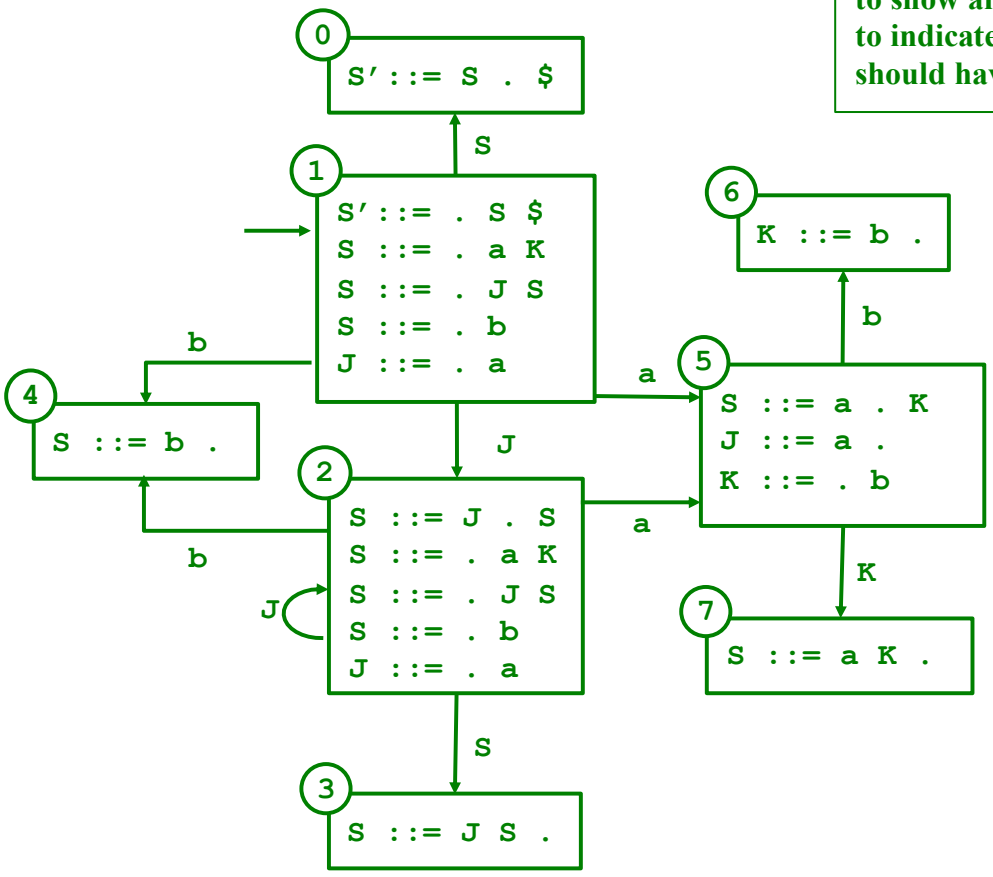
## Sample Solution

**Question 5.** (32 points) The you're-probably-not-surprised-to-see-it LR parsing question. Here is a small grammar, complete with the extra *S*′::=*S*$ rule to handle end-of-file in the generated parser.

1. *S*′ ::= *S* $ ($ represents end-of-file)
2. *S* ::= a *K*
3. *S* ::= *J S*
4. *S* ::= b
5. *J* ::= a
6. *K* ::= b

(a) (12 points) Draw the LR(0) state machine for this grammar.

**Note: many solutions failed to show an incoming arrow to indicate the start state. It should have been included.**




(b) (8 points) Compute *nullable* and the FIRST and FOLLOW sets for the nonterminals *S*, *J*, and *K* in the above grammar:

| Symbol | nullable | FIRST | FOLLOW |
|---|---|---|---|
| *S* | **no** | **a, b** | **$** |
| *J* | **no** | **a** | **a, b** |
| *K* | **no** | **b** | **$** |

(continued on next page)

**Sample Solution**

**Question 5.** (cont.) Grammar repeated from previous page for reference:

1. $S'$ ::= $S$ `$`  (`$` represents end-of-file)
2. $S$ ::= `a` $K$
3. $S$ ::= $J$ $S$
4. $S$ ::= `b`
5. $J$ ::= `a`
6. $K$ ::= `b`

(c) (8 points) Write the LR(0) parse table for this grammar based on the LR(0) state machine in your answer to part (a).

| State | Shift/Reduce Actions | | | GOTO | | |
|---|---|---|---|---|---|---|
| | a | b | $ | S | J | K |
| 0 | | | accept | | | |
| 1 | s5 | s4 | | g0 | g2 | |
| 2 | s5 | s4 | | g3 | g2 | |
| 3 | r3 | r3 | r3 | | | |
| 4 | r4 | r4 | r4 | | | |
| 5 | r5 | s6, r5 | r5 | | | g7 |
| 6 | r6 | r6 | r6 | | | |
| 7 | r2 | r2 | r2 | | | |

(d) (2 points) Is this grammar LR(0)? Explain why or why not.

**No. There is a shift/reduce conflict in state 5.**

(e) (2 points) Is this grammar SLR? Explain why or why not.

**No. The shift/reduce conflict in state 5 occurs when the next input is `b`. Since `b` is in the follow set of *J*, we can't resolve the shift/reduce conflict by removing the r5 reduce action from that state.**

**Question 6.** (14 points) LL grammars. Consider the following grammar:

*P* ::= *R* `b`
*R* ::= *P S* `a` | `c`
*S* ::= *P* | `b`

(a) (6 points) Demonstrate that this grammar does not satisfy the LL(1) condition. Hint: you may find it useful to compute nullable and the FIRST and FOLLOW sets for some or all productions, but you are not required to do so, as long as you can give a reason the grammar is not LL(1).

**An easy way to see this is to look at the two productions for *R*. For *R* ::= `c`, the FIRST set of the right-hand side is {`c`}. For *R* ::= *P S* `a`, the FIRST set of *P S* `a` includes FIRST(*R*), because of the production *P* ::= *R* `b`, and that set includes `c`. So a predictive top-down parser cannot determine which production to use to expand *R* when the next input symbol is `c`.**

(b) (8 points) Rewrite the grammar so that it is LL(1). Your answer must generate the same language as the above grammar but it should not contain any conflicts that would violate the LL(1) condition.

**First, we will eliminate indirect left recursion by choosing an arbitrary order of *S*, *R*, *P* to deal with the nonterminals. We start by expanding *S* in all of the productions that use it:**

***P* ::= *R* `b`**
***R* ::= *P P* `a` | *P* `b a` | `c`**

**We then expand R in all of the productions that use it:**

***P* ::= *P P* `a b` | *P* `b a b` | `c b`**

**There is nothing to be done for *P* because it is now the only nonterminal remaining. Therefore, we move on to dealing with direct left recursion using the standard solution:**

***P* ::= `c b` *tail***
***tail* ::= *P* `a b` *tail* | `b a b` *tail* | ε**

**We have arrived at a grammar that can be used for predictive parsing and generates the same language as the grammar given in the problem.**

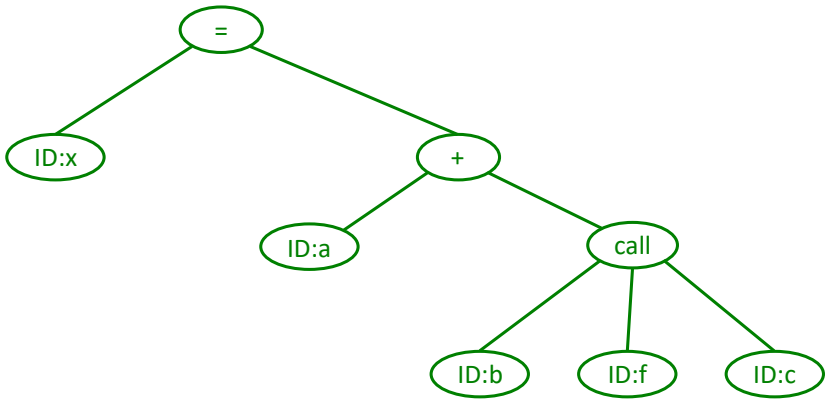
**Sample Solution**

**Question 7.** (14 points) Semantics. Suppose we have the following statement in a MiniJava (*not* full Java) program:

```
x = a+b.f(c);
```

(a) (6 points) Draw an abstract syntax tree (AST) for this statement in the blank space at the bottom of the page. You are not expected to remember the exact names of the classes or node types in the MiniJava AST package used in the project code, but your answer should have the appropriate level of abstraction and structural detail that is found there, and the nodes should have reasonable names. In case it is useful, remember that a copy of the MiniJava grammar is attached at the end of the exam.

(b) (8 points) Annotate your AST by writing next to the appropriate nodes the checks or tests that should be done in the static semantics/type-checking phase of the compiler to ensure that this statement does not contain any errors. You do not need to specify an attribute grammar – just show the necessary tests. If a particular test applies to multiple nodes you can write it once and indicate which nodes it applies to, as long as your meaning is clear and readable.




**Here is a list of the checks that need to be made, identified by node(s):**

- **ID:`x`, ID:`a`, ID:`b`, and ID:`c`: verify that identifiers are declared and in scope**
- **`=`: verify that the type of the + expression is assignment-compatible with the type of the left-side ID:`x`; verify that the left-side ID:`x` designates an assignable location (lvalue)**
- **`+`: verify that the two operands have compatible types for addition**
- **`call`:**
  - **Verify that the type of expression ID:`b` (the first subtree) is a reference type and the type has a 1-parameter method named `f`**
  - **Verify that the type of the expression ID:`c` is assignment-compatible with the declared parameter type of method `f`.**

**Notes: The actual MiniJava AST node for method call has an expression list as its third subtree. Solutions that showed an expression list containing a single expression (ID:c) were also correct. Solutions that were somewhat different but still had this level of detail, as opposed to a full concrete parse tree, also received credit.**