

## CSE 401/M501 24sp Midterm Exam 5/3/24

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There are 7 questions worth a total of 100 points. Please budget your time so you get to all of the questions. Keep your answers brief and to the point.

The exam is closed books, closed notes, closed electronics. However, you may have one 5x8 notecard for reference with any hand-written information you wish on both sides. Please turn off all cell phones, personal electronics, alarm watches, and pagers, and return your tray tables and seat backs to their full upright, locked positions. Sound or video recording, the taking of photographs, and time travel are prohibited.

If you have a question during the exam, please raise your hand and someone will come to help you.

**There is an extra blank page at the end of the exam you can use if your answer(s) do not fit in the space provided.** Please indicate on the original page(s) if your answer(s) is(are) continued on that last page.

After the blank page with extra space for answers is a copy of the MiniJava grammar. You should remove that page from the exam and use it for reference as needed.

Please wait to turn the page until everyone is told to begin.

Score \_\_\_\_\_

1 \_\_\_\_\_ / 18

2 \_\_\_\_\_ / 10

3 \_\_\_\_\_ / 12

4 \_\_\_\_\_ / 36

5 \_\_\_\_\_ / 8

6 \_\_\_\_\_ / 14

7 \_\_\_\_\_ / 2

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**Question 1.** (18 points) Regular expressions and DFAs. *Gaussian integers* are complex numbers whose real and imaginary parts are integers. They have the same form as ordinary complex numbers  $a+bi$ . Integers  $a$  and  $b$  are decimal integers and  $i$  is a symbol that represents the square root of -1. More precisely, for this problem, Gaussian integers are strings  $a+bi$  with the following properties:

- $a$  and  $b$  are non-negative decimal integers containing one or more decimal digits 0 through 9, and they can start with any digit including 0.
- A number can have both a real ( $a$ ) and an imaginary ( $bi$ ) part or just a real part or just an imaginary part. If it has both parts, the real part must come first. If it has only one part, the  $+$  symbol connecting the parts is omitted.
- If both the real and imaginary parts are present, they are connected by the symbol  $+$ . (To simplify the problem, it is not possible to use  $-$  to connect the parts.)
- The coefficient  $b$  of the imaginary term can be omitted. The symbol  $i$  by itself means the same as  $1i$ .

Examples of legal Gaussian integers using these rules:  $3+14i$ ,  $0078+01i$ ,  $3+i$ ,  $42$ ,  $17i$ ,  $0+17i$ ,  $i$ ,  $0$ ,  $0i$ ,  $0+0i$ ,  $3+0i$ .

Examples of strings that are not Gaussian integers using these rules:  $+1+2i$  (leading  $+$  symbol),  $5-6i$  ( $-$  symbol),  $-5$  (leading  $-$ ),  $+i$  ( $+$  sign used when no real part),  $3+4$  (multiple real parts),  $3i+6i$  (multiple imaginary parts).

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**Question 1 (cont.)** (a) (8 points) Give a regular expression that generates all strings that are legal Gaussian integers according to the rules on the previous page.

Fine print: You must restrict yourself to the basic regular expression operations covered in class and on homework assignments:  $rs$ ,  $r|s$ ,  $r^*$ ,  $r^+$ ,  $r^?$ , character classes like  $[a-cxy]$  and  $[\text{^aeiou}]$ , abbreviations *name=regex*, and parenthesized regular expressions. No additional operations that might be found in the “regex” packages in various Unix programs, scanner generators like JFlex, or programming language libraries are allowed.

(b) (10 points) Draw a DFA that accepts all valid Gaussian integers described above and generated by the regular expression from part (a).

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**Question 2.** (10 points) Scanners. A scanner ought to be able to process any sort of text input, regardless of whether the file contents are actually a program in the language the scanner was intended to process.

What happens if we use a scanner for MiniJava to process the following input?

```
this is !a#bin@ryString 011101[1101]
```

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 %” would be fine). The token list should include any tokens found after any error(s) in the input, i.e., scanning should continue after discovering an error. 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 should remove it from the exam and use it for reference while you answer this question. You should assume that the scanner processes MiniJava syntax as defined in that grammar, with no extensions or changes to the language. Also recall that the MiniJava project defines an <IDENTIFIER> as a sequence of letters, digits, and underscores, starting with a letter, and uppercase letters are distinguished (different) from lowercase; and an <INTEGER\_LITERAL> is a sequence of decimal digits not starting with 0, or the number 0 by itself, denoting a decimal integer value.

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**Question 3.** (12 points) Ambiguity. We've been hired by the departments of tourism of the Carolinas and the Dakotas to write a grammar to generate slogans to attract visitors to their states. Below is a grammar that our Grammar Committee came up with in response to the request:

$$\begin{aligned} G &::= \text{Visit } A D P \mid \text{Visit } D P \\ A &::= \text{Spectacular} \mid \text{Wonderful} \mid \text{Scenic} \\ D &::= \text{North} \mid \text{South} \\ P &::= \text{Dakota} \mid \text{Carolina} \end{aligned}$$

Notes: whitespace in the grammar is only for readability and is not part of the grammar or the strings generated by it. Each of the words like `Wonderful` in a grammar production should be treated as a single terminal symbol, not as individual letters.

(a) (5 points) Give a rightmost derivation of the sentence `Visit Scenic South Dakota`.

(b) (7 points) Is this grammar ambiguous? If so, give a proof that it is by showing two distinct leftmost derivations for some string generated by the grammar. If not, give an informal, but precise, argument why it is not ambiguous.

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**Question 4.** (36 points) The “OMG! Not this again!!” parsing question. Consider the following grammar. The nonterminal  $C$  is the start symbol of the grammar, and the extra  $C' ::= C \$$  rule needed to handle end-of-file in an LR parser has been added for you.

- |                  |             |                |
|------------------|-------------|----------------|
| 0. $C' ::= C \$$ | (\$ is EOF) | 3. $S ::= y C$ |
| 1. $C ::= S e$   |             | 4. $S ::= z$   |
| 2. $C ::= x$     |             |                |

(a) (16 points) Draw the LR(0) state machine for this grammar. When you finish, you should number the states in the final diagram in whatever order you wish so that you can use the state numbers in later parts of this question. The state numbers should be successive integers starting with 0, 1, 2, 3, ....

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**Question 4.** (cont.) Grammar repeated from previous page for reference:

- |                                 |                |
|---------------------------------|----------------|
| 0. $C' ::= C \$$ ( $\$$ is EOF) | 3. $S ::= y C$ |
| 1. $C ::= S e$                  | 4. $S ::= z$   |
| 2. $C ::= x$                    |                |

(b) (8 points) Write the LR(0) parser table for the LR parser DFA shown in your answer to part (a). To save time, an empty table is provided below. However, it probably has more rows than you need. Use only as many rows as needed and leave the rest blank.

State #	e	x	y	z	\$	C	S
0							
1							
2							
3							
4							
5							
6							
7							
8							
9							
10							
11							
12							
13							
14							
15							

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**Question 4.** (cont.) Grammar repeated from previous pages for reference:

- |                  |             |                |
|------------------|-------------|----------------|
| 0. $C' ::= C \$$ | (\$ is EOF) | 3. $S ::= y C$ |
| 1. $C ::= S e$   |             | 4. $S ::= z$   |
| 2. $C ::= x$     |             |                |

(c) (3 points) Is this grammar LR(0)? Explain why or why not. Your answer should describe **all** of the problems that exist if the grammar is not LR(0) by identifying the relevant state number(s) in your answers to parts (a) and (b) and the specific issues in those state(s) (i.e., something like “state 47 has a shift-reduce conflict if the next input is blah”, but with, of course, correct state numbers and details from your parser). If the grammar is LR(0), you should give a technical explanation why it is (this can be brief).

(d) (6 points) Complete the following table showing the FIRST and FOLLOW sets and nullable for each of the nonterminals in this grammar. You should include \$ (the end-of-file marker) in the FOLLOW set for any nonterminal where it is appropriate.

	FIRST	FOLLOW	nullable
$C$			
$S$			

(e) (3 points) Is this grammar SLR? Give a brief technical explanation why or why not.



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**Question 5.** (8 points) Top-down parsing. Take another look at the grammar from the previous problem, but omitting the  $C' ::= C \$$  rule that was added for LR parsing:

- |                |                |
|----------------|----------------|
| 1. $C ::= S e$ | 3. $S ::= y C$ |
| 2. $C ::= x$   | 4. $S ::= z$   |

(Recall that  $C$  is the start symbol for this grammar.)

Is this grammar suitable for constructing a top-down LL(1) predictive parser? If so, explain why. If not, explain why not, and, if possible, construct a different grammar that generates the same language that is suitable for a top-down LL(1) predictive parser, or explain why this can't be done.

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**Question 6.** (14 points) Semantics. Suppose we have the following statement in a MiniJava program:

```
a[s.gen().foo(x+y)] = y;
```

(a) (7 points) At the bottom of this page, draw an abstract syntax tree (AST) for this assignment statement. You should use appropriate names for the AST nodes, and have an appropriate level of abstraction and structural detail similar to the AST nodes in the MiniJava project AST classes, but don't worry about matching the exact names or details of classes or nodes found in the MiniJava starter code.

(b) (7 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 errors. If a particular check or 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. You may assume that `int` is the only numeric type in MiniJava, but remember that MiniJava also has `boolean` and `object` (class) types.

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**Question 7.** (2 free points) (All reasonable answers receive the points. All answers are reasonable as long as there is an answer. 😊)

(a) (1 point) What question were you expecting to appear on this exam that wasn't included?

(b) (1 points) Should we include that question on the final exam? (circle or fill in)

Yes

No

Heck No!!

\$!@\$^\*% No !!!!!

Yes, yes, it *must* be included!!!

No opinion / don't care

None of the above. My answer is \_\_\_\_\_.

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**Extra space for answers, if needed.** Please be sure to label which question(s) are answered here, and be sure to put a note on the question page so the grader will know to look here.