

COMS W4115

Programming Languages and Translators

Homework Assignment 2

Prof. Ronghui Gu Due March 11th, 2019
Columbia University at 11:59PM PM

Submit your assignment as a single PDF file on Courseworks with the code for Problem 1 as a zip.

Do this assignment alone. You may consult the instructor or a TA, but not other students. You may not consult solutions from earlier semesters. **Since the amount of time before the deadline is closer than we originally intended, only your best 80pts will count towards your grade.**

1. **20pt** Extend the three-slide “calculator” example shown in the OCaml slides (the source is also available on the class website) to accept variables named with identifiers consisting of lowercase letters, assignment to those variables, and sequencing using the “;” operator. For example,

```
foo = 3; bar = baz = 6; foo * bar + baz
```

should print “24”

Use a string-to-integer Map to track variable variables. Add tokens to the parser and scanner for representing assignment, sequencing, and variable names.

The ocamllex rule for the variable names, which converts the letters a–z into the corresponding literals, is

```
| ['a'-'z']+ as id { VARIABLE(id) }
```

The new ast.mli file is

```
type operator = Add | Sub | Mul | Div
type expr =
  Binop of expr * operator * expr
  | Lit of int
  | Seq of expr * expr
  | Asn of string * expr
  | Var of string
```

Make sure your code compiles without warnings

2. **10pt** Write a regular expression for floating constants according to the following (after K&R):

A floating constant consists of an integer part, a decimal point, a fraction part, an e or an E, and

an optionally signed integer exponent. The integer and fraction parts both consist of a sequence of digits. Either the integer part, or the fraction part (not both) may be missing; either the decimal point or the e/E and the exponent (not both) may be missing.

Hint: make sure your regular expression accepts floating constants such as 1. 0.5e-15 .3E+3 .2 1e5 3.5E-4 but not integer constants such as 42

3. **10pt** Draw a DFA for a scanner that recognizes and distinguishes the following set of keywords. Draw accepting states with double lines and label them with the name of the keyword they accept. Follow the definition of a DFA given in class.

fun function a let asp open full fell operator

4. **20pt** Construct nondeterministic finite automata for the following regular expressions using Thompson’s algorithm (Algorithm 3.23, p. 159, also shown in class), then use the subset construction algorithm to construct DFAs for them using Algorithm 3.20 (p. 153, also shown in class).

- (a) $a a^* b$
- (b) $(ab | b)^* a$
- (c) $((a | e) ba)^*$

Number the NFA states; use the numbers to label DFA states while performing subset construction, e.g., like Figure 3.35 (p. 155).

5. **20pt** Using this grammar, whose three terminals are a , b , and c ,

$$\begin{aligned} E &\rightarrow a F b \\ E &\rightarrow c \\ F &\rightarrow E a F \\ F &\rightarrow E \end{aligned}$$

- (a) Construct a rightmost derivation for $aacacbb$ and show the handle of each right-sentential form.

- (b) Show the steps of a shift-reduce (bottom-up) parser corresponding to this rightmost derivation.
- (c) Show the concrete parse tree that would be constructed during this shift-reduce parse.
6. **20pt** Build the LR(0) automaton for the following ambiguous grammar. **if**, **else**, and **null** are terminals; the third rule indicates T may be the empty string. Indicate the state in which the shift/reduce conflict appears.

$$\begin{aligned}
 S' &\rightarrow S \\
 S &\rightarrow \mathbf{if} S T \\
 S &\rightarrow \mathbf{null} \\
 T &\rightarrow \\
 T &\rightarrow \mathbf{else} S
 \end{aligned}$$

Check your work by running “ocamlyacc -v” on the grammar below and looking through the “.output” file. Include annotated snippets from the .output file that confirm your answer.

```

%token IF ELSE NULL
%start s
%type <int>s

%%

s : IF s t    { 0 }
  | NULL      { 0 }

t : /* empty */ { 0 }
  | ELSE s      { 0 }

```

Acknowledgment

The assignment is implemented by Ryan Bernstein TA for COMS W4115 Programming Languages and Translators, Spring 2019, Columbia University, based on the materials designed by Prof. Stephen A. Edwards.