COS 320: Spring 2017 Midterm Examination

March 16, 2017

Name: _____

You have 1:20 to answer the following questions. This midterm is closed book/closed notes. For partial credit, show all work. Write your name on the bottom of every page. Write out and sign the Honor Code pledge below before turning in the test.

"I pledge my honor that I have not violated the Honor Code during this examination."

Problem 1: (20%)
Do the following:

A: For the alphabet a, b, c, give a compact regular expression for all strings containing exactly one a.

B: If a *Deterministic Finite Automaton* (DFA) exists for your regular expression, show one. If a DFA cannot exist, explain why not. Transitions can be labeled with any number of symbols (understood as an alternation of symbols written as "a,b,c" or "[a-c]"), but cannot otherwise contain regular expressions. Minimize the number of states.

Problem 2: (35%)
Consider the following grammar:

$A \rightarrow B$
$B \rightarrow$ x
$B \rightarrow$ x B
$B \rightarrow$ y

A: Is this grammar in LL(1)? Prove it.

B: Is this grammar in LR(1)? Prove it.

C: Is this grammar in SLR? Prove it.

D: Is this grammar in LR(0)? Prove it.

E: Is this grammar in LALR(1)? Prove it.

Problem 3: (20%)

Consider the FUN language from the lectures on typing, as summarized below.

$$
\begin{array}{rcl}
f & ::= & \textbf{fun}\ f(id : \tau_0) : \tau_1\ =\ e \\
e & ::= & (e) \mid id \mid num \mid e_0; e_1 \mid e_0 \oplus e_1 \mid\ \ominus e \mid \langle e_0, \ldots, e_n \rangle \mid e_0(e_1) \\
 & & \mid e : \tau \mid \textbf{if}\ e_0\ \textbf{then}\ e_1\ \textbf{else}\ \ e_2 \mid \textbf{if}\ e_0\ \textbf{then}\ e_1 \mid \textbf{while}\ e_0\ \textbf{do}\ e_1 \\
 & & \mid \textbf{let}\ id = e_0\ \textbf{in}\ e_1 \mid \textbf{ref}\ e \\
\oplus & ::= & + \mid -\ \mid *\ \mid \&\mid \mid\mid \mid <\ \mid =\ \mid := \\
\ominus & ::= & - \mid \textbf{not} \mid\ ! \mid \#i \\
\tau & ::= & \textbf{int} \mid \langle \tau_0, \ldots, \tau_n \rangle \mid \tau_0 \to \tau_1 \mid \tau\ \textbf{ref} \mid (\tau)
\end{array}
$$

$$\frac{}{\Gamma \vdash id : \Gamma(id)}\, ID \qquad \frac{n \in \{\ldots, -1, 0, 1, \ldots\}}{\Gamma \vdash n : \textbf{int}}\, NUM$$

$$\frac{\Gamma \vdash e_1 : \textbf{int} \quad \Gamma \vdash e_2 : \tau \quad \Gamma \vdash e_3 : \tau}{\Gamma \vdash \textbf{if}\ e_1\ \textbf{then}\ e_2\ \textbf{else}\ \ e_3 : \tau}\, ITE$$

$$\frac{\Gamma \vdash e_1 : \sigma \quad \Gamma[x : \sigma] \vdash e_2 : \tau}{\Gamma \vdash \textbf{let}\ x = e_1\ \textbf{in}\ e_2 : \tau}\, LET \qquad \frac{\Gamma \vdash e_1 : \tau\ \textbf{ref} \qquad \Gamma \vdash e_2 : \tau}{\Gamma \vdash e_1 := e_2 : \langle\rangle}\, WRITE$$

$$\frac{\Gamma \vdash e : \tau}{\Gamma \vdash \textbf{ref}\ (e : \tau) : \tau\ \textbf{ref}}\, REF \qquad \frac{\Gamma \vdash e : \langle \tau_0, \ldots, \tau_n \rangle \quad (0 <= i <= n)}{\Gamma \vdash \#i\ e : \tau_i}\, TUP$$

$$\frac{\Gamma[x : \tau_1][f : \tau_1 \to \tau_2] \vdash e : \tau_2}{\Gamma \vdash \textbf{fun}\ f(x : \tau_1) : \tau_2\ =\ e : \tau_1 \to \tau_2}\, FUNC$$

For the given function declaration *foo, perform the type checking proof.*

$$\textbf{fun}\ foo(y : \langle \textbf{int ref}, \textbf{int}, \textbf{int} \rangle) : \langle\rangle\ =$$

$$\textbf{if}\ (\#1\ y)\ \textbf{then let}\ x = \textbf{ref}\ 3\ \textbf{in}\ x\ :=\ \#2\ y\ \textbf{else}\ \#0\ y\ :=\ 5$$

Problem 4: (10%)

Write an ambigiuous grammer and prove that it is ambiguous.

Problem 5: (15%)

For each of the listed errors, specify the error type (Lexical, Syntactic, Semantic) and name the compiler phase likely to find the error. Include a short justification of no more than 2 sentences. State assumptions.

- *A hexadecimal number contains the letter G.*

- *A function call has too many arguments.*

- *"else if" in a language that requires "elif".*

- *A nested function in a language that does not support nested functions.*

- *A space between ">" and "=".*