Solutions to the 2003 Sample Exam for CSE3322

Question 1

(a) 3
(b) 3
(c) 5, the value is `~1`
(d) 3
(e) 5, used to hide the definition of a datatype
(f) 2
(g) 1
(h) 5, it will return $V = c, W = a$
(i) 3
(j) 5, 22 will be written
(k) 3
(l) 3
(m) 5
(n) 4
(o) 4.

Question 2

```
fun digitToString i = str (chr (i + ord(#"0")));
( * or
fun digitToString 0 = "0"
 |  digitToString 1 = "1"
 |  digitToString 2 = "2"
 |  digitToString 3 = "3"
 |  digitToString 4 = "4"
 |  digitToString 5 = "5"
 |  digitToString 6 = "6"
 |  digitToString 7 = "7"
 |  digitToString 8 = "8"
 |  digitToString 9 = "9" ;* )

fun posIntToString i =
  if i < 10 then digitToString i
  else (posIntToString (i div 10))^
       (digitToString (i mod 10));

fun intToString i =
  if i < 0 then "~"^posIntToString (~i)
  else posIntToString i;
```

Question 3

```
datatype FS = File of string * (char list)
           | Directory of string * (FS list)

fun name (File(n,_)) = n^" "
  | name (Directory(n,_)) = n^" "

fun ls (Directory(_,cs)) = concat (map name cs)
  | ls f = name f
```

Question 4

(a) Call-by-name parameter passing works by textually replacing the formal parameters in the abstraction body by the actual parameters.

(b) Algol 60 and C macros both use call by name parameter passing.

(c) It isn't used because it is hard to understand behavior of imperative programs (i.e. programs which update variable values.) As an example consider the program from the lecture notes

```
void swap(int x, y)
{
int t;
t := x; x := y; y := t;
}
```

which has strange behaviour with the call `swap(i,a[i])`.

Question 5

(a)

$$
\begin{aligned}
&FIRST(S) = FIRST(X) + \{d, \epsilon\} = \{a, c, d, e, \epsilon\} \\
&FIRST(X) = FIRST(Y) + FIRST(Z) + \{a\} = \{a, c, e\} \\
&FIRST(Y) = \{c\} \\
&FIRST(Z) = \{e\} \\
&FOLLOW(S) = \{\$\} \\
&FOLLOW(X) = FIRST(S) - \{\epsilon\} + FOLLOW(S) = \{a, c, d, e, \$\} \\
&FOLLOW(Y) = FOLLOW(X) = \{a, c, d, e, \$\} \\
&FOLLOW(Z) = \{b\} + FOLLOW(Y) = \{a, b, c, d, e, \$\}
\end{aligned}
$$

(b) The parsing table is:

	a	b	c	d	e	$
S	P1		P1	P2	P1	P3
X	P6		P4		P5	
Y			P7			
Z					P8	

the productions are numbered in their original order:

$$
\begin{array}{llll}
(1) & S & \rightarrow & X\ S \\
(2) & S & \rightarrow & d\ S \\
(3) & S & \rightarrow & \epsilon \\
(4) & X & \rightarrow & Y \\
(5) & X & \rightarrow & Z\ b \\
(6) & X & \rightarrow & a\ Y \\
(7) & Y & \rightarrow & c\ Z \\
(8) & Z & \rightarrow & e
\end{array}
$$

(c) Yes, the table shows no conflicts.

(d) The parsing for *dace* proceeds as follows:

$S\$$	$dace\$$	$P2$
$dS\$$	$dace\$$	adv
$S\$$	$ace\$$	$P1$
$XS\$$	$ace\$$	$P6$
$aYS\$$	$ace\$$	adv
$YS\$$	$ce\$$	$P7$
$cZS\$$	$ce\$$	adv
$ZS\$$	$e\$$	$P8$
$eS\$$	$e\$$	adv
$S\$$	$\$$	$P3$
$\$$	$\$$	$accept$

Question 6

(a) The parser would not be able to decide which of the productions $X \to Y$ or $X \to Z\ b$ to use when trying to expand an X.

(b) The productions from (a) need to be modified such that they use distinct lookahead. This is done by "unfolding" the productions for Y and Z into those for X. The modified grammar is:

$$\begin{array}{lcl} S & \to & X\ S \ \mid\ d\ S \ \mid\ \epsilon \\ X & \to & c\ Z \ \mid\ e\ b \ \mid\ a\ c\ Z \\ Z & \to & e \end{array}$$

Note that you could also expand the Z production into X completely.

$$\begin{array}{lcl} S & \to & X\ S \ \mid\ d\ S \ \mid\ \epsilon \\ X & \to & c\ e \ \mid\ e\ b \ \mid\ a\ c\ e \end{array}$$

Question 7

(a)

The collection of sets of LR(0) items is constructed as follows:

$$
\begin{array}{lcl}
I_0 & = & \{ \\
 & & S' \rightarrow \cdot S \\
 & & S \rightarrow \cdot a\ X \\
 & & \} \\
goto(I_0, S) & = & I_1 \\
 & = & \{ \\
 & & S' \rightarrow S \cdot \\
 & & \} \\
goto(I_0, a) & = & I_2 \\
 & = & \{ \\
 & & S \rightarrow a \cdot X, \\
 & & X \rightarrow \cdot b\ X, \\
 & & X \rightarrow \cdot b\ Y, \\
 & & \} \\
goto(I_2, X) & = & I_3 \\
 & = & \{ \\
 & & S \rightarrow a\ X \cdot \\
 & & \} \\
goto(I_2, b) & = & I_4 \\
 & = & \{ \\
 & & X \rightarrow b \cdot X \\
 & & X \rightarrow b \cdot Y \\
 & & X \rightarrow \cdot b\ X, \\
 & & X \rightarrow \cdot b\ Y, \\
 & & Y \rightarrow \cdot c, \\
 & & \} \\
goto(I_4, X) & = & I_5 \\
 & = & \{ \\
 & & X \rightarrow b\ X \cdot \\
 & & \} \\
goto(I_4, Y) & = & I_6 \\
 & = & \{ \\
 & & X \rightarrow b\ Y \cdot \\
 & & \} \\
goto(I_4, c) & = & I_7 \\
 & = & \{ \\
 & & Y \rightarrow c \cdot \\
 & & \}
\end{array}
$$

(b) $FOLLOW(S) = FOLLOW(X) = FOLLOW(Y) = \{\$\}$.
The SLR table is

state	action				goto		
	a	b	c	$	S	X	Y
0	s2				1		
1				accept			
2		s4				3	
3				r1			
4		s4	s7			5	6
5				r2			
6				r3			
7				r4			

Productions are again numbered in their order in the augmented grammar:

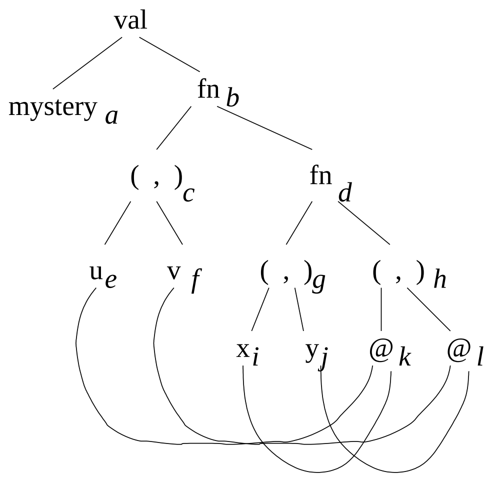
$$
\begin{array}{llll}
(0) & S' & \rightarrow & S \\
(1) & S & \rightarrow & a\ X \\
(2) & X & \rightarrow & b\ X \\
(3) & X & \rightarrow & b\ Y \\
(4) & Y & \rightarrow & c
\end{array}
$$

(c)

STACK	INPUT	ACTION
0	$a\ b\ b\ c$ $	shift 2
0 a 2	$b\ b\ c$ $	shift 4
0 a 2 b 4	$b\ c$ $	shift 4
0 a 2 b 4 b 4	c $	shift 7
0 a 2 b 4 b 4 c 7	$	reduce 4, goto 6
0 a 2 b 4 b 4 Y 6	$	reduce 3, goto 5
0 a 2 b 4 X 5	$	reduce 2, goto 3
0 a 2 X 3	$	reduce 1, goto 1
0 S 1	$	accept

Question 8

(a) Give its syntax tree and assign a type variable to each subexpression.



(b) Generate a set of type equations (or constraints) on the type variables based on the annotated syntax tree from (a)

$$
\begin{array}{ll}
a = b & \text{val} \\
c = e \times f & \text{tuple creation} \\
h = k \times l & \text{tuple creation} \\
g = i \times j & \text{tuple creation} \\
e = i \to k & \text{function application} \\
f = j \to l & \text{function application} \\
b = c \to d & \text{function definition} \\
d = g \to h & \text{function definition}
\end{array}
$$

(c) Solve the type equations from (b) and give the type for `mystery`.

After solving we end up with

$$a = ((i \to k) \times (j \to l)) \to (i \times j) \to (k \times l)$$