School of Mathematical and Computational Sciences

Indian Association for the Cultivation of Science

Compiler Construction: COM 5202

Tutorial IX (18 March 2026)

M. Sc Semester IV: 2025-2026 *Instructor:* Goutam Biswas

Exercise 1.

(a) *Consider the following grammar of strings over* $\Sigma = \{0, 1\}$.

$$\begin{array}{lrcl} 1: & N & \to & L \\ 2: & L & \to & L\ B \\ 3: & L & \to & B \\ 4: & B & \to & 0 \\ 5: & B & \to & 1 \end{array}$$

Define appropriate attributes of non-terminals and give an attribute grammar to interpret the string as 2's complement numeral.

(b) *Draw the parse tree for "11011", and decorate it with the values of attributes at every node.*

Exercise 2. *Consider the grammar* $G = (\{i, f, v\}, \{D, ID, FD, IS, FS, IV, FV\}, P, D)$, *where the production rules are the following:*

$$\begin{array}{rrcl} 1: & D & \to & ID \\ 2: & D & \to & FD \\ 3: & ID & \to & IS\ i \\ 4: & FD & \to & FS\ f \\ 5: & IS & \to & IS\ IV \\ 6: & IS & \to & IV \\ 7: & FS & \to & FS\ FV \\ 8: & FS & \to & FV \\ 9: & IV & \to & v \\ 10: & FV & \to & v \end{array}$$

(a) *Justify that the grammar is not* $LR(1)$.

(b) *Is it* $LR(k)$ *for any* $k \in \mathbb{N}$?

(c) *Can you modify the grammar to an equivalent* $LALR(1)$ *grammar that is not* $LR(0)$?

(d) *Is there an equivalent* $LR(0)$ *grammar?*

Exercise 3. *Consider the following grammar* G_3 *with* E *as the start symbol.*

$$\begin{array}{lcl} E & \to & E\ -\ T \mid T \\ T & \to & T\ /\ F \mid F \\ F & \to & ic \mid (\ E\ ) \end{array}$$

We have removed the left-recursion from G_3 and introduced four more non-terminals M_1, M_2, M_3, M_4 to obtain the following grammar G_{3a}.

$$
\begin{array}{rcl}
E & \rightarrow & T\ M_1\ E' \\
M_1 & \rightarrow & \varepsilon \\
E' & \rightarrow & -\ T\ M_2\ E' \mid \varepsilon \\
M_2 & \rightarrow & \varepsilon \\
T & \rightarrow & F\ M_3\ T' \\
M_3 & \rightarrow & \varepsilon \\
T' & \rightarrow & /\ F\ M_4\ T' \mid \varepsilon \\
M_4 & \rightarrow & \varepsilon \\
F & \rightarrow & ic \mid (\ E\ )
\end{array}
$$

(a) *Compute First and Follows of different non-terminals of G_{3a}.*

(b) *The grammar G_{3a} is augmented with the special start symbol S and the rule $S \rightarrow E\ \$$. The new grammar is G_{3b}.*

$$
\begin{array}{rcl}
0: S & \rightarrow & E\ \$ \\
1: E & \rightarrow & T\ M_1\ E' \\
2: M_1 & \rightarrow & \varepsilon \\
3: E' & \rightarrow & -\ T\ M_2\ E' \\
4: E' & \rightarrow & \varepsilon \\
5: M_2 & \rightarrow & \varepsilon \\
6: T & \rightarrow & F\ M_3\ T' \\
7: M_3 & \rightarrow & \varepsilon \\
8: T' & \rightarrow & /\ F\ M_4\ T' \\
9: T' & \rightarrow & \varepsilon \\
10: M_4 & \rightarrow & \varepsilon \\
11: F & \rightarrow & ic \\
12: E & \rightarrow & (\ E\ )
\end{array}
$$

The $LR(0)$ automaton

$q_0:$	$S \to \bullet E\$$	$E \to \bullet T M_1 E'$	$T \to \bullet F M_3 T'$
	$F \to \bullet ic$	$F \to \bullet (E)$	
$q_1:$	$S \to E \bullet \$$		
$q_2:$	$E \to T \bullet M_1 E'$	$M_1 \to \varepsilon$	
$q_3:$	$T \to F \bullet M_3 T'$	$M_3 \to \varepsilon$	
$q_4:$	$F \to ic\bullet$		
$q_5:$	$F \to (\bullet E)$	$E \to \bullet T M_1 E'$	$T \to \bullet F M_3 T'$
	$F \to \bullet ic$	$F \to \bullet (E)$	
$q_6:$	$S \to E\$\bullet$		
$q_7:$	$E \to T M_1 \bullet E'$	$E' \to \bullet - T M_2 E'$	$E' \to \bullet$
$q_8:$	$T \to F M_3 \bullet T'$	$T' \to \bullet / F M_4 T'$	$T' \to \bullet$
q_9	$F \to (E\bullet)$		
$q_{10}:$	$E \to T M_1 E'\bullet$		
$q_{11}:$	$E' \to - \bullet T M_2 E'$	$T \to \bullet F M_3 T'$	$F \to \bullet ic$
	$F \to \bullet (E)$		
$q_{12}:$	$T \to F M_3 T'\bullet$		
$q_{13}:$	$T' \to / \bullet F M_4 T'$	$F \to \bullet ic$	$F \to \bullet (E)$
$q_{14}:$	$F \to (E)\bullet$		
$q_{15}:$	$E' \to -T \bullet M_2 E'$	$M_2 \to \bullet$	
$q_{16}:$	$T' \to /F \bullet M_4 T'$	$M_4 \to \bullet$	
q_{17}	$E' \to -T M_2 \bullet E'$	$E' \to \bullet - T M_2 E'$	$E' \to \bullet$
$q_{18}:$	$T' \to /F M_4 \bullet T'$	$T' \to \bullet / F M_4 T'$	$T' \to \bullet$
$q_{19}:$	$E' \to -T M_2 E'\bullet$		
$q_{20}:$	$T' \to /F M_4 T'\bullet$		

The $SLR(1)$ parsing table

State	*Action*						*Goto*								
	$-$	$/$	*ic*	(	)	\$	E	T	F	E'	T'	M_1	M_2	M_3	M_4
q_0	$-$	$-$	s_4	s_5	$-$	$-$	1	2	3	$-$	$-$	$-$	$-$	$-$	$-$
q_1	$-$	$-$	$-$	$-$	$-$	A	$-$	$-$	$-$	$-$	$-$	$-$	$-$	$-$	$-$
q_2	r_2	$-$	$-$	$-$	r_2	r_2	$-$	$-$	$-$	$-$	$-$	7	$-$	$-$	$-$
q_3	r_7	r_7	$-$	$-$	r_7	r_7	$-$	$-$	$-$	$-$	$-$	$-$	$-$	8	$-$
q_4	r_{11}	r_{11}	$-$	$-$	r_{11}	r_{11}	$-$	$-$	$-$	$-$	$-$	$-$	$-$	$-$	$-$
q_5	$-$	$-$	s_4	s_5	$-$	$-$	9	2	3	$-$	$-$	$-$	$-$	$-$	$-$
q_6	$-$	$-$	$-$	$-$	$-$	$-$	$-$	$-$	$-$	$-$	$-$	$-$	$-$	$-$	$-$
q_7	s_{11}	$-$	$-$	$-$	r_4	r_4	$-$	$-$	$-$	10	$-$	$-$	$-$	$-$	$-$
q_8	r_9	s_{13}	$-$	$-$	r_9	r_9	$-$	$-$	$-$	$-$	12	$-$	$-$	$-$	$-$
q_9	$-$	$-$	$-$	$-$	s_{14}	$-$	$-$	$-$	$-$	$-$	$-$	$-$	$-$	$-$	$-$
q_{10}	$-$	$-$	$-$	$-$	r_1	r_1	$-$	$-$	$-$	$-$	$-$	$-$	$-$	$-$	$-$
q_{11}	$-$	$-$	s_4	s_5	$-$	$-$	$-$	15	3	$-$	$-$	$-$	$-$	$-$	$-$

State	*Action*						*Goto*								
	$-$	$/$	*ic*	(	)	\$	E	T	F	E'	T'	M_1	M_2	M_3	M_4
q_{12}	r_6	$-$	$-$	$-$	r_6	r_6	$-$	$-$	$-$	$-$	$-$	$-$	$-$	$-$	$-$
q_{13}	$-$	$-$	s_4	s_5	$-$	$-$	$-$	$-$	16	$-$	$-$	$-$	$-$	$-$	$-$
q_{14}	r_{12}	r_{12}	$-$	$-$	r_{12}	r_{12}	$-$	$-$	$-$	$-$	$-$	$-$	$-$	$-$	$-$
q_{15}	r_5	$-$	$-$	$-$	r_5	r_5	$-$	$-$	$-$	$-$	$-$	$-$	17	$-$	$-$
q_{16}	r_{10}	r_{10}	$-$	$-$	r_{10}	r_{10}	$-$	$-$	$-$	$-$	$-$	$-$	$-$	$-$	18
q_{17}	s_{11}	$-$	$-$	$-$	r_4	r_4	$-$	$-$	$-$	19	$-$	$-$	$-$	$-$	$-$
q_{18}	r_9	s_{13}	$-$	$-$	r_9	r_9	$-$	$-$	$-$	$-$	20	$-$	$-$	$-$	$-$
q_{19}	$-$	$-$	$-$	$-$	r_3	r_3	$-$	$-$	$-$	$-$	$-$	$-$	$-$	$-$	$-$
q_{20}	r_8	$-$	$-$	$-$	r_8	r_8	$-$	$-$	$-$	$-$	$-$	$-$	$-$	$-$	$-$

(c) *Associate bison rules with the production rules of the grammar (no type-tag is needed).*

(d) *Parse and take semantic action for the input* $5 - 2 - 1$ *and* $5 - 4/2$.