

1.  $E \rightarrow E_{1 \text{ or } 8} +_6 T_9$
2.  $E \rightarrow T_2$
3.  $T \rightarrow T_{2 \text{ or } 9} *_7 F_{10}$
4.  $T \rightarrow F_3$
5.  $F \rightarrow ({}_4 E_8)_{11}$
6.  $F \rightarrow \text{id}_5$

	id	+	*	(	)	eof	E	T	F
0									
1									
2									
3									
4									
5									
6									
7									
8									
9									
10									
11									

**ACTION**
**GOTO**

Figure 1: Grammar  $G_1$  and an LALR Parser for that Grammar

The action of an LALR parser for grammar  $G_1$  on the string  $(x+y*z)*x$

0:(x+y*z)*x\$	0(4E8+6T9*7z5:)*x\$
s4	r6, goto 10
0(4:x+y*z)*x\$	0(4E8+6T9*7F10:)*x\$
s5	r3, goto 9
0(4x5:+y*z)*x\$	0(4E8+6T9:)*x\$ T->T*F
r6, goto 3	r1, goto 8
0(4F3:+y*z)*x\$ F->x	0(4E8:)*x\$ E->E+T
r4, goto 2	s11
0(4T2:+y*z)*x\$ T->F	0(4E8)11:*x\$
r2, goto 8	r5, goto 3
0(4E8:+y*z)*x\$ E->T	0F3:*x\$ F->(E)
s6	r4, goto 2
0(4E8+6:y*z)*x\$	0T2:*x\$ T->F
s5	s7
0(4E8+6y5:*z)*x\$	0T2*7:x\$
r6, goto 3	s5
0(4E8+6F3:*z)*x\$ F->y	0T2*7x5:\$
r4, goto 9	r6, goto 10
0(4E8+6T9:*z)*x\$ T->F	0T2*7F10:\$
s7	r3, goto 2
0(4E8+6T9*7:z)*x\$	0T2:\$
s5	r2, goto 1
	0E1:\$
	halt

Let  $G_2$  be the following ambiguous grammar, which illustrates the “dangling else” problem. The Parser table has a shift-reduce conflict, which we resolve using the “closest if” rule. Informally, the alphabet symbols have the following meanings:

- S** statement
- L** list of statements
- a** statement with no control structure
- w** while condition
- i** if condition
- e** else
- b** begin
- n** end

1.  $S \rightarrow a_2$
2.  $S \rightarrow w_3 S_4$
3.  $S \rightarrow i_5 S_6$
4.  $S \rightarrow i_5 S_6 e_7 S_8$
5.  $S \rightarrow b_9 L_{10} n_{11}$
6.  $L \rightarrow L_{10} S_{12}$
7.  $L \rightarrow \text{epsilon}$

	a	w	i	e	b	n	eof	S	L
0									
1							halt		
2									
3									
4									
5									
6									
7									
8									
9									
10									
11									
12									

ACTION                      GOTO

**Figure 2:**  $G_2$  and its LALR Parser Table, to Fill in

We can avoid the conflict by choosing an unambiguous context-free grammar equivalent to  $G_2$ , namely  $G_3$  below.

1.  $S \rightarrow M_2$
2.  $S \rightarrow U_3$
3.  $M \rightarrow a_4$
4.  $M \rightarrow w_5 M_6$
5.  $U \rightarrow w_5 U_7$
6.  $U \rightarrow i_8 S_9$
7.  $M \rightarrow i_8 M_2 e_{10} M_{11}$
8.  $U \rightarrow i_8 M_2 e_{10} U_{12}$
9.  $M \rightarrow b_{13} L_{14} n_{15}$
10.  $L \rightarrow L_{14} S_{16}$
11.  $L \rightarrow \text{epsilon}$

Informally, the alphabet symbols have the following meanings:

- S** statement
- M** matched statement
- U** unmatched statement
- L** list of statements
- a** statement with no control structure
- w** while condition
- i** if condition
- e** else
- b** begin
- n** end

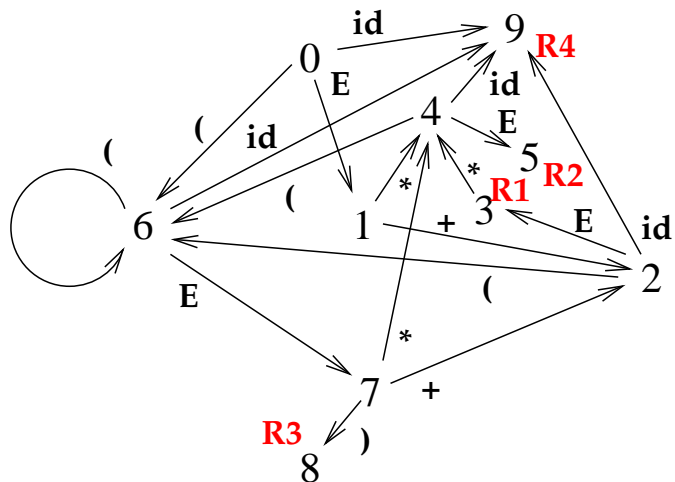
	a	w	i	e	b	n	eof	S	M	U	L
0	s4	s5	s8		s13			1	2	3	
1							halt				
2	r1	r1	r1	s10	r1	r1	r1				
3	r2	r2	r2		r2	r2	r2				
4	r3	r3	r3	r3	r3	r3	r3				
5	s4	s5	s8		s13				6	7	
6	r4	r4	r4	r4	r4	r4	r4				
7	r5	r5	r5		r5	r5	r5				
8	s4	s5	s8		s13			9	2	3	
9	r6	r6	r6		r6	r6	r6				
10		s5	s8		s13				11	12	
11	r7	r7	r7	r7	r7	r7	r7				
12	r8	r8	r8		r8	r8	r8				
13	r11	r11	r11		r11	r11					14
14	s4	s5	s8		s13	s15		16	2	3	
15	r9	r9	r9	r9	r9	r9	r9				
16	r10	r10	r10		r10	r10					

ACTION

GOTO

**Figure 3:** LALR Parser Table for the Unambiguous Grammar  $G_3$

1.  $E \rightarrow E_{1 \text{ or } 7} +_2 E_3$
2.  $E \rightarrow E_{1 \text{ or } 3 \text{ or } 7} *_4 E_5$
3.  $E \rightarrow ({}_6 E_7)_8$
4.  $E \rightarrow \text{id}_9$



	id	+	*	(	)	eof	E
0							
1							
2							
3							
4							
5							
6							
7							
8							
9							
	ACTION					GOTO	

Figure 4: LALR Parser Table for an Ambiguous Grammar Equivalent to  $G_1$