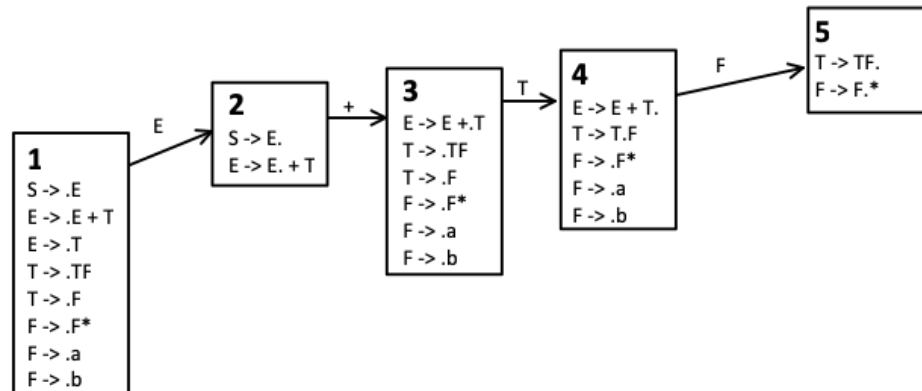


1.

- a.
- $\text{first}(H) = \{h\}$
 - $\text{first}(E) = \{e, \epsilon\}$
 - $\text{first}(B) = \{b, g\}$
 - $\text{first}(F) = \{f\} + \text{first}(E) + \text{first}(H) = \{f, e, h, \epsilon\}$
 - $\text{first}(A) = \text{first}(B) + \text{first}(F) = \{b, g, f, e, h, \epsilon\}$
- $\text{follow}(A) = \{\$, c\}$
- $\text{follow}(B) = \text{first}(A) = \{b, g, f, e, h\}$
- $\text{follow}(E) = \text{follow}(A) + \text{first}(F) + \text{first}(H) = \{\$, c, f, e, h\}$
- $\text{follow}(F) = \text{first}(E) + \text{follow}(B) + \text{follow}(A) = \{\$, e, b, g, f, h, c\}$
- $\text{follow}(H) = \text{follow}(F) = \{\$, e, b, g, f, h, c\}$
- b.
- $\text{first}(C) = \{h, \epsilon\}$
 - $\text{first}(B) = \{g, \epsilon\}$
 - $\text{first}(A) = \{d\} + \text{first}(B) + \text{first}(C) = \{d, g, h, \epsilon\}$
 - $\text{first}(S) = \text{first}(A) + \text{first}(C) + \{b\} + \text{first}(B) + \{a\} = \{d, g, h, \epsilon, b, a\}$
- $\text{follow}(S) = \{\$\}$
- $\text{follow}(A) = \text{first}(C) + \text{first}(B) + \text{follow}(S) = \{h, g, \$\}$
- $\text{follow}(B) = \text{follow}(S) + \{a\} + \text{first}(C) + \text{follow}(A) = \{\$, a, h, g\}$
- $\text{follow}(C) = \text{first}(B) + \text{follow}(S) + \{b\} + \text{follow}(A) = \{\$, b, h, g\}$

2.

a.

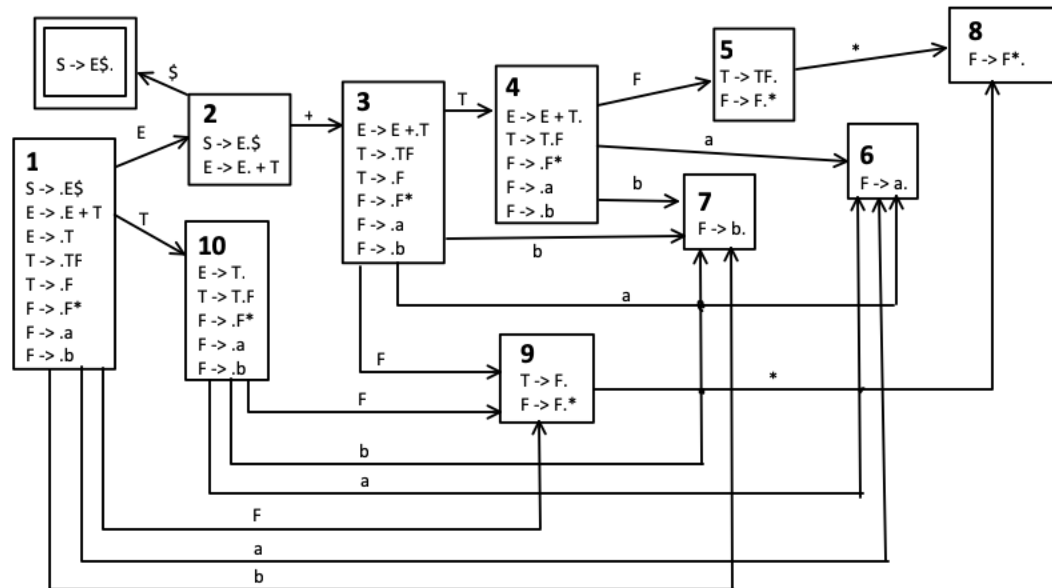


LR(0):

this grammar is not LR(0). As shown by the partial DFA, there occurs a shift-reduce conflict in state 5

SLR(1):

this grammar is SLR(1)



1. $E \rightarrow E+T$

2. $E \rightarrow T$

3. $T \rightarrow TF$

4. $T \rightarrow F$

5. $F \rightarrow F^*$

6. $F \rightarrow a$

7. $F \rightarrow b$

Follow(E) = {+, \$}

Follow(T) = {\$, +, a, b}

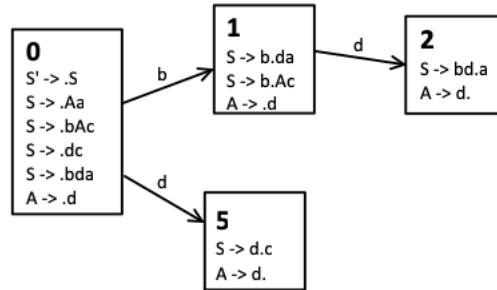
Follow(F) = {*, \$, +, a, b}

Action					Goto			
	*	+	a	b	\$	E	T	F
1			S9	S7		I2	I10	I9
2		S3			accept			
3			S6	S7			IT	
4		R1	S6	S7	R1			I5
5	S8	R3	R3	R3	R3			
6	R6	R6	R6	R6	R6			
7	R7	R7	R7	R7	R7			
8	R5	R5	R5	R5	R5			
9	S8	R4	R4	R4	R4			
10		R2	S6	S7	R2			I9

b.

LR(0):

this grammar is not LR(0), at states 5 and 2 we have a shift-reduce conflict



SLR(1):

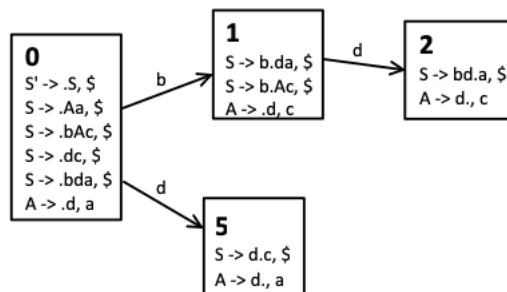
follow(S) = {\$}

follow(A) = {a, c}

this grammar is not SLR(1) either. The shift-reduce conflict in state 5 is between shifting c and reducing to non-terminal S, in state 2 is between shifting a and reducing to S. Since the follow set of S contains a and c, we cannot reduce this conflict with SLR(1).

LALR(1):

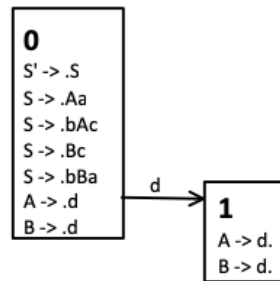
This grammar is LALR(1).



Once we add the lookaheads to each LR(0) item, the shift-reduce conflicts are reduced. In state 2, the shift symbol a is different from A's lookahead symbol c and in state 5 the shift symbol c is different from A's lookahead symbol a. We can deduce from the grammar rules that no other items will have the same grammar rules as state 2 or 5, so these two items will not be merged by any other items in LALR(1). Therefore, it is safe to say that this grammar LALR(1).

c.

LR(0):



This grammar is not LR(0), in state 1 there is a reduce-reduce conflict. Thus LR(0) fails.

SLR(1):

This grammar is not LR(1) either, in the partial DFA of LR(0), state 1 has two reduce rules deriving from non-terminals A and B. If we check the follow set of non-terminals we will find out:

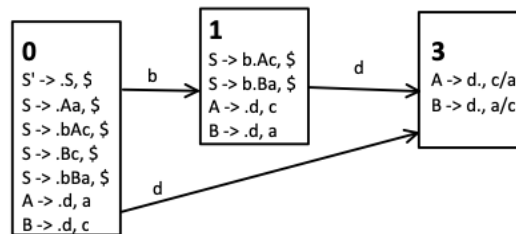
Follow(S) = {\$}

Follow(A) = {a, c}

Follow(B) = {a, c}

among which the follow sets of A and B are identical. Thus, SLR(1) cannot resolve the reduce-reduce conflict in state 1.

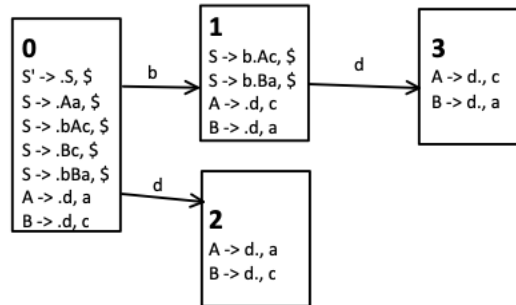
LALR(1):



This grammar is not LALR(1) either. In state 0 and 1, we see there is an identical set of grammar rules derived from non-terminal A and B. They have different lookahead symbols in state 0 and state 1. Yet in state 3, after being dynamically merged, these two rules face reduce-reduce conflict again because their sets of lookahead symbols are merged as well.

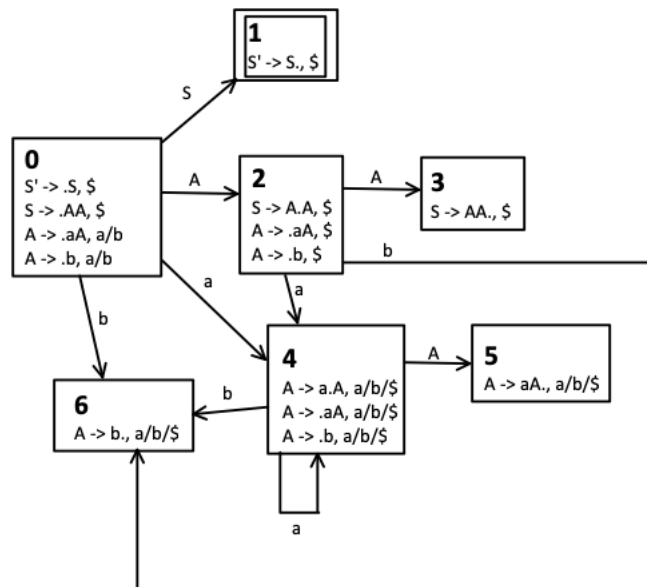
CLR(1)

This grammar is CLR(1).



CLR(1) solves the reduce-reduce conflict in LALR(1) by splitting the old state 3 into two states with identical grammatical rules but different sets of lookaheads. Unlike in LALR(1), state 1 and 0 herein branch to two separate states, leading to more items than LR(0)/LALR(1). Other branches in this CLR(1) DFA all lead a single-rule items and thus shouldn't have any conflicts. Therefore, this grammar is CLR(1).

3.



1. $S \rightarrow AA$
2. $A \rightarrow aA$
3. $A \rightarrow b$

Action			Goto		
	a	b	\$	S	A
0	S4	S6		I1	I2
1			accept		
2	S4	S6			I3
3			R1		I5
4	S4	S6			I5
5	R2	R2	R2		
6	R3	R3	R3		

Input: "abaab\$"
action: shift 4

0	a
---	---

Input: "abaab\$"
action: shift 6

4	b
0	a

Input: "abaab\$"
action: reduce 3

6	
4	b
0	a

Input: "abaab\$"
action: goto 5

4	A
0	a

Input: "abaab\$"
Action: reduce 2

5	
4	A
0	a

Input: "abaab\$"
action: goto 2

0	A

Input: "abaab\$"
action: shift 4

2	a
0	A

Input: "abaab\$"
action: shift 4

4	a
2	a
0	A

Input: "abaab\$"
Action: shift 6

6	
4	b
4	a

Input: "abaab\$"
Action: goto 5

2	a
0	A

4	A
4	a
2	a
0	A

Input: "abab\$" ~~abab~~
 Action: reduce 2

Input: "abab\$" ~~abab~~
 action: goto 3

5	A
4	a
2	a
0	A

2	A
0	A

Input: "abab\$" ~~abab~~
 Action: reduce 1

Input: "abab\$" ~~abab~~
 Action: goto 1

3	A
0	A

0	S
---	---

Input: "abab\$" ~~abab~~
 Action: shift \$

Input: "abab\$" ~~abab~~
 action: accept

1	S
---	---

	\$
1	S