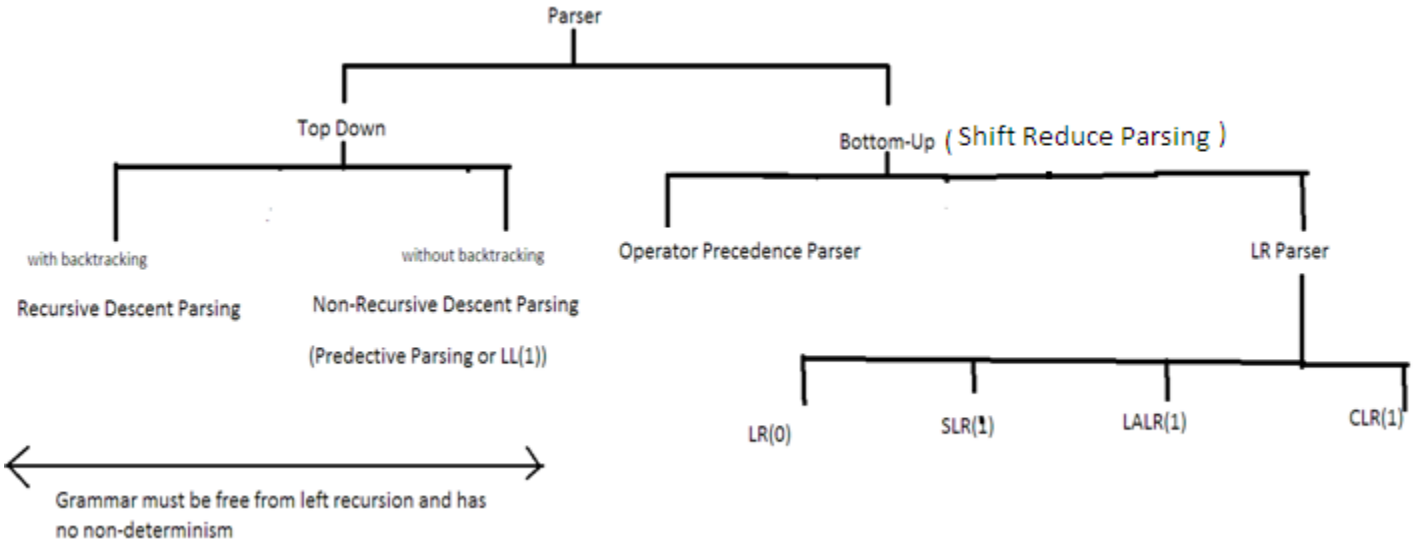
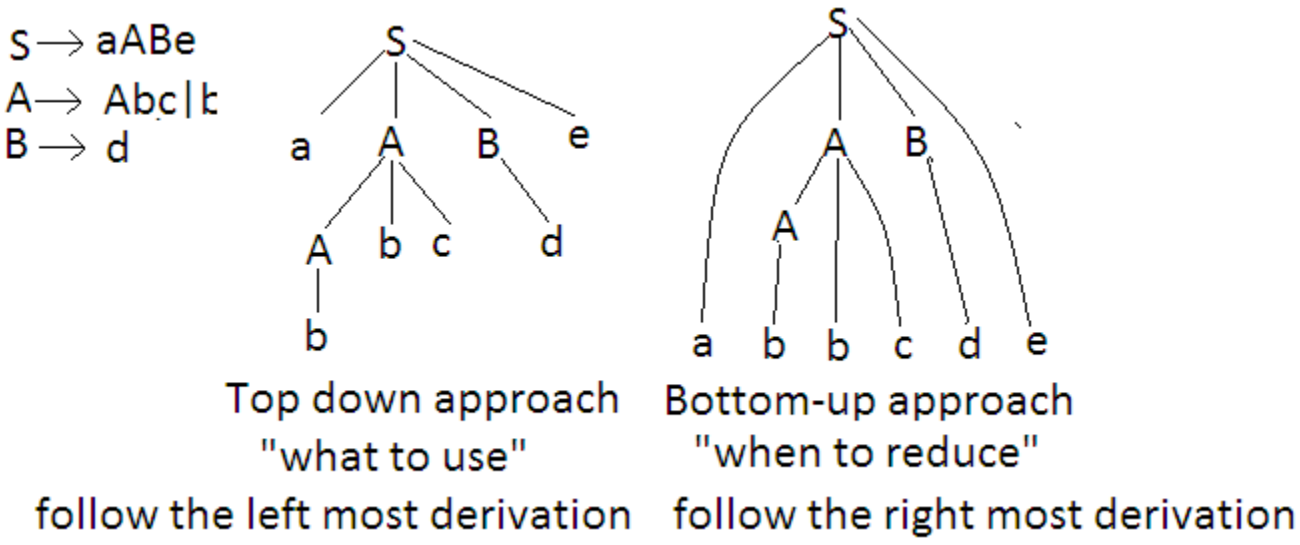
Parser



Example:-



Top-down Parsing:-

When the parser starts constructing the parse tree from the start symbol and then tries to transform the start symbol to the input, it is called top-down parsing.

Recursive Descent Parsing(Uses Backtracking):-

The idea of recursive-descent parsing is extremely simple.We view the grammar rule for a non-terminal A as a definition for a procedure that will recognize an A. The right hand side of the grammar rule for A specifies the structure of the code for this procedure , the sequence of terminals and non-terminal in a choice correspond to matches of the input and calls other procedure ,while choices correspond to alternatives (switch case or if statement) within the code.

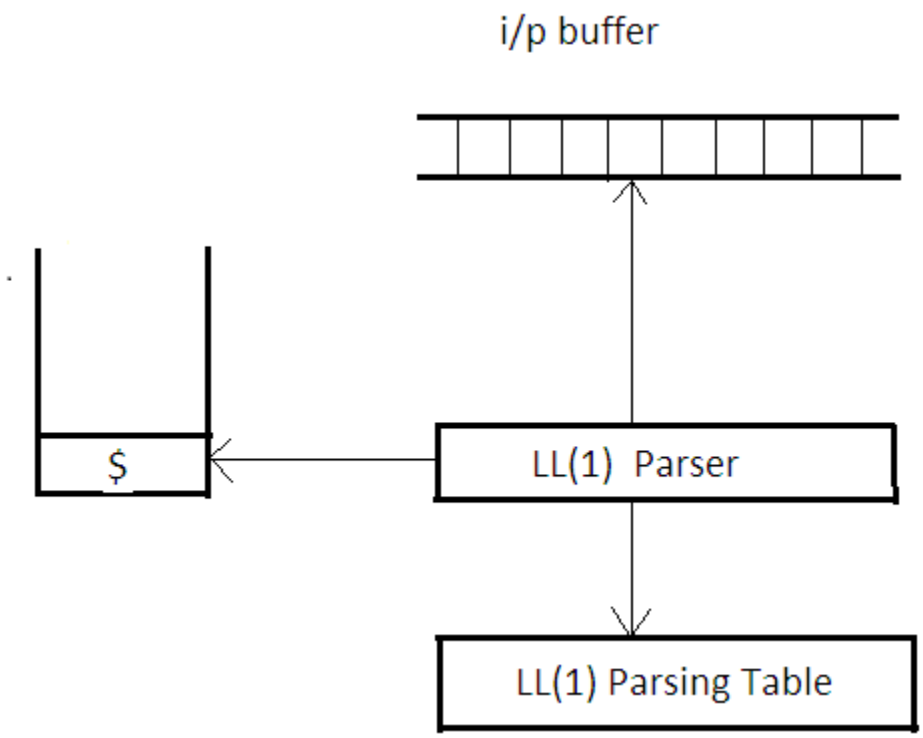
Ex:-

$$E \rightarrow iE'$$
$$E' \rightarrow +iE' \mid \in$$

```
main()
{
E();
if(l==’$’)
        printf(“parsing successful”);
}
E()
{
        if(l==’i’)
        {
                match(‘i’);
                E'();
        }
}
E'( )
{
        if(l==’+’)
        {
                match(‘+’);
                match(‘i’);
                E'( );
        }
        else
                return;
}
```

Disadvantage:- Stack overflow

Non-Recursive Descent Parsing(LL(1) Parsing):-



Algorithms:-

repeat

let X be the top stack symbol and '**a**' the symbol pointed by pointer

if X is a terminal or $ then

if X=a then

pop X from the stack and move pointer forward

else

error()

else

if M[X,a]= $X \rightarrow Y_1Y_2\ldots\ldots\ldots\ldots Y_k$ then begin

pop X from the stack

push $Y_k, Y_{k-1}\ldots\ldots\ldots\ldots Y_1$ onto the stack with Y_1 on top

output the production $X \rightarrow Y_1Y_2\ldots\ldots\ldots\ldots Y_k$

else

error();

Until X=$

Constructing LL(1) Parsing Table (Predective Parsing):-

Method:-

1. For each production A→α of the grammar do step 2 and 3.
2. For each terminal a in First(α) , add A→α to M[A,a]
3. If ϵ is in First(α) , add A→α to M[A,b] for each terminal b in Follow(A). If ϵ is in First(α) and $ is in Follow(A) , add A→α to M[A,$]
4. Make each undefined entry of M be error.

To compute First and Follow of all grammar symbol:-

Ex.

	First	Follow
S→ABCD	{b,c}	{$}
A→b | ϵ	{b,ϵ}	{c}
B→c	{c}	{d}
C→d	{d}	{e}
D→e	{e}	{$}
S→ABCDE	{a,b,c}	{$}
A→a | ϵ	{a,ϵ}	{b,c}
B→ b | ϵ	{b,ϵ}	{c}
C→ c	{c}	{d,e,$}
D→ d | ϵ	{d,ϵ}	{e,$}
E→ e | ϵ	{e,ϵ}	{$}
S→Bb | Cd	{a,b,c,d}	{$}
B→aB | ϵ	{a,ϵ}	{b}
C→cC | ϵ	{c,ϵ}	{d}
$E\rightarrow TE'$	{id,(}	{$,)}
$E' \rightarrow +TE' \mid \epsilon$	{+,ϵ}	{$,)}
$T\rightarrow FT'$	{id,(}	{+,$,)}
$T' \rightarrow * FT' \mid \epsilon$	{*,ϵ}	{+,$,)}
F→id | (E)	{id,(}	{*,+,$,)}
S→ACB | CbB | Ba	{d,g,h,b,a,ϵ}	{$}
A→da | BC	{d,g,h,ϵ}	{h,g,$}
B→g | ϵ	{g,ϵ}	{$,a,h,g}
C→h | ϵ	{h,ϵ}	{g,b,h,$}

S→aABb	{a}	{$}
A→c | ϵ	{c, ϵ}	{d,b}
B→d | ϵ	{d,ϵ }	{b}
S→aBDh	{a}	{$}
B→cC	{c}	{g,f,h}
C→bC | ϵ	{b,ϵ}	{g,f,h}
D→EF	{g, f, ϵ }	{h}
E→g | ϵ	{g, ϵ }	{f,h}
F→f | ϵ	{f, ϵ }	{h}

Ex.

Parse the string ***id+id*id*** with the grammar below by using LL(1) parsing techniques or predictive parsing techniques.

$$E \rightarrow TE'$$
$$E' \rightarrow +TE' \mid \epsilon$$
$$T \rightarrow FT'$$
$$T' \rightarrow * FT' \mid \epsilon$$
$$F \rightarrow id \mid (E)$$

Solution:-

LL(1) or predective parsing table

	id	**+**	*****	**(**	**)**	**$**
E	$E \rightarrow TE'$			$E \rightarrow TE'$		
E'		$E' \rightarrow +TE'$			$E' \rightarrow \epsilon$	$E' \rightarrow \epsilon$
T	$T \rightarrow FT'$			$T \rightarrow FT'$		
T'		$T' \rightarrow \epsilon$	$T' \rightarrow * FT'$		$T' \rightarrow \epsilon$	$T' \rightarrow \epsilon$
F	F→id			F→(E)		

Working:-

Stack	Input	Output
$E	id+id*id$	
$$E^{'}T$$	id+id*id$	E→$$TE^{'}$$
$$E^{'}T^{'}F$$	id+id*id$	T→F$$T^{'}$$
$$E^{'}T^{'}id$$	id+id*id$	F→id
$$E^{'}T^{'}$$	+id*id$	
$$E^{'}$$	+id*id$	$$T^{'} \rightarrow \epsilon$$
$$E^{'}T+$$	+id*id$	$$E^{'} \rightarrow +TE^{'}$$
$$E^{'}T$$	id*id$	
$$E^{'}T^{'}F$$	id*id$	T→F$$T^{'}$$
$$E^{'}T^{'}id$$	id*id$	F→id
$$E^{'}T^{'}$$	*id$	
$$E^{'}T^{'}F*$$	*id$	$$T^{'} \rightarrow *FT^{'}$$
$$E^{'}T^{'}F$$	id$	
$$E^{'}T^{'}id$$	id$	F→id
$$E^{'}T^{'}$$	$	
$$E^{'}$$	$	$$T^{'} \rightarrow \epsilon$$
$	$	$$E^{'} \rightarrow \epsilon$$

Bottom-up Parsing(Shift -Reduce Parsing):-

In Bottom-up parsing we start with sentence and try to apply the production rules in reverse order to finish up with the start symbol of the grammar.This corresponds to starting at leaves of the parse tree , and working back to root. Bottom –up parsing is also known as shift-reduce parsing.

Ex.-

Parse the string **abbcde** by following grammar using Shift -Reduce technique.

S→aABe
A→Abc | b
B→d

Solution:-

abbcde→aAbcde→aAde→aABe→S

Handle:-

A handle is a substring that matches the right hand side of a production and replacing RHS by LHS must be step in the reverse rightmost derivation that ultimately leads to the start symbol.If replacing a string does not ultimately lead to the start symbol it can not be handle.

String	Handle	Production Rule
abbcde	b	A→b
aAbcde	Abc	A→Abc
aAde	d	B→d
aABe	aABe	S→aABe

Operator Precedence Parsing:-

Operator grammar:- In an operator grammar,no production rule can have

- ϵ at the right side
- two adjacent non-terminal at the right side

Ex.

E→E+E | E*E | id (operator grammar)

E →EAE | id (not operator grammar)
A→ + | *

S→SAS | a (not operator grammar)
A→bSb | b

S→SbSbS | SbS | a (operator grammar)
A→bSb | b

Operator-precedence table:-

	id	+	*	$
id		>	>	>
+	<	>	<	>
*	<	>	>	>
$	<	<	<	

Algorithms:-

set i/p pointer to the first symbol of w$
repeat forever
if $ is on top of the stack and i/p points to $ then
return
else
let a be the topmost terminal symbol on the stack and let b be the symbol pointed to by i/p pointer
if a<b or a=b then
push b onto the stack advance i/p pointer to the next i/p symbol.
else if a>b then
pop the stack until the top stack terminal is related by < to the terminal most recently popped
else
error

Ex.

Parse the string id+id*id by the operator precedence parsing techniques.

E→E+E
E→E*E
E→id

Stack	Input	Production Rule
$	id+id*id$	-
$id	+id*id$	Shift
$	+id*id$	Reduce(E→id)
$+	id*id$	Shift
$+id	*id$	Shift
$+	*id$	Reduce(E→id)
$+*	id$	Shift
$+*id	$	Shift
$+*	$	Reduce(E→id)
$+	$	Reduce(E→E*E)
$	$	Accept

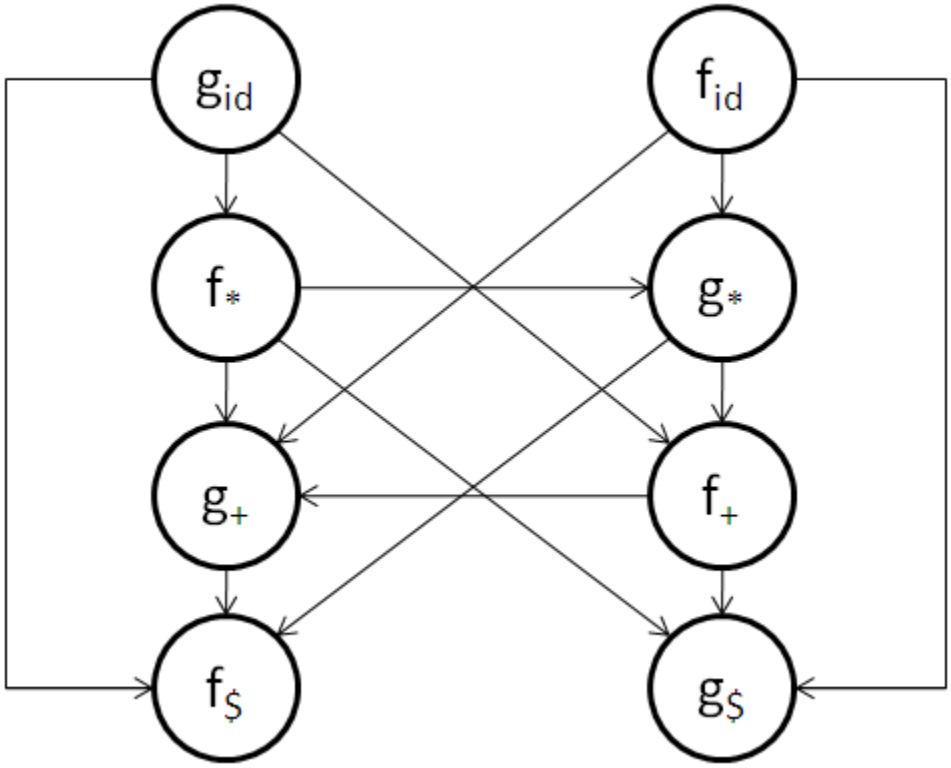
Note :- Disadvantages of operator precedence table is there are n^2 entries in the precedence table, where n is no of operator.

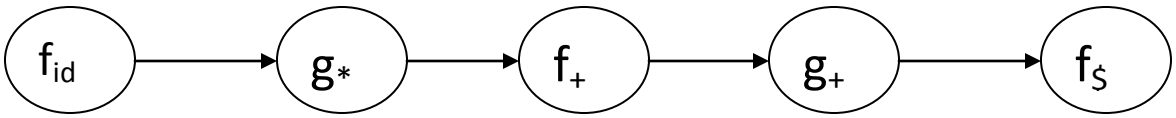
Time Complexity is $O(n^2)$

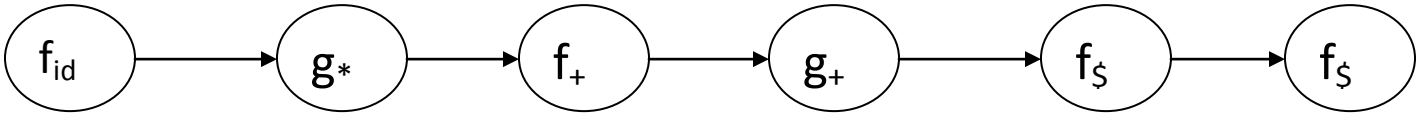
Precedence function:-

Compilers using operator-precedence parser need not store the table of precedence relation. The table can be encoded by two precedence function f and g that map terminal symbol to integers.

1. f(a)<g(b) whenever a<b
2. f(a)=g(b) whenever a=b
3. f(a)>g(b) whenever a>b







Function Table:-

	id	+	*	$
f	4	2	4	0
g	5	1	3	0

Note:-

Function table represent the same information which operator precedence table representing with less storage.

Disadvantages:-

Error checking capability is less than operator precedence table.

Leading and Trailing Method:-

Algorithms:

begin

for each production $A \rightarrow B_1B_2 \ldots\ldots\ldots\ldots B_n$

for i=1 to n-1

if B_i and B_{i+1} are both terminal then

$B_i=B_{i+1}$

if i<=n-2 and B_i and B_{i+2} are both terminal and B_{i+1} is non-terminal then

$B_i=B_{i+2}$

if B_i is terminal and B_{i+1} is non-terminal then

for all a in LEADING(B_{i+1})

set B_i<a

if B_i is non-terminal and B_{i+1} is termnal then

for all a in TRAILING(B_i)

set a>B_{i+1}

end

Ex.

Compute the leading and trailing for non-terminal E,T,F in following grammar

$$E \rightarrow E+T \mid T$$
$$T \rightarrow T*F \mid F$$
$$F \rightarrow (E) \mid id$$

	Leading	Trailing
E	{+ , * , (, id }	{ + , * ,) , id }
T	{* , (, id }	{ * ,) , id }
F	{ (, id }	{) , id }

Question:-

Consider the following grammar-

$$S \rightarrow (L) \mid a$$

$$L \rightarrow L , S \mid S$$

Construct the operator precedence parser and parse the string (a , (a , a)).

Solution-

The terminal symbols in the grammar are { (,) , a , , }

We construct the operator precedence table as-

	a	(	)	,	$
a		>	>	>	>
(	<	>	>	>	>
)	<	>	>	>	>
,	<	<	>	>	>
$	<	<	<	<	

Operator Precedence Table

Parsing Given String-

Given string to be parsed is **(a , (a , a))**.

We follow the following steps to parse the given string-

Step-01:

We insert $ symbol at both ends of the string as-

$ (a , (a , a)) $

We insert precedence operators between the string symbols as-

$ < (< a > , < (< a > , < a >) >) > $

Step-02:

We scan and parse the string as-

$ < (**< a >** , < (< a > , < a >) >) > $

$ < (S , < (**< a >** , < a >) >) > $

$ < (S , < (S , **< a >**) >) > $

$ < (S , **< (S , S) >**) > $

$ < (S , **< (L , S) >**) > $

$ < (S , **< (L) >**) > $

$ **< (S , S) >** $

$ **< (L , S) >** $

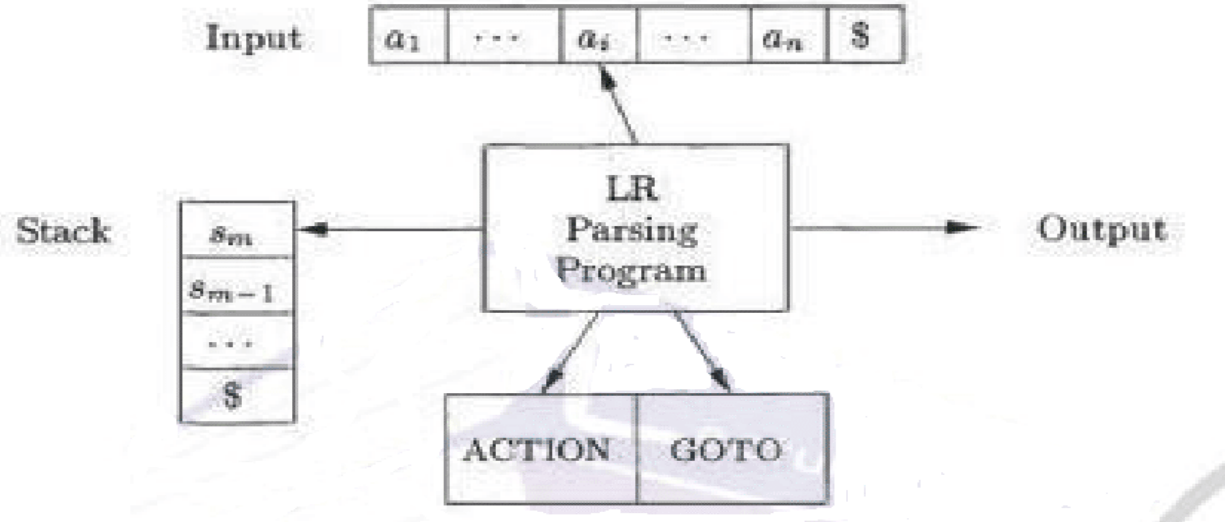
$ **< (L) >** $

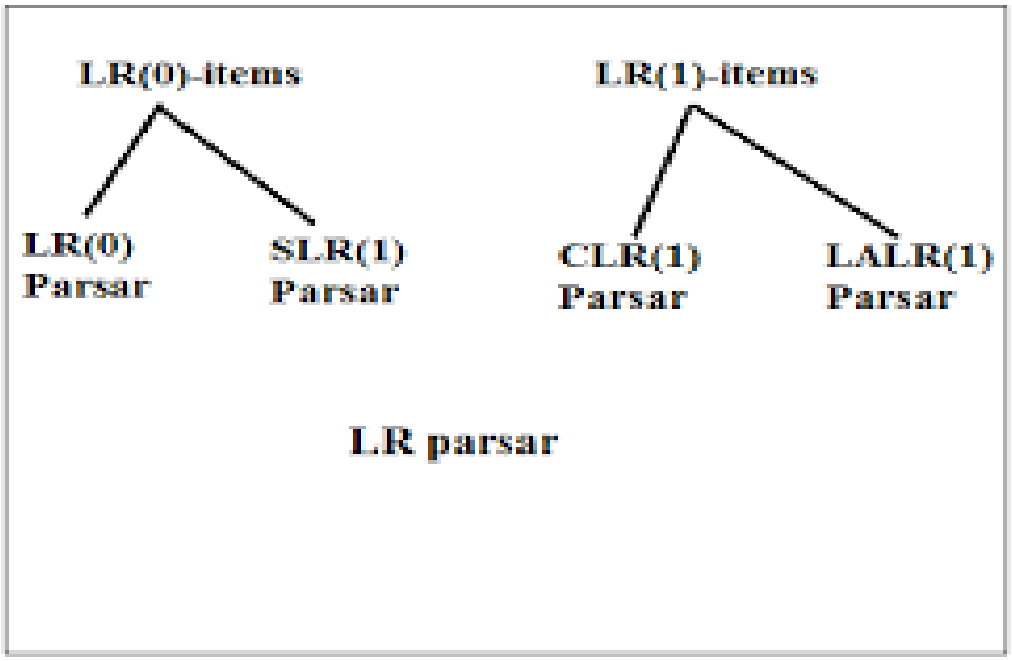
$ **< S >** $

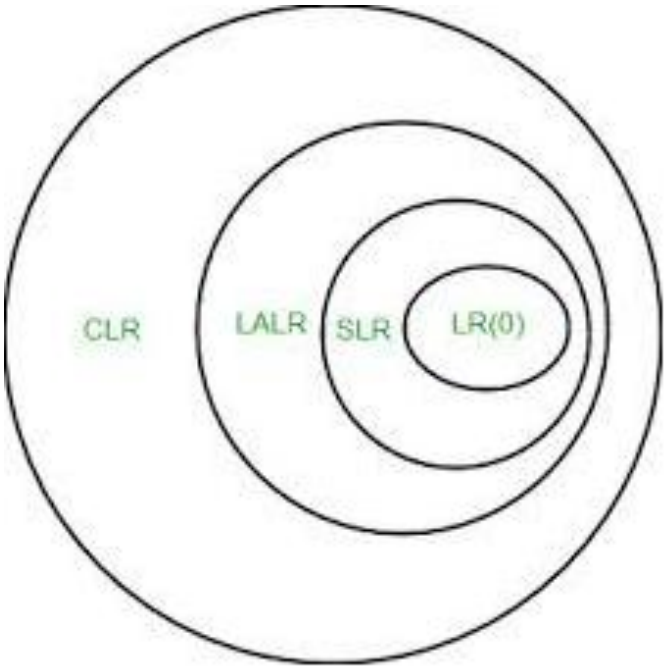
$ $

LR Parsing:-

A large class of grammar can be parsed using LR(k) parsers. Here L is for left to right scanning of the input string. R is for constructing the right most derivation in the reverse and k represents number of input symbols under look-ahead pointer used to making parsing decisions.







LR(0)Item:-

Item for a grammar G is a production of G with a dot(.) at some position of the right side. That is if we have a production A→ a BC in grammar G than items of G are

A→ .a BC
A→ a. BC
A→ a B.C
A→ a BC.

If G has null production (A→ϵ) than

A→• is an item of G

Closure operation:-

If I is a set of item for a grammar G, then closure (I) is the set of items constructed from I by the two rules:

1. Initially, every item in I is added to closure(I)
2. If A→α.Bβ is in closure(I) and B→ɣ is a production, then add the B→.ɣ to I, if it is not already there. We apply this rule until no more new items can be added to closure(I).

GOTO operation:-

If I is a set of LR(0) items and X is a grammar symbol symbol(terminal or non-terminal) then goto (I,X) is defined as follows

If $A \rightarrow \alpha.X\beta$ in I then every item in closure ($\{A \rightarrow \alpha X.\beta\}$) will be in goto(I,X).

Parser Action:-

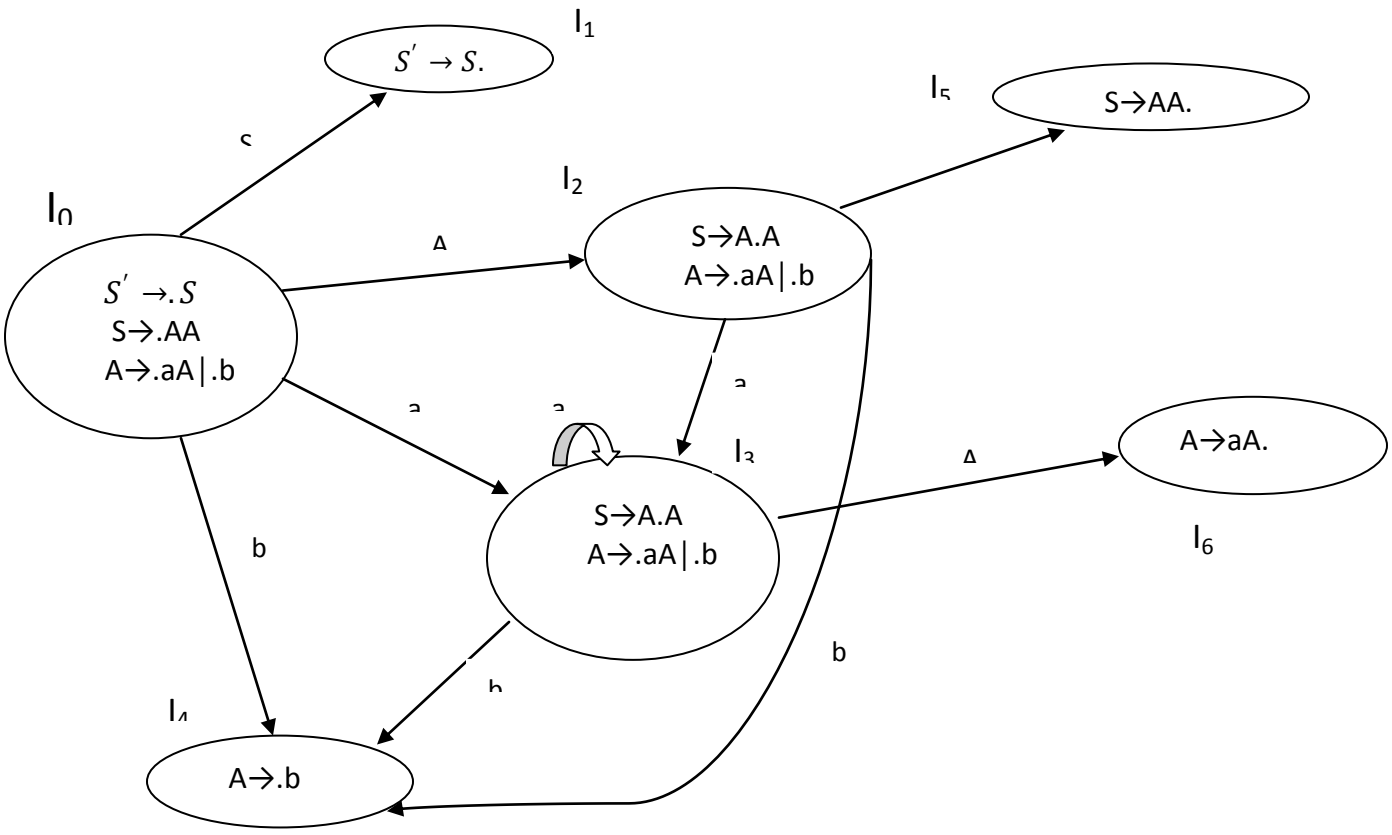
1. if Action [s_m , a_i] =shift s , the parser executes a shift move, entering the configuration
   ($s_0x_1s_1x_2$……x_ms_m a_i s, a_{i+1}……a_n\$)
2. if Action[s_m,a_i]=reduce $A \rightarrow \beta$, then parser executes a reduce move ,entering the configuration
   ($s_0x_1s_1x_2$……$x_{m-1}s_{m-1}$ As, a_ia_{i+1}……a_n\$)
   Where r is the length of β and s=GOTO[s_{m-r} , A].
   Here the parser popped first 2r symbols(r state symbols and r grammar symbols)off the stack, exposing state s_{m-r} . The parser then pushed s, entry for GOTO[s_{m-r}, A], onto the stack. The current input symbol is not changed in a reduce move.
3. if Action[s_m , a_i]=accept parsing is completed.
4. if Action [s_m,a_i]=error , the parser has discovered and error and calls an error recovery routine.

Algorithms:-

Set i/p pointer to point the first symbol of w$
Repeat forever
begin
Let S be the state on top of the stack and a the symbol pointed to by i/p pointer
If action [s,a]=shift S' then
Push a then S' on top of the stack advance i/p pointer to the next input symbol.
else if action[s,a] =reduce A→β then
pop 2*│β│ symbol off the stack. Let S' be the state now on top of the stack.
Push A then goto [S',A] on top of the stack.
Output the production A→β
else if action[S,a]=accept then
return
else
error();
end

Ex. Parse the string "**aabb"** by LR(0) parsing technique?

S→AA
A→aA │ b



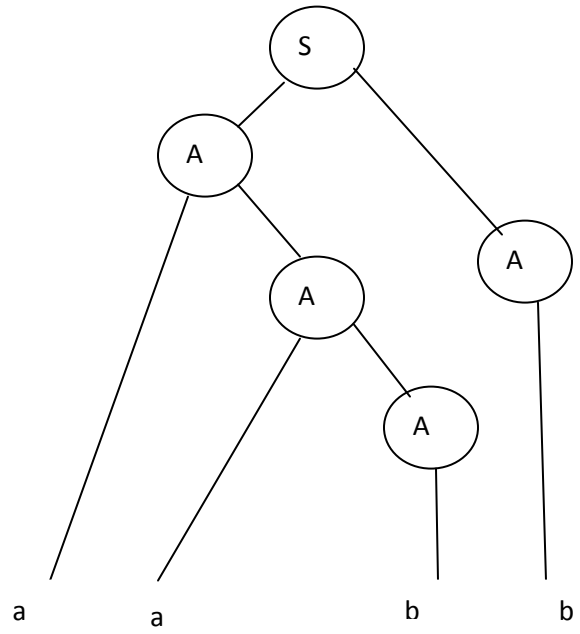
Canonical collection of LR(0) item

LR(0) Table

State	Action			Goto	
	a	**b**	**$**	**A**	**S**
0	S_3	S_4		2	1
1			Accept		
2	S_3	S_4		5	
3	S_3	S_4		6	
4	r_3	r_3	r_3		
5	r_1	r_1	r_1		
6	r_2	r_2	r_2		

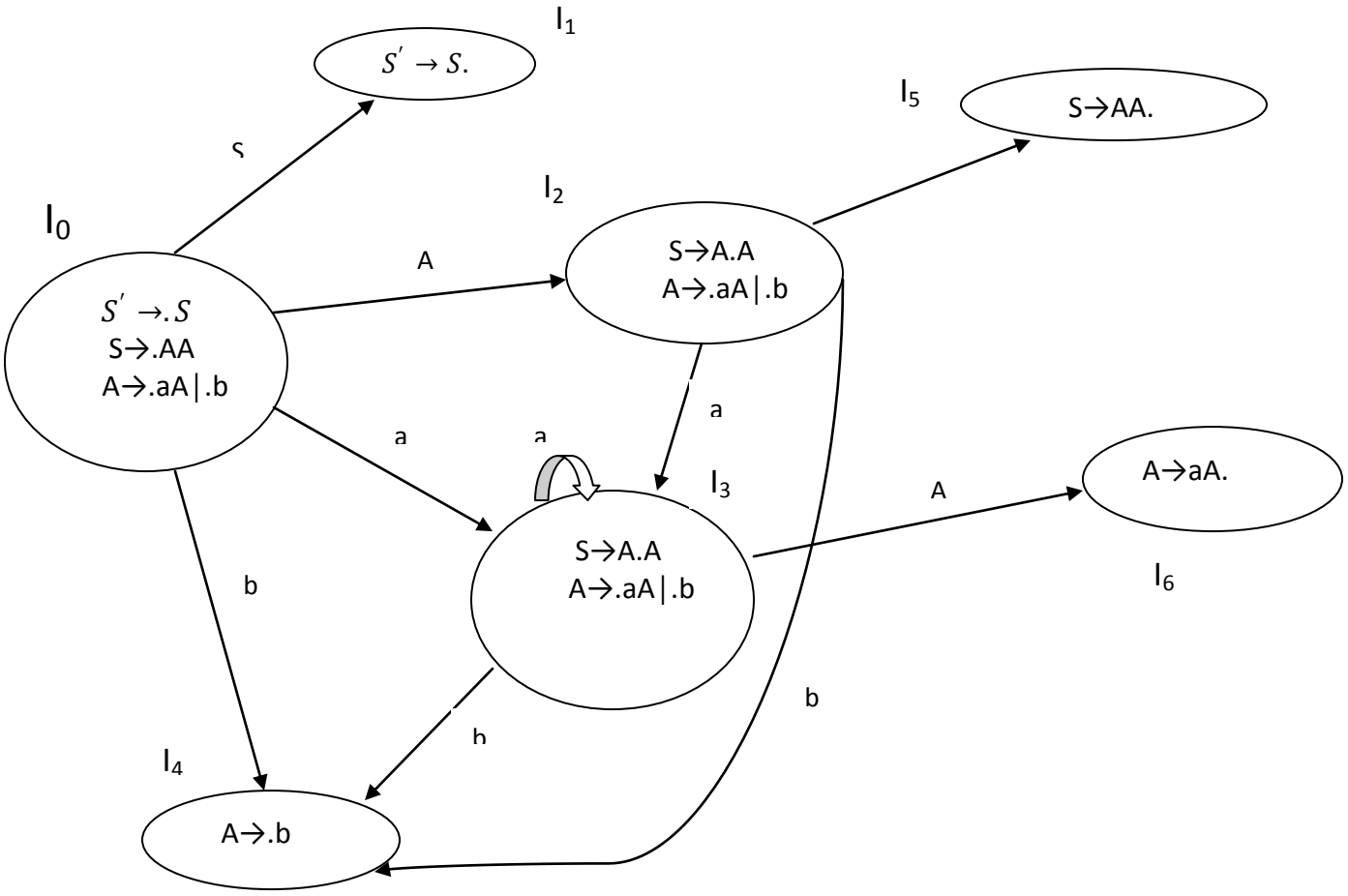
Working:-

Stack	Input	Action	Output
0	aabb$	S_3(shift)	
0a3	abb$	S_3(shift)	
0a3a3	bb$	S_4(shift)	
0a3a3b4	b$	r_3(reduce)	A→b
0a3a3A6	b$	r_2(reduce)	A→aA
0a3A6	b$	r_2(reduce)	A→aA
0A2	b$	S_4(shift)	
0A2b4	$	r_3(reduce)	A→b
0A2A5	$	r_1(reduce)	S→AA
0S1	$	Accept	



Ex. Parse the string "**aabb"** by SLR(1) parsing technique?

S→AA
A→aA | b



Canonical collection of LR(0) item

Algorithm 4.46: Constructing an SLR-parsing table.

INPUT: An augmented grammar G'.

OUTPUT: The SLR-parsing table functions ACTION and GOTO for G'.

METHOD:

1. Construct $C = \{I_0, I_1, \ldots, I_n\}$, the collection of sets of LR(0) items for G'.

2. State i is constructed from I_i. The parsing actions for state i are determined as follows:

   (a) If $[A \to \alpha \cdot a\beta]$ is in I_i and $\text{GOTO}(I_i, a) = I_j$, then set $\text{ACTION}[i, a]$ to "shift j." Here a must be a terminal.

   (b) If $[A \to \alpha \cdot]$ is in I_i, then set $\text{ACTION}[i, a]$ to "reduce $A \to \alpha$" for all a in $\text{FOLLOW}(A)$; here A may not be S'.

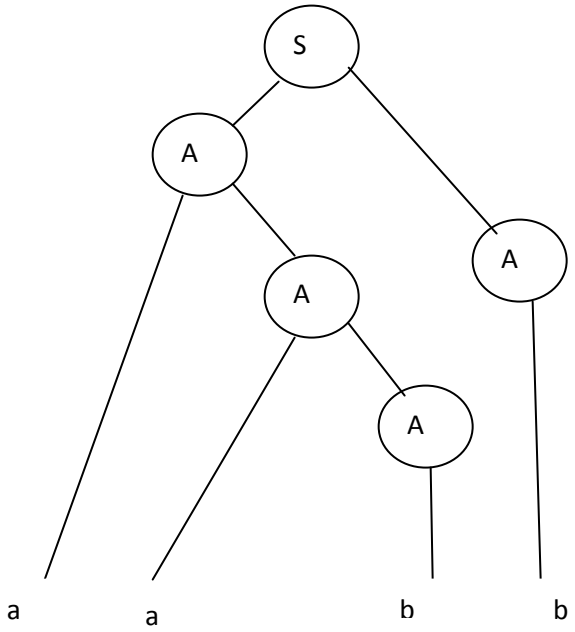
   (c) If $[S' \to S \cdot]$ is in I_i, then set $\text{ACTION}[i, \$]$ to "accept."

SLR(1) Parsing Table:-

	Action			**Goto**	
	A	B	$	A	S
0	S_3	S_4		2	1
1			Accept		
2	S_3	S_4		5	
3	S_3	S_4		6	
4	r_3	r_3	r_3		
5			r_1		
6	r_2	r_2	r_2		

Working:-

Stack	Input	Action	Production Used
0	aabb$	S_3(shift)	-
0a3	abb$	S_3(shift)	-
0a3a3	bb$	S_4(shift)	-
0a3a3b4	b$	r_3(reduce)	A→b
0a3a3A6	**b**$	r_2(reduce)	A→aA
0a3A6	b$	r_2(reduce)	A→aA
0A2	b$	S_4(shift)	-
0A2b4	$	r_3(reduce)	A→b
0A2A5	$	r_1(reduce)	S→AA
0S1	$	Accept	

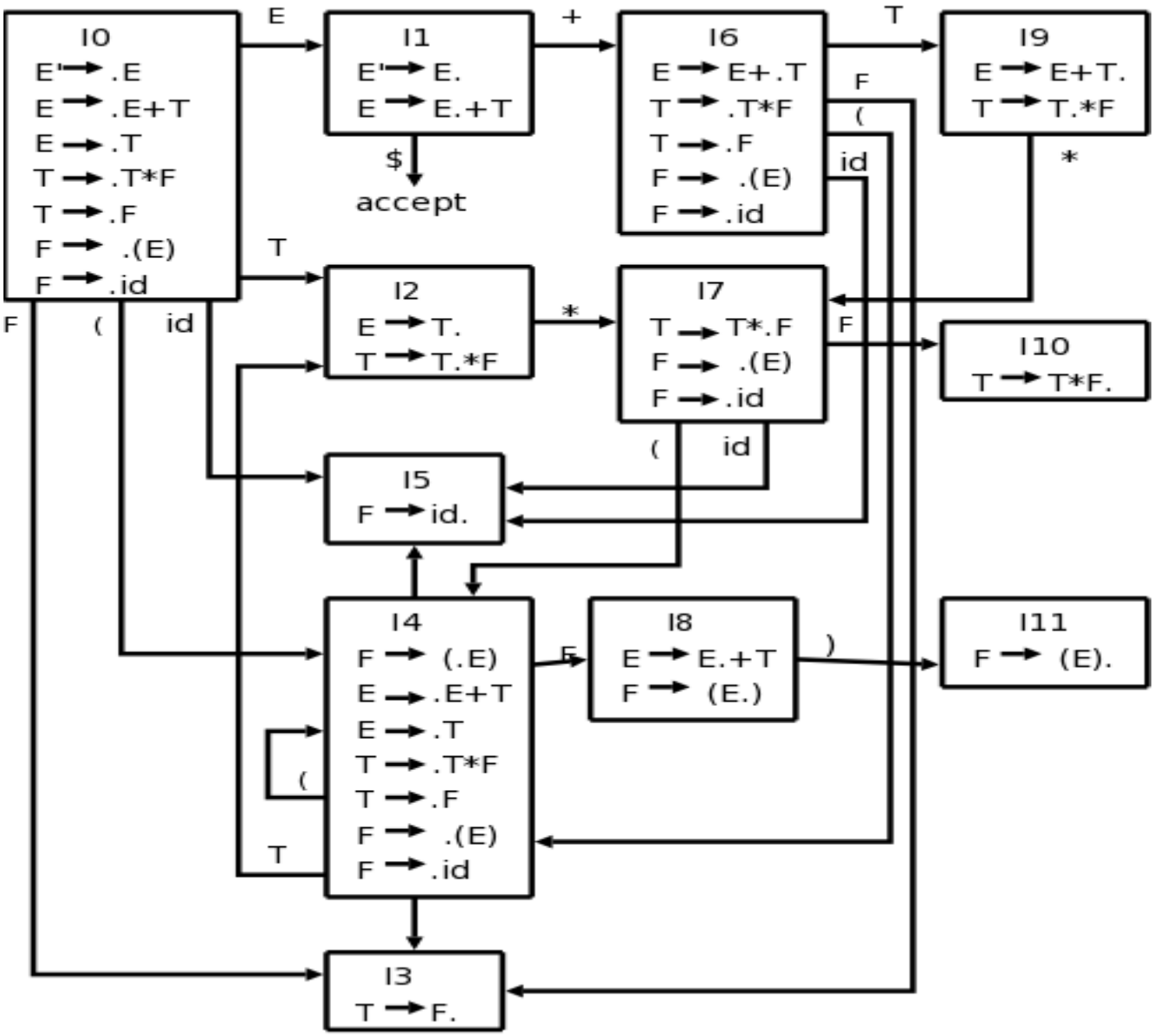


Parse Tree

Ex. Draw the canonical collection of LR(0) item of the following grammar

E→E+T
E→T
T→T*F
T→F
F→ (E)
F→ id

Solution:-



LR (1) item:-

LR (1) item is a collection of LR (0) items and a look ahead symbol.
LR (1) item = LR (0) item + look ahead
The look ahead is used to determine that where we place the final item.
The look ahead always add $ symbol for the argument production.

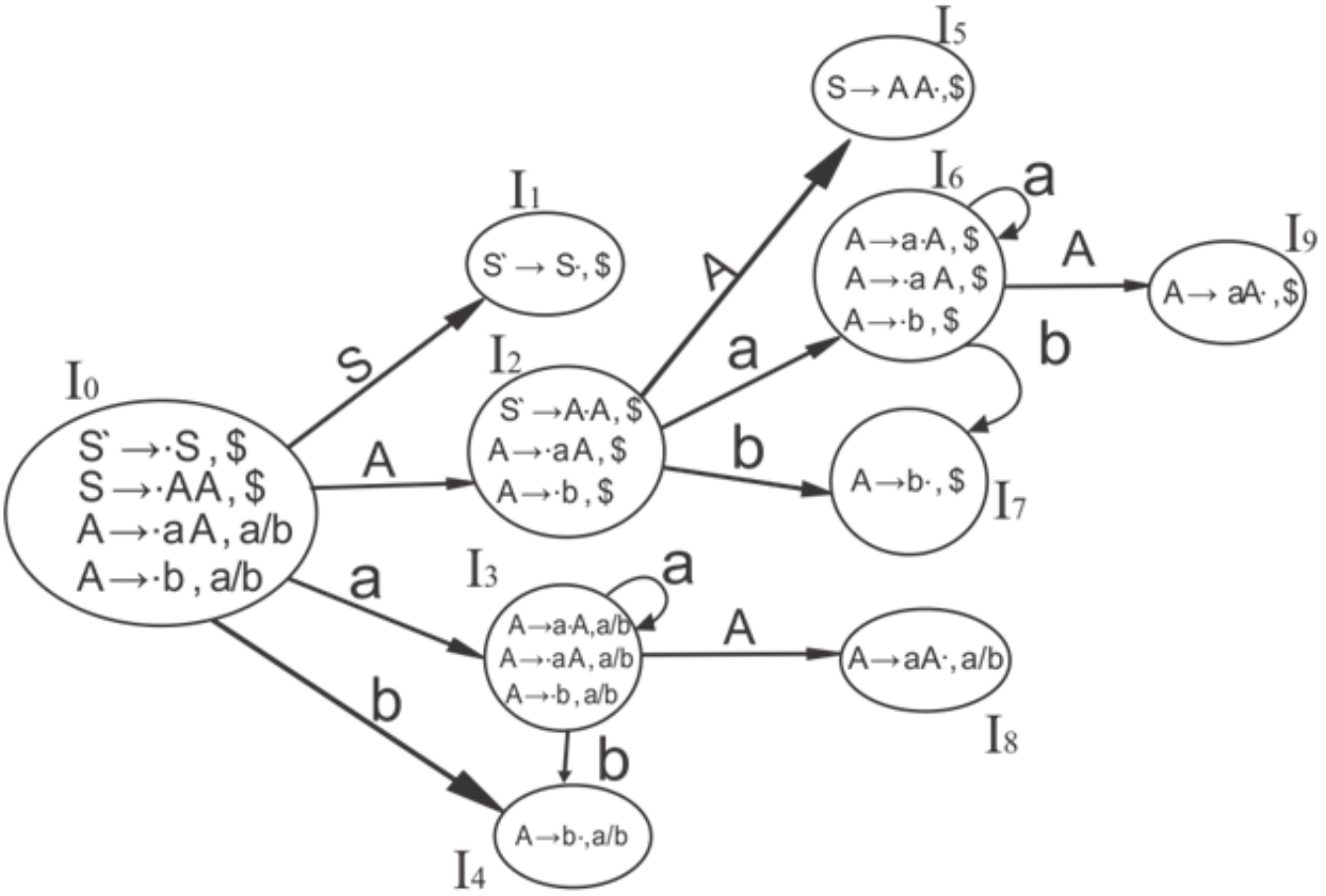
Algorithms of Constructing Canonical Collection of LR(1) item:-

```
SetOfItems CLOSURE(I) {
    repeat
        for ( each item [A → α·Bβ, a] in I )
            for ( each production B → γ in G' )
                for ( each terminal b in FIRST(βa) )
                    add [B → ·γ, b] to set I;
    until no more items are added to I;
    return I;
}

SetOfItems GOTO(I, X) {
    initialize J to be the empty set;
    for ( each item [A → α·Xβ, a] in I )
        add item [A → αX·β, a] to set J;
    return CLOSURE(J);
}

void items(G') {
    initialize C to {CLOSURE({[S' → ·S, $]})};
    repeat
        for ( each set of items I in C )
            for ( each grammar symbol X )
                if ( GOTO(I, X) is not empty and not in C )
                    add GOTO(I, X) to C;
    until no new sets of items are added to C;
}
```

Ex. Parse the string "aabb" by CLR(1) parsing techniques considering the following grammar.

S→AA
A→aA | b

Canonical Collection of LR(1) item:-

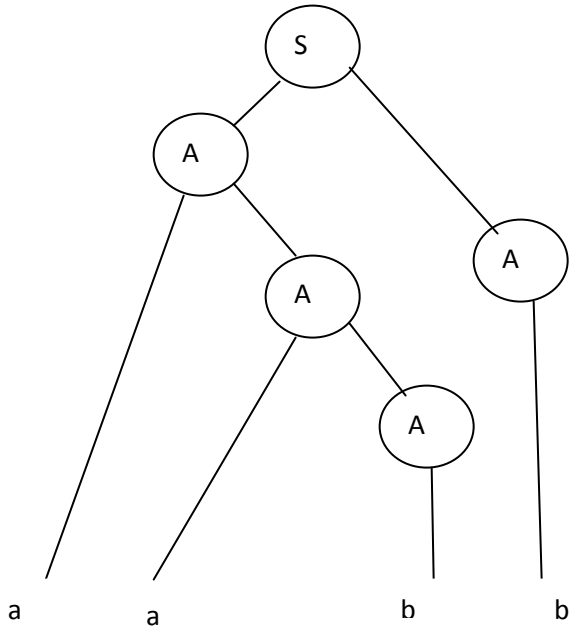


CLR(1) Table:-

State	Action			Goto	
	a	**b**	**$**	**S**	**A**
0	S_3	S_4		1	2
1			Accept		
2	S_6	S_7			5
3	S_3	S_4			8
4	r_3	r_3			
5			r_1		
6	S_6	S_7			9
7			r_3		
8	r_2	r_2			
9			r_2		

Working:-

Stack	Input	Action	Production Used
0	aabb$	S_3(shift)	-
0a3	abb$	S_3(shift)	-
0a3a3	bb$	S_4(shift)	-
0a3a3b4	b$	r_3(reduce)	A→b
0a3a3A8	b$	r_2(reduce)	A→aA
0a3A8	b$	r_2(reduce)	A→aA
0A2	b$	S_7(shift)	-
0A2b7	$	r_3(reduce)	A→b
0A2A5	$	r_1(reduce)	S→AA
0S1	$	Accept	-



Parse Tree

Ex. Parse the string "aabb" by LALR(1) parsing techniques considering the following grammar.

$S \rightarrow AA$
$A \rightarrow aA \mid b$

LALR(1) table:-

State	Action			Goto	
	A	**b**	**$**	**S**	**A**
0	S_{36}	S_{47}		1	2
1			Accept		
2	S_{36}	S_{47}			5
36	S_{36}	S_{47}			89
47	r_3	r_3	r_3		
5			r_1		
89	r_2	r_2	r_2		

Working:-

Stack	Input	Action	Production Used
0	aabb$	S_{36}(shift)	-
0a36	abb$	S_{36}(shift)	-
0a36a36	bb$	S_{47}(shift)	-
0a36a36b47	b$	r_3(reduce)	$A \rightarrow b$
0a36a36A89	b$	r_2(reduce)	$A \rightarrow aA$
0a36A89	b$	r_2(reduce)	$A \rightarrow aA$
0A2	b$	S_{47}(shift)	-
0A2b47	$	r_3(reduce)	$A \rightarrow b$
0A2A5	$	r_1(reduce)	$S \rightarrow AA$
0S1	$	Accept	-

SR Conflict:- In a parsing table, if a cell has both shift move as well as reduce move then shift reduce conflict arises

RR Conflict:-In a parsing table , if a cell has 2 different reduce moves then reduce-reduce conflict occurs.

Ex.
S→AaAb
S→BbBa
A→ϵ
B→ϵ