disadvantages of recursive descent parsing are :

(*i*) The very large parsers often produced.

(*ii*) The tendency for actions which are part of different phases of compilation to appear in the same function bodies.

The following are the requirements for effective use of recursive descent :

(*i*) A good grammar transform that will usually be able to transform a grammar into LL(1) form.

(*ii*) The ability to represent the equivalent of the recursive descent parser in tabular form. This means that the parser, instead of entering and leaving functions as it checks the input text, will instead move about the tabular equivalent of the grammar, stacking return addresses as necessary.

Example 5.11. Consider the following grammar

$$S \rightarrow AaAb / BbBa$$

$$A \rightarrow \epsilon$$

$$B \rightarrow \epsilon$$

Test whether the grammar is LL(1) or not, and construct a predictive parsing table for it.

Solution. Given grammar is as follows :

$$S \rightarrow AaAb / BbBa$$
$$A \rightarrow \epsilon$$
$$B \rightarrow \epsilon$$

Let us calculate First and Follow :

$$\text{First }(S) = \text{First }(AaAb) \cup \text{First }(BbBa)$$
$$\text{First }(AaAb) = \text{First }(A) - \{\epsilon\} \cup \text{First }(aAb) = \{a\}$$
$$\text{First }(BbBa) = \text{First }(B) - \{\epsilon\} \cup \text{First }(bBa) = \{b\}$$

So

$$\text{First }(S) = \{a\} \cup \{b\} = \{a, b\}$$
$$\text{First }(A) = \{\epsilon\}$$
$$\text{First }(B) = \{\epsilon\}$$

Follow (S) = \$

Follow $(A) = \{a, b\}$ (since in $S \rightarrow AaAb$, A is followed by both a and b)

Follow $(B) = \{b, a\}$ (since in $S \rightarrow BbBa$, B is followed by both b and a)

Now let us calculate select ( ) for different productions :

$$\text{Select }(S \rightarrow AaAb) = \text{First (First }(AaAb)\text{ Follow }(S))$$
$$= \text{First }(\{a\}, \{\$\}) = a$$
$$\text{Select }(S \rightarrow BbBa) = \text{First (First }(BbBa)\text{ Follow }(S))$$
$$= \text{First }(\{b\}\ \{\$\}) = \text{First }(b\$) = b$$
$$\text{Select }(A \rightarrow \epsilon) = \text{First (First }(\epsilon)\text{ Follow }(A))$$
$$= \text{First }(\{\epsilon\}\ \{a, b\}) = \text{First }(\{a, b\}) = \{a, b\}$$
$$\text{Select }(B \rightarrow \epsilon) = \{a, b\}$$

Here S (non-terminal) is in the left hand side of two productions as :

$$S \rightarrow AaAb / BbBa$$

So Select $(S \rightarrow AaAb) \cap (S \rightarrow BbBa)$

Now let us make

$$= a \cap b$$
$$= \phi$$

So we can say that S follows LL(1) properties, now finally we can say that given grammar is LL(1).

Now it is easy to construct the parse table by the help of select ( ).

	a	b	\$
S	$S \rightarrow AaAb$	$S \rightarrow BbBa$	
A	$A \rightarrow \epsilon$	$A \rightarrow \epsilon$	
B	$B \rightarrow \epsilon$	$B \rightarrow \epsilon$	

Fig. 5.18.

Since Select $(S \to AaAb) = a$

Select $(S \to BbBa) = b$

Select $(A \to \in) = \{a, b\}$

Select $(B \to \in) = \{a, b\}$

Example 5.12. Consider the following grammar :

$$S \to 1AB/\in$$
$$A \to 1AC/0C$$
$$B \to 0S$$
$$C \to 1$$

and test that whether the grammar is LL(1) or not.

Solution. Let us calculate First and Follow :

$$\begin{aligned}
\text{First }(S) &= \text{First }(1\ AB) \cup \text{First }(\in) = \{1, \in\} \\
\text{First }(A) &= \{1, 0\} \\
\text{First }(B) &= \{0\} \\
\text{First }(C) &= \{1\} \\
\text{Follow }(S) &= \{\$\} \\
\text{Follow }(A) &= \text{First }(A) \cup \text{First }(B) = \{1, 0\} \cup \{0\} = \{1, 0\} \\
\text{Follow }(B) &= \text{Follow }(S) = \$
\end{aligned}$$

Now only S and A derives two productions as

$$S \to 1AB, \quad S \to \in$$

and

$$A \to 1AC, \quad A \to 0C$$

$$\begin{aligned}
\text{Select }(S \to 1AB) &= \text{First (First }(1AB)\text{ Follow }(S)) \\
&= \text{First }(\{1\}\ \{\$\}) = \{1\} \\
\text{Select }(S \to \in) &= \text{First (First }(\in)\text{ Follow }(S)) \\
&= \text{First }(\in\ \$) = \{\$\} \\
\text{Select }(A \to 1AC) &= \text{First (First }(1AC)\text{ Follow }(A)) \\
&= \text{First }(\{1\}, \{1, 0\}) \\
&= \text{First }(11, 10) \\
&= \{1\} \\
\text{Select }(A \to 0C) &= \text{First (First }(0C)\text{ Follow }(A)) \\
&= \text{First }(\{0\}\ \{1, 0\}) \\
&= \text{First }(01, 00) = \{0\}
\end{aligned}$$

Now following condition should hold for LL(1) grammar :

$$\begin{aligned}
\text{Select }(S \to 1\ AB) &\cap \text{Select }(S \to \in) \\
&= \{1\} \cap \{\$\} = \phi \\
\text{Select }(A \to 1\ AC) &\cap \text{Select }(A \to 0C) \\
&= \{1\} \cap \{0\} = \phi
\end{aligned}$$

So here both S and A are following LL(1) property so we can say that grammar is LL(1).

Example 5.13. Calculate the First, Follow and Select for following given grammar :

$$S \rightarrow A$$
$$A \rightarrow aB/Ad$$
$$B \rightarrow bBC/f$$
$$C \rightarrow g$$

Solution. By calculating select for S, A, B and C we can design the pridictive parsing table for the given grammar.

$$\text{First }(S) = \text{First }(A) = \{a\}$$
$$\text{First }(B) = \{b, f\}$$
$$\text{First }(C) = \{g\}$$
$$\text{Follow }(S) = \{\$\}$$
$$\text{Follow }(A) = \{d\}$$
$$\text{Follow }(B) = \text{First }(C) = \{g\}$$
$$\text{Follow }(C) = \text{Follow }(B) = \{g\}$$

So
$$\text{Select }(S \rightarrow A) = \text{First (First }(A)\text{ Follow }(S))$$
$$= \text{First }(\{a\} \times \{\$\}) = \{a\}$$
$$\text{Select }(A \rightarrow aB) = \{a\}$$
$$\text{Select }(A \rightarrow Ad) = \{a\}$$
$$\text{Select }(B \rightarrow bBC) = \{b\}$$
$$\text{Select }(B \rightarrow f) = \{f\}$$
$$\text{Select }(C \rightarrow g) = \{g\}$$

Example 5.14. Construct M-table for following grammar :

$$S \rightarrow iEtSS_1/a$$
$$S_1 \rightarrow eS/\in$$
$$E \rightarrow b$$

Solution.
$$\text{First }(S) = \{i, a\}$$
$$\text{First }(S_1) = \text{First }(eS) \cup \text{First }(\in) = \{e, \in\}$$
$$\text{First }(E) = \text{First }(b) = \{b\}$$
$$\text{Follow }(S) = \{\$\}$$

Now by
$$S \rightarrow iEtSS_1,\ \text{Follow }(E) = \{t\}$$
$$\text{Follow }(S) = \text{First }(S_1) - \{\in\} \cup \text{Follow }(S)$$
$$= \{e, \in\} - \{\in\} \cup \{\$\}$$
$$= \{e, \$\}$$
$$\text{Follow }(S_1) = \text{Follow }(S) = \{e, \$\}$$

By $S_1 \to eS$

$$\text{Follow}(S) = \text{Follow}(S_1) = \{e, \$\}$$

Now calculate select by the help of First and Follow :

$$\begin{aligned}
\text{Select}(S \to iEtSS_1) &= \text{First}(\text{First}(iEtSS_1)\ \text{Follow}(S)) \\
&= \text{First}(\{i\}\ \{e, \$\}) = \text{First}(ie, i\$) \\
&= \{i\} \\
\text{Select}(S \to a) &= \text{First}(\text{First}(a)\ \text{Follow}(S)) = \text{First}(ae, a\$) \\
&= \{a\} \\
\text{Select}(S_1 \to eS) &= \text{First}(\text{First}(eS)\ \text{Follow}(S_1)) \\
&= \text{First}(\{e\}, \{e, \$\}) = \text{First}(e, e\$) \\
&= \{e\} \\
\text{Select}(S_1 \to \in) &= \text{First}(\text{First}(\in)\ \text{Follow}(S_1) = \text{First}(\{\in\}, \{e, \$\}) \\
&= \text{First}(e, \$) = \{e, \$\} \\
\text{Select}(E \to b) &= \text{First}(\text{First}(b)\ \text{Follow}(E)) \\
&= \{b\}
\end{aligned}$$

Now entries of M-table can be very easily filled by the looking the select for every production as follows :

	i	a	b	e	t	$
S	$S \to iEtSS_1$	$S \to a$				
S_1				$S_1 \to eS$ $S_1 \to \in$		$S_1 \to \in$
E			$E \to b$			

Fig. 5.19.

$$\begin{aligned}
M(S, i) &= S \to iEtSS_1 && (\text{Since select for } S \to iEtSS_1 \text{ is } i) \\
M(S, a) &= S \to a && (\text{Since select } (S \to a) = \{a\} \\
M(S_1, e) &= S_1 \to eS && (\text{Since select } (S_1 \to eS) = \{e\} \\
&= S_1 \to \in && \text{and select } (S_1 \to \in) = \{e, \$\}) \\
M(S_1, \$) &= S_1 \to \$ \\
M(E, b) &= E \to b
\end{aligned}$$

So clearly once we calculate the select then it becomes very easy to design the M-table for given grammar.

Since M-table have double entries for $M[S_1, e]$ as $S_1 \to eS$ and $S_1 \to \in$ so given grammar is not LL(1).

Example 5.15. Construct the M-table for given grammar :

$$\begin{aligned}
S &\to aBDh \\
B &\to cC
\end{aligned}$$

$C \to bC/\in$
$D \to EF$
$E \to g/\in$
$F \to f/\in$

Solution.

$$\text{First}(S) = \text{First}(aBDh) = \{a\}$$
$$\text{First}(B) = \{c\}$$
$$\text{First}(C) = \{b, \in\}$$
$$\text{First}(D) = \text{First}(EF) = \text{First}(E) - \{\in\} \cup \text{First}(F) \quad ...(1)$$
$$\text{First}(E) = \{g, \in\}$$
$$\text{First}(F) = \{f, \in\}$$

So

$$\text{First}(D) = \{g, \in\} - \{\in\} \cup \{f, \in\} \text{ by } (1)$$
$$= \{g, f, \in\}$$
$$\text{Follow}(S) = \$$$

(*a*) Using the production $S \to aBDh$ we can get

$$\text{Follow}(B) = \text{First}(Dh) = \text{First}(D) - \{\in\} \cup \text{First}(h)$$
$$= \{g, f, \in\} - \{\in\} \cup \{h\} = \{g, f, h\}$$
$$\text{Follow}(D) = \text{First}(h) = \{h\}$$

(*b*) Using the production $B \to cC$, we will get

$$\text{Follow}(C) = \text{Follow}(B) = \{g, f, h\}$$

(*c*) By using the production $C \to bC$, we will get

$$\text{Follow}(C) = \text{Follow}(C) = \{g, f, h\}$$

(*d*) Now by using the production $D \to EF$ we will get

$$\text{Follow}(E) = \text{First}(F) - \{\in\} \cup \text{Follow}(D)$$
$$= \{f, \in\} - \{\in\} \cup \{h\} = \{f, h\}$$
$$\text{Follow}(F) = \text{Follow}(D) = \{h\}$$

Now let us calculate select as follows :

$$\text{Select}(S \to aBDh) = \text{First}(\text{First}(aBDh)\ \text{Follow}(S))$$
$$= \text{First}(\{a\}, \{\$\}) = \text{First}(a\$) = \{a\}$$
$$\text{Select}(B \to cC) = \text{First}(\text{First}(cC)\ \text{Follow}(B))$$
$$= \text{First}(\{c\}\ \{g, f, h\}) = \{c\}$$
$$\text{Select}(C \to bC) = \text{First}(\text{First}(bc)\ \text{Follow}(C)$$
$$= \text{First}(\{b\}\ \{g, f, h\}) = \{b\}$$
$$\text{Select}(C \to \in) = \text{First}(\text{First}(\in)\ \text{Follow}(C))$$
$$= \text{First}(\{\in\}\ \{g, f, h\} = \{g, f, h\}$$
$$\text{Select}(D \to EF) = \text{First}(\text{First}(EF)\ \text{Follow}(D))$$
$$= \text{First}(\{g, f, \in\}\ \{h\})$$
$$= \text{First}(gh, fh, \in h)$$
$$= \{g, f, h\}$$

Similarly :

$$\text{Select } (E \to g) = \{g\}$$
$$\text{Select } (E \to \in) = \{f, h\}$$
$$\text{Select } (F \to f) = \{f\}$$
$$\text{Select } (F \to \in) = \{h\}$$

Now we can design *M*-table as follows :

$M(S, a) = S \to aBDh$ (Since select $(S \to aBDh) = \{a\}$)

$M(B, c) = B \to cC$ (Since select $(B \to cC) = \{c\}$)

$M(C, b) = C \to bC$ (Since select $(C \to bC) = \{b\}$)

$M(C, g/f/h) = C \to \in$ (Since select $(C \to \in) = \{g, f, h\}$)

$M(D, g/f/h) = D \to EF$ (Since select $(D \to EF) = \{g, f, h\}$)

$M(E, g) = E \to g$ (Since select $(E \to g) = \{g\}$)

$M(E, f/h) = E \to \in$ (Since select $(E \to \in) = \{f, h\}$)

$M(F, f) = F \to f$ (Since select $(F \to f) = \{f\}$)

$M(F, h) = F \to \in$ (Since select $(F \to \in) = \{h\}$)

Now we can design M-table as follows :

	a	***b***	***c***	***g***	***f***	***h***	***$***
S	$S \to aBDh$						
B			$B \to cC$				
C		$C \to bC$		$C \to \in$	$C \to \in$	$C \to \in$	
D				$D \to EF$	$D \to EF$	$D \to EF$	
E				$E \to g$	$E \to \in$	$E \to \in$	
F					$F \to f$	$F \to \in$	

Fig. 5.20.

EXERCISE

1. Consider the following grammar :

$$S \to AaAbBbBa$$
$$A \to \in$$
$$B \to \in$$

Is the grammar LL(1) ?

2. Given a grammar :

$$E \to E + T/T$$
$$T \to T * F/F$$
$$F \to id$$

which is a set of valid items for a viable prefix it.