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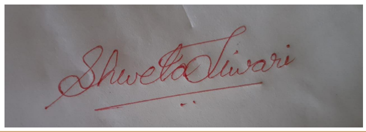

CD: COMPILER DESIGN

TOPIC On : UNIT-2 PREDICTIVE PARSER/NON-RECURSIVE DESCENT/NON-RECURSIVE PREDICTIVE/LL(1)

By SHWETA TIWARI

Under On: Basic Parsing Techniques

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II. PREDICTIVE PARSER/NON-RECURSIVE DESCENT/NON-RECURSIVE PREDICTIVE/LL(1)

Predictive Parser:

A grammar after eliminating left recursion and left factoring can be parsed by a recursive descent parser that needs no backtracking is called a predictive parser. Let us understand how to eliminate left recursion and left factoring.

Non-recursive Predictive Parsing:

It is possible to build a non-recursive predictive parser by maintaining a stack explicitly, rather than implicitly via recursive calls. The key problem during predictive parsing is that of determining the production to be applied for a non-terminal. The non-recursive parser in Fig1 looks up the production to be applied in a parsing table.

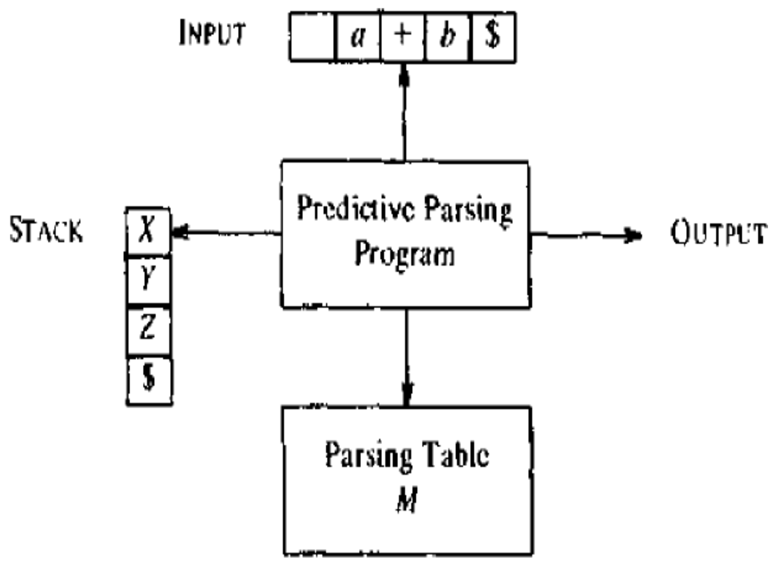

Fig 1 Model of a Non-recursive predictive parser

A table-driven predictive parser has an input buffer, a stack, a parsing table, and an output stream. The input buffer contains the string to be parsed, followed by $, a symbol used as a right end marker to indicate the end of the input string. The stack contains a sequence of grammar symbols with $ on the bottom, indicating the bottom of the stack. Initially, the stack contains the start symbol of the grammar on top of S. The parsing table is a two-dimensional array *M[A,a],*where *A* is a non-terminal, and *a* is a terminal or the symbol $.

Construction of (LL1) parser:

There are five steps involved in this process:

1. Elimination of left recursion.

2. Elimination of left factoring.

3. Calculator of FIRST() And FOLLOW() of Grammar/Production.

4. Construction of parsing table.

5. Check whether the input string is accepted or not.

STEP-1 Elimination of left recursion.

Eliminating Left Recursion:

A grammar is said to be left recursive if it has a non-terminal A such that there is a derivation A=>Aα for some string α. Top-down parsing methods cannot handle left-recursive grammars. Hence, left recursion can be eliminated as follows:

*If there is a production **A → Aα | β** it can be replaced with a sequence of two productions

A → βA'

A' → αA' | ε

*If there is a production **A → Aα1|Aα2|… | β1| β2|…** it can be replaced with a sequence of two productions

A → β1A'|β2A|...

A' → α1A'|α2A |..| ε

Without changing the set of strings derivable from A.

Example : Consider the following grammar for arithmetic expressions:

E → E+T | T

T → T*F | F

F → (E) | id

First eliminate the left recursion for E as

E → TE'

E' → +TE' | ε

Then eliminate for T as

T → FT '

T'→ *FT ' | ε

Thus the obtained grammar after eliminating left recursion is

E → TE'

E' → +TE' | ε T → FT '

T'→ *FT ' | ε

$F \rightarrow (E) \mid id$

Algorithm to eliminate left recursion:

1. Arrange the non-terminals in some order $A_1, A_2 \dots A_n$.
2. **for** i := 1 to n do begin

    for j := 1 to i-1 do begin

        replace each production of the form $A_i \rightarrow A_j \gamma$

        by the productions $A_i \rightarrow \delta_1 \gamma \mid \delta_2\gamma \mid \dots \mid \delta_k \gamma$.

        where $A_j \rightarrow \delta_1 \mid \delta_2 \mid \dots \mid \delta_k$ are all the current Aj-productions;

    end

    eliminate the immediate left recursion among the A_i- productions

end

STEP-2 Elimination of left Factoring.

Left factoring:

Left factoring is a grammar transformation that is useful for producing a grammar suitable for predictive parsing. When it is not clear which of two alternative productions to use to expand a non-terminal A, we can rewrite the A-productions to defer the decision until we have seen enough of the input to make the right choice.

If there is any production $\mathbf{A \rightarrow \alpha\beta_1 \mid \alpha\beta_2|...|\gamma1|\gamma2...}$, it can be

rewritten as

$\mathbf{A \rightarrow \alpha A'|\gamma1|\gamma2}$

$\mathbf{A' \rightarrow \beta_1 \mid \beta_2}$

Consider the grammar,

$S \rightarrow iEtS \mid iEtSeS \mid a$

$E \rightarrow b$

Here,***i,t,e*** stand for **if ,the**,and **else** and **E** and **S** for “expression” and “statement”.

After Left factored, the grammar becomes

$S \rightarrow iEtSS' \mid a$

$S' \rightarrow eS \mid \varepsilon$

$E \rightarrow b$

STEP-3 Calculator of FIRST() And FOLLOW() of Grammar/Production.

These functions are FIRST() and FOLLOW().

Rules for FIRST():

1. If **X is terminal**, then **FIRST(X) is {X}.**
2. If **X → ε** is a production, then **add ε to FIRST(X).**
3. If **X is non-terminal and X → aα** is a production then **add a to FIRST(X).**
4. If X is non-terminal and X → Y 1 Y2…Yk is a production, then place a in FIRST(X) if for some i, a is in FIRST(Yi), and ε is in all of FIRST(Y1),…,FIRST(Yi-1); that is, Y1,….Yi-1 => ε. If ε is in FIRST(Yj) for all j=1,2,..,k, then add ε to FIRST(X).

Rules for FOLLOW():

1. If **S is a start symbol**, then F**OLLOW(S) contains $.**
2. If there is a production **A → αBβ,** then everything in **FIRST(β) except ε** is placed in **FOLLOW(B).**
3. If there is a production **A → αB, or a production A → αBβ** where **FIRST(β) contains ε,**then everything in **FOLLOW(A) is in FOLLOW(B).**

STEP-4 Construction of Parsing Table.

Predictive parsing table construction:

The construction of a predictive parser is aided by two functions associated with a grammar

Algorithm for construction of predictive parsing table:

Input : Grammar G

Output : Parsing table M

Method :

1. For each production A → α of the grammar, do steps 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 an error.

Construction of predictive parsing table(Rules in simple form)

Additional for understanding rules

For each production A → α

1. Find **FIRST(α)** and for each terminal in **FIRST(α).** Make an entry **[A → α]** in the table.
2. If **FIRST(α) contains ε** as **terminal,** then **FOLLOW(A)** for each terminal in **FOLLOW(A).** Make an entry **[A → α] i**n the table.
3. If **FIRST(α) contains ε** and **FOLLOW(A) contains $** terminal, then make an entry **[A → α]** in the table **for $.**
4. Make each undefined entry of M be an error.

STEP-5 Check whether the input string is accepted or not.

Predictive Parser Model (Algorithm)

The program considers X, the symbol on top of the stack, and a, the current input symbol. These two symbols determine the action of the parser. There are three possibilities.

1. If **X = a =$,** the parser halts and announces successful completion of parsing.
2. If **X =a ≠$,** the parser pops X off the stack and advances the input pointer to the next input symbol.
3. If **X is a nonterminal,** the program consults entry **M[X,a]** of the parsing table M. This entry will be either an X-production of the grammar or an error entry. If, for example, **M[X,a] = {X→UVW},** the parser replaces X on top of the stack by WVU (with U on top). If M[X, a] = error, the parser calls an error recovery routine.

Algorithm : Non-recursive predictive parsing.

Input: A string w and a parsing table M for grammar G.

Output: If w is in L(G), a leftmost derivation of w; otherwise, an error .

Method: Initially, the parser is in a configuration in which it has $$ on the stack with S, the start symbol of G on top, and w$ in the input buffer. The program that utilizes the predictive parsing table M to produce a parse for the input.

```
set ip to point to the first symbol of w$:
repeat
    let X be the top stack symbol and a the symbol pointed to by ip;
    if X is a terminal or $ then
        if X = a then
            pop X from the stack and advance ip
        else error()
    else      /* X is a nomerminal */
        if M[X,a] =X→Y1Y2…….Yk, then
            begin
                pop X from the stack:
                push Yk , Yk - 1 Y1 , onto the stack, with Y1 on top;
```

```
            output the production X→Y1Y2 …..Yk
        end
    else error()
until X ≠$     /* stack is empty*/
```

Example:

Consider the following grammar:

E → E+T | T

T → T*F | F

F → (E) | id

There are five steps involved in this process:
1. Elimination of left recursion.
2. Elimination of left factoring.
3. Calculator of FIRST() FOLLOW of Grammar/Production.
4. Construction of parsing table.
5. Check whether the input string is accepted or not.

STEP-1 Elimination of left recursion.

- After eliminating left recursion the grammar is E → TE'

E' → +TE' | ε

T → FT '

T'→ *FT ' | ε

F → (E) | id

STEP-2 Elimination of left factoring.

- There is no left factoring in above grammar.

E → TE'

E' → +TE' | ε

T → FT '

T'→ *FT ' | ε

F → (E) | id

STEP-3 Calculator of FIRST() FOLLOW of Grammar/Production.

FIRST( ) :

E → TE'

E' → +TE' | ε

T → FT '

T'→ *FT ' | ε

F → (E) | id

FIRST(E) = { (, id}

FIRST(E') ={+ , ε }

FIRST(T) = { (, id}

FIRST(T') = {*, ε }

FIRST(F) = { (, id }

FOLLOW( ):

FOLLOW(E) = { $,) }

FOLLOW(E') = { $,) }

FOLLOW(T) = { +, $,) }

FOLLOW(T') = { +, $,) }

FOLLOW(F) = {+, * , $,) }

STEP-4 Construction of parsing table.

- Construction the parsing table through "Construction of parsing table Algorithm(Rules)".
  Predictive parsing table for the given grammar is shown in Fig 2.

M[X,a]	**id**	**+**	*****	**(**	**)**	**$**
E	E →TE'			E →TE'		
E'		E' →+TE'			E' →ε	E' →ε
T	T →FT'			T →FT'		
T'		T' →ε	T' →*FT'		T' →ε	T' →ε
F	F →**id**			F → (E)		

Fig 2 Parsing table

STEP-5 Check whether the input string is accepted or not.

STRING w=id+id*id

- **Add $ in the end of the given string w which will be taken as INPUT BUFFER and $ must be STACK in bottom.**
- Follow the **Predictive Parser Model (Algorithm/Rules)**.
- With input **id+id*id** the predictive parser makes the sequence of moves shown in Fig 3.

STACK	INPUT	OUTPUT
$E	**id+id*id$**	E →TE’
$E’T	**id+id*id$**	T →FT’
$E’T’F	**id+id*id$**	F →**id**
$E’T’**id**	**id+id*id$**	pop
$E’T’	**+id*id$**	T’ →ε
$E’	**+id*id$**	E’ →+TE’
$E’T+	**+id*id$**	pop
$E’T	**id*id$**	T →FT’
$E’T’F	**id*id$**	F →**id**
$E’T’**id**	**id*id$**	Pop
$E’T’	***id$**	T’ →*FT’
$E’T’F*	***id$**	Pop
$E’T’F	**id$**	F →**id**
$E’T’**id**	**id$**	Pop
$E’T’	**$**	T’ →ε
$E’	**$**	E’ →ε
$	**$**	Accept

Fig 3 Moves made by predictive parser on input **id+id*id**

Syntax Tree of string (w=id+id*id) by using this above table.

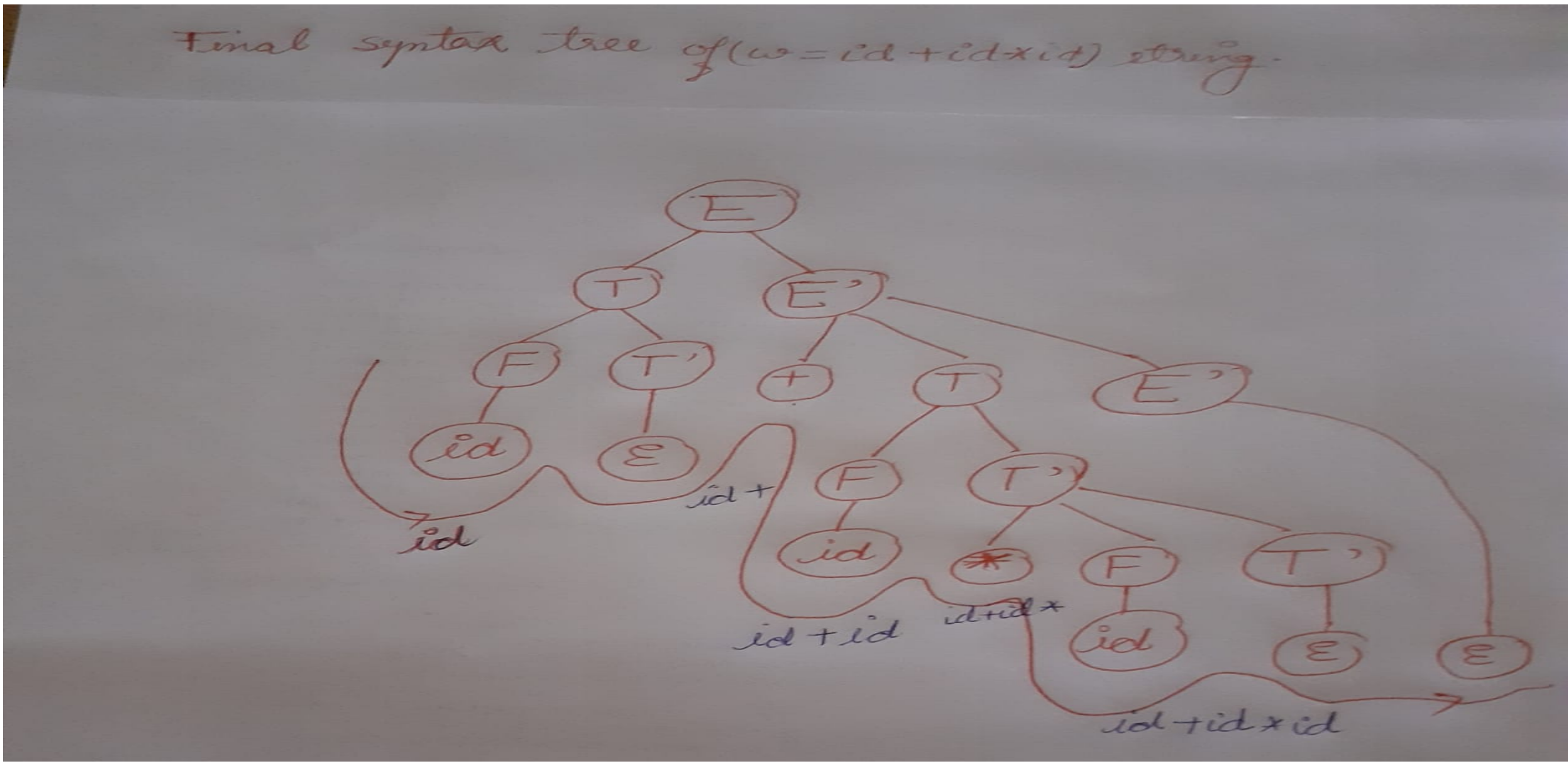

Fig 4 Syntax Tree

Question-1. : Construct parsing table of given grammar and check whether a string w=id+id is accepted or not. if string is accepted, then draw a Syntax tree of string w=id+id. Grammar is:

E → E+T | T
T → T*F | F

F → (E) | id

Other Example

LL(1) Grammars:

For some grammars the parsing table may have some entries that are multiply-defined. For example, if G is left recursive or ambiguous , then the table will have at least one multiply-defined entry. A grammar whose parsing table has no multiply-defined entries is said to be LL(1) grammar.

Example: Consider this following grammar:

S→ iEtS | iEtSeS | a

E → b

After eliminating left factoring, we have

S→ iEtSS' | a S'→ eS | ε

E → b

To construct a parsing table, we need FIRST() and FOLLOW() for all the non-terminals.

FIRST(S) ={ i, a }

FIRST(S') = {e, ε }

FIRST(E) = { b}

FOLLOW(S) = { $,e }

FOLLOW(S') = { $,e }

FOLLOW(E) = {t}

Parsing Table for the grammar:

NON-TERMINAL	a	b	e	i	t	$
S	S → a			S → iEtSS'		
S'			S' → eS S' → ε			S' → ε
E		E → b				

Since there are more than one production for an entry in the table, the grammar is not LL(1) grammar.