CS & IT ENGINEERING

Compiler Design

Lexical Analysis & Syntax Analysis

Lecture No. 5

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TOPICS TO BE COVERED

01 First & Follow Sets

02 LL(1) Parser

03 LL(1) CFG

04 LL(1) Table

05 LL(1) Algorithm

First(X) : { t | t is derived as 1st symbol from X }

$X \rightarrow \boxed{a}bc \mid \boxed{d}efg \mid \varepsilon$

First(X) = {a, d, ε}

Follow(X) = { t | t is derived as 1[st] symbol after X }

$S \rightarrow AaB$

$A \rightarrow Ab \mid Ac \mid d$

$B \rightarrow a \mid Ac \mid f$

Follow(A) = {a, b, c, e}

FIRST and FOLLOW Sets Computation

① $S \rightarrow \varepsilon$

$\text{FIRST}(S) = \{\varepsilon\}$

$\text{FOLLOW}(\underset{\substack{\downarrow \\ \text{Start Symol}}}{S}) = \{\$\}$

FIRST and FOLLOW Sets Computation

② $S \to Sa \mid Sb \mid c$

FIRST(S) = { c }

FOLLOW(S) = { \$, a, b }

FIRST and FOLLOW Sets Computation

③ $S \rightarrow A$

$A \rightarrow a$

$FIRST(S) = \{a\}$

$FIRST(A) = \{a\}$

$FOLLOW(S) = \{\$\}$

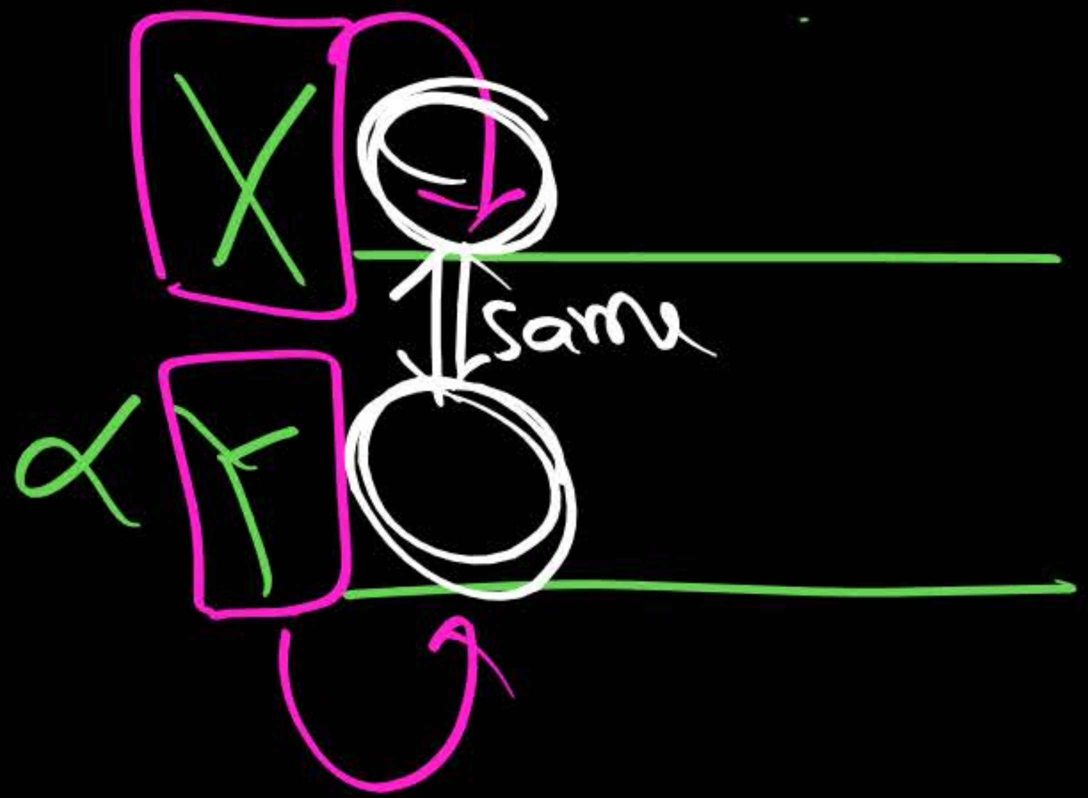
$FOLLOW(A) = \{\$\}$

$$\boxed{S} \rightarrow \boxed{A}$$

$Follow(A) = Follow(S)$

Note: If $\boxed{X} \rightarrow \alpha \boxed{Y}$ then

$$\text{Follow}(Y) = \text{Follow}(X)$$



FIRST and FOLLOW Sets Computation

4.

$$S \rightarrow AB$$
$$A \rightarrow ab \mid \varepsilon$$
$$B \rightarrow cd \mid \varepsilon$$

$\text{FIRST}(S) = \{a, c, \varepsilon\}$

$\text{FIRST}(A) = \{a, \varepsilon\}$

$\text{FIRST}(B) = \{c, \varepsilon\}$

$\text{Follow}(S) = \{\$\}$

$\text{Follow}(A) = \{c, \$\}$

$\text{Follow}(B) = \text{Follow}(S) = \{\$\}$

FIRST and FOLLOW Sets Computation

(5)

7.7

$S \to aAbB \mid bAaB \mid \varepsilon$

$A \to S$

$B \to S$

First(S) = {a, b, ε}

First(A) = First(S) = {a, b, ε}

First(B) = First(S) = {a, b, ε}

Follow(S) = {\$} ∪ Follow(A) ∪ Follow(B)

= {a, b}   = ~~{\$}~~

= {\$, a, b}

Follow(A) = {a, b}

Follow(B) = Follow(S)

= {\$, a, b}

Follow(S)	Follow(A)	Follow(B)
$A \to \boxed{S}$	$a\boxed{A}bB$	$S \to aAb\boxed{B}$
$B \to \boxed{S}$	$b\boxed{A}aB$	$S \to bAa\boxed{B}$

FIRST and FOLLOW Sets Computation

⑥ 7.6

$P \rightarrow x\boxed{Q}RS$

$Q \rightarrow yz \mid z$

$R \rightarrow w \mid \varepsilon$

$S \rightarrow y$

$First(P) = \{x\}$

$First(Q) = \{y, z\}$

$First(R) = \{w, \varepsilon\}$

$First(S) = \{y\}$

Follow(Q) = First(RS) = {w, y}

$Follow(P) = \{\$\}$

$Follow(Q) = \{w\} \cup First(S)$

$= \{w, y\}$

$Follow(R) = First(S) = \{y\}$

$Follow(S) = Follow(P) = \{\$\}$

FIRST and FOLLOW Sets Computation

⑦ $S \rightarrow ABC$

$A \rightarrow a$

$B \rightarrow b$

$C \rightarrow d$

$Fi(S) = \{a\}$

$Fi(A) = \{a\}$

$Fi(B) = \{b\}$

$Fi(C) = \{d\}$

$Fo(S) = \{\$\}$

$Fo(A) = \{b\}$

$Fo(B) = \{d\}$

$Fo(C) = Fo(S) = \{\$\}$

FIRST and FOLLOW Sets Computation

(8) ***

$S \rightarrow AB\boxed{C}$

$A \rightarrow ab \mid \varepsilon$

$B \rightarrow cde \mid \varepsilon$

$C \rightarrow f \mid \varepsilon$

$Fi(S) = \{a, c, f, \varepsilon\}$

$Fi(A) = \{a, \varepsilon\}$

$Fi(B) = \{c, \varepsilon\}$

$Fi(C) = \{f, \varepsilon\}$

$Fo(S) = \{\$\}$

$Fo(A) = \{c, f, \$\}$

$Fo(B) = \{f, \$\}$

$Fo(C) = Fo(S) = \{\$\}$

Note :

If $S \rightarrow \underbrace{\overset{t_1 \dots}{A}\;\overset{}{\underset{\varepsilon}{B}}\;\underset{\varepsilon}{C}}_{}$ and

$|First(A)| = 1$

$|First(B)| = 2$

$|\underbrace{First(C)}_{\text{only 3 symbols}}| = 3$

then Find max & min size of First(S).

$1 \leq |First(S)| \leq 4$.

Min case :

$First(A) = \{t_1\}$ → not Epsilon

$|First(S)| = 1$

Max case :

$Fi(A) = \{\varepsilon\}$

$Fi(B) = \{t_1, \varepsilon\}$

$Fi(C) = \{t_2, t_3, t_4\}$ (or ε)

$First(S) = \{t_1, t_2, t_3, t_4\}$ (or ε)

FIRST and FOLLOW Sets Computation

⑨

$E \rightarrow aX$

$X \rightarrow +TX \mid \varepsilon$

$T \rightarrow b$

$Fi(E) = \{a\}$

$Fi(X) = \{+, \varepsilon\}$

$Fi(T) = \{b\}$

$Fo(E) = \{\$\}$

$Fo(T) = \{+, \$\}$

$Fo(X) = \{\$\}$

FIRST and FOLLOW Sets Computation

(10) $E \to E+b \mid b$

$Fi(E) = \{b\}$

$Fo(E) = \{\$, +\}$

(11) $S \to Sa \mid b$

$Fi(S) = \{b\}$

$Fo(S) = \{a\}$

FIRST and FOLLOW Sets Computation

(12) $S \rightarrow AB$

$A \rightarrow a$

$B \rightarrow b$

	S	A	B
First	{a}	{a}	{b}
Follow	{$}	{b}	{$}

(13) $S \rightarrow [S] \mid a$

$Fi(S) = \{[, a\}$

$Fo(S) = \{\$,]\}$

FIRST and FOLLOW Sets Computation

14 $S \rightarrow aSb \mid \varepsilon$

$Fi(S) = \{a, \varepsilon\}$

$Fo(S) = \{\$, b\}$

FIRST and FOLLOW Sets Computation

15. $S \rightarrow a\boxed{S}b\boxed{S}c \mid d$

$First(S) = \{a, d\}$

$Follow(S) = \{\$, b, c\}$

FIRST and FOLLOW Sets Computation

16. $S \rightarrow AA \mid b$

$A \rightarrow cd \mid \varepsilon$

$S \rightarrow \boxed{A}\,A$

c

ε

$S \rightarrow A\,\boxed{A}$

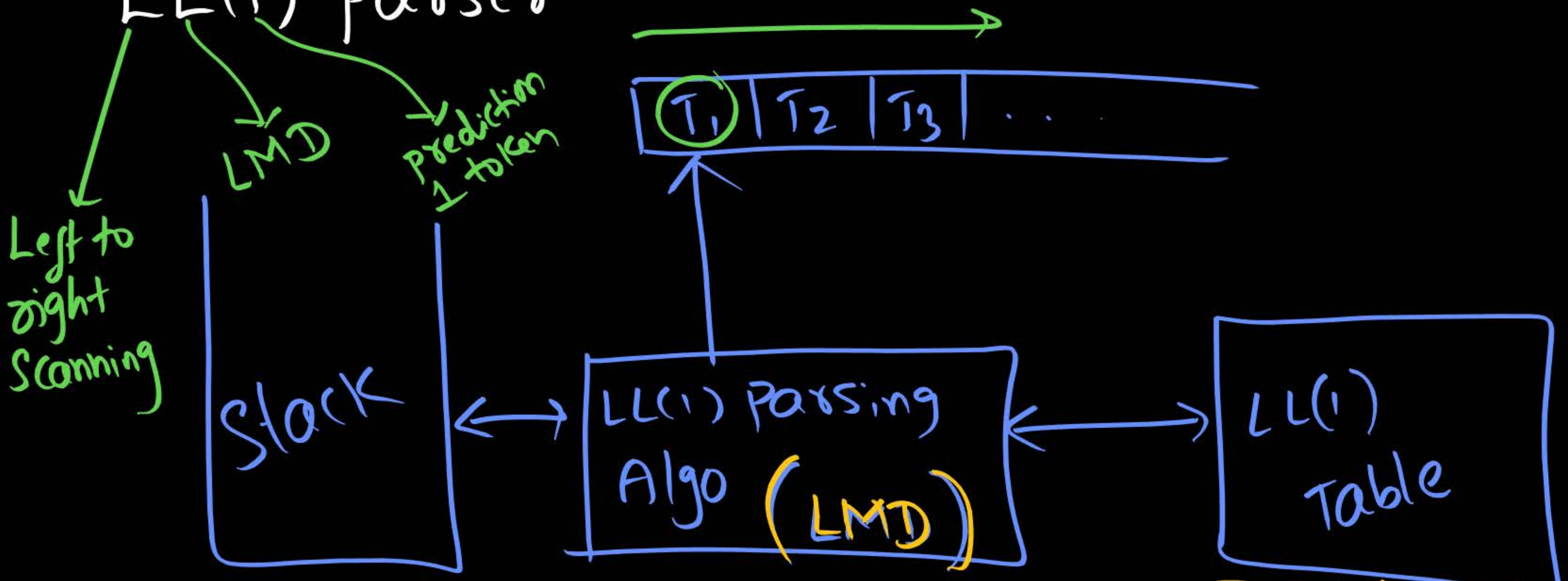
$Fi(S) = \{c, \varepsilon, b\}$

$Fi(A) = \{c, \varepsilon\}$

$Fo(S) = \{\$\}$

$Fo(A) = \{c, \$\}$

LL(1) Parser



To construct this table, we need LL(1) CFG.

LL(1) CFG :

Method 1 : If we construct LL(1) Table and no multiple entries in the table for given CFG then we say CFG is LL(1).

Method 2 : Short cut

(I) $A \rightarrow \alpha_1 | \alpha_2$

$Fi(\alpha_1) \cap Fi(\alpha_2) = \phi$

(II) $A \rightarrow \alpha | \epsilon$

$Fi(\alpha) \cap Fo(A) = \phi$

How to write LL(1) CFG ?

Step 1: Take Unambiguous CFG

$\Downarrow$ Eliminate Left recursion

Step 2: Convert to non left rec CFG

$\Downarrow$ Apply Left factoring

Step 3: Convert to Left factored CFG

$\Downarrow$ If LL(1) Table has no multiple entries

It is LL(1) CFG

LL(1) Table construction:

Step1: compute FIRST set for every non-terminal

Step2: If any FIRST set contain ϵ then only compute Follow set for that non-terminal

Step3: Using step1 & step2, fill the table.

① $S \rightarrow a$

$|V| \times (|T|+1)$

$\underbrace{|V|}_{\#\text{rows}} \times \underbrace{(|T|+1)}_{\#\text{columns}}$

$\text{First}(\underset{\text{row}}{S}) = \{\underset{\text{column}}{a}\}$

LL(1)	a	\$
S	Find S production that derives 'a' as 1st symbol $S \rightarrow a$	

This table is not having multiple entries,

So, given CFG is LL(1).

Note : I) If every entry of LL(1) table has

$\underbrace{\text{atmost 1}}_{\substack{(\le 1) \\ = 0 \text{ or } 1}}$ production, given CFG is LL(1)

II) Follow set helps to fill the table with the productions those derive ε

② $S \rightarrow aSb \mid \varepsilon$

$Fi(S) = \{a, \boxed{\varepsilon}\}$

find production that derives ε

$Follow(S) = \{\$, b\}$

	a	b	\$
S	$S \rightarrow aSb$	$S \rightarrow \varepsilon$	$S \rightarrow \varepsilon$

$S\ b$

$\$$

ε

(3) $S \to A$

$A \to b \mid \epsilon$

$Fi(S) = \{b, \boxed{\varepsilon}\}$

$Fi(A) = \{b, \boxed{\varepsilon}\}$

$Follow(S) = \{\$\}$

$Follow(A) = \{\$\}$

	b	\$
S	$S \to A$	$S \to A$
A	$A \to b$	$A \to \varepsilon$

⇐ only S prod.

⇐ only A production

OR

	b	\$
S	A	A
A	b	ε

fill only RHS

Note :

	a	b	$
S	$S \to abA$	$S \to bb$	
A		$A \to b$	

$\Rightarrow$

$S \to abA \mid bb$

$A \to b$

We can find CFG using Table

Note: Ambiguous CFG never be LL(1)

Summary

- First & Follow
- LL(1) Table Constru
- LL(1) CFG ?

Next: LL(1) Algo ?

$\Longrightarrow$ LR parsers


THANK YOU
GW
SOLDIERS !