CS & IT ENGINEERING

Compiler Design

Lexical Analysis & Syntax Analysis

Lecture No. 6

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Follow SET

LL(1) parser

- LL(1) CFG
- LL(1) Table
- LL(1) Algorithm

FOLLOW SET :

1. $S \rightarrow a$

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

$\boxed{\text{If } S \text{ is start symbol then } \$ \in Follow(S)}$

$S\$$

special end terminal

② $S \rightarrow Sa \mid Sb \mid c$

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

③ $S \rightarrow S\boxed{a}c \mid S\boxed{b}d \mid e$

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

Note:

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

$S\alpha$

$\Downarrow$

$a\boxed{A}\alpha$

Follow(A) = we should compute Follow(S)

If $X \rightarrow \alpha\boxed{Y}$ then Follow(Y) = Follow($\overset{LHS}{X}$)

④ $\boxed{S} \rightarrow a\boxed{A} \mid bSd \mid c$

$A \rightarrow \boxed{A}e \mid Sg \mid f$

$\text{Follow}(S) = \{\$, d, g\}$

$\text{Follow}(A) = \{e\} \cup \text{Follow}(S) = \{e, \$, d, g\}$

(5) $S \to A\boxed{B}$ Follow(LHS) S

$A \to a$

$B \to b$

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

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

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

⑥ $S \rightarrow \boxed{A}B$ no symbol

$A \rightarrow a$

$B \rightarrow \varepsilon$

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

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

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

⑦ $S \rightarrow \boxed{A}B$

$A \rightarrow a$

$B \rightarrow bc \mid \varepsilon$

Abc

A

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

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

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

Follow(A)

$S \rightarrow \boxed{A}B$

bc
or
ε

$S \rightarrow Abc$

$S \rightarrow A$

Compute FIRST & FOLLOW Sets :

① $S \to SS \mid (S) \mid a$

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

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

$Follow(S) = ?$

① $S \to \boxed{S}S \Leftarrow \{(, a\}$

(. . . .

a . . . .

~~②~~ $S \to S\boxed{S}$ Follow(S) = Follow(S)

③ $S \to (\boxed{S}) \Leftarrow \{)\}$

a

(S)

S S

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

(. . . –

a . . . –

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

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

SS

a

(S)

$$X \rightarrow \alpha \boxed{Y}$$

$\rightarrow$ Follow(LHS)

$$\cancel{S \rightarrow S \boxed{S}}$$

$\rightarrow$ Follow(LHS)
S

② $E \to \underbrace{E+E}_{a\ldots} \mid \underbrace{E*E}_{a\ldots} \mid a$

$\text{FIRST}(E) = \{a\}$

$\text{FOLLOW}(E) = \{\$, +, *\}$

$\text{Follow}(E) = \{\$\} \cup \{+\} \cup \cancel{\text{Follow}(E)} \cup \{*\} \cup \cancel{\text{Follow}(E)}$

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$E \rightarrow E+T \mid a$

$T \rightarrow F*T \mid b$

$F \rightarrow (E) \mid c$

FIRST(E) = {a}

FIRST(T) = {b, c, (}

FIRST(F) = {(, c}

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

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

Follow(F) = {*}

④ ***

$S \rightarrow ABC$

$A \rightarrow ab \mid \varepsilon$

$B \rightarrow ef \mid \varepsilon$

$C \rightarrow gh \mid \varepsilon$

$First(S) = \{a, e, g, \varepsilon\}$

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

$First(B) = \{e, \varepsilon\}$

$First(C) = \{g, \varepsilon\}$

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

$Follow(A) = \{e, g, \$\}$

$Follow(B) = \{g, \$\}$

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

LL(1) parser :

→ one token prediction

→ LMD

→ left to Right scan

LL(1) Parser

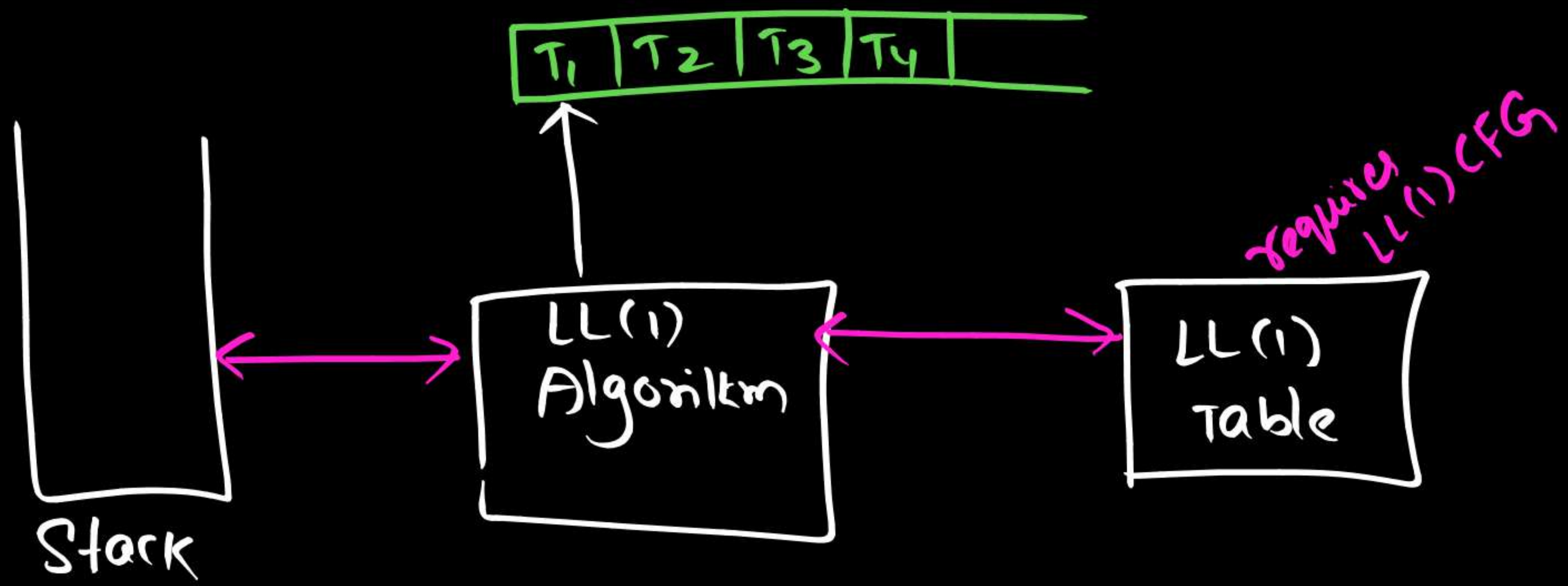
- It follows LMD
- TOP-down parser
- predictive parser
- $\underbrace{\text{Recursive Descent}}_{\text{writing procedure for each production}}$ OR $\underbrace{\text{Non-Recursive Descent}}_{\text{Table Implementation}}$

$S \rightarrow a$

```
S( )
{ ch=getchar();
  if ch=='a'
  :
}
```

	a
S	$S \rightarrow a$

LL(1) Parser Configuration :



I) LL(1) CFG

II) LL(1) Table

III) LL(1) Algorithm

How to write LL(1) CFG ?

Step 1 : Take Unambiguous CFG

$\Downarrow$ Eliminate Left Recursion

Step 2 : Unambiguous & Non Left Rec CFG

$\Downarrow$ Apply Left Factoring

Step 3 : Unambiguous, Non left Rec, and Left Factored CFG

$\Downarrow$ Using First & Follow sets, construct LL(1) Table

Step 4 : If no multiple productions in the same entry of table then CFG is LL(1).

How to construct LL(1) Table ?

① $S \to Aa$

$A \to b \mid \epsilon$

Step1: Compute FIRST set for every non-terminal

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

$\text{FIRST}(A) = \{b, \boxed{\epsilon}\}$

Because of this ϵ, we require Follow(A).

Step2:

If any FIRST set contain ϵ then Compute Follow set only for that non-terminal

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

Step3: construct Table

LL(1)	a	b	\$
S	$S \to Aa$	$S \to Aa$	
A	$A \to \epsilon$	$A \to b$	

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

$$\boxed{\begin{aligned} &S \rightarrow Aa \checkmark \\ &A \rightarrow b \mid \varepsilon \checkmark \end{aligned}}$$

It is LL(1) $\{b\} \cap Fo(A)$

$\{b\} \cap \{a\} = \phi$

Short cut :

i) $X \rightarrow \alpha_1 \mid \alpha_2$

If $Fi(\alpha_1) \cap Fi(\alpha_2) \neq \phi$ then not LL(1)

ii) $X \rightarrow \alpha \mid \varepsilon$

If $Fi(\alpha) \cap Fo(X) \neq \phi$

then not LL(1)

S	we will have only S productions
A	" " " A "
B	" " " B "

when you look at FIRST set

	a
S	Fill this entry with all productions of S they derive 'a' as 1st symbol $S \to a$ $S \to ab$

$S \to \boxed{a} \mid \boxed{a}b \mid cab$

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

When we look at Follow set

	t
S	Fill null production of S

$S \rightarrow \varepsilon$ (Direct)
$S \rightarrow AB$ (Indirect)

$\text{Follow}(S) = \{t, \ldots\}$

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

$A\,b\,c\,d$

$\Downarrow$

what is First terminal ? $= a$

$A \rightarrow ade$

$A \rightarrow \varepsilon$

$= \text{Follow}(A)$

$= b$

② $S \rightarrow aSb \mid \varepsilon$

$Fi(aSb) \cap Fo(S)$

$\{a\} \cap \{b, \$\} = \phi$

It is LL(1).

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

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

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

Every entry of table has atmost one production

③ $S \to Sa \mid b$

Method 1 :

given CFG is having Left Recursion

⇓

So, not LL(1).

Method 3:

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

	a	b	\$
S		$S \to Sa$ $S \to b$	

more than one production in some entry. So, not LL(1).

Method 2 :

$$\underset{\{b\}}{Fi(Sa)} \cap \underset{\{b\}}{Fi(b)} \neq \phi$$

Note 1: Every LL(1) CFG is

I) Unambiguous

II) Non Left Recursive

III) Left Factored

Note 2: If CFG is unambiguous, Non left Rec, and Left factored then CFG need not be LL(1)

④ $S \rightarrow aSa \mid \varepsilon$

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

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

	a	\$
S	$S \rightarrow aSa$ $S \rightarrow \varepsilon$	$S \rightarrow \varepsilon$

$Fi(aSa) \cap Fo(S)$

$\{a\} \cap \{a, \$\} \neq \phi$

a is common

	a
S	multiple production

Identify CFG is LL(1) or not.

1. $S \to a$ LL(1)

2. $S \to SS \mid \varepsilon$ not LL(1)

3. $S \to a \mid ab$ not LL(1)

4. $S \to Sab \mid \varepsilon$ not LL(1)

5. $S \rightarrow Ab \mid Ba$

$Fi(Ab) \cap Fi(Ba)$

$\{a\} \cap \{a\} \neq \phi$

$A \rightarrow ab$ ✓

$B \rightarrow ac$ ✓

It is not LL(1)

⑥ $S \rightarrow Aa \mid Bb \mid acd \mid \varepsilon$

$A \rightarrow d$ ✓

$B \rightarrow ab$ ✓

not LL(1)

$Fi(Bb) \cap Fi(acd)$

$\{a\} \cap \{a\} \neq \phi$

Summary

- → Follow Set ✓
- → LL(1) Table ✓
- → What is LL(1) CFG ?
- → How to identify CFG ?

Next: LL(1) Algo


THANK YOU
GW
SOLDIERS !