# Computer Science

# Theory of Computation

Regular Languages & Non Regular Languages

Lecture No.- 4

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# Recap of Previous Lecture

Topic — Regular Languages ✓

Topic — Non-regular Languages ✓

# Topics to be Covered

| Topic | Regular Grammar |
| --- | --- |

# Regular Language (Type-3 Language)

- It is a language represented by regular expression
- " " " " FA
- " " " " Regular Grammar (Type-3 Grammar)

# Regular Grammar

Grammar (G) = (V, T, P, S)

- V → Set of variables (non-terminals)
- T → Set of terminals
- P → Set of production rules
- S → start symbol

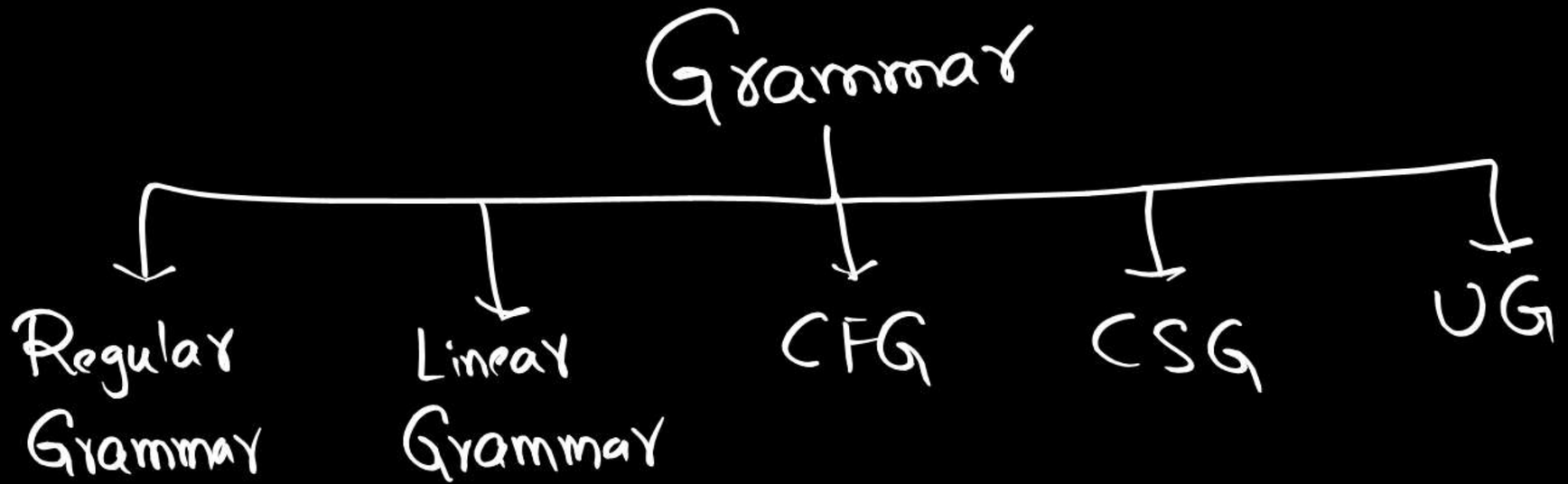
$S \rightarrow a \mid bS$

$V = \{S\}$ $P = \{S \rightarrow a, S \rightarrow bS\}$

$T = \{a, b\}$ $S = S$

# Grammar

↳ It is set of rules which represents a language.



$V = \{S, A\} = S + A$

$T = \{a, b, c\} = a + b + c$

| $V\,T^*$ | $T^*\,V$ |
| --- | --- |
| V | V |
| VT | TV |
| VTT | TTV |
| VTTT | TTTV |

| VV | TTT | VT |
| --- | --- | --- |
| SS | aaa | Sa |
| SA | aab | Sb |
| AS | aac | Sc |
| AA | aba | Aa |
| | abb | Ab |
| | abc | Ac |
| | ⋮ | |
| | ccc | |

# Regular Grammar

↳ It is RLG or LLG

## Right Linear Grammar

Each rule appears in

| $V \to T^*V$ | $T^*$ |
|---|---|

$S \to abA$

$A \to aS \mid \varepsilon \mid ab$ } RLG

## Left Linear Grammar

$V \to VT^* \mid T^*$

$S \to Sab \mid \varepsilon$

## Linear Grammar

$V \to T^*VT^*$

or

$T^*$

$S \to aaSb \mid c$

# Regular Grammar

I. RLG , II. LLG , III , RG

① $S \to \varepsilon$ — I ✓, II ✓, III ✓

② $S \to S \mid ab$ — I ✓, II ✓, III ✓

③ $S \to aS \mid abS \mid cd \mid \varepsilon$ — I ✓, II ✗, III ✓

④ $S \to aS \mid bba \mid Saa$ — I ✗, II ✗, III ✗

# Regular Grammar Vs Regular Language :

① $S \rightarrow a$ $\quad L = L(S) = \{a\}$

② $S \rightarrow ab \mid \varepsilon$ $\quad L = L(\overset{\text{start}}{S}) = \{\varepsilon, ab\}$

③ $A \rightarrow a \mid b \mid \varepsilon$ $\quad L = L(\overset{\text{start}}{A}) = \{\varepsilon, a, b\}$

④ $S \rightarrow ab \mid aaa \mid a$ $\quad L = \{a, ab, aaa\}$

⑤ $S \rightarrow Aa$

$A \rightarrow b$

$L = L(S) = \{ba\}$

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⑥ $S \rightarrow Aa$

$A \rightarrow b \mid c$


$L = (b+c)a$

$= \{ba, ca\}$

(7) $P \rightarrow aQ$ (start)

$Q \rightarrow x \mid \varepsilon$

$L = L(P) = \{a, ax\}$

$Q = x + \varepsilon$

$P = a.Q = a(x+\varepsilon)$

$= ax + a$

⑧ $S \rightarrow Aa$

A is useless

$L = \phi = \{\}$

⑨ $S \rightarrow Aa \mid Bb$

$A \rightarrow d$

$L = \{da\}$

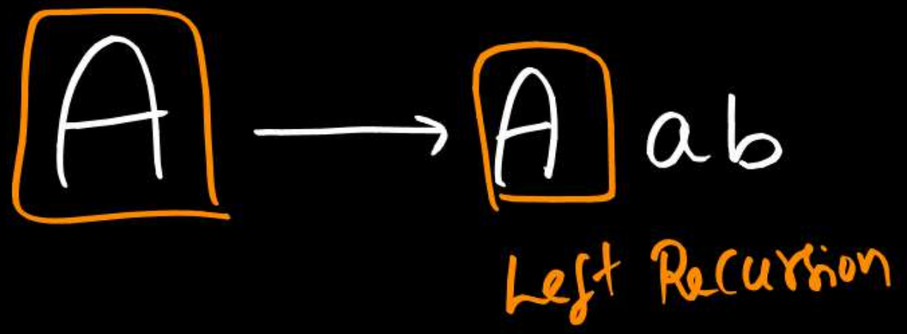
⑩ $S \rightarrow Aa \mid Bb$

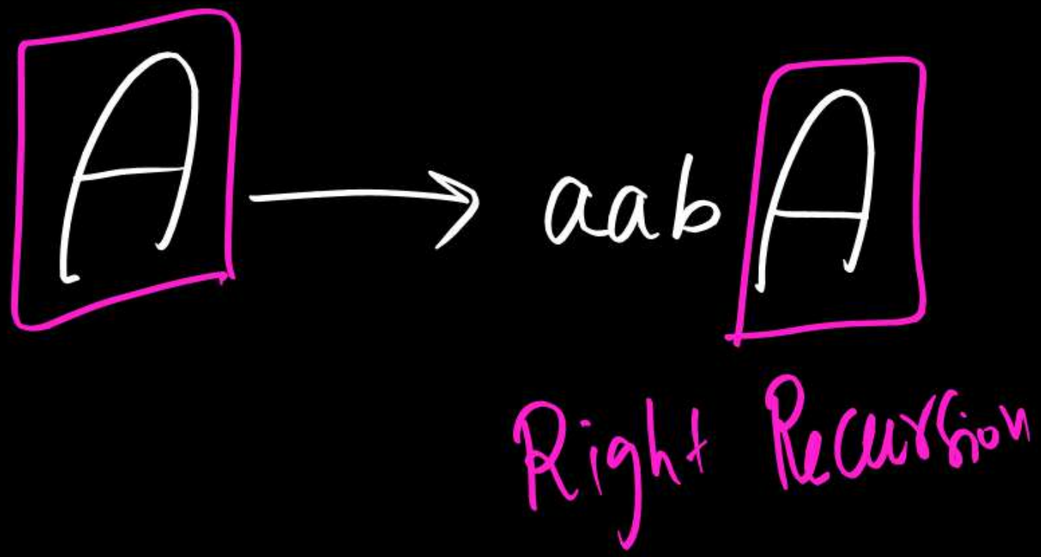
$A \rightarrow d$

$C \rightarrow e$

$L = S = Aa = da$

$L = \{da\}$


A → A ab
Left Recursion


A → aab A
Right Recursion

# Regular Grammar

(11) $S \rightarrow Sa$

$L = \phi = \{\ \}$

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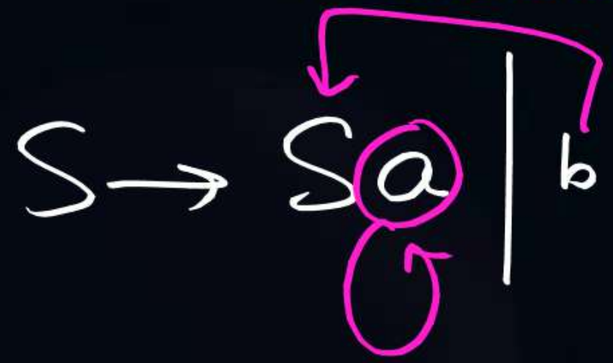
(12) $S \rightarrow Sa \mid b$



$L = ba^*$

$b\checkmark = ba^0$

$ba\checkmark = ba^1$

$baa\checkmark = ba^2$

$baaa\checkmark = ba^3$

$S$

$Sa$

$Saa$

$baa$

# Regular Grammar

(13) $S \rightarrow Sa \mid \varepsilon$ $\quad L = \varepsilon a^* = a^*$

(14) $S \rightarrow Sa \mid a$ $\quad L = aa^* = a^*a = a^+$

(15) $S \rightarrow Saa \mid \varepsilon$ $\quad L = (aa)^* = \{a^n \mid n = \text{even}\}$

(16) $S \rightarrow Saa \mid a$ $\quad L = \{a^n \mid n = \text{odd}\} = a(aa)^* = (aa)^*a$

# Regular Grammar

$$X \rightarrow X\alpha \mid \beta$$

$$L = \beta\alpha^*$$

# Regular Grammar

17. $S \to aS \mid b$ $\quad L = a^* b$

18. $S \to aS \mid \varepsilon$ $\quad L = a^*$

19. $S \to aS \mid a$ $\quad L = a^* a = a^+$

20. $S \to abS \mid \varepsilon$ $\quad L = (ab)^*$

21. $S \to aaS \mid a$ $\quad L = (aa)^* a = a(aa)^*$

$= \{a^n \mid n = \text{odd}\}$

(22) $S \rightarrow Sa \mid b \mid c$

$Sa^*$ $\quad b+c$

$L = (b+c)a^*$

$= ba^* + ca^*$

(23) $S \rightarrow Sa \mid b \mid c \mid d$

$L = (b+c+d)\,a^*$

(24) $S \rightarrow Sa \mid Sb \mid c$

$S(a+b)$

$= c(a+b)^*$

c ✓

ca ✓

cb ✓

caa ✓

cab ✓

cba ✓

cbb ✓

# Regular Grammar

(25) $S \rightarrow Sa \mid Sb \mid \varepsilon$ $\quad L = (a+b)^*$

(26) $S \rightarrow aS \mid bS \mid \varepsilon$ $\quad L = (a+b)^*$

(27) $S \rightarrow Sa \mid Sb \mid a$ $\quad L = a\,(a+b)^*$

(28) $S \rightarrow Sa \mid Sb \mid b$ $\quad L = b\,(a+b)^*$

# Regular Grammar

(29) $S \to Sa \mid Sb \mid a \mid b$

$S(a+b)$ , $a+b$

$L = (a+b)(a+b)^* = (a+b)^+$

(30) $S \to aS \mid bS \mid a \mid b$

$L = (a+b)^+$

(31) $S \to aS \mid aaS \mid \varepsilon$

$L = (a+aa)^* = a^*$

(32) $S \to aS \mid aaaS \mid \varepsilon$

$L = a^*$

(33) $S \to Aa$

$A \to Aa \mid Ab \mid \varepsilon$

$A = (a+b)^*$

$L = S = Aa$

$= (a+b)^* a$

(34) $S \to aA$

$A \to aA \mid bA \mid \varepsilon$

$L = a(a+b)^*$

(35)

$S \rightarrow aA \mid bA$

$A \rightarrow bB$

$B \rightarrow aB \mid bB \mid \varepsilon$

$B = (a+b)^*$

$A = bB = b(a+b)^*$

$S = (a+b)A$

$= (a+b)\,b(a+b)^*$

$= (ab+bb)(a+b)^*$

# Regular Grammar

(36) $S \to aA \mid bA$

$A \to a \mid b$

$L = \{w \mid w \in \{a,b\}^*, |w| = 2\}$

$= (a+b)^2$

(37) $S \to aA \mid bA$

$A \to aB \mid bB$

$B \to aB \mid bB \mid \varepsilon$

$L = (a+b)^2 (a+b)^*$

$= \{w \mid w \in \{a,b\}^*, |w| \geq 2\}$

(38) $S \to aA \mid bA \mid \varepsilon$

$A \to a \mid b \mid \varepsilon$

$L = (a+b+\varepsilon)^2$

(39) $S \to bS \mid aA$

$A \to bA \mid aB$

$B \to bB \mid \varepsilon$

$B = b^*$

$A \to bA \mid ab^*$

$A = b^*ab^*$

$L = \{w \mid w \in \{a,b\}^*, n_a(w) = 2\}$

$S \to bS \mid ab^*ab^*$

$S = L = b^*ab^*ab^*$

# Regular Grammar

*** (40)

$S \rightarrow aA$

$A \rightarrow bS \mid c$

$A = bS + c \rightarrow (1)$

bS will be solved later

$S \rightarrow a(A)$

$\Downarrow$

$S \rightarrow a(bS + c)$

$\Downarrow$

$S \rightarrow abS \mid ac$

$L = (ab)^* ac$

(41)

$S \to Aa \mid f$

$A \to Sb \mid Bc$

$B \to Se$

$B = Se \to (1)$

$A = Sb + Bc$

$A = Sb + Sec \to (2)$

$S \to Aa \mid f$

$\overset{!!}{\Rightarrow} S \to (Sb + Sec)a \mid f$

$\overset{!}{\Rightarrow} S \to Sba \mid Seca \mid f$

$L = f(ba + eca)^*$

H.W.

(42)

$S \to aA$

$A \to bB$

$B \to aB \mid bB \mid \varepsilon$

$L = ab(a+b)^*$

(44)

$S \to aS \mid A$

$A \to bA \mid \varepsilon$

$L = a^* b^*$

(43)

$S \to aS \mid bS \mid aA$

$A \to bB$

$B \to \varepsilon$

$L = (a+b)^* ab$

(45)

$S \to Sb \mid A$

$A \to Aa \mid \varepsilon$

$L = a^* b^*$

(46) $S \to bS \mid bA$

$A \to aA \mid a$

$L = b^* ba^+$

$= b^+ a^+$

(47) $S \to bS \mid A$

$A \to aA \mid a$

$L = b^* a^+$

(48) $S \to Sa \mid Ab$

$A \to Ab \mid b$

$L = b^+ ba^*$

(49) $S \to aS \mid bS \mid A$

$A \to abB$

$B \to aB \mid bB \mid \varepsilon$

$L = (a+b)^* ab(a+b)^*$

(50) $S \to Aa$

$A \to Ba$

$B \to Ba \mid Bb \mid a$

$L = a(a+b)^* aa$

# 2 mins Summary

**Topic** Regular Grammar ✓

# THANK - YOU