CS & IT ENGINEERING

THEORY OF COMPUTATION

Grammar

Lecture - 1

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Recap of Previous Lecture

Topic ?????

Regular language

1. ~~Detection~~
2. ~~closure properties~~

Topics to be Covered

Topic — Grammar

Topic — ?? ① Grammar Construction

Topic — ?? ② Grammar ⇒ Language

Topic — ?? ③ Types of Grammars

Topic : Grammar

$\alpha \longrightarrow \beta$

$\alpha = \beta$

- Set of rules used to describe strings of a language is known as grammar.
- Formal definition of grammar is

$A \to a$
$A \to b$

Ex:

1. $S \to ABC$
2. $A \to a \mid b$
2. $B \to b \mid c$
2. $C \to d \mid a$

$G = (N, T, P, S)$

- **N :-** non terminals (or) variables $= \{S, A, B, C\}$
- **T :-** Terminals $= \{a, b, d\}$
- **P :-** no. of productions $\{4\}$
- **S :-** Starting symbol

$\{S\}$

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Topic : Derivation

- The process of deriving strings from the given grammar known as derivation.
- The derivation can be either left most derivation (or) right most derivation

- **Left most derivation:**

  It is the derivation in which left most non terminal is replaced by its R.H.S part at every step.

- **Right most derivation:**

  It is a derivation in which right most non terminal is replaced by its R.H.S part at every step.

Ex:-

$S \to ABC$

$A \to a$

$B \to b$

$C \to d$

Derivation

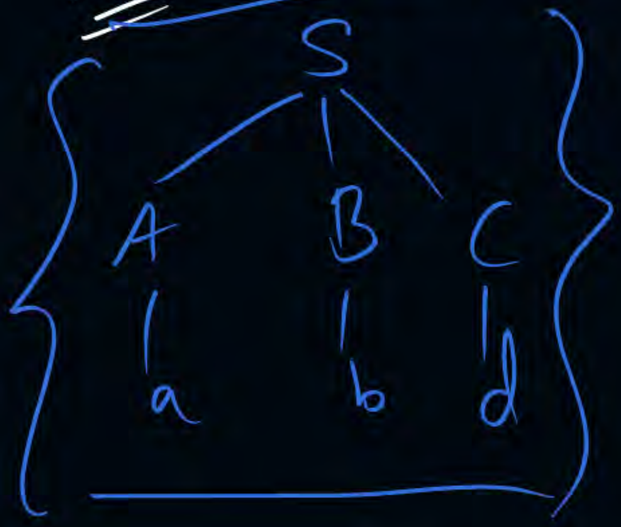
S

ABC

a b d

abd

Parse tree (a) Derivation tree



L.M.D

S

$A\underline{B}C$

$aB\underline{C}$

$ab\underline{C}$

abd

R.M.D

S

$AB\underline{C}$

$A\underline{B}d$

$Ab\underline{d}$

abd

Derivation Tree (or) Parse Tree

- Tree representation of the derivation is known as derivation tree.
- All leaf node of the parse tree is known as yield of parse tree .
- while reading yield from left to right sentence of the grammar can be generate.

Sentential form

- Each step in the derivation is one sentential form.
- Hence sentential form is combination of terminals & non terminals (sentence also can be included)
- If the derivation is left most then sentential form is left sentential form.
- If the derivation is right most then sentential is right sentential form
- Every grammar represents only one language but for one language more than one grammar may exist.
- For regular languages there exist a grammar known as regular grammar.

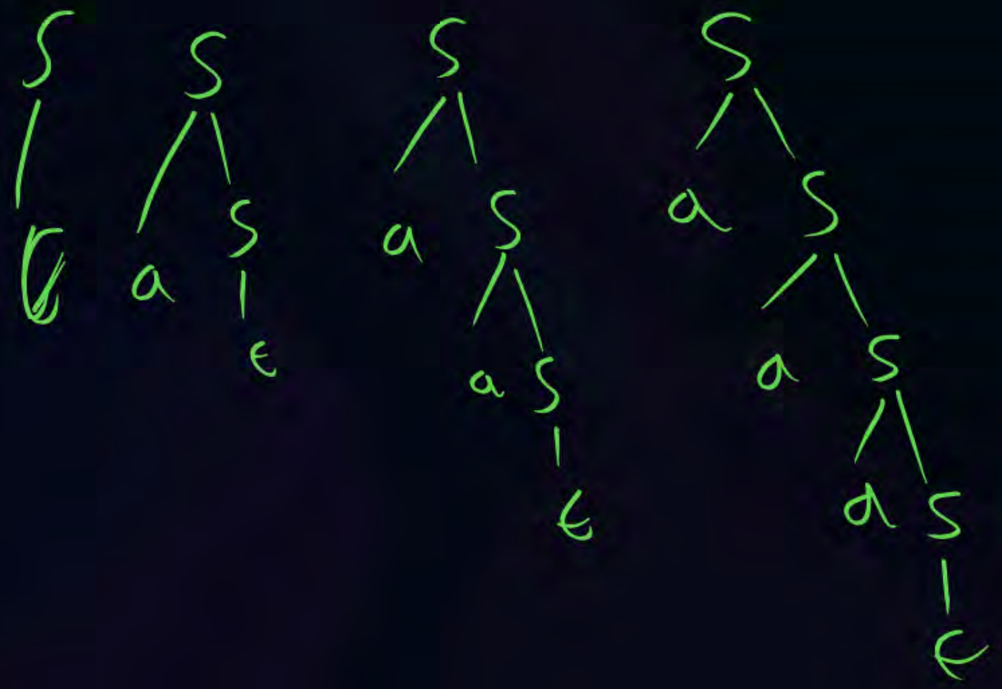
- Context free language there exist a grammar known as context free grammar.
- Context sensitive language there exist a grammar known as context sensitive grammar.
- For recursive enumerable language there exist a grammar known as unrestricted grammar.

[NAT]

Recursion

#Q. Identify language generated by following grammar.

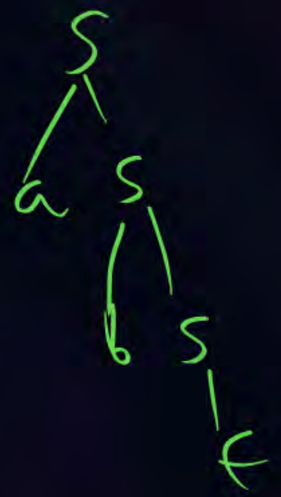
① $S \rightarrow aS \mid \epsilon$ $= \{\epsilon, a, a^2, a^3, \cdots\} = a^*$



[NAT]

#Q. Identify language generated by following grammar.

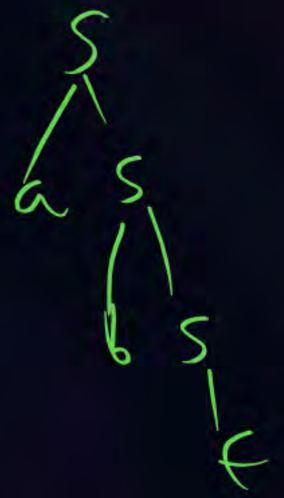
② $S \to aS \mid bS \mid \epsilon \Rightarrow \{\epsilon, a, a^2, \ldots ab, ba \ldots, b, b^2, \ldots\} = (a+b)^*$



[NAT]

#Q. Identify language generated by following grammar.

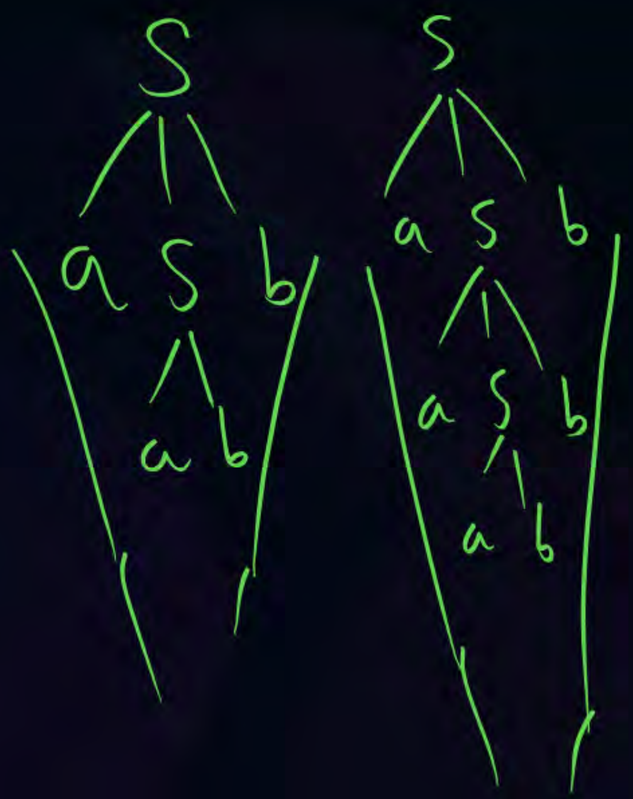
② $S \rightarrow aS \mid bS \mid \epsilon \Rightarrow \{\epsilon, a, a^2, \ldots ab, ba \ldots, b, b^2, \ldots\} = (a+b)^*$



[NAT]

#Q. Identify language generated by following grammar.

$S \to aSb \mid ab \quad = \{ab, a^2b^2, a^3b^3, \ldots\} = \{a^n b^n \mid n \geq 1\}$



[NAT]

#Q. Identify language generated by following grammar.

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

$\equiv S \to aAb \mid bAa$

$(a+b)^* \{ A \to aA \mid bA \mid \epsilon \}$

$S \to aAa \mid bSb \mid a \mid b$

[NAT]

#Q. Identify language generated by following grammar.

$S \to aSa \mid bSb \mid a \mid b = \{a, b, aba, bab, aaa, abaaba \cdots\}$

odd length Palindrome

$L = \{wxw^R \mid w \in (a+b)^* \; x \in (a+b)\}$

[NAT]

#Q. Identify language generated by following grammar.

$\{a^n b^n c^m \mid n, m \geq 1\}$

$S \rightarrow AB$

$\{a^n b^n\}$ $A \rightarrow aAb \mid ab$

$\{c^m\}$ $B \rightarrow cB \mid c$

[NAT]

$\{a^n b^n c^m \mid n, m \geq 0\}$

#Q. Identify language generated by following grammar.

$S \rightarrow AB$

$\{a^n b^n\}$ $A \rightarrow aAb \mid \epsilon$

$\{c^m\}$ $B \rightarrow cB \mid \epsilon$

[NAT]

$L = \{a^n b^n c^m d^m \mid \begin{matrix} n \geq 1 \\ m \geq 0 \end{matrix}\}$

#Q. Identify language generated by following grammar.

$S \rightarrow A\ B$

$a^n b^n$ $\quad A \rightarrow aAb \mid ab$

$c^m d^m$ $\quad B \rightarrow cBd \mid \epsilon$

[NAT]

$L = \{a^n b^m c^m d^n / n, m \geq 1\}$

#Q. Identify language generated by following grammar.

$S \rightarrow aSd / aAd$

$\{b^m c^m\}$ $A \rightarrow bAc / bc$

[NAT]

$a\ a^2, a^3$

#Q. Construct grammar for the following languages.

$L = a^*$

[NAT]

#Q. Construct grammar for the following languages.

$L = \{a^n b^n c^m \mid \underset{m \geq 0}{n \geq 1}\}$

$S \rightarrow \underset{1}{A}\,\underset{4}{B}$

$A \rightarrow \underset{2}{aAb} \mid \underset{3}{ab}$

$B \rightarrow \underset{4}{cB} \mid \underset{5}{\epsilon}$

[NAT]

#Q. Construct grammar for the following languages.

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

$S \to aAa \mid bAb \mid a \mid b$

$A \to aA \mid bA \mid \epsilon$

[NAT]

#Q. Construct grammar for the following languages.

$L = \{a^n b^m / (n+m) \text{ is even}\}$

$(aa)^*(bb)^* + a(aa)^* b(bb)^*$

6 productions

$S \to AB \mid aAbB$

$(aa)^*$ $A \to aaA \mid \epsilon$

$(bb)^*$ $B \to bbB \mid \epsilon$

[NAT]

#Q. Construct grammar for the following languages.

$L = \{a^n b^m / (n+m) \text{ is odd}\}$

$a(aa)^*(bb)^* + (aa)^* b(bb)^*$

$S \to aAB \mid AbB$

$A \to aaA \mid \epsilon$

$B \to bbB \mid \epsilon$

[NAT]

#Q. Construct grammar for the following languages.

$$L = \{a^n b^n c^m d^m \mid \begin{matrix} n \geq 0 \\ m \geq 1 \end{matrix}\}$$

$$\begin{cases} S \to AB \\ A \to aAb \mid \epsilon \\ B \to cBd \mid cd \end{cases}$$

[NAT]

#Q. Construct grammar for the following languages.

$L = \{a^n b^{2n} / n \geq 1\}$

$S \rightarrow aSbb / abb$

aaa bbbbbb

[NAT]

#Q. Construct grammar for the following languages.

$L = \{a^n b^{n+m} c^m / n, m \geq 1\}$

$a^n b^n b^m c^m$

5 productions

$(a^n b^n)$ $S \to AB$

$A \to aAb \mid ab$

$(b^m c^m)$ $B \to bBc \mid bc$

[MCQ] $\{a^2b^n\} \cup \{a^n b^2\}$ GATE 2025 [1 Mark]

#Q. Consider the following context-free grammar G, where S, A, and B are the variables (non-terminals), a and b are the terminal symbols, S is the start variable, and the rules of G are described as:

$S \rightarrow aaB \mid Abb$

$A \rightarrow a \mid aA \rightarrow \{a^n\}$

$B \rightarrow b \mid bB \rightarrow \{b^n\}$

Which ONE of the languages $L(G)$ is accepted by G?

A $L(G) = \{a^2b^n \mid n \geq 1\} \cup \{a^n b^2 \mid n \geq 1\}$

B $L(G) = \{a^n b^{2n} \mid n \geq 1\} \cup \{a^{2n} b^n \mid n \geq 1\}$

C $L(G) = \{a^n b^n \mid n \geq 1\}$

D $L(G) = \{a^{2n} b^{2n} \mid n \geq 1\}$

THANK - YOU