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THEORY OF COMPUTATION

- GODEL : Logic is limited
- Turing : Model for computation
- POST
- Chomsky Heirarchy

→ 2 types of computer

Acceptors: Yes/No, given lang. Accept or Not Accept.

Transducer: computational
x is given f(x) can be computed.

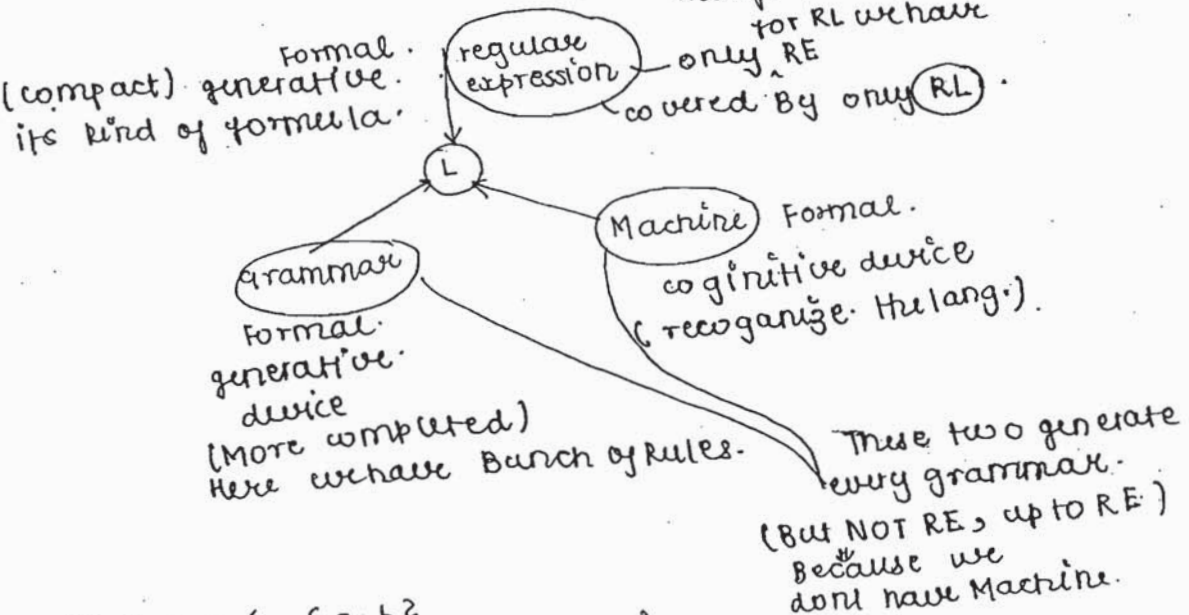
- every problem has associated with language.. we bother about acceptance of language. if we can accept the language. we can say problem is solvable.

chapter-0

- Language : collection of strings
  - grammar:
  - Machine:

Language can be described by grammar.

- (L) Informal (can't list all the things in language)



1. Alphabet = $\Sigma = \{a, b\}$
2. String
3. concatenation
4. Reversal
5. Length of a string
6. NULL string. = "ϵ"
7. PREFIX
8. SUFFIX
9. substring
10. substring.
11. Powers of a string $(\omega)^n$.
12. Σ^*, Σ^+
13. $L \subseteq \Sigma^*$.
14. CHOMSKEY HEIRARCHY
14. ~~operat~~ Representations of Language

- Language

1. alphabet:

14. Representation of Language 6 → 3 Formal, 3 Informal.

15. operations on language.
union, intersection, $\bar{L}$, $L_1 - L_2$, $L_1 \oplus L_2$

16. concatenation of Lang.

$$L_1 \cdot L_2 = \{uv \mid u \in L_1, \& v \in L_2\}$$

17. $L^R = \{w^R \mid w \in L\}$ Reversal of language.

18. L^*, L^+

L^* contain ϵ every possible combination of strings.

L^+ Not contain ϵ

$L^+ = L^* - (\epsilon)$ ⟶ This is Not correct statement.

• **Alphabet**: a Non-empty finite set of symbols.

$\Sigma = \{\}$ Not alphabet

- $\Sigma = \{a\}$, $\Sigma = \{1\}$, $\Sigma = \{2\}$ $\Sigma = \{3\}$ (1 symbol) unitary alphabet
- $\Sigma = \{a, b\}$, $\Sigma = \{1, 0\}$ Binary alphabet (2 symbol).

$\Sigma = \{1, 11, 111 \ldots\}$ This is Not allowed, No of symbols should be finite.

$\{0, 1, 2\} = \{0, 1, 2\}$

both alphabet same, order dont matter.

symbol $\Sigma = \{\underbrace{01}_{\text{compound symbol}}, 10\}$.

$\Sigma = \{01, 10, 1, 0\}$ This is Not valid symbol 01 or 10 cant break further.

• **String**: sequence of 0 or more finite symbols taken from the alphabet

sequence : order is important.

$\Sigma = \{a, b\}$.

a^{100} is valid string ? ⇒ Yes.

aaa ... 100 times valid.

aabb(1) valid ? ⇒ No symbols can be taken from alphabet.

baab = baba Not equal string, 'sequence should be follow'

$(ab)^2 \neq a^2b^2$ Not valid in TOC.

abab ≠ aabb

• **concatenation**:

if u = 01

v = 100

uv = 01|100 concatenation

Here $uv \neq vu$.

for all (u, v)

where u = 00

v = 000.

$uv = vu$ True Here

so Not for all (u, v); $uv \neq vu$.

- it is associative
  $u(vw) = (uv)w$
- Not communicative.

- The length of u·v will always be equal to (u+v).

u = 01 = 2

v = 100 = 3

uv = 01100 ⇒ length is (2+3) = 5

- The length of v i

v = 100 $v^R = 001 \Rightarrow v^R \neq v$

For all u and v $uv \neq vu$ False

• $v = v^R$ iff v is a palindrome

Palindrome

- even (because length is integer). : EP
- odd. : OP.

Palindrome Language $= \{ \underset{EP}{ww^R} \cup \underset{OP}{wxw^R} \mid w \in \Sigma^*, x \in \Sigma \}$ (x is 1 bit)

$\Downarrow$ $\Downarrow$

1001 10001

$\{ w \in \Sigma^* \mid w = w^{\overline{x}} \}$

• Properties of Reversal

$(v^R)^R = v$

(Reversal of Reversal).

$(u \cdot v)^R = v^R u^R$

$(xyz)^R = z^R y^R x^R$.

• Length :

No of symbols present in strings.

if $\Sigma = \{0,1,2\}$.

→ How many 5 length string possible. if $\Sigma = \{a,b\}$.

0 length → 1 (i.e ε)

1 length → a, b → $|\Sigma| = 2$

2 length → ab, ba, aa, bb → $|\Sigma|^2$. (cardinality of Σ.)

⋮

n length → $|\Sigma|^n$.

So of length '3' 2^3 ⇒ for $\Sigma = \{a,b,c\} \Rightarrow |\Sigma| = 3$.

length '5' 3^5

ww^R How many even palindrome of length 10.

$\Sigma = \{0,1\}$

$\overline{2}\ \overline{2}\ \overline{2}\ \overline{2}\ \overline{2} \mid - - - - -$

(2^5).

even palindrome $= |\Sigma|^{n/2}$

- ODD ⇒ length 13. check even → 12. $\Sigma = \{0,1\}$

$|\Sigma|^{\frac{12}{2}}$ $\quad |2|^6 \Rightarrow 2^6 \times 2$ odd palindrome.

upto length 10, even palindrome. $\Sigma \{0,1\}$

0	length ⟶	$2^{0/2} = 1$
2	"	$2^{2/2} = 2$
4	"	$2^{4/2} = 4$
8	"	$2^{8/2} = 2^4$
10	"	$2^{10/2}$

- **NULL string:**
  it is only string of length '0'

lang with Null string. $|\{\varepsilon\}|$ ⟶ cardinality.

$|\varepsilon| = 0$.

$|\{\}| = 0$.

empty language.

- language has cardinality.
  where
  Null Reverse is Reverse
  Null is identity element for concatenation.

- $(\Sigma^*, \cdot, \varnothing)$ ← groupoid, operator, semi-group.
  ↓ Algebra.

- $|\{0,1\}|^5 \longrightarrow |\{0,1\}|$
  How many fn possible
  all string of length 5.

$|\Sigma|^5 \longrightarrow \Sigma$ possible function.

cardina. $= 2^5$ $\qquad 2$.

$|B|^{|A|}$ function possible $= \underline{\underline{2^{(2^5)}}}$

7. PREFIX : Prefix is set of strings. so P(w) is

$P(w) = \{u \mid w = uv\}$

- prefix of 001 = $\boxed{\epsilon} \cdot 001$
  = $\boxed{0} \cdot 01$
  = $\boxed{00} \cdot 1$
  = $\boxed{001} \cdot \epsilon$
- Null string is prefix of every string
- and $\underline{w}$ is also the prefix of $\underline{w}$ string

8. SUFFIX

$S(w) = \{v \mid w = uv\}$

$\epsilon \cdot \boxed{0\,0\,1}$

1, 01, 001, ϵ.

string w of length ⇒ $|w| = n$ so $(n+1)$ prefix are there.

- $|\text{Prefix}(w)| = n+1$.
- $|w| = n$
- same for suffix
- for any length prefix or suffix is unique.

for $\Sigma = \{a, b, c, d, e\}$

How many prefix of length 3 = 1
always 1 upto the length of string.

- 000 - $\{\epsilon, 0, 00, 00\}$.

$\boxed{\text{prefix}(w) \cap \text{suffix}(w) \supseteq \{\epsilon, w\}}$ true. (⊇ : superset)

'⊂' wrong
'=' wrong

- substring : $\{x \mid w = uxv\}$ — By making $u = \epsilon \rightarrow$ prefix, $v = \epsilon \rightarrow$ suffix, $v, u = \epsilon \rightarrow$ allowing middle strings

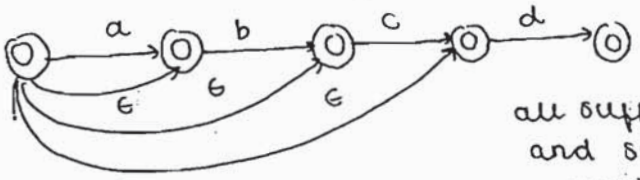
  any sequence of 0 or more consequtive symbols in 'w'

  for abcde

  $\epsilon \rightarrow$ ✓
  ab → ✓
  bcd → ✓
  cde → ✓
  bce → x sequence failed.

- substring includes all prefix and suffix.

$\boxed{\text{prefix}(w) \cup \text{suffix}(w) \subseteq \text{substring}}$



all suffix prefix accept and substring also accepted (n+1) states needed.

10. w^n : powers of string

Here it is concatenation.

$w^0 = \epsilon$ → for concatenation ϵ is identity for $w^0 = \epsilon$

$w = 001$

$w^1 = w$

$w^2 = w \cdot w$

$w^3 = w \cdot w^2$.

w^{-1} → has no meaning

because $u \cdot u^{-1} \neq \epsilon$

There is nothing which adds in string, so strings becomes, string length always ↑.

→ $(\Sigma^*, \cdot, \emptyset)$ → Monoid

closure → groupoid. ✓

→ TOC dont allow -ve Numbers.

(powers). a^m where $m > 0$.

- powers of w are commutative.

$(001)^0 = \epsilon$

$(001)^1 = 001$.

$(001)^2 = 001001$.

$(001)^3 = \underline{001}\,\underline{001}\,\underline{001} = (001)^2 \cdot (001)$

$(ab)^{18}\,(ab)^2 = (ab)^{20}$

$(ab)^2\,(ba)^2 \neq (ab)^4$

$a^m a^n b^n c^n = a^{m+n} b^n c^n$.

11 Σ^* : $\quad \Sigma^* = \Sigma^0 \cup \Sigma^1 \cup \Sigma^2 \cup \Sigma^3 \ldots$

$\Sigma^0 = \epsilon$

$\Sigma^+ = \Sigma^1 \cup \Sigma^2 \cup \Sigma^3$.

$\boxed{\Sigma^+ = \Sigma^* - \epsilon}$ positive closure of 'Σ'

'*' closure (Kleene closure) $\Rightarrow \Sigma^* = \Sigma^0 \cup \Sigma^1 \cup \Sigma^2 \cup \Sigma^3 \ldots$

Kleene star operator.

- $\Sigma = \{a\}$

$\Sigma^* = \{\epsilon, a, aa, aaa \ldots\}$.

- Language is infinite but alphabet is finite