

①

(i) $\neq a$

(ii) c

(iii) Terminals \rightarrow { that, this, a, the, book, flight, meal, man, booth, include, read, does }.

NonTerminals \rightarrow { S, NP, NOM, VP, Del, Noun, verb, Aux }.

(IV) PDA Rules.

$PDA = \{ \{q\}, \{ \text{all the } \overset{\leq}{\text{terminals}} \}, \delta, q, z_0, \Gamma, \# \}$

Rules

① $\delta(q, \epsilon, z_0) = (q, S2)$

② For all NT,

$\delta(q, \epsilon, S) = \{ (q, NP VP), (q, Aux NP VP), (q, VP$

$\delta(q, \epsilon, \overset{NP}{\cancel{NP}}) = (q, Del NOM)$

$\delta(q, \epsilon, NOM) = \{ (q, Noun), (q, Noun non$

$\delta(q, \epsilon, VP) = \{ (q, verb), (q, verb NP) \}$

$$\delta(q, \epsilon, \text{Del}) = \{ (q, \text{that}), (q, \text{this}), (q, a), (q, \text{the}) \}$$

$$\delta(q, \epsilon, \text{Noun}) = \{ (q, \text{book}), (q, \text{flight}), (q, \text{meal}), (q, \text{man}) \}$$

$$\delta(q, \epsilon, \text{Aux}) = (q, \text{does})$$

$$\delta(q, \epsilon, \text{Verb}) = \{ (q, \text{book}), (q, \text{include}), (q, \text{read}) \}$$

⑤ For all Terminals,

$$\begin{array}{l} \delta(q, \text{that}, \text{that}) = (q, \epsilon) \\ \delta(q, \text{this}, \text{this}) = (q, \epsilon) \end{array} \quad \left| \quad \begin{array}{l} \delta(q, a, a) = (q, \epsilon) \\ \delta(q, \text{the}, \text{the}) = (q, \epsilon) \end{array} \right.$$

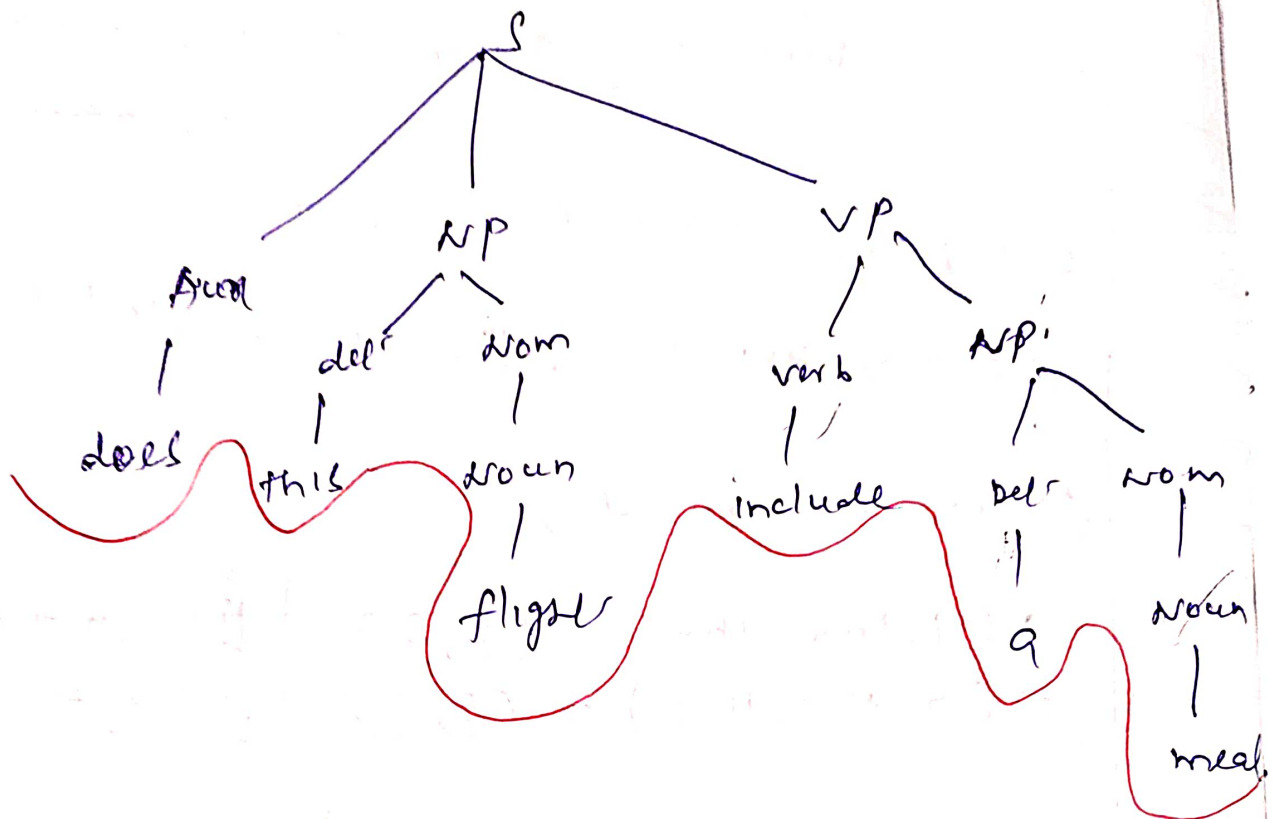
$$\begin{array}{l} \delta(q, \text{book}, \text{book}) = (q, \epsilon) \\ \delta(q, \text{flight}, \text{flight}) = (q, \epsilon) \end{array} \quad \left| \quad \begin{array}{l} \delta(q, \text{meal}, \text{meal}) = (q, \epsilon) \\ \delta(q, \text{man}, \text{man}) = (q, \epsilon) \end{array} \right.$$

$$\begin{array}{l} \delta(q, \text{book}, \text{book}) \neq (q, \epsilon) \\ \delta(q, \text{include}, \text{include}) = (q, \epsilon) \end{array} \quad \left| \quad \begin{array}{l} \delta(q, \text{read}, \text{read}) = (q, \epsilon) \\ \delta(q, \text{does}, \text{does}) = (q, \epsilon) \end{array} \right.$$

⑥ Final transition,

$$\delta(q, \epsilon, \text{20}) = (q, \epsilon)$$

(v) $w =$ "does this flight include a meal"



(v) Simplification

- (i) no useless symbols.
- (ii) no ϵ productions.
- (iii) Elimination of unit prod.

(a) $S \rightarrow VP$
 $\rightarrow verb$
 $\rightarrow book / include / read,$

$\therefore S \rightarrow book / include / read,$

(b) $VP \rightarrow verb$
 $\rightarrow book / include / read,$

$\therefore VP \rightarrow book / include / read,$

(vi) CNF conversion

$S \rightarrow \text{Aux} \cdot \text{NP} \cdot \text{VP}$ not in CNF

$\left. \begin{array}{l} S \rightarrow \text{Aux} \cdot X \\ X \rightarrow \text{NP VP} \end{array} \right\}$ in CNF.

(2)

(i) $\star \circ$

(ii) not regular (b)

(iii) $L = \{x^n y^n \mid n \geq 1\}$

(iv) $\$ \vdash \vdash \vdash \vdash L = x^n y^n$

(u) equal no. of red & yellow.

$P = \left[\begin{array}{l} \therefore S \rightarrow x S y \end{array} \right] / \text{rej}$ Grammar (P1)

$G = (\{S\}, \{x, y\}, P, S)$

(v) PDA transition

For red cube \rightarrow push into the stack

yellow cube \rightarrow pop from the stack.

$$\delta(q_0, x, z_0) = (q_0, x, z_0)$$

$$\delta(q_0, x, \epsilon) = (q_0, x, \epsilon)$$

$$\delta(q_0, y, x) = (q_1, \epsilon)$$

$$\delta(q_1, y, x) = (q_1, \epsilon)$$

$$\delta(q_1, \epsilon, z_0) = (q_2, \epsilon)$$

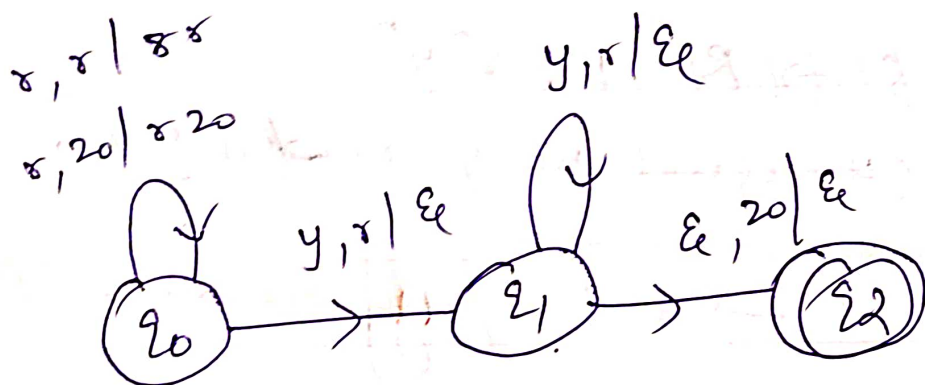
(vi)

$$CFG = (S, \{x, y\}, P, S)$$

$$PDA = (\{q_0, q_1, q_2\}, \{x, y\}, \{x, z_0\}, \delta, q_0, z_0, q_2, \epsilon)$$

(vii) PDA Diagram

(3)



(viii) check for $x^3 y^3$

$$\begin{aligned} \delta(q_0, \underline{x x x y y y}, \underline{z_0}) &\rightarrow (q_0, \underline{x x y y y \epsilon}, \underline{x z_0}) \\ &\rightarrow (q_0, x y y y \epsilon, x x z_0) \\ &\rightarrow (q_0, \underline{y y y \epsilon}, \underline{x x x z_0}) \end{aligned}$$

~~$\rightarrow (q_1, \underline{y}y\underline{\epsilon}, \underline{r}r\underline{z_0})$
 $\rightarrow (q_1, \underline{y}\underline{\epsilon}, \underline{r}z_0)$
 $\rightarrow (q_1, \underline{\epsilon}, \underline{z_0})$
 $\rightarrow (q_2, \epsilon)$~~

~~\hookrightarrow Accept~~

$(q_0, yyyrrr, z_0) \vdash (q_0,$

There is no transition for (q_0, y, z_0) , so the string "yyyrrr" is 3 consecutive yellow followed by 3 consecutive red can not be taken.

③

(i) a

(ii) c

(iii) Remove NULL production.

$STMTS \rightarrow \underline{\epsilon} \mid STMT \mid STMTS$

NULL prod. is, $STMTS \rightarrow \epsilon$

$BLOCK \rightarrow STMT \mid \{STMTS\}$

$BLOCK \rightarrow STMT \mid \{STMTS\} \mid \{ \}$

$STMTS \rightarrow STMT \cdot STMTS \mid STMT$

(IV) Remove ^{UNIT}~~NULL~~ production.

BLOCK \rightarrow STMT \rightarrow UNIT prod.

BLOCK \rightarrow a | constant | $\text{EXPR} + \text{EXPR}$ | $\text{EXPR} - \text{EXPR}$ |
 $\text{EXPR} * \text{EXPR}$ | $\text{EXPR} / \text{EXPR}$ | if (EXPR) BLOCK |
while (EXPR) BLOCK | do BLOCK while (EXPR) |

stmts \rightarrow STMT & STMTS | a | constant

(V) Remove useless symbols.
no useless symbols -