Symbol	Definition
$G(C,R)$	Ontology graph
$C=\{c_1,c_2,\ldots,c_n\}$	Set of concepts constituting the vertices of the ontology graph
$R=\{R_{ij} \mid i=1,\ldots,n,\ j=1,\ldots,n,\ j>i\}$	Set of relations constituting the edges of the ontology graph
$R_{ij}=\{r_{ij}^1,r_{ij}^2,\ldots,r_{ij}^m,\ m<n\}$	Set of relations between concepts c_i and c_j in $G(C,R)$
$Q=\{(k_t,c_t)\}$	Query as a collection of pairs (keyword, concept)
$G_Q(C_Q,R_Q)$	Query sub-graph for query Q
$C_Q=\{c_t \mid (k_t,c_t)\in Q\}$	Set of concepts constituting the query sub-graph
$R_Q=\{\overline{R}_{ij} \mid 1\le i\le n,\ 1\le j\le n,\ j>i\}$	Set of relations constituting the query sub-graph
$\overline{R}_{ij}=\{\overline{r}_{ij} \mid c_i,c_j\in C_Q,\lvert R_{ij}\rvert\ge 1\}$	Set of relations between c_i and c_j in the query sub-graph
$\eta_{ij}=\lvert\overline{R}_{ij}\rvert$	Number of relations between c_i and c_j in $G_Q(C_Q,R_Q)$
$A=(AC,AR)$	Graph-based annotation (AC and AR are the sets of concepts and relations)
$AR_{ij}=\{r_{ij}^d \mid r_{ij}^d\in AR,\ 1\le d\le m\}$	Set of relations between c_i and c_j in AR
$G_{Q,p}(C_{Q,p},R_{Q,p})$	Page sub-graph for page p given the query Q
$C_{Q,p}=\{c_t \mid c_t\in C_Q\cap AC\}$	Set of concept of page sub-graph $G_{Q,p}(C_{Q,p},R_{Q,p})$
$R_{Q,p}=\{\overline{r}_{ij} \mid c_i,c_j\in G_{Q,p}\}$	Set of relations of page sub-graph $G_{Q,p}(C_{Q,p},R_{Q,p})$
$\delta_{ij}=\lvert AR_{ij}\rvert$	Number of relations c_i and c_j in $G_Q(C_Q,R_Q)$
$\tau_{ij}=P(\overline{r}_{ij},p)=\delta_{ij}/\eta_{ij}$	Relation probability for $\overline{r}_{ij}$ in page p given the query Q
$SF_{Q,p}(l)$	Set of spanning forests (l edges) for page p and query Q
$SF_{Q,p}^f(l)$	f-th spanning forest (l edges) for page p and query Q
$\sigma_{Q,p}(l)=\lvert SF_{Q,p}(l)\rvert$	Number of spanning forests (l edges) for page p and query Q
$P(Q,p,l)$	Constrained relevance score for page p , query Q , relevance class l
$ps_{Q,p}$	Relevance score of page p for a given query Q

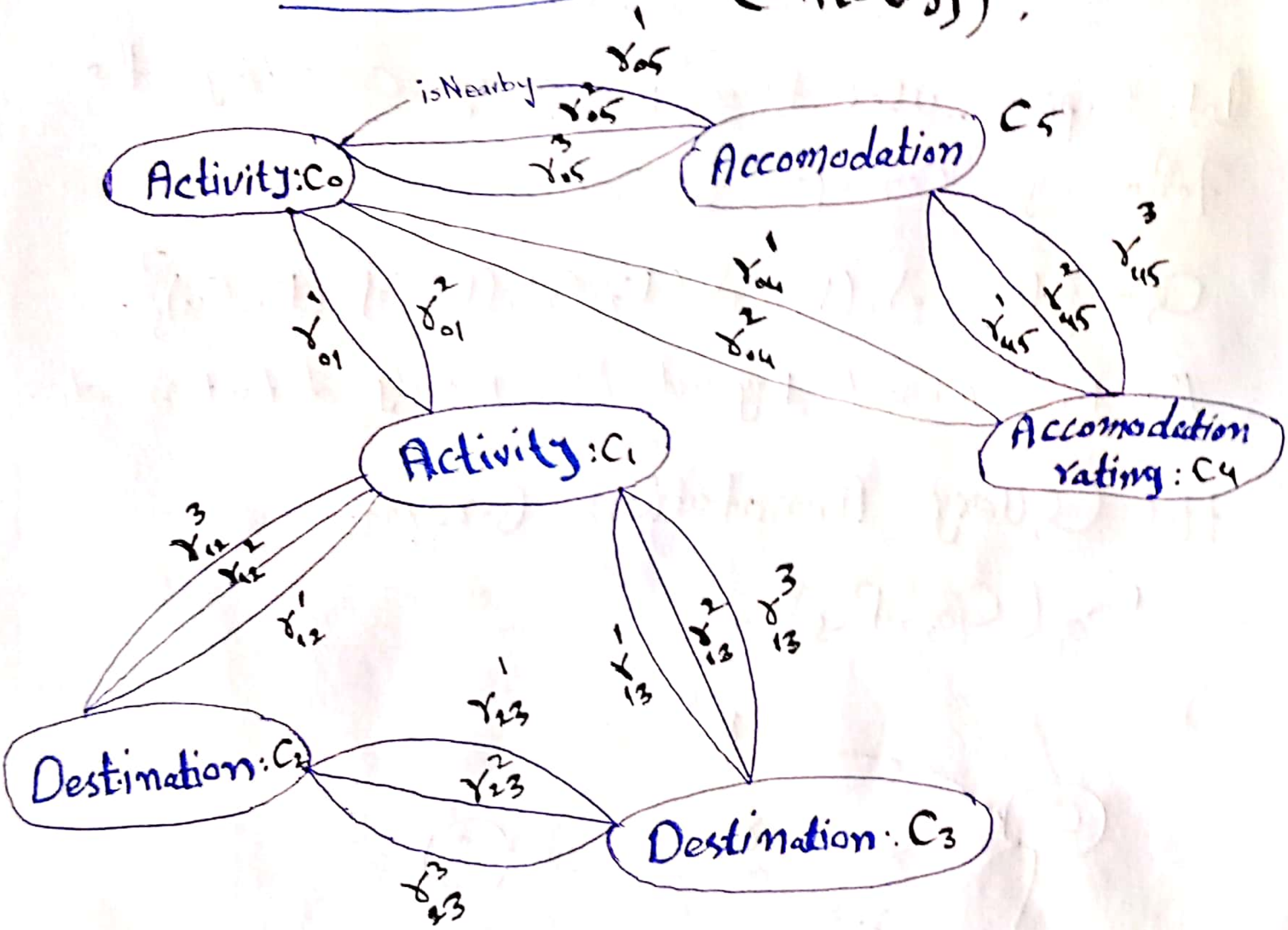
```
Label the edges in G_{Q,r} with an index ranging from 1 to R_{Q,r}
Define variables e and a to index graph edges
Set  η_e = η_ij        //number of relations linking concepts
                       //i and j in the ontology graph (edge e ∈ R_{Q,r})
Set  δ_e = δ_ij        //number of relations linking concepts
                       //i and j in the page sub-graph (edge e ∈ R_{Q,r})
Set  r_e = η_ij / δ_ij //relation probability for edge e
Mark all the edges in G_{Q,r} as not visited
Allocate weight vector W of size |C_{Q,r}|-1
                      // W[l] stores the accumulated constrained
                      //probabilities for page forests of length l
Allocate vector Σ of size |C_{Q,r}|-1
                      // Σ[l] stores the number of page forests
                      //for a given length l
Initialize W and Σ to zero

for e=1 , e≤|R_{Q,r}| , e=e+1
  mark edge e as visited
  visit(e,e,1,r_e)
   W[1]=W[1]+r_e
   Σ[1]=Σ[1]+1

function visit(o,e,l,s)
  a=e+1
  while a≤|R_{Q,r}| and l≤|C_{Q,r}|-1
    if a is not visited and a is safe
       //(does not introduce cycles, checked through DFS)
       mark edge a as visited
       visit(o,a,l+1,s×r)
       W[l+1]=W[l+1]+s
       Σ[l+1]=Σ[l+1]+1
       set edge a as not visited
    else
       a=a+1
```

Dry Run

Knowledge Base (Ontology).



$$C = \{C_0, C_1, C_2, C_3, C_4, C_5\}.$$

$$R = \{R_{01}, R_{04}, R_{05}, R_{12}, R_{13}, R_{23}, R_{45}\}.$$

Here Every each element of Set R represent diffrent Set. Such as:

$$R_{01} = \{\gamma^1_{01}, \gamma^2_{01}\}.$$

Step#01

User Query

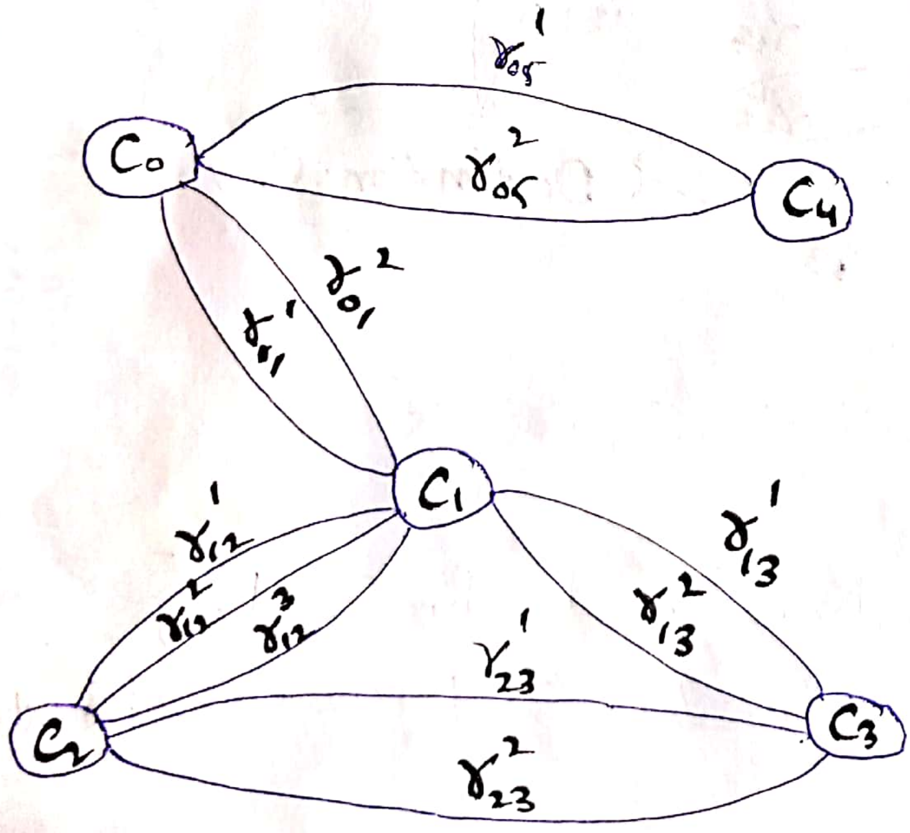
lets suppose user types the query consisting the following Concepts:-

$$Q = \{(K_0, C_0), (K_1, C_1), (K_2, C_2), (K_3, C_3), (K_4, C_4)\}.$$

Here K_i represent keywords like Activity, destination etc.

~~Ac~~ Query Annotation Graph:-

$G_Q(C_Q, R_Q)$:-

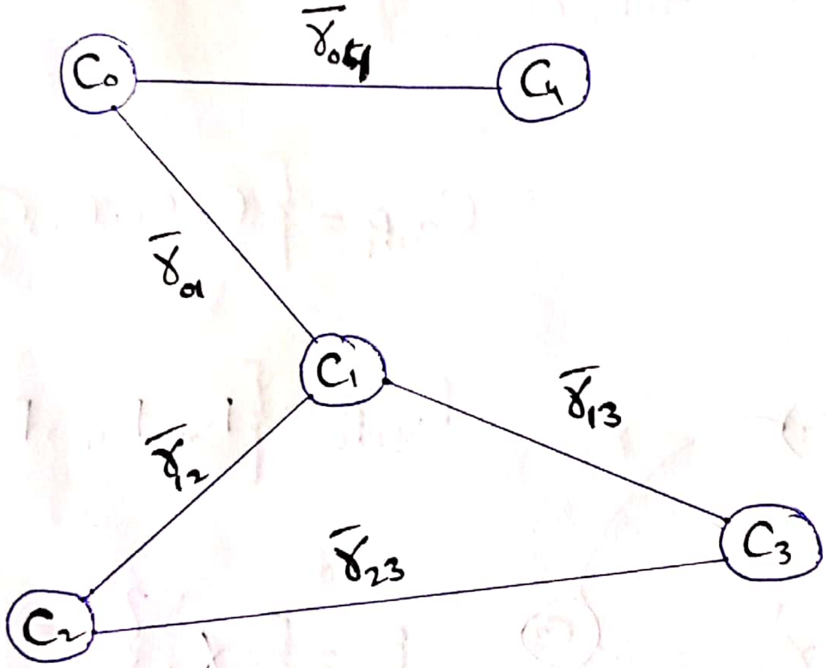


$$C_Q = \{C_0, C_1, C_2, C_3, C_4\}.$$

$$R_Q = \{R_{01}, R_{05}, R_{12}, R_{13}, R_{23}\}.$$

and $R_{01} = \{\gamma^1_{01}, \gamma^2_{01}\}$.

Query Sub-Graph:-



Number of relation b/w i and j Concepts:-

r_{ij}	η_{ij}	fre
$\bar{r}_{01}$	η_{01}	2
$\bar{r}_{12}$	η_{12}	3
$\bar{r}_{04}$	η_{04}	2
$\bar{r}_{13}$	η_{13}	2
$\bar{r}_{23}$	η_{23}	2

(Table: 1)

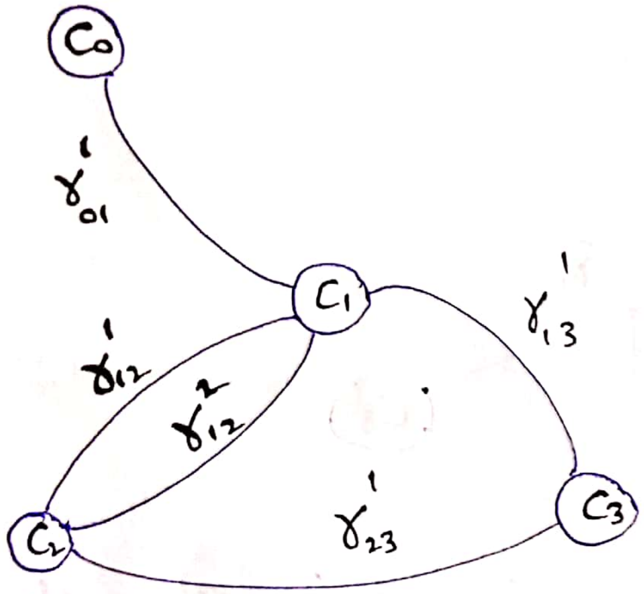
Step#02

when user presses the Search button then suppose there are two pages where the concepts mentioned in the Query are founded.

So,

Page one Annotation Graph:-

$G_{q,p_1}(C_{q,p_1}, R_{q,p_1})$:-



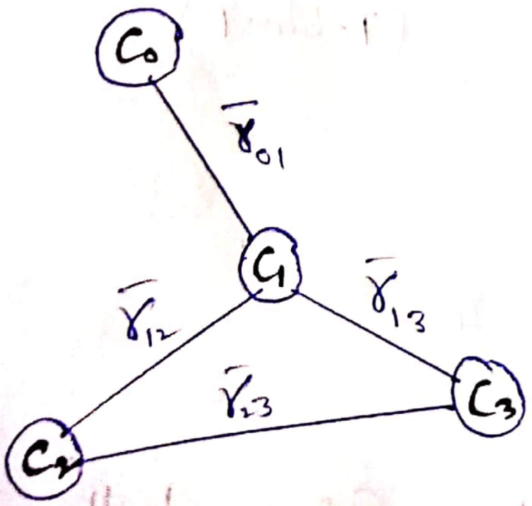
$C_{q,p_1} = \{C_0, C_1, C_2, C_3\}$

$R_{q,p_1} = \{R_{01}, R_{12}, R_{13}, R_{23}\}$

and

$R_{01} = \{\gamma^1_{01}\}$.

Page One Sub-Graph:-

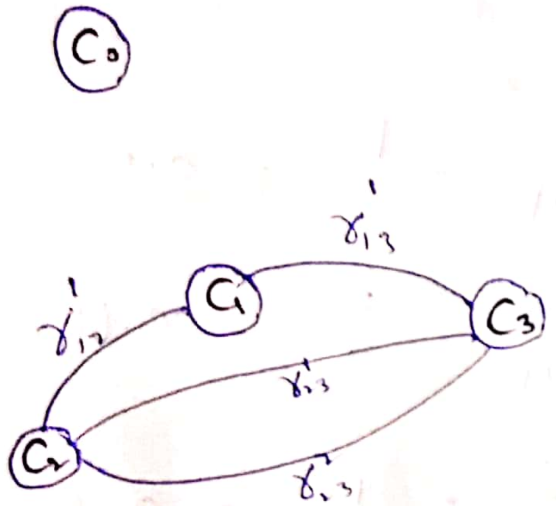


$\bar{\gamma}_{ij}$	δ_{ij}	fre
$\bar{\gamma}_{01}$	δ_{01}	1
$\bar{\gamma}_{12}$	δ_{12}	2
$\bar{\gamma}_{13}$	δ_{13}	1
$\bar{\gamma}_{23}$	δ_{23}	1

Table(1)

Page Two Annotation Graph:-

$G_{q,P_2}(C_{q,P_2}, R_{q,P_2})$:-



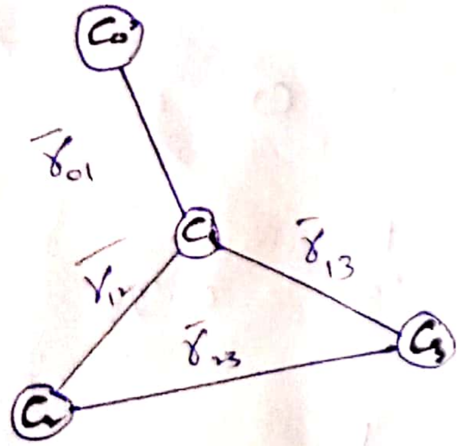
$\because \left\{ \begin{array}{l} \delta_{ij} = \text{Number of relations} \\ \text{b/w } i \text{ and } j \text{ concepts.} \end{array} \right.$

$C_{q,P_2} = \{C_0, C_1, C_2, C_3\}$

$R_{q,P_2} = \{R_{01}, R_{12}, R_{13}, R_{23}\}$.

$R_{01} = \{\ \}$.

Page Two Sub-Graph:-



$\bar{r}_{ij}$	δ_{ij}	fre
$\bar{r}_{01}$	δ_{01}	0
$\bar{r}_{12}$	δ_{12}	1
$\bar{r}_{13}$	δ_{13}	1
$\bar{r}_{23}$	δ_{23}	2

Table(3).

Step# 03.

Relational Probability (J_{ij}):-

Page one:

$$P(\bar{\gamma}_{01}, P_1) = J_{01} = \frac{\delta_{01}}{\eta_{01}} = 1/2 = 0.5$$

$$P(\bar{\gamma}_{12}, P_1) = J_{12} = \frac{\delta_{12}}{\eta_{12}} = \frac{2}{3} = 0.66$$

$$P(\bar{\gamma}_{13}, P_1) = J_{13} = \frac{\delta_{13}}{\eta_{13}} = 1/2 = 0.5$$

$$P(\bar{\gamma}_{23}, P_1) = J_{23} = \frac{\delta_{23}}{\eta_{23}} = 1/2 = 0.5$$

Page Two:-

$$P(\bar{\gamma}_{01}, P_2) = J_{01} = \frac{\delta_{01}}{\eta_{01}} = \frac{0}{2} = 0$$

$$P(\bar{\gamma}_{12}, P_2) = J_{12} = \frac{\delta_{12}}{\eta_{12}} = 1/3 = 0.33$$

$$P(\bar{\gamma}_{13}, P_2) = J_{13} = \frac{\delta_{13}}{\eta_{13}} = 1/2 = 0.5$$

$$P(\bar{\gamma}_{23}, P_2) = J_{23} = \frac{\delta_{23}}{\eta_{23}} = \frac{2}{2} = 1$$

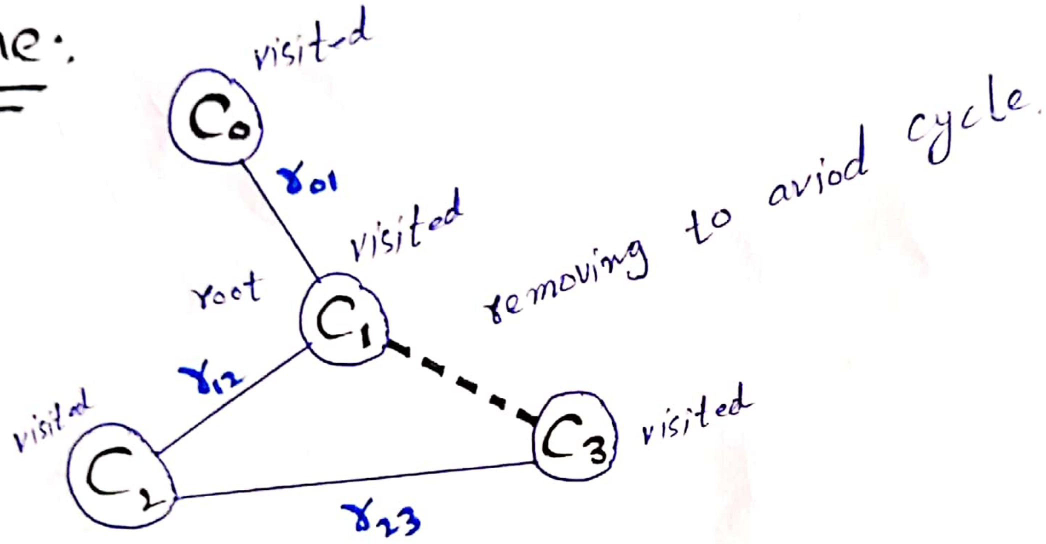
Step # 04

Generating page spanning forests:-

Page one:

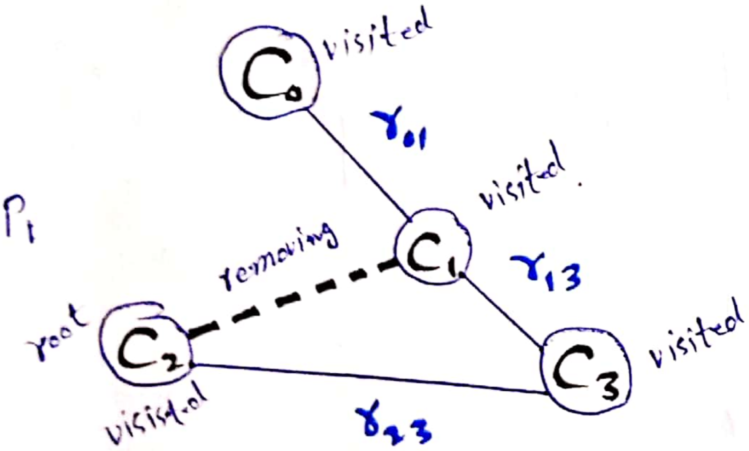
=>

$S^{1}F_{q,P_1}$

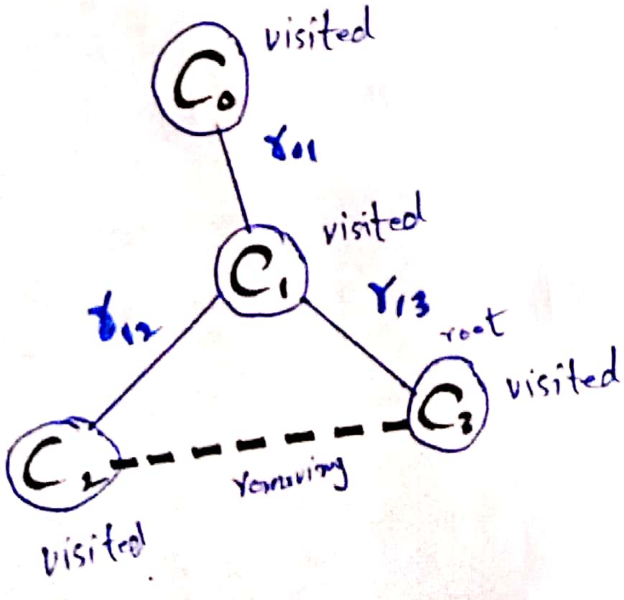


=>

$S^{2}F_{q,P_1}$



$S^{3}F_{q,P_1}$



$\therefore$ Number of spanning forest $= \sigma_{q,p}$

$$\Rightarrow S^{1}F_{q,P_1} = S^{2}F_{q,P_1} = S^{3}F_{q,P_1} = \frac{1}{\sigma_{q,p}}.$$

$$= \frac{1}{3}$$

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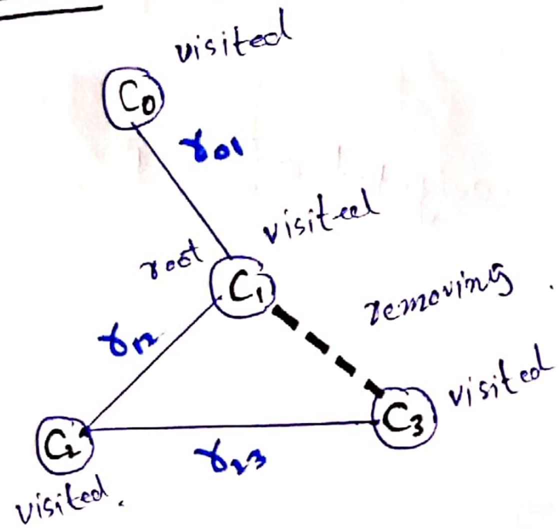
Page Two

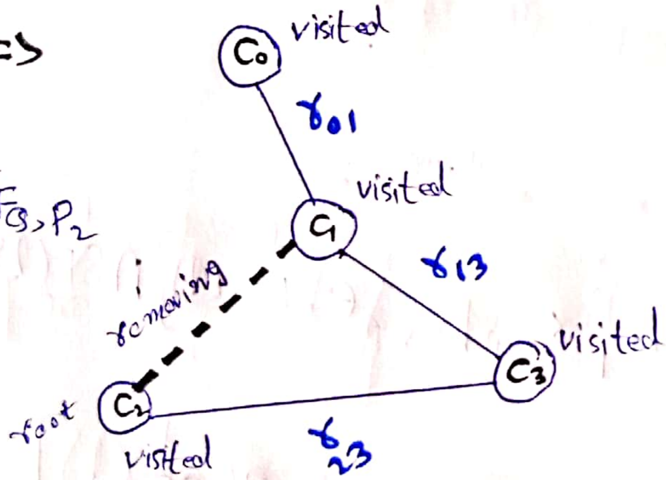
$\Rightarrow$

SF^{1}_{G,P_2}



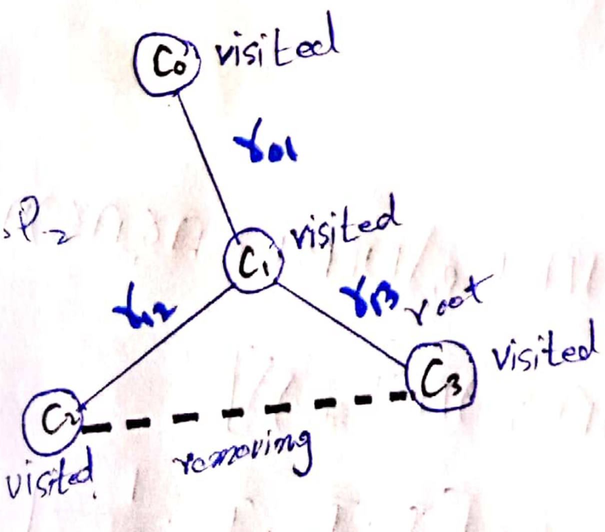
$\Rightarrow$

SF^{2}_{G,P_2}



$\Rightarrow$

SF^{3}_{G,P_2}



$\sigma_{G,P}$ = Number of spanning forest.

$$\Rightarrow SF^{1}_{G,P_2} = SF^{2}_{G,P_2} = SF^{3}_{G,P_3} = \frac{1}{\sigma_{G,P_2}}$$

$$= \frac{1}{3}$$

Step#05.

Minimum Length of spanning forest.

Page one:

l = No. of Non-zero weighted edges − 1

$l = 4 - 1 = 3.$

Page Two:

$l = 3 - 1 = 2.$

Step#06:-

Page Relevence Score:-

$$P(G,P,l) = P\left[\bigcup_{q=1}^{|SF_{G,P}(l)|} \left(\cap \{ \gamma_{ij,p} \mid \gamma_{ij,p} \in SF^{q}_{G,P}(l) \} \cap SF^{q}_{G,P}(l)\right)\right]$$

$$= \sum_{q=1}^{|SF_{G,P}(l)|} \prod_{\gamma_{ij,P} \in SF^{q}_{G,P}(l)} P(\bar{\gamma}_{ij} P) \cdot P(SF^{q}_{G,P}(l))$$

Page One:

$$P(G,P_1,3) = \left[P((\gamma_{01} \cap \gamma_{12} \cap \gamma_{23}) \cap SF^{1}_{G,P_1}) \cup (P((\gamma_{01} \cap \gamma_{13} \cap \gamma_{23}) \cap SF^{2}_{G,P_1})) \cup (P((\gamma_{01} \cap \gamma_{12} \cap \gamma_{13}) \cap SF^{3}_{G,P_1}))\right]$$

$$= \left[J_{01} \cdot J_{12} \cdot J_{23} \cdot \frac{1}{\sigma_{G,P_1}}\right] + \left[J_{01} \cdot J_{13} \cdot J_{23} \cdot \frac{1}{\sigma_{G,P_1}}\right] + \left[J_{01} \cdot J_{13} \cdot J_{12} \cdot \frac{1}{\sigma_{G,P_1}}\right]$$

$$= [(J_{01} \cdot J_{12} \cdot J_{23}) + (J_{01} \cdot J_{13} \cdot J_{23}) + (J_{01} \cdot J_{13} \cdot J_{12})] / \sigma_{q,P_1}$$

$$= [\tfrac{1}{2} \times \tfrac{2}{3} \times \tfrac{1}{2} + \tfrac{1}{2} \times \tfrac{1}{2} \times \tfrac{1}{2} + \tfrac{1}{2} \times \tfrac{1}{2} \times \tfrac{2}{3}] / 3$$

$$= (\tfrac{1}{6} + \tfrac{1}{8} + \tfrac{1}{6}) / 3$$

$P(q, P_1, 3) = 0.1527$

Page Two:-

$$P(q, P_2, 2) = [P((\gamma_{12} \cap \gamma_{23}) \cap SF^1_{q,P_2})] \cup (P((\gamma_{12} \cap \gamma_{13}) \cap SF^2_{q,P_2})) \cup$$
$$(P((\gamma_{23} \cap \gamma_{13}) \cap SF^3_{q,P_2}))$$

$$= [J_{12} \cdot J_{23} \cdot \frac{1}{\sigma_{q,P_2}}] + [J_{12} \cdot J_{13} \cdot \frac{1}{\sigma_{q,P_2}}] + [J_{23} \cdot J_{13} \cdot \frac{1}{\sigma_{q,P_2}}]$$

$$= (J_{12} \cdot J_{23} + J_{12} \cdot J_{13} + J_{23} \cdot J_{13}) / \sigma_{q,P_2}$$

$$= (\tfrac{1}{3} \times 1 + \tfrac{1}{3} \times \tfrac{1}{2} + 1 \times \tfrac{1}{2}) / 3$$

$$= (\tfrac{1}{3} + \tfrac{1}{6} + \tfrac{1}{2}) / 3$$

$$= 0.333\dot{3}$$

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Step#07

Final Page Relevance Score:-

$$PS_{Q,P} = P(Q, P, Max(l)) + max(l) \mid P(Q,P,l) \neq 0$$

Page One :-

$$PS_{Q,P_1} = 0.1527 + 3$$

$$= 3.1527 \quad , \in [l, l+1] \rightarrow \text{satisfied.}$$

Page Two.

$$PS_{Q,P_2} = 0.3333 + 2$$

$$= 2.3333 \quad , \in [l, l+1] \rightarrow \text{satisfied}$$

Step#08:-

Ranking:-

Arranging page relevance score in decreasing order

$\Rightarrow$ P_1 3.1527

P_2 2.3333

Hence Page one will be shown before the page two.

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