Name- Abhinav Kumar Ranjan
Roll No.- G24AI1006

Major Exam April 2025

Sub- Social Network Analysis
(Code: CSL7390)

Question - 1

Answer - (a)

Incidence Matrix to Adjacency Matrix

The incidence matrix provided is:

$$\begin{vmatrix} 1 & 0 & 0 \\ 1 & 1 & 1 \\ 0 & 1 & 0 \\ 0 & 0 & 1 \end{vmatrix}$$

The matrix structure has been given the namel. Each edge in an incidence matrix corresponds to a row and every node has its designated column. Each entry of value '1' shows that the node has an incidence with the edge. A simple undirected graphs contains exactly two adjacent nodes for every single edge within it.

From the incidence matrix

- Edge 1 connect Node 1 and Node 2
- Edge 2 connect Node 2 and Node 3
- Edge 3 connects Node 2 and Node 4

→ The Connection, relationship between nodes in a graph Structure appear in adjacency matrix format. The adjacency matrix contains value 1 in Position (i, j) and (j, i) when node i and Node j having an edge, otherwise both Position Contain 0.

The adjacency matrix will represent node to node Connection.

$$\begin{array}{c c} & \begin{array}{cccc} 1 & 2 & 3 & 4 \end{array} \\ \begin{array}{c} 1 \\ 2 \\ 3 \\ 4 \end{array} & \begin{bmatrix} 0 & 1 & 0 & 0 \\ 1 & 0 & 1 & 1 \\ 0 & 1 & 0 & 0 \\ 0 & 1 & 0 & 0 \end{bmatrix} \end{array}$$

$\boxed{\text{Answer} - (B)}$

Ans → Option-(B) → Erdős-Rényi (Random Network) Model.

→ In the Erdős-Rényi model the edges connect randomly because every edge formation remains isolated from other edges.

$\boxed{\text{Answer} - (C)}$

Ans → Option-(C) → Nash Equilibrium

→ Player reach a stable position known as Nash Equilibrium when none of them achieve higher rewards through independent Strategy modifications.

$\boxed{\text{Answer — (d)}}$

Answer → Option – (B) Assortative Mixing

→ Under the Concept of Assortative Mixing Similar nodes establish Connects with each other.

$\boxed{\text{Answer — (e)}}$

Answer – option → (D) Because it quantifies how often a node lies on the Shortest paths between other nodes.

→ The measurement technique called Betweenness Centrality evaluate node based on their capacity to link other nodes because it determines information flow efficiencies.

$\boxed{\text{Answer — (f)}}$

Answer → option – (C) > The presence of many nodes with very high degrees (hubs) that maintain Connectivity.

→ Scale-free Network (Hubs) operate through Central nodes which serve a Crucial Connectors. So their attack Vulnerability becomes particularly pronounced.

$\boxed{\text{Answer — (g)}}$

Answer → option – (A) The number of intra-community edges is Significantly ~~~~ higher than expected in a random network with the same degree Sequence.

→ The goal of community detection (Modularity) is to identify 4 communities through dense connection within those group compared to random chance expectation.

$\boxed{\text{Answer}-(h)}$

Answer → option-(B) $\frac{2}{5}$

→ Jaccard Coefficient,

Neighbours of X: A, B, C, D
Neighbours of Y: C, D, E.

Intersection: C, D (2 nodes)
Union: A, B, C, D, E (5 nodes)

$$\text{Jaccards Coefficient} = \frac{\text{Intersection}}{\text{Union}} = \frac{2}{5} = 0.4$$

The Jaccard's coefficient calculates set (neighbors) similarity by dividing the overlapping intersection by their combined elements.

$\boxed{\text{Answer}-(i)}$

Answer → option-(B) → LTM uses edge probabilities independently; LTM uses a weighted sum of active neighbors compared to a node threshold.

→ CH operates through independent edge probabilities but LTM adopts a threshold-based method which takes the weighted sum of neighbors impact.

Answer-(j)

Answer -> Option-(B) -> Because aggregating features, from dissimilar neighbors can blur the node's own represen-tative features, making Classification harder.

-> When heterophily occurs during GCN and Hetereophily Operations it become difficult to Classify nodes because they lose their individual Characteristic's through the features aggregation process from dissimilar neighbors.

Question - 2

Answer - 2

Influenza Spread and Vaccination

→ For reducing influenza transmission to 5% level a combined approach of Centrality measurement should be used to determine who get vaccinated first.

→ A high value of betweenness Centrality reveals that the node function as a "bridge" through which the disease transmit to numerous other connection. The immunization of these specific people break transmission pathways between different segment of the network.

→ High, degree Centrality helps identify "hubs" which possess numerous connection since they have the potential to infect multiple other people.

→ A Computation betweenness and degree Centrality should be performed for every individual.

→ A list of ranked people forms based on the Centrality measurement result.

→ The group of people selected for vaccination needs a strong ranking in both Centrality measures.

→ Additional individual should be included for vaccination until 5% coverage is reached if the top selected candidates do not suffice.

Justification →

→ A combined approach delivers better results since betweenness centrality identifies network bridge which link different network section while degree centrality distinguishes hubs that spread widely.

→ Vaccinating key hubs and bridges provides maximum efficiency by controlling both small outbreaks and widespread distribution of the ~~value~~ virus.

Question - 3

Answer.

Suggested Collaborators features

Links Prediction → System utilizes linking prediction algorithms that generate potential collaboration prediction through the analysis of current co-authorship and citation data.

→ When researchers A and B demonstrate numerous joint authors link with each other scientist a link prediction method could indicate potential collaboration between them.

→ Through Node2Vec the system creates vector representa-tions of researchers based on network structural information. Embedding that align with each other between researchers demonstrates similar research interest and collaboration potential.

Homophily

→ Due to the natural human technology of homophily the System will provide recommendation related to researchers within similar academic fields.

→ Due to encouraging diverse Collaborative ties the system requires a diversity matric within it recommendation functionality. Although the link prediction score may be slightly lower the system will give priority to research links that combine field from distinct areas.

Question-4

Answer-(a)

Girvan-Newman Core Idea

→ The Girvan-Newman algorithms detects Communities through a processing method which successively eliminates edges connecting different commmunities.

Answer-(b)

Edge Betweenness Centrality

→ Edge Betweenness Centrality analyzes the number of times an edge lies between all pairs of nodes to discover these edges. ~~ed~~

→ Edges with high betweenness values link seperate commmunities according to this method.

Answer – (c)

Computational limitation

→ The cost of computational increases substantially when calculating edge betweenness centrality on extensive network especially when they involve frequent edge removal operation.

Answer – (d)

Louvain Method

→ The Louvain method function as a scalable approach which uses greedy optimization to shift nodes between communities during its iterative process.

Question – 5

Ans – (a)

PageRank Algorithm

→ According to PageRank the importance of nodes depends on both the quantity and quality of incoming links passing through them.

→ Page importance derives from other pages that link to it.

Answer - (b)

Damping Factor (d)

→ During random web navigation a surfer has a probab-ility expressed through the Damping factor (d) either to pause their link clicks or to move to an arbitrary page.

Answer - (c)

Dangling Nodes

→ The lack of outgoing links from Dangling Nodes makes Page Rank flow through the network. We handle this condition using an equal distribution among all network nodes.

→ Each iteration distribution the rank of dangling nodes across all network nodes in an equal way.

Question - 6

	Strategy A	Strategy B
Strategy U	(3, 2)	(0, 1)
Strategy L	(2, 0)	(2, 3)

Answer - (a)

→ A Strategy pair where player can improve their payoff by unilatrally changing their Strategy.

→ Check each pair :-

(U, A) : Payoff (3, 2)

→ Player 1 : Switch to L → 2 < 3, no improve

→ Player 2 : Switch to B → 1 < 2, no improve

→ Nash equilibrium.

(U, B) : Payoff (0, 1)

→ Player 1 : Switch L → 2 > 0, improve

→ Not Nash

(L, B) : Payoff (2, 3)

→ Player 1 : Switch to U → 0 < 2 No improve

→ Player 2 : switch to A → 0 < 3 , no improvement

→ Nash equilibrium.

∴ There are two pure strategy nash equilibrium : (U, A) & (L, B).

Ans - (b)

→ Player 1 play U with probability P, L with probability 1 − P.

→ Player 2's strategy.

→ Expected payoff for Player 2 if changing strategy A

$$E[A] : P \times 2 + (1-P) \times 0 = 2P$$

→ Expected payoff for Player 2 if changing strategy B.

$$E[B] = P \times 1 + (1-P) \times 3$$

$$= P + 3(1-P)$$

$$= P + 3 - 3P = 3 - 2P$$

Answer- C

For Player 2 :

$E[A] = 2P = 2 \times 0.7 = 1.4$

$E[B] = 3-2P = 3-2 \times 0.7 = 1.6$

Since $E[B] > E[A]$. Player 2 Could choose Strategy $\underline{B}$.

For Player 1. $(0.7U, 0.3 2)$

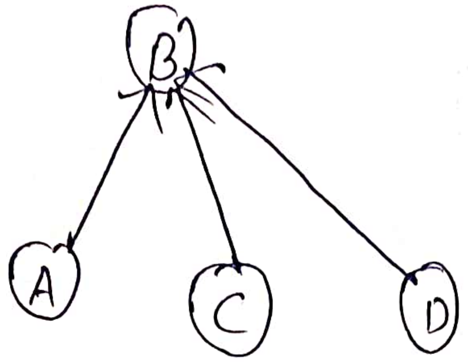
Expected payoff $= 0.7 \times 0 + 0.3 \times 2$

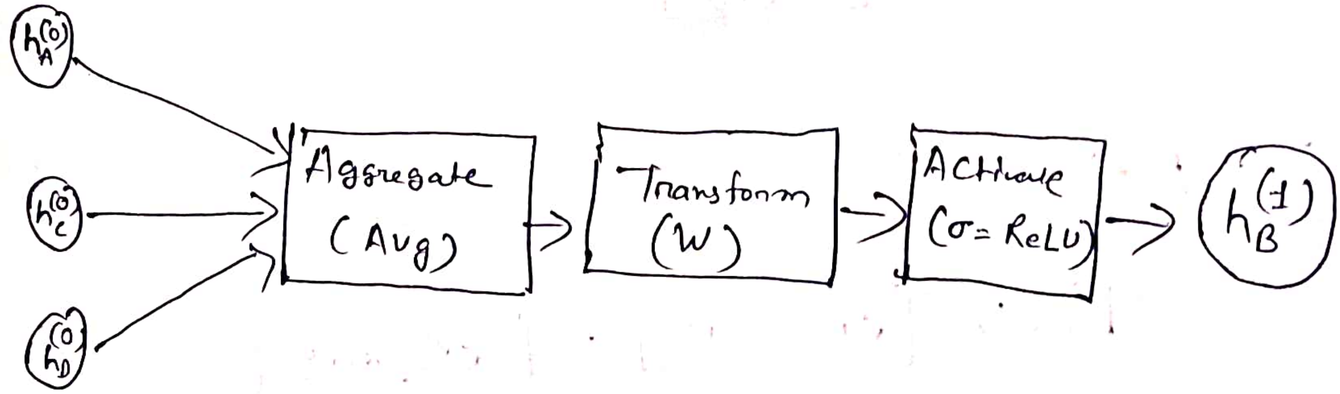
$= 0.6$ (when player 2 choose B)

The expected outcomes for player 1 receives a payoff of 0.6 & player 2 receive payoff of 1.6.

Question - 7

Answer - 7





Graph Neural Network feature update

Given,

Directed edge $A \to B$
$C \to B$
$D \to B$

Weighted matrix $W = \begin{bmatrix} 0.5 & 0 \\ 0.1 & 0.2 \end{bmatrix}$

Step-1 Aggregate neighbor features.

$$h_A^{(0)} + h_C^{(0)} + h_D^{(0)} = \begin{bmatrix} 1 \\ 1 \end{bmatrix} + \begin{bmatrix} 0 \\ 3 \end{bmatrix} + \begin{bmatrix} 2 \\ 3 \end{bmatrix}$$

$$\begin{bmatrix} 3 \\ 6 \end{bmatrix}$$

$$h^0_{N(B)} = \frac{1}{3}\begin{bmatrix} 3 \\ 6 \end{bmatrix} = \begin{bmatrix} 1 \\ 2 \end{bmatrix}$$

Step. 2. Transform

$$W\begin{bmatrix}1\\2\end{bmatrix} = \begin{bmatrix}0.5 & 0\\0.1 & 0.2\end{bmatrix}\begin{bmatrix}1\\2\end{bmatrix}$$

$$= \begin{bmatrix}0.5\\0.1\times 1+0.2\times 2\end{bmatrix}$$

$$= \begin{bmatrix}0.5\\0.1+0.9\end{bmatrix}$$

$$= \begin{bmatrix}0.5\\0.5\end{bmatrix}$$

Step. 3. Activate →

$$\text{ReLU}\,[0.5,\ 0.5] = [0.5,\ 0.5]$$

Final Answer $h_B^{(1)} = [0.5\,;\ 0.5]$.