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1 a

Given Incidence Matrix

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

Consider rows as nodes - 4 nodes

Consider columns as edges - 3 edges

-> Find adjacency matrix by following below mapping

Edge 1 connects node A & B

Edge 2 connects node B & C

Edge 3 connects node B & D

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

1 b

Ans B. Erdos - Renyi (Random network Model)

- It creates edges between pairs of nodes is formed independently with equal probability

1.c

Ans C. Nash Equilibrium

- It states where no player can benefit by unilaterly changing their strategy, assuming all other players are holding their strategies constant.

1.d

B. Assortative Mixing.

– The tendency of nodes in a network to connect with other nodes that have similar characteristics.

1.e

D. Because it quantifies how often a node lies on the shortest paths between other nodes.

1.f

C. The presence of many nodes with very high degrees (hubs) that maintain connectivity.

1.g

A. The number of intra-community edges is significantly higher than expected in random network with the same degree sequence.

1.h

X : A, B, C, D

Y : C, D, E .

~~A∪B = 5~~ $X \cup Y = 5$

~~A∩B~~ $X \cap Y = 2$

Jaccard Coefficient = $\frac{2}{5}$

B : $\frac{2}{5}$

① i

A. ICM uses edges probabilities independently; LTM uses a weighted sum of active neighbors compared to a node threshold.

① ;

B. Because aggrigating features from dissimilar neighbours can blur the nodes own representative features, making classification order.

② Vaccination Strategy using network analysis

a. Betweenness centrality - It helps to identify nodes that act as bridges between different communities. These nodes often lie on the shortest paths between many pairs of nodes and control the flow of the infection between different parts of the network.

b. Degree centrality - It helps to identify high degree nodes that have many connections and higher potential to spread the virus.

(4) a.

The core idea behind Girvan-Newman algorithm is to identify communities in a network by interatively removing edges with high betweenness centrality until the network breaks down into smaller, well defined groups.

(4) b

Betweeness centrality measures how often a node lies on the shortest path between other nodes in a network.

- It helps to calculate betweenness centrality for all edges in the network.
- Removing the edge with highest betweenness centrality.

(4) c

Major computational limitation of Girvan-Newman algorithm is its high computational complexity.

- For a network n nodes & m edges will calculate with O(nm) time.
- This calculation must be repeated after removing each edge.
- ~~overall~~ this makes the algorithm impractical for large networks with thousands / millions of nodes & edges.

(5)

4d Louvain method provides a more scalable alternative for optimizing modularity through.

- Local optimization - It starts by assigning each node to its own community. then iteratively moves individual nodes to communities that result in the largest increase in modularity

- Hierarchical Aggregation - It creates new network where nodes are the communities found in previous stage.

- Iteration on Reduced network - It repeats the process on this smaller network, allowing it to detect multilevel community structure.

5a PageRank Algorithm

- Intuition behind page-Rank is based on the idea that the popularity of a webpage is determined not only by the number of incoming links but also by the kind of incomings links. citations from highly ranked pages contribute more than lower ranked webpages.

5.b Role of damping factor (d).

Damping factor (d) represents the probability that the random Surfer will follow an outgoing link rather than randomly teleporting to another page..

5.c Problems with Dangling nodes.

- Dangling nodes create a leak in pageRank calculation.
- It causes all pageRank values to approach zero.

(6) Given payoff Matrix

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

6.a Pure Strategy

(U, A) - player-1 gets 3, player 2 get 2

(U, B) - player 1 gets 0, player 2 gets 1

(L, A) - player 1 gets 2, player 2 get 0

(L, B) - player 1 gets 1, player 2 gets 3

6.b

~~For~~ Expected payoffs for A

$E[A] = p \times 2 + (1-p) \times 0 = \underline{2p}$

Expected payoffs for B

$E[B] = p \times 1 + (1-p) \times 3 = p + 3 - 3p = \underline{\underline{3-2p}}$

6.c

Expected outcome of $p = 0.7$

$E[A] = 2p = 2 \times 0.7 = \underline{\underline{1.4}}$

$E[B] = 3 - 2p = 3 - 2 \times 0.7 = \underline{\underline{1.6}}$

7.

Neighbours of B $N(B) = \{A, C, D\}$

Given feature vectors

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

Find average of initial feature vectors.

$$h_{N(B)}^{(0)} = \frac{1}{3}\left(h_A^{(0)} + h_C^{(0)} + h_D^{(0)}\right)$$

$$= \frac{1}{3}\left(\begin{bmatrix} 1 \\ 1 \end{bmatrix} + \begin{bmatrix} 0 \\ 3 \end{bmatrix} + \begin{bmatrix} 2 \\ 2 \end{bmatrix}\right)$$

$$= \frac{1}{3}\begin{pmatrix} 3 \\ 6 \end{pmatrix} = \underline{\underline{\begin{matrix} 1 \\ 2 \end{matrix}}}$$

Given weight Matrix

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

$$W \times h_{N(B)}^{(0)} = \begin{bmatrix} 0.5 & 0 \\ 0.1 & 0.2 \end{bmatrix}\begin{bmatrix} 1 \\ 2 \end{bmatrix}$$

$$= \begin{bmatrix} 0.5\times 1 + 0\times 2 \\ 0.1\times 1 + 0.2\times 2 \end{bmatrix}$$

$$= \begin{bmatrix} 0.5 + 0 \\ 0.1 + 0.4 \end{bmatrix}$$

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