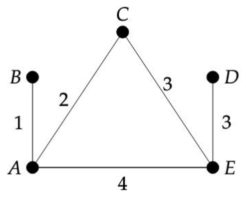
Centrality metrics

Subtask 1

1.1 - Summary of centrality metrics

- path-based centrality [4]
  - temporal closeness
  - temporal betweenness
- spectral centrality [3, 4, 5]
  - temporal communicability centrality [4]
  - temporal eigenvector-based [5]
    - generalization by using a supra-centrality matrix
    - joint, marginal and conditional centralities
    - average centrality over time, first-order mover scores
  - temporal page rank [3]



[4]

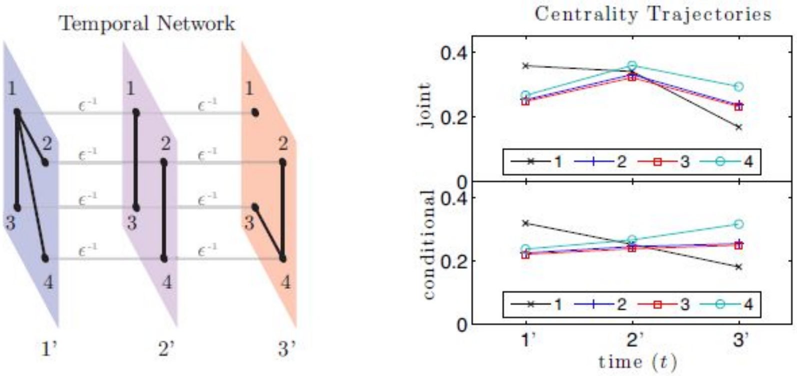
$$\mathbb{C}(\epsilon) = \begin{bmatrix} \epsilon\mathbf{C}^{(1)} & \mathbf{I} & 0 & \cdots \\ \mathbf{I} & \epsilon\mathbf{C}^{(2)} & \mathbf{I} & \ddots \\ 0 & \mathbf{I} & \epsilon\mathbf{C}^{(3)} & \ddots \\ \vdots & \ddots & \ddots & \ddots \end{bmatrix}$$

[5]

Subtask 1

1.2 - What would be the impact on centrality metric if we ignore the temporal aspect

- aggregation: could simulate information going from the future to the past [4]
- unable to examine trajectories and temporal states [5]



[5]

Subtask 1

1.3 - What are the assumptions (constraints, hyperparameters) involved in temporal-based centrality measurements?

- online algorithms [4]
  - only applicable for networks with slow dissemination rate
- shortest path-based (hyperparameter t) [4]
  - snapshot method
    - looks at aggregated time period (chronological order disregarded)
    - paths in between snapshot time periods not taken into consideration
  - Temporal closeness
    - considered paths only in certain time interval
  - higher order aggregate network
    - disregards chronological order within aggregation
  - representation as global importance (single value)
- eigenvector-based: [5]
  - discrete representation
  - supra-centrality matrix nonnegative and irreducible
  - hyperparameter: ϵ for temporal coupling strength

additional notes we had for slide 4:

- eigenvector-based: [5]
  - discrete representation (and continuous with binned timestamps)
  - time (interlayer) edges are undirected -> no causality represented
  - C has to be nonnegative and irreducible (for every w respectively e) ->network constraints:
    - network associated with C (if it would display a new graph as adjacency matrix without considering time extra) has to be strongly connected
    - sufficient: when all centrality matrices Ct are nonnegative and sum over those has strongly connected associated network
  - hyperparameter: w respective e, weights the influence of interlayer connections (how much the other timesteps influence a timestep) i.e. defines the (temporal) coupling, very important
  - computational cost NT x NT can be high for large networks with many timesteps
- online algorithm: node is updated every time network changed [4]

Subtask 2

2.1 - Summarize the temporal effect on centrality

general effect: times are considered in addition to topological aspects -> shortest temporal path based on topology and latency [6]

comparison of different centrality metrics for dynamic networks (temporality) on different datasets from several domains [7]

- different centrality metrics lead to different results (not necessarily one definitive central node)
- centrality is meaningless as a metric if dataset is extremely dynamic and does not have longer-term center
- nodes that are temporarily inactive might still have high centrality value (on important temporal path)
- low global average centrality might give false impression for important but only temporarily active nodes

=> snapshot method only applicable to a limited extent [7]

=> temporal eigenvector less accurate than temporal closeness (considers paths that can go backwards in time) [6, 7]

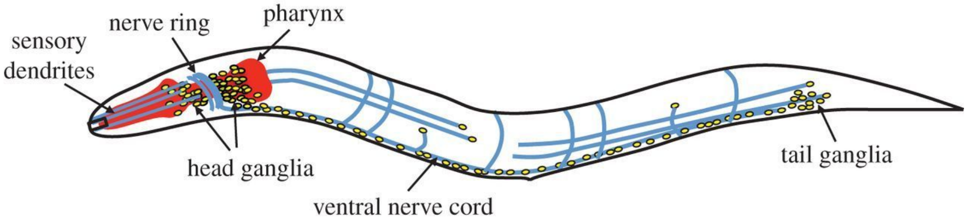
Subtask 2

2.2. - three networks that, in your opinion, are most closely related to the the phenomenon of event propagation on an evolving graph

- urban transport system (spatio-temporal) [6]
  - propagation of passenger travel
  - speed: averaged speed of serving trains in time interval

[8]

- biological neural network (spatio-temporal) [6]
  - signal transmission between neurons
  - structure: synaptic connections



[9]

- mobile phone communication (temporal only) [6]
  - calls and sms as edges

Subtask 2

2.3 - What are the types of node importance (or phenomenon) that temporal-based centrality metric helps to capture?

- node aspects: spatial, temporal and topological [6]
- how quickly information from the node reaches the rest of the network -> temporal in-closeness [6]
  - temporal in-closeness: based on distances to all nodes
- how much the network relies on the node for connecting -> path betweenness [6]
  - path betweenness: based on shortest paths that pass through it
  - in experiments: mostly affects the giant strong component size
- how important the node is for fast information propagation throughout the network -> betweenness efficiency [6]
  - betweenness efficiency: takes the reciprocal temporal distance of shortest paths through node into account
  - in experiments: mostly affects the temporal efficiency/robustness

Subtask 2

2.4 - What are the limitations of the temporal-based centrality measures to rank or identify nodes by importance?

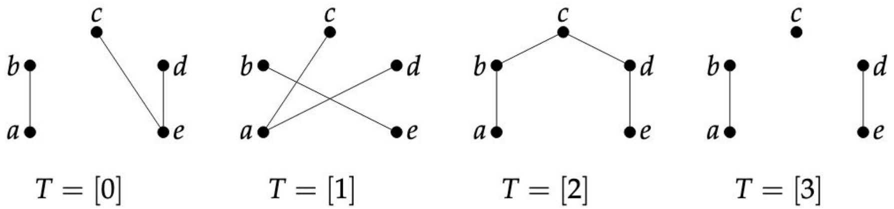


Figure 1.4: A representation of a dynamic graph in the form of 4 snapshots representing each 1 instant.

[4]

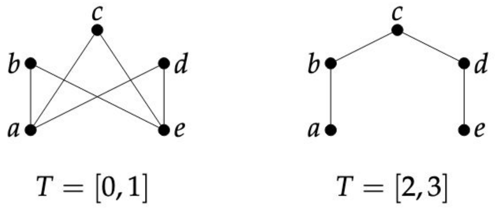


Figure 1.5: A representation of a dynamic graph in Figure 1.4 in the form of 2 snapshots representing each 2 instants.

[4]

additional notes we had for slide 9:

- the observation window plays a role (is a parameter) [6]
- purely temporal without spatial: assumption of instantaneous propagation (not considering spatial aspect: distance and speed), temporally shortest path: only considers (minimum) latency and not (minimum) distance, in their experiments: attacks were then not so effective [6]
- limit of temporal in-closeness: does not represent how much the network relies on the node for connecting (source of fragility) [6]
    - in their experiments: mostly identifies sink nodes for information flow -> their deactivation does not have so much influence on the network performance -> TC-based attack not so effective
- limit of path betweenness: does not represent which nodes are important for fast propagation throughout the network [6]
- limit of degree-based: does not consider global network information [6]
    - in their exp. : D-based attack not so effective

Usage in WPs

- in WP 2: failure in more central nodes probably spreads faster

- in WP 3: could use centrality to identify which nodes to attack
  - like in paper [6]

Sources

papers

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graphics

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