Outline
Temporal graphs: models
"Journeys": temporal paths
References

Slight introduction to temporal networks

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Please go to http://www.cs.upc.edu/~csn for all course's
material, schedule, lab work, etc.

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Temporal network
Informal definition

A *temporal network* is a network that changes over time, a.k.a.

- time-evolving network
- dynamic graph or network, etc.

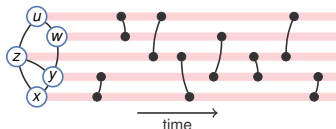Many examples exist: messaging, Twitter, Facebook, email networks, ...

In general, we can add/delete vertices and/or edges.

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modeling activity in networks

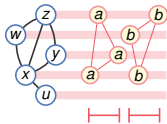**1.** network nodes perform actions (e.g., posting messages)
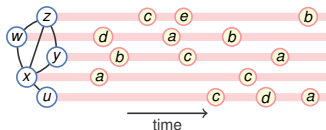
2. network nodes interact with each other
(e.g., a "like", a repost, or sending a message to each other)

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[1]Slide from Aris Gionis.

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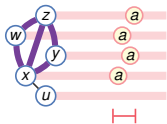"Journeys": temporal paths
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many novel and interesting concepts

new pattern types
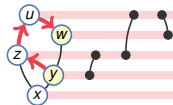
temporal information paths

new types of events

network evolution

2

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[2]Slide from Aris Gionis.

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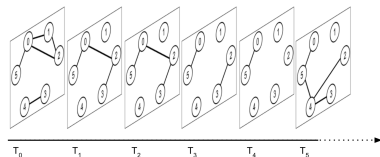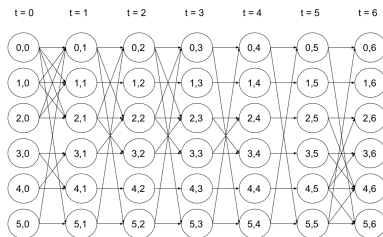References
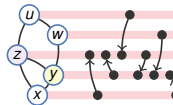
Representing temporal networks

We find several ways of representing temporal networks

- ▶ Aggregated static networks
- ▶ Flow-path model
- ▶ Snapshot model
- ▶ Stream of time-stamped edges

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Analyzing temporal networks
From [1]

- ▶ Maintenance Methods
  "[...] it is desirable to provide methods that can maintain these results continuously and incrementally over time. [...]"
  Examples: [4, 2, 3]

- ▶ Analytical Evolution Analysis
  "[...]such models are focused on modeling the change, rather than correcting or adjusting for the staleness in the results of data mining algorithms on networks."
  Examples: [6, 5]

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A central concept in evolution analysis: paths [7, 5]

- ▶ path: sequence of edges
- ▶ temporal path: sequence of time-respecting edges or journey
- ▶ journeys that have the earliest arrival times are called **foremost** journeys
- ▶ journeys with the smallest topological distance are referred to as the **shortest** journeys
- ▶ journey that takes the smallest amount of time is called the **fastest**

This idea of temporal path is the basis of extending PageRank [6] and extending betweenness [5] for temporal networks.

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References

[1] Charu Aggarwal and Karthik Subbian. Evolutionary network analysis: A survey. *ACM Computing Surveys (CSUR)*, 47(1):10, 2014.

[2] Kyung Soo Kim and Yong Suk Choi. Incremental iteration method for fast pagerank computation. In *Proceedings of the 9th International Conference on Ubiquitous Information Management and Communication*, page 80. ACM, 2015.

[3] Rohit Kumar, Toon Calders, Aristides Gionis, and Nikolaj Tatti. Maintaining sliding-window neighborhood profiles in interaction networks. In *Joint European Conference on Machine Learning and Knowledge Discovery in Databases*, pages 719–735. Springer, 2015.

[4] Naoto Ohsaka, Takanori Maehara, and Ken-ichi Kawarabayashi. Efficient pagerank tracking in evolving networks. In *Proceedings of the 21th ACM SIGKDD International Conference on Knowledge Discovery and Data Mining*, pages 875–884. ACM, 2015.

[5] Amir Afrasiabi Rad, Paola Flocchini, and Joanne Gaudet. Computation and analysis of temporal betweenness in a knowledge mobilization network. *Computational social networks*, 4(1):5, 2017.

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References (cont.)

[6] Polina Rozenshtein and Aristides Gionis. Temporal pagerank. In *Joint European Conference on Machine Learning and Knowledge Discovery in Databases*, pages 674–689. Springer, 2016.

[7] B Bui Xuan, Afonso Ferreira, and Aubin Jarry. Computing shortest, fastest, and foremost journeys in dynamic networks. *International Journal of Foundations of Computer Science*, 14(02):267–285, 2003.