# presentation notes

## before introduction

- ever taken a graph course: street maps big motivational example
- i thought: give me big servers and 1000 years & i can build google maps!
- But: bus, tram and trains aren't waiting for you!
- go home now: takes longer, than going home in 10 minutes -> time changes something about the route that I take -> deeper: time changes the graph representation of city
- questions emerge
  - what exactly does time change?
  - how could we model this change?
  - do our normal algorithms work?

## Motivation

### clip school day

- show clip
- french researchers: put RFID on everybody in a school -> track proximity & social interactions
- only info:
  - who is teacher/student
  - proximity every x minutes
  - class mates
- visualization possible
- why interesting? INCREDIBLE story telling
- temporal graph rich in information
- studying this: insights in

### Google maps

- what does google maps use temporal data for:
  - account for traffic
  - road closures
  - transit schedules
- e.g. Bus departs in 15 mins -> travel distance of bus depends on departure -> some connections might not exist at some points in time
- pretend for now: modified Dijkstra/A* is used for shortest path calculations (heuristic for A* takes both spatial as well as temporal information into account)

### Distributed systems

- many applications: rely on large p2p (peer to peer) systems -> prone to errors

- availability of distributed resources -> e.g. server might fail at some point in time or have throttled bandwidth -> should adapt to changes with:
  - self organization
  - self healing
  - self adaption
- temporal reachability queries
- or: study some properties that hold under any circumstance (e.g. small temporal diameter, . . . )

#### for physical/chemical model

- real-world temporal changes can be modeled with temporal graphs
- paper: how do chemicals react in dissolved organic matter !?
- no more questions xD

#### dissemination processes

- How does information, a disease, behaviour, . . . spread over time in a network?
- corona pandemics -> determine bottlenecks, who to vaccinate and accelerators
- identify critical times and nodes
- e.g. social media: understand spread of viral hashtag

#### How to (visually) represent temporal graphs

- normal graphs: strong representation
- dilemma: how to show the third (temporal) dimension?
- research topic
- some ideas in pictures
  1. flow of time symbolized horizontal axis
  2. edge labels (more about that later)
  3. actual passage of time
  4. 3 dimensional drawing -> here: domain-specific

## How to model temporal graphs

- static graph G = (V, E) where every edge is labeled with 0 or more natural numbers
- labels correspond to time steps (-> seconds, days, months; when each edge is available) -> more general: any discrete artificial measure of time

#### labeled and temporal graphs

- first: take a step back
- labeled graph $G = (V, E, \lambda)$
- in general case: labels can be anything

- NOW: temporal graphs -> no labels for vertices -> Z is set of natural numbers (2^N)
- why on one slide? -> closely related
- interpretation of labeled graph as temporal graph possible and vice versa
- e.g. proper edge-labeling
- looks trivial, but has deeper meaning!
- no 2 edges appear at same time
- exercise!!!

**Transitivity of reachability in static graphs**

- not my only proof, i swear :)
- no rigeous proof, but rather intuition
- please ignore that we haven't defined reachability exactly yet and use the analogue of reachability on static graphs

-> not transitive - what can we learn from this? - fundamental structural differences between static and temporal graphs - ideas and algorithms that rely on transitivity of reachability in static graphs might not work in temporal graphs -

**Second notation**

- time edges
- exercise!!!

**static expansion of graphs**

- notion of storing separate graph per time step
- advantages:
  - use existing algorithms
  - simple representation (both visually and computationally)
  - in real life: speed up by parallelization
- disadvantages:
  - memory consumption/graph size: $|V| \cdot \alpha(\lambda)$
  - redundant information
  - doesn't scale to high temporal resolution

**journeys**

- nearly last basic concept we'll cover
- first: repeat path in static graph
- walk is a finite/infinite sequence of edges
- path is a walk where all vertices are distinct -> note: therefore also all edges are distinct

- central concept -> also exists on temporal graphs

### computing the foremost journey

- problem statement:
  - given source node s and a start time $t$ compute the foremost s-w journey for all $w \in V$

## dissemination processes

- never seen such a funny start of a paper section
- deep down mathematicians are just gossips lol

### what processes exist?

- spread of information, rumor, fake news, disease, ...
- commonly studied:
  - spread research findings
  - spread information or maybe even ad campaign in a social network
  - spread of diseases in communities
- things that are studied (in the more traditional setting of dissemination):
  - source of information
  - medium of spread -> social network, publications
  - timing
- has been shown shown that underlying network structure can strongly affect dynamic processes -> big difference to analysis of static graph
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  ## network structure affects speed and extent of spreading

- now, very concrete use case: vaccination problem

### vaccination problem

- refers to challenge of effectively planning and executing vaccination campaigns
- we focus on theoretical analysis of temporal network to identify critical nodes and times
- assumption: there are individuals who, through their behavior, are more likely than average to become infected and to spread the disease further
- key questions include:
  - who should be vaccinated first? -> corona: old people and personal that is critical for infrastructure, health system

  - How can we minimize the spread of the disease? -> open up, but when?
  - What role does timing play in vaccination strategy? -> how should vaccination be prioritized?
- already know basic terms: but overall goal: herd immunity
- herd immunity: occurs when a large enough fraction $f$ of a community is immune to disease, thus limiting its ability to spread -> lower f by strategically vaccinating people in risk

**vaccination problem - more technical problem statement**

- How can we optimally choose a fraction $f$ of a population to vaccinate using only local information?
  - optimally: economically? mortality? DALYs (Disability adjusted life years)?
  - vaccinate: instant and 100% effective
  - local information: query nodes about information about neighbors but not more

**Neighbourhood vaccination protocol**

> choose a person at random among all persons that have been involved in at least one contact at time t*, ask her to name someone she met, vaccinate this other person, and repeat until a desired fraction of the vertices are vaccinated - talk through example - important properties of vaccination protocol - only uses local information - why is it good? - sample people in proportion to their degree - importance of person is proportional to $deg^2$ - infection rate ~ degree - spreading rate (once infected) ~ degree

**Modelling dissemination processes with temporal graphs**

- nodes represent individuals, groups or organizations
- edges represent interactions
- time labels represent the time of interaction
- for now: interactions are all of equal, very short length
- example: could be the truly underlying graph of static example earlier

**The infection process**

- new type of temporal graph representation:
  - basically static expansion of temporal graph
  - every row is one person
  - x-axis: time
  - vertical lines represent contact
- split given data into two parts:

1. learning period

- then: vaccinate (instantaneously) and disease starts at one source node

2. simulate spreading of disease with SIS (Susceptible-infected-susceptible) simulations
    - two groups: either susceptible or infected
    - we assume: infected stay infected, since our simulation time is very short