Week 10

Diffusion and influence

Tuesday, October 26

INFO 5613: Network Science

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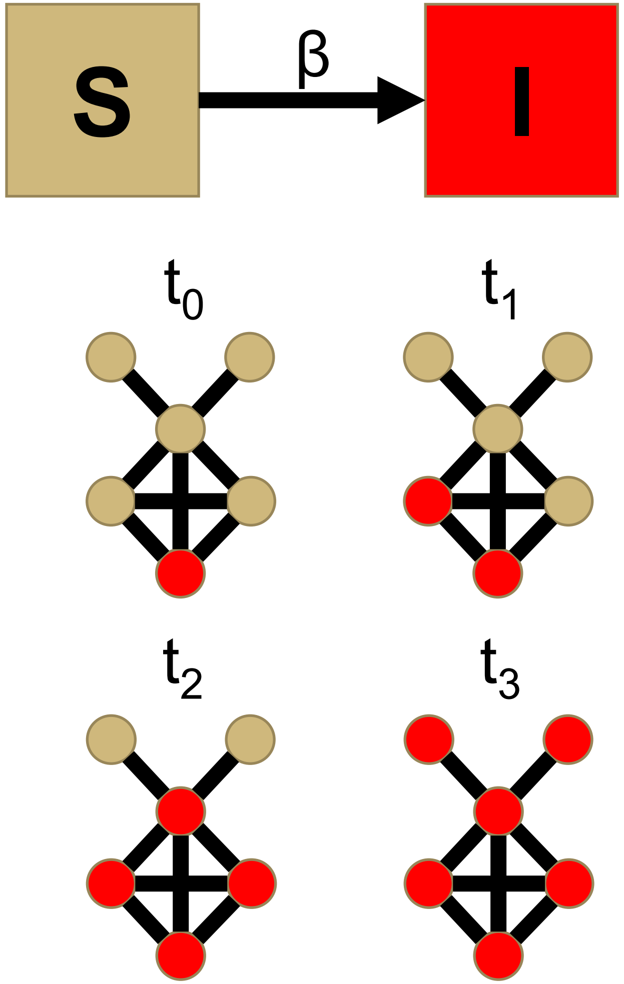
Agenda

- Networks are not static! Nodes' attributes change in time
  - Diffusion causes nodes' attributes to influence neighbors and spread over network
  - Relevant for understanding spread of agents in epidemiology, sociology, *etc*.

- Compartmental models → nodes transition between attribute states with some probability
- Threshold models → nodes transition between attribute states only if neighbor threshold exceeded
- Profile models → nodes have an internal state checks their ability to adopt or reject

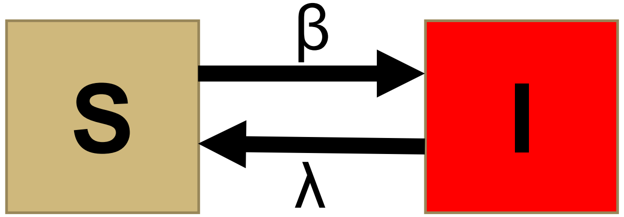
- Network structure plays a profound role in whether and how quickly agents spread across network

Compartmental models: SI

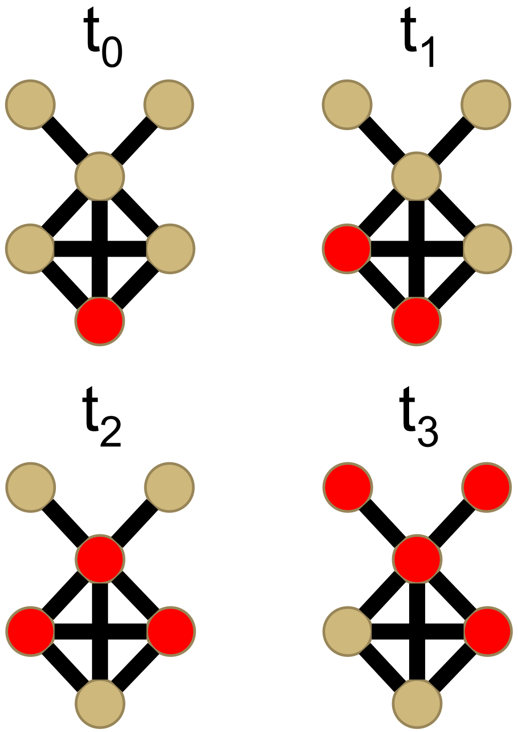


- Nodes have two states: susceptible (S) or infected (I)
  - Can only transition from susceptible to infected state
- If a susceptible node's neighbor is infected, with probability β the node becomes infected as well
  - Each infected neighbor has independent chance to infect a node
- Once infected, nodes stay infected
- All (connected) nodes inevitably become infected
  - Focus on differences in infection times for different network structures

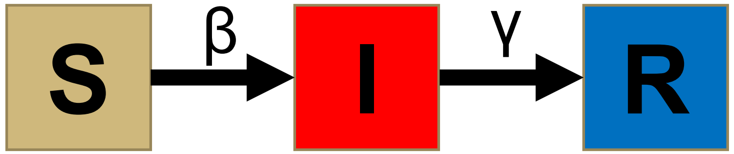
Compartmental models: SIS



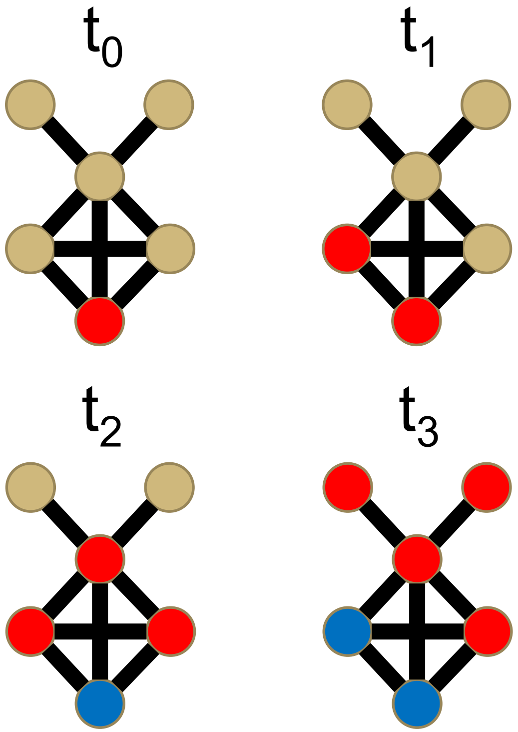
- Nodes have two states: susceptible (S) or infected (I)
- Two transitions
  - From susceptible to infected: β
  - From infected back to susceptible: λ
- At each time step, infected nodes try to infect susceptible neighbors and infected nodes revert to being susceptible
- Whether infectious agent takes over network depends on values of β, λ, and network structure
  - Parameter space of many combinations



Compartmental models: SIR



- Nodes have three states: susceptible (S), infected (I), recovered (R)
- Two transitions
  - From susceptible to infected: β
  - From infected to recovered: γ
- At each time step, infected nodes can infect susceptible neighbors and infected nodes can convert to recovered
- Whether infectious agent takes over network depends on values of β, γ, and network structure
  - Parameter space of many combinations with different outcomes



Compartmental models: Extensions

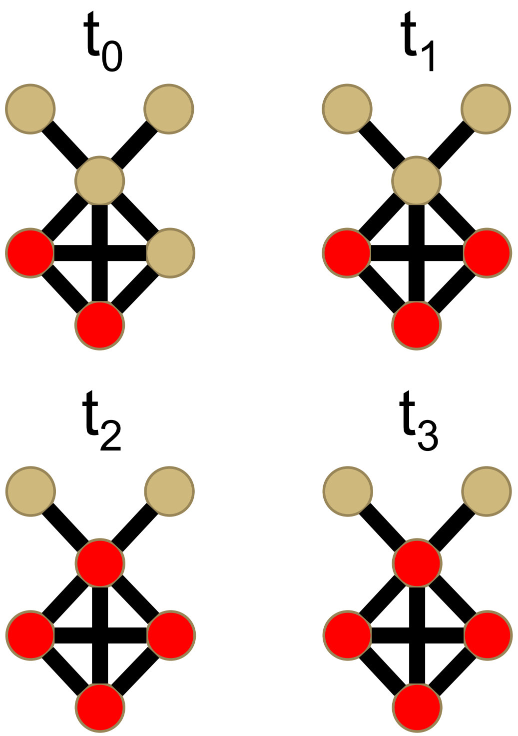
- SIRS: susceptible, infected, recovered, susceptible
- SEIS: susceptible, exposed, infected, susceptible
- SEIR: susceptible, exposed, infected, recovered

- Carriers, vaccinations, maternal immunity, vital/demographic processes

- Pros: Relatively simple to predict “mean field” outcomes using differential equations
- Cons: Nodes are passive, mean field predictions

Threshold models

- Nodes have more agency over whether they become infected
  - Commonly used for studying collective action, social movements, *etc*.
  - Sometimes called “complex” contagion, related to “network effects”
- A modified SI model where spread is deterministic, not probabilistic
- If a fraction of a node’s neighbors are infected, then the node is immediately infected
  - If the threshold isn’t exceeded, the node remains susceptible
  - Threshold = 0.5 in example in right
- Thresholds could be identical or vary across nodes, time, *etc*.



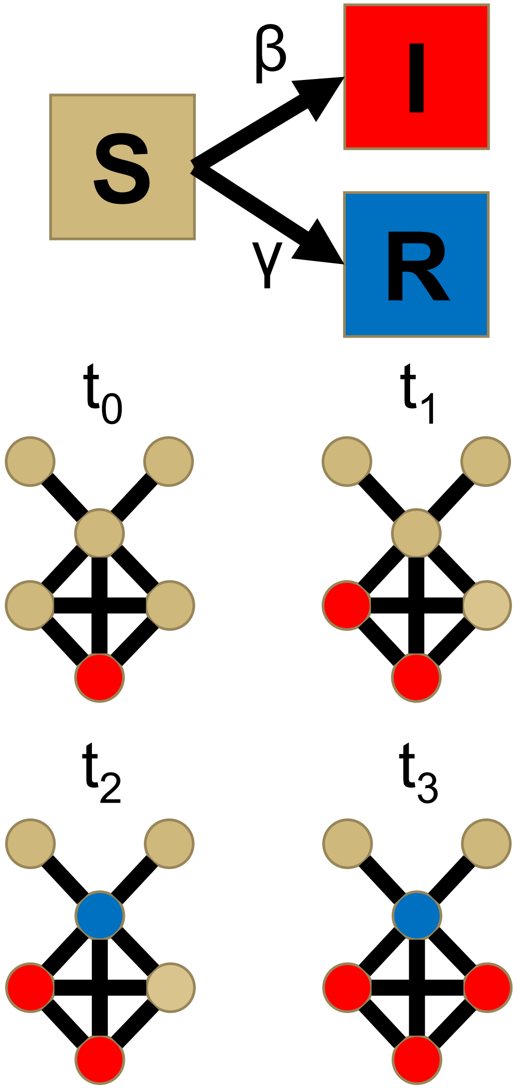
https://ndlib.readthedocs.io/en/latest/reference/models/epidemics/Threshold.html

Profile models

- More agentic, nodes have an internal profile/preference

- Another modified SI (or SIR) model, probabilistic
- A susceptible node is exposed and adopts if it exceeds an internal threshold
  - If the threshold isn't exceeded, node remains susceptible
- Model also can allow nodes to transition to Removed immediately
  - Exposure to an idea causes them to reject it

- Profiles can vary across nodes, time, *etc*.



Reading responses

Readings

- Readings
  - Valente, T. W. (2012). Network interventions. Science, 337(6090): 49–53
  - Guilbeault, D., Becker, J., and Centola, D. (2018). Complex contagions: A decade in review. In Lehmann, S. and Ahn, Y.-Y., editors, *Complex Spreading Phenomena in Social Systems*, pp. 3–25.

- What is an example of a network diffusion process in the context of your research? What are the nodes and edges? What is spreading? How passive or active are nodes in shaping the diffusion process? What kinds of models (epidemic, threshold, voter, profile, etc.) do a good job of capturing the spreading mechanism(s)? What are some nuances of the spreading process that complicate the models we've discussed?
- Valente (2012) discusses different strategies for intervening in networked behaviors and evaluating their effects. What are real and/or speculative examples of some of these types of interventions in your research? What kinds of data collection and analysis strategies would need to be in place to evaluate the effectiveness of these interventions? How would you go about selecting a network intervention given the competing pressures for efficiency, effectiveness, ethics?
- Guilbeault, Becker, & Centola (2018) review decades of scholarship about social contagions with a focus on the idea of "complex contagions". What makes a contagion "complex" and distinct from a "simple" contagion? What kinds of clues would lead you to interpret an observed diffusion in your research to be complex rather than simple? What are the potentials and/or consequences for trying to engineer contagions that have complex compared to simple mechanisms?

Examples of network diffusion

- EO: Opportunity and perceptions of authenticity in music industry
- MG: Users’ propensity to spread information online not uniform but tied to ideology and values
- SD: Spread of captioning norms among TikTok users as a threshold or profile model
- DD: Spread of social values accepting/rejecting violence against women through social groups
- JT: State policy diffusion
- JG: Ideology of social media users spreading based on their following/content behaviors
- CM: Threshold models for removing harmful content from social media
- DR: Consumer attitudes towards artificial sweeteners as a threshold model
- LD: Spread of scientific articles and rumors about COVID+fertility
- LJ: SUIR model of intention to leave a conflict zone driving sentiment and conflict

Network intervention strategies

- CD: Two-step flow, ethics of network intervention designs
- ED: Interventions with glitch aesthetics that reveal the structure to participants?
- HB: Leader-follower clusters less likely to cause virality than convincing brokers
- SD: Measuring induction strategies in asymmetric/competitive networks
- YL: Cancer metastasis as a kind of network alteration strategy
- JS: Coupling of crypto offerings and Discord behavior

Complex contagions

- KW: Conspiracy theories spreading online, multiple/embedded exposure, fit of contagion with users
- BW: Social/ecological consequences of engineering contagions like crop adoption

Module Assignment 3 & Final Assignment

Module Assignment 03

- November 19 (Friday before Fall Break)

- Opening bid:
  - "Network contrarian" op-ed → "everything we're doing about X is wrong because we've ignored networks"
  - Classic 750-1000 words and 10-12 short (75-100 word) paragraphs intended for a general audience
    - The OpeEdProject: https://www.theopedproject.org/oped-basics/
    - Paragraphs 1-2: Hook (why should someone care?) and nut (what's your contribution?)
    - Paragraphs 3-5: Define the problem
    - Paragraphs 6-8: Outline the solution
    - Paragraphs 9-10: "To be sure" making anticipating and making concecessions to critics
    - Paragraphs 11-12: Summarize and call-to-action

Next class

Week 11 readings

- Similarity, homophily, and network endogeneity

- McPherson, M., Smith-Lovin, L., and Cook, J. (2001). Birds of a feather: Homophily in social networks. Annual Review of Sociology, 27:415–444
  - Influential (>18,000 cites) paper, summarizes large literate about similarity dynamics on networks
- Rivera, M. T., Soderstrom, S. B., and Uzzi, B. (2010). Dynamics of dyads in social networks: Assortative, relational, and proximity mechanisms. Annual Review of Sociology, 36(1):91–115
  - Focus on distinct mechanisms that generate clusters of similar social agents in networks