Lecture Notes: Social Networks: Models, Algorithms, and Applications
Lecture 21: April 3, 2012
Scribes: **Geoffrey Fairchild** and Jason Fries

1 Hospitals as Social Networks

Definition 1 *A nosocomial infection (also called a hospital-acquired infection or HAI) is an infection that originates or occurs in a hospital.*

Definition 2 *A contact network is a network in which edges model explicit interactions between vertices. Contact networks are useful in epidemiological studies because they model our current understanding of germ theory (i.e., that diseases are microorganisms spread by human contact).*

Why are hospitals of particular interest to epidemiologists?

- People are sicker (i.e., they are more susceptible).
- There are records we can use to build a contact network.
- Patterns of interaction are constrained by architecture, job type, and time of day.

In this lecture, we looked at two papers which modeled disease spread in hospitals.

2 Ueno and Masuda[2]

Hospital structure and data used:

- 482-bed hospital in Tokyo
- 16 units
- 129 rooms (37 rooms are single-bed rooms)
- staff (doctors and nurses) are "assigned" to departments
  - Doctors are assigned to a department but may visit multiple units (≤ 5 units in practice).
  - Nurses are assigned to a unit and see patients from > 1 department.
  - Patients are contained in multiple units and departments.
- Units contain patients from multiple departments.
- Departments assign patients to many units.
- Patients are assigned to one nurse.
- Patients are assigned ≥ 1 doctor.

The contact network Ueno and Masuda generate is static (i.e., it doesn't change with time), undirected (i.e., doctors and patients are equally likely to infect each other), and unweighted (i.e., frequency of contact is ignored). Six edge types are derived from their data:

- nurse-patient (nurse assignment)
- nurse-nurse (unit assignment)
- patient-patient (roommates)
- doctor-doctor ("team" assignment)
- doctor-patient
- doctor-nurse

Data and contact network limitations:

- Hospital staff other than nurses and doctors are ignored (e.g., phlebotomists, X-ray techs, housekeeping, etc.).
- Casual contacts (e.g., contacts during lunch breaks or staff meetings) aren't modeled.
- They generate their network using data coming from only two days: one weekday and one weekend day.

They use an SIR model for their simulations.

- Probability of infection in time Δt is λ.
- Probability of infection scales linearly with number of neighbors infected.
- If Δt is small, $Prob[S \to I]$ depends on λN (where N is the number of infected neighbors), and one recovery event occurs per unit time on average.
- Exponential distributions are used for infection and recovery.

λ controls R_0 directly in their simulations. Simulations are run, and they report the attack rate (the percentage of people that got infected). Results were averaged over 100 replicates. They suggest three interventions:

- reassign patients to medical doctors
- dissolve medical doctor teams
- introduce single rooms (i.e., remove all patient-patient edges)

Their primary conclusion is the following:

> *Both the intervention and vaccination results suggest that medical doctors that link different wards are main spreaders of nosocomial pathogens.*

However, as discussed in class, this is of course true! This conclusion is a direct result of the construction of their contact network in which doctors have the most contacts.

3 Polgreen, Tassier, Pemmaraju, and Segre[1]

Hospital structure and data used:

- 700-bed hospital (University of Iowa Hospitals and Clinics - UIHC)
- 6654 contacts observed by graduate students ("shadow data")

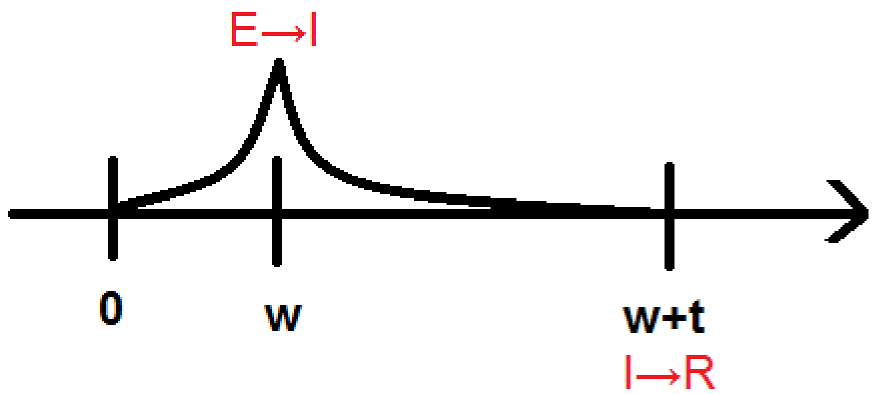

Figure 1: How transitions between disease states are modeled in this paper. The incubation period w is measured in days and represents the period after initial infection where symptoms appear. Infected agents recover t days after symptoms first appear. The period leading up to state I is modeled as exponential growth, and the period between state I and state R is modeled as exponential decay.

- 16 job types (e.g., doctors, nurses, physical therapists, etc.) were each observed for a total of 40 hours
- Contacts are egocentric (as opposed to sociocentric) meaning that they are one-sided. This is because each student only followed one person at a time.

A large symmetric 16×16 matrix was created where each entry in the matrix represents the probability of contact between job types i and j. Physical contact, hand hygiene events, and length of contact were recorded. The generated contact network is dynamic, so edges form and dissolve with time. An SEIR model was used for simulations. Figure 1 shows how transitions between states is modeled. Patients are discharged and replaced with probability $\frac{1}{d}$ where d is the average length of stay ($d \approx 3$ in this paper). Replacements enter in state S. Transmission is a product of transmissibility (property of I) and susceptibility (property of S).

4 Conclusion

So, which model is more meaningful? Which paper provides better insights in HAIs? The truth is that while we can make claims supported by empirical data generated by complex simulations, we can never truly say that model A is better than model B. There are no ground truth data, so validation is impossible. Simulations must be carefully planned, parameters must be expertly selected, and data must be as thorough as possible to ensure that simulations can lead to meaningful conclusions.

References

[1] Philip M Polgreen, Troy Leo Tassier, Sriram Venkata Pemmaraju, and Alberto Maria Segre. Prioritizing healthcare worker vaccinations on the basis of social network analysis. *Infection Control and Hospital Epidemiology*, 31(9):893–900, September 2010.

[2] Taro Ueno and Naoki Masuda. Controlling nosocomial infection based on structure of hospital social networks. *Journal of Theoretical Biology*, 254(3):655–666, October 2008.