Lecture 8: Adaptive Networks and Analysis

Complex Systems 530

Adaptive networks

- Dynamics of and on networks—model variables on the network cause network changes, which in turn affect the variables on the network
  - Feedback between process on network and the network itself
- Relatively new field, growing area of research

Examples

- Organism development (nodes as cells), regulatory network changes (nodes as genes/proteins) as genes are activated or during carcinogenesis, etc.

- Neuronal plasticity - neuron connections change as a function of firing rate, etc. Hebbian learning: “neurons that fire together, wire together”

- Self-organization of ecological communities (nodes as species, edges as relationships)—dynamics of invasion, extinction, adaptation, and speciation

Examples

- Epidemiological networks - modeling changes in contact networks as a function of disease dynamics (quarantine, social distancing, etc.)

- Social communities - changes in connections between individuals over time (political networks, friendship networks, etc.)

- Power grids - nodes can be removed if they fail

- And many more!

Social distancing and disease dynamics

- When individuals are ill, they may disconnect from their network edges to avoid getting others sick (or because symptoms make them stay home)
- Susceptibles may disconnect from infectious neighbors to avoid getting sick
- How would each of these be different in a model?

Social distancing and disease dynamics

- How to implement social distancing?
- Ordering for rules? (Three processes: infections, recoveries, tie-dissolution)
  - For asynchronous node updating, what order to evaluate events?
  - If synchronous, can evaluate all events based on last timestep then update

Social distancing and disease dynamics

- Should ties be dropped completely or should they be reduced? We can model this as weighted edges where the weights change as a function of infection status

- Should we include tie reformation after the illness has passed—should ties return to the same people or connect to new people?

- Let's try implementing it!

Mean field models

Mean-field models of networks

- Mean-field analysis of networks is more common than for CA—and often more useful
    - Lower dimension approximation of the model, often more tractable to implement and analyze
- Mean field models are easiest to work with for networks with less explicit clustering, e.g. Erdös-Renyi graphs
- But can be used for a range of network types!

Mean-field models of networks

- Mean field models are often used without ever going to the network formulation—many differential equation models, Markov models, etc. are mean-field approximations of network or individual-based models

- We often start with these when:

  - We're modeling populations without too much heterogeneity

  - We don't need specific individual behaviors—total numbers of people will work

Mean-field models of networks

- How to determine?
  - Very similar to how we did for CA models!
  - However, CA models had clear ‘neighbor’ structure due to lattice—now we have more complicated neighborhoods
- Example: infectious disease model on an Erdös-Renyi graph

Network SIR Mean Field Model

- Work on board!
- Also try coding to compare
- Note: mean field model will work better when we have a large population, since it captures average behavior—so if stochasticity is playing a large role, can be problematic
  - That said, we can also write a stochastic model describing the total population dynamics

For next time…

- Reading
  - Sayama Chapter 18