Modeling Complex Systems (CS/CSYS 302), Fall 2019

Assignment #4 of 4
Done in groups of 3. Due on Blackboard by midnight on Friday, November 22nd. Your write-up should contain everything but the codes, such as any necessary figures as well as your answers to the questions. Make sure to justify your answers to each question. Codes should be submitted separately as readable text files (e.g. .py, .cpp, .m, .R).

Dynamics on Networks

- *Epidemic spreading* on the configuration model allows us to test simple targeted vaccination strategies since not all individuals (nodes) are considered equal. Let us consider a simple example on an endemic Influenza epidemic, and test the impact of vaccination strategies knowing that around 40% of adults tend to get vaccinated.

  a) Write a heterogeneous mean-field system for an SIS epidemic model on a configuration model network. You should obtain a system of equations for $\dot{I}_1, \ldots, \dot{I}_{k_{\max}}$, where $k_{\max}$ is the largest degree in the network. Feel free to nondimensionalize your system if you wish.

  b) Modify the above system of equations by adding new compartments for vaccinated nodes. Assume that around vaccinated nodes, the transmission rate (both to and from these nodes) is reduced by a factor ρ. For example, each susceptible individual with degree k should move from compartment S_k^V to I_k^V with probability $\rho\beta k\theta$ (where θ is defined in Eq. (10) of "Mean-field Models on Networks" handout).

  c) Using the integrator of your choice, test how strong ρ needs to be to eradicate an outbreak with the following parameters: transmission rate $\beta = 0.3$ (week^{-1}) and recovery rate $\alpha = 1$ (week^{-1}) in a population with a geometric degree distribution $p_k = p(1-p)^k$ with $p = 1/4$. Assume that a random 40% of the population gets vaccinated.

  d) Repeat *c)* but now assume that the vaccination campaign convinced the 40% of nodes with highest degree to get vaccinated.

- The *voter model* is the simplest computational analogy to social debate and allows us to study the ability of a network to reach a consensus. Nodes are typically in one of two states (say red and blue), and at every time step, a random node adopts the state of one of its neighbours, also chosen randomly.

  a) Using the network you chose in Assignment 3, implement the voter model and run it on your network using some initial conditions (i.e. 50% red and 50% blue randomly distributed). Averaged over a few runs, does the network tend reach consensus? If so, how fast? Try a few different initial conditions.

b) Now, find the degree distribution of your network and run the voter model again using the resulting configuration model network. How do the dynamics compare to the real network?

c) Provide a small toy example of when a network and a corresponding configuration model network can have quite different dynamics for the voter model.

Agent-based Models

- Read Chapter 19.1-19.3 of your textbook.
- Propose an agent-based model for one of the systems we have studied in class or from one of your previous assignments. You don't have to code anything, just briefly indicate the system/research question you are modeling and answer the following questions:
  - What are the agents? What is the environment?
  - What are the static/dynamic attributes of agents, and how do agents interact? What are the static/dynamic attributes of the environment, and how do agents interact with it?
  - Describe how your ABM can be studied in a scientifically meaningful way. Is your ABM and chosen system better suited for a "bottom-up" study (i.e. approach A in 19.2, pp. 431), or a "top-down" study (approach B)?
  - Why might an agent-based model be a better choice for capturing important phenomena in your system than other modeling approaches we have seen?