SWEN90004
Modelling Complex Software Systems

Lecture Cx.10
Networks II: Networks and ABMs

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Recap

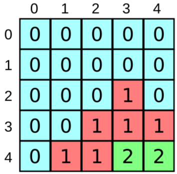
- Networks can be used to represent the structure of complex systems – the pattern of interactions between their components
- We can describe the structure of networks in terms of quantitive properties such as density, degree distribution, characteristic path length, clustering coefficient, etc.
- A range of network models have been proposed to describe the structure of real world complex systems, including:
  - small world networks
  - scale free networks
- We discussed how regular 1D and 2D lattices could be used to describe the structure of interactions in 1D and 2D cellular automata.
- Today we will switch focus from network *structure* to network *dynamics*.

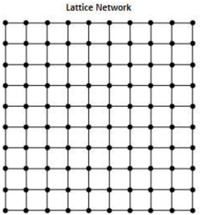
Network dynamics

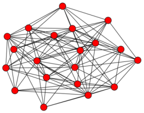
Two types of network dynamic are often considered:

- the network structure may remain static, but the *state* of nodes changes—dynamics *on* networks
- the network structure changes—dynamics *of* networks

Dynamics *on* networks—SIR disease model

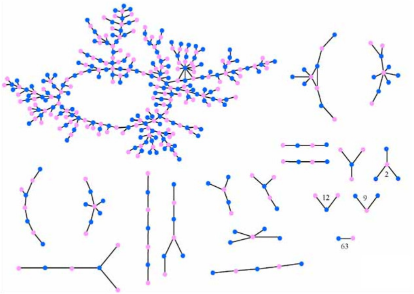






In week 3, we explored a Cellular Automata model of disease transmission on a 2D grid. As a grid can be represented as a regular lattice, it is straightforward to generalise our approach to consider the spread of infection across any network.

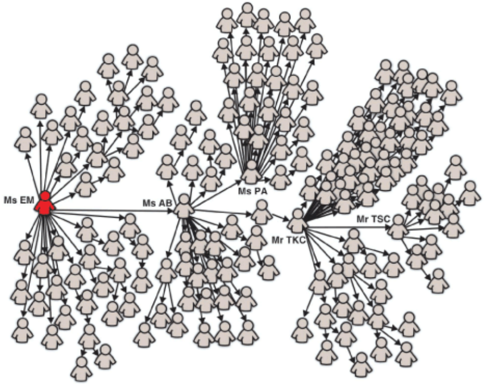
Dynamics *on* networks—SIR disease model



- what effect might network structure have on the dynamics of disease spread?
- which nodes in a network are at greatest risk:
  - of being infected?
  - of infecting others?
- what does this suggest about approaches to preventing the spread of infection?

Dynamics *on* networks—SIR disease model

The spread of Severe Acute Respiratory Syndrome (SARS) in 2002–2003.



Netlogo model: Virus on a Network

Dynamics *of* networks

The growth model we used for creating scale-free networks and the rewiring model we used for creating small world networks are simple examples of network dynamics

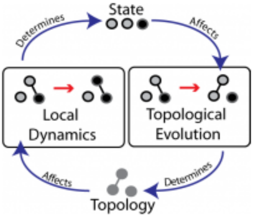
In these models, the *state* of a node can be unimportant.

More complex dynamic behaviour is possible if both network state *and* network structure are changing at the same time.

Consider our SIR disease model on a network:

- under what conditions might we expect edges to be rewired?
- what effect might this have?

Adaptive networks



For example, consider a road network:

- nodes are locations that people travel between
- edges are roads between locations that people travel on
- roads have a capacity: if two many people travel along a certain road, it may become congested (a property of the network's *state*)
- in response to this congestion, new roads may be built (a change to the network's *structure*)
- this may, in turn, cause the patterns of travel to change

Networks and ABMs

What is the relationship between agent-based models (or multi-agent systems) and networks?

In the simplest case, agents are mapped to the nodes of a network, and the network topology determines patterns of interaction between agents.

Network (as opposed to spatial) models are useful when:

- the *relationships* among agents are more important than their physical locations; eg, a model of information spreading through a population (potentially via phone or email), versus a model of a fire spreading through a forest
- interactions between agents are not grounded in physical proximity; eg, a model of interacting software agents, versus a predator-prey model.

What are other complex systems in which network structure may be more appropriate than spatial structure?