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Transmission of Information (and Disease) in a Network

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Overview/Outline

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- Introduction
  - Using Infection Models for the Spread of Info
- Infection Models:
  - Susceptible-Infected-Resistant (S-I-R) Model
  - Susceptible-Infected-Susceptible (S-I-S) Model
  - Extensions to the SIR/SIS models
- Common Extensions
- Derivative: Panic Spread Model

Introduction

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- Epidemic Models were originally created to show the spread of an infection throughout the populace
- Agents are nodes on a connected graph, with the edges indicating social or physical contact
- Agents can be in one of three states:
  - **Susceptible** (*Not yet infected*)
  - **Infected**
  - **Resistant** (*Recovered and resistant to the infection*)

Introduction (2)

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- Originally, mathematical (deterministic) models were employed for the spread of infection
- Later models are stochastic: each contact has a possibility of transmitting the infection
- Agents and contacts are homogeneous
  - All contacts are equally likely to spread the infection

Information as Illness

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- The flow of information through a network can be described as analogous to the spread of a disease (Bailey, 1975)
  - Information flow models can therefore benefit from the research done on infectious diseases
  - Such models have been shown to fit real world data of information diffusion.

@RealWorld #example

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- To illustrate the utility of the analogy, consider the following scenario on Twitter:
  - A susceptible individual (S) is exposed to a bit of information via a friend's tweet
  - That person may be influenced (infected) by the information (I) and reTweet (or discuss with others)
  - Result: The exposure to that information increases and it diffuses throughout the network

Immunity or Death: SIR Models

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- Used to model lethal diseases and those which confer immunity (such as chicken pox).
- Agents are initially ***Susceptible*** (S)
- Exposure to the disease via contact with an infected agent may lead to the agent becoming ***Infected*** (I)
- The disease then runs its course in the agent, who recovers and becomes ***Resistant*** (R)
  - When modeling virulent diseases, state R becomes "Removed"

Spread of Disease

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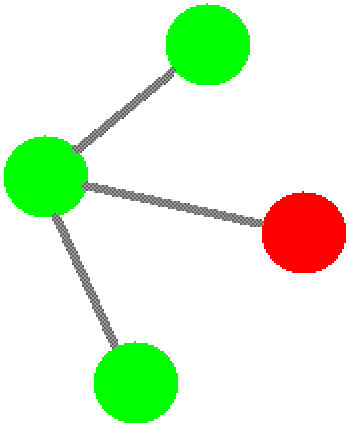
Each time unit:

- Susceptible agents in contact with infected agents may succumb.
- Infected agents may recover (after the incubation period)



- The run ends when the disease dies out
- Generally, some nodes remain infection-free.

What's the story, SIR?

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- When applied to information diffusion, SIR models are used to model the flow of information that is unlikely to change (static) and important (salient), such as:
  - Exposure to a completely new topic
  - Safety Warnings
    - (Before people started checking on Snopes, at least)
  - The spread of rumours

SIR States of Information

- ***Susceptible*** (S) agents have not yet been exposed to the new information
- ***Infected*** (I) agents have received the new information, and are influenced (motivated) enough to share it with neighbours.
- ***Resistant*** (R) agents have either assimilated or rejected the new information, such that:
  - They no longer share the information, and
  - Further exposure to the information has no effect

General Observations

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- With even modest probabilities of transmission, the infection spreads across the majority of the network
- The size of the initial infection has little effect.
- Increasing the time to recovery increases the probability of the whole network being infected
- The behaviour of the model is highly dependant on average node degree
  - Low degree increases the chance that a recovered node will act as a firewall for others
  - High interconnectivity provides multiple paths to infection

Getting sick again: SIS Models

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- Used to model diseases from which people recover and can then again be reinfected, (such as colds and STDs).
- Agents are initially ***Susceptible*** (S)
- Exposure to the disease via contact with an infected agent may lead to the agent becoming ***Infected*** (I)
- The disease then runs its course in the agent, who recovers and returns to the ***Susceptible*** (S) state

What's the Story, SIS?

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- SIS models are applied to different areas of information diffusion, such as:
  - Emotionally Charged Information
    - Resulting in panic, for instance
  - Changing Information
    - Nodes become susceptible when the information has changed sufficiently
  - False Information which can be disproved
    - Such as the Swift Boat Messaging in the 2004 Presidential Election

SIR/SIS Limitations

- A few limitations of these models…
  - Agent Heterogeneity
    - Agents are identical, without individual differences in resiliency or behaviour in the face of infection
  - Simplistic Networks
    - All contact is treated equal, without regard to degree of contact (or trust, in the case of information)
  - Single Infection/Information
    - Model shows the flow of a single event (bit of information): useful for disease, less so for info

Extensions: SIRS Models

- SIRS models are extensions of SIS models in which infected agents ***may*** develop an immunity
  - Most Infected agents return to ***Susceptible*** (S)
  - Some agents, however, build an immunity and become ***Resistant*** (R)
  - When dealing with information diffusion, these models are used in similar ways to SIS models, with agents gaining resistance to the false or emotionally charged information

Extensions: Fading Resistance

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- An alternate form of SIRS model, in which agents become ***Resistant*** (R) after infection
  - Over time, however, the Resistance fades, and agents return to ***Susceptible*** (S)
  - In cases of information diffusion, agents which have assimilated (or rejected) information are able to resist further exposure to that information for a time
    - The constant pressure of the information eventually succeeds (or causes them to doubt their counter-information)

Extensions: SIR Mutation

- Agents are immune to strains of diseases like those they've previously recovered from.
- The disease mutates with each attempted transmission
  - Such models generate periods of outbreaks, followed by periods of relative calm (eg – the flu)
  - Used to model the spread of dynamic information
    - Agents ignore additional information similar to what they have already heard, but react to new information

Derivative: Panic Spread

- This model shows how the spread of distorted information in a social network leads to panic
  - Agents each have a local copy of information, which they may share at each time slice with a single neighbour
  - The information may be distorted in the sending (probability increases with distance)
  - Sufficiently distorted information generates "concern", which fades over time

Panic Spread Model (2)

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- When concern exceeds a threshold, the agent panics:
  - Panicked agents shout out their most recent information to each of their neighbours
  - If the agent remains panicked, it will continue to shout periodically (the frequency is a parameter)
  - Panicked agents still process information from other agents, which may further increase their concern

Panic Model: Observations

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- The resulting behaviour varies with the parameters. Some interesting features (beyond the obvious):
  - When the average degree remains relatively low, generally, the result is segments of the network which are resistant (if not immune) to panic.
  - In some cases, panic spreads across the network, but most of the network returns to a calm state.
  - The model can enter quasi-equilibrium states, where panic oscillates only across certain areas

The Future of Panic

- Replace the bitstring with a value; use Gaussian noise instead of mutation
- Give agents *expected* value
  - Concern is generated based on how much the shared information differs from the agent expectation
  - Expected values are modified as additional input is received
    - Boiled frog effect?

Thank you!

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