A confusion of contagions:

- Is Harry Potter some kind of virus?
- What about the Da Vinci Code?
- Does Sudoku spread like a disease?
- Religion?
- Democracy...?

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**Contagion**

**Naturomorphisms**

- “The feeling was contagious.”
- “The news spread like wildfire.”
- “Freedom is the most contagious virus known to man.”
  — Hubert H. Humphrey, Johnson’s vice president
- “Nothing is so contagious as enthusiasm.”
  — Samuel Taylor Coleridge

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**Social contagion**

Optimism according to Ambrose Bierce: (￼)

The doctrine that everything is beautiful, including what is ugly, everything good, especially the bad, and everything right that is wrong: ... it is hereditary, but fortunately not contagious.

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**Social contagion**

Eric Hoffer, 1902–1983

There is a grandeur in the uniformity of the mass. When a fashion, a dance, a song, a slogan or a joke sweeps like wildfire from one end of the continent to the other, and a hundred million people roar with laughter, sway their bodies in unison, hum one song or break forth in anger and denunciation, there is the overpowering feeling that in this country we have come nearer the brotherhood of man than ever before.

- Hoffer (￼) was an interesting fellow...
The spread of fanaticism


Quotes-abundance:
➤ "We can be absolutely certain only about things we do not understand."
➤ “Mass movements can rise and spread without belief in a God, but never without belief in a devil."
➤ “Where freedom is real, equality is the passion of the masses. Where equality is real, freedom is the passion of a small minority.”

Imitation

“When people are free to do as they please, they usually imitate each other.”
—Eric Hoffer

“Never Underestimate the Power of Stupid People in Large Groups.”

The collective...

Contagion

Definitions
➤ (1) The spreading of a quality or quantity between individuals in a population.
➤ (2) A disease itself: the plague, a blight, the dreaded lurgi, ...
➤ from Latin: con = 'together with' + tangere 'to touch.'
➤ Contagion has unpleasant overtones...
➤ Just Spreading might be a more neutral word
➤ But contagion is kind of exciting...

Examples of non-disease spreading:

Interesting infections:
➤ Spreading of buildings in the US. (33)
➤ Viral get-out-the-vote video. (33)

Contagions

Two main classes of contagion
1. Infectious diseases: tuberculosis, HIV, ebola, SARS, influenza, ...
2. Social contagion: fashion, word usage, rumors, riots, religion, ...
The standard SIR model \[^8\] is the basic model of disease contagion.

**Three states:**
1. \( S \) = Susceptible
2. \( I \) = Infective/Infectious
3. \( R \) = Recovered or Removed or Refractory

\( S(t) + I(t) + R(t) = 1 \)

Presumes random interactions (mass-action principle)
- Interactions are independent (no memory)
- Discrete and continuous time versions

**Example:**
- Discrete time automata example:
  - Transition Probabilities:
    - \( \beta \) for being infected given contact with infected
    - \( r \) for recovery
    - \( \rho \) for loss of immunity

**Original models attributed to**
- 1920's: Reed and Frost
- 1920's/1930's: Kermack and McKendrick \[^5, 7, 6\]

**Coupled differential equations with a mass-action principle**

\[
\frac{d}{dt} S = -\beta IS + \rho R \\
\frac{d}{dt} I = \beta IS - rI \\
\frac{d}{dt} R = rI - \rho R
\]

\( \beta, r, \) and \( \rho \) are now rates.

**Reproduction Number \( R_0 \):**
- \( R_0 = \) expected number of infected individuals resulting from a single initial infective
- \( \beta > 1 \) is epidemic threshold: If \( R_0 > 1 \), 'epidemic' occurs.

**Mathematical Epidemiology**

**Discrete time automata example:**

**Independent Interaction models**

**Differential equations for continuous model**

\[
\frac{d}{dt} S = -\beta IS + \rho R \\
\frac{d}{dt} I = \beta IS - rI \\
\frac{d}{dt} R = rI - \rho R
\]

**Reproduction Number \( R_0 \):**
- **Discrete version:**
  - Set up: One Infective in a randomly mixing population of Susceptibles
  - At time \( t = 0 \), single infective random bumps into a Susceptible
  - Probability of transmission = \( \beta \)
  - At time \( t = 1 \), single Infective remains infected with probability \( 1 - r \)
  - At time \( t = k \), single Infective remains infected with probability \( (1 - r)^k \)

**Original models attributed to**
- 1920's: Reed and Frost
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**Coupled differential equations with a mass-action principle**

\[
R_0 = \beta + (1 - r)\beta + (1 - r)^2\beta + (1 - r)^3\beta + \ldots
\]

\[
= \beta \left( \frac{1}{1 - (1 - r)} \right) = \beta / r
\]

For \( S_0 \) initial infectives \( (1 - S_0) = R_0 \) immune:

\[
R_0 = S_0 \beta / r
\]
Independent Interaction models

For the continuous version

Second equation:

\[
\frac{dI}{dt} = \beta SI - rI = (\beta S - r)I
\]

- Number of infectives grows initially if

\[
\beta S(0) - r > 0 \implies \beta S(0) > r \implies \beta S(0)/r > 1
\]

- Same story as for discrete model.

Independent Interaction models

Example of epidemic threshold:

\[
\text{Fraction infected}
\]

\[
R_0
\]

- Continuous phase transition.
- Fine idea from a simple model.

Disease spreading models

For novel diseases:

1. Can we predict the size of an epidemic?
2. How important is the reproduction number $R_0$?

$R_0$ and variation in epidemic sizes

$R_0$ approximately same for all of the following:

- 1918-19 “Spanish Flu” ~ 500,000 deaths in US
- 1957-58 “Asian Flu” ~ 70,000 deaths in US
- 1968-69 “Hong Kong Flu” ~ 34,000 deaths in US
- 2003 “SARS Epidemic” ~ 800 deaths world-wide

Size distributions

Size distributions are important elsewhere:

- earthquakes (Gutenberg-Richter law)
- city sizes, forest fires, war fatalities
- wealth distributions
- ‘popularity’ (books, music, websites, ideas)
- Epidemics?

Power laws distributions are common but not obligatory...
Really, what about epidemics?

- Simply hasn’t attracted much attention.
- Data not as clean as for other phenomena.

Feeling Ill in Iceland

Caseload recorded monthly for range of diseases in Iceland, 1888-1990

- Treat outbreaks separated in time as ‘novel’ diseases.

Power law distributions

Measured values of $\gamma$:

- measles: 1.40 (low $\psi$) and 1.13 (high $\psi$)
- pertussis: 1.39 (low $\psi$) and 1.16 (high $\psi$)

- Expect $2 \leq \gamma < 3$ (finite mean, infinite variance)
- When $\gamma < 1$, can’t normalize
- Distribution is quite flat.

Resurgence—example of SARS

- Epidemic slows... then an infective moves to a new context.
- Epidemic discovers new ‘pools’ of susceptibles: Resurgence.
- Importance of rare, stochastic events.
The challenge

So... can a simple model produce

1. broad epidemic distributions and
2. resurgence?

Size distributions

Simple models typically produce bimodal or unimodal size distributions.

This includes network models: random, small-world, scale-free, ...

Exceptions:
1. Forest fire models
2. Sophisticated metapopulation models

Sophisticated metapopulation models

- Community based mixing: Longini (two scales).
- Eubank et al.’s EpiSims/TRANSIMS—city simulations.
- Spreading through countries—Airline: Germann et al., Corlizza et al.
- Vital work but perhaps hard to generalize from...
- ⇒ Create a simple model involving multiscale travel
- Multiscale models suggested by others but not formalized (Bailey, Cliff and Haggett, Ferguson et al.)

Burning through the population

Forest fire models: [9]
- Rhodes & Anderson, 1996
- The physicist’s approach: “if it works for magnets, it’ll work for people...”

A bit of a stretch:
1. Epidemics ≡ forest fires spreading on 3-d and 5-d lattices.
2. Claim Iceland and Faroe Islands exhibit power law distributions for outbreaks.
3. Original forest fire model not completely understood.
Improving simple models

Contexts and Identities—Bipartite networks

- boards of directors
- movies
- transportation modes (subway)

Idea for social networks: incorporate identity.

Identity is formed from attributes such as:

- Geographic location
- Type of employment
- Age
- Recreational activities

Groups are crucial...

- formed by people with at least one similar attribute
- Attributes ⇔ Contexts ⇔ Interactions ⇔ Networks. [11]

Infer interactions/network from identities

Distance makes sense in identity/context space.

Generalized context space

(Blau & Schwartz [1], Simmel [10], Breiger [2])

A toy agent-based model

Geography—allow people to move between contexts:

- Locally: standard SIR model with random mixing
- discrete time simulation
- $\beta =$ infection probability
- $\gamma =$ recovery probability
- $P =$ probability of travel
- Movement distance: $Pr(d) \propto \exp(-d/\xi)$
- $\xi =$ typical travel distance

A toy agent-based model

Schematic:
- Define $P_0 = $ Expected number of infected individuals leaving initially infected context.
- Need $P_0 \geq 1$ for disease to spread (independent of $R_0$).
- Limit epidemic size by restricting frequency of travel and/or range.

### Example model output: size distributions

- Flat distributions are possible for certain $\xi$ and $P_0$.
- Different $R_0$’s may produce similar distributions.
- Same epidemic sizes may arise from different $R_0$’s.

### Model output—resurgence

**Standard model:**

- Transition in expected final size based on typical movement distance (sensible).

**Standard model with transport:**

- Transition in expected final size based on typical number of infectives leaving first group (also sensible).
- Travel advisories: $\xi$ has larger effect than $P_0$.
Conclusions

What to do:
- Need to separate movement from disease
- \( R_0 \) needs a friend or two.
- Need \( R_0 > 1 \) and \( P_0 > 1 \) and \( \xi \) sufficiently large for disease to have a chance of spreading

More wondering:
- Exactly how important are rare events in disease spreading?
- Again, what is \( N \)?

Predicting social catastrophe isn’t easy...

“Greenspan Concedes Error on Regulation”
- ... humbled Mr. Greenspan admitted that he had put too much faith in the self-correcting power of free markets . . .
- “Those of us who have looked to the self-interest of lending institutions to protect shareholders’ equity, myself included, are in a state of shocked disbelief”
- Rep. Henry A. Waxman: “Do you feel that your ideology pushed you to make decisions that you wish you had not made?”
- Mr. Greenspan conceded: “Yes, I’ve found a flaw. I don’t know how significant or permanent it is. But I’ve been very distressed by that fact.”

New York Times, October 23, 2008 (¶)
Economics, Schmeconomics

Alan Greenspan (September 18, 2007):

“I’ve been dealing with these big mathematical models of forecasting the economy...

If I could figure out a way to determine whether or not people are more fearful or changing to more euphoric,

I don’t need any of this other stuff.

I could forecast the economy better than any way I know.”

Jon Stewart:

“You just bummed the @*!# out of me.”

References


References II


References III


