Module 1

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Topics

- Introduction to Computational Social Systems (CSS)

Introduction to Computational Social Systems

Agenda

- What is Social Systems?
- What is computational Social Systems
- What are the problems/research areas?
- What is Social Network Analysis?

“System”

- System: a group of interacting, interdependent components that form a complex whole.[Montuori 2011]
  - System is a concept
  - Components can be natural or human-made
  - functional relationship between components
- Boundaries: barriers that define a system and distinguish it from other systems in an environment.
- Examples
  - Natural system – human body, solar system
  - Man made systems – automobile, microprocessor
  - Organized system – social systems
- Overall behavior may be more the sum of parts (emergent behavior)

System cont.

- Examples of System Theories:
  - Complex system
  - Chaos theory
  - Control theory
  - Dynamical systems theory
  - ..
  - …

What is a social system?

Social System

- Social system is “the patterned network of relationships constituting a coherent whole that exist between individuals, groups, and institutions.” (Merriam-Webster)
    - Orderly and systematic arrangement of social interactions
- All social organizations are social systems
- Individuals/groups interact with each other
    - Guided by cultural factors, norms and practices
- In social systems
    - Individuals may have specialized function/role

What are the characteristics of a social system?

Characteristics of a Social System

- Social system is based on the interactions of individuals and groups
- Interaction must carry meaning.
- Social system is a unit with various components such as institutions, customs, traditions, laws etc.
- Social system is related with cultural system.
- Environment has an impact over the social system

What are the elements of a social system?

Elements of Social System

- Belief and Knowledge
  - Common belief drive coordinated action by individuals
- Sentiment
  - “What we feel”
  - Various types: e.g. intellectual, ethical and religious
- Goal or objective
  - Accomplishing a particular end through appropriate interactions
  - E.g. basic necessities such as food, clothing etc.
- Norms
  - Standards for “right” or “wrong”
  - Changes over time
  - Varies among social system

Elements of Social System cont.

- Status and role:
  - Status or position may be ascribed (conferred by society) or achieved (by individual effort)
- Rank or Standing
  - Relative importance in a social system
- Power
  - Capacity to control others.
- Sanction
  - Rewards and penalties given out for inducing conformity
- Facility
  - Mean to achieve ends within a system

Computational Social System

- Modeling, simulation, analysis, and understanding of social systems from the analytic, quantitative, and/or computational perspectives.
  - Social Systems can include man–man, man–machine, and machine–machine organizations in both cooperative and adversarial situations.

Challenges of Computational Social Systems

- Individual and group behaviors are hard to predict
  - Focus on explainability
- Cross-disciplinary
- New field – theories and methodologies are emerging
- Validation is challenging
  - large-scale systems cannot be reproduced in a traditional lab setting
  - In silica simulations are more prevalent
- Security and privacy concerns
  - Models are mostly data driven

Interdisciplinary Science

- Computer Science
  - Human-Computer Interaction (HCI)
  - Network Modeling and Simulation
  - Machine Learning
  - Parallel and Distributed computing
  - …..
- Social Science
  - Psychology
  - Economics
  - Anthropology
  - …..
- Mathematics
- Physics
- Statistics

Flood of Online Social information

- Lots of behavioral information!
  - Twitter: 500 million tweets per day[1], 330 million monthly active users[2]
  - Facebook: 2.7 billion monthly active users [3]
  - Whatsapp: > 2 billion monthly active users [4]
- Lots of real time behavioral information!!
- How is social information different from other information?

[1]http://www.internetlivestats.com/twitter-statistics/
[2]http://www.statista.com/statistics/282087/number-of-monthly-active-twitter-users/
[3]http://www.statista.com/statistics/264810/number-of-monthly-active-facebook-users-worldwide/
[4] http://www.statista.com/statistics/260819/number-of-monthly-active-whatsapp-users/

Other Emerging Areas

- Social Computing
- Computational social science
- Socio-technical networks
- Social simulation
- ……

Social Computing

- "Social Computing refers to systems that support the gathering, representation, processing, use, and dissemination of information that is distributed across social collectivities….”[1]

- “Use of computational devices to facilitate or augment the social interactions of their users, or to evaluate those interactions in an effort to obtain new information.“[2]

[1]"Social Computing", Introduction to Social Computing special edition of the Communications of the ACM, edited by Douglas Schuler, Volume 37 , Issue 1 (January 1994), Pages: 28 – 108
[2] *Social Computing* in Encyclopedia of Information Science and Technology, Third Edition. IGI Global, 2014, p. 6754.

Selected Research Areas in Social Computing

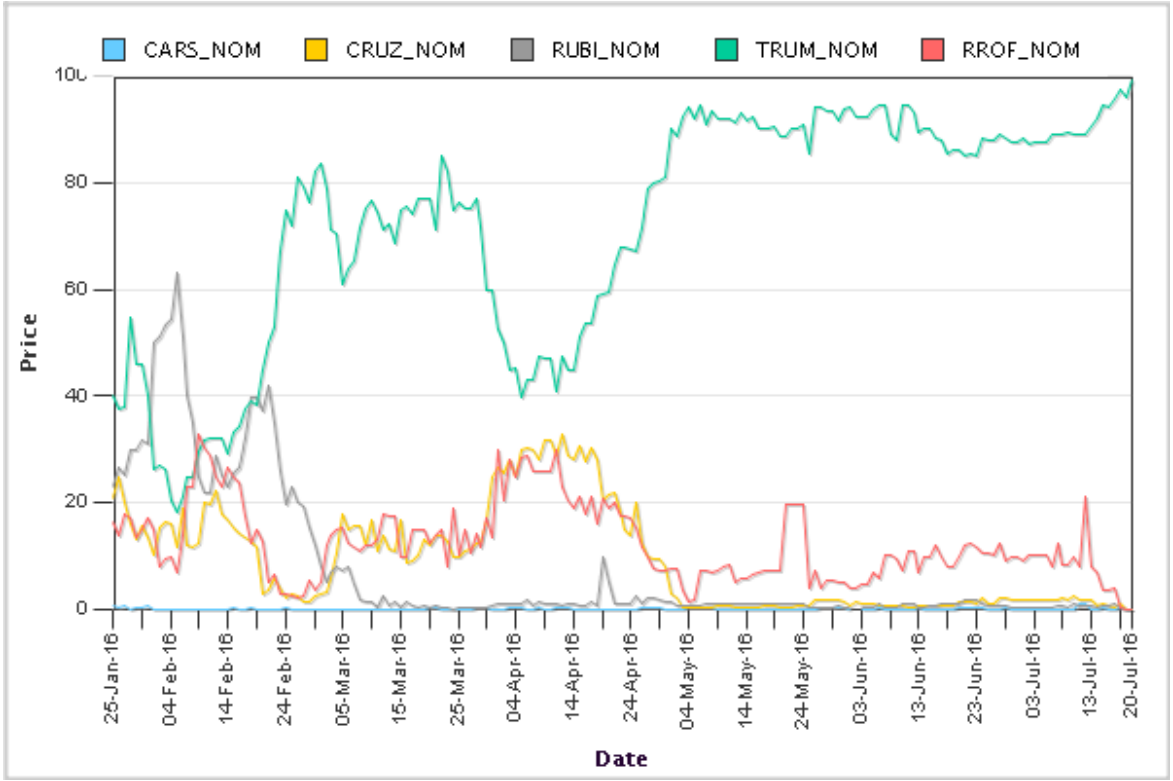
- Social media analysis
- Social network models
- Complex networks
- Prediction markets/crowd sourcing
- Human computation
- ……

Social Media Analysis

- Utilize online information from blogs, Facebook likes, tweets, Instagram, etc.
- Numerous applications
  - Product popularity
  - Political leanings
  - Detect service degradation and outages
  - “Find the Red Balloons” – DARPA Network Challenge https://www.darpa.mil/about-us/timeline/network-challenge

Prediction Markets

- Utilize humans within a futures market framework
  - Don’t have to use experts
- Helps to aggregate information and provide prediction of event outcomes.
- Exchanges
  - Hollywood Stock Exchange (HXS), http://www.hsx.com/
  - Iowa Electronic Markets (IEM) https://tippie.biz.uiowa.edu/iem/



2016 Republican Presidential Nomination

Source: Iowa Electronic Markets (IEM) https://tippie.biz.uiowa.edu/iem/

Human Computation

- “…a paradigm for utilizing human processing power to solve problems that computers cannot yet solve.”*

*von Ahn, L. Human Computation. Doctoral Thesis. UMI Order Number: AAI3205378, CMU, (2005)

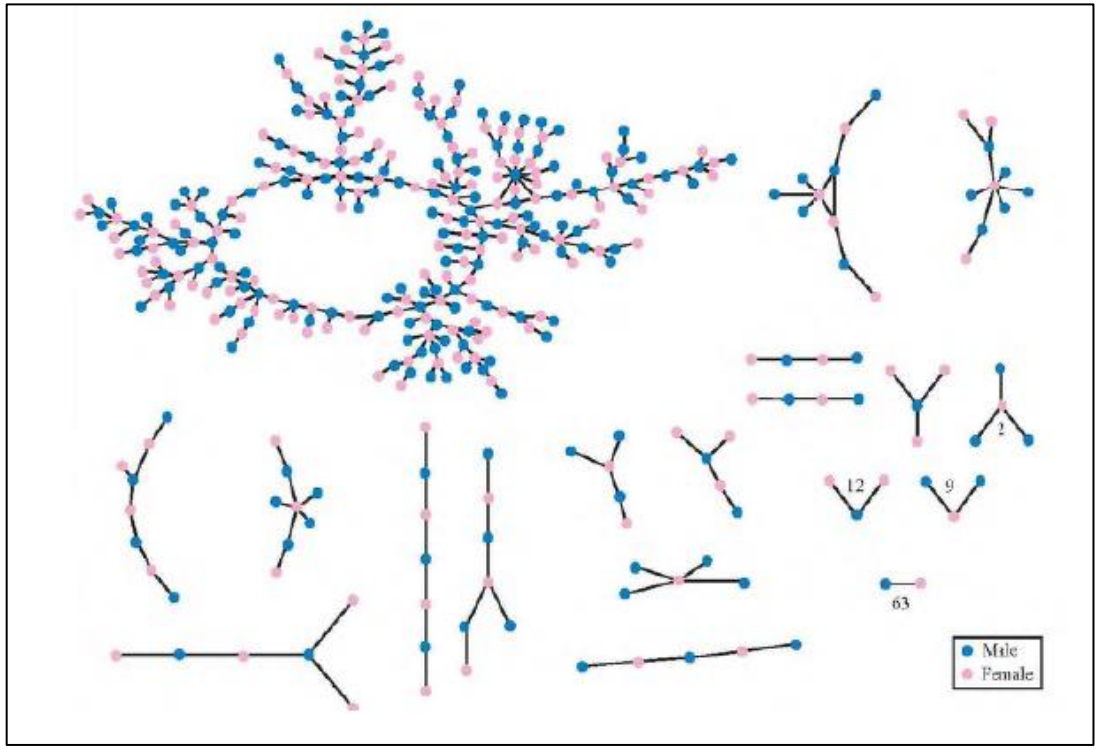
CAPTCHA ("Completely Automated Public Turing test to tell Computers andHumans Apart")
Source: Wikipedia

Social Structure

- Many different definitions:
  - Arrangement of social relationships and interactions that restricts/supports/directs social behaviors
- Particular arrangement of inter-related components of the system as well as their statuses and roles.
- Social structure are based on:
  - Normative system
  - Position system
  - Sanction system

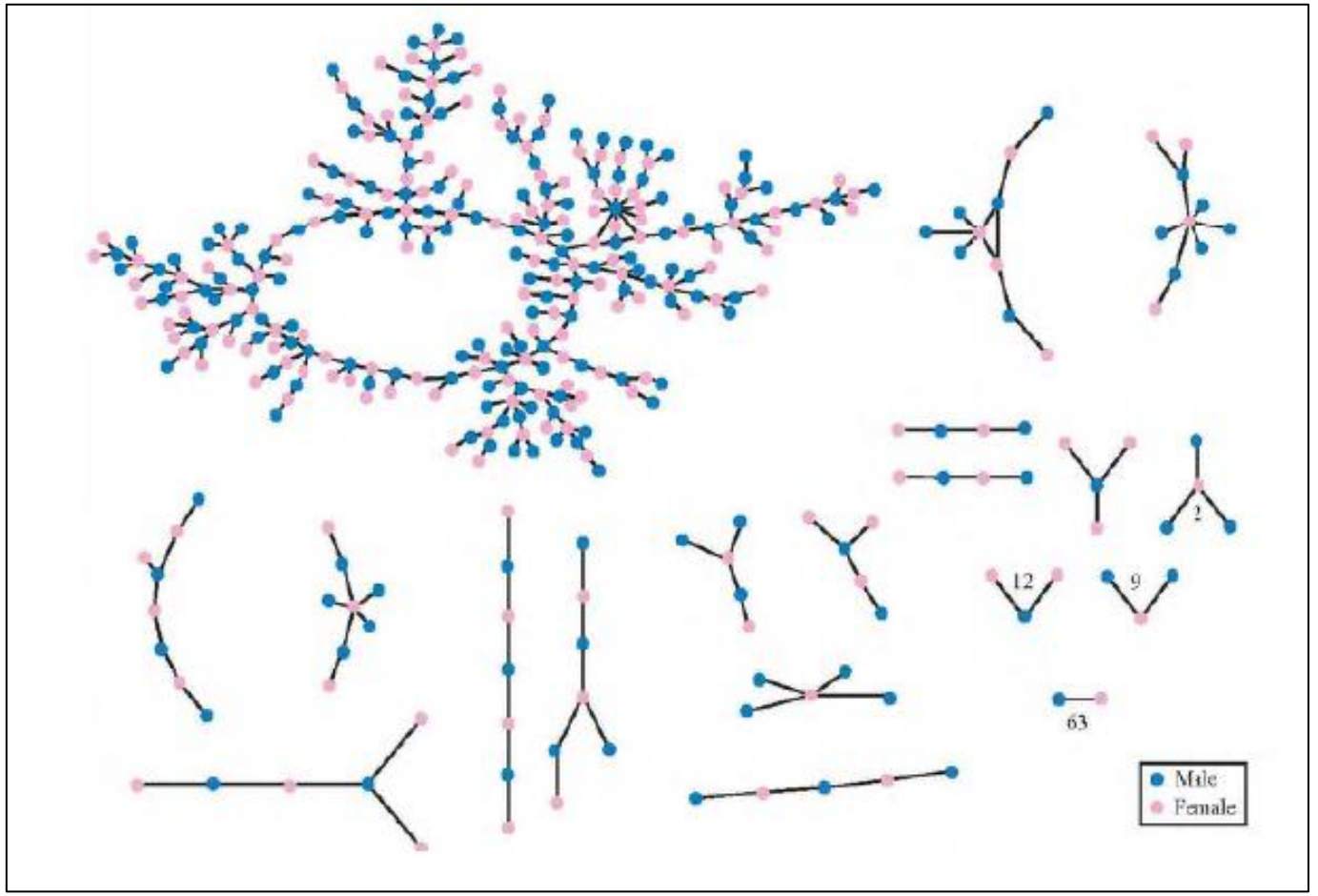
Social network models

- Several question crop up when analyzing social information
  - Who is the most influential person in the social group?
  - How popular can an idea or sentiment become?
  - How stable is the social group?
- Structure can provide clues
- Represent social information as a network of actors and their relationships



Source: Bearman, Peter S., James Moody, and Katherine Stovel. "Chains of affection: The structure of adolescent romantic and sexual networks," American journal of sociology 110.1 (2004): 44-91.

What insights can you get from this Social Networks?



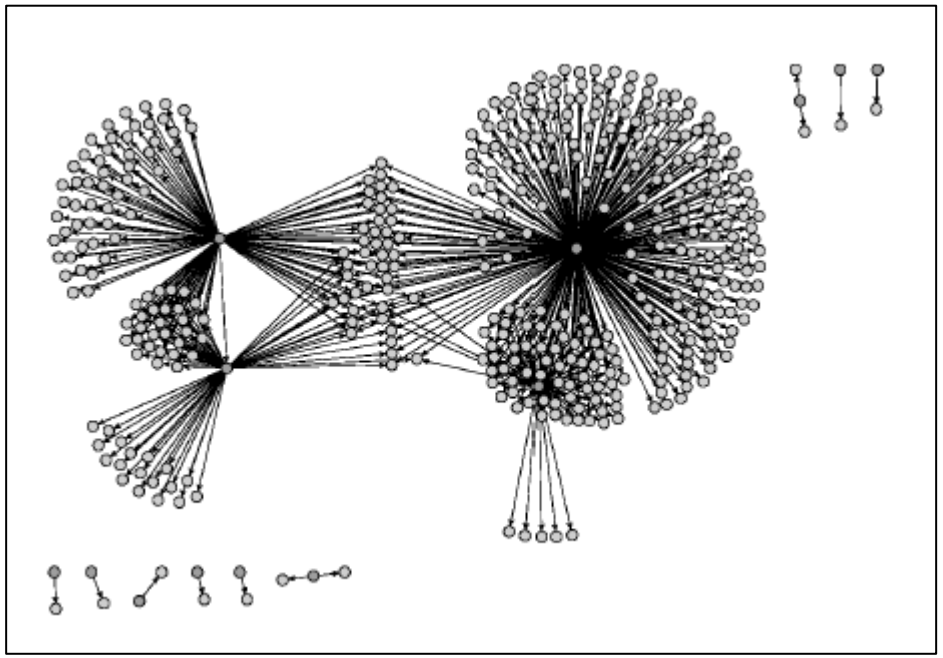
Social network models cont.

- Apply graph theory concept and algorithm to analyze data
- Helps visualize the data
- Social network Analysis – a set of algorithms and metrics to help analyze and quantify

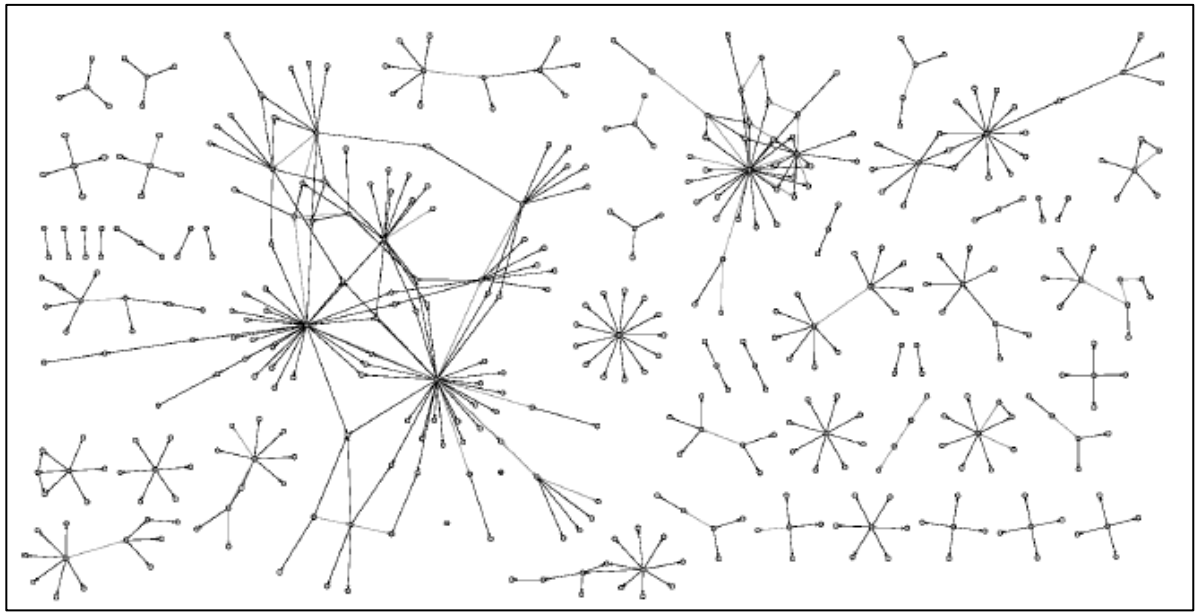
Our Specific Focus

- Social Network based representation, modeling, simulation and analysis
- Dealing with Big Data issues of volume and velocity
  - Utilize parallel/distributed algorithm designs
  - Utilize parallel/distributed computing platforms such as Hadoop and Spark
- Map concepts and theories from the social sciences to social network models and metrics
- Application domain: epidemiology
- Agent Based modeling techniques (if time permits)

Viral Marketing



Recommendation network for Japanese graphic novel "Oh My Goddess!: Mara Strikes Back."

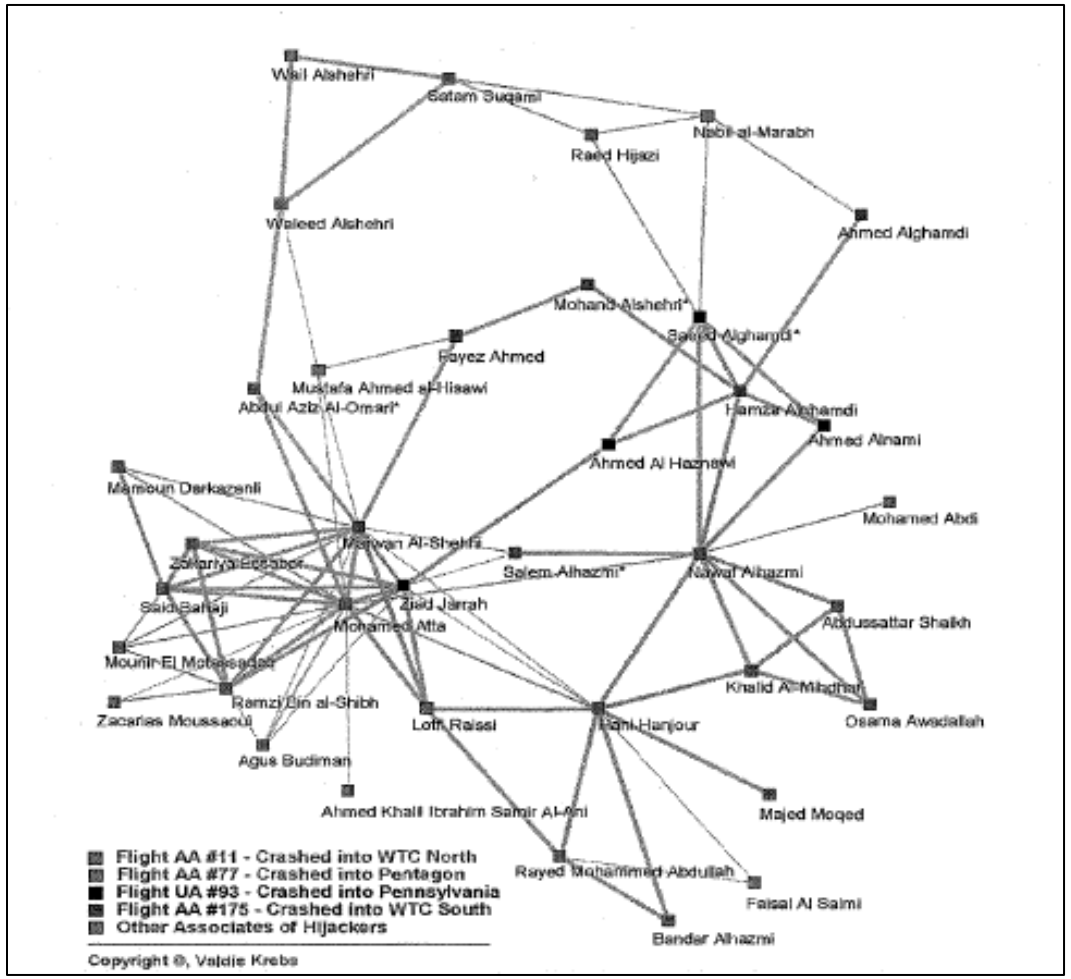


Recommendation network for "First Aid for the USMLE Step"

Source: Jure Leskovec, Lada A. Adamic, and Bernardo A. Huberman. 2007. The dynamics of viral marketing. *ACM Trans. Web* 1, 1, Article 5 (May 2007)

Challenge: Volume and velocity!!

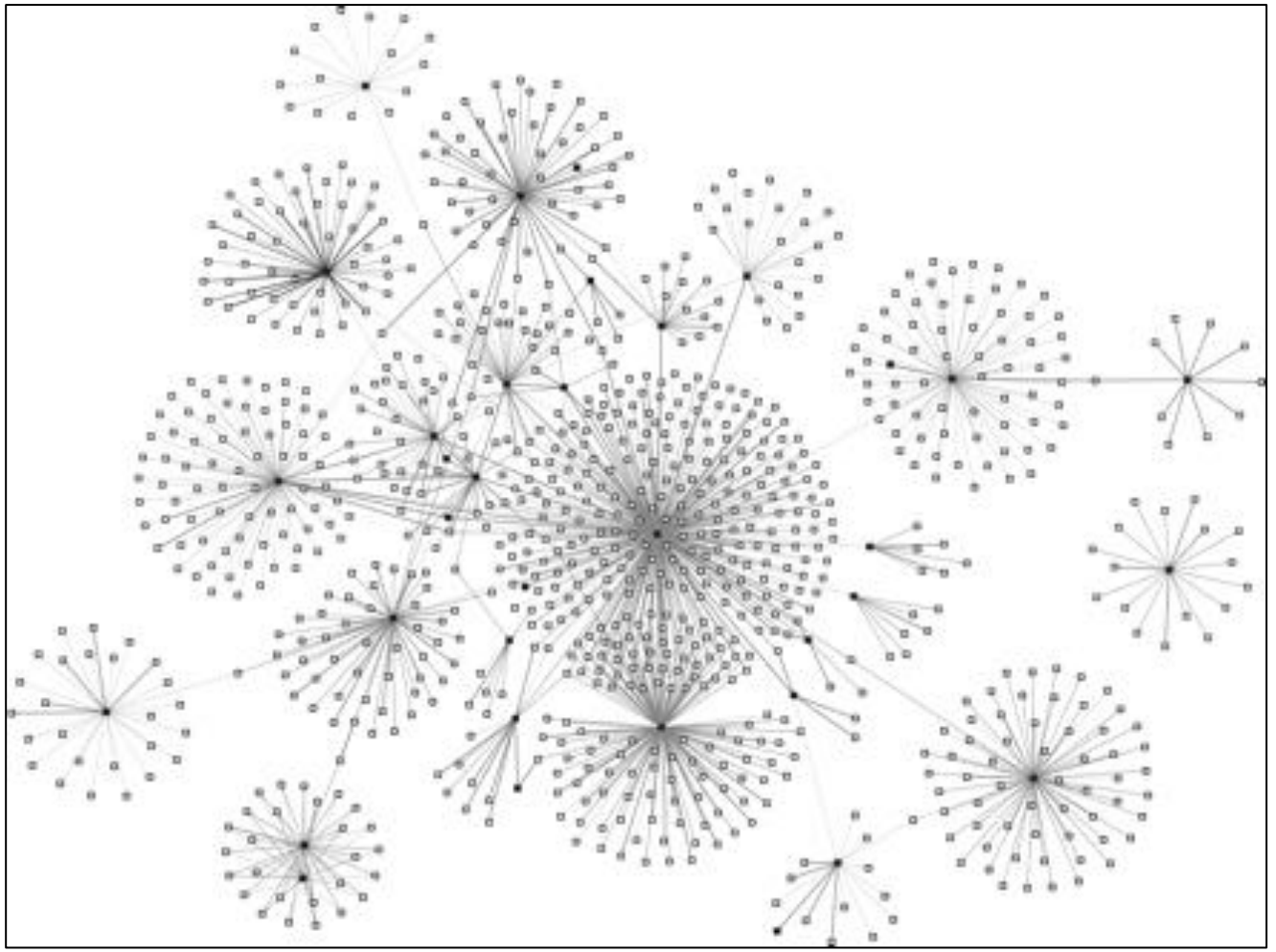
Terror Networks: 9/11 Hijackers



Challenge: Incomplete data

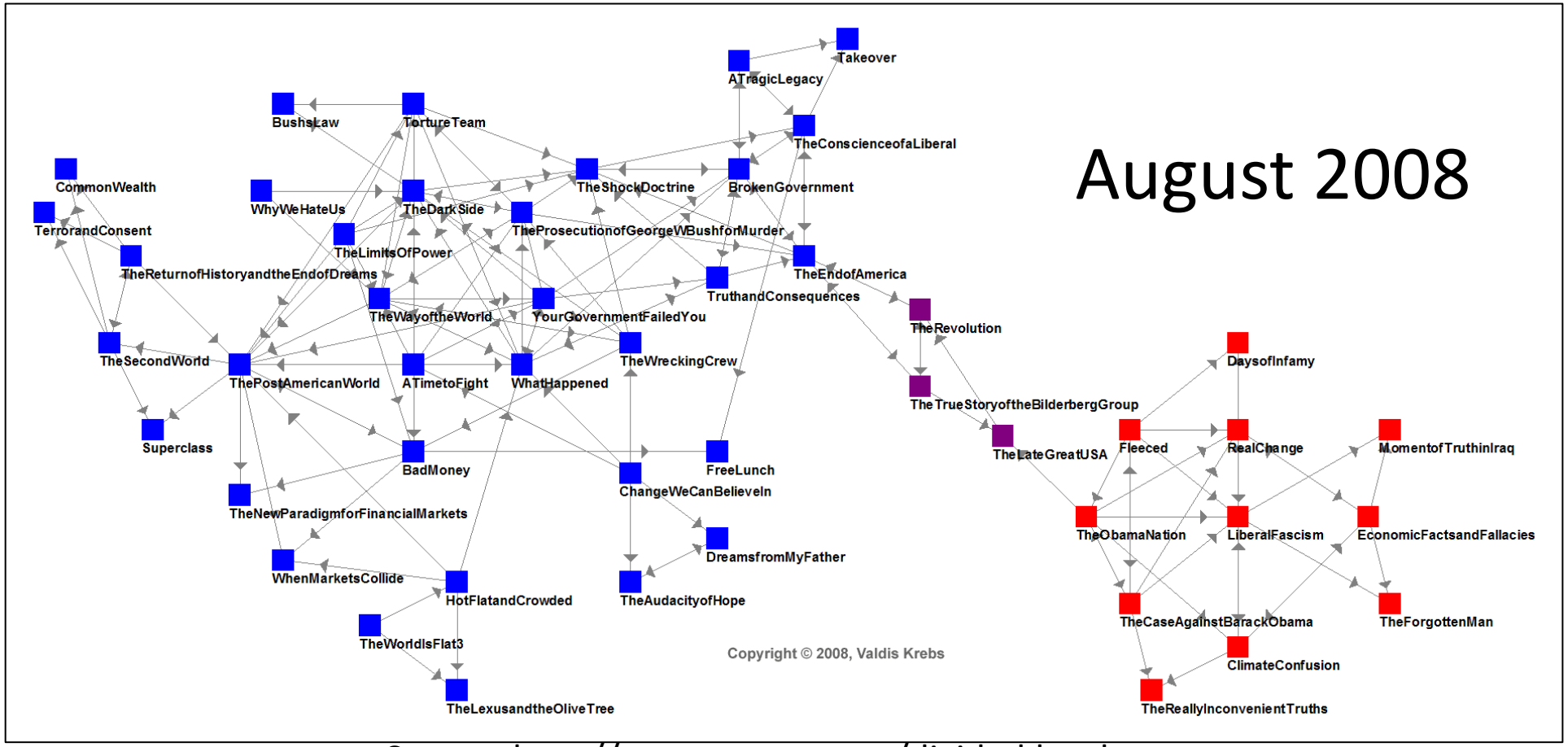
Source: Krebs, Valdis E. "Mapping networks of terrorist cells." Connections 24.3 (2002): 43-52.

Social Grouping



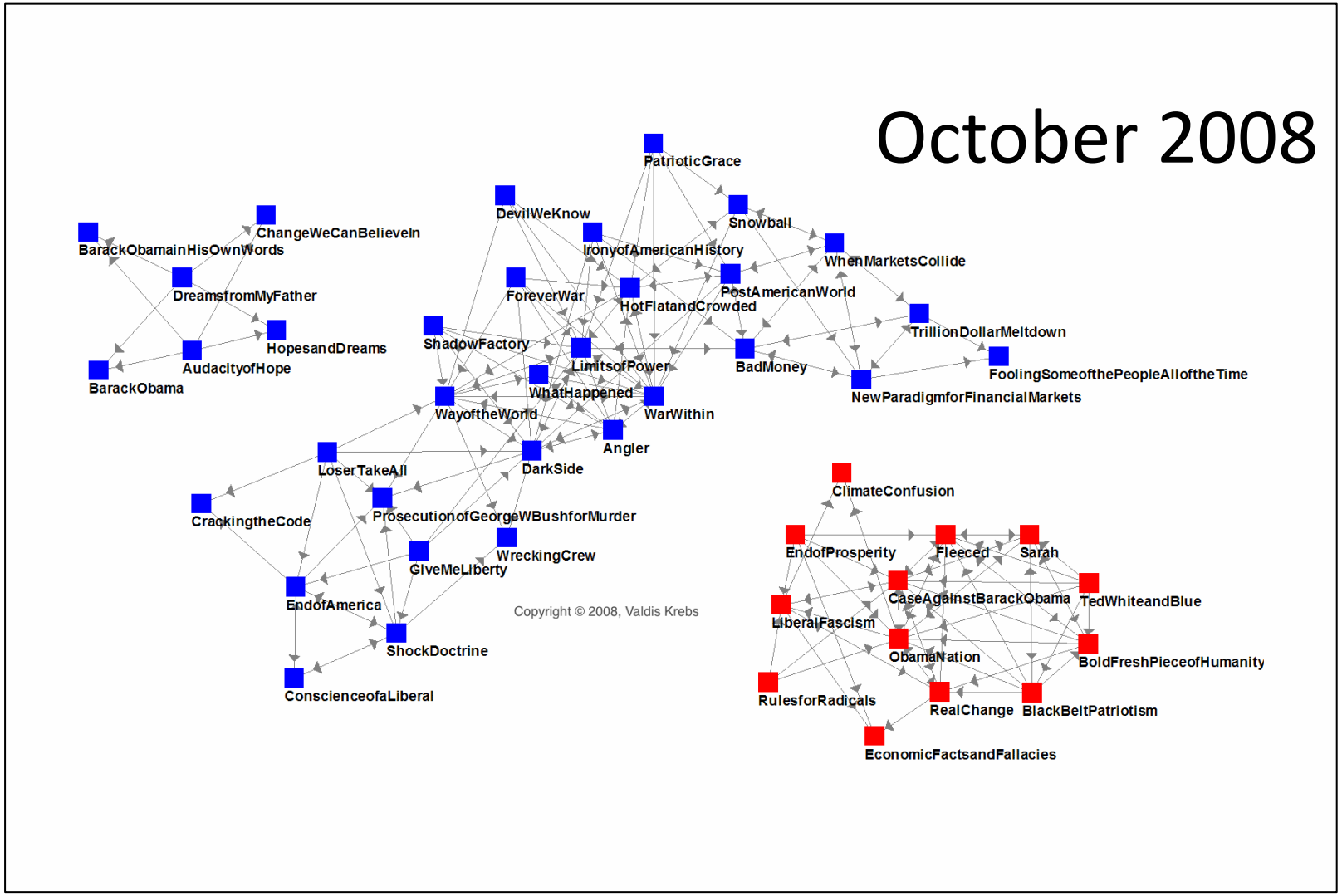
Source: Andre M, Ijaz K, Tillinghast JD, et al. Transmission Network Analysis to Complement Routine Tuberculosis Contact Investigations. American Journal of Public Health. 2007;97(3):470-477.

Book Purchase and Political Leaning



Source: http://www.orgnet.com/divided.html

Book Purchase Network cont.



Source: http://www.orgnet.com/divided.html

Complex Systems

The Army Ant – Simple or Complicated or Something else

- Half a million army ants in a colony
- No one is in charge of this army; it has no commander.
- Each individual ant is nearly blind and minimally intelligent
- Swarms over, kills, and efficiently devours all prey in its path.
- In a day, destroys the edible life the size of a football field
- In the night, the ants build a chain-mail ball a yard across made up of the workers' linked bodies, sheltering the young larvae and mother queen at the center.
- When dawn arrives, the routine continues

Complex System

- Complex: (Latin = with + fold/weave (com + plex))
- Made up of multiple parts; intricate or detailed.
- Not simple or straightforward.
- Simple systems: An oscillator, a pendulum, a spinning wheel, an orbiting planet
- Complicated systems: Mechanical watches, airplanes, ...

Complexity vs. Complicated

- A car is not complex, just complicated. – Cars do exhibit “unwanted functionality”
- Complicated Systems: Often difficult to describe but succumb to divide-and-conquer (reductionist) approaches.
- Complicated is easier to cope with than complex – Seth Bullock – Numerous techniques to resolve complicated systems – As a last resort, use brute force/trial and error

Complex System cont.

- “Complexity science is not a single theory: it encompasses more than one theoretical framework and is highly interdisciplinary, seeking the answers to some fundamental questions about living, adaptable, changeable systems.” [Wikipedia]
- “... there is no universally accepted definition of a complex system ... most researchers would describe a system of connected agents that exhibits an emergent global behavior not imposed by a central controller, but resulting from the interactions between the agents.” Nino Boccara in *Modeling Complex Systems*
- “...complexity theory seeks to understand how order and stability arise from the interactions of many components according to a few simple rules.” Philip Ball in Critical Mass

Complex System - Definition

- Distributed system of many interrelated (possibly networked) parts with no centralized control exhibiting emergent behavior
- Complex systems exhibit these key characteristics:
  - Non-linearity
  - Emergence
  - Self-organization
- Complexity ensues by system adapting to its environment

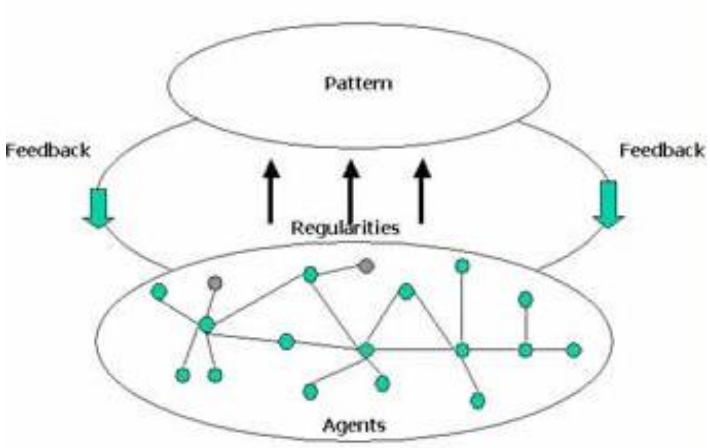
Why Define Complexity?

- To estimate how long a particular system will take (e.g. to solve a problem)
- To understand the limits of prediction, approximation, and simulation
- To answer fundamental scientific questions
  - E.g. Does complexity increase through evolution – biological or otherwise?
- Can we quantify the increase in complexity over time?

Complex Systems

A *complex system* is any system:

- That involves a (large) number of elements, arranged in structure(s) which can exist on many scales
- These elements interact locally
- Structures go through a process of change not describable by a single rule or reducible to a single level of explanation
- Features emerge that cannot be predicted from the current description of the structure(s)



Examples of Complex Systems

- human societies
- financial systems
- cells
- ant colonies
- weather systems
- ecosystems
- animal societies
- disease ecologies
- brains
- social insects
- geophysical systems
- the world wide web

- i.e., everything that's interesting...

What are Complex Systems?

- **At their lowest level, they are comprised of a set of individual *agents (a general term!)***
  - Agents are *heterogeneous*, differing in important characteristics.
  - Agents are *indivisible*
  - Agents are/may be *organized* into some sort of group or hierarchy, which is/ may be structured. These organizational structures in turn influence system dynamics.
- **The system is *dynamic* – it changes over time:**
  - The agents interact, adapt and undergo natural selection in response to their own environment. The system dynamics are *non-linear*.
  - Agent change often occurs in response to *feedback* from their actions.
- **Complex systems may possess the characteristic of *emergence*.**
  - The macro- or system-level behavior that emerges from the activities and behaviors of the component parts of the system, but which cannot be explained at the agent level alone.
  - It's usually the system-level behavior that intrigues us.

Computational Social Systems and Complex Systems Problem?

- Most pre-computational social science models are linear:
  - Linearity is based on independence of elements
  - Linearity is a good modeling technique for simple systems
  - The linearity assumption implies that the whole is equal to the sum of its parts!
- We know a lot about:
  - Individuals (through surveys)
  - Aggregated as groups and populations
  - On a domain-specific basis
- We know a lot less about interactions among individuals and groups:
  - How social structures form; how protocols emerge and the interactions in large groups and among subgroups
  - How and why do group structures (and their protocols) change
  - What the content of interaction is: influence, power, imitation, exchange, association

BUT:

- **Social science systems are not simple,….**
- **The whole may be greater (or lesser) than the sum of its parts!!**
- **Modeling the dynamics is (very) hard …**

Complex Systems: Non-Linear Interactions

- For linear systems:
  - a small change to a system's components → a small change at the system level
- For non-linear systems:
  - a small change to a system's components → large/small/no change at the system level

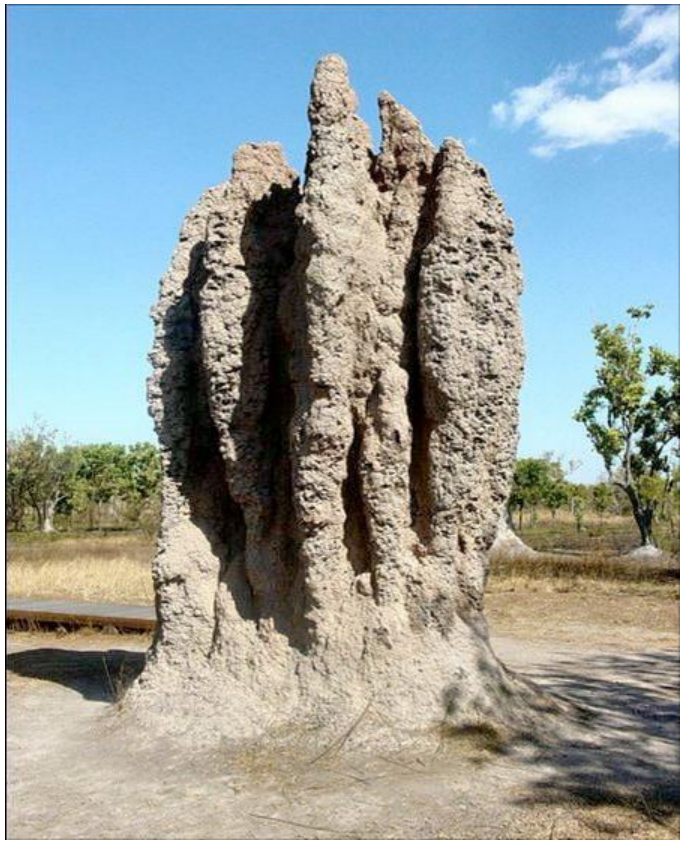
Complex Systems: Emergence

- Emergence: Rather than being planned or controlled the agents in the system interact in apparently random ways.
  - From these interactions patterns emerge which inform the behavior of the agents within the system and the behavior of the system itself.
- Seen in various systems across domains:
  - For example a termite hill is a wondrous piece of architecture with a maze of interconnecting passages, large caverns, ventilation tunnels and much more. Yet there is no grand plan, the hill just emerges as a result of the termites following a few simple local rules.

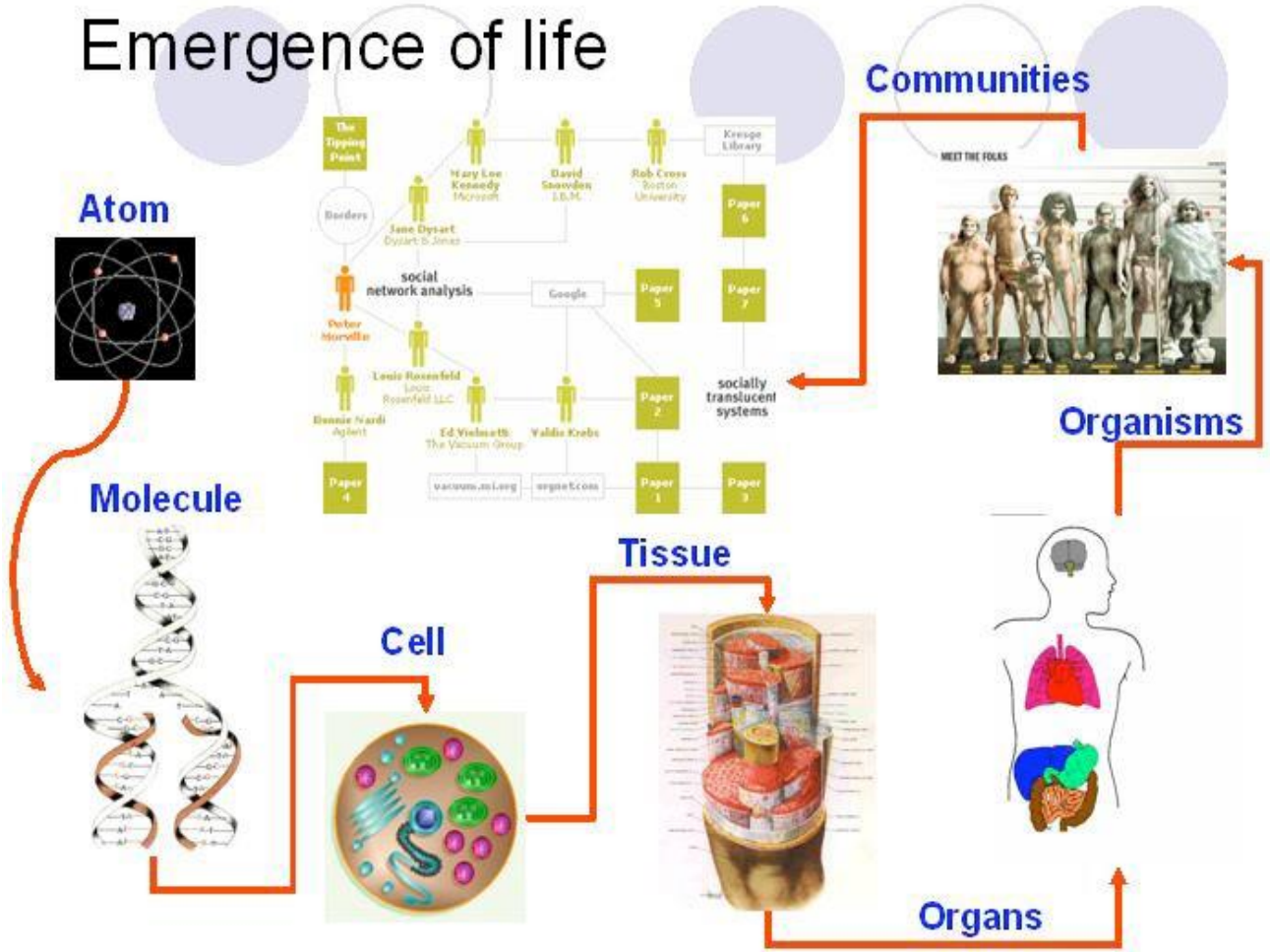
Complex Systems: A Natural Emergent System

- Ant behavior is determined by the local interactions of many ants
- Exemplar of a “superorganism”
- A superorganism is any aggregate of individual organisms that behaves like a unified organism.
- Members of a superorganism have highly specialized social cooperative instincts, divisions of labor, and are unable to survive away from their superorganism for very long.

Termite Ant Cathedral Mound

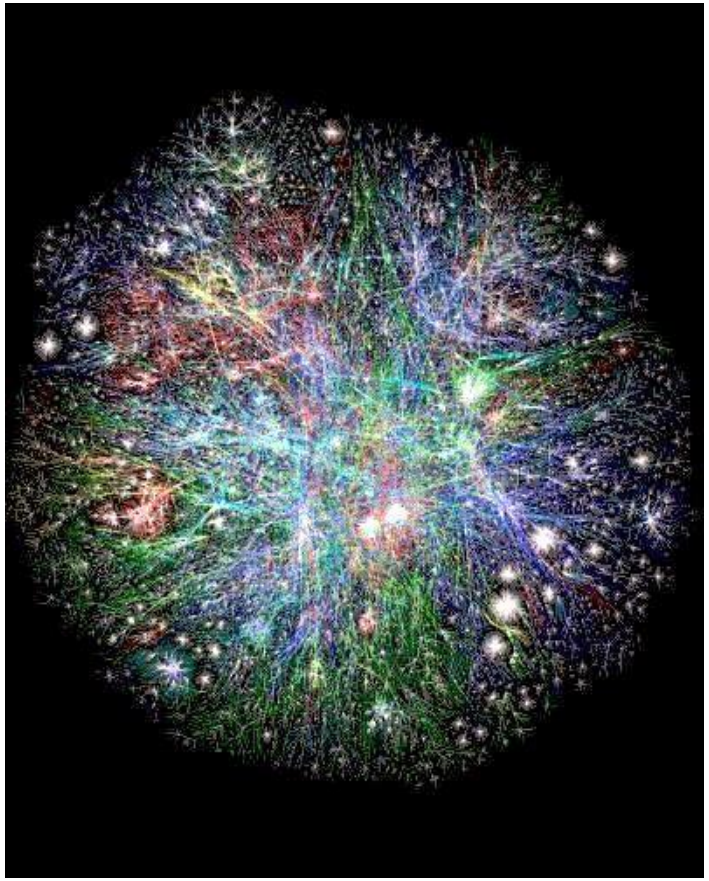


Complex Systems: Man made Emergent System



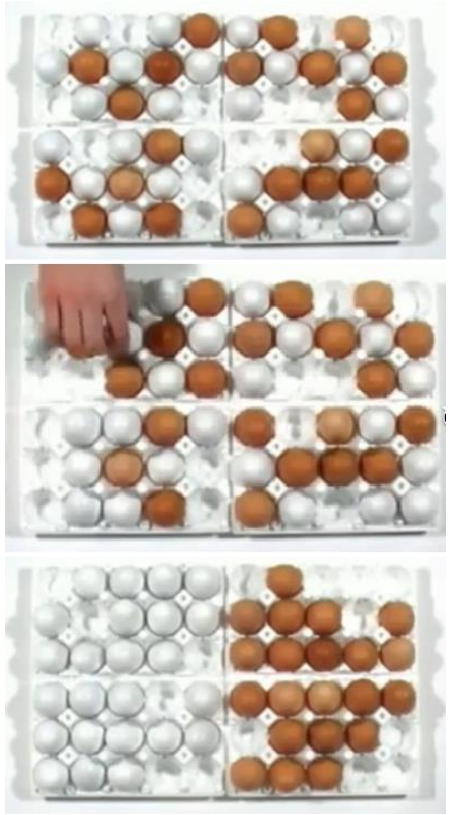
Complex Systems: Man made Emergent System

- **World Wide Web (WWW)**
  - No centralized control
  - Exponential increase in diversity of information
  - Websites arise and disappear seemingly at random (not necessarily true)
  - Number of links pointing to page follow a power law
  - A few pages are linked to many times and majority are seldom linked to



Complex Systems: Emergence in Social Systems

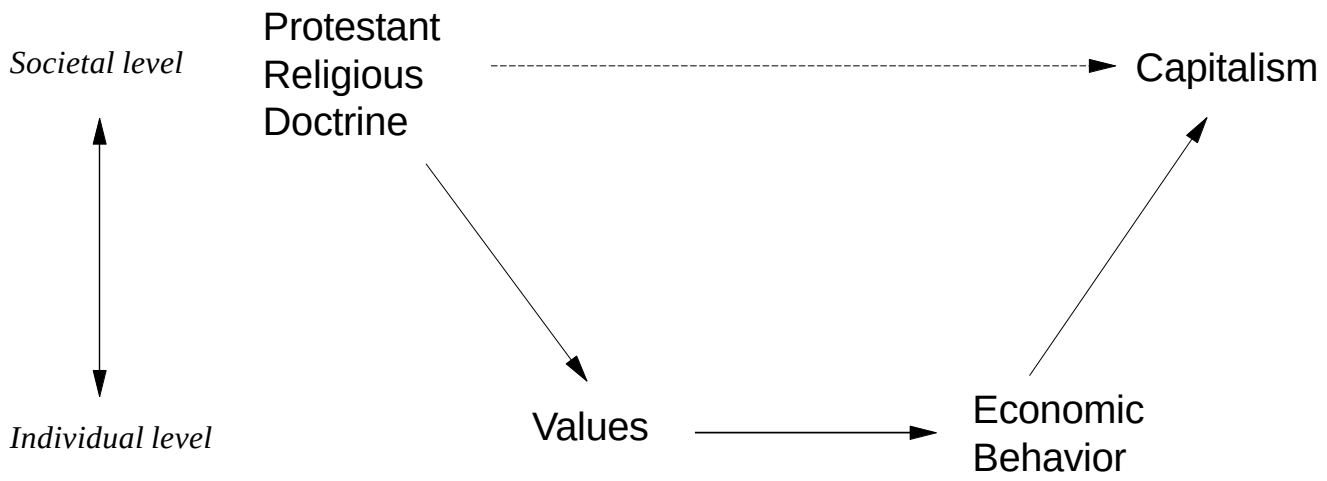
- "Micromotives and Macrobehavior"
  - Segregation



Thomas Schelling (Economist/Nobel Laureate)

https://www.youtube.com/watch?v=JjfihtGefxk

Complex Systems: Emergence in Social Systems



- Understand macrophenomena arises from microbehavior which in turn depends on macrophenomena (James Coleman in Foundations of Social Theory)

Complex Systems: Multi-Scale

- Multi-scale descriptions are needed to understand complex systems:
  - Complexity arises at different levels
  - Mathematical tools must scale
  - Need to understand behavior propagation across levels
  - Ex: Weather - (cyclones, tornadoes, dust devils)
- Fine scales influence large scale behavior:
  - Ex: Neurophysiology - a nerve cell action triggering a muscle
  - Ex: Economy/society - the relevance of individuals to larger scale behaviors

Complex Systems: Man made Emergent System

- Stock Market(s):
  - No leader
  - Each investor is an agent – has a limited knowledge of the market, has to abide by some rules
  - Patterns of working of the market emerge: but how?

- https://www.wnycstudios.org/podcasts/radiolab/episodes/91500-emergence

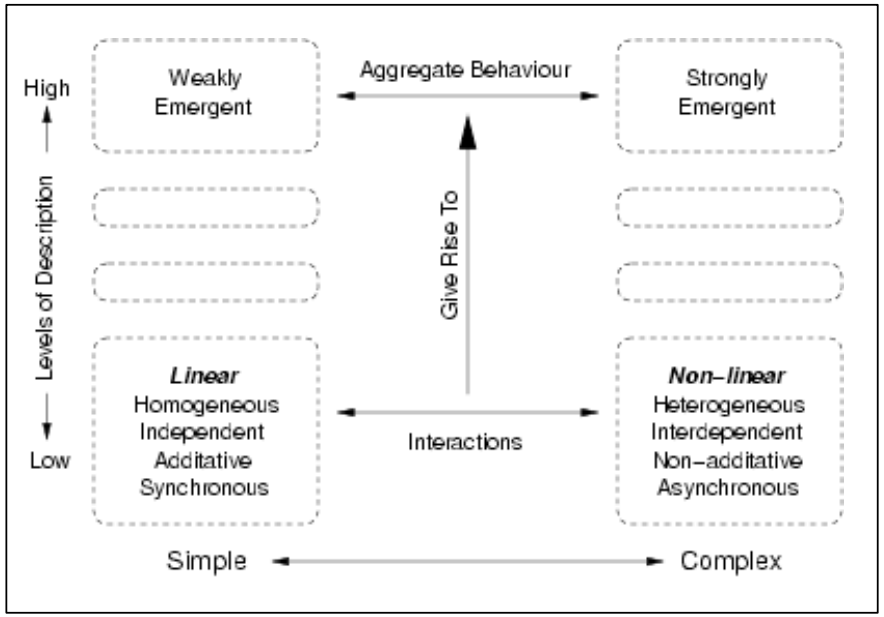
Types of Emergence

Weak Emergence

- The emergence results from a linear combination of the system components
- The emergent qualities are reducible to the individual components – Newtonian Physics

Strong Emergence

- The behavior of the Whole cannot be predicted from the parts since the combinations are non-linear in this case
- The emergent qualities are irreducible to the system components – systems theory of Physics



Self Organization

"Order is not pressure which is imposed on society from without, but an equilibrium which is set up from within."

- José Ortega y Gasset, Mirabeau and Politics, 1927-

- The spontaneous emergence of large-scale spatial, temporal, or spatiotemporal order in a system of locally interacting, relatively simple components.
- Self-organization is a bottom-up process where complex organization emerges at multiple levels from the interaction of lower-level entities.
- Objective of self organization:
  - Self-optimization
  - Self-healing/protection
- Tell-tale signs of self-organization are usually statistical properties shared with self-organizing physical systems

Complex Systems: Self-organization

- How come geese fly in organized V-shaped flocks, and fish swim in schools?
  - Is there a leader? Maybe the one in front?