Social Networks: New Paradigms for Modeling, Applications, Computations, and Visualization

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UMASS Amherst Student Chapter of INFORMS
Operations Research / Management Science Seminar Series
November 19, 2004
Support

Support for this research has been provided by the National Science Foundation under Grant No.: IIS-0002647 under the Management of Knowledge Intensive Dynamic Systems (MKIDS) program. This support is gratefully acknowledged.

This project involves also researchers from Carnegie Mellon University, University of Michigan, Stanford, and the University of California at Irvine.
Support

This grant has provided support for students, travel, books, supplies, computers, as well as for the Supernetworks Laboratory for Computation and Visualization in the Isenberg School of Management.

The support is acknowledged with gratefulness.
The Supernetworks Lab
A Story About How Social Networks Evolve

• During the Spring/Summer of 2002 Professor Nagurney held the Distinguished Chaired Fulbright/University of Innsbruck Professorship at the Institute of Economic Theory at the Business School, SOWI, at the University of Innsbruck, Austria, where Tina was studying…
Outline of Presentation

• Introduction to social networks
  – History of social network theory
  – Applications
  – Dynamic social network theory

• The framework of supernetworks

• Supernetworks consisting of social networks and economic networks
Definition of Social Networks

• “A social network is a set of actors that may have relationships with one another. Networks can have few or many actors (nodes), and one or more kinds of relations (edges) between pairs of actors.” (Hannemann, 2001)
History (based on Freeman, 2000)

- 17th century: Spinoza developed first model
- 1937: J.L. Moreno introduced sociometry; he also invented the sociogramm
- 1948: A. Bavelas founded the group networks laboratory at MIT; he also specified centrality
History (based on Freeman, 2000)

• 1949: A. Rapaport developed a probability based model of information flow.

• 50s and 60s: Distinct research by individual researchers

• 70s: Field of social network analysis emerged.
  – New features in graph theory – more general structural models
  – Better computer power – analysis of complex relational data sets
Representation of Social Networks

• Matrices

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• Graphs
Graphs - Sociograms
(based on Hanneman, 2001)

• Labeled circles represent actors
• Line segments represent ties
• Graph may represent one or more types of relations
• Each tie can be directed or show co-occurrence
  – Arrows represent directed ties
Graphs – Sociogramms 2
(based on Hanneman, 2001)

• Strength of ties:
  – Nominal
  – Signed
  – Ordinal
  – Valued
Sources: http://www.andrew.cmu.edu/user/krack/krackplot/mitch-circle.html
http://www.andrew.cmu.edu/user/krack/krackplot/mitch-anneal.html
Connections (based on Hanneman, 2001)

• Size
  – Number of nodes

• Density
  – Number of ties that are present/the amount of ties that could be present

• Out-degree
  – Sum of connections from an actor to others

• In-degree
  – Sum of connections to an actor
Distance (based on Hanneman, 2001)

- **Walk**
  - A sequence of actors and relations that begins and ends with actors
- **Geodesic distance**
  - The number of relations in the shortest possible walk from one actor to another
- **Maximum flow**
  - The amount of different actors in the neighborhood of a source that lead to pathways to a target
Some Measures of Power
(based on Hanneman, 2001)

• **Degree**
  – Sum of connections from or to an actor

• **Closeness centrality**
  – Distance of one actor to all others in the network

• **Betweenness centrality**
  – Number that represents how frequently an actor is between other actors’ geodesic paths
Cliquettes and Social Roles
(based on Hanneman, 2001)

- **Cliquettes**
  - Sub-set of actors
    - More closely tied to each other than to actors who are not part of the sub-set

- **Social roles**
  - Defined by regularities in the patterns of relations among actors
Examples of Applications
(based on Freeman, 2000)

• Visualizing networks

• Studying differences of cultures and how they can be changed

• Intra- and interorganizational studies

• Spread of illness, especially HIV
Commercial Application

Source: http://www.orgnet.com/sna.html
Dynamic Networks  (based on Carley, 2003)

• Limitations to traditional social network analysis
  – Focused on small bounded networks
    • With 2-3 types of links among one type of nodes
  – At one point of time
  – Close to perfect information
Dynamic Networks  (based on Carley, 2003)

- Dynamic networks
  - Meta matrix
  - Treating ties as probabilistic
  - Combining social networks with cognitive science and multi-agent systems
  - Networks and agents co-evolve
Applications of Dynamic Network Analysis (DNA) (based on Carley, 2003)

• The possible effects of biological attacks on cities (BioWar, Carley et al, 2002)

• Evaluation of information security within organizations (ThreatFinder, Carley, 2001)

• Evaluation of how to build stable adaptive networks with high performance and how to destabilize networks (DyNet, Carley et al, 2002)
Dynet

Database of Organizational Scenarios

Characteristics Of known or Hypothetical Network or Cellular Organization

Network Profile
- Attack Scenario
- Critical Individuals
- Observe Dynamics

Roles of Social Networks in Economic Transactions

• Examples from Sociology
  – Embeddedness theory
    • Granovetter (1985)
    • Uzzi (1996)

• Examples from Economics
  – Williamson (1983)
  – Crawford (1990)
  – Muthoo (1998)
Roles of Social Networks in Economic Transactions

- Examples from Marketing
  - Relationship marketing
    - Ganesan (1994)
    - Bagozzi (1995)
Novelty of Our Research

• Supernetworks show the dynamic co-evolution of economic (product, price and even informational) flows and the social network structure
• Economic flows and social network structure are interrelated
• Network of relations has a measurable economic value
A Multidisciplinary Approach

Supernetworks

Computer Science  Engineering
Management Science  Economics and Finance
Tools That We Have Been Using

• Network theory
• Optimization theory
• Game theory
• Variational inequality theory
• Projected dynamical systems theory (which we have been instrumental in developing)
• Network visualization tools
Applications of Supernetworks

- Telecommuting/Commuting Decision-Making
- Teleshopping/Shopping Decision-Making
- Supply Chain Networks with Electronic Commerce
- Financial Networks with Electronic Transactions
- Reverse Supply Chains with E-Cycling
- Energy Networks/Power Grids
- Knowledge Networks
The Supernetwork Team
Supernetworks Integrating Social Networks with Other Networks

• We have formulated and analyzed supernetworks consisting of:
  – Supply chain and social networks
  – Financial and social networks
  – International supply chain and social networks
  – International financial and social networks
Supernetworks Integrating Social Networks with Other Networks

- Decision-makers in the network can decide about the relationship levels $[0,1]$ that they want to establish.
- Establishing relationship levels incurs some costs.
- Higher relationship levels
  - Reduce transaction costs
  - Reduce risk
  - Have some additional value ("relationship value")
Supernetworks Integrating Social Networks with Other Networks

Dynamic evolution of

- Product transactions/financial flows and associated prices on the supply chain network/financial network with intermediation
- Relationship levels on the social network
Supernetwork Structure: Integrated Supply Chain/Social Network System
Multicriteria Decision-Makers

- Manufacturers and Retailers try to
  - Maximize profit
  - Minimize risk
  - Maximize relationship value
  - Individual weights assigned to the different criteria
Supernetwork Structure: Integrated Financial/Social Network System
Supernetwork Structure: Integrated Global Supply Chain/Social Network System
Supernetwork Structure: Integrated Global Financial/Social Network System
Types of Simulations

- We can simulate
  - Changes in production, transaction, handling, and relationship production cost functions
  - Changes in demand and risk functions
  - Changes in weights for relationship value and risk
  - Addition and removal of actors
  - Addition and removal of multiple transaction modes
  - Addition and removal of countries and currencies
The Virtual Center for Supernetworks Webpage
The Virtual Center for Supernetworks at the Isenberg School of Management, under the directorship of Anna Nagurney, the John F. Smith Memorial Professor, is an interdisciplinary center.

**NEW!** The Supernetwork Sentinel Fall 2004 Issue
**NEW!** Isenberg School of Management Website
**NEW!** Papers on Dynamic Supernetworks

**NEW!** INFORMS Student Chapter Fall 2004 Seminar Series!!!

Mission: The mission of the Virtual Center for Supernetworks is to foster the study and application of supernetworks and to serve as a resource to academia, industry, and government on networks ranging from transportation, logistical, telecommunication, and power networks to economic, environmental, financial, knowledge and social networks.

The applications of Supernetworks include: transportation, logistics, critical infrastructure, telecommunications, power and energy, electronic commerce, supply chain management, environment, economics, finance, knowledge and social networks, and decision-making.

Funding for the Center has been provided by:
The National Science Foundation
The AT&T Foundation
The Rockefeller Foundation
The John F. Smith Memorial Fund of the University of Massachusetts
The Isenberg School of Management - University of Massachusetts.
Summary

• We model the behavior of the decision-makers, their interactions, and the dynamic evolution of the associated variables.
• We study the problems qualitatively as well as computationally.
• We develop algorithms, implement them, and establish conditions for convergence.
• We have studied to-date "good behavior." Fascinating questions arise when there may be situations of instability, multiple equilibria, chaos, cycles, etc.
References


References


http://faculty.ucr.edu/%7Ehanneman/SOC157/TEXT/TextIndex.html


http://supernet.som.umass.edu
References


The full text of the papers can be found under Downloadable Articles at:

http://supernet.som.umass.edu
Thank you!

The Virtual Center for Supernetworks