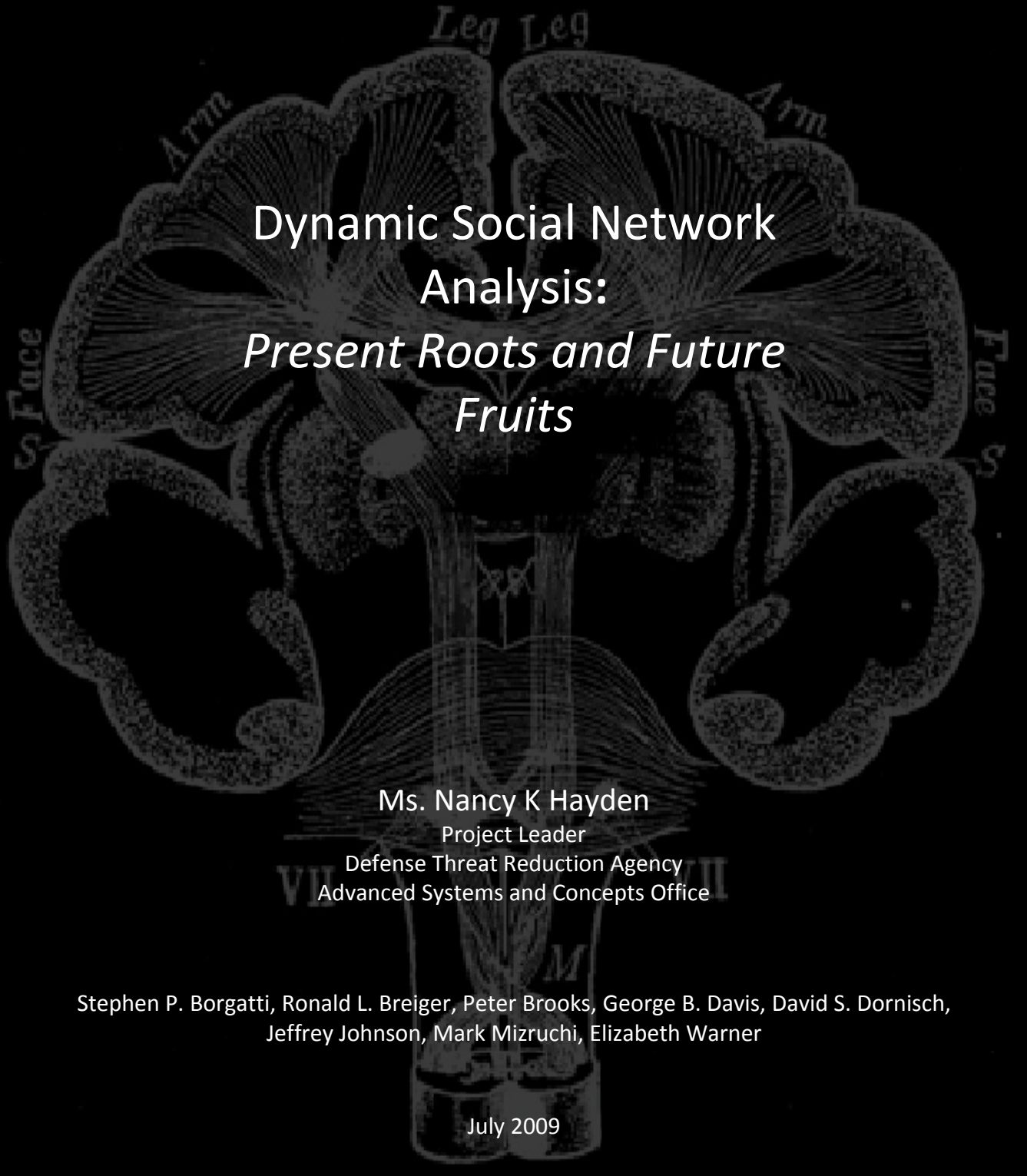

Dynamic Social Network Analysis: *Present Roots and Future Fruits*

Ms. Nancy K Hayden
Project Leader
Defense Threat Reduction Agency
Advanced Systems and Concepts Office

Stephen P. Borgatti, Ronald L. Breiger, Peter Brooks, George B. Davis, David S. Dornisch, Jeffrey Johnson, Mark Mizruchi, Elizabeth Warner

July 2009

DEFENSE THREAT REDUCTION AGENCY • ADVANCED SYSTEMS AND CONCEPTS OFFICE
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The mission of the Defense Threat Reduction Agency (DTRA) is to safeguard America and its allies from weapons of mass destruction (chemical, biological, radiological, nuclear, and high explosives) by providing capabilities to reduce, eliminate, and counter the threat, and mitigate its effects.

The Advanced Systems and Concepts Office (ASCO) supports this mission by providing long-term rolling horizon perspectives to help DTRA leadership identify, plan, and persuasively communicate what is needed in the near term to achieve the longer-term goals inherent in the agency's mission. ASCO also emphasizes the identification, integration, and further development of leading strategic thinking and analysis on the most intractable problems related to combating weapons of mass destruction.

For further information on this project, or on ASCO's broader research program, please contact:

Defense Threat Reduction Agency
Advanced Systems and Concepts Office
8725 John J. Kingman Road
Ft. Belvoir, VA 22060-6201

ASCOinfo@dtra.mil

Or, visit our website:
http://www.dtra.mil/asco/ascoweb/index.htm

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Many people contributed to the preparation of this report, and are due acknowledgement and thanks. First and foremost are the workshop participants themselves, whose intellectual capital was freely shared for the benefit of DTRA/ASCO in this endeavor. This report is a concerted effort to represent their thoughts as accurately as possible, but in the end it must be recognized as an interpretation, not direct reproduction, of the presentations and discussions. Each of the presenters generously provided copies of their materials and background reference materials for use in the report, as well as contributing their time to edit the written summary of their individual remarks. The background reference materials provided by the participants are listed at the end of each of the summaries. Footnotes and additional references contained within them, however, are the sole responsibility of the author. They have been provided, at the author's discretion, for the reader who may be unfamiliar with some of the concepts or citations brought up in the summaries. A glossary has been provided for the same reason.

EXECUTIVE SUMMARY

In today's threat environment, social networks have come to be thought of as broad organizing concepts for national security policy-making. The Advanced Systems and Concepts Office of the Defense Threat Reduction Agency (DTRA/ASCO) is examining implications of this conceptualization by evaluating:

- What types of questions can be addressed through the framework of social networks?
- How confident can one be in the conclusions based on social network analysis (SNA)?
- What kind of long term understanding does the social network paradigm promote, and what might it miss?
- What role does SNA have to play in DTRA's mission for countering Weapons of Mass Destruction (WMD)?
- What are the best practices for applying SNA and where does the best expertise lie?
- What research may be needed to enhance the potential of SNA to further DTRA's goals?

To facilitate this evaluation, ASCO invited a small group of leading researchers in SNA to come together at the DTRA Headquarters with government program managers and analysts from the intelligence community to discuss—from both theoretical and applied research perspectives—the state of the art in SNA, experiences with its application within the US government, and research efforts currently underway and/or needed to advance the state of the art, and the promise and limits to its potential.

ASCO conducted this two day seminar on 14-15 February 2008 at the unclassified and classified levels. The program was organized around themes of (1) theoretical underpinnings of SNA, (2) state of the art in SNA applications, (3) collective wisdom on issues, research needs, and recommendations, and (4) SNA applications to national security. A key question asked of the participants in the unclassified session was, "What are the optimal investments in SNA (for further research as well as for applications) that can be made by DTRA and by other government agencies?" At the classified level, we reviewed the types of use cases being addressed by SNA methodology within the IC, insights provided, the technologies utilized, and unmet needs. In addressing these questions, participants were asked to think about the subject of tacit knowledge: not just where they recommended that SNA had been or could be useful, but also where they advised it should ***NOT*** be relied upon.

The workshop began with academic subject matter experts describing current theoretical understanding of SNA and its potential for application to problem spaces of interest to DTRA.[1] Professor Steve Borgatti (University of Kentucky) led off with an overview of the SNA paradigm, its

[1] See Appendix III for bios of presenters and participants. Most of the academic experts are also consultants and/or researchers for the US government.

theoretical foundations, and current research efforts to develop an overarching theoretical framework that spans across social science disciplines. Professor Jeff Johnson (East Carolina University) followed with a presentation on data issues in applications and interpretations of SNA results. Carnegie Mellon University doctoral student George Davis, who is a research fellow under Dr. Kathleen Carley at the Center for Computational Analysis of Social and Organizational Systems (CASOS), described current advances in computational methodologies available to analysts for dynamic, path-dependent social network analysis. Professor Mark Mizruchi (University of Michigan) then spoke on the problems of determining causality and developing prescriptive actions based on SNA.

This academic interchange was followed by a panel of government personnel who shared their experiences with applications of SNA on national security problems that ranged from the tactical to the strategic. A round table discussion followed, in which all participants joined in exploration of how to build bridges that could be sustained between ongoing academic research efforts and the evolving needs of both government analysts and policy decision-makers for responsible and informed use of SNA in national security applications. Professor Breiger closed with a summary of the current status of SNA, challenges, and promises for the future, as seen from the perspective of academia shaped through the interactions with government users during the seminar.

I. INTRODUCTION
DR. MICHAEL WHEELER, DIRECTOR, DTRA/ASCO

Dr. Wheeler is currently on detached duty to DTRA from the Institute for Defense Analysis. He has a long career moving in and out of the policy, strategy, and operations communities dealing with WMD issues.

Dr. Mike Wheeler's opening remarks set the context for the workshop in terms of DTRA's mission, ASCO's role in helping DTRA achieve that mission, and the workshop goals to help bridge the gap that often exists between the academic and government WMD policy communities. He challenged the participants with questions to consider during the course of the two days.

The mission of the Defense Threat Reduction Agency (DTRA) is to help safeguard America and its allies from weapons of mass destruction (WMD) by providing capabilities to reduce, eliminate, and counter the threat, and mitigate its effects. The Advanced Systems and Concepts Office (ASCO) supports this mission by providing long-term rolling horizon perspectives. ASCO emphasizes the identification, integration, and further development of leading strategic thinking and analysis on the most intractable problems related to combating WMD. In shaping its research portfolio in support of its mission to the DTRA, DOD, and broader national security community, ASCO considers the threat environment at various levels spanning geographic regions, state and non-state actors.

The organizing principles for framing threats are important in determining strategic responses. During the Cold War, deterrence was one such organizing principle – in fact a primary one. In today's threat environment, social networks have come to be thought of as an organizing concept, as evidenced by the significant attention that social network analysis (SNA) is receiving from policy-makers.[2] But what, exactly, does this concept bring to the table? What types of questions can be addressed through the lens of social networks? How confident can one be in the conclusions based on social network concepts? What kind of long term understanding does the social network paradigm promote? Should the social network paradigm be elevated to the level of an organizing principle for national security, as deterrence has been in the past?

[2] Social networks have become an organizing principle across many sectors of our society, not just national security policy making. In an on-line interview on the subject of spread of behaviors, values, and emotional states through social networks, Harvard physician and sociologist Nicolas Christakis, says, "Nowadays, most people have these very distinct visual images of networks because in the last ten years they have become almost a part of pop culture. But social networks were studied in this kind of way beginning in the 1950s — actually there was some work done in the 1930s and even earlier by a sociologist by the name of Georg Simmel — with a culmination in the 1970s with seminal work that was done by sociologists at that time (people like Mark Granovetter, Stan Wasserman, Ron Burt, and others). But all these were still very small-scale networks; networks of three people or 30 people — that kind of ballpark. But we are of course connected to each other through vastly larger, more complex, more beautiful networks of people. Networks of thousands of individuals, in fact. These networks are in a way living, breathing entities that reproduce, and that have a kind of memory. Things flow through them and they have a purpose and can achieve different things from what their constituent individuals can. And they are very difficult to understand." See http://www.edge.org/3rd_culture/christakis08/christakis08_index.html

The choice of organizing principles for national security impacts a broad community of interest that includes academic researchers, government analysts, and federal policy makers. This intersection of communities is important – and not unfamiliar – territory. Both during and after the Cold War, for example, US government policies on deterrence have been informed by leading theorists from academia. On the subject of bridging the gap between academics and policy-makers, the late Alexander George put forward the importance of the concept of "generic knowledge," which builds on systematic examination of past experiences to identify when particular strategies will be more or less effective.[3] For George, generic knowledge complements two other types of knowledge: conceptual models of strategies and actor-specific knowledge.

It is in this vein of creating generic knowledge from past experience that ASCO invited a small group of leading researchers in SNA to come together with government officials at the DTRA Headquarters for a seminar to discuss—from both theoretical and applied research perspectives—the state of the art in SNA, areas of research efforts currently underway or needed to advance the state of the art, and the promise and limits to its potential relative to our mission space for national security. A key question asked of the participants was, "What are the optimal investment opportunities that can be made by DTRA and by other agencies?" In addressing this question, participants were asked to think about the subject of tacit knowledge: not just where they recommended that SNA could be useful to the DTRA mission space, but also where they advised it should ***NOT*** be relied upon.

[3] Alexander L. George (1993) *Bridging the Gap: Theory and Practice in Foreign Policy,* Washington, DC: United States Institute of Peace. In a career that spanned nearly six decades, Alexander George made a number of contributions in the fields of political psychology, international relations, and social science methodology. George's research programs on coercive diplomacy and deterrence included arguments about the impact of the asymmetry of motivation, strategies for "designing around" a deterrent threat, the controllability of risks, the importance of images of the adversary, and the need for actor-specific models of the adversary. George's theoretically and methodologically integrated research program contributed important concepts to national security analysis regarding the proper role of theory and awareness of the need for conditional generalizations that are historically grounded, sensitive to context, bounded by scope conditions, and useful for policymakers. He established the indispensability of process-tracing in theoretically-driven case studies.

II. THEORETICAL UNDERPINNINGS OF SOCIAL NETWORK ANALYSIS
Dr. STEPHEN BORGATTI, UNIVERSITY OF KENTUCKY

Dr. Borgatti is a Professor at the University of Kentucky in the Management Department of the Gatton College of Business and Economics where he holds an Endowed Chair. His primary research interest is social network analysis. He also has an interest in cultural domains and knowledge management. He is a Senior Editor at Organization Science, and sits on the editorial boards of Journal of Management, Computational and Mathematical Organizational Theory, Journal of Social Structure, and Field Methods.

Professor Borgatti's opening talk for the seminar provided a historical overview of theoretical underpinnings of Social Network Analysis (SNA), reviewed basic theoretical concepts, discussed examples of how those concepts have been applied in practice, and outlined some of the technical and conceptual issues that often arise in application to real world problems.

Historical Overview of Theoretical Underpinnings

The fundamental difference between network and non-network paradigms for studying social phenomena is that the network paradigm explains a social system in terms of structural properties – the lasting patterns of relationships between social units, the processes that occur through those relationships and the affect of those relationships and processes on social units and their functionality.[4] The roots of SNA can be traced as far back as the 1700's to early work in topology and graph theory by Euler and Hamilton. Applications to studies of networks in social systems began with Durkheim and Simmel at the turn of the century, and continued with the development of sociometry during the 1930s.[5] These applications were followed by contributions from the fields of psychology with the formal definition of cliques in the 1940s.[6] Through the 1950s and 1960s additional contributions to the field of sociometry came from developments within anthropology -- such as kinship algebra, the use of networks to represent social interactions in case studies by John Barnes, Elizabeth Botts, and Clyde Mitchell from the Manchester School, and other new concepts for ethnographic research.[7] These developments coincided with the formalization by Frank Harary of

[4] The SNA structural analysis approach based on relationships between social units is in contrast to at least four other paradigms: (i) reductionist attempts which focus on individuals; (ii) "structuralism" stressing the causal primacy of abstract concepts such as cognitive maps; (iii) technological and material determinism; and (iv) "structural equation" models that analytically connect variables (as opposed to graphically connecting social units).
[5] The field of sociometry was founded by Moreno in the 1930's to study interpersonal relations in small groups. Moreno invented the sociogram to depict the interpersonal structure of small groups. This invention was quickly picked up by other researchers due to two unique modeling characteristics that carried over into social network analysis: visual representation of group structure and probabilistic representation of structural outcomes. (Wasserman and Faust, 2007).
[6] Social psychologists in the 1940s and 1950s used experimentally designed communication structures for studying group processes. (For a review, see Freeman, Roeder, and Mulholland, 1980). Participants in these studies were depicted graphically as actors with channels of communications between them. The experiments led to theorizing on the impact of structural arrangement on group problem solving and individual performance, which in turn required formal statements relating structural properties of the experimental arrangements to outcomes. The concepts of actor centrality and group centralization were developed as measures of structural properties.
[7] Anthropologists in the 1950s and 1960s felt that new concepts and terminology were needed to explain the complexity and fluidity of social interactions observed in ethnographic field work. Concepts such as density, span,

graph theory for further advancement of network concepts to represent phenomena within social systems.[8] (The close association between graph theory and social network analysis has continued to this day, with many of the leading researchers in both fields regularly attending the same annual conferences.) In the 1970s, sociology emerged as a distinct, modern scientific discipline with the establishment of professional journals, conferences, and associations.[9] During this time, a structuralist agenda formed within the community known as the "Harvard Revolution", building on the small-world work of Stanley Milgram in the late 1960s, the discovery of vacancy chains by Harrison White and the "strength of weak s" by Mark Granovetter.[10]

With the advent of personal computing during the 1980s, computational methods became easily available that greatly enhanced the descriptive power of SNA, and network research blossomed in the decade that followed.[11] The Cambridge University Press series on structural analysis in the social sciences published an exhaustive text in 1994 on social network analysis text by Stanley Wasserman and Katherine Faust which has been reprinted fifteen times as of 2007.[12,13] Standardized SNA software packages, such as UCINET IV and Pajek became available for public use, reflecting the

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connectedness, clusterability, and multiplexity were formalized and began to come into common usage to describe properties of social structures and individual social environments. Network analysis came to be used by these researchers as a way of talking about observed social phenomena as well as providing a new theoretical perspective. Historical reviews cited by Wasserman and Faust (2007) include Barnes (1972), Whitten and Wolfe (1973), Mitchell (1974), and Foster (1978/9).

[8] Frank Harary was a prolific mathematician, known as the Father of Modern Graph theory. As his work became formally available in text books, the power of this form of mathematics to study social networks was brought to bear as methodologists discovered that matrices were well suited to represent social network data.

[9] According to the Craig Calhoun, in the Dictionary of Social Science, sociology as a distinct field is the systematic study of society, including patterns of social relations, social stratification, social interaction, and culture. Fields within the discipline concentrate on how and why people are organized in society, either as individuals or as members of associations, groups, and institutions. Theorists (such as Durkheim, Marx, Spencer, Pareto, Weber) wrote influential and foundational work in sociology during the late 19th and early 20th centuries. However, they did not regard themselves as sociologists, but more general social scientists engaged in the study of a broad number of social topics that included religion, economics, history, politics, education and law. The study of sociology as a separate science gained momentum after World War II, with the parallel development of numerous social movements, new theoretical concepts and frameworks regarding social struggle and conflict, and new qualitative and quantitative research methods.

[10] The so-called Harvard Revolution was led by Harrison White, who left University of Chicago in 1963 to become a professor of sociology at the Harvard Department of Social Relations. He pioneered the concept of social roles being created by position in patterns of relationships, allowing scientists new ways to measure society that were not based on statistical aggregates. See http://en.wikipedia.org/wiki/Harrison_White Research into social worlds organized as dense groups with weak ties between them is ongoing, and the subject of a recent best seller book by Duncan Watts at Columbia University, *Six Degrees*.

[11] With the advent of personal computing, additional social and life science research areas that adopted the network paradigm for analysis on a large scale included economics, biology, neurology, ecology, health and medicine, military and political science, environmental management, and business management.

[12] The series edited, by Mark Granovetter, presents approaches that explain social behavior and institutions by reference to relations among persons and organizations. Other books in the series include: Ronald Brieger's Social Mobility and Social Structure, Mark Mizruchi's Intercorporate Relations: The Structural Analysis of Business, David Knokes' Political Networks: The Structural Perspective, and Kyriakos Kontopoulos' The Logics of Social Structure.

[13] Stanley Wasserman and Katherine Faust (2007) Social Network Analysis: Methods and Applications, Cambridge University Press, NY, NY.

growing trend among academics in the social sciences for relational thinking.

In the last two decades, physicists have developed generalized approaches for network analysis from the perspective of statistical mechanics, and have popularized this analysis as a "new science" within the paradigm of complex adaptive systems.[14] This research community encourages and supports network researchers seeking universal laws that might apply to all networks regardless of the type of entities and/or system which comprise the network (e.g., electromechanical, chemical, physical, biological, social).[15] In contrast to these cross-disciplinary teams of scientists, whose goal is to explain common structural and behavioral characteristics across networks, most network researchers in the social sciences generally hold that social networks have distinct governing logics (such as who trust whom or who dislikes whom) and different antecedents and consequences from other types of networks. Hence, network theorizing in the social sciences has been more particularistic and cognizant of contextual differences. For example, whereas much of the network research by physicists draws from statistical mechanics and percolation theory for its theoretical foundations, network research in the social sciences is informed by sociological, psychological, anthropological and economic theory.

Key Concepts in SNA Paradigms

The paradigm of SNA uses mathematical graphs in which vertices (nodes) represent social actors, and edges (links) represent a variety of dyadic relationships such as similarities, social relations, interactions, and flows. Here, *similarities* refer to shared states such as being members of the same club, or being physically proximate, and are often viewed as precursors or facilitators of the other kinds of ties (such as social relations and interactions). *Social relations* refer to a variety of persistent dyadic states, such as kinship relations (i.e., being brother or sister to someone), role-based relations (i.e., being the friend or the boss of someone), affective relations (i.e., disliking someone), and relational cognitions (i.e., knowing what someone else knows about). *Interactions* refer to transitory (but possibly frequently recurring) events. Examples are talking with someone, having

[14] A prominent example is Notre Dame physics professor Albert Lazlo-Barabasi, whose work appeals to general and expert audiences alike. Barabasi's best seller book, *Linked: The New Science of Networks* (Perseus, Cambridge, MA, 2002), written for the general public, has been translated into Czech, Chinese, Finish, Hebrew, Hungarian, Italian, Japanese, Korean, and Turkish. Equally popular (among a smaller community of physicists and network researchers) are his more technical publications, such as the book written with sociologists Mark Newman and Duncan Watts, *The Structure and Dynamics of Networks* (and the Physics Review article written with Reka Albert, Statistical Mechanics of Scale-Free Network, which has been cited in over 5000 scholarly publications.

[15] A number of research institutions -- such as The Santa Fe Institute and the New England Complex Systems Institute -- have been formed for this purpose. The Santa Fe Institute was founded in New Mexico in 1984 as a collaborative community of multi-disciplinary academic experts (many of whom were Nobel laureates), for the study of complexity. A key area of research has been on networks. See Santa Fe Institute web site for detailed history, research projects, and academic community: http://www.santafe.edu/about/index.php . The New England Complex Systems Institute in Cambridge, MA focuses on the behavior patterns of complex systems and their interactions with the environment. Its faculty and staff come primarily from MIT, Harvard, and Brandeis, with affiliates from other universities and academic institutions across the country. See website: http://www.necsi.edu/necsi/index.html

sex with someone, and meeting with someone. *Flows* refer to what may be transmitted during interactions. Examples are information, material goods, and diseases.

SNA begins by theorizing properties of networks and proceeds by asking what determines these properties and what consequences they have for the nodes or the network as a whole. A basic tenet in social network research is that the structure of a network is as important in determining what happens within that network as are the properties of its individual units (e.g., the nodes). For example, the success of a basketball team is a function not only of how good the players are, but also of how they work together.

Social network researchers have developed a rich set of concepts to describe these network structures and the positions of nodes within them. Structural properties are characterized at three levels—group, node (or unit, agent), and dyads (Figure 1). The network structure (topology) is defined in terms of group properties (Figure 2). Nodal properties—which determine the opportunities and constraints that the actor represented by that node will face—are defined as a function of node position. Relationships between nodes are described as properties at the dyad level, where a dyad consists of two nodes and the lines between them. Structural properties of dyadic relationships describe both proximity of nodes - such as adjacency and geodesic distance; and equivalency of nodes – both "structural" and "regular."[16] Structural properties of nodes are determined by position and include closeness, degree, and betweenness, which go into defining the overall centrality of nodes.[17] Subgroup identification is a key aspect of network analysis in which special classes of clusters—such as cliques, factions, clans, sets, and k-plexes—are identified.[18] Overall network properties include concepts that define the network's cohesion – such as density, average path length, and fragmentation[19]; and those that define its shape – such as scale-free, small-

[16] **Structural equivalence** is a mathematical property of subsets of actors in a network (or nodes in a graph). Two actors are structurally equivalent if they have identical ties to and from all other actors in the network. Actors who are **regularly equivalent** have identical ties and from equivalent actors (Wasserman and Faust 2007, p. 356, 474). The difference between structural and regular equivalence is that for regular equivalence, actors must have the same kinds of ties to the same kinds of actors -- but not to the exact same actors as is necessary for structural equivalence.

[17] **Closeness** is a measure related to actor centrality, and involves a calculation of the distance that an actor is to all other actors in a set of actors. Central nodes have minimum steps when relating to all other nodes, minimizing the shortest paths, or "geodesic distance". This effectively equates closeness to an idea of minimum distance.

[18] **Clusters** occur in signed graphs, if one can partition the nodes of the graph into a finite number of subsets such that each positive line joins two nodes in the same subset and each negative line joins two nodes in different subsets. The subsets derived in this way are called clusters. See glossary for definitions of the special classes of clusters.

[19] **Cohesion** occurs within a network, or among subsets of actors in a network among whom there are relatively strong, direct, intense, frequent, or positive ties (Wasserman and Faust 2007, p. 249). At the network level, group cohesion refers to the overall connectedness or knittedness of a network. Density, average path length, and fragmentation are measures of network cohesion. **Density** is the number of lines in a simple network, expressed as a proportion of the maximum possible number of lines (Nooy, Mrvar, Batagelij, 2007, p. 319). **Average path length** is the average number of steps along the shortest paths for all possible pairs of network nodes (Albert and Barabasi, 2002). A graph is **connected** if there is a path between every pair of nodes in the graph. In contrast, a graph in which all nodes are isolated from each other is maximally **fragmented** (Wasserman and Faust, 2007, p. 109). Different algorithms to measure fragmentation take into account the number of components, or subgroups, in a network, as well as the size and shape of those components (Borgatti, 2006). Methods that identify cohesive

world, and core-periphery.[20]

The "classical research agenda" can be categorized as either antecedent or consequent (predictive) and asks questions about the influence of dyadic relationships, nodal properties, and overall network properties (Figure 3). Predictive SNA research can be further broken down into categories based on the explanatory paradigms assumed in the research design (Figure 4).

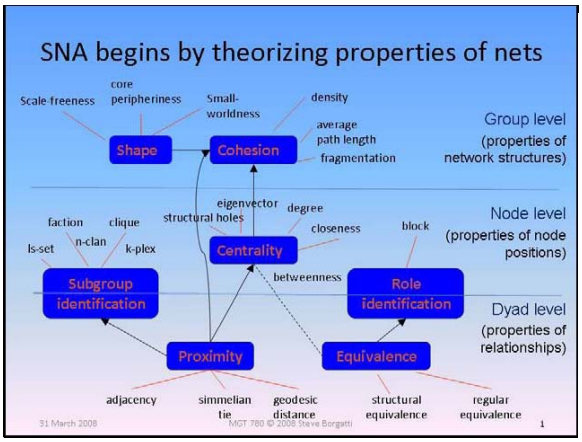

Figure 1.

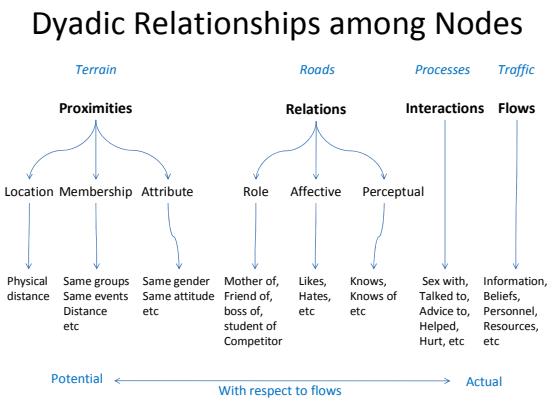

Figure 2.

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subgroups attempt to formalize the intuitive and theoretical notion of social group using a variety of social network properties similar to those for networks (Wasserman and Faust 2007, p. 319).

[20]A **scale-free network** is a network whose degree distribution is characterized by a power law function, which means that a rescaling of the function's argument changes the constant of proportionality but preserves the shape of the function itself. Such networks are widely studied for their universal properties, which scale invariant (Albert and Barabasi, 2002). **Small world** networks have small path lengths (like random graphs) and high clustering (like regular lattices). Such networks display enhanced signal-propagation speed, computational power, and synchronizability (Watts and Strogatz, 1998). Three different intuitive concepts of **core-periphery** network structures used by social network researchers are elsewhere summarized by Borgatti as i) a group or network that cannot be subdivided into exclusive cohesive subgroups or factions, although some actors may be much better connected than others; ii) a two-class partition of nodes where one class is the core and the other is the periphery, and all nodes belong to a single group either as core members or peripheral members; iii) a continuous model resembling a cloud of points in Euclidean space with a physical center and periphery of where nodes that occur near the center are those that are proximate not only to each other but to all nodes in the network, while nodes that are on the outskirts are relatively close only to the center (Borgatti and Everett, 1999). In all cases, the notion of a core-periphery structure synthesizes the concepts of network shape and centrality (Carrington, Scott and Wasserman, 2007, p. 68).

Classical Network Research Agenda

NETWORK PROPERTIES	Dyadic Relationship e.g., valence of tie; strength of tie; bridgingness	Node Position e.g., betweenness centrality; structural holes	Network Structure e.g., density; avg path length; clustering coef, fragmentation
Antecedents	What determines what kind of relationship will exist between a given pair of actors?	What determines who will occupy what position in a network?	Why does a network have the structure it does? How do structures evolve?
Consequences	What does it mean for a pair of actors to have a certain kind of relationship? What rights & obligations are entailed?	What are the opportunities & constraints that result from occupying a certain position in the network?	How does a network's structure (i.e., a group's structure) affect what happens to that group?

Figure 3.

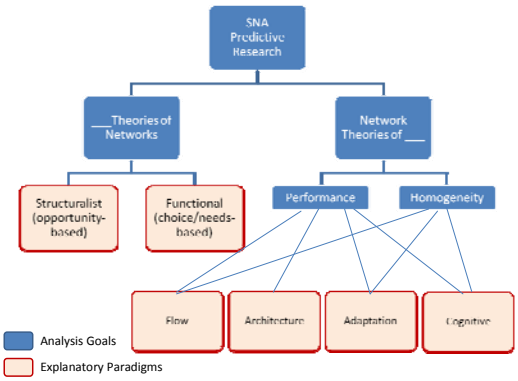

Figure 4.

Challenges in Current SNA Applications for National Security

Borgatti's research to find key players in a social network illustrates some current challenges that must be addressed for using SNA in predictive analysis. The Key Player Project, funded by the Office of Naval Research, asks how one can identify "key players" in networks for a variety of purposes, including:

1. Disrupting a network by removing key players
2. Enhancing a network by helping key players
3. Influencing the network by identifying and influencing the key opinion leaders
4. Learning from the network by watching most carefully the players who are "in the know"
5. Redirecting flows in the network toward more convenient or beneficial nodes by removing key players.

Each of these analytic purposes lead to different solution sets in different areas of application, as exemplified in Figure 5.

Key Player Needs by Field

	DISRUPT	PROTECT	INFLUENCE	LEARN	REDIRECT
SECURITY	Who to **arrest or discredit** to disrupt ops	Who to **protect** among allied group	Who to turn or plant info with	Who is best positioned to know most	Who to remove to redirect flows
PUBLIC HEALTH	Who to **immunize or quarantine**		Who to select as PHAs for interventions	Who to study explain spread	
MANAGEMENT	Who to hire away from competitor	Who to give more of a stake in org to avoid turnover	Who to get on board before launching reorg		Who to add/replace to remove drag on good emps
MARKETING		Which happy users to empower	Identify key mavens to sell on your stuff		

Borgatti's research has shown that removing key nodes in an enemy network carries a long term risk. When a key player is eliminated in order to fragment a network, the ties among the other players may grow back, perhaps between multiple players. The result may be a stronger network that is more difficult to contain (Borgatti, 2006).

There are two issues that present additional challenges when identifying sets of key players for the purpose of disrupting a network. These are the "design issue" and the "ensemble issue."[21] The design issue refers to the fact that social network measures of nodal importance (e.g., centrality measures) calculated by off-the-shelf software packages are not designed to solve the key player intervention problem, and are in fact suboptimal. As shown in Figure 6, eliminating the node with the highest value of node centrality (a common solution algorithm in off-the-shelf software) does not fragment the network. Instead, it is the removal of node 8, which has a "suboptimal" centrality measure (according to traditional software design algorithms) that will provide optimal fragmentation of the network.

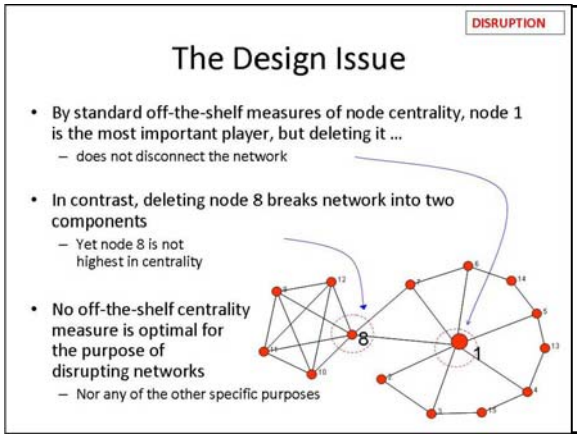

Figure 6.

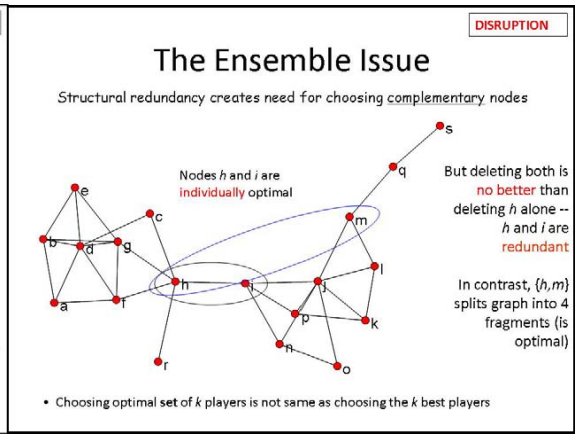

Figure 7.

The ensemble issue refers to the fact that when a set of *k* key players is to be chosen for optimally fragmenting the network, the best combination to remove does not necessarily consist of the top *k* nodes when measured individually for centrality, due to graph-theoretic redundancy.[22] Figure 7 illustrates this problem. In Figure 7, nodes *h* and *i* individually have the two highest centrality measures in the network (traditional software solution algorithm), but removing both as a set does no more to fragment the network than removing either one alone. In contrast, although node *m* has a smaller centrality measure than node *i*, removal of nodes *h* and *m* as a set will result in higher fragmentation than removal of *h* alone.

Promises of SNA for Future National Security Applications

SNA promises to make contributions in the study of propagation of belief and value systems, if used with appropriate underlying social science theory. Current research in this area employs the concepts of "prospects" and "levers." A lever is a friendly agent that is in a position to influence many unfriendly agents, directly and indirectly. A prospect is an unfriendly node that is surrounded by many friendly nodes, which can potentially influence the unfriendly node.

[21] For more discussion of these issues, see Borgatti (2003)

[22] Two nodes are redundant if together they reach no more than either does alone.

Borgatti is currently involved in a basic science research project that promises to address a critical gap in SNA –an overarching theoretical framework to inform a broad scope of questions that might be asked of SNA relative to combating WMD. This project, called the integrated Adversarial Network Theory (iANT) Project, is funded through a two-year basic science research grant from DTRA/RD, and tackles the huge research challenge of the depth of theorizing necessary for using social networks to adequately cover DTRA's problem space. The research will pull together theories and empirical results from all of the social sciences into a paper that unifies extant social network theory to the extent possible.[23]

The relevant actors in the iANT project may consist of individuals, organizations, societies and nations. Their interactions may be embedded in a variety of social, psychological, economic and cultural contexts, implicating all of the social sciences. This begs the question "Do we need a different theory for every network/people/context?" The iANT project is also looking at less daunting challenges, such as how to develop the right level of theory, and how to communicate such a theory.

In concluding, Borgatti recommended that DOD develop a "Top 100 Problem" list with examples and ask the SNA community what SNA can do to solve these problems. In attempting to answer these questions, the SNA community and DOD will learn where theories need more specificity and where the community needs to perform more empirical research. He also suggested that the empirical research should be conducted on populations other than U.S. students and corporate managers.

References

Borgatti, S.P., Carley, K., and Krackhardt, D. 2006. Robustness of Centrality Measures under Conditions of Imperfect Data. *Social Networks* 28: 124–136.

Borgatti, S.P. 2005. Centrality and network flow. *Social Networks*. 27(1): 55-71.

Borgatti, S.P. 2006. Identifying sets of key players in a network. *Computational, Mathematical and Organizational Theory*. 12(1): 21-34

Borgatti, S.P. 2003. The Key Player Problem. In *Dynamic Social Network Modeling and Analysis: Workshop Summary and Papers*, R. Breiger, K. Carley, & P. Pattison, (Eds.) National Academy of Sciences Press,. Pp. 241-252.

Freeman LC (1979) Centrality in social Networks: Conceptual Clarification. Social Networks 1:215-239.

[22] This project builds from earlier research by Borgatti described in the proceedings of a workshop convened by the National Academy of Sciences in 2002 on behalf of the Office of Naval Research, *Dynamic Social Network Modeling and Analysis: Workshop Summary and Papers*, By Ronald L. Breiger, Kathleen M. Carley, Philippa Pattison, National Research Council (U.S.). Committee on Human Factors, National Academies Press, 2003.

III. TOPICAL PRESENTATIONS AND DISCUSSIONS

The following three presentations introduced topics that challenge the community of SNA theoreticians, tool developers, and analyst users alike:

1. *Attributing causality in SNA*
2. *Data issues in conducting and validating SNA, and*
3. *Fusing theoretical understanding, software advancements, and user needs into transparent and readily available, standardized capabilities*

These short presentations provided context for the ensuing discussions that included all participants.

1. ATTRIBUTING CAUSALITY IN SNA
PROFESSOR MARK MIZRUCHI, UNIVERSITY OF MICHIGAN

Professor Mizruchi holds joint appointments as a professor in the Ross School of Business and in the Department of Sociology at the University of Michigan. He specializes in the economic and political behavior of large American corporations, using the methods of social network analysis. His current projects include a study of the globalization of American banking, a study of the use of social networks in the deal-making process in a major commercial bank, and a study of the changing nature of the American corporate elite.

Professor Mizruchi provided highlights of the current state of the art for interpreting results of SNA in terms of causality attribution from network analysis in studying large organizations, the impact of network structures on organizational decision-making, and the unresolved challenges in these applications.

A principal assumption of network analysis is that the structure of relations reveals the content of those relations. People studying organizational behaviors recognized early on that this approach held great promise, as relationships are known to affect organizational interests and functioning, but are often hard to observe or measure. In the late 1970s and early 1980s, much of the research into the functioning of organizations using a network analysis approach was largely descriptive.[24] An example is the work that was done on understanding corporate director links. Several researchers provided extensive discussions of the properties of inter-firm networks, but there was little attempt to demonstrate their behavioral consequences.[25] By the end of the 1980s, the focus of research on corporate directors had shifted to outcomes: the effect of inter-firm network ties on firms' political behavior; the effect of network ties on anti-takeover provisions, acquisitions, and firm structures[26]; there was also an emerging literature on the effect of individual-level networks on promotion within the firm.[27] These outcome-oriented applications necessitated models of causality between structure and behavior in order to make meaningful inferences from results of SNA.

[24] In Borgatti's terms, this work focused on network structure as antecedent to observed functioning.
[25] See, for example, Mizruchi, 1982; Roy, 1983.
[26] See Mizruchi, 1996 for a review of this literature.
[27] Burt, 1992

By the mid-1990s, enough evidence had been generated through research efforts to substantiate that associations existed between social networks and organizational behaviors, but many questions remained unresolved—such as where the networks came from in the first place, and whether the associations between networks and behavior were really causal. For example, researchers had shown that the presence of bankers on a firm's board of directors was correlated with the firm's use of debt[28]; but it was possible that the decision to use debt preceded the board appointment.[29] Similarly, it had been shown that occupancy of structural holes[30] can predict whether one is rapidly promoted within a firm, but it is possible that the rapid promotion is the cause of one's occupancy of structural holes.[31] Bankers' network ties have been found to be associated with the size of their bonuses.[32] But it is possible that the network ties are a consequence of prior strong performance. One difficulty, then, is to show that the network effects on behavior are fully exogenous.

Another difficulty in attributing causality is the synergistic, co-evolutionary nature of network ties between actors, and the cultural beliefs of the actors in the network. That is, network ties may result not only from the dependence of actors on one another, but from the personal characteristics of the actors and the larger culture as reflected in belief systems and norms. Yet culture, knowledge, and norms may emerge from the prior network ties as well. One possible way to address this issue experimentally might be to place actors with different personal characteristics into structural holes, and see if the effects of hole occupancy vary, and if so, how. Another approach could be for researchers to set up either random or uniform networks,[33] and observe whether or not occupants of structural holes emerge. Alternatively, experiments can be set up in which bridges within network structures are broken, and observations are made to see if new paths form.[34] This might have relevance to the analysis of terrorist networks.

A topic raised during the discussion following this presentation was the importance of being able to characterize complex strategic policy decisions and subsequent actions as part of a continuum process rather than treating them as a single point in which "the decision" is made. How, for example, would one treat the Joint Integrating Concept for Combating Weapons of Mass Destruction as a network? This question raised the issue of when the fundamental concept of the network

[28] Mizruchi and Stearns, 1994
[29] Mizruchi, 1996; see Mizruchi, Stearns, and Marquis, 2006, for an attempt to account for historical variation in the effect of network ties on firms' use of debt financing.
[30] A structural hole is a position in a network characterized by ties to others who are themselves disconnected from one another. Occupants of these positions have been shown to experience a range of advantages. See Burt, 1992.
[31] Mizruchi, Stearns, and Fleischer, 2008
[32] Mizruchi, Stearns, and Fleischer, 2008
[33] A **random network** is one in which ties between actors are randomly assigned, or distributed in no evident pattern. A **uniform network** is one in which all actors have the same number of ties, to the same types of other actors.
[34] Such experiments could be set up in a lab, through computer simulations, or possibly in an organizational setting (although the latter might be problematic, since it might have real, and possibly negative, consequences for the organization).

paradigm does and does not provide representational value for insights into organizational decision-making.

References

Burt, Ronald S. 1992. *Structural Holes: The Social Structure of Competition*. Cambridge: Harvard University Press.

Mizruchi, Mark S. 1982. *The American Corporate Network, 1904-1974*. Beverly Hills, CA: Sage Publications.

Mizruchi, Mark S. 1996. "What Do Interlocks Do? An Analysis, Critique, and Assessment of Research on Interlocking Directorates." *Annual Review of Sociology*, 22: 271-298.

Mizruchi, Mark S. and Linda Brewster Stearns. 1994. "A Longitudinal Study of Borrowing by Large American Corporations." *Administrative Science Quarterly*, 39: 118-140.

Mizruchi, Mark S., Linda Brewster Stearns, and Anne Fleischer. 2008. "Getting a Bonus: Performance, Social Networks, and Reward Among Commercial Bankers." Unpublished manuscript, Department of Sociology, University of Michigan.

Mizruchi, Mark S., Linda Brewster Stearns, and Christopher Marquis. 2006. "The Conditional Nature of Embeddedness: A Study of Borrowing by Large U.S. Firms, 1973-1994," *American Sociological Review*, 71: 310-333.

Roy, William G. 1983. "The Unfolding of the Interlocking Directorate Structure of the United States." *American Sociological Review*, 48: 248-257.

2. DATA AND VALIDATION ISSUES
PROFESSOR JEFFREY JOHNSON, EAST CAROLINA UNIVERSITY

Dr. Johnson is a University Distinguished Research Professor in the Sociology department at East Carolina University. Trained as a cultural anthropologist, Professor Jeffery Johnson has a unique specialty in gathering field data on social networks and roles within small groups in extreme and isolated environments, and has used that expertise as a consultant to various USG agencies. Much of his teaching and research program is focused around the use of social network theories and methods for understanding social structure and organization.

Dr. Johnson provided introductory remarks for a discussion on issues around the "data-greedy" nature of social network analysis and the difficulties associated with collecting data, knowing when you have a complete data set, and the interconnection between validating data and analysis results.

The collection of adequate, validated data is a major problem when trying to model a social network and understand how it functions. Compared to the collection of other types of data in the social sciences, the collection of social network data can be quite challenging with significant consequences. This short paper discusses the nature and impact of some of those challenges: missing data, data reliability and accuracy, primary versus secondary data,[35] and design of network measurements and their relevance to the context and nature of data collection.

A major threat to the validity of social network research stems from missing data. Missing data can result from sources that include:

1. The *improper specification* of network boundaries, on theoretical or other grounds, which may result in data not being collected.
2. Second, network surveys, like other social science surveys, are extremely susceptible to *non-response bias*. Respondents may refuse to answer some, or even all, network survey questions because they are too busy or because they deem the questions sensitive and better left unanswered. Network analysis is more sensitive to this missing data than many other social science analysis methods, as missing actors and their links can affect structural and analytical outcomes at both the network and individual levels.

The severity of the consequence of missing data depends on many factors, including the nature of the network being studied. For a given social network analysis, the design of the study, the choice of the sample population, and the design of the instrument used to gather data, can reduce threats to validity of the results.[36] The stronger the structure of the network, the more dominant the structure

[35] Primary sources are eyewitness accounts of the events described. Secondary sources consist of indirect evidence obtained from primary sources (Singleton and Straits, 1999, p. 380)

[36] In his research, Johnson has shown the importance of distinguishing between formal, informal, and latent social roles in networks and the need to gather data on all three for proper specification of a network to understand emergent network properties, such as adaptability, cohesion, robustness, and stability. In this work, he notes that although formal aspects of groups are important, such as those discussed by Mizruchi, much of network dynamics

remains, even with missing data, either random or biased. That is, a strong structure will emerge, even with poor data. This can be a blessing (when the results are valid in spite of data sparseness) or a curse (when the results appear robust but are invalid). Which it is needs to be well understood by the analyst, but is hard to determine.

Social science research has had to deal for many years with issues of error and bias introduced by the data issues noted above and more.[37] In many cases, the errors are well behaved and can be controlled, measured, and sometimes remediated through standard procedures developed over the years in social science research. It is important for the social network analyst to be familiar with these corrective procedures.[38]

Network data can come from a variety of different sources but it generally boils down to a distinction between primary versus secondary types of data. Some of the more common forms of primary data collection – such as survey instruments and interviews -- are shown in Table 1. These different forms of primary data collection have pros and cons as indicated. However, they all share the key benefits of primary data collection, which include greater flexibility in the type, measurement, and number of relations to be studied, and ability to incorporate corrective measures for bias directly into the design. Similarly, they share some of the more problematic sources of bias in primary data – such as non-response and accuracy.[39]

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are the result of informal influences and the interaction between formal and informal processes. Some of the informal roles can be hidden, dormant, or latent and emerge only when circumstances warrant. The presence or absence of these informal social roles and nature of latent roles have an impact on a network's emergent properties, yet may often be overlooked when gathering data as they are hard to specify a priori (Johnson et al, 2003).

[37] The definition of bias in the social sciences is in part philosophical, depending on ones view of objectivity and truth - positivist, realist, relativist, constructionist, postmodern, etc. A common understanding among social scientists (qualitative or quantitative) for bias is any systematic (in contrast to random or haphazard) deviation from validity, or to some deformation of research practice that produces such deviation (Hammersly and Gomm, 1997, paragraph 1.7). This definition obviously depends on the concept of validity, and the ability to show a relationship between the research and an objective reality. In its most extreme form, this approach holds that research, when it is properly executed, will produce conclusions whose validity follows automatically (either inductively or deductively) from the 'givenness' of the data on which they are based. The sources of data are treated as independent of, and as imposing themselves on, the researcher. conceptions of the nature of any inference involved can vary, for example it may be deductive or inductive. But, whatever its form, it is taken to produce conclusions whose validity is certain, given the truth of the premises (Hammersly and Gomm, 1997, paragraph 4.4)

Questions around error and bias are a key aspect of research design in the social sciences, as the introduction of some bias is unavoidable. Bias enters into the very selection of problems for study as well as the preference for certain research strategies. Common sources of bias can come from nonrandom sampling associated with persons, settings, instruments, and outcomes or events; they can also come from lack of heterogeneity and overgeneralization. These can be particularly troublesome in social network analysis.

[38] For example, in probability sampling, best practices have established accepted response rates for various types of data gathering through surveys, questionnaires, interviews, etc. If responses are below these traditional standards, one must seriously question the validity of models built on the data. Ideally, for social networks, every person in the group under study should be interviewed.

[39] Many of the systematic errors in social science research arise from respondent's reactions to participating in the research. When the respondent's response to a measure is affected by the process of observation or measurement (such as giving an answer that is believed to be desired), the reliability and accuracy comes into question. Cultural issues can also play a large factor, if the data collection does not account for cultural differences.

Form of Data Collection/Interview	Issues of Sensitivity	Interviewer Response Effects	Ability to Establish Rapport	Thoroughness (Ability for Elicitation)	Ease of Administration
Face-to-Face	Moderate	Moderate	Moderate-High	High	Low-Moderate
Self-Administered	Low	Low	Low	Low	Moderate
Mail Out	Low	Low	Low	Low	High
On Line	Low	Low	Low	Low	High
Phone	Moderate	Low-Moderate	Low-Moderate	Moderate	Moderate
Group Setting	Low-Moderate	Low-Moderate	Moderate	Low-Moderate	Moderate

Table 1. Primary Source Data Collection Methods in Social Science Research

Secondary sources already exist somewhere in print or can be found electronically. Examples are historical marriage records, social networking pages, and newspaper articles. Because they are historical and fixed, secondary data dictate and limit the types of relations and levels of measurements that can be used in the course of the research. Collection of data from secondary sources can be easier (e.g., data mining), but there are many threats to the validity of secondary source data. Questions that a must be asked about data in order to assess the validity of a social network analysis include the following:

- Do dyadic ties in records (e.g., e-mails) have the same meaning as from primary sources?
- Do the records document meaningful events?
- Are the records biased in the way that they are constructed, that is do they fit an agenda or reflect biases of the actors recording them?
- Can the data be compared over various timeframes?[40]

When designing network measurements for which one obtains data, many additional questions surface:

- What level of measurement is appropriate for the social ties of interest?
- What is the psychometric meaningfulness of the measure?
- What is the ability of the measure to compare meaningfully across subjects/actors?
- What method gets the highest compliance, particularly in a repeated measure or longitudinal design?

Typological data decisions to be made in social network analysis include: the type of relation (friendship, liking, or interaction); the type of metric (binary, ratings, or rankings); the timeframe

[40]Comparisons across timeframes using longitudinal designs provide stronger inferences about directions of causal relationships, and studies of process and patterns of change.

(retrospective, prospective, or anticipatory). The researcher must be aware of relational salience in a given cultural context—some cultures are more or less willing to talk about others or refer to others.

In summary, data quality is essential—garbage in, garbage out. Cognitive data from a small number of knowledgeable informants can be used to construct a reasonably accurate picture of a whole network. The more central the actor is, the more accurate the perception will be. When data is missing, the observed data can be used to weight estimates of tie and nodal characteristics and contribute to triangulation on the existence of nodes and ties. Lessons learned from reliability and validity in data collection can (and should) be used to help assess the validity of network ties and actors in producing data sets. Bayesian weighting is one such method that can be used to better estimate the presence or absence of nodes and ties.[41]

References

Johnson, J. C., L. Palinkas, and J. Boster, Informal Social Roles and the Evolution and Stability of Social Networks, in (Breiger et al 2003), pp. 121-132

Singleton, Royce A. and Bruce C. Straits, Approaches to Social Research, Oxford University Press, NY,NY, 1999.

Wasserman, Stanley and Joseph Galaskiewicz, Advances in Social Network Analysis: Research in the Social and Behavioural Sciences,

Pedro Domingos: Bayesian Averaging of Classifiers and the Overfitting Problem. ICML 2000: 223-230.

Breiger, Ronald, Kathleen Carley and Phillipa Pattison, Dynamic Social Network Modeling

[41] Bayesian inference methods are used in the assessment of probabilities, where additional information can refine estimations of the likelihood of events. The essence of the Bayesian approach is to provide a mathematical rule explaining how you should change your existing beliefs in the light of new evidence. In other words, it allows scientists to combine new data with their existing knowledge or expertise. Mathematically, in its simplest form, Baye's rule states that, given evidence of the occurrence of event e, the probability that event R has the value of r, is given by the equation, $P(R=r|e)=[P(R=r)*P(e|R=r)]/P(e)$. For a model that includes possibility of multiple mutually exclusive and exhaustive events, R_i, Baye's rule states that for any event E, $P(R_i| E) = [P(R_i)* P(E| R_i)]/\sum^{k}_{j=1} P(R_j)*P(E| R_j)$. The point here is that the likelihood of two different social network models, given a certain data set characterized as event E, can be compared through a weighting procedure based on Baye's rule to give an indication of the most likely. This approach is used as an alternative to hypothesis testing in model building, and has the advantage of testing the likelihood of the model as a whole, considering all possible parameter values. In addition, it is often cited as correcting the problem of overfitting – that is inferring too much structure for the data represented. However, whether or not Bayesian weighting (or averaging) corrects or exacerbates the overfitting problem is an unresolved area of academic debate. See, for example, Domingos, 2000. These and other statistical advances in social network analysis were the subject of several papers in the National Research Council Workshop Report on Dynamic Social Network Modeling and Analysis (Brieger, Carlson, and Pattison, ed., 2003).

and Analysis: Workshop Report and Summary, National Research Council, National Academies Press, Washington DC, 2003.

Johnson, J.C. and M. L. Miller, "Deviant social Positions in Small Groups: The Relation between Role and Individual", Social Networks 5:51-69, 1983.

Johnson, J.C. and B.R. Finney, "Structural Approaches to the Study of Groups in Space: A Look at Two Analogs", Journal of social Behavior and Personality 1(3): 325-347, 1986.

Johnson, J. C., J. Boster, and L. Palinkas, "Social Roles and the Evolution of Networks in Isolated Extreme environments", The Journal of Mathematical sociology, …..

Johnson, J.C., and D. Parks, "Communication Roles, Perceived Effectiveness, and Satisfaction in an Environmental Management Program", Journal of Computational and Mathematical Organizatoin Theory Vol 4(3) 23-239, 1998.

3. SNA AS AN INTEGRATIVE METHODOLOGY
MR. GEORGE DAVIS, CARNEGIE MELLON UNIVERSITY

George B. Davis is a Ph.D candidate at the Carnegie Mellon University in Pittsburgh, PA where he received his B.S. in Computer Science in 2003 and a Masters of Computation, Organizations and Society in 2007. Mr. Davis' research interests include Network Analysis, Strategic Network Formation and Spatial Logistical Networks.

Mr. Davis provided an overview of dynamic SNA modeling capabilities and discussed different aspects of the utility of diverse types of network analysis models

Current Capabilities for Dynamic Analysis

Network models can be used to identify targets of interest in adversarial networks. Understanding the network facilitates disrupting it by identifying people who are critical to the network's movement or access to resources, or who can provide information about the network, or who can, if influenced, impact the network activity. Modeling can also be used to assess the impact of actions taken. However, model outputs should be interpreted in light of the data quality, data and model bias and assumptions encoded in the model.

Because networks model fine-grained relations on individuals, they require significant data and supervision relative to coarser alternatives, such as large scale econometrics. Network models are best applied to analyze activities which produce large volumes of data (such as communications) and on populations with complex structure (such as cellular organizations) that are thus poorly understood by coarser methods.

Meta-matrix analyses, i.e., multi-modal analyses, are needed to identify the key players and how to influence them. Modeling can indicate whether two critical actors are linked and the potential impact of isolation. The analytical modeling provides the ability to conduct "what-if" exercises to explore possible impacts of proposed actions to influence or disrupt the network.

Social network analysis is sometimes assumed to apply only to networks of individual humans bound by social ties. However, understanding real world systems may also require understanding non-social ties, such as those between people and resources, tasks, knowledge and locations. Networks including multiple types of nodes are called multi-modal, or, when represented in matrix form, a meta-matrix. Analysis of these kinds of networks can allow us to extend typical SNA groups (such as identifying critical actors) to non-human elements such as resources and locations, and to give new criteria for critical individuals such as access to exclusive resources. Dynamic Network Analysis (DNA) is the term given by Mr. Davis and Dr. Carley's group to the use of multiple node types, as well as temporal and spatial attributes, in modeling as much detail regarding a system as is supported by the data. It is often hard to get adequate data for accurate static network analysis; dynamic analysis, demands even more data. This is in contrast (as complement, not replacement) to the approach of reducing available data to a single "True" social network.
Modeling a network necessarily involves simplifying to some extent. A balance must be made

between a depth versus clarity of representation. Even complex, multi-modal networks are already summaries of even more complex processes. To maintain necessary realism in a representation, we need rigorous ways to extract accurate model networks from data on real systems. Success will be measured by accurately accomplishing a task in the original system from the predicted behavior in the model. It is important to re-contextualize an analysis when applying it to a real system.

> State of the Art: SNA and Dynamic Network Analysis (DNA) can be integrated with existing sensor systems of all types. Sampling can be used to get dynamic data sets in existing contexts. However, complex networks are simplifications, so an analyst must understand how they simplify.

Key Challenges and Questions

- Often models don't distinguish between a lack of data and data confirming the absence of a tie.
- What is our ability to distinguish between a lack of data and data confirming the absence of a tie? How do we capture emergent data?
- "Cold spots" in networks are sometimes just as important as active nodes. How do we capture such metrics?
- A data-driven problem and a theoretical exploration may require very different approaches.
- We need to be able to integrate behavioral aspects and human factors into an understanding of a network and its contexts.
- How does one use data to assess different aspects of intent: proximate, situated, persistent, strategic, and committed? Is it: Believable? Deducible? Answerable? What are the collectivity effects?

References

The following technical reports produced by researchers at Carnegie Mellon University provide examples of applying network analysis concepts and techniques to data from automatically collected spatial and/or temporal sensors.

Davis, George & Carley,Kathleen. (2007). Simultaneous Inference of Places, Activities, and Behavioral Classes in Maritime GPS Traces. ***Carnegie Mellon University, School of Computer Science, Institute for Software Research, Technical Report, CMUISRI07113***.

Davis, George & Carley,Kathleen. (2007). Computational Analysis of Merchant Marine Global Positioning Data. ***Carnegie Mellon University, School of Computer Science, Institute for Software Research, Technical Report, CMUISRI07109***.

This paper on detection and analysis of the group spends significant discussion on proper contextualization of a computational technique.

Davis, G.B., Carley, K.M., Clearing the FOG: Fuzzy, overlapping groups for social networks, Soc Netw (2008), doi:10.1016/j.socnet.2008.03.001

This is a recent CASOS paper that demonstrates contextualization in an unusual domain (medical discourse communities) as well as a formal "sensor system" (paper copublication).

Malin, Bradley & Carley, Kathleen. (2007). A longitudinal social network analysis of the editorial boards of bioinformatics and medical informatics journals. ***Journal of the American Medical Informatics Assoc***, 14, 340-348.

This is Kathleen's original description of Dynamic Network Analysis as incorporating multiple entity types, change over times, large networks, and uncertainty.

Carley, Kathleen. (2003). Dynamic Network Analysis. Pp. 133-145 in Committee on Human Factors, National Research Council, ***Dynamic Social Network Modeling and Analysis: Workshop Summary and Papers***, edited by R. Breiger, K. Carley, P. Pattison. Washington, DC: National Academies Press.

IV. GOVERNMENT USERS' PANEL

A panel made up of government representatives was convened to discuss how SNA is being or could be used to meet National Security objectives. Each panel member spoke on their personal/professional experience with SNA to address US government problems. These applications range from strategic long-range planning to short term, operational action guidance.

Dr. David Dornisch, U.S. Government Accountability Office (GAO)

Dr. Dornisch discussed three applications of SNA at the GAO. While SNA holds promise to help the GAO analysts operate more efficiently, there are significant difficulties in applying SNA to GAO problems. These have as much to do with organizational resistance as with the method itself. Methodologically, it is difficult to translate network analytic concepts into useful GAO-type questions. This is due primarily to two factors: "interorganizational" surveys are very difficult and there are problems working with bi-modal data. Organizational challenges include the relevance of SNA in a high-pressure setting with tight timeframes and a need for parsimonious, non-theoretical reports. Because of clients' limited knowledge of network analysis, there is a need for developing better graphics and for synthesizing large quantities of data.

Dr. Peter Brooks, Office of the Director of National Intelligence

Dr. Peter Brooks from the Office of the Director of National Intelligence participated in the Government Panel. He offered, for inclusion in the seminar report, a new DNI report on data mining, which is included in the appendix and which can be downloaded at:

<http://odni.gov/reports/data_mining_report_feb08.pdf>

Dr. Elizabeth Warner, Joint Improvised Explosive Device (IED) Defeat Organization (JIEDDO) Operational Cell

The objective of using SNA at JIEDDO is to provide situational awareness for defeating IEDs. SNA approaches to answering situational awareness questions have parallels to operations research. As in operations research, when being used in contexts of high-stakes, operational decision-making, it is vitally important that the analytic community (in this case, SNA experts) help customers understand what products and methods are appropriate to different situations.

Questions of network scalability and data collection arise in this application, with no common answers apparent. Timeliness constraints and data completeness are the key challenges. These are being addressed at JIEDDO in three ways:

- Data:
    - Data collection and management
    - Development of human terrain teams (Human terrain teams markedly and positively impact data collection and fidelity)
    - Development of relational data bases

- Sensitivities:
  - Network techniques
  - Integration of other analytic capabilities
  - Understanding that not all networks are equal
- Computational models:
  - Potential to provide insight into missing data[42]
  - Potential to model "what if" scenarios
  - What is the impact of tactical SNA-informed actions?
  - How do you measure the effectiveness of analysis, particularly when events are avoided or prevented?

Dr. Elisa Bienenstock, National Security Innovations

Utilization of SNA to meet operational needs of government will require turbo-charging the methodology relative to what is required for research. Issues include meeting critical time scales, dealing with large but incomplete datasets, and the realization that implications of the findings have consequences. State of the art software packages for SNA require sophisticated knowledge of programming and familiarity with network methodology. This currently creates a problem in government applications, where the norm is often that analysis is performed by people without extensive training in SNA.

Some methods that have proven useful over the years in decision-making analysis in a national security context–such as game theory–can be combined with SNA. The strength of this combination is that it integrates the rational actor decision-making framework with the relational analysis of SNA.[43] This combination of Game Theory and SNA is an example of promising avenues to investigate to advance SNAs potential value. Indeed, there is a lot of work to be done in utilizing what is already doable with SNA along these lines.

A major barrier to advancement of SNA within the government is the misconception that the use of link charts within the Intelligence Community signals the use of SNA, which it does not.

Main points made by panel members:

- SNA is applicable across many government agencies at different levels of analysis from tactical to strategic. There are different challenges, however, to be overcome, depending on the application. Thus must involve knowledgeable analysts working in partnership with the government customer for appropriate use and inferences.
- SNA is a piece of a puzzle, but is not a silver bullet.
- A central voice within organizations for providing emphasis on SNA can facilitate the use of

[42] Workshop participants observed that this might be addressed by an expanded sensitivity analysis, rather than by data imputation. However, the effects would depend on the theroetical/substantive model being implemented.

[43] Bienenstock and Bonacich Game-Theory Models for Exchange Networks:Experimental Results, Sociological Perspectives, Vol. 36, No. 2,(Summer, 1993), pp. 117-135, University of California Press

best practices and expertise, consolidate funding for leveraging efforts effectively, and encourage appropriate interpretation of results.

- Example: Human terrain teams now have their own committee under the Office of the Secretary of Defense for oversight and have $60M funding.
    - Better integration and/or means for interaction is needed between academics and practitioners.

V. ROUND TABLE DISCUSSION

The participants at the seminar joined in a roundtable discussion to summarize the implications of the presentations. Outstanding questions and Comments generated were:

- What are some of the methods available and appropriate to quantify uncertainty in data, theory, and modeling methods? How well are these articulated by the SNA community?
- Can we predict how well a model will perform? Estimate uncertainties?

Note: The SNA experts asserted that there were, indeed methods and procedures by which the performance and uncertainty of social network models can be, should be, and are routinely assessed. However, they acknowledged that the SNA community had done a poor job of communicating what those were and providing academically rigorous discussion of such methods. This is a technical gap that should be addressed in the future by the SNA community.

- What is the predictive value of SNA? For instance, why can't SNA predict national elections?
    - What is missing from attempts to do so?
    - Can we remove some constraints?
    - Do we need different data?
    - The academic community struggles with understanding what a policy maker expects of SNA. In light of that, they are concerned with how SNA can provide inputs to the policy making process with the proper caveats.
- Decoupling of emergent networks, and/or fragmentation of existing networks, is a key indicator of changes in network(s). However, the path that follows is important to observe to know if that change will be persistent. Too often an analysis stops short of asking the following questions:
    - Will new paths develop?
    - How might the network reform?
    - Can SNA be used to study the effects of "Black Swans"? If so, what are the best ways to do so?
    - How far can one extrapolate from data known to exist?

These latter two questions did not have any ready answers from the participants. Emergent thematic elements of participants' discussion were the following:

- For better or worse, many parts of DOD desire and expect SNA to be predictive (e.g., predict the Hamburg terrorist cell). This can be a problem.
- Problems emerge when integrating network analyses. At the strategic level a key question is: Where (i.e., on which actors, based on which relationships, with what boundaries, and at

what level) am I going to concentrate the analysis?

- Some generalizations of meta-patterns may be useful to reduce "surprise."
- Compare difficulty of turbulence predictions to SNA predictions.
- Blogs can serve as proxies for social contexts in some instances (e.g., Danish cartoons)
- Suggestions:
    - Identify the top 10 problems within each primary government user, and from that compile a list of "Top 100" research problems for the academic community to tackle.
    - Develop a directory of existing SNA data bases with information on the purpose, quality, pedigree, resources, strengths, and weaknesses.
    - Develop a secure internet database of SNA data bases.

VI. SNA STATE OF ART, PROMISES, AND CHALLENGES
PROFESSOR RONALD BREIGER, UNIVERSITY OF ARIZONA

Professor Breiger is a Professor of Sociology at University of Arizona. His interests include social networks, stratification, mathematical models, theory, and measurement issues in cultural and institutional analysis. http://www.u.arizona.edu/~breiger/

The final seminar agenda item was a presentation by Professor Ron Breiger. He provided his view of the state of the art for SNA, in the context of what he has seen of U.S. Government needs, both as an academic researcher and as he heard the day's briefings. He discussed areas where he saw promise that SNA could be applied and challenges where he felt research should be focused.

Assessment of State of Art, Needs, and Opportunities

The state of the art in SNA embodies concepts that can be readily applied today. The Sinjar Report from the Counter Terrorism Center (CTC) in the Department of Social Sciences at the US Military Academy (www.ctc.usma.edu) provides an example of one such opportunity today with public resources at hand. The Sinjar report is an analysis of over 600 individual records on foreign fighters entering Iraq via Syria between August 2006 and August 2007. Among the many reasons the CTC work is impressive is that the data and interpretive reports are public, thus allowing SNA researchers in the academic community to learn more about important problems and to test their own network analyses. (Public sharing of data by the Government with the SNA community, in cases where such sharing is appropriate, had been a point featured in the 2003 National Research Council report.)[44]

The concept of "structural equivalence" might be used to aid in the disambiguation of individuals' identities in networks and to discover data coding errors. The example echoes a point made by Dr. Bienenstock: that we are not yet at a stage where SNA can be completely automated, and that the calibration of multiple methods on the same datasets is desirable.

Professor Breiger introduced his discussion of the promises of SNA with reference to a 2006 statement of Nancy Hayden's on the need for theoretical understanding of "the social meaning" of links and structures, or what she termed "an interpretive science of sensemaking."[45] Professor Breiger had felt that quite a few of the day's presenters had referred to some aspect of this need for an interpretive frame for SNA. He noted the recent increase in attention within social science (sociology in particular) to works spanning SNA and cultural analysis. In using the term "culture" he wished to avoid many of the usual connotations with reference to "national culture," "national

[44] National Research Council (2003). *Dynamic Social Network Modeling and Analysis: Workshop Summary and Papers*. Ronald Breiger, Kathleen Carley, and Philippa Pattison, editors. Committee on Human Factors. Board on Behavioral, Cognitive, and Sensory Sciences, Division of Behavioral and Social Sciences and Education. Washington, DC: The National Academies Press. Online at www.nap.edu. The emphasis on public data sharing with the SNA community appears, e.g., on p. 14 and pp. 369-70.

[45] Nancy K. Hayden, "Assessing Threats and Risks: A Wickedly Complex Problem," presented at JTAC, University of Chicago, April 2006.

character," or "ultimate values." Instead, he urged a focus on "local practices, in context," including sets of skills, styles, and habits from which people actively construct strategies for action, and modify those strategies as events unfold.[46] He felt that this level of meaningful activity, closer to "ground-level," was one of great relevance to, e.g., the activities that Elizabeth Warner referred to in her presentation on the analysis of social networks on and near the battlefield. Moreover, with reference to a line of research of Steve Borgatti's,[47] Professor Breiger argued that, without culture, network analysts can "get it wrong." Specifically, with reference to the hugely popular concept of network "centrality," this line of Borgatti's research shows that specification of local practices (whether "what is flowing" through given network connections is gossip, emotional support, used goods, viral infection, package delivery, money exchange, and so forth) is necessary prior to pressing any of the "compute centrality" buttons available in software programs, in order to employ the particular mathematical form of centrality (geodesics, paths, walks, trails, and so on) that is relevant to the given network and analytical problem.

Professor Breiger went on to review other recent developments relevant to an interpretive frame for SNA. One means of adding a temporal dimension to networks is provided by recent work on narrative networks. Harrison White writes that a network tie "can be seen as the whole set of stories defining the historical relation of [a given] pair of identities…. Conversely, a story can be equated to a set of ties."[48] A forceful illustration of such ideas is Tammy Smith's reconstruction of narrative sequences of events as told by members of different groups (Italian and Croatian migrants from the Adriatic region of Istria) under conditions of extreme ethnic conflict. Of particular interest are events at the boundary of the conflicting narratives, which may act as bridges between them, crystallizing new meanings.[49]

At a different level, new methods for tracing the unfolding of network evolution during intervals as short as several seconds are being developed.[50] To research the frameworks of meanings constructed by social actors as they structure their networks and formulate and carry out strategies of action, quantitative and formal techniques are very useful but often need to be combined with qualitative forms of research, as illustrated in a recent study of youth activist networks in Brazil.[51]

The "local practices" approach to culture might, Professor Breiger suggested, have particular

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[46] Ann Swidler (1986), "Culture in Action: Symbols and Strategies."*American Sociological Review* **51**: 273-86.
[47] Stephen P. Borgatti (2005), "Centrality and Network Flow." *Social Networks* **27**: 55-71.
[48] Harrison C. White (1992), *Identity and Control: A Structural Theory of Social Action* (Princeton University Press); 2nd ed. to be released in 2008.
[49] Tammy Smith (2007), "Narrative Boundaries and the Dynamics of Ethnic Conflict and Conciliation." *Poetics* **35**: 22-46.
[50] For example, James Moody, Daniel A. McFarland and Skye Bender-DeMoll (2005), "Dynamic Network Visualization: Methods for Meaning with Longitudinal Network Movies" *American Journal of Sociology* **110**: 1206-1241
[51] Ann Mische (2007), *Parisan Publics: Communication and Contention across Brazilian Youth Activist Networks* (Princeton University Press).

relevance for the study of strategic cultures. Documents and concepts (such as ideas, statements, or sentences concerning what to do) are two distinct orders of information that might be related to each other, and their overall patterning discovered by an analyst, via techniques such as Galois lattices or related methods that are employed by social scientists to study similar situations.[52] In this sense, a "strategic culture" is an interrelated network of concepts of action, where the relations are the documents (or persons) that share them.

Two additional ideas on networks and culture were suggested by Professor Breiger. Cultural forms of social interaction (such as household visits to mark the Lunar New Year in China) provide occasions to model networks at a more macro level, such as relations among occupational groups.[53] Second, the degree of success of organizations in cooperating to enhance the development of civil society may be assessed using SNA, as illustrated in Doerfel and Taylor's study of the network dynamics of interorganizational cooperation in Croatia.[54]

Turning finally to the subject of Challenges, Professor Breiger raised two concerns. First, the analysis of social networks is by no means a "silver bullet" or a set of techniques that can be applied without a great deal of work in defining what the problem is and how a specific analysis might address that problem. There is a need to "think outside the (computer) screen," Professor Breiger suggested, and the more automated the analysis, the more worried Professor Breiger was that opportunities for insight and discovery might be passed by.

Professor Breiger suggested that it is useful to distinguish two forms of generality of relevance to network analysis. One type of approach is to get at fundamental principles of networks by abstracting away from context, or by beginning with elementary network processes and "letting them run" – in effect, by removing networks from context. This is a fine approach, one that contains much brilliant work, that suggests useful applications, and that should continue to be centrally supported, for all these reasons. But Professor Breiger nonetheless wanted to contrast this approach with another, in which generality is attained by modeling networks *within* their context. For example, Mark Mizruchi has asked: how does the network among corporations (measured by interlocks among boards of directors) affect the corporations' contributions to political parties and candidates?[55] Another example of a useful question (with reference to the CTC's Sinjar study): What is a theory of recruitment to jihadi activism (and how might that theory involve networks in analyzing the dynamic

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[52] John W. Mohr and Vincent Duquenne (1997), "The Duality of Culture and Practice…," *Theory and Society* **26**: 305-56; see also Ronald L. Breiger and John W. Mohr (2004), "Institutional Logics from the Aggregation of Organizational Networks: Operational Procedures for the Analysis of Counted Data." *Computational & Mathematical Organization Theory* **10**: 17– 43.

[53] Yanjie Bian, Ronald Breiger, Deborah Davis, and Joseph Galaskiewicz (2005), "Occupation, Class, and Social Networks in Urban China." *Social Forces* **83** (2005): 1443-68.

[54] Marya L. Doerfel and Maureen Taylor (2004), "Network Dynamics of Interorganizational Cooperation: The Croatian Civil Society Movement."*Communication Monographs* **71**: 373-94.

[55] Mark S. Mizruchi (1992), *The Structure of Corporate Political Action: Interfirm Relations and their Consequences* (Harvard University Press).

trajectories of recruits)? Questions such as these imply, in contrast to the first approach to generality, the use of social networks to model the context, rather than to begin by stripping the context away. Here the emphasis is on the wider, substantive questions to which a formal network analysis might contribute – if that formal analysis is positioned usefully and correctly with reference to the broader questions posed. Professor Breiger thought that George Davis's presentation on dynamic modeling did an exemplary job of illustrating both of these forms of relevance.

The final challenge that Professor Breiger posed was the following. Granted that SNA and DNA shine a bright light on many problems of great analytical and substantive importance, what other important concerns might be left in the shadows of that light? We need answers to this question in order to place bounds on the usefulness of the network approach as it is instantiated in any particular applications, governmental or academic, as well as for purposes of improving that approach. Professor Breiger suggested some candidates for concerns that might be pushed into the shadows, to the detriment of clear thinking about important problems:

- *Social movements*. Various accounts in the media and elsewhere in the public domain portray a widespread, popular involvement of people participating in various forms of activity (ranging from negative opinions of the West to legal forms of protest to extreme violence) across the Middle East and elsewhere, for example creating a link between opposition to the Soviet army in Afghanistan and opposition to Coalition military forces in Iraq or to NATO forces in Afghanistan. Portrayal of opposition groups as "terrorist networks" may obscure forms of movement activity that, to be correctly understood analytically and as objects of government policy, need to be understood in terms of social movements. Here the concept of "network" crowds out and obscures the concept of social movement.
- *Religious sects or movements; political dissidents*. The concern here is similar to the one above.[56]
- *Historical Memory*. Collective memory is the phrase sociologists use to refer to ways in which various interested social groups engage in contention over how important historical events are to be interpreted. It is argued, for example, that Abraham Lincoln as a symbol of racial equality is a relatively recent development.[57] Struggles among factions of terrorist or dissident groups, as well as struggles between such groups and governments, are in part correlated with these kinds of symbolic struggles. (Recall for example the furor over depiction of the Prophet Mohammed in Danish newspaper cartoons.) But if "network analysis" is understood as the study of static structures or as an application of purely formal dynamics, then the concept pushes aside the study of how people and groups struggle to

[56] See e.g. Albert J. Bergesen, ed. (2008), *The Sayyid Qutb Reader: Selected Writings on Politics, Religion, and Society* (New York and London:Routledge).

[57] Barry Schwartz (1997), "Collective Memory and History: How Abraham Lincoln Became a Symbol of Racial Equality," *The Sociological Quarterly* **38**: 469-96; Barry Schwartz (1996), "Memory as a Cultural System: Abraham Lincoln in World War II." *American Sociological Review* **61**: 908-27.

reinterpret their past.

- *Institutions and States*. It seemed to Professor Breiger to be a commonplace that writers in the media and elsewhere identify "terrorist networks" with "the new terrorists of today who are different because they are non-state actors." In this way, the concept of "network" is opposed to the idea that terrorists might be guided (the old-fashioned way, or in innovative new ways) by states and by the institutional agencies of states. The identification of "networks" with non-state actors is clearly and seriously misleading, and thus detrimental to productive analysis, to the extent that it is known that states do actively or covertly sponsor or support terrorist groups or activities.

In concluding his comments, Professor Breiger pointed to a recent BAA suggesting that these analytic challenges are to an increasing extent being understood and addressed by DTRA.

VII. SUMMARY, DISCUSSION POINTS, AND THEMES

The following questions and/or key discussion points arose during the day:

- Dynamic SNA and theoretical underpinnings
    - How has SNA evolved over the past the five years to contribute to, or draw upon, theoretical social science inquiry?
    - How have new concepts in theory of social networks contributed to advancements in SNA? In what application areas have these advancements had an impact?
    - What is meant by "dynamic" social network analysis? In response to what factors are social networks transformed? In what contexts are these factors activated? What types of social network transformations are possible, and what combination of contexts and factors contribute to that outcome?
    - How can one move beyond the intuitive visualization of network data toward a well-defined methodology with rigorous analytical strategy.
- Dynamic SNA and Methodology
    - What are the gaps and challenges in SNA and how are they being addressed? Some examples:
        - Incorporation of culture, customs, lifestyles, and other behavioral aspects, into multi-level systems
        - Theoretical formulation, representation, interpretation and validation of emergent phenomena and network structures
        - Multi-layer scaling between different types of networks and sub-networks (e.g., large-scale variations in time constants, distance parameters)
        - Structural analysis and inference/predictions about future network behavior
        - Sensitivity analysis and uncertainty measurements in social networks
- What is the role of SNA as a tool: Forensic? Diagnostic? Theoretical? Prescriptive? Predictive?
- Can SNA help look at problems 10-20 years into the future? How?
- How can the participating agencies, academic institutions, and/or other research entities focus SNA efforts to achieve a coherent understanding for developing and/or implementing SNA tools? Some ideas were:
    - Build a "Top 10" list of problems that USG wishes to use SNA to address, both within participating agencies and integrally across agencies. Develop research priorities around the gaps that currently exist in addressing such problems.
    - Identify a set of goals for research, common to the DOD and other government agency (OGA) practitioners.
    - Better articulate the formal theory of SNA in order to
        - Understand its utility relative to different problems
        - Comprehend how it works with other methods for "holistic" solutions

        - More broadly incorporate and address cultural factors
- How can the participating agencies leverage each other's resources?
    - Share data among DOD and OGA practitioners
    - Make completed networks and analyses available across organizations

Discoveries and Themes:

1. SNA is being used by academics and USG agencies on a spectrum of problems ranging from tactical to operational to strategic. These applications, and the degree of data granularity in the analyses, were quite diverse, as were the specific tools used.
2. While there does appear to be some convergence on publically available "best practice tools," none of these are particularly user-friendly and packaged for off-the shelf applications without some degree of individualized training and/or interaction with the developer.[58] At least two USG entities were building their own in-house tools.
3. To the participants' knowledge, none of the tools have been used in formal benchmarking exercises against one another.
4. Individual practitioners apply criteria for establishing analytic "validity" on a case-by-case basis, with no agreed upon standard in the field for defining "successful" application of SNA tools, or best practice approaches to uncertainty and sensitivity quantification.
5. Data gathering and structuring is a major effort for SNA (usually at least 2/3 of the analysis effort). There is much room for improving efficiency and advancing research within the community by collaboration among analysts on all aspects of data in the SNA process. Similarly, the basic and applied research may be vastly improved by creating a means for archiving and sharing "built networks."
6. There is a lack of understanding by many users of exactly what SNA is and is not and where to go to learn best practices. This may be due in part to a need for better articulation of the theoretical framework within which SNA fits as an analysis tool, as well as needs for methodological improvements. The DOD, other government agencies, and academia, though they sometimes have conflicting needs that require respect (e.g., classified data versus open access), can often benefit by working together on a common set of goals and by coordinating research projects where appropriate, thereby leveraging each organization's resources.
7. Social network theory is a relatively underdeveloped area within the field, whether as to: 1) the types of social networks there are, and how they may be differentiated, 2) the source and nature of network dynamics, and/or 3) the relationships between social networks and other social existents with which they are interwoven, including groups, movements, organizations, institutions, nations, civilizations, cultures and other forms of social structure. It is important that social network theory keep pace with data-based empirical networks and formal models in order to provide short-term focus and longer-term scientific progress. Since considerable

[58] Commonly referenced tools, available for free download and supported by a community of users, are UCINET developed and maintained by Borgatti, http://www.analytictech.com/downloaduc6.htm, ORA and other dynamic network analysis tools at Carnegie Mellon University, http://www.casos.cs.cmu.edu/computational_tools/tools.html, and PAJEK developed for analysis and visualization of large networks http://pajek.imfm.si/doku.php

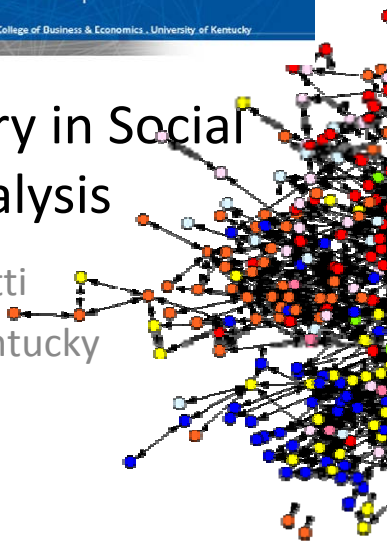
potentially useful data is not available, and some can never be available, especially individual and collective intentionality, coherent and effective theory will be a critical component.

To facilitate continued exploration and progress on these issues, ASCO recommends making this seminar an annual event. The annual seminar could provide a venue for government organizations to discuss their programs, identify common issues, and propose and adopt research goals. Researchers from academic institutions could in turn be asked to brief the government on what's new, different, or changed in the field and hear from the government what improvements are needed for applications of concern to the national security community. In this way, the community will be able to focus their attention on identification of the most useful SNA development efforts. Discussions could be conducted in a classified session on one day to identify key USG applications and problems of interest; only a subset of academics will be able attend. A second day of unclassified briefings and discussions would follow.

ANNEX I – PRESENTATIONS

Overview of Theory in Social Network Analysis

Steve Borgatti
University of Kentucky



Objective

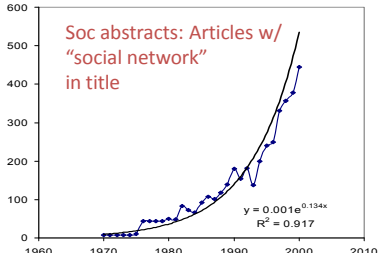
- I was tasked with providing a …

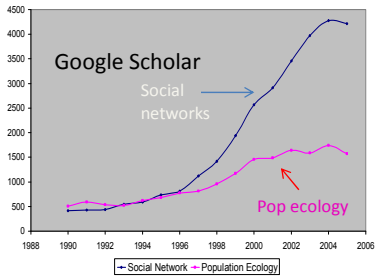
> ".. .discussion that reviews the different theoretical paradigms assumed in the foundations of SNA construction …"
>
> --- Nancy Hayden

- Already on my mind …
  - Recent address at social network conference
  - DTRA grant to develop "an integrated theory of social networks"

Some difficulties with the task

- Rising popularity of network analysis has created much room for confusion and chaos (the other C^2)
  - Confusion with link analysis / data mining
  - Confounding with non-social networks
  - Cultural differences among academic fields (e.g., physicists & sociologists)
  - Consultant quackery
  - Cultural differences between academics and military/gov





C^2C^5

Example: The "N" word

From DTRA BAA: "We want to predict when **networks** will emerge"

No. Different from groups. Today's terrorists are organized as networks

No. It's a new organizational form, and we need new netcentric warfare and network science and dynamic network analysis to defeat them

I hate to interrupt your increasingly long monologue, but is there anything you can tell me that I can actually use?

You mean groups?

All groups are networks. The US Army is a network, in fact, a collection of networks. You just mean that the network structure of terrorist groups is less hierarchical / more decentralized than, say, armies or states.

Look, a network is a collection of ties of a given type among a set of nodes. If I pick the people in this room to be my nodes, I can look at all kinds of ties among them, such as friendships, collaboration, deference, and map them out. Each type of tie forms a network. Analyzing that network helps understand the dynamics & outcomes …

Agenda

- Overview of the field as a discipline
- Characterizing network theorizing
- KeyPlayer project
- Where do we go from here?

Development of the Field

- 1900s
  - Durkheim
  - Simmel
- 1930s Sociometry
  - Moreno; Hawthorne studies
  - Erdos
- 1940s Psychologists
  - Clique formally defined
- 1950s Anthropologists
  - Barnes, Bott & Manchester school
- 1960s Anthros & graph theorists
  - Kinship algebras; Mitchell
  - Harary establishes graph theory w/ textbooks, journals, etc
- 1970s Rise of Sociologists
  - Modern field of SN is established (journal, conference, assoc, etc)
  - Structuralist agenda set
  - Milgram small-world (late '60s)
  - White; Granovetter weak ties
- 1980s Personal Computing
  - IBM PC & network programs
- 1990s Adaptive Radiation
  - UCINET IV released; Pajek
  - Wasserman & Faust text
  - Spread of networks & relational thinking; Rise of social capital,
- 2000s Physicists' "new science"
  - Scale-free
  - Small world

Formal Organization

- Professional association (since '78)
  - Int'l Network for Social Network Analysis - www.insna.org
  - Incorporated 1993
- No department of Social Network Analysis
  - But a few centers …

- Academic Centers
  - LINKS (U of Kentucky)
  - Network Roundtable (U of Virginia)
  - CASOS (Carnegie Mellon)
  - Networked Governance (Harvard)
  - Watson Research Center (IBM)
  - NICO (Northwestern)
  - ISNAE
  - IMBS (UC-Irvine)
  - Coalition Theory Network (European consortium)
  - CCNR (Notre Dame, Physics)
  - Nuffield Network Researchers (Oxford)
  - Bader Lab (U of Toronto, Biology)
  - CSSS (U of Washington, Statistics)

Conferences & Workshops

- Sunbelt annual conference (since '79)
  - 2001: Budapest, HUNGARY
  - 2002: New Orleans, USA
  - 2003: Cancun, MEXICO
  - 2004: Portorôs, SLOVENIA
  - 2005: Los Angeles, USA
  - 2006: Vancouver, CANADA
  - 2007: Corfu, GREECE
  - 2008: St Pete, Florida, USA
  - 2009: San Diego, USA
  - 2009: Trento, ITALY

- Regular Training Workshops
  - Sunbelt social networks conference
    - 1-day workshops
  - Academy of Management
  - University of Essex, UK
    - 2-week
  - CARMA
    - 1-week
  - ICPSR-Michigan
  - LINKS center, U of Kentucky
    - Coming soon!

Resources

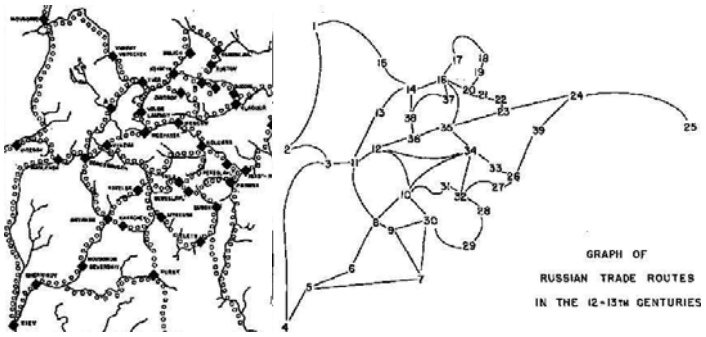
- Specialized journals
  - Social Networks, (since '79)
  - CONNECTIONS, official bulletin of INSNA
  - Journal of Social Structure (electronic)
  - CMOT
- Specialized Textbooks
  - Kilduff & Tsai, 2004
  - Scott, John. 1991/2000
  - Degenne & Forsé. 1999
  - Wasserman & Faust. 1994
- Specialized software
  - UCINET 6/NETDRAW;
  - PAJEK
  - SIENA
  - STRUCTURE; GRADAP; KRACKPLOT
- Listservs & Groups
  - SOCNET listserv (1993)
  - REDES listserv
  - UCINET user's group

What's distinctive about SNA theory?

- Social actors not viewed as independent of each other
  - Embedded in a rich web of social relations and interactions
  - Not so much atoms as molecules
  - Lack of independence has theoretical and statistical implications
- Who you are connected to – where you are located in the network – affects what happens to you
  - Social environment as determinative
  - Opportunities and constraints you will encounter

The network model

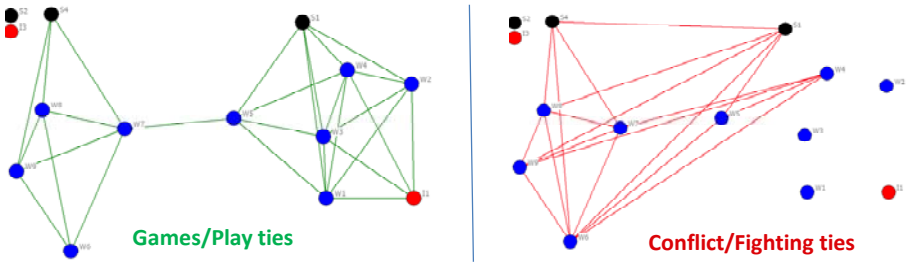
- Model groups/populations as networks of ties
  - Function of model is to focus on what's important



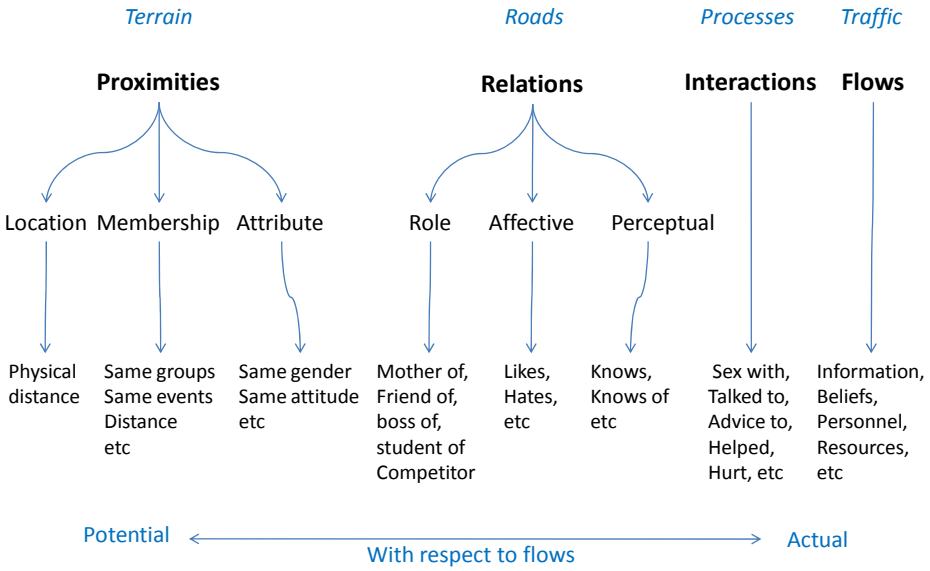
Pitts, 1978/79. The Medieval River Trade Network of Russia Revisited. Social Networks 1:285-292

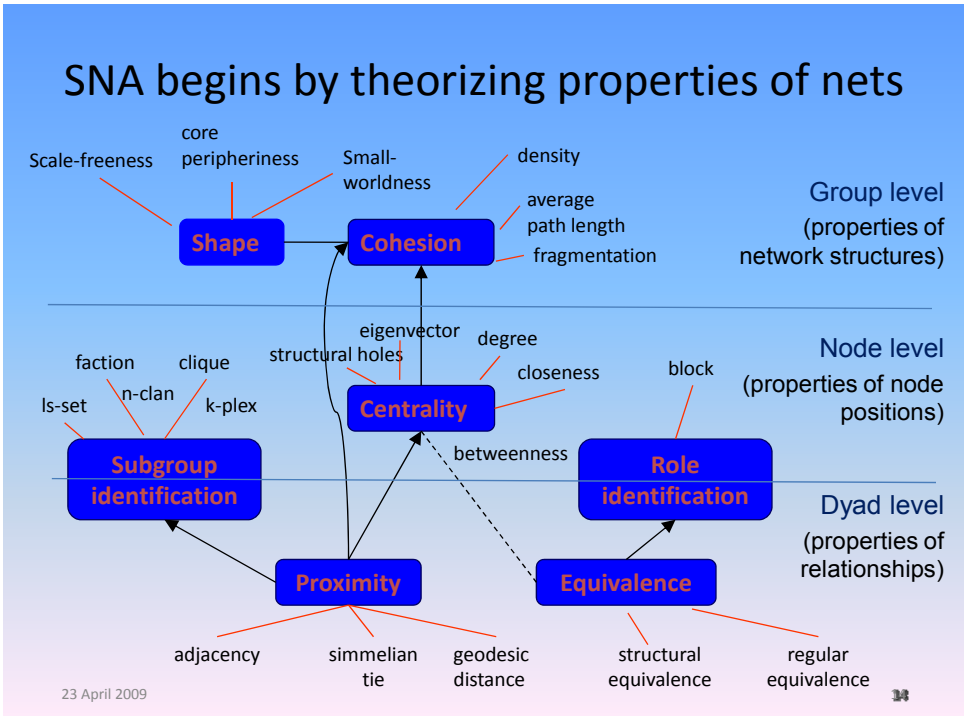
So what's a network?

- Set of actors
  - In turn, may be modeled as bundles of attributes
- Set of multiplex relationships among pairs of actors
  - Multiple kinds of tie (aka relations)



Dyadic Relationships among Nodes





SNA proceeds by asking

- What determines these properties?
  - Antecedents or causes of network properties
- What are the consequences of those properties?
  - What do network properties cause?

Classical Network Research Agenda

NETWORK PROPERTIES	Dyadic Relationship e.g., valence of tie; strength of tie; bridgingness	Node Position e.g., betweenness centrality; structural holes	Network Structure e.g., density; avg path length; clustering coef, fragmentation
Antecedents	Who chooses whom and why? Predicting **tie formation**, maintenance, decay	Who will occupy what position in a network? E.g. predicting **centrality**	Why does a network have the structure it does? (e.g., scale-free; small world) How do **structures evolve**?
Consequences	What rights & obligations are entailed by given relations? E.g., predicting attitude transfer	What are the op-portunities & constraints that result from occupying a certain position in the network?	How does a network's structure (i.e., a group's structure) affect what happens to that group?

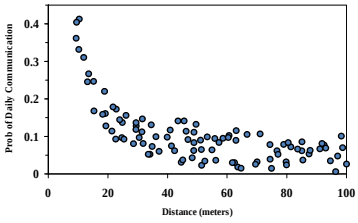
Catalogue of antecedents & consequences

- Review of empirical findings

Antecedents of Dyadic Relationships

- Structuralist / opportunity-based
  - Spatial-temporal proximity
  - Activity foci
  - Opportunity transitivity
  - Multiplexity
  - Role / rules (e.g., ISO9000)
- Functionalist / needs & benefits
  - Similarity attraction
  - Status attraction
  - Dependence / exchange-theoretic
  - Balance or dissonance theoretic

Communication as a function of physical distance



Confiding between & within genders

	Male	Female
Male	1245	748
Female	970	1515

Challenges in explaining dyadic relationships

- Multitude of possible tie types
  - Determinants of friendship not same as advice etc.
  - Tend to group at level of expressive/instrumental etc.
- Context, conditions, moderators
  - When do birds of a feather flock together and when do opposites attract?
  - Cultural differences, goal contexts
- Separating relational stages/actions
  - Making overtures vs maintaining a relationship
- Lack of distinction between relations, interactions, flows friendship → communication → info transfer

Classical Network Research Agenda

NETWORK PROPERTIES	Dyadic Relationship e.g., valence of tie; strength of tie; bridgingness	Node Position e.g., betweenness centrality; structural holes	Network Structure e.g., density; avg path length; clustering coef, fragmentation
Antecedents	What determines what kind of relationship will exist between a given pair of actors?	What determines who will occupy what position in a network?	Why does a network have the structure it does? How do structures evolve?
Consequences	What does it mean for a pair of actors to have a certain kind of relationship? What rights & obligations are entailed?	What are the opportunities & constraints that result from occupying a certain position in the network?	How does a network's structure (i.e., a group's structure) affect what happens to that group?

What kinds of consequences have been studied?

List of favorite topics explained by network theories in Management journals

- Attitude similarity
- Job satisfaction & commitment
- Power
- Leadership
- Getting a job
- Getting ahead
- Employee performance
- Team performance
- Turnover
- Conflict
- Organizational citizenship behavior (OCB)
- Creativity & Innovation
- Unethical behavior

Courtesy of Dan Brass

Explaining Node Consequences

Dimension	Performance	Homogeneity
Why is …	S(A) > S(B)	S(A) = S(B)
Example:	**Social Capital** studies. e.g. Status attainment as a function of social access to resources	**Diffusion/Adoption** studies e.g., Adoption of attitude as a function of attitudes of alters
View of DV:	Value-loaded	Neutral
DV typically expressed as:	Monadic Node property e.g., degree of success	Dyadic or Monadic e.g., has same attitude as e.g., which attitude node has
Typical scale type of DV:	Continuous e.g., degree of success	Categorical e.g., 1=same attitude, 0=different attitude

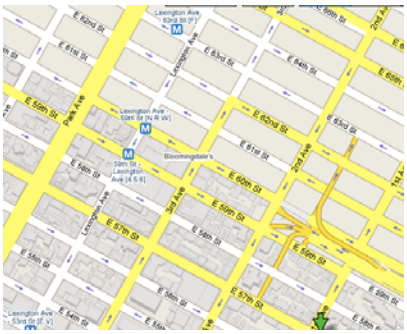
*DV = Dependent Variable

Explanatory Paradigms

- It's the environment, stupid!
  - Hallmark of SNA is to look outside the node to explain what happens to the node
  - Very rich conception of environment that includes
    - Not just who you are connected to, but
    - How your contacts are connected to each other, and, ultimately
    - Your position in the larger network
- Within this basic concept, multiple approaches
  - Flow perspective
  - Architecture perspective
  - Adaptation perspective
  - Cognitive association perspective

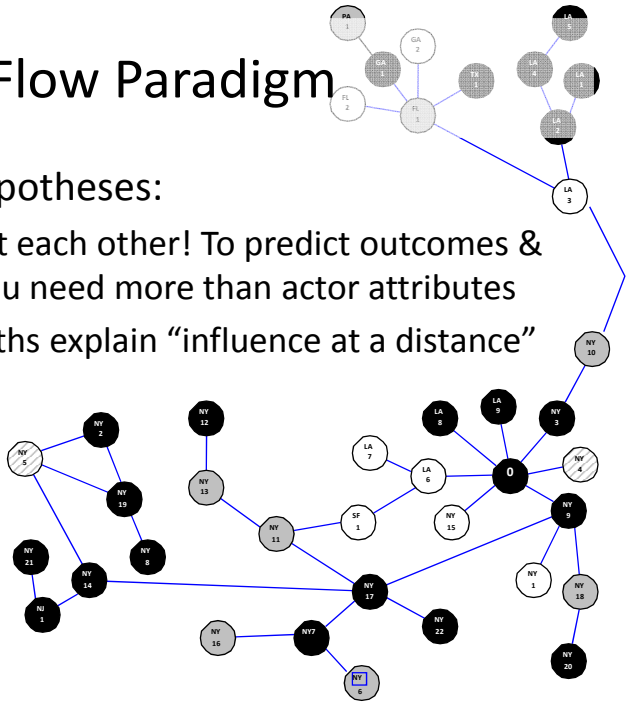
Flow Perspective

- Ties are conduits, such as pipes, through which things flow
  - Resources, information, innovations, viruses, etc
  - Roads and traffic



Flow Paradigm

- Canonical hypotheses:
  - Actors affect each other! To predict outcomes & behavior, you need more than actor attributes
  - Network paths explain "influence at a distance"



Discovery of HIV by Bill Darrow at the CDC

Network of sexual relations among first AIDS patients

Flow-based Theories

Explaining PERFORMANCE

- Social Resource Theory (Lin; Flap).
  - Successful people are those that suck resources (e.g., money, information) through their social ties
  - You are only as good as your personal network

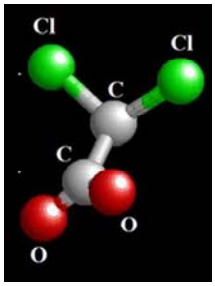
$$s_i = \sum_j a_{ij} s_j$$

Explaining HOMOGENEITY

- Diffusion Models
  - Attitudes, ideas, diseases etc transmitted from person to person via interaction
  - Mechanisms such as influence, imitation, learning
  - Specific submodels specifying conditions under which, say, imitation occurs, or the number of converts are needed in your personal network before you convert

Architecture Perspective

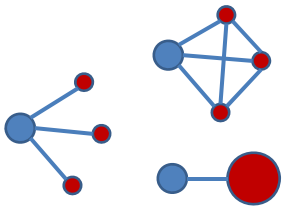
- Ties seen as girders, beams, joists, columns, etc that create framework or structure
  - Ties bind together nodes into a larger object with new function
    - Emergent properties; sui generis
  - Constructing molecules from arrangements of atoms
    - Again, properties of the whole are not the same as those of its constituents



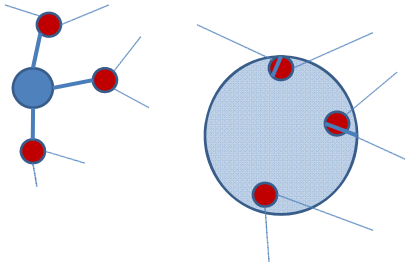
Architecture-based theories

Explaining PERFORMANCE

- Power benefits of structural holes (Burt)
  - Easier to negotiate with 3 separate nodes acting independently than 3 connected nodes acting as 1
    - E.g., WGA union

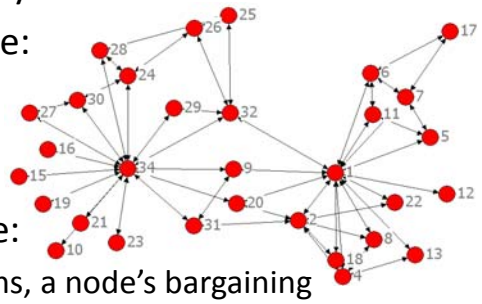


- Agents
  - Others act on your behalf, effectively becoming another arm

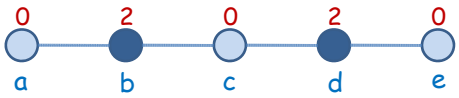


Adaptation Perspective

- Ties seen as defining a social environment
- Node respond similarly to similar environments
- Homogeneity example:
  - Equally central nodes develop similar personalities

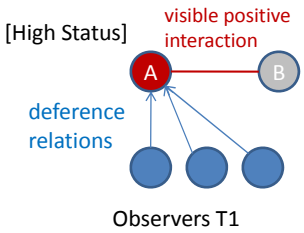


- Performance example:
  - In bargaining situations, a node's bargaining strength depends on the weakness of its partners



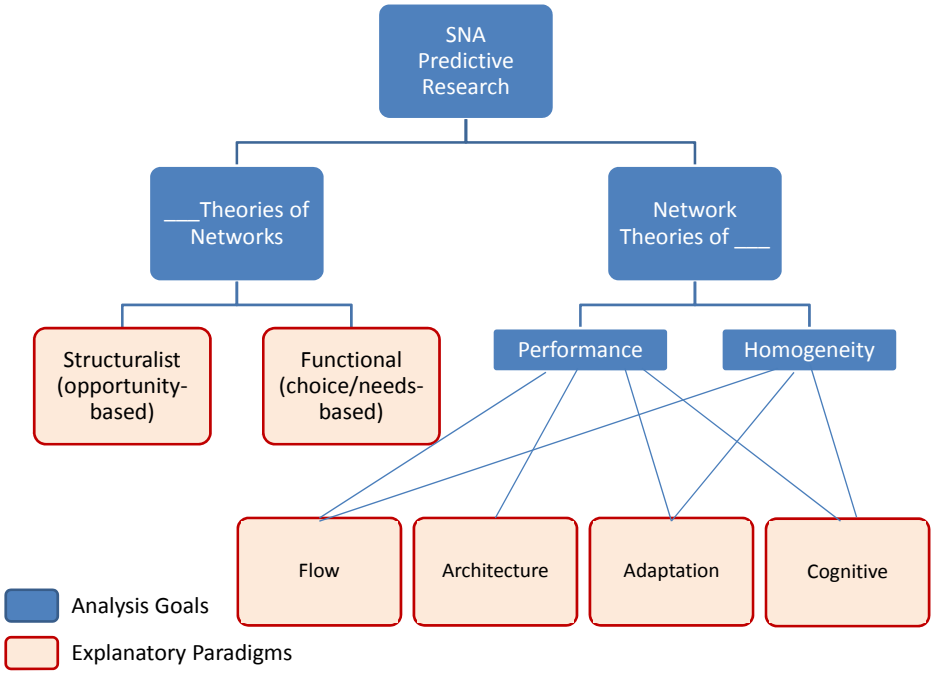
Experimental exchange networks

Cognitive Association Perspective



Explaining HOMOGENEITY

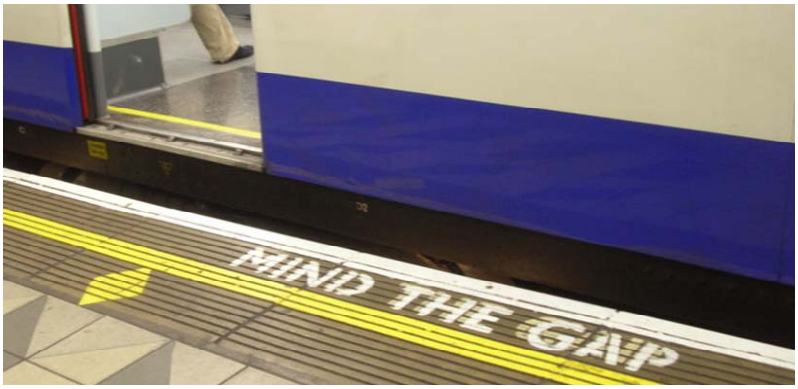
- Inference of similarity due to association
  - True in its consequences



Moving from research to application

- Prediction to optimization

  Antecedents → Network Variables → Outcomes



Key Player Project

Who are the key players in a network?

- It depends on …
  - whether you are looking for individuals or ensembles
  - the purpose
- On the value of problem-centered research

Funded by the
Office of Naval Research
Thanks Rebecca Goolsby!

Borgatti, S.P. 2003. The Key Player Problem. Pp. 241-252 in *Dynamic Social Network Modeling and Analysis: Workshop Summary and Papers*, R. Breiger, K. Carley, & P. Pattison, (Eds.), National Academy of Sciences Press.

Why do we want to know who the key players are?

We want to **remove them** – to maximally **disrupt** the network	**DISRUPT**
We want to **help** them – in order to make network as a whole **function better**	**ENHANCE**
We want to identify key opinion leaders – to influence the network	**INFLUENCE**
We want to know who is in the know – so we can question or surveil them	**LEARN**
We want to remove them – to redirect flows in the network toward more convenient players -- pruning	**REDIRECT**

Key Player Needs by Field

	DISRUPT	PROTECT	INFLUENCE	LEARN	REDIRECT
SECURITY	Who to **arrest or discredit** to disrupt ops	Who to **protect** among allied group	Who to turn or plant info with	Who is best positioned to know most	Who to remove to redirect flows
PUBLIC HEALTH	Who to **immunize or quarantine**		Who to select as PHAs for interventions	Who to study explain spread	
MANAGE MENT	Who to hire away from competitor	Who to give more of a stake in org to avoid turnover	Who to get on board before launching reorg		Who to add/replace to remove drag on good emps
MARKETING		Which happy users to empower	Identify key mavens to sell on your stuff		

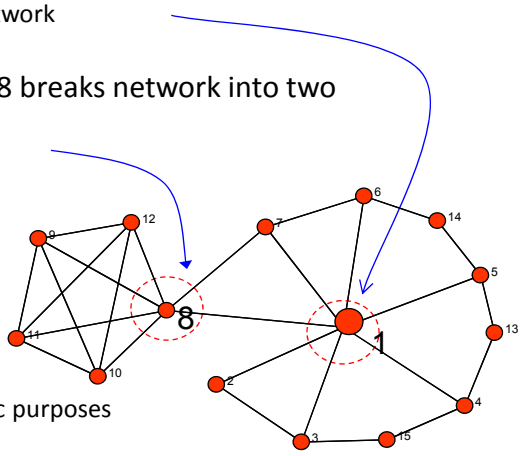
KeyPlayer Research Objectives

- Develop metrics to quantify potential disruption, influence, surveillance etc.
  - Off-the-shelf SNA measures not optimized for these tasks
- Develop combinatorial optimization algorithms and fast heuristics for maximizing metrics given solution parameters
- Predict what happens to the network post-intervention

DISRUPTION

The Design Issue

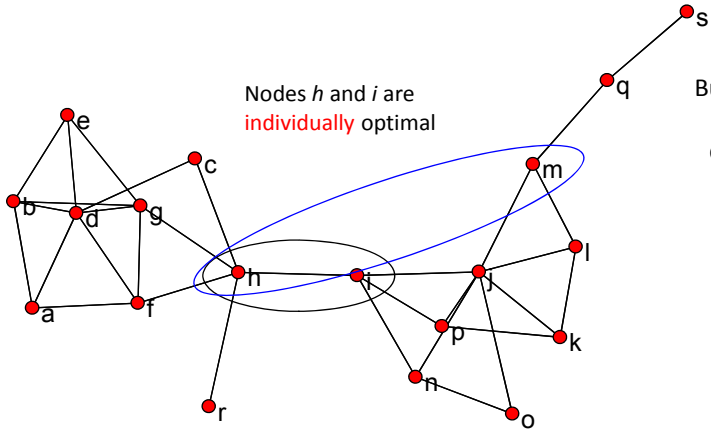
- By standard off-the-shelf measures of node centrality, node 1 is the most important player, but deleting it …
  - does not disconnect the network
- In contrast, deleting node 8 breaks network into two components
  - Yet node 8 is not highest in centrality
- No off-the-shelf centrality measure is optimal for the purpose of disrupting networks
  - Nor any of the other specific purposes



DISRUPTION

The Ensemble Issue

Structural redundancy creates need for choosing complementary nodes



Nodes *h* and *i* are individually optimal

But deleting both is no better than deleting *h* alone -- *h* and *i* are redundant

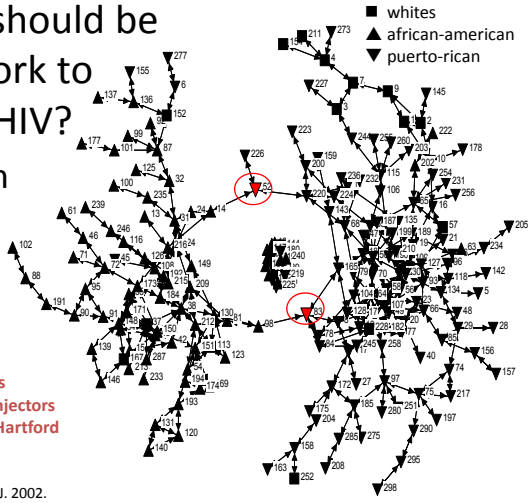
In contrast, {*h*,*m*} splits graph into 4 fragments (is optimal)

- Choosing optimal **set** of *k* players is not same as choosing the *k* best players

No. of components $CR = \frac{c-1}{n-1}$	**CR = 0.00**	**CR = 0.12**
No. of disconnected pairs $F = 1 - \frac{2\sum_{j<i} r_{ij}}{n(n-1)}$	**F = 0.111**	**F = 0.529**
Distance-weighted fragmentation $dwF = 1 - \frac{2\sum_{i>j} \frac{1}{d_{ij}}}{n(n-1)}$	**DF = 0.556**	**DF = 0.851**

Disruption Example – health context

- Which <u>two</u> people should be isolated from network to slow the spread of HIV?
  - KeyPlayer algorithm identifies the two red nodes

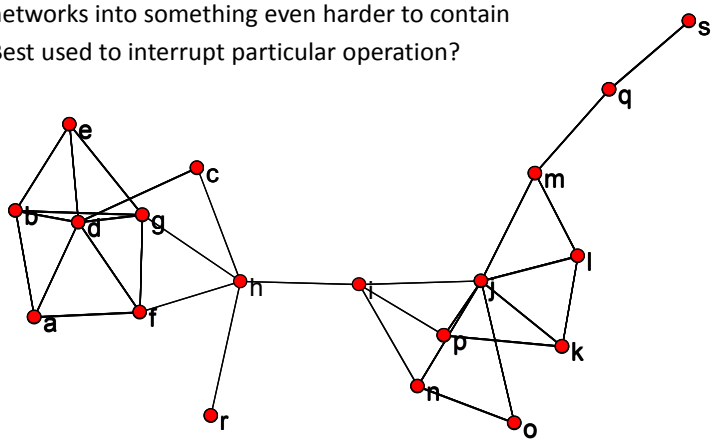


Friendship ties among drug injectors on streets of Hartford

Weeks, M.R., Clair, S., Borgatti, S.P., Radda, K., and Schensul, J.J. 2002.
Social networks of drug users in high risk sites: Finding the connections. *AIDS and Behavior* 6(2): 193-206

Caveats

- Strategy of disrupting networks by removing key nodes may be dangerous long-term
  - Ties grow back. Fragmentation strategy may effectively shape enemy networks into something even harder to contain
  - Best used to interrupt particular operation?



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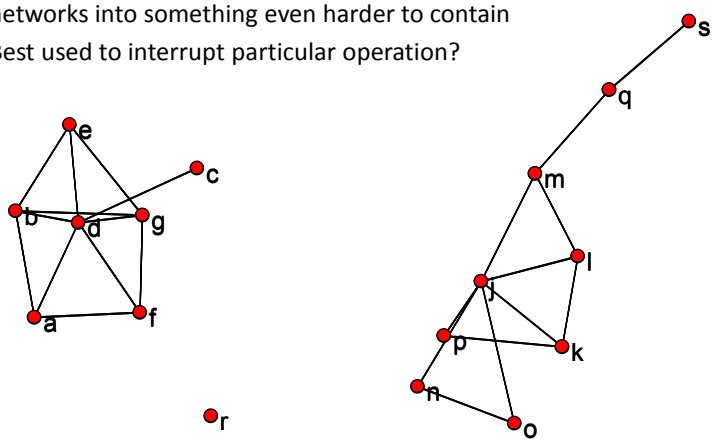
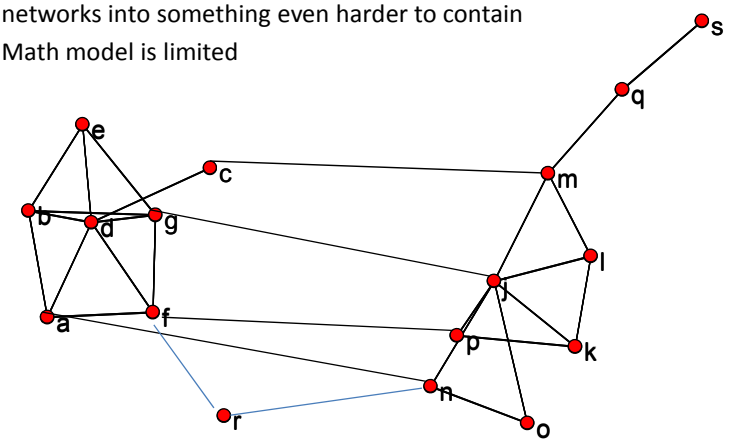


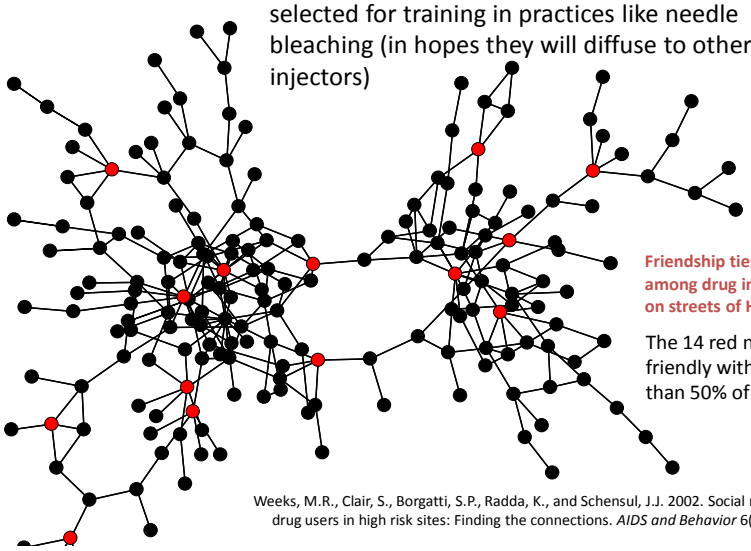
Caveats

- Strategy of disrupting networks by removing key nodes may be dangerous long-term
  - Ties grow back. Fragmentation strategy may effectively shape enemy networks into something even harder to contain
  - Math model is limited



Influence Example – health context

Which small set of drug injectors should be selected for training in practices like needle bleaching (in hopes they will diffuse to other injectors)



Friendship ties among drug injectors on streets of Hartford

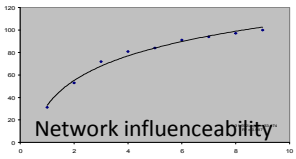
The 14 red nodes are friendly with more than 50% of network

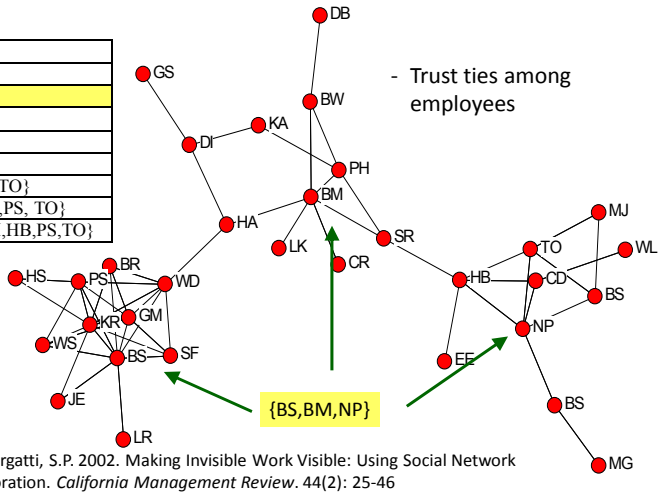
Weeks, M.R., Clair, S., Borgatti, S.P., Radda, K., and Schensul, J.J. 2002. Social networks of drug users in high risk sites: Finding the connections. *AIDS and Behavior* 6(2): 193-206

Influence Example – mgmt context

- Major change initiative is planned. Which small set of employees should we select for intensive indoctrination? in hopes they will diffuse positive attitude/knowledge to others

K	%	KP-Set
1	31	{KR}
2	53	{BM,BS}
3	72	{BM,BS,NP}
4	81	{BM,BS,DI,NP}
5	84	{BM,BS,DI,KR,NP}
6	91	{BM,BS,DI,HB,KR,TO}
7	94	{BM,BS,BS2,DI,HB,PS,TO}
8	97	{BM,BS,BS2,CD,DI,HB,PS, TO}
9	100	{BM,BS,BW,BS2,CD,DI,HB,PS,TO}





Data from: Cross, R., Parker, A., & Borgatti, S.P. 2002. Making Invisible Work Visible: Using Social Network Analysis to Support Strategic Collaboration. *California Management Review*. 44(2): 25-46

Prospects and Levers

- Objective
  - Use network influence models to maximize persuasive efforts
  - Illustrate how network perspective can be used to work with/through networks rather than against them
- Assumptions:
  - All nodes can be measured with respect to friendliness or unfriendliness to our cause (can be yes/no as well)
  - We know who influences whom
    - E.g., among physicians we have who receives referrals from whom

Borgatti, S.P. and Plant, E. 2008. Prospects and Levers. To be submitted to *Social Networks*

Prospects

- Prospects are "unfriendly" nodes that are surrounded by (influenced by) "friendlies"
  - By activating the nearby friendlies, we can try to "turn" the prospect
- Simplest formulation: $p_i = u_i \sum_j a_{ji} f_j$ (Friendliness of neighborhood)
  - u_i refers to unfriendliness of prospect *i*, a_{ji} indicates extent that *j* influences *i*, f_j gives the friendliness of node *j*. A node *i* gets a high score if currently unfriendly but surrounded by many friendlies
- Metrics of prospectness provide a way of prioritizing who to go after first
  - Identifying the low hanging fruit

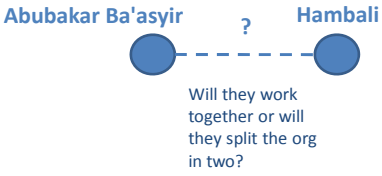
Levers

- Levers are friendly nodes that have influence ties to unfriendly nodes.
  - If activated, can be directed to try to "turn" the unfriendlies who are influenced by them
  - Metrics identify who to activate (e.g., by incentivizing) in order maximize contagion effect per resource dollars
- Simplest formulation: $l_i = f_i \sum_j a_{ij} u_j$
- Incorporating indirect influence: $l_i = f_i \sum_j \alpha^{d_{ij}} a_{ij} u_j$

u_i refers to unfriendliness of prospect *i*, a_{ji} indicates extent that *j* influences *i*, f_j gives the friendliness of node *j*. d_{ij} is the length of the shortest path from *i* to *j*. α is a constant controlling attenuation of influence across long paths.

Conclusion

- High-level outline of SNA theorizing
  - Paradigms, family trees and generic theories
  - Lenses for intelligence analysts
    - applying theories focuses attention on key things
    - analysis checklist



ANTECEDENTS OF TIES
Spatial-temporal proximity
Activity foci
Opportunity transitivity
Multiplexity
Role / rules (e.g., ISO9000)
Similarity attraction
Status attraction
Dependence / exchange-theoretic
Balance or dissonance theoretic

Network action perspective

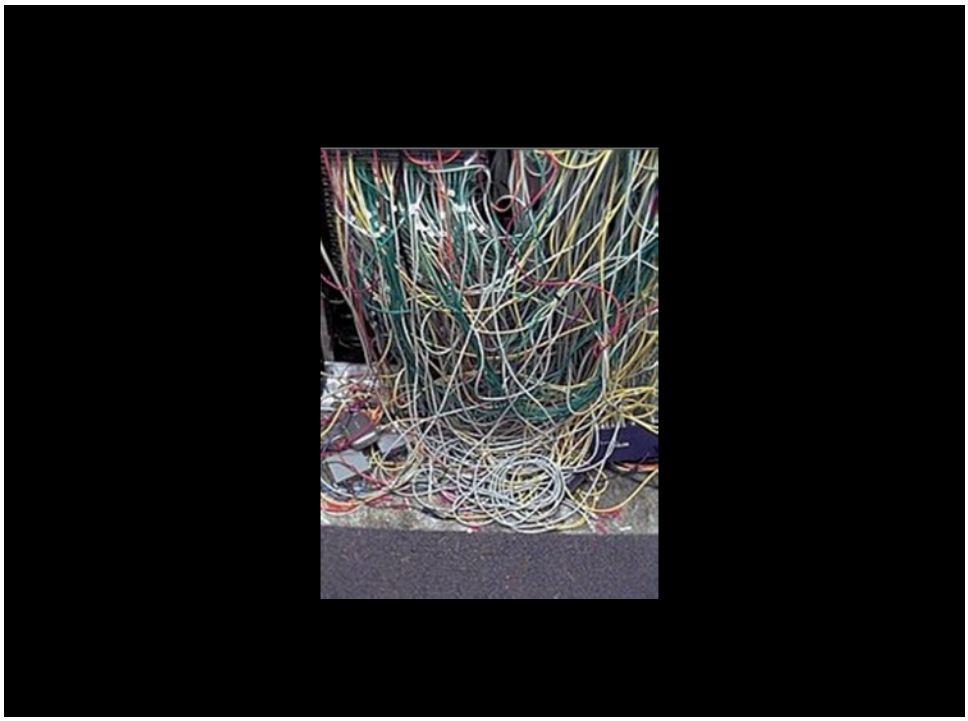
- Embeddedness
  - Army's new operational manual emphasizes population in which combatants are embedded
  - Can't just analyze ties among terrorists
- Cohesion reduction strategies, manipulating centrality, talking to A in order to move B

Conclusion – cont.

- Intro to KeyPlayer project
  - Optimization (control) versus prediction
    - In principle, the same. In practice, until we try to control, we don't know how inadequate our predicting is
  - Status of math/sim models
    - Need for breadth, judgment, larger thoughts. What we do in one arena affects the other

a process suggestion

- Develop a top 100 problem list
  - List of specific problems that DoD would like better solutions for
    - Explain them in detail, with examples
  - Ask the network community what SNA can do to solve these problems
  - Trying to answer will tell us where our theories need more specificity and where we need more empirical research
- Sponsor empirical work on populations other than US students and corporate managers



Classical Network Research Agenda

NETWORK PROPERTIES	Dyadic Relationship e.g., valence of tie; strength of tie; bridgingness	Node Position e.g., betweenness centrality; structural holes	Network Structure e.g., density; avg path length; clustering coef, fragmentation
Antecedent	…nes … …exist … pair	What determines who will occupy what position in a network?	Why does a network have the structure it does? How do structures evolve?
Consequences	…rs to …nd of relationship? What rights & obligations are entailed?	What are the op-portunities & constraints that result from occupying a certain position in the network?	How does a network's structure (i.e., a group's structure) affect what happens to that group?

e.g., Who will emerge as a central player? What leads to marginality?

Antecedents of Network Position e.g., node centrality

- Roll up of dyad-level models
  - Role / rule models (e.g., firm ceo)
  - Dependency models
    - Having something others need, e.g., expertise, power
  - Proximity / Prototypicality models
    - Physically centrality →socially central
    - Being prototypical w/ respect to culturally important attribs, e.g. being white male in white male society
  - Cross-Centrality
    - Being central in advice network leads to centrality in friendship
- Personality & skill models
  - Emotional intelligence, charisma, self-monitoring, extraversion etc
- Association models
  - Status rub-off, guilt by association

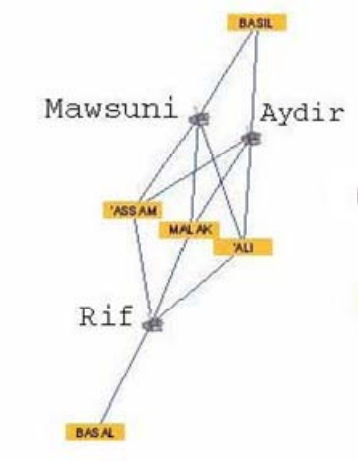
SNA State of Art, Promises and Challenges

Ron Breiger
University of Arizona
Breiger@Arizona.Edu

Current **state of art**:
--Concepts that can be applied

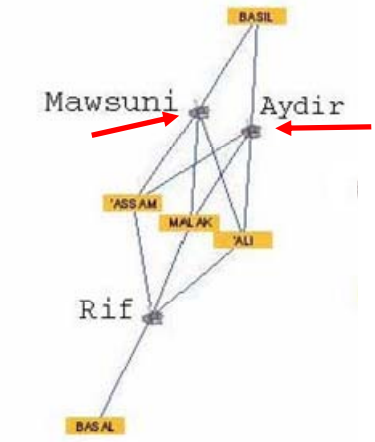
CTC (West Point) Sinjar report a detail of the network diagram*

*An article in the *Washington Post* (Jan. 21 '08) led me to the CTC website, where the data and report are publicly available.

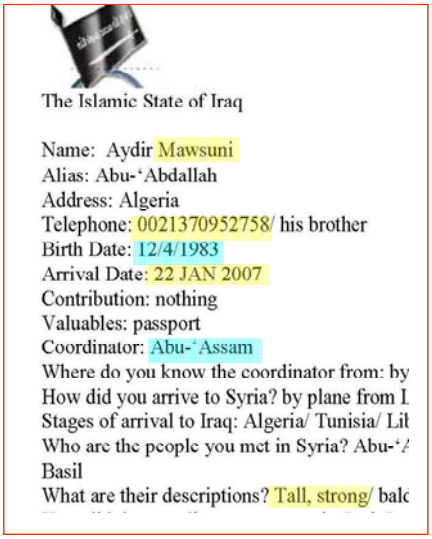


CTC (West Point) Sinjar report a detail of the network diagram

Structurally equivalent nodes (indicated by red arrows)

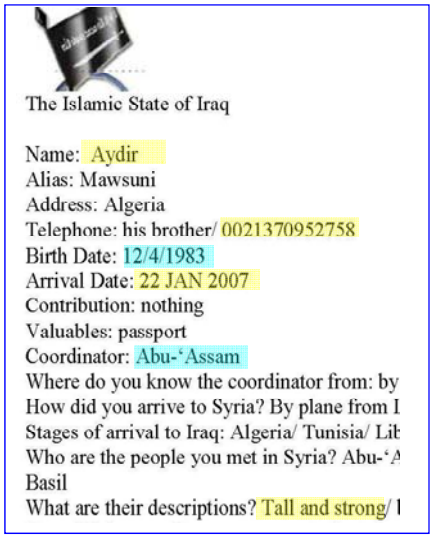


Structural equivalence ***sometimes*** means same identity; here, I believe "Mawsuni" == "Aydir"



The Islamic State of Iraq

Name: Aydir Mawsuni
Alias: Abu-'Abdallah
Address: Algeria
Telephone: 0021370952758/ his brother
Birth Date: 12/4/1983
Arrival Date: 22 JAN 2007
Contribution: nothing
Valuables: passport
Coordinator: Abu-'Assam
Where do you know the coordinator from: by
How did you arrive to Syria? by plane from I
Stages of arrival to Iraq: Algeria/ Tunisia/ Lit
Who are the people you met in Syria? Abu-'A
Basil
What are their descriptions? Tall, strong/ bald



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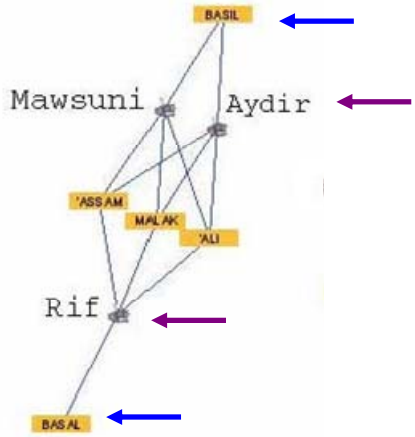
Stages of arrival to Iraq: Algeria/ Tunisia/ Lit
Who are the people you met in Syria? Abu-'A
Basil
What are their descriptions? Tall and strong/ I

CTC (West Point) Sinjar report
a detail of the network diagram

Generalized equivalence classes (shown in blue and purple)



Promises:

Networks as an aid to the study of meaning and interpretation

---

We need some theoretical understanding of ***the social meaning*** of links and structures, an interpretive science of sense-making.

--paraphrasing the audio of Nancy Hayden's talk (""Assessing Threats and Risks: A Wickedly Complex Problem") at JTAC, U of Chicago, April 2006

"Networks and Culture" – Looking Backward 21 Years to 1987

CLASSIFICATION IN ART*

PAUL DIMAGGIO

"… ***genres*** consist of those sets of works which bear similar relations to the same sets of persons. The logic behind this imagery will be **familiar to students of network analysis** as one of '***structural equivalence***' (White et al. 1976; Burt 1980)."

A fr
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class
expl
Soci
hier
formal characteristics of social structure, the organization of educational systems, and internal relations among cultural dimensions. The dynamics of ritual classification are mediated according to whether artistic production is carried out through commercial, professional, or bureaucratic means.

American Sociological Review, 1987, Vol. 52 (August:440–455)

"Networks and Culture" – Looking Backward 21 Years to 1987

DAVID JACOBSON
Department of Anthropology, Brandeis University

The Cultural Context of Social Support and Support Networks

"Just as researchers have viewed social support as **an entity** rather than as **an interpretation** of behavior, …network analysts have paid little attention to the fact that a network consists of social relationships that are based on cultural assumptions. **Analysts have focused on the characteristics of networks rather than on their cultural foundations**."

What I mean by "culture"

- **Not** "national culture" or "national character" or "ultimate values," but rather
- Local practices, in context. Repertoires or "tool kits" of skills, styles, and habits from which people construct strategies for action (Swidler).
- We are suspended in webs of meaning that we ourselves have spun (Geertz).

Citations:

Ann Swidler, "Culture in Action: Symbols & Strategies." *American Sociological Review* 51 (1986): 273-86

Clifford Geertz, *The Interpretation of Cultures: Selected Essays* (Basic Books, 1973)

Without cultural context, network analysis can get it wrong

Centrality and network flow☆

Stephen P. Borgatti*

Department of Organization Studies, Boston College, Carroll School of Management, Chestnut Hill, MA 02467, USA

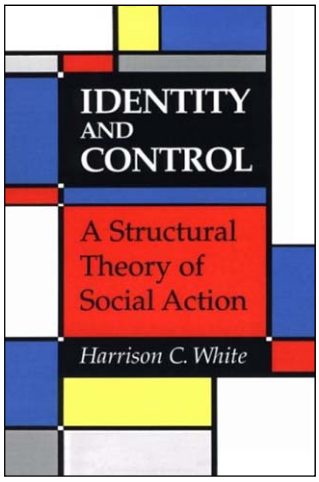
Abstract

Centrality measures, or at least popular interpretations of these measures, make implicit assumptions about the manner in which traffic flows through a network. For example, some measures count only geodesic paths, apparently assuming that whatever flows through the network only moves along the shortest possible paths. This paper lays out a typology of network flows based on two dimensions of variation, namely the kinds of trajectories that traffic may follow (geodesics, paths, trails, or walks) and the method of spread (broadcast, serial replication, or transfer). Measures of centrality are then matched to the kinds of flows that they are appropriate for. Simulations are used to examine

Citation: *Social Networks* 27 (2005): 55-71

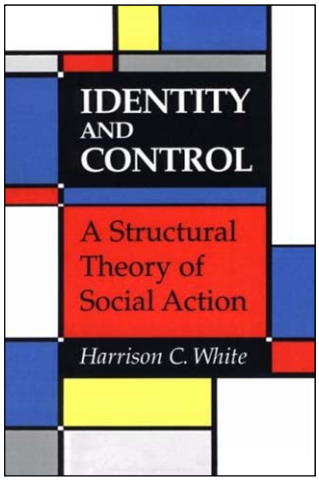
See also: David R. Schaefer, PhD diss, U Arizona, 2006

Narrative Networks (White 1992)



"A [network] tie can be seen as the whole set of stories defining the historical relation of that pair of identities."

Narrative Networks (White 1992)



"A [network] tie can be seen as the whole set of stories defining the historical relation of that pair of identities."

"Conversely, a story can be equated to a set of ties."

Narrative Networks (Smith 2007)

ELSEVIER

Available online at www.sciencedirect.com
ScienceDirect

Poetics 35 (2007) 22–46

POETICS

www.elsevier.com/locate/poetic

Narrative boundaries and the dynamics of ethnic conflict and conciliation

Tammy Smith *

Department of Sociology, Columbia University, 413 Fayerweather Hall, MC-2551, 1180 Amsterdam Avenue, New York, NY 10027, USA

Available online 15 December 2006

Abstract

Fiercely competing identity narratives provide the foundation for what often appear to be intractable ethnic conflicts. This article considers how an ethnically mixed group from the region of Istria, a site of violence between Italians and Slavs in the first half of the 1900s, has overcome persisting conflict through changes in their original identity narratives. I employ the network representation of life-stories to examine the relations among abstract elements located within the conceptual boundary between the narratives of

Narrative Networks (Smith 2007)

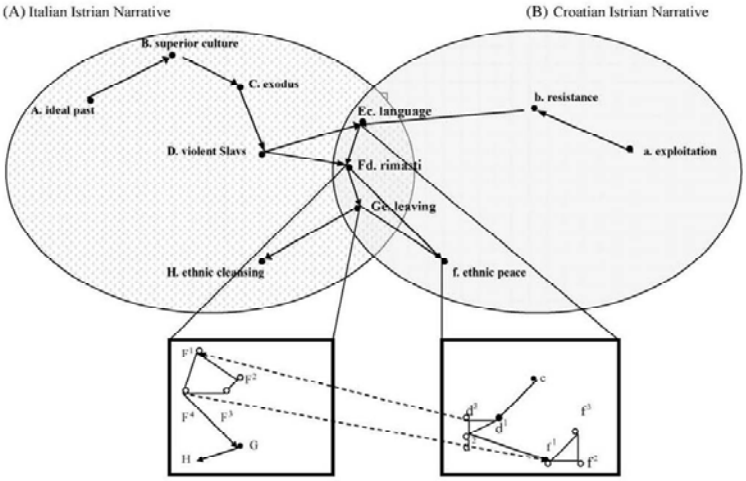
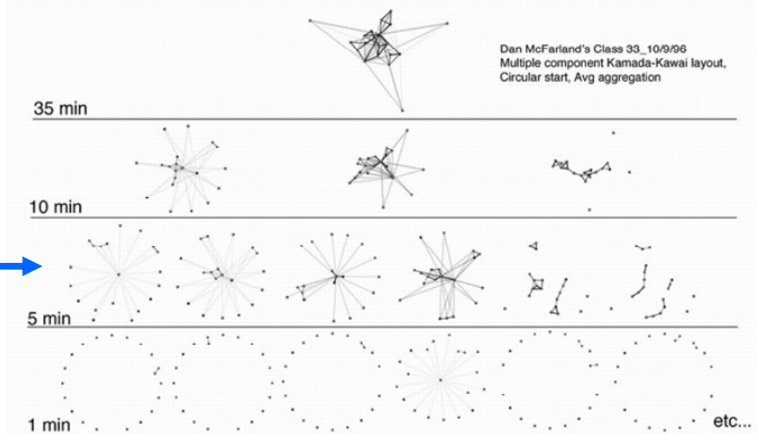


Fig. 5. Interaction of Istrian boundary concepts. *Note*: New arcs, or links, between events that define boundary elements are shown by dashed lines in the highlighted boxes. Since narrative A and narrative B represent two discrete narratives, element A in narrative A does not describe the same set of events as element a in narrative B. Only elements along the

Networks-Agency-Discourse (McFarland)

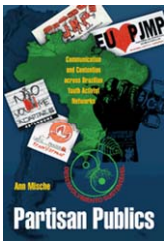
Resistance as a Social Drama: A Study of Change-Oriented Encounters[1]

Daniel A. McFarland
Stanford University



Partisan Publics (Mische 2007)

Ann Mische, Partisan Publics: Communication and Contention across Brazilian Youth Activist Networks. Princeton University Press, Dec. 2007.



"I wanted to study not just the structure of relations, but also the way that individuals and groups made sense of these networks and responded to the opportunities and dilemmas that they posed…. This book is my attempt to give voice to the contradictions and possibilities of these networks." – Ann Mische, Partisan Publics

Promises:

Networks and the analysis of strategic cultures

Duality of Culture & Practices (Mohr & Duquenne, 1997)

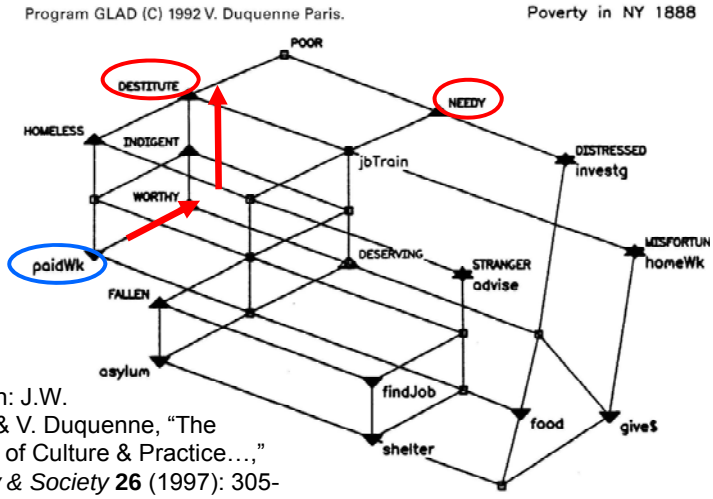


Figure 3. Lattice diagram: Duality of categories and practices – 1888.

Citation: J.W. Mohr & V. Duquenne, "The Duality of Culture & Practice…," *Theory & Society* **26** (1997): 305-56.

Promises:

Cultural ties define macro-social structure

Occupational networks in urban China: data

- Each household completed a daily log recording their social interactions during 6 days of New Year celebration in 1998.
- Representative samples from 4 cities: Shanghai, Tianjin, Wuhan, Shenzhen
- We coded household visits based on job of host and visitor
- (20 →) 13 occupational categories
- 80% of labor force in urban China have one of these jobs

Citation: Yanjie Bian, Ronald Breiger, Deborah Davis, Joseph Galaskiewicz, "Occupation, Class, and Social Networks in Urban China." *Social Forces* 83 (2005): 1443-68.

New Year's Visits among 13 Occupations

Householder 's occupation	New Year visitor's occupation													Total
	1	2	3	4	5	6	7	8	9	10	11	12	13	
1. Cadre	13	17	8	13	6	6	11	5	19	8	9	2	1	118
2. Manager	34	63	41	40	48	34	61	22	52	48	39	16	5	503
3. Scientist/professor	2	13	14	11	14	9	11	6	9	11	5	4	1	110
4. Teacher	6	8	4	13	4	6	8	3	6	7	6	1	0	72
5. Professional	6	13	8	10	14	12	13	7	14	14	9	4	0	124
6. Doctor/nurse	6	12	8	8	7	13	11	7	6	8	7	5	1	99
7. Accountant/sales	7	19	9	14	13	18	26	10	16	17	14	5	3	171
8. Legal/police	4	6	2	3	1	6	5	5	8	7	4	2	0	53
9. Admin/clerk	10	11	6	7	6	10	18	11	12	13	10	4	3	121
10. Industrial	2	13	5	9	7	10	11	3	8	26	16	8	2	120
11. Chauffeur	3	7	0	6	2	3	6	3	4	6	9	3	1	53
12. Service/commercial	6	18	6	10	4	12	23	8	15	27	19	15	2	165
13. Domestic worker	2	3	1	1	0	2	2	3	0	4	2	2	3	25
Total	101	203	112	145	126	141	206	93	169	196	149	71	22	1734

Intensities of Interaction, Four-Class Blockmodel for H4

Cadre	**0.29**	0.32	0.32	-0.03	-0.03	-0.13	-0.13	-0.13	-0.13	-0.16	-0.16	-0.16	-0.16
Legal	0.32	**0.29**	0.32	-0.03	-0.03	-0.13	-0.13	-0.13	-0.13	-0.16	-0.16	-0.16	-0.16
Admin	0.32	0.32	**0.29**	-0.03	-0.03	-0.13	-0.13	-0.13	-0.13	-0.16	-0.16	-0.16	-0.16
Business	-0.02	-0.02	-0.02	**0.13**	0.01	0.13	0.13	0.13	0.13	-0.12	-0.12	-0.12	-0.12
Manager	-0.02	-0.02	-0.02	0.01	**0.13**	0.13	0.13	0.13	0.13	-0.12	-0.12	-0.12	-0.12
Scientist	-0.06	-0.06	-0.06	-0.02	-0.02	**0.70**	0.21	0.21	0.21	-0.13	-0.13	-0.13	-0.13
Teacher	-0.06	-0.06	-0.06	-0.02	-0.02	0.21	**0.70**	0.21	0.21	-0.13	-0.13	-0.13	-0.13
Profession	-0.06	-0.06	-0.06	-0.02	-0.02	0.21	0.21	**0.70**	0.21	-0.13	-0.13	-0.13	-0.13
Medical	-0.06	-0.06	-0.06	-0.02	-0.02	0.21	0.21	0.21	**0.70**	-0.13	-0.13	-0.13	-0.13
Industrial	-0.24	-0.24	-0.24	0.04	0.04	-0.21	-0.21	-0.21	-0.21	**0.86**	0.41	0.41	0.41
Chauffer	-0.24	-0.24	-0.24	0.04	0.04	-0.21	-0.21	-0.21	-0.21	0.41	**0.86**	0.41	0.41
Service	-0.24	-0.24	-0.24	0.04	0.04	-0.21	-0.21	-0.21	-0.21	0.41	0.41	**0.86**	0.41
Nanny	-0.24	-0.24	-0.24	0.04	0.04	-0.21	-0.21	-0.21	-0.21	0.41	0.41	0.41	**0.86**

Promises:

Dynamic network analysis of the development of civil society

Communication Monographs
Vol. 71, No. 4, December 2004, pp. 373–394

Routledge
Taylor & Francis Group

Network Dynamics of Interorganizational Cooperation: The Croatian Civil Society Movement

Marya L. Doerfel & Maureen Taylor

Throughout the world, social cause organizations and independent media organizations work together, despite their differences and competition with each other for resources, toward creating civil society. This paper assesses the network dynamics of a system of cooperative competitors in Croatia. The research is framed from the theoretical perspectives of resource dependency, cooperation competition, and structural holes with results

Secretary Gates on the importance of civil society (networks)

- Interview with National Public Radio, 1/17/08
- **Q:** **"Does your experience in the Cold War also inform some of your recent remarks about so-called soft power? You – I'll summarize – encouraged the United States to spend more money and effort on nonmilitary means of influence abroad […]"**
- **A:** "Absolutely. I mean, when the Cold War was at its height, the U.S. Agency for International Development had something like 16,000 employees. It has 3,000 now. One of the points that I make, if you took all Foreign Service officers in the world — about 6,600 — it would not be sufficient to man one carrier strike group."

Promises:

Network models for attribute data
and for biographical relatedness

Singular Value Decomposition: $X = USV^T$

Usual formulas: My versions:

$(X^T X)^{-1} X^T y = b$ $VS^{-1}U^T y = b$

$Xb = \hat{y}$ $\left[UU^T\right] y = \hat{y}$

Citation: Breiger, keynote address, INSNA conference, 2005.

Singular Value Decomposition: $X = USV^T$

[U^TU] is a network among the cases.
It is of size n x n.
[U^TU] is symmetric and idempotent.

$$Xb = \hat{y} \quad \left[UU^T\right]y = \hat{y}$$

Singular Value Decomposition: $X = USV^T$

$$[U^TU]_{ij} = \|u_i\| \, \|u_j\| \cos(u_i, u_j)$$

$$Xb = \hat{y} \quad \left[UU^T\right]y = \hat{y}$$

Example: Regression study of Franco Modigliani's "Savings Hypothesis"
(Sterling 1977; Belsley, Kuh & Welsch 1980)

N=50 countries.

Dependant Variable = Average aggregate personal savings rate in country i, over the period 1960-1970

Variable	b	s.e.
POP15	–.461	0.145
POP75	–1.69	1.08
DPI	–.0003	0.0009
ΔDPI	0.41	0.196

Example of $[UU^T]$ for 4 Countries

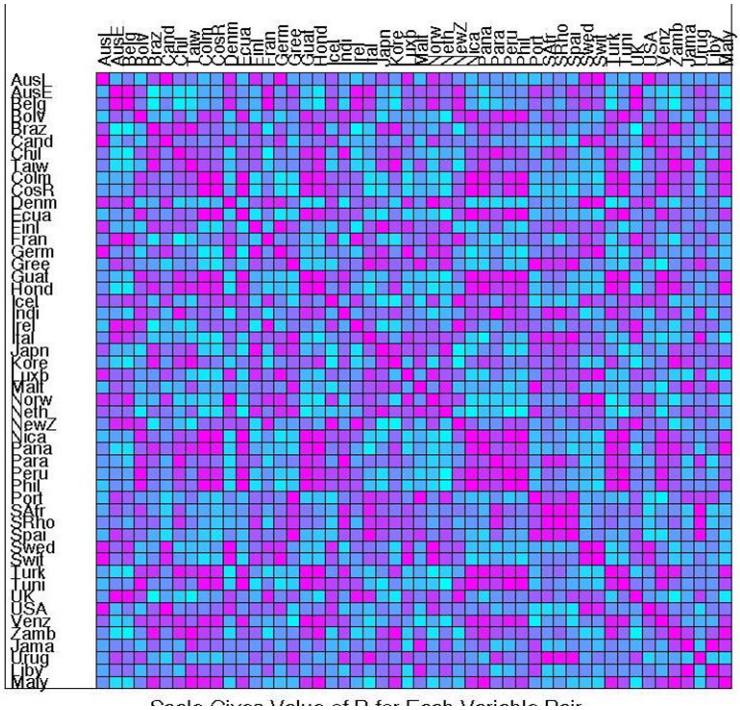
	CA	US	PR	GR	[…]			
CA	0.16	0.23	-0.05	-0.05	…	y_1	=	$\hat{y}_1$
US	0.23	0.33	-0.09	-0.08	…	y_2		$\hat{y}_2$
PR	-0.05	-0.09	0.10	0.09	…	y_3		$\hat{y}_3$
GR	-0.05	-0.08	0.09	0.10	…	y_4		$\hat{y}_4$
[…]	…	…	…	…	...	…		…

$$[UU^T]_{ij} = d_i * d_j * \cos(u_i, u_j)$$

		CA	US	PR	GR	[…]
CA	0.40	1.00	0.98	-0.44	-0.37	…
US	0.58	0.98	1.00	-0.49	-0.45	…
PR	0.31	-0.44	-0.49	1.00	0.95	…
GR	0.31	-0.37	-0.45	0.95	1.00	…
[…]	…	…	…	…	…	…

4 kinds of network (at least!)

- Social network (who likes whom…)
- Affiliation network
- Niche overlap network -- McPherson
- Network of profile similarity
  - Blau, Laumann, Fischer, McPherson, Marsden, Burt
  - I argue that multiple regression is a special case of a network of profile similarity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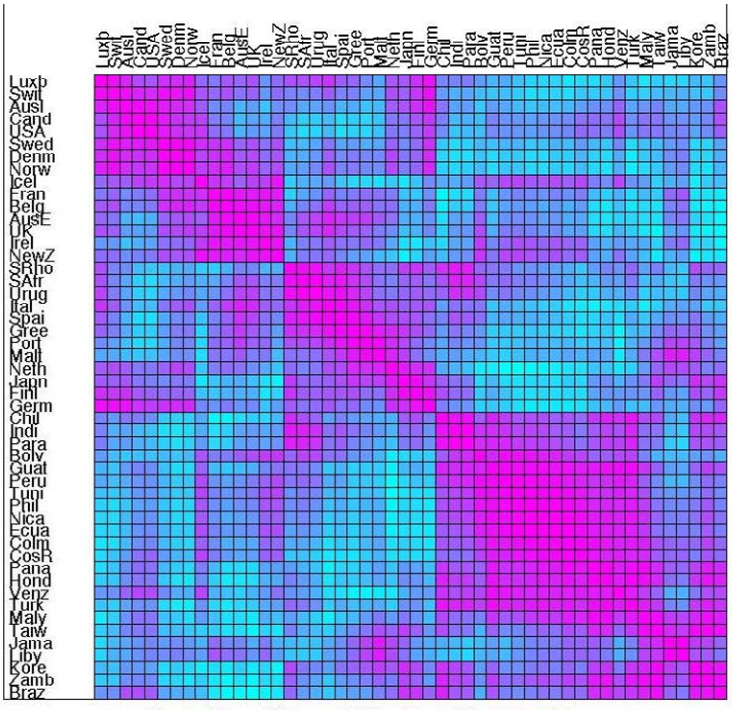
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Tuni
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Ecua
Colm
CosR
Pana
Hond
Venz
Turk
Maly
Taiw
Jama
Liby
Kore
Zamb
Braz

Contribution to Y-hat by block: block 2

	block 1	block 2	block 3	block 4	Y-hat
S. Rhodesia	-2.19	12.41	1.73	0.06	**12.01**
South Africa	1.49	7.48	2.01	-0.32	**10.66**
Uruguay	2.28	9.17	1.29	-1.24	**11.50**
Italy	4.99	8.36	-0.27	-0.73	**12.35**
Spain	2.31	9.73	0.16	0.24	**12.44**
Greece	2.40	11.41	-1.22	1.20	**13.79**
Portugal	1.70	10.05	-0.83	2.33	**13.26**
Malta	1.27	8.07	-0.34	3.50	**12.51**
Netherlands	4.10	9.91	-2.41	2.62	**14.22**
Japan	-1.39	15.67	-2.72	4.27	**15.82**
Finland	2.13	9.81	-0.57	1.55	**12.92**
Germany(F.R.)	6.14	7.61	-1.16	0.14	**12.73**

Extension to Autocorrelation Models

- Spatial or network autocorrelation

(Ord '75, Doreian & Hummon '76, Doreian '81, Marsden & Friedkin '93)

$$\hat{y} = \rho W y + X b$$

- Equivalent expression of same model:

$$\hat{y} = [\rho W + U U^{T} (I - \rho W)] y$$

Challenges:
Thinking outside the (computer) screen

Two kinds of generality in network theory

- **A. Networks removed from context**
  - Get at fundamental principles of networks by abstracting away from context or by beginning with elementary network processes and "letting them run“
    → lab experiments, multi-agent simulations, AI
  - Example question: How does a general process (like "preferential attachment") affect networks (emergence of "hubs")?

Two kinds of generality in network theory

- **A. Networks removed from context**
  - This is good, contains much brilliant work, suggests useful applications, should *of course* continue to be centrally supported,
  - but I nonetheless want to contrast it with another productive kind of generality.

Two kinds of generality in network theory

- **A. Networks removed from context**
- **B. Networks as probes to understand the contexts <u>in which</u> they are naturally embedded.**
  - **"Generality" is a tool kit that can be applied across various real-world situations or contexts.**
  - **The formal network is not separated from the social world.**

Two kinds of generality in network theory

- A. Networks removed from context
- **B. Networks <u>within</u> context**
  - **Example question: Mizruchi, political contribution networks vs. board interlocks**
  - **Another example question: What is the pattern of flows of foreign fighters into Iraq? What is a theory of recruitment to jihadi activism (and how might that theory involve networks)?**

Citation: Mark S. Mizruchi, *The Structure of Corporate Political Action: Interfirm Relations and Their Consequences*, Harvard U Press, 1992.

Two kinds of generality in network theory

- A. Networks removed from context
- **B. Networks <u>within</u> context**
  - **"In a single sentence, the Chicago school thought—and thinks—that one cannot understand social life without understanding the arrangements of particular social actors in particular social times and places" (Abbott 1997, p. 1152).**

Citation: Andrew Abbott, "Of Time and Space: The Contemporary Relevance of the Chicago School." *Social Forces* **75** (1997): 1149-1182.

Two kinds of generality in network theory

- **Abbott (p. 1166), a methodology for contextualist sociology:**
  - **We require ways of discovering natural histories: long, consistent patterns of events.**
  - **Ways of parsing careers—complex sequences with substantial environmental determinism.**
  - **Ways of describing interactional fields**
  - **Ways of investigating complex spatial interdependencies**
  - **(I would add) multiple networks.**

Challenges:

Understand the bias built into network metaphors

What does the metaphor of "social networks" hide?

- Social movement?
- Religious sect?
- Political dissidents?
- Historical memory?
- Economic organization?
- Institutions and states?

What does the metaphor of "social networks" hide?

DTRA BAA HDTRA1-06-CWMDBR, April 2006:

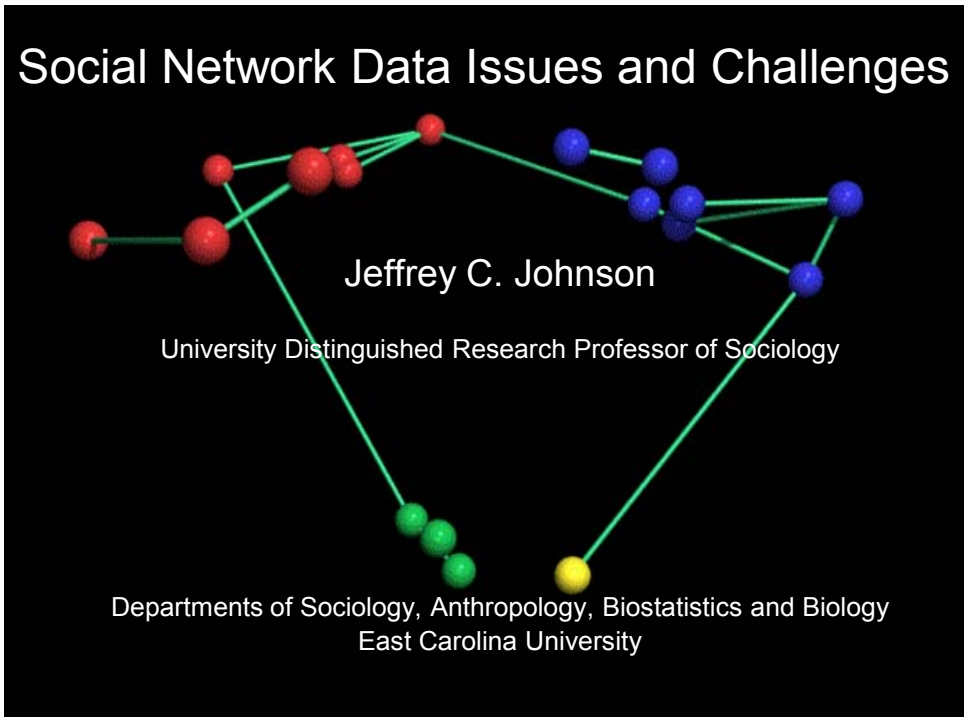
- "Although theoretical arguments on social networks underlie the analyses in many […] studies, there has been a significant lack of integration of all relevant areas of the social sciences. For example, political science offers insights on certain aspects of social networks, as does sociology, psychology, cultural anthropology, and organizational studies. The computational social sciences also offer insights ….
- "The fundamental reason for this lack of integration is that a broad, generic, adaptable, flexible and modular theory of social networks that spans all relevant disciplines has not been realized."

Hearty thanks to

Nancy Hayden,

Ross Amico,

ASCO and DTRA



Data Challenges

- Compared to the collection of other types of data in the social sciences (e.g., attribute based survey data) the collection of social network data can be quite challenging.
- A major threat to validity in social network research stems from problems of missing data that are due to a number of different sources at a number of different stages in the research process.
- One major contributor to missing data is non-response in network surveys.

Sources of Missing Data

- Missing data can enter into the picture if the network boundaries are not properly specified on theoretical or other grounds.
- Network surveys are extremely susceptible to non-response bias in that missing actors and their links can affect structural and analytical outcomes at both the network and individual levels.
- Respondents can refuse participation, can refuse to answer some or all network survey questions due to such things as interviewee burden or question sensitivity and may drop out of a longitudinal study prematurely as a result.
- The design of the study and subsequent sample or instrument design (e.g., types and forms of relational questions) for a given social network problem and context can also be important in limiting threats to validity (and this can vary cross-culturally).
- Issues of respondent reliability and accuracy have been clearly been shown to produce error of various kinds (but the error is often well behaved).
- Secondary source data can have their own inherent biases.

- We need to be aware of factors that minimize threats to validity in the collection of social network data, particularly in the complete network context.

Network Science: What's Involved?

- DATA
  - Network Data (Interaction, Advice)
  - Non-Network Data (Nonstructural Attributes)
  - Sources of Data (Primary/Secondary)
  - Measuring Ties (Level of Measurement)
- Theory (The Substance)
  - Describe
  - Explain
  - Predict
- Measures and Scope (e.g., Centrality, Clustering Coefficient)
  - Structural Features at Various Levels (Individual Actor, Group, Society)
- Theory Testing and Models (The Formalization and Validation of The Theory)
  - Standard attribute based models (linear regression)
  - Cross-sectional statistical models(ERGM, MCMC)
  - Dynamic models (SIENA)

How important is data?

Data Issues—Access, Completeness, Reliability, Validity, Etc.

A Perfect Data World

Data Sources

- Network data can come from a variety of different sources but it generally boils down to a distinction between primary versus secondary types of data.
- Secondary sources are those that already exist somewhere in print (e.g., fish exchange records, historical marriage records) or can be found electronically (e.g., Enron emails, Social Networking pages, newspaper articles).
- Secondary data by its historical and/or fixed nature dictates and limits the type of relations and levels of measurement that can be used in the course of the research.
- Primary data collection allows a greater deal of flexibility in the type, measurement and number of relations to be studied.

Forms of primary data collection and their features.

Form of Data Collection/Interview	Issues of Sensitivity	Interviewer Response Effects	Ability to Establish Rapport	Thoroughness (Ability for Elicitation)	Ease of Administration
Face-to-Face	Moderate	Moderate	Moderate-High	High	Low-Moderate
Self-Administered	Low	Low	Low	Low	Moderate
Mail Out	Low	Low	Low	Low	High
On Line	Low	Low	Low	Low	High
Phone	Moderate	Low-Moderate	Low-Moderate	Moderate	Moderate
Group Setting	Low-Moderate	Low-Moderate	Moderate	Low-Moderate	Moderate

A Perfect Data World Part 2

Informant Accuracy
What People Do, What People Say and What We Can

Expect People to Remember

Informant Accuracy in Networks: The Debate in the 80s

- The Bernard, Killworth at al. series on informant accuracy in social networks
- The Romney, Faust, Weller responses that looked at accuracy, activity and correlations to the aggregate (influenced the development of the cultural consensus model)
- The Freeman, Freeman, Romney response that informants are more accurate in reporting long term patterns
- The more recent research on ego biases in cognitive networks (Kumbasar, Batchelder, Romney, Krackhardt, Johnson)
- These all have implications on methods for assessing and weighting the reliability and validity of network data

Data Aside 1
How to measure social ties?

The Imperfect World of Data Collection

Network Measurement: Theory and Praxis

- Level of measurement for social ties
- Psychometric meaningfulness; the ability to compare across subjects/actors
- Practical aspects of collection: What method gets the highest compliance particularly in a repeated measures or longitudinal design?

Example Debate

- What type of relation? Friendship, Liking, Interaction
- What type of metric? Binary, Ratings, Rankings
- What temporal constraint? Retrospective, Prospective, Anticipatory
- The players: Lin Freeman and Kim Romney
- The Question: Ratings or Rankings?

The Imperfect World of Data Collection

Culture and Network Data

- Need to be aware of relational salience in a given cultural context.

- Follows that the sensitivity of relational questions varies cross-culturally (some cultures are more or less willing to talk about others or refer to others)

Threats to Validity in Secondary Source Data

- Collection can be easier (data mining), but…
- Do dyadic ties in records have the same meaning (e.g., emails)?
- Often records actually document non-events (e.g., Congressional Record).
- Records may be biased in that they are constructed to fit some agenda or reflect actor biases (e.g., South Pole Manager Reports, Alaskan fish camp effort records).
- Are records temporally comparable, at the same scale, etc.?

Data Aside
Network Boundaries, Status, Cognitive Networks and Task Compliance

Status and Informant Overload

Tradeoff Between Network Size and Elicitation Task Constraints

- Wanted to collect cognitive networks
- Interviewing high status actors with limited time and patience (e.g., President Pro Tem of the NC Senate)
- Bounded the network with only the most essential political players
- Used a freelist approach to identify actors most important in the political process surrounding this piece of legislation
- Used a fixed choice methodology to reduce the number of comparisons

Social/Cognitive Knowledge

Cognitive Social Networks

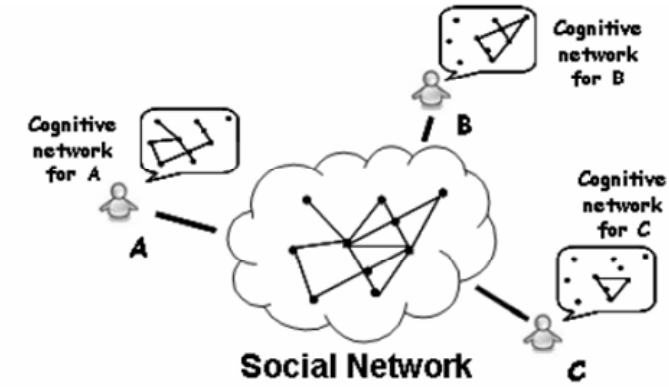
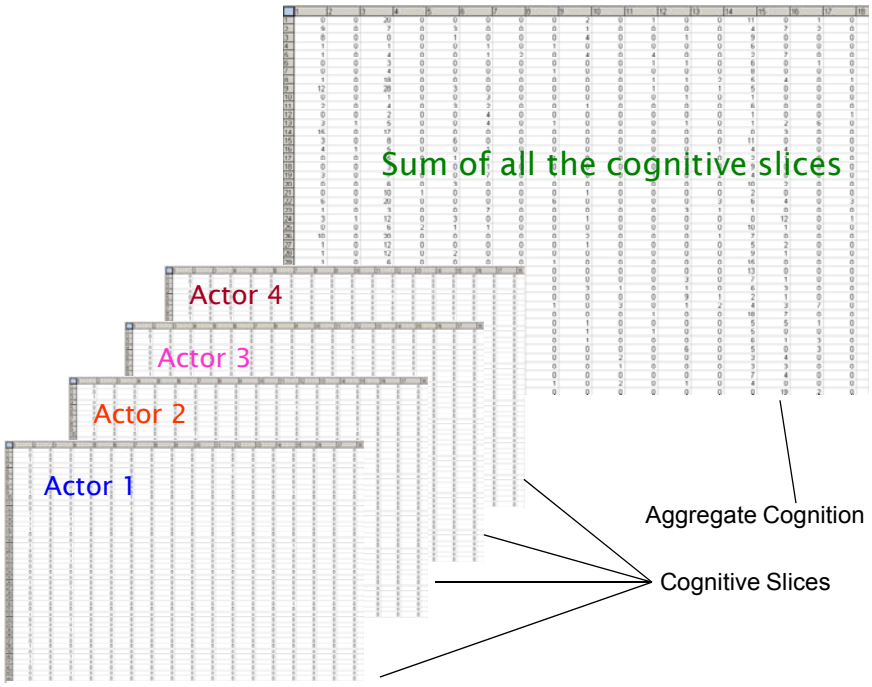


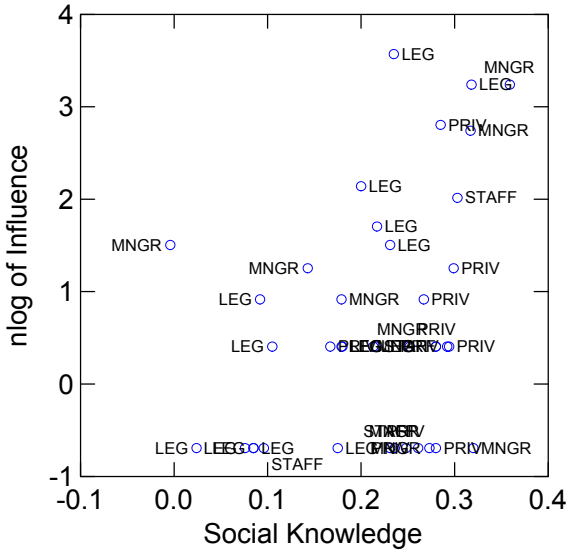
Figure 1. Illustration of a Socio-cognitive network



Features of Cognitive Social Networks

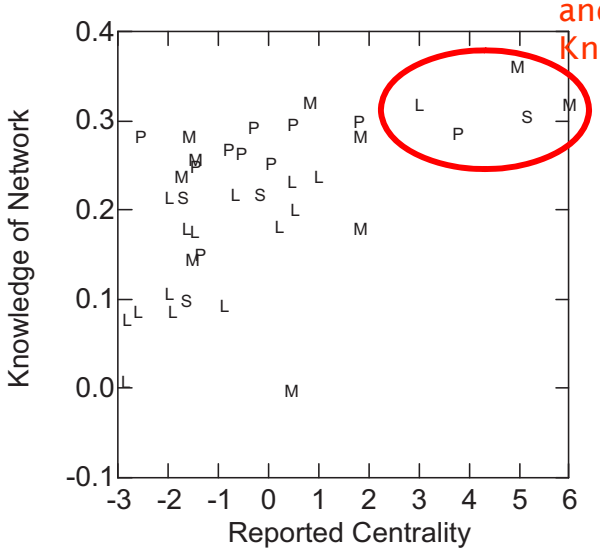
- Individual cognitive slices vary in accuracy
- More active (and powerful) actors tend to have the most accurate understanding of the network
- Aggregations of individual cognitive nets tend to produce a more valid picture of the true network
- The more slices the better
- Can construct a reasonably accurate network from a few aggregated cognitive slices-- Particularly if obtained from active and powerful actors)

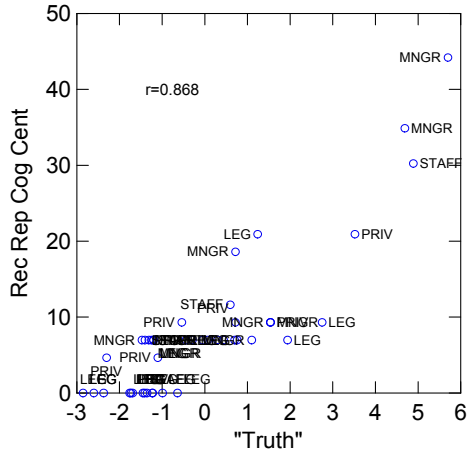
Relationship between power and network knowledge

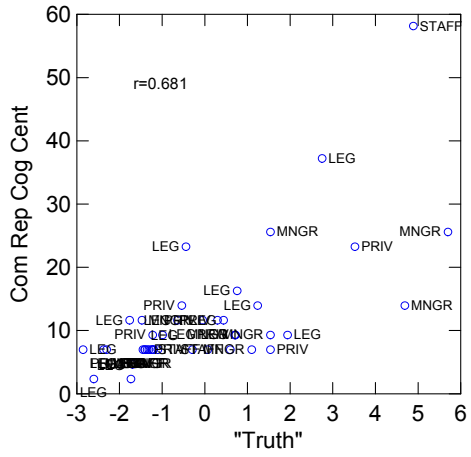


Relationship between activity and knowledge

High Activity and High Knowledge



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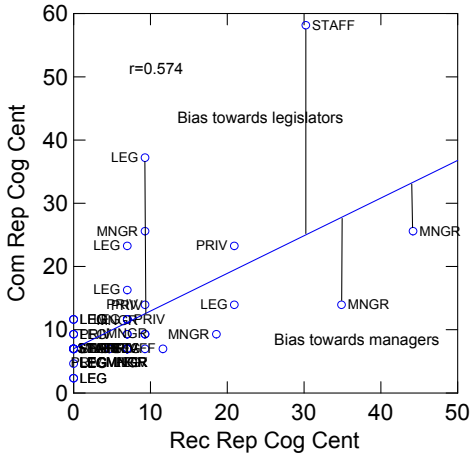
Com Rep Cog Cent
"Truth"
STAFF
LEG
MNGR
PRIV


r=0.574
Bias towards legislators
Bias towards managers
Com Rep Cog Cent
Rec Rep Cog Cent
STAFF
LEG
MNGR
PRIV

Cognitive Estimates of Networks

- Cognitive data from a small number of knowledgeable informants can be used to construct a reasonably accurate picture of a whole network
- The more central the actor the more accurate their perception
- This data can be used to weight estimates of tie and nodal characteristics
- Contributes to triangulation on the existence of nodes and ties

Remarks

- Data quality is essential; garbage in garbage out
- Lessons learned from reliability and validity in data collection can be used to help assess the validity of network ties and actors in producing data sets (e.g., using Bayesian weighting to better estimate the presence or absence of nodes and ties)

Dynamic Network Analysis

George B. Davis, Kathleen M. Carley

{gbd, carley}@cs.cmu.edu

Center for Computational Analysis of
Social and Organizational Systems
http://www.casos.cs.cmu.edu/

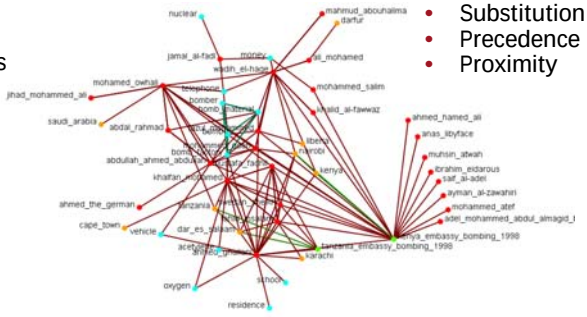
What is a network?

Nodes

- People
- Units of action
- Coalition partners
- Departments
- Resources
- Ideas or Skills
- Events
- Nation-states

Ties Between Nodes (links)

- Who do you like or respect?
- Transfer of resources
- Authority lines
- Association or affiliation
- Alliance
- Substitution
- Precedence
- Proximity



Networks are ubiquitous

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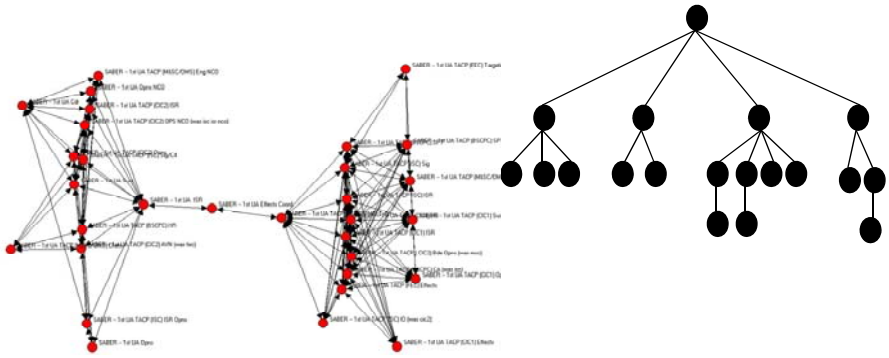
Informal and Formal Structure



Each person is embedded in many networks

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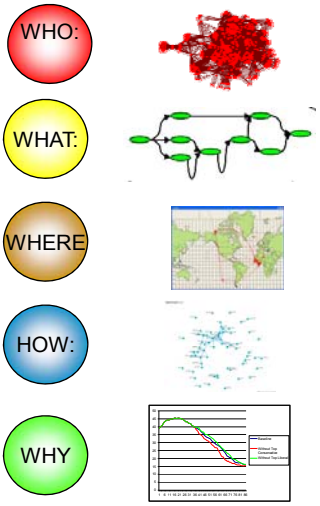
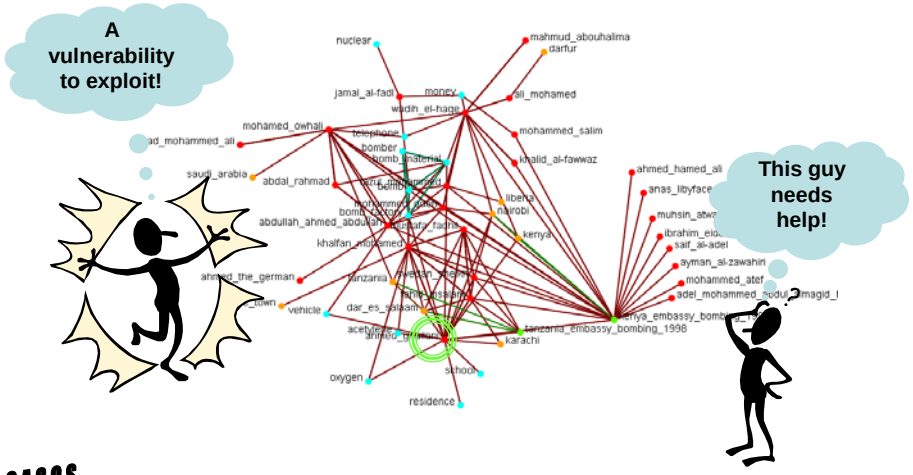
Need to Reason About Many Kinds of Networks

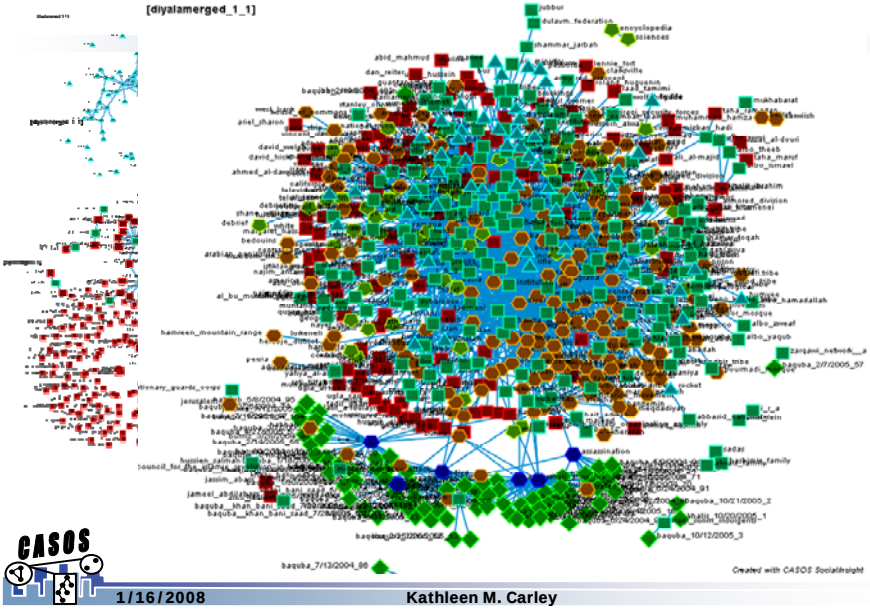


- WHO
  - Social network
  - Ethnic network
  - Organizational network
  - Country alliance network
- WHAT
  - Resource ownership netwoork
  - Task Network (Gant chart)
- WHERE
  - maps – sharing boundaries
- HOW
  - semantic networks – ideas to ideas
- WHY
  - belief network – cascades of beliefs
- Activity network – who does what
- Capability network – who has what

Network Analysis Enables Both Management and Disruption



Examining the Meta-Network



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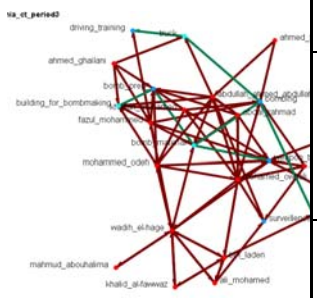
Key Players

ORA: Key Entity Report



	HighBetweenness low Degree Connects groups mohamed_owhali	Task Exclusivity Critical role fazul_mohammed
Degree Centrality In the Know wadih_el-hage	Betweenness Power wadih_el-hage	Expertise Exclusivity Critical expertise bin-laden
Eigenvector Centrality Central core mohamed_owhali	Cognitive Demand Emergent leader fazul_mohammed	Resource Mobilization Critical access abdullah

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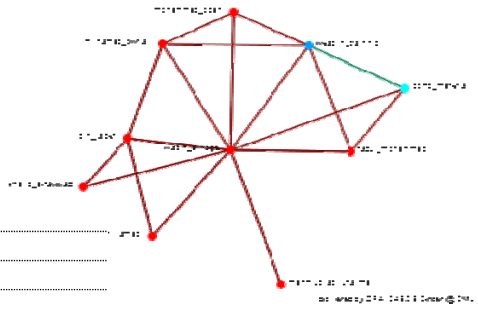
How to Influence

ORA: Sphere of Influence

Node Type	Size	Percent
agent	8	+50%
knowledge	2	+50%
location	2	+3%
resource	1	+25%
task	1	+20%



Name	Value
alias	wadih_hage
hostility_level	1
joined_al_qaeda	1989
left_al_qaeda	1998
nationality	lebanese
nationality_relation	hostile
nyi	prosecutor
source_date	2006-05-10
suspected_terrorist	yes

Most similar other – jamal al-fadil

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Are Two Critical Actors Linked?

ORA: PathFinder

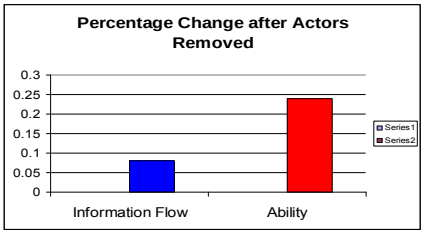
tariq_al-fadli

mohammed_atta

Potential Impact of Isolation

ORA: Immediate Impact Report

- Isolation of top 10 actors with special expertise:
  - Reduces the rate with which information diffuses by 8%
  - Decreases overall ability by 24%
  - Capability Reduction: Appears to remove direct access to 10 critical and 20 overall resources
  - Increases Ali Gufron's influentialness – so that he moves from number 4 to number 2
- New emergent leaders
  1. 0.0174 said_mortazavi
  2. 0.0137 kamal_kharazi
  3. 0.0127 reza_asefi
  4. 0.0120 morteza_sarmadi
  5. 0.0100 hashemi_shahroudi
- Value of "lowest" old emergent leader was .0246



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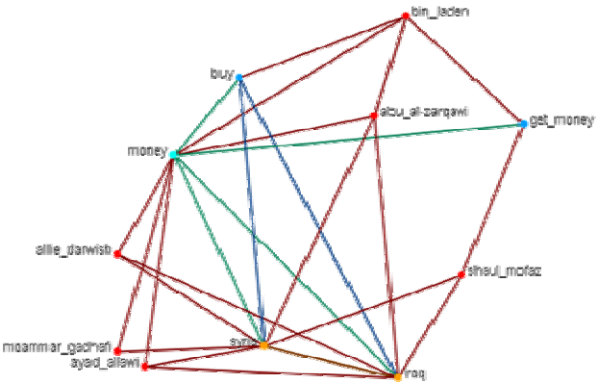
Mission: Stop Money Flow from Syria to Iraq

1. Identify points of contact between Syria and Iraq
2. Do any of these individuals have a relation to money?
3. Possible points to inhibit money flow:
   - Allie Darwish
   - Ayad Allawi
   - Abu Al Zaqawi
   - Shaul Mofaz



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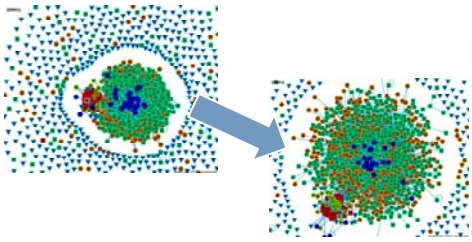
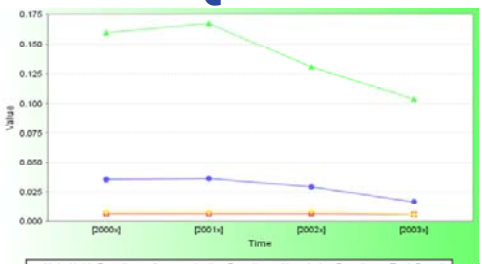
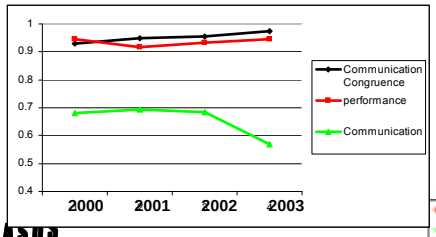
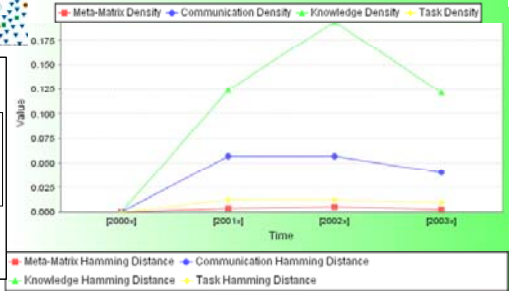
Change 2000-2003 al Qa'ida









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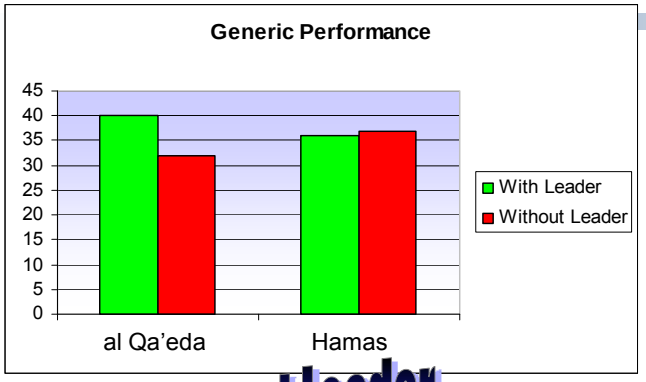
What If Analysis



New Emergent Leader


Bin Laden


al-Zawahiri


Yassin


Rantisi

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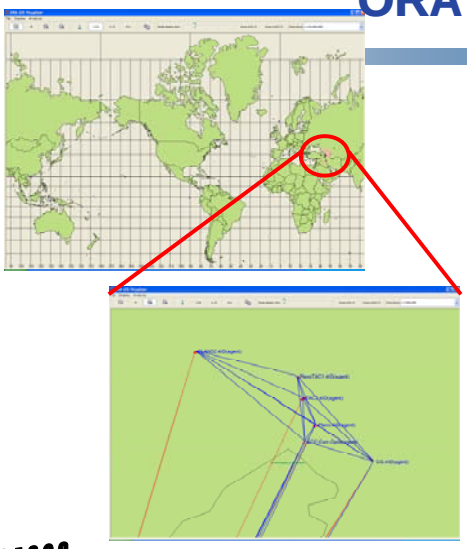
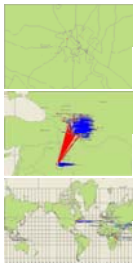
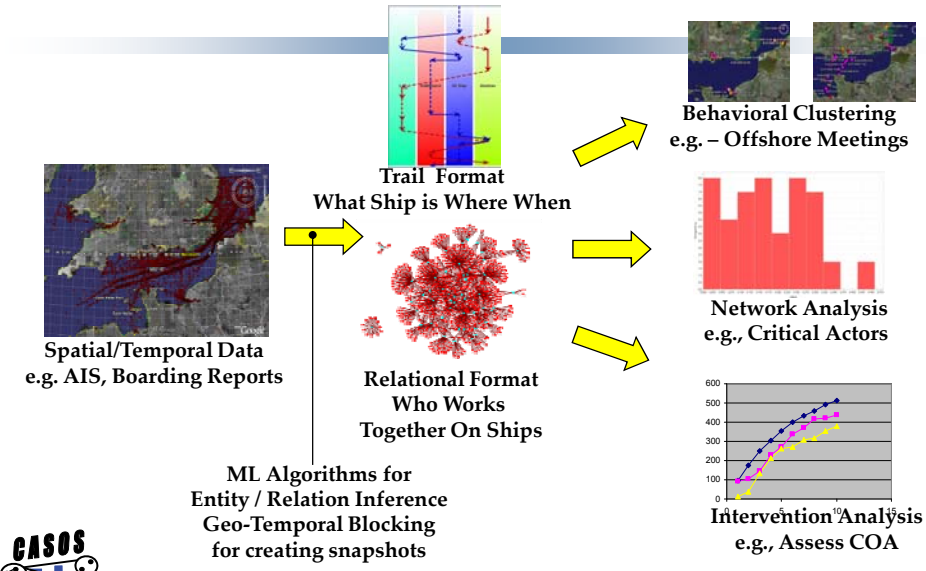
ORA GIS



- Correlate physical / social distance
- Detect loci of activity
- Consider spatial impact on network interventions



Alternative Application: MMV



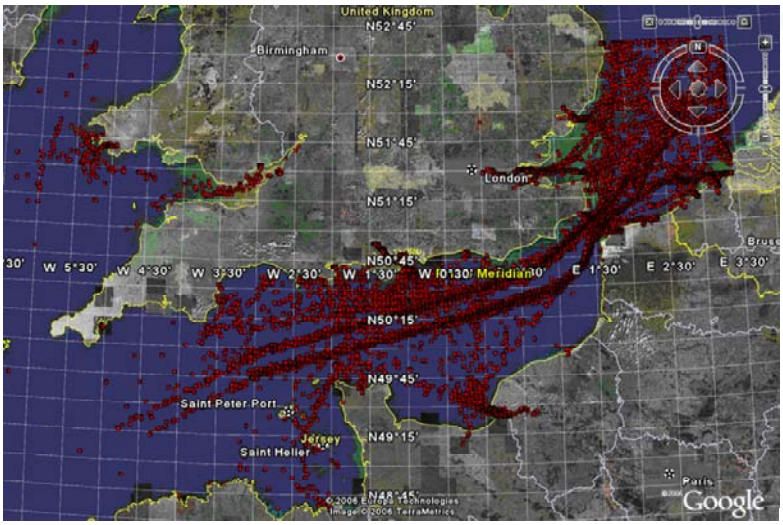
What Can Network Analysis Models be Used For?

- IDENTIFY Targets of Interest: Given network of insurgents, crossing country borders, with limited information on access to resources, activities, etc.
  - Identify people who if arrested or detained will disrupt movement
  - Identify people with access to critical resources
  - Identify people who can provide information about the network
  - Identify people who, if influenced, can impact the network activity
- Assess potential impact of isolation of target of interest or removal of resource
  - Immediately (short term impact)
  - After the network has had time to "heal"
- Identify critical differences in groups
- Identify how to influence a target and who/what a target might influence
- Assess the "health" of the organization
- Identify possible areas where there might be missing data
- Assess change in groups over time
- Understand how a social network is geographically distributed

George's Soapbox: Networks as Useful Simplification

- True vs. Useful
- Complex networks summarize even more complex processes
- Need for rigorous ways to extract networks from existing data captured from systems
  - Streams of observations in time / space → relationships
- Success = accomplishing a task in the original system (prediction, intervention, etc)

The English Channel Dataset



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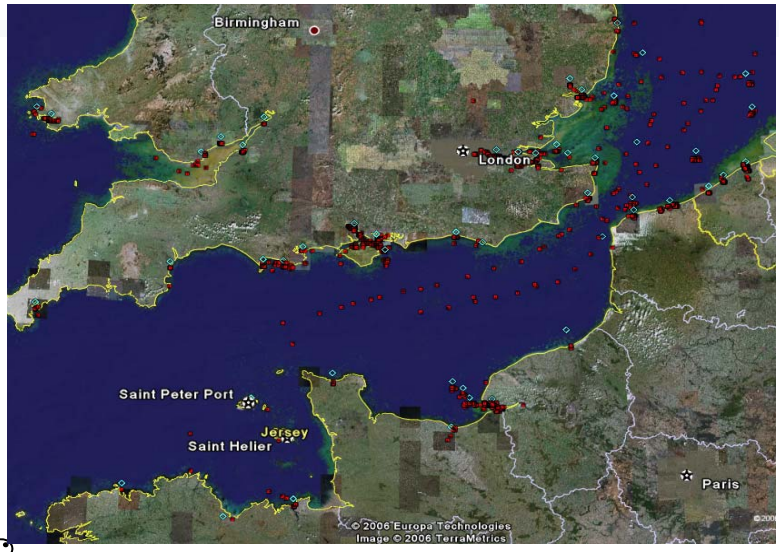
K-Means "Points of Interest"



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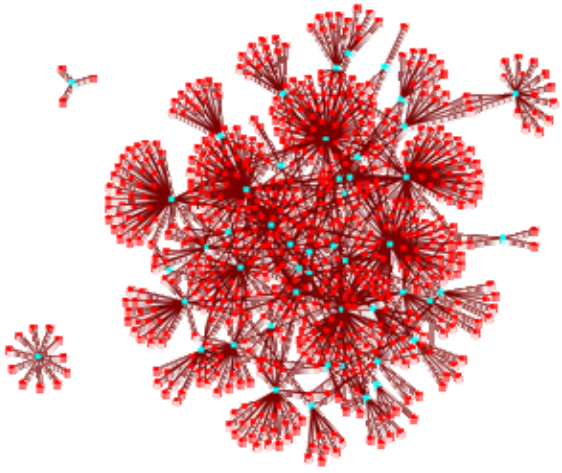
Ship x Location Network



1709 Ships (Red), 51 Locations of Interest (Blue)

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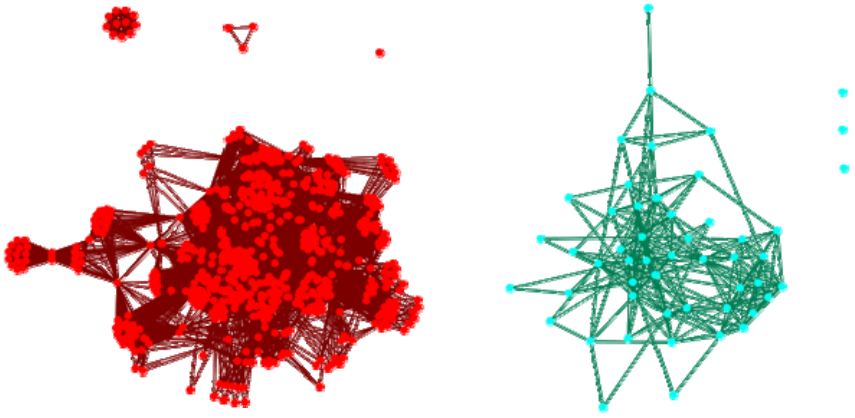
1-Mode Derived Networks



Ship x Ship *Location x Location*

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Node Level Measures

Node	Total Degree		Betweenness Centrality		Eigenvector Centrality	
	Ship ID	Score	Ship ID	Score	Ship ID	Score
1	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
2	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
3	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
4	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
5	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]

(a) Top Centrality Scores for Ship Degree ⇒ Ship Network

Node	Total Degree		Betweenness Centrality		Eigenvector Centrality	
	Place ID	Score	Place ID	Score	Place ID	Score
1	33	[illegible]	20	[illegible]	33	[illegible]
2	28	[illegible]	33	[illegible]	28	[illegible]
3	32	[illegible]	32	[illegible]	6	[illegible]
4	6	[illegible]	6	[illegible]	15	[illegible]
5	15	[illegible]	15	[illegible]	32	[illegible]

(b) Top Centrality Scores for Ground Stop Place ⇒ Place Network

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Soapbox Takeaway

- SNA / DNA can be integrated with existing sensor systems *of all types*
- Even complex networks are simplifications, so it's important to understand *how* they simplify
- Importance of re-contextualizing analysis when applying to real system

Thanks!

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The Issue of Causality in Social Network Analysis

Mark S. Mizruchi
University of Michigan

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Introduction

- **The traditional principle of network analysis:**

  the structure of relations reveals the content of those relations

- **Circa late-1970s, early 1980s, much network research was descriptive**

  example: work on corporate director links

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Introduction

- The "so what?" question

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Introduction

- The "so what?" question
- The Bavelas-Leavitt experiments (late 1940s)
- Granovetter's *Getting a Job* (1974)
- But not much else by early-1980s

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Introduction

- The focus shifted to outcomes by the late-1980s:
- effect of interfirm network ties on firm political behavior
- effect of network ties on anti-takeover provisions, acquisitions, firm structures
- individual-level effects on promotion within firm

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Problems in Identifying Network Effects

By the mid-1990s there was a lot of evidence that networks mattered

But

a) Where did the networks come from in the first place? And

b) Were these effects really causal?

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Problems in Identifying Network Effects

Prior cause of networks?

Example: effect of bankers on board on firms' use of debt

But what if the decision to use debt preceded the board appointment?

Lagging the board variable won't solve the problem

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Problems in Identifying Network Effects

Prior cause of networks?

Example 2: structural holes lead to rapid promotion

But what if rapid promotion leads to sparse networks?

And what about selection into the hole? Note Mouw study

Addressing the Problem, I

Example: bankers' network ties affect their bonuses

Problem: the network ties might have been affected by prior performance

Proposed solution: lag the dependent variable (last year's bonus)

But data are not always available

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Causes of Network Ties?

Two primary factors:

Personal characteristics of the actors

Culture (as in belief systems, norms)

Causes of Network Ties?

Two primary factors:

Personal characteristics of the actors

Culture (as in belief systems, norms)

But culture/ knowledge/ norms may emerge from prior network ties

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Addressing the Problem, II

a) Place different personality types into structural holes; see if effects vary

b) Set up random or uniform network; see if hole occupants emerge

c) Set up structure with bridges, break the bridges, see if/how new paths form

d) Why computational modeling may not work

Addressing the Problem, III

Non-experimental situations:

ethnographic work, narrative analysis

This approach has problems, but also potential, and may be necessary

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Further Issues

- Units of analysis in above studies have been individual actors or dyads; what about structure? But see Mizruchi and Marquis (2006)
- New work on network structures is highly sophisticated, but may be recreating the same problems as the earlier work, in terms of being descriptive

NETWORK ANALYSIS AT THE U.S. GAO: Applications and Challenges

David Dornisch, Ph.D.
U.S. Government Accountability Office
Senior Social Science Analyst
dornischd@gao.gov

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1

My Role and Experiences at GAO

- My Role: Senior Social Science Analyst in Applied Research and Methods Division
  - Internal research design, methodology, and analysis consultant on audits, evaluations, and reviews of U.S. Government programs and agencies
  - Current focuses: international development and security, public health, emergency and pandemic preparedness
- Experiences to Date
  - Increasing interest at GAO in network analysis
  - Reflects increasing salience of interagency/ intergovernmental and public-private coordination in government programs
- But Big Challenges – How to demonstrate how network analytic concepts can be of use?

2

GAO Research Questions Suggest Use for Network Analysis

- Non-Profits in Gulf Coast
  - What **models of collaboration** illustrate the successes and challenges of delivering federally funded nonprofit services to Gulf Coast residents?
- Pandemic Influenza
  - **How is the federal government coordinating with the private sector** to protect of the nation's critical infrastructure in the event of an influenza pandemic in the transportation, food, water, energy, and telecommunications sectors.
  - **How are selected states** and local jurisdictions **involving the federal government, other state and local governments, tribal nations, non-profits, and the private sector** in pandemic planning?
- Navy's Surface Ship Rotational Crewing
  - Assess the extent to which the navy systematically collected and **shared lessons learned** from recent ship rotational crewing experiments
- Insurgents and Armed Groups in Iraq
  - Who are the armed groups operating in Iraq and how has their **cooperation** with each other changed over the past year?
  - What is the **nature of the links** between these groups and the Iraqi security forces, government ministries, political parties, and other external parties?

3

Questions that network analysis might help inform

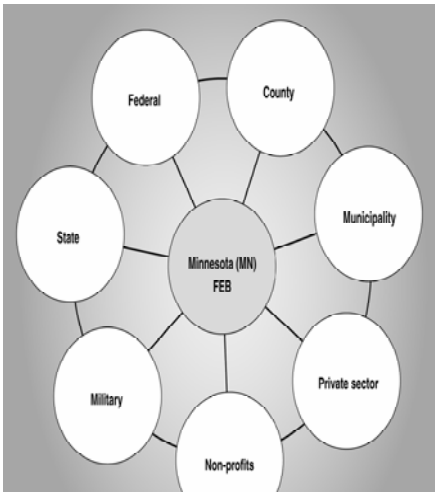
- How are x, y, and z agencies coordinating?

But more specifically:

- Which entities or sets of entities are **key players** in the coordination? What makes them key players?
- To what extent and where is the network most **vulnerable to disruption**? Where are the **bottlenecks**?
- **How well connected** are the entities that are supposed to be coordinating? And across functional, hierarchical, or organizational boundaries?
- **Redundancies**: Too many/too little?
- **Network change**: Is a network becoming more or less integrated, more or less dense, more or less centralized?

4

Application 1: Federal Executive Boards



- Based on Two Planning Exercises in Minnesota from 2007
- Obtained lists of participants
- Produced some breakouts of participants into functional subgroupings
- Ended up with simple hub and spokes picture
- Limited – no data on ties among FEB partners

5

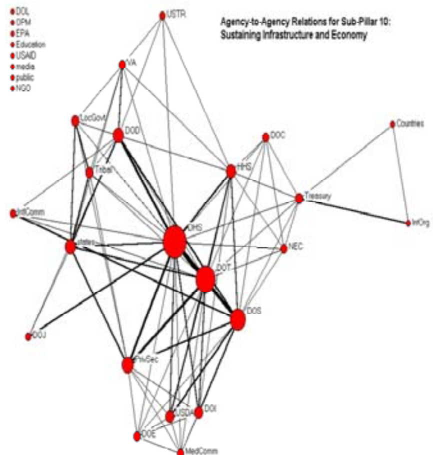
Application 2: National Pandemic Strategy Implementation Plan

- Project on coordination among federal agencies and public and private organizations in the pandemic area
- Preliminary work on the national pandemic implementation plan
  - Databased 324 Action Items
  - Initially Two-Mode Data – Agencies by Actions
  - Converted it to one-mode
- Illustrated structure with a variety of network operations
  - Additional analyses set cut-off at four ties or more

6

Application 2: The Data

		1 DH	2 DO	3 DO	4 DO	5 DO	6 DO	7 DO	8 DO	9 DO	10 OP	11 EP	12 Ed	13 HH	14 NE	15 Tr	16 US	17 US	18 US	19 VA	20 st	21 Lo	22 Tr	23 In	24 Co	25 In	26 Pr	27 Me	28 me	29 pu	30 NG
1	DHS	19	1	4	1	2	2	0	6	11	0	0	0	3	1	1	0	2	1	1	3	1	1	0	0	1	4	1	0	0	0
2	DOC	1	1	0	0	0	0	0	1	1	0	0	0	1	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
3	DOD	4	0	7	0	0	1	0	2	1	0	0	0	1	0	0	0	0	1	2	2	1	1	0	0	1	0	0	0	0	0
4	DOE	1	0	0	1	1	0	0	1	1	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	1	1	0	0	0
5	DOI	2	0	0	1	2	0	0	2	2	0	0	0	1	0	0	0	2	0	0	0	0	0	0	0	0	1	1	0	0	0
6	DOJ	2	0	1	0	0	2	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0
7	DOL	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
8	DOS	6	1	2	1	2	0	0	7	5	0	0	0	2	1	1	0	2	0	0	0	0	0	0	0	2	2	1	0	0	0
9	DOT	11	1	1	1	2	0	0	5	12	0	0	0	2	1	1	0	2	0	0	3	1	1	0	0	1	4	1	0	0	0
10	OPM	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
11	EPA	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
12	Education	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
13	HHS	3	1	1	0	1	0	0	2	2	0	0	0	3	1	1	0	1	1	1	0	0	0	0	0	0	0	0	0	0	0
14	NEC	1	1	0	0	0	0	0	1	1	0	0	0	1	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
15	Treasury	1	1	0	0	0	0	0	1	1	0	0	0	1	1	3	0	0	0	0	0	0	0	2	1	0	0	0	0	0	0
16	USAID	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
17	USDA	2	0	0	1	2	0	0	2	2	0	0	0	1	0	0	0	2	0	0	0	0	0	0	0	0	1	1	0	0	0
18	USTR	1	0	1	0	0	0	0	0	0	0	0	0	1	0	0	0	0	1	1	0	0	0	0	0	0	0	0	0	0	0
19	VA	1	0	2	0	0	0	0	0	0	0	0	0	1	0	0	0	0	1	4	1	1	1	0	0	0	0	0	0	0	0
20	states	3	0	2	0	0	1	0	0	3	0	0	0	0	0	0	0	0	0	1	5	2	2	0	0	0	2	0	0	0	0
21	LocGovt	1	0	1	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	1	2	2	2	0	0	0	1	0	0	0	0
22	Tribal	1	0	1	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	1	2	2	2	0	0	0	1	0	0	0	0
23	IntOrg	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2	0	0	0	0	0	0	0	2	1	0	0	0	0	0	0
24	Countries	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	1	1	0	0	0	0	0	0
25	IntlComm	1	0	1	0	0	0	0	2	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2	0	0	0	0	0
26	PrivSec	4	0	0	1	1	0	0	2	4	0	0	0	0	0	0	0	1	0	0	2	1	1	0	0	0	4	1	0	0	0
27	MedComm	1	0	0	1	1	0	0	1	1	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	1	1	0	0	0
28	media	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
29	public	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
30	NGO	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0



(Source: National Strategy for Pandemic Influenza Implementation Plan)

7

Application 2: Some Analyses

#1: Freeman Centrality

		1 Degree	2 NrmDegree	3 Share
1	DHS	47.000	14.734	0.167
9	DOT	38.000	11.912	0.135
8	DOS	28.000	8.777	0.099
26	PrivSec	18.000	5.643	0.064
3	DOD	17.000	5.329	0.060
20	states	16.000	5.016	0.057
13	HHS	15.000	4.702	0.053
5	DOI	12.000	3.762	0.043
17	USDA	12.000	3.762	0.043
22	Tribal	9.000	2.821	0.032
21	LocGovt	9.000	2.821	0.032
15	Treasury	9.000	2.821	0.032
19	VA	8.000	2.508	0.028
4	DOE	7.000	2.194	0.025
27	MedComm	7.000	2.194	0.025
2	DOC	6.000	1.881	0.021
14	NEC	6.000	1.881	0.021
25	IntlComm	5.000	1.567	0.018
18	USTR	4.000	1.254	0.014
6	DOJ	4.000	1.254	0.014
23	IntOrg	3.000	0.940	0.011
24	Countries	2.000	0.627	0.007
7	DOL	0.000	0.000	0.000
16	USAID	0.000	0.000	0.000
10	OPM	0.000	0.000	0.000
11	EPA	0.000	0.000	0.000
12	Education	0.000	0.000	0.000
28	media	0.000	0.000	0.000
29	public	0.000	0.000	0.000
30	NGO	0.000	0.000	0.000

#2: Hierarchical Components

```
                                                  C         E
                              I       T           o         d
              P           L   n       r           u M       u
              r   s       o T t       e I         n e       c       p
              i   t       c r l       a n         t d       a U m   u
              v   a     U G i C       s t U       r C       t S e   b
        D D D D S H t D D S   o b o D D N u O S   i o D O E i A d l N
        H O O O e H e O O D V v a m O O E r r T   e m O P P o I i i G
        S T S D c S s I J A A t l m C E C y g R   s m L M A n D a c O

                2 1 2       1 1 2 2 2       1 1 2 1 2 2     1 1 1 1 2 2 3
 Value  1 9 8 3 6 3 0 5 6 7 9 1 2 5 2 4 4 5 3 8 4 7 7 0 1 2 6 8 9 0
 -----  - - - - - - - - - - - - - - - - - - - - - - - - - - - - - -
11.000  XXX . . . . . . . . . . . . . . . . . . . . . . . . . . .
 6.000  XXXXX . . . . . . . . . . . . . . . . . . . . . . . . . .
 5.000  XXXXX . . . . . . . . . . . . . . . . . . . . . . . . . .
 4.000  XXXXXXXXX . . . . . . . . . . . . . . . . . . . . . . . .
 3.000  XXXXXXXXXXXXX . . . . . . . . . . . . . . . . . . . . . .
 2.000  XXXXXXXXXXXXXXXXXXXXXXXXXXX . . . XXX . . . . . . . . . . .
 1.000  XXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXX . . . . . . . .
 0.000  XXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXX
```

#3: Two-Mode Core-Periphery

Starting fitness: 0.392
Final fitness: 0.643

Blocked Adjacency Matrix

		15C	16C	17C	4C	5C	20C	7C	8C	9C	10C	25C	12C	13C	14C	21C	19C	3C	1C	2C	6C	18C	22C	23C	24C	11C	26C	27C	28C
1	DHS	1	1	1	1	1	1	1	1	1		1	1	1	1		1				1					1	1	1	1
9	DOT	1	1	1	1	1		1		1	1		1		1		1				1								
3	DOD						1					1	1	1		1						1			1				
4	DOE									1																			
5	DOI				1					1																			
6	DOJ											1														1			
7	DOL																												
8	DOS				1	1				1			1	1			1		1										
2	DOC																1												
10	OPM																												
11	EPA																												
12	Education																												
13	HHS				1		1										1												
14	NEC																1												
15	Treasury																1	1		1									
16	USAID																												
17	USDA				1					1																			
18	USTR						1																						
19	VA						1									1							1	1					
20	states		1	1							1	1				1													
21	LocGovt		1													1													
22	Tribal		1													1													
23	IntOrg																	1		1									
24	Countries																			1									
25	IntlComm												1						1										
26	PrivSec		1	1		1				1																			
27	MedComm									1																			
28	media																												
29	public																												
30	NGO																												

Density matrix

	1	2
1	0.617	0.235
2	0.084	0.032

8

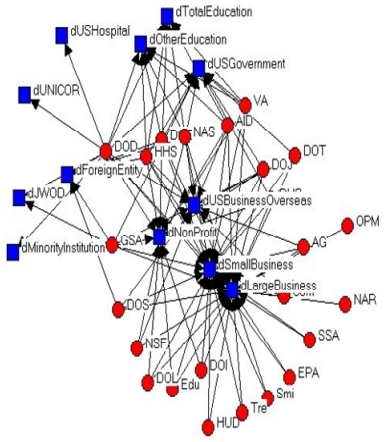
What do you do with this evaluatively?

- My suggestions for further Pandemic research
  - Use it as a benchmark, and evaluate agencies on the existence of a substantively meaningful tie
  - Conduct network survey of plan implementation to drill down into agency subcomponent ties
  - Maybe look at and relate types of ties (advice, information, funding) across and within agencies?

9

Application 3: Bi-Modal Federal Procurement Data

- There's a lot of bi-modal out there
- 2006 funding (contracts) by 56 federal agencies of 12 types of recipient organizations
- Cut-off at $100,000
- Nice two-mode graph
  - Shows overall structure of flows graphically
  - Break-out of both agencies and types into most central group, secondary group, and peripheral group



10

Application 4: U.S. PEPFAR (Bush Admin. AIDS Program) Program

- Survey of PEPFAR Country Team Officials:

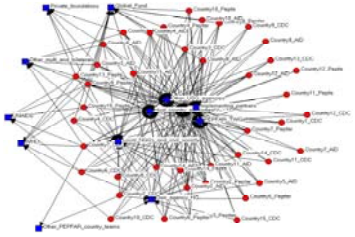
  "To what extent does your PEPFAR country team collaborate with the following organizations when determining which interventions to use?"

  - Bi-Modal again ('1' if very great/great; 0 otherwise)
  - Types of Organizations:

PEPFAR technical working groups	Other PEPFAR country teams	UNAIDS WHO
Host country technical working groups	Host country authorities	Global Fund
Own agency headquarters	Implement-ing partners	Other multilateral and bilateral donors
Other US government agencies	Local NGOs or civil society groups	Private foundations

11

Bi-Modal PEPFAR Collaboration Results



```
Starting fitness: 0.801
Final fitness: 0.803

                                 1 1 1 1
                 1 2 3 4 5 6 7   5 5 0 1 2 3
                 P H O O L H I   O U W G O P
                 ---------------------------
22     Country8_AID | 1 1 1 1 1 |     1
23 Country9_Pepfar | 1 1   1 1 1 |   1 1 1 1 1
 3 Country2_Pepfar | 1 1 1 1 1 1 |
 4     Country2_CDC | 1 1 1   1 1 | 1
16     Country6_CDC | 1 1 1 1 1 1 |
16     Country6_AID |   1   1 1 1 |           1 1
 7     Country3_CDC | 1 1 1 1   1 |         1
 8     Country3_AID | 1 1 1   1 1 |       1 1 1 1
40 Country15_Pepfa |   1 1 1 1 1 |   1 1 1 1
10     Country4_CDC |   1 1 1 1 1 |         1
42     Country8_AID | 1 1 1 1 1 1 |         1
17 Country7_Pepfar | 1 1 1   1 1 |
18     Country7_CDC | 1 1 1 1 1 1 | 1 1 1   1
35 Country13_Pepfa |   1 1 1 1 1 |   1 1 1 1 1
31     Country11_AID | 1 1 1 1 1 1 |
                 ---------------------------
 5     Country2_AID |   1 1 1 1 1 |
12 Country5_Pepfar |   1 1 1   1 |
13     Country5_AID |   1 1 1   1 |         1
 9 Country4_Pepfar |   1   1 1 1 |         1
20 Country0_Pepfar | 1 1   1   1 |         1
 6 Country3_Pepfar |   1 1   1 1 |
 1 Country1_Pepfar | 1 1   1   1 |           1 1
 2     Country1_CDC | 1 1       1 |
24     Country9_CDC |   1       1 |
25     Country9_AID |   1   1   1 |
26 Country10_Pepfa | 1 1       1 1 |       1
27     Country10_CDC | 1 1         |     1
28     Country10_AID | 1 1       1 1 |       1
29 Country11_Pepfa | 1 1         1 |
30     Country11_CDC |   1     1   1 |
31     Country4_AID |   1   1 1 1 1 |         1
32 Country12_Pepfa |   1         1 |
33     Country12_CDC | 1           1 |
34     Country12_AID |   1   1   1 1 |
14 Country6_Pepfar |   1       1 1 |
36     Country13_CDC |   1   1   1 |
37 Country14_Pepfa | 1 1 1 1 1 1 1 |
38     Country14_CDC | 1 1 1 1 1 1 |
39     Country14_AID | 1 1 1 1 1 1 |
19     Country7_AID | 1           1 |
41     Country15_CDC | 1   1       1 |
21     Country9_CDC |   1 1 1 1 1 1 |

Density matrix

      1       2
 ------- -------
1 0.851 0.348
2 0.586 0.045
```

12

Technical/Analytical Issues: It's Interesting, but…

- Difficult to be normative about which structural patterns are ideal – It depends on context
- Difficult translating network analytical conceptions into useful GAO-type questions, e.g.
  - Centrality – how do you use in a typical GAO report?
  - Cliques, core-periphery, blockmodels, small worlds?
- "Interorganizational" surveys very difficult
- More specific problems with bi-modal data
  - Tough to convey the two-mode idea
  - High n affiliations and related issue of arbitrary unimodal cut-off
  - Available software provides few tools for generating bi-modal metrics

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Broader Key Challenges

- Organizational challenges
  - Making network analysis relevant in a high pressure setting
    - Tight timeframes
    - Need for parsimony in reports
    - Reports are non-theoretical
  - Clients' limited general knowledge of network analysis
    - Typical interest: Graphics, Synthesis of large quantities of data
  - People see it as a lot of work!
- Network analysis is a tool, not an answer

14

Looking Forward

- How to make network analysis salient to people working on tight timeframes, facing a lot of competing pressures, and with limited knowledge?

15

DTRA/ASCO Workshop on Dynamic Social Network Analysis: Present Roots and Future Fruits

To Use Social Network Analysis: The Challenge of Utilizing SNA

Ft. Belvoir, Virginia
February 14, 2008

Dr. Elisa Jayne Bienenstock
Chief Human Sciences Officer, NSI
Mathematical Sociologist
(818) 625-9047; ejb@natlsec.com

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Social Network Analysis (SNA) the Map and the Myth

"Social Network Analysis" means different things to different people, and there are many misconceptions:

Map: SNA as Link Charts

- Analysts who do "link analysis" are complacent that they are doing SNA
- They are resistant to learn SNA
- They sell their product as SNA

Myth: SNA as "Numbers"

- There is an expectation that SNA can be automated to provide quick, correct and deep insight into large social systems
- There is the myth that the key to a social system can be reduced to a simple "one number" solution

DANGER: Failure to produce results is interpreted as a failure of SNA not a failure of the bad methods **impersonating** SNA

SNA is more than Visualization or Algorithms: it is subtle interpretation of the math providing sociological meaning

Government's Appetite: Near term Needs versus R&D

- Utilization of Social Network Analysis to meet the operational needs of government will require turbo-charging the methodology relative to what is required for research
  - The time scale is critical
  - The Data are incomplete
  - The implications of the findings has consequences
- Dangers:
  - Datasets are large
  - there is little knowledge of context
  - analysis must be done FAST
  - those performing the analysis will not be trained SNA experts

Dynamic Network Analysis: Fact or Fishing?

Social Networks, as studied are not necessarily "dynamic" in any obvious way: "Dynamic Network Analysis" refer to very different visions of SNA

Fact: Longitudinal Analysis of an Empirical Network:

Challenge: Determining if the network is dynamic or static?

How much change or activity on the network indicates real "change" not noise

How can an analyst distinguish new information about the data from a meaningful change in structure?

Fishing: Predicting how the network will evolve

Challenge: Merging SNA with Agent Based Modeling / Game Theory / Decision Theory to anticipate network change

In fact to do either well may require advances in both. Computational models may be required to parameterize empirical analysis while longitudinal techniques may be required to analyze computational models

Example: Game Theory and Social Network Analysis (SNA)

- Game Theory: Mathematical Model of Micro **economic** processes
  - Assumptions about behavior (preferences hierarchy; maximize utility)
  - Contingent behavior
  - Non-cooperative: Cooperation
  - Cooperative: Coalition formation and resource distribution
- Social Network Analysis: Mathematical model of **sociological** processes
  - Graphs represent people and relations
  - Micro – Macro / Macro – Micro
  - Power / Status / Groupings

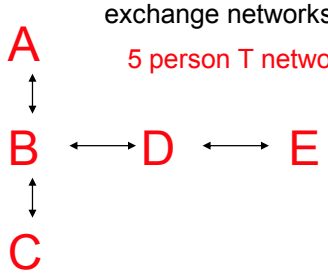
"Economics is all about how people make choices; sociology is all about how they don't have any choices to make" *Duesenberry, James 1960*

Combining Game Theory and Social Network Analysis (SNA)

- Similarities between game theory and SNA are obvious:
  - Focus on power, distribution, stability, equity, efficiency
- Differences between game theory and SNA are subtle:
  - Game Theory: Free market and individual choice; Economic
  - SNA: Constraints; Social
- "Social structure differentially constrains actors in their ability to take action. Actions taken are therefore a joint function of actors pursuing their interest to the limit of their ability where both interest and ability are patterned by social structure." (Burt, 1982)
- Combining Game Theory and SNA allows a model of options and outcomes given constraints
  - Model NETWORK GAMES where the "games" are constrained within graphs
  - Area within SNA is exchange network analysis that focuses on economic or commodity exchange within networks

Combining Game Theory and Social Network Analysis (SNA)

- **Social Exchange Networks**
  - Exchange of commodities is different than exchange of information so traditional SNA metrics do not work
  - Power is manifest in the ability to accumulate resources
  - Who has power is obvious for simple networks, but not for more complex networks
  - Game Theory is useful is determine power positions in exchange networks



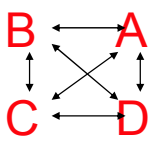
5 person T network

Example of Networked Exchange Situation

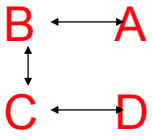
Social Exchange Networks

- Game theory solution concepts can be used to model exchange games, but the exchange game is different than a traditional game theory situation
- Different patterns of constraints produce different outcomes:
- SNA makes game theory sensitive to actual opportunity structures rather than assuming a free market

Free Market

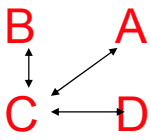


Constrained Market I



4 person chain

Constrained Market II

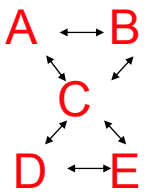


4 person star

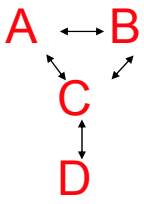
Social Exchange Networks

- Laboratory experiments have been used to determine which solution concepts of network measures best describe power hierarchies, coalition structures and resource distributions in a large number of small (3-8) person networks
- Game theory solution concepts have been proven useful in accurately predicting power hierarchies and coalition patterns
- Networks include 3, 4 and 5 person chain, 5 person T, and many other networks:

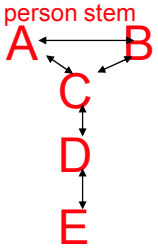
5 person hourglass



4 person stem

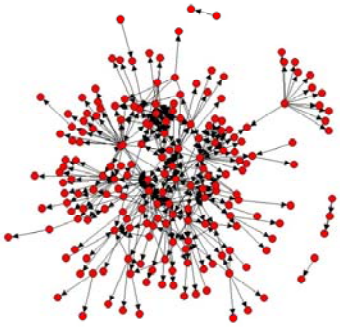


5 person stem



To Apply to Real Networks would require Block Models

- First step is to reduce the graph using block modeling techniques
- Block membership differentiated by color



To Apply to Real Networks would require Block Models

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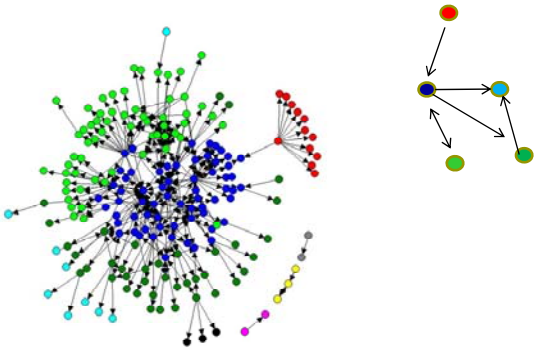
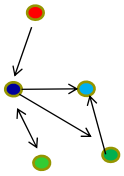


Block Models

- The second step is to focus only on the relationship between blocks
- This reduced graph provides a simple view of the macro level structure
- The resemblance to the experimental exchange networks is obvious
- Applying Game Theory to these networks is completely plausible



Conclusions

- There is a lot of work to do to utilize what is already doable and many avenues to investigate to advance SNAs potential value

Game Theory

- A set of related models: “a rigorous consistent superstructure into which separate models all nicely fit.” (Shubik, 1984).
- A “patchwork” theory: “a surprisingly large number of ingenious and insightful solution concepts for N-person cooperative game theory have been proposed by many different authors. Each solution addresses some particular aspect of societal rationality, that is the possible proposed or predicted behavior of rational individuals in mutual interaction.” (Shubik, 1984)
- Formalization of essential elements of assorted interactions
  - Use solution concepts to provide insight into non-obvious processes: Nash, Core, Shapley Value, Kernel …
  - “Names” for assorted “games”
    - Isolate important characteristics of a situation
    - Find similarities in what otherwise appear different situations
- Compare and contrast; generalize; determine resource distribution (optimal; equitable); determine efficiency and stability of solutions etc…

Social Network Analysis (SNA)

- Focus:
  - Complexity reduction (identifying similar roles within a network)
  - Block modeling
  - Homomorphic (many to one) representation of complex graph to simple graph
  - Actors with similar patterns of ties are grouped to reduce redundancy
  - Roles and positions and the relations between them are considered rather than all individuals separately

Social Network Analysis (SNA)

- A focus on relations between social entities: “Network analysis provide(s) explicit formal statements and measures of social structural properties” (Wasserman and Faust 1994)
- Makes explicit “Phrases such as webs of relationships, closely knit networks of relations, social role, social position, group, clique, popularity, isolation, prestige, prominence and so on are given mathematical definitions” (Wasserman and Faust 1994)
- Network Analysis uses graph theory and assorted algebras to formally characterize social relations beyond dyads and focus on:
  - Power distributions
  - Resources distributions
  - Efficiency / Stability
  - Complexity reduction (identifying similar roles within a network)
  - Network classification (identifying similar network types)

ANNEX II – PARTICIPANTS

Name	E-mail Address	Organization
Amico, Ross	ross.amico@ngc.com	DTRA (NGIT)
Bienenstock, Elisa	ejb@natlsec.com	National Security Innovations
Birt, Sabrina	sabrina.birt@baesystems.com	DIA (BAE Systems)
Borgatti, Stephen P.	sborgatti@uky.edu	Univ. of Kentucky
Breiger, Ronald	breiger@arizona.edu	Univ. of Arizona
Brooks, Peter	petersb2@dni.gov	DNI
Davis, George	george.b.davis@gmail.com gbd@cs.cmu.edu	Carnegie Mellon University
Denison, Tim	tedenison@gmail.com	NSA
Dileonardo, Alfred	alfred.dileonardo@nga.mil	USSOCOM
Dornisch, David	dornischd@gao.gov	GAO
Farmer, Tony	farmer7@llnl.gov	LLNL
Glasgow, Kimberly	kaglasg@nsa.gov	NSA
Glass, Kristen	kglass@icasa.nmt.edu kglass609@comcast.net	ICASA, NM Tech
Hayden, Nancy	nancy.hayden@dia.mil nkhayden@sandia.gov	DTRA
Holvenstot, Chad	chad.d.holvenstot@saic.com	USSOCOM
Johnson, Jeffrey	johnsonje@ecu.edu	East Carolina Univeristy
Kendle, Megan	mkendle@jwac.mil	JWAC
Mizruchi, Mark	mizruchi@umich.edu	Univ. of Michigan
Olsen, Mardann	mardann.olsen@ngc.com	DTRA (NGIT)
Ortiz, Anna Maria	ortizA@gao.gov	GAO
Pope, Brian	brian.pope@spadac.com	USSOCOM
Rowland, Jayme	jayme.rowland@dia.mil	DIA

Name	E-mail Address	Organization
Sallach, David	sallach@anl.gov	Argonne Nat. Labs
Santos, Eunice	santos@cs.vt.edu	Virginia Tech
Shilling, Billy	bshilling@nmic.navy.mil	Office of Naval Intelligence
Stuart, Laura	lstuart@jwac.mil	JWAC
Toliver, John	jtoliver@jwac.mil	JWAC
Ward, Robert (Beau) D. (MITRE)	rdward@mitre.org	Office of Naval Research
Warner, Elizabeth	warner_elizabeth@bah.com	JIEDDO (BAH)
Wightman, Richard	richard.wightman@ngc.com	DTRA (NGIT)
Wyman, Bruce	bruce.wyman@ngc.com	DTRA (NGIT)

ANNEX III - BIOGRAPHIES

Stephen P. Borgatti

Dept. of Management, *Gatton College of Business*

University of Kentucky

Lexington, KY 40506 USA

Tel: +1 859 257 2257

Fax: + 1 859 257 3577

Email: sborgatti@uky.edu

Web Sites: www.socialnetworkanalysis.com

www.analytictech.com

Stephen P. Borgatti, Ph.D, is a professor in the Management Department at the University of Kentucky's Gatton College of Business and Economics. Named a Chellgren Endowed Professor by the Chellgren Center for Undergraduate Excellence, Dr. Borgatti's primary research interest is focused on social network analysis, but he maintains an active interest in cultural domains and knowledge management.

Dr. Boragatti is the Senior Editor at *Organization Science*, and sits on the editorial boards of the *Journal of Management*, *Computational and Mathematical Organizational Theory*, *Journal of Social Structure*, and *Field Methods*. He is a past President of the International Network for Social Network Analysis (INSNA), the professional association for social network researchers and remains a member of INSNA's Board of Directors.

Selected Publications:

Y. Chen, G. Paul, R. Cohen, S. Havlin, S. P. Borgatti, F. Liljeros, and H. E. Stanley, "Percolation Theory and Fragmentation Measures in Social Networks", *Physica A* 378, 11 19.

Chen, Y., Paul, G., Cohen, R., Havlin, S., Borgatti, S. Liljeros, F., Stanley, H.E. 2007. Percolation theory applied to measures of fragmentation in social networks. Phys Rev E Stat Nonlin Soft Matter Phys. 2007 Apr ;75 (4 Pt 2):046107 17500961

Borgatti, S.P. [forthcoming]. 2-Mode Concepts in Social Network Analysis. *Encyclopedia of Complexity and System Science*.

DeJordy, R., Borgatti, S.P., Roussin, C. and Halgin, D. 2007.Visualizing Proximity Data. *Field*

Methods.19: 239-263

Ronald L. Breiger

Dept. of Sociology

University of Arizona

Tucson, AZ 85721-0027

Tel: +520.621.3297

Fax: +520.621.9875

Email: Breiger@Arizona.Edu

Website: www.u.arizona.edu/~breiger/

Ronald Breiger (A.B. Brandeis, 1970; PhD Harvard, 1975) taught at Harvard (Assistant to Associate Professor) and Cornell (Professor to Goldwin Smith Professor of Sociology) before coming to the University of Arizona as a visiting professor in 1999 and as a tenured faculty member in the Department of Sociology in 2000. His interests include social networks, stratification, mathematical models, theory, and measurement issues in cultural and institutional analysis. With Linton Freeman, he served as editor (1999-2006) of the journal *Social Networks*. He chaired a 2002 National Academy of Sciences workshop on dynamic social network modeling and analysis, and is a recipient (2005) of the Simmel Award of the International Network for Social Network Analysis.

Selected Publications:

Ray-May Hsung, Nan Lin, and Ronald L. Breiger (eds.), **Contexts of Social Capital: Social Networks in Communities, Markets, and Organizations.** New York: Routledge.

Ray-May Hsung and R.L. Breiger, "Position generators, affiliations, and the institutional logics of social capital: A study of Taiwan firms and individuals." Chapter in Hsung et al. (eds.), ibid.

R.L. Breiger, "Culture and Classification in Markets: An Introduction." *Poetics* 33 (3-4), 2005.

Yanjie Bian, Ronald Breiger, Deborah Davis, and Joseph Galaskiewicz, "Occupation, Class, and Social Networks in Urban China." Social Forces 83 (2005): 1443-1468.

Ronald Breiger, Kathleen Carley, and Philippa Pattison (editors), *Dynamic Social Network Modeling and Analysis: Workshop Summary and Papers*. National Research Council, Committee on Human Factors. Washington, DC: National Academies Press, 2003. Online at www.nap.edu.

Peter Brooks

Peter Brooks is currently the Program Manager for the ProActive Intelligence (PAINT) Program of the Intelligence Advanced Research Projects Activity (IARPA). PAINT combines advanced modeling theories and applications to create new interagency methods to address the hardest intelligence targets. Key areas for PAINT include computational models of decision-making and the influence of social and cultural factors. Prior to his assignment at IARPA, Dr. Brooks has been with the Institute for Defense Analyses. There he led studies of advanced technologies and new operational concepts for DoD, DARPA, and other government agencies.

George B. Davis

PhD Candidate, CASOS Lab

Computations, Organizations and Society

School of Computer Science

Carnegie Mellon University

Pittsburgh, PA 15213

Email: gbd@cs.cmu.edu

Website: http://www.cs.cmu.edu/~gbd/#Personal

George B. Davis is a Ph.D candidate at the Carnegie Mellon University in Pittsburgh, PA, where he received his B.S. in Computer in 2003. Mr. Davis' research interests include Network Analysis, Strategic Network Formation and Spatial Logistical Networks.

Selected Publications:

"Factoring Games to Isolate Strategic Interactions." George B. Davis, Michael Benisch, Kathleen M. Carley, Norman M. Sadeh. Autonomous Agents and Multiagent Systems (AAMAS), 2007.

"Algorithms for Rationalizability and CURB Sets." Michael Benisch, George B. Davis, Tuomas Sandholm. American Association of Artificial Intelligence Conference (AAAI , 2006. Extended version: Submitted to Games and Economic Behavior, 2006.

"Clearing the FOG: Understanding Interstitial Relationships with Fuzzy, Overlapping Groups." George B. Davis, Kathleen M. Carley.Social Networks, under review.

David S. Dornisch

Tel: (202) 512-3273

Email: dornischd@gao.gov

David S. Dornisch is Senior Social Science Analyst in the Applied Research and Methods Team of the U.S. Government Accountability Office, where he has worked since 2002. He received a Ph.D. in Sociology at Cornell University in 1997. At the GAO, he provides a wide array of methodology and analysis services to GAO evaluation teams, including research design, survey development, focus groups and other small group methods, and quantitative and qualitative data analysis. He has been listed as a key contributor in 35 GAO publications, focusing primarily on international development and public health, as well as national security. His current research project is a study of methodological and analytical applications of network analysis to public sector collaboration issues. In his previous academic work, he studied network emergence and transformation processes in Poland and Eastern Europe.

Recent GOA Reports Include:

Global Health: Spending Requirement Presents Challenges for Allocating Prevention Funding under the President's Emergency Plan for AIDS Relief. (April 2006)

Trade Adjustment Assistance: Most Workers in Five Layoffs Received Services, but Better Outreach Needed on New Benefits. (January 2006)

Foreign Assistance: Middle East Partnership Initiative Offers Tools for Supporting Reform, but Project Monitoring Needs Improvement. (August 2005)

Other Publications:

Network Analysis Of Public Sector Coordination And Collaboration: Conceptual and Methodological Applications. Proceedings of First International Conference on Computational Cultural Dynamics. College Park, MD: University of Maryland. 2007.

The Social Embeddedness of Polish Regional Development: Representative Institutions, Path Dependencies, and Network Formation. In Tomasz Zarycki and George Kolankiewicz, eds. Regional Issues in Polish Politics. London: University College London-SSEES. 2003.

The Evolution of Post-Socialist Projects: Downsizing, Diversification, and Investment in a Polish Region. Regional Studies 36(3): 307-28. 2002.

Competitive Dynamics in Polish Telecommunications: Growth, Regulation, and Privatization of an Infrastructural Multi-Network. Telecommunications Policy (6): 381-407. 2001.

Jeffrey Johnson, Ph.D.

East Carolina University

Office: Flanagan 135

Tel: 252.328.1753

Email: johnsonje@ecu.edu

Website: http://personal.ecu.edu/johnsonje

Jeffrey Johnson is a University Distinguished Research Professor at East Carolina University. Much of his teaching and research program is focused around the use of social network theories and methods for understanding social structure and organization.

Dr. Johnson is interested in the influence of technological, ecological, and environmental factors on the organization of work, leisure, and cognition, particularly in groups in extreme and isolated environments. Recent substantive interests have focused on the relationship between cognition and social structure, with the majority of which has focused on these concerns among the maritime peoples of the Pacific basin, especially the insular Central Pacific, the Caribbean, the Arctic, the Antarctic, and coastal North America. Interdisciplinary in both training and orientation, Dr. Johnson has had teaching experience in economics, anthropology, sociology, statistics, and Pacific studies.

Selected Publications and Papers:

"Beliefs about and responses to childhood ear infections: A study of parents in Eastern North Carolina." Social Science & Medicine. 2002. 54:1153-1165. (with Curry, Mathews, Daniel & Mansfield).

Elicitation Techniques in Interviewing. (2002) In Handbook of Interview Research (J. Gubrium and J. Holstein, eds.), pp 491-514, Sage: Newbury Park (with Weller).

"Network Role Analysis in the Study of Food Webs: An Application of Regular Role Coloration." Journal of Social Structure. 2001. 2(3):1-22.(with Borgatti, Luczkovich & Everett).

"Predictors of Behavior and Performance in Extreme Environments: The Antarctic Space Analogue Program". Aviation, Space, and Environmental Medicine.2000. 71(6):619-612. (with Palinkas, Gunderson, Holland, & Miller).

Mark S. Mizruchi

Stephen M. Ross School of Business

Department of Sociology

University of Michigan

Ann Arbor, MI 48109

Tel: (734) 764-7444

Fax: (734) 763-6887

Email: mizruchi@umich.edu

Website: http://www-personal.umich.edu/~mizruchi/

Mark S. Mizruchi is a Professor of Sociology and Business Administration at the University of Michigan and is a key scholar new economic sociology and network analysis applied to both economic and political phenomena. A native of Cortland and Syracuse, New York, Dr. Mizruchi received his B.A. at Washington University (St. Louis) in 1975 and his Ph.D. at the State University of New York at Stony Brook in 1980. Dr. Mizruchi's research focuses on corporate political behavior, social determinants of corporate financing, corporate boards and governance, and uncertainty and ambiguity in bank decision-making.

Selected Publications:

Mizruchi, Mark S., Linda Brewster Stearns, and Christopher Marquis, "The Conditional Nature of Embeddedness: A Study of Borrowing by Large U.S. Firms, 1973-1994," American Sociological Review, 2006, 71:310-333.

Mizruchi, Mark S. and Christopher Marquis, "Egocentric, Sociocentric, or Dyadic? Identifying the Appropriate Level of Analysis in the Study of Organizational Networks," Social Networks, 2006, 28:187-208.

Byrd, Daniel T. and Mark S. Mizruchi, "Bankers on the Board and the Debt Ratio of Firms," Journal of Corporate Finance, 2005, 11:129-173.

Mizruchi, Mark S. and Howard Kimeldorf, "The Historical Context of Shareholder Value Capitalism," Political Power and Social Theory, 2005, 17:213-221.

Elizabeth Warner

Booze Allen Hamilton

Tel: (703) 902-6865

Email: warner_elizabeth@bah.com

Elizabeth Allen Warner is a social network analyst employed by Booz Allen Hamilton. She currently supports the Joint Improvised Explosive Device Defeat Organization (JIEDDO) at the Counter IED Operational Integration Center (COIC) as the lead social network analyst. Ms. Warner works closely with deployed US forces to provide insights into the networks constructing and using IEDs, and works closely with other community members to share operational lessons learned. Over the last four years, Ms Warner has supported several undisclosed clients in the Intelligence and DoD Communities, as well as a number of other civilian USG agencies such as NASA and the Department of Homeland Security. Her projects have included R&D for sensitivity analysis of network techniques, development and testing of computational network models, and more recently application of network techniques to battlefield operations. Ms. Warner holds a BA in Neuroscience from Hamilton College and a certificate in Computational Social Science (CSS) from George Mason University where she is completing coursework and other requirements for a MA in CSS.

Selected Publications:

Wu J, Ohlsson M, Warner EA, Loo KK, Hoang TX, Voskuhl RR, Havton LA. Apoptosis of Oligodendrocyte Processes in Spinal Cord Gray Matter During Chronic Experimental Autoimmune Encephalomyelitis. Submitting for review at *Experimental Neurology*, October 2007.

Westerlund, U, Hoang, TX, Franchini, BT, Warner, EA, Svensson, M, Kornblum, H, Havton, LA. Functional Recovery After Adult Human Neural Stem Cell Grafting In a Chronic Cauda Equina-Injury Model. Composing and submitting for review at *Experimental Neurology*, July 2005.

Nieto JH, Hoang TX, Warner EA, Franchini BT, Westerlund U, Havton LA (2005). Titanium mesh implantation – a method to stabilize the spine and protect the spinal cord following a multilevel laminectomy in the adult rat. *J Neurosci Methods* 147 (1): 1-7.

Warner, EA, Hoang, TX, Franchini, BT, DeYoung, D, Havton, LA (2005). Differential Distribution of Growth Associated Protein (GAP-43) in the Motor Nuclei of the Conus Medullaris in Adult Rats. *Exp Brain Res* 161: 527-531.

ANNEX IV – AGENDA

Dynamic Social Network Analysis Seminar

14 February 2008

8:00 – 9:00	Welcome and Introductions	
	DTRA/ASCO Welcome	*Mike Wheeler – 30 min*
	Agenda	*Nancy Kay Hayden – 5 min*
	Facility and Logistics	*Ross Amico – 5 min*
	Introductions	*All – 20 min*
9:00 – 9:45	Theoretical Underpinnings of SNA: Steve Borgatti	
	Sociological (and other) paradigms; Relationships between structural representation models and measures, theoretical behavioral mechanisms, and foundational postulates of social action systems; Major theoretical fissures; Roles for SNA in broader context of social inquiry, analytic methods and concept development.	
9:45 – 10:15	Q&A Discussion	
10:15 – 10:30	Break	
10:30 – 11:00	SNA and Data: Jeff Johnson	
11:00 – 11:30	SNA and Dynamic Modeling: George Davis	
11:30 – 12:00	SNA as an Integrative Methodology: Mark Mizruchi	
12:00 – 12:15	Break and Get Lunches	
12:15 – 13:00	Facilitated Discussion during Working Lunch	
	Topics include: appropriate and inappropriate uses of SNA; Approaches to quantifying and communicating uncertainty and confidence intervals; Relationship between level of analysis, model construction, and choice of measures; Key challenges for moving state of art forward at theoretical and applied levels; What can government sponsored research do/not do?	
13:00 – 15:15	Panel: Use of SNA for National Security	
	Dr. Dornisch – Use of SNA for GAO policy decision makers *Dr. Brooks – Public/private proactive intelligence applications* *Dr. Warner – Battlefield applications: lessons learned in adapting SNA to USG-tailored problems* *Dr. Beinenstock – Merging Approaches: Game Theory and SNA* *Santos – Discussant: Key themes summarized*	
15:15 – 15:30	Break	
15:30 – 16:30	Roundtable Discussion	
16:30 – 17:15	Summary: SNA State of Art, Promises and Challenges: Ron Brieger	

17:15 – 17:30 Wrap-Up

ANNEX V – GLOSSARY OF TERMS[59]

[59] Unless otherwise noted, all glossary terms are from Nooy, Mrvar, and Batagelj (2007).

Dyad	An unordered pair of nodes and the lines between them. (Nooy, Mrvar, and Bataglelj, 2007, p. 319)
Adjacency	Two nodes are adjacent if there is a tie (link, edge) present between the two actors (units) who are represented by the two nodes in the graph.
Structural equivalence	Two nodes i and j are structurally equivalent if and only if the ties (links, edges) from i terminate at exactly the same nodes as ties from j, and ties to i originate from the same nodes as the ties to j. Structurally equivalent nodes have identical ties to and from identical actors on all relations.
Geodesic	The shortest path between two nodes. Geodesic distance between two nodes is the length of the geodesic between them, where the length is measured in terms of the number of lines (ties, links, edges) in the geodesic. (Wasserman and Faust, 2007, p. 95; 357; 110)
Closeness Degree	The number of lines (ties, links, and edges) that are incident with it. Equivalently, the degree of a node is the number of nodes adjacent to it. (Wasserman and Faust, 2007, p183-184; 100)
Betweeness	The proportion of geodesics (shortest paths) from one node to another that pass through the given node. (Freeman, 1979)
Density	(Of a network) is the ratio of the number of lines (ties, links, edges) present to the maximum number possible, if all nodes were connected to all other nodes by one and only one line.
Path	A sequence of nodes and lines, starting and ending with nodes, in which 1) each node is incident with the lines following and preceding it in the sequence, 2) all nodes and all lines are distinct.
Path length	The number of lines in a path. (Wasserman and Faust, 2007, p. 101; 105-107).
Fragmentation	A measure of the disconnectivity of the network.
Component	A subgraph in which there is a path between all pairs of nodes and there is no path between a node in the subgraph and any node not in the subgraph (Wasserman and Faust, 2007, p. 109).

Borgatti's publications online: http://www.analytictech.com/borgatti/publications.htm

Barabasi:
"Statistical mechanics of complex networks," R. Albert and A.-L. Barabási, Rev. of Mod. Phys. **74** , 47 (2002).
"Linked: The New Science of Networks," A-L. Barabási (Perseus Publishing, Cambridge 2002).

"Scale-Free Networks," A.-L. Barabási and E. Bonabeau, Sci. Amer. **288** , Issue 5, 60 (2003).

"Error and attack tolerance in complex networks," R. Albert, H. Jeong, and A.-L. Barabási, Nature **406** , 378 (2000).

"Bose-Einstein condensation in complex networks," G. Bianconi and A.-L. Barabási, Phys. Rev. Lett. **86** , 5632-5635 (2001).

"Collective dynamics of 'small-world' networks," DJ Watts and S.H. Strogatz, Nature. 1998 Jun 4;393(6684):440-2.

Hammersley, M. and Gomm, R. (1997) 'Bias in Social Research' *Sociological Research Online*, vol. 2, no. 1, <http://www.socresonline.org.uk/socresonline/2/1/2.html>