



# INTRODUCTION

### MGT 780 Social Network Analysis

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### In this presentation ...

- SNA as a discipline
- What is distinct
- Overview of theoretical concepts
- A few methodological issues

Painting by Idahlia Stanley



# **Formal Organization**

### Professional Assoc. (since '78)

- Int'l Network for Social Network Analysis -<u>www.insna.org</u>
- Incorporated 1993
- No dept. of Social Network Analysis
  - But a few centers …

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
  - Coming soon!

### Resources

### Specialized journals

- Social Networks, (since '79)
- CONNECTIONS, official bulletin of INSNA
- Journal of Social Structure (electronic)
- CMOT
- Textbooks
  - Kilduff & Tsai, 2004
  - Scott, John. 1991/2000
  - Degenne & Forsé. 1999
  - Wasserman & Faust. 1994

### Software

- UCINET 6/NETDRAW;
- PAJEK
- SIENA
- STRUCTURE; GRADAP; KRACKPLOT

### Listservs & Groups

- SOCNET listserv (1993)
- REDES listserv
- UCINET user's group

## **Explosive Growth**



Embeddedness, social capital, SRT, collab theory
 TCE, RD, Institutional theory, transactional knowledge, etc

- Google page rank
- Social networking software
- Management consulting
- Network organizations
- Anti-terrorism
- Epidemiology



# **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)
- 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 & dyadic thinking; Rise of social capital,
- 2000s Physicists' "new science"
  - Scale-free
  - Small world



## What is distinctive about the field?

### The phenomena: What we study

- Social relations among entities, conceptualized as a social network
- The methodology: How we study it
  - Units of observation (cases) are dyads, not individual actors
  - Variables are relations, not actor attributes
  - Dyadic, autocorrelated data require different statistical methods
- The theory: How we understand it
  - Model groups as networks
  - Theoretical constructs such as centrality, structural equivalence, bridging holes, etc.
  - No single theory of everything, but common perspective

Focus of this presen tation

### I arrange network theory in layers ...

#### **Knowledge Layer**

- Empirical findings
- Network antecedents
- Network consequences

#### **Construct Layer**

- Theoretical vocabulary
- System properties / vars

#### **Paradigm Layer**

- Deepest metaphors
- Taken for granted axioms
- Generative models

# PARADIGM LAYER

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### What is a Network?

A set of actors (nodes, points, vertices)

- Individuals (e.g., persons, chimps)
- Collectivities (e.g., firms, nations, species)
- A set of ties (links, lines, edges, arcs) of a given type that connect pairs of actors
  - Directed or undirected
  - Valued or presence/absence
- Set of ties of a given type constitutes a social relation
- Different relations have different structures & consequences

000 scientists



### Case Study: Simple Answers

Who you ask for answers to straightforward questions.



Cross, R., Borgatti, S.P., & Parker, A. 2001. Beyond Answers: Dimensions of the Advice 10 January 2008 Network. 759 6 20 Network 759 6 20 Network 14

### **Problem Reformulation**

#### Who you see to help you think through issues



Cross, R., Borgatti, S.P., & Parker, A. 2001. Beyond Answers: Dimensions of the Advice 10 January 2008 Network. 300 arWerWork B29(3): 215-235

## **Relations Among Organizations**

#### As corporate entities

- sells to, leases to, lends to, outsources to
- joint ventures, alliances, invests in, subsidiary
- regulates
- Through members
  - ex-member of (personnel flow)
  - interlocking directorates
  - all social relations

### **Internet Alliances**



# Co-Membership > 27%



### Ties $\rightarrow$ Networks

- Dyads link up to form networks
- Networks have paths
  - Indirect connections between nodes not directly connected
  - Paths permit indirect influence and flows
- Networks have structure
  - Patterns of connectivity
    - Clumpy networks
    - Core/periphery structures
  - Topological features have consequences
    - Searchability
    - Exploitability

# Ties as Conduits

ТΧ

NY

Certain ties can serve as pipes or roads that enable flows/traffic (and in their absence, prevent it)

- Information, solutions, material aid, resources
- Attitudes, behaviors, practices
- Interpersonal models of diffusion, influence

NY 21

Case study: Diffusion of AIDS

Sexual relations among patients with rare cancers --- Bill Darrow, CDC

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NY 13

> NY 11

> > NY

NY

### **Ties as Scaffolding**

Emergent, non-reductionist, non-individualist, nonessentialist, holist, structuralist flavor to some research



## **Opportunities & Constraints**

A person's position in a social network (i.e., social capital) determines in part the set of opportunities and constraints they will encounter

 Marxian notion of relation to means of production



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### Human Capital and Social Capital

How far can you get on human capital alone?Betting on social capital



**GUIDING THEORETICAL PRINCIPLES** 

### Rate of return on human capital

Burt: A person's connections determine the rate of return on human capital



# Think like a network theorist ...

![](_page_24_Figure_1.jpeg)

## **Fundamentals**

### Non-atomism

- Actors do not act or exist independently
- Have ties/relations to other actors
- Relations are at least as important determinants of actor attributes (e.g., performance or internal structure) as other attributes are

### Multiplexity

- Actors can have multiple different relations with the same others
- Different relations have different functions or effects
- Network model
  - Ties link up to form networks whose paths connect distant nodes
  - Actors locations within these networks affect their outcomes

Key theoretical constructs that are "good to think with"

# **CONSTRUCT LAYER**

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## **Multiple Levels of Analysis**

### Dyad (relationship) level

- Network data is fundamentally dyadic
  - Who is friends with whom in an office
  - Distance in meters between people's desks
  - Marriage ties among families in Renaissance Florence
  - Business ties among the same families
- Node (actor) level
  - Can aggregate to the node level (e.g., no. of friends)
  - Or measure aspects of a node's position in the network
- Group (network) level
  - Aggregation to the group or whole network level (e.g., no. of ties within group
  - Or measure aspects of network shape (e.g. centralization)

![](_page_28_Picture_0.jpeg)

### Beware the Micro/Macro distinction

### In organizational studies

- Micro refers to studies in which the actors are persons
  - Personality → Status
- Macro refers to studies in which the actors are firms
  - Firm size → Profits

But in network research ...

- Micro means focus on actors
  - Which could be firms ...
- Macro means focus on the network in which actors are embedded

## Families of Network Concepts

![](_page_30_Figure_1.jpeg)

# Density of ties

Density = proportion of pairs of actors that are actually tied
 In some contexts, could be thought of as measure of social capital

![](_page_31_Figure_3.jpeg)

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**GROUP** level of analysis

# Case Study: Entwistle et al study of help with the rice harvest

![](_page_32_Figure_2.jpeg)

Village 1

Data from Entwistle et al

#### **GROUP** level of analysis

# Social Capital?

![](_page_33_Figure_2.jpeg)

### Village 2

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Data from Entwistle et al

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# **Core/Periphery Structures**

### Core/Periphery

- Network consists of single group (a core) together with hangers-on (a periphery),
  - Core connects to all
  - Periphery connects only to the core
- Short distances, good for transmitting information, practices
- Identification with group as whole
- E.g., structure of physics

### Clique structure

- Multiple subgroups or factions
- Identity with subgroup
- Diversity of norms, belief
- E.g., structure of social science

![](_page_34_Picture_14.jpeg)

## **On Innovation and Network Structure**

"I would never have conceived my theory, let alone have made a great effort to verify it, if I had been more familiar with major developments in physics that were taking place. Moreover, my initial ignorance of the powerful, false objections that were raised against my ideas protected those ideas from being nipped in the bud."

- Michael Polanyi (1963), on a major contribution to physics

![](_page_35_Picture_4.jpeg)

### GROUP level of analysis Case Study: Johnson's study of morale at the South Pole

![](_page_36_Figure_1.jpeg)

### **Node Level Variables**

![](_page_37_Figure_2.jpeg)

### Year 1

#### Year 4

White House Diary Data, Carter Administration

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Data courtesy of Michael Link

# Case Study: Consulting Firm

![](_page_38_Figure_2.jpeg)

Cross, Parker, & Borgatti, 2002. Making Invisible Work Visible. California Management Review. 44(2): 25-46

# **Changes Made**

- Cross-staffed new internal projects
  - white papers, database development
- Established cross-selling sales goals
  - managers accountable for selling projects with both kinds of expertise
- New communication vehicles
  - project tracking db; weekly email update
- Personnel changes

#### NODE level of analysis

## 9 Months Later

![](_page_40_Figure_2.jpeg)

Cross, Parker, & Borgatti, 2002. Making Invisible Work Visible. California Management Review. 44(2): 25-46

### **Betweenness Centrality**

How often a node lies along the shortest path between two other nodes

Defined as:

$$b_k = \sum_{i,j} \frac{g_{ikj}}{g_{ij}}$$

where gij is number of geodesic paths from i to j and gikj is number of those paths that pass through k

- Seen as index of potential for gatekeeping, brokering, controlling the flow, and also of liaising otherwise separate parts of the network;
- Expected to correlate with power and access to diversity of what flows; potential for synthesizing

NODE level of analysis

# Case Study: Pitts' analysis of Moscow's emergence to pre-eminence

![](_page_42_Figure_2.jpeg)

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## Position in the River Network

![](_page_43_Figure_2.jpeg)

### Dyad Level of Analysis

How one kind of tie between nodes begets another
 Case Study: Tom Allen (1977) study of physical proximity and amount of communication

![](_page_44_Figure_2.jpeg)

**Distance (meters)** 

Antecedents of network variables Consequences of network variables Relations with other schools of thought

# **KNOWLEDGE LAYER**

### **Causality and Network Research**

![](_page_46_Figure_1.jpeg)

#### TYPES OF SIMPLE HYPOTHESES

	Independent Variable	Dependent Variable	Example Study
Dyad Level	Network tie	Network tie	doing business w/ ea other → friendship
	Network tie	Attribute similarity	Friends → similar political attitudes
	Attribute similarity	Network tie	Smoking → friendship
Node Level	Node level network property	Node level network property	Degree → betweenness
	Node level network property	Actor attribute	Centrality $\rightarrow$ performance
	Actor attribute	Node level network property	Good looks → centrality
Group Level	Group level network property	Group level network property	Density → Avg path length
	Group level network property	Other group attribute	Density → team performance
	Other group attribute	Group level network property	Prop women → density of trust ties

# **Antecedents of Network Variables**

#### Dyad level – who has ties with whom?

- Homophily
  - Propinquity
  - Common affiliation
  - Socially significant attributes
- Status
  - Preferential attachment, etc.
- Triadic balance theory
  - A—B and A—C tends to lead to B—C
  - Strength of tie
- Multiplexity
  - Cross-sectional, longitudinal
- Node characteristics
  - Personality  $\rightarrow$  centrality
- Network (group) characteristics
  - Small world networks (clumpy networks with short distances)
  - Scale-free networks (skewed degree distributions)

![](_page_48_Figure_18.jpeg)

	Male	Female
Male	1245	748
Female	970	1515

## **Consequences of Network Variables**

Ends	Explaining Variance in Performance	Explaining Social Homogeneity
Means	(social capital)	(adoption)
Connectionist mechanisms (flows thru ties)	Success comes from obtaining resources <u>through</u> social ties; Lin's social resource theory	People have same behavior because they directly <b>influence</b> each other & transmit ideas, beliefs, etc.
Topological mechanisms (emergent properties of topology)	Network positions /shapes provide opportunities for exploitation; Burt's autonomy theory	People have same behavior because their network positions are similar (and affect them similarly); same <b>social</b> <b>environment</b>

Borgatti, S.P. and Foster, P. 2003. The network paradigm in organizational research: A review and typology. *Journal of Management*. 29(6): 991-1013

# The Frontier

![](_page_50_Picture_1.jpeg)

# Where the energy is

Stochastic methods – ERGM, SIENA
 Analyzing transactions & interactions

- Network evolution
- Simulation, what-if analysis, optimization
- Data imputation
- Large networks
  - Processes and structures
  - Technical issues

## Trends & Buzzwords

Is the field getting too popular too fast?

# of Social Capita Papers Embeddedness Weak ties Network ties "Networking" 1975 1985 1995 Time WARNING: Totally made-up data! Do not take seriously! DEGREES Do fads sweep out equal areas under the graph? A CONNECTED AGE UNCAN J. WATTS 10 January 2008 MGT 780 © 2008 Steve Borgatti

**Small worlds** 

**Communities?** 

Scale-free

A few notes on **METHODOLOGY** 

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# Mainstream Logical Data Structure

Cases

(entities)

### 2-mode rectangular matrices

- Rows (cases) are entities, e.g., persons
- Columns (variables) are attributes of the cases
- Analysis consists of correlating columns
  - Typically identify one column as the thing to be explained
  - We explain one attribute as a function of the others

Variables (attributes)

	Age	Sex	Education	Income
1001				
1002				
1003				
1004				
1005				

# Network Logical Data Structures

#### Adjacency matrices

#### Incidence matrix

![](_page_55_Figure_3.jpeg)

#### Proximity

	Jim	Jill	Jen	Joe
Jim	-	3	9	2
Jill	3	-	1	15
Jen	9	1	-	3
Joe	2	15	3	-

	Friendship	Proximity
Jim - Jill	1	3
Jim - Jen	0	9
Jim - Joe	1	2
Jill - Jen	1	1
Jill - Joe	0	15
Jen - Joe	1	3

- Multiple relations for same set of actors
- Each relation is a (dyadic) variable
  - But can also be aggregated to node/group level
- Cases are pairs of actors
- Some hypotheses can be phrased in terms of correlations between relations

### **Ego Network Analysis**

![](_page_56_Figure_1.jpeg)

Combine the perspective of network analysis with the data of mainstream social science

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### What is an ego network?

A focal actor (the respondent, called ego), together with the actor's contacts (called alters), and, often, a limited set of ties among the alters

![](_page_57_Picture_2.jpeg)

### Ego Network Data Collection

- (Random) survey of members of a population
- Ask respondents (egos) about their contacts (alters)
  - E.g., who they confide important matters with
  - Contacts identified by nicknames or aliases
- Characterize relationship with each alter
- Obtain attribute data about each alter (ego's perception)
- Optionally obtain ego's perception of which alters have ties with which other alters

## Ego vs Full Data Collection

### **Ego Network**

- Never use roster method (always unaided recall)
- Ask many relational questions
- Ask relational questions in two stages
- Ask respondents to provide data about their alters
  - Because alters are not interviewed

### **Full Network**

- Use rosters whenever possible
- Typically ask very few questions
- Ask questions only once
- Only ask respondents about themselves
  - Because alters will be interviewed as well

### Ego Network Analysis

- Cannot use analysis techniques that depend on the whole network, such as position-based methods
- Only use techniques that evaluate a node's immediate neighborhood
  - Network composition assessments, E.g., % of women
  - Selection & influence: Investigating homophily / heterophily
  - Homogeneity / heterogeneity, e.g., % alter income variance
  - Social capital: e.g., access to wealth & power
  - [if alter-alter ties are available] Structural holes & other local density assessments
    - Are my friends friendly with each other?