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2 History of social network analysis

The roots of social network thinking are to be found in relational or structural approaches to social analysis that developed in classical sociology. While some approaches to sociology and anthropology used the ideas of culture and cultural formation to explain social patterns of feeling, thought, and behaviour, and others stressed the material environment and the physicality of the body as crucial determinants, a particularly important strand of social thought focused its attention on the actual patterns of interaction and interconnection through which individuals and social groups are related to each other. In some cases this involved a conception of the 'social organism', or social system, as a structure of institutions that constrain the subjectivity and actions of those who occupy positions within those institutions. For other theorists, however, greater attention was given to the immediate face-to-face encounters through which individuals relate to each other and that are constantly refigured through the actions of these individuals.

It was among the latter theorists that the metaphors of the social 'network' and its equivalents—such as the social 'web' or

the social 'fabric'—first emerged. German social theorists such as Ferdinand Tönnies and Georg Simmel took up this idea in their 'formal sociology', seen as a sociology of the 'forms' of interaction that carry and contain the diverse subjectively meaningful contents that motivate the actions of individuals. The translation of this work and the publication of much of it in the *American Journal of Sociology* encouraged many US sociologists of the first decade of the twentieth century to pursue an 'interactionist' approach to social life. Charles Cooley, Albion Small and George Mead were, perhaps, the leading figures in this movement of thought. In Germany itself, the sociologies of Alfred Vierkandt and Leopold von Wiese explored the interweaving of actions into large-scale social forms such as the market and the state. A number of these theorists explicitly adopted a terminology of 'points' and 'lines' to depict the networks of connections that tie individuals into the 'knots' and 'webs' of social structure. Wiese (1931) was, perhaps, among the very first to use these quasi-mathematical ideas explicitly in a theoretical monograph, labelling points with letters and referring to the directionality and circularity of interweaving lines of connection.

Sociometry, small groups, and communities

The earliest empirical work on small groups and communities occurred in the United States, where researchers with a background in psychology and psychoanalysis undertook a series of investigations into the friendship choices made in educational contexts by school children and college students. Friendship

choices among classmates were seen as a way of exploring the cohesion of school class groups and the relative popularity of particular pupils. Growing out of a long tradition of child study that had peaked with Stanley Hall's (1904) developmental study of adolescence, the earliest published report on friendship networks was that of Helen Bott (1928), who studied play activities among nursery school children.

The leading influence in the development of this work, however, was an Austrian psychoanalyst who had migrated to the United States. Influenced by the way in which Alfred Vierkandt had combined a relational focus with a phenomenological concern for the meanings and emotional significance of relationships, Jacob Moreno devised systematic formal methods for charting social relations among children. Moreno's aim was both to measure and to draw social relations, referring to his work as 'sociometry' and to his drawings as 'sociograms' (Moreno 1934).

Moreno observed children's interaction and counted the numbers of friendship choices made and received by different class members, combining these into sociograms that depicted each child as a point and their friendship choices as lines with arrow heads. These arrow heads showed the direction in which a choice was made: distinguishing 'outgoing' choices directed *at* others from 'incoming' choices received *from* others. This method allowed Moreno to identify the most popular 'stars' of attraction and the relative 'isolates' who received few or no friendship choices. An example of one of his sociograms is shown in Figure 1. Moreno was also able to see whether certain children attempted to make friends with others but were not able to secure reciprocal choices from those they sought out. Through

Figure 1 An acquaintanceship sociogram
(Source Moreno 1934: 145)

compiling the various friendship choices made by class members into a single sociogram, Moreno aimed to use a sociometric investigation to model the overall connectedness and emotional climate of the group (see Jennings 1948).

One influence on Moreno's work was the tradition of *Gestalt* psychology. Kurt Lewin, also a German émigré to the United

States, was even more firmly embedded in this tradition of analysis and pioneered a more general psychology of small groups. *Gestalt* psychology involves a focus on the mental structures that allow people to organise and make sense of their experiences, basing its ideas on observations of non-human primates (see Köhler 1917). Lewin aimed to translate this basic idea to the social level, aiming to show that the social structures of groups are the means through which their actions are organised and constrained. His investigations into social groups were concerned, then, with how such structures are produced and the effects they have on the communication and actions of their members.

Lewin's starting point was to see groups as 'fields' of interaction—hence his adoption of the term 'field theory' to describe his approach. A group field is the life space within which people act, and their friendship choices and other social relations are to be understood as creating forces of attraction and repulsion within the field that constrain the flow of ideas through the group. A particular individual, for example, is able to communicate ideas only through his or her direct contacts or through intermediaries who are able to pass them on. The diffusion of ideas, then, depends upon the structure of group relations within which the communicating individuals are located.

The work of Lewin inspired a series of experimental studies that led to the establishment of 'group dynamics' as a specialism within social psychology (Cartwright and Zander 1953; Harary and Norman 1953). It was in this specialism that researchers began to use more systematic mathematical arguments to model group structure. Using the mathematical approach called graph

theory, which investigates the formal properties of networks, or 'graphs', of all kinds, they began to operationalize ideas of the 'density' of sociograms and the 'centrality' of individuals. In graph theory, the formal properties of points and lines in a network become the objects of a mathematical analysis that discloses the constraints that shape network form.

Researchers in group dynamics constructed formal models of group structure, such as the star, the 'Y', the chain, and the circle (see Figure 2), and held that these structures had very different implications for effective communication because some individuals are in critical 'central' positions. If a group is structured into a long chain of connections in which information is communicated by passing it through a series of intermediaries, then it is likely that meanings will become slightly distorted and altered with each step in the flow of communication. Much as happens in the children's game of Chinese Whispers, the message received at the end of the chain may be quite different from that sent at the beginning. In a group in which there are many direct connections and alternative channels of communication, on the other hand, meanings are less likely to alter as they flow through the group because the multiple channels introduce 'corrections' and so greater conformity in thought and behaviour is to be expected.

Intermediaries in social groups, especially those at the centres of 'stars', have been seen as the potentially more powerful members of their groups: they are the influential opinion leaders because of their central locations within the group. Research in group dynamics has explored the ways in which relations of dependence within groups can enhance or diminish power and

Figure 2 Sociometric structures: star, Y, chain, circle

foster particular structures of leadership (French and Raven 1959). Other investigators have focused rather more on the extent to which social relations are reciprocated and, therefore, the patterns of 'balance' and imbalance that characterise different groups (Davis 1963). The research of Festinger (1957) linked this with ideas of subjective mental balance in attitudes and ideas so as to explore particular patterns of group response (Festinger *et al.* 1956).

In the 1930s, George Lundberg (1936; Lundberg and Steele 1938) had extended basic sociometric techniques to the study of village communities, but it was not until the 1950s that sociometric techniques really began to move beyond small and experimental groups to larger groups in real settings. The Canadian social psychologist Elizabeth Bott—daughter of the pioneering sociometric researcher Helen Bott—worked at the Tavistock Institute, where sociometry and group dynamics had its British base. Here she carried out a comparative study of working-class and middle-class couples in London. Bott (1957) showed that members of each class were embedded in different,

class-specific, structures of kinship and friendship and that these networks influenced their 'conjugal' domestic relations within their households. She examined, in particular, gender differences in social networks and conjugal roles.

Bott worked closely with social anthropologists who were already beginning to explore the implications of Alfred Radcliffe-Brown's (1940) view that the social relations of tribal societies could be investigated through constructing models of the 'structural forms' of these relations. John Barnes (1954) brought these ideas together in his report on the communal structure of the fishing village of Bremnes in western Norway and his work proved particularly influential in the work in Central Africa that Max Marwick was establishing as an offshoot of the Department of Sociology and Social Anthropology at Manchester University. Clyde Mitchell, Scarlett Epstein, Bruce Kapferer, and others worked severally on a series of studies of community and kinship and their effects on gossip and strikes. These studies were brought together in an influential collection that aimed to show the power of graph theory as a model for social relations in complex societies (Mitchell 1969).

From the late 1960s, researchers in the United States took advantage of the advances being made in the use of computers for data analysis and began to apply more systematic and rigorous ideas in their studies of larger community and economic networks. Granovetter (1974) looked at friendship relations as sources of information about job opportunities and developed the influential idea that people acquire the most useful information from their more distant ties. When a job opportunity becomes available locally, information flows quickly and rapidly

through the dense and well-connected local networks and everyone tends to acquire the same information. More distant job opportunities, however, come to be known about only by those with generally looser connections beyond their immediate locality. Those with such connections may, therefore, have a distinct advantage in their job search activities as they will have more opportunities than those with only locally dense connections (see Figure 3). Granovetter (1973) described this as the thesis of the strength of weak ties.

Figure 3 Strong and weak ties

Wellman (1979; Wellman and Hogan 2006; see also Fischer 1977; 1982) used social survey methods to collect information on friendship and kinship relations in Toronto, Canada. His aim was to explore whether individuals relied exclusively on local connections or were able to keep in touch with those who had moved away to other parts of the city or country. He was able to examine people's range of immediate social contacts, the frequency and perceived intensity of these ties, and the opportunities provided by the telephone and the car to maintain contacts over extended distances.

Bearden and his colleagues (1975; and see Mizruchi 1982; Mintz and Schwartz 1985) investigated corporate

board-level connections in top US companies, while Helmers and his colleagues (1975) undertook a similar study in the Netherlands and rapidly extended this into an international comparison (Stokman *et al.* 1985). This research highlighted the relative 'centrality' of banks and financial companies in corporate networks and the changing relationships between financial and industrial companies in major economies. They documented structures of coordination and communication among large business enterprises and pointed to their effects on economic performance and class cohesion.

Cliques, roles, and matrices

The work of the Manchester anthropologists studying African societies was not the first attempt by social anthropologists to investigate social networks. Lloyd Warner worked in the Durkheimian tradition of Radcliffe-Brown and had undertaken a conventional study of kinship among native Australians before moving to the United States and joining with the psychologist Elton Mayo to undertake an anthropological study of a Chicago factory and its workforce. This pioneering use of anthropological techniques to study 'advanced' societies proved important in generating an alternative to purely sociometric studies.

Industrial psychologists working at the Hawthorne electrical works in Chicago had been undertaking experimental studies on the effects of physical conditions on work satisfaction and output. They had discovered that improving the heating and lighting conditions, allowing rest periods, and other physical

alterations to the workplace improved worker morale and led to greater productivity. They were confused to find, however, that similar changes occurred when physical conditions were restored to their original state or even allowed to deteriorate. Uncertain how to interpret these findings, they called on Mayo and Warner to advise them. It was soon concluded that the workers were responding to the experiment itself rather than to the changes in physical conditions. The managers had specially selected a group to study, had located them in an area of the factory separate from other workers, and had, for the first time, seemed to show an interest in their welfare. This phenomenon became known as the 'Hawthorne effect' in experimental studies.

In arriving at these conclusions, Mayo and Warner pursued their own observational and experimental studies in the factory. Of particular importance was their observational study of a wiring room where they observed friendly and hostile interactions, cooperation, and offers of help (Roethlisberger and Dickson 1939). Some of their findings were reported as sociograms, though they seem to have been inspired by the electrical wiring diagrams that abounded in the factory rather than by published sociometric work. Their most important work, however, used tabular or matrix representations to depict the formation of 'cliques'. Presenting observed interactions in a table in which the rows represent individuals and the columns represent the occasions in which they participate, allowed the researchers to identify those individuals who interact frequently and the occasions or circumstances in which they interact. They identified a clique in the wiring room that comprised those who tended to help each other and a set of isolates who found it difficult to get

Figure 4 Clique structure
Source: Roethlisberger and Dickson (1939: 507)

help when it was needed and drew this as a diagram (see Figure 4). Cliques were seen as formal representations of the commonly expressed idea that people may feel they are part of an ‘in-crowd’ or that they are outsiders to it.

Warner decided to pursue similar issues through a community study in the New England town of Newburyport. Regarding this as a typical American town with its roots in the early colonial period, he referred to it as ‘Yankee City’ in his published studies (Warner and Lunt 1941; 1942; Warner and Srole 1945; Warner and Low 1947; Warner 1963). Later in the 1930s he supervised a similar study in the equally old southern town of Natchez, referring to this as ‘Old City’ (Davis *et al.* 1941). In these studies, Warner and his teams explored the formation of ‘cliques’, understood as informal communal groupings based on feelings of intimacy and solidarity and that existed alongside the formal associations of church, business, leisure, and politics. This relationship between communal and associational patterns, informal and formal ties,

can be seen in relation to Tönnies (1887) earlier suggestions on the relationship between *Gemeinschaft* and *Gesellschaft*.

The Warner research showed that people tend to be members of numerous overlapping cliques and that it is through the intersection of cliques that overarching structures of community solidarity and cohesion are produced. Warner and his colleagues argued that examination of the pattern of rows and columns in a data table can show the existence of cliques and the relationships among them. Instead of using sociograms, they reported the cliques in Venn diagrams in which circles and ellipses represented sets of interacting individuals, as they had done in the Hawthorne studies (see Figure 5). At an aggregate level for the whole community they allocated individuals to a social class and then represented each social class as a row in a matrix of connections among the various cliques. This procedure allowed them to identify the macro-structural positions found in the communities. Their research highlighted social divisions of both class and ethnicity, showing the existence of a rigid 'colour line' separating black and white communities.

Figure 5 Overlapping cliques in a social hierarchy

George Homans (1950) undertook a systematic review of small-group studies, aiming at a theoretical synthesis of ideas. At the heart of this synthesis was his use of sociometric ideas of the frequency and direction of social relations, but he also explored the matrix methods used by Warner for clique identification. Revisiting the analyses of informal interaction undertaken in Natchez by Warner's team, he began to develop a systematic method of matrix analysis that has since become a central part of social network analysis. Homans looked at the meetings of 18 women at 14 social events, as represented in an 18×14 matrix, and claimed that a simultaneous manual rearrangement of rows and columns could bring out the internal clique structure. A matrix is typically arranged in an arbitrary order, listing individuals and events alphabetically or, at best, chronologically. Shuffling the order of rows and columns until a strong pattern appears in the cells discloses the structure that is hidden by these arbitrary arrangements.

This kind of trial and error rearrangement is slow and cumbersome, even for a relatively small group, and Homans's method was not pursued until much later. It did, however, point the way towards systematic investigations of structural positions within networks of the kind that were being suggested by the social anthropologist Nadel (1957). Aiming at a formal, mathematical approach to anthropology, Nadel showed that algebraic methods for set analysis could be used to model the 'roles' within a social structure. Where sociometric uses of graph theory focused on the actual interactions of particular individuals, algebraic set theories focused on the positions and roles that these individuals occupied and at role relations at the level of the social structure as a whole.

Algebraic and matrix methods were developed by Harrison White and others (1963; Lorrain and White 1971) and they were able to take advantage of advances in computing to undertake matrix rearrangements for large-scale social networks. In an approach that they called ‘blockmodelling’, they saw blocks of cells in a matrix as representing the structural positions that Nadel had sought (White *et al.* 1976; Boorman and White 1976). The individuals who occupy each position are ‘structurally equivalent’ to each other: they are, for network purposes, interchangeable, and their individual characteristics and connections can be disregarded. Thus, all fathers may be expected to relate in similar ways towards their sons and daughters, while all teachers may be expected to relate in similar ways towards pupils. The characteristics of roles are social facts that are independent of the particular attitudes and outlooks of their individual occupants.

Figure 6 Blockmodel role structure

Space and distance

The sociometric uses of graph theory measured the ‘distance’ from one individual to another by the number of links that must be traversed to connect the two. This is a useful measure

of closeness, but it does not correspond to the everyday idea of distance as something measured across a physical space. In a sociogram, the physical arrangement of points is arbitrary, limited only by the aesthetic attempt to minimise overlaps among the lines. A measure of physical distance, however, requires a non-arbitrary representation of the data. The distance between two towns in miles, for example, can be measured 'as the crow flies' rather than by traversing a network of roads (of varying length) and intersections. A number of network researchers have, therefore, attempted to construct models of 'social space' in which straight line, 'crow flies' distances can be measured (Bogardus 1925; 1959). Embedding a network of connections in such a space allows both the pattern of connections and relative distances to be studied.

In some applications, a simple idea of perceived social distance has been used. Individuals may be presented with a simple friendship chart (see Figure 6) and asked to plot the position of those they know in terms of their subjective or emotional distance: close friends, people who you are acquainted with on a day-to-day basis, or more distant friends. The resulting chart gives a visual representation of a person's social world in terms of the degree of intimacy they have with various numbers of other people (Wallman 1984: 61, 66–7; Spencer and Pahl 2006). These charts have provided a useful approach to affective personal networks.

A more formal idea of social space was inherent in the early work of Lewin, but it really developed as a formal method in psychology. Psychometric studies of attitudes had used methods of 'scaling' to show the relative strength of attitudes and this led

Figure 7 Affective distance in friendship

to attempts to measure two or more attitudes through the intersection of their scales in a cognitive space that could be taken to represent a structural part of the mind. Such approaches were called smallest space analysis (SSA) because they involved an attempt to define the smallest number of dimensions (scales) that would represent a particular cluster of attitudes. This approach was generalised as multidimensional scaling (Kruskal and Wish 1978) and began to be applied to social phenomena

as a way of reporting structural features of social space (Coxon 1982; and see applications in Hope 1972).

Of particular importance in plotting networks in social space have been the methods of factor analysis and principal components analysis, both of which attempt the construction of a smallest-dimension social space in which clusters of individuals or positions can be represented. The most recent development of this approach has been multiple correspondence analysis (Rouanet and Le Roux 2009), a version of which was used in the stratification studies undertaken by Bourdieu (1979). Computer programs now produce multidimensional scaling images that show the actual social distance between points, as shown in Figure 8.

Multidimensional scaling was applied in a study of communities by Edward Laumann (1966; 1973; and see Laumann and Pappi 1976). Focusing on positions rather than individuals, Laumann

Figure 8 Multidimensional scaling of a network

traced the friendship patterns of those in particular occupational categories. The frequency of friendship ties among pairs of positions was taken as a measure of the distance between the positions and computerised techniques were used to generate an overall space in which the classes could be mapped according to their friendship distance. This was, therefore, an attempt to measure differential association among social classes. Laumann's study generated a three-dimensional model of community structure in which the same social classes could be represented as clouds or clusters of points.

One of the most influential studies that used multidimensional scaling was that of Joel Levine (1972) on interlocking corporate directorships. Using data on large US banks in 1966, Levine constructed measures of similarities in patterns of connection around each of the principal banks. He subsequently used this method to produce a comprehensive 'atlas' of corporate connections (Levine 1984).

Advances in computer software have made it very easy to carry out multidimensional scaling. One of the leading software programs (PAJEK) uses a spring-embedding technique to position a network in a multidimensional space and allows the network to be rotated for the visual inspection of its structure.

Dynamics and social change

The majority of the early studies of social networks have been static and descriptive. They have reported on the features of social networks as they exist at a particular time, but they have

not generally attempted to explore the internal dynamics that lead a network to change from one state to another. Where a concern for time and change has been apparent, this has involved the construction of a series of cross-sectional studies with processes of change imputed but not directly studied (see Scott and Grifff 1984; Scott and Hughes 1980). A move towards dynamic models is a relatively recent phenomenon and has come about through work by physicists who have been unaware of previous research by social psychologists, social anthropologists, and sociologists.

Motivated by an apparent decline in fundamental theoretical problems in physics itself, a number of physicists have explored the possible extensions of mathematical models from physics to other intellectual fields. Barabási (2002) has been the leading advocate of the application of physical models to social and economic phenomena, seeing himself as a pioneer in virgin territory (Scott 2011b). Highlighting the importance of a paper by Watts and Strogatz (1998), Barabási has produced an approach that, for all its numerous limitations, does provide some novel ideas that have helped to bring about a greater awareness of the importance of dynamic analysis.

Work in this area has used Stanley Milgram's (1967; Travers and Milgram 1969) studies of 'small worlds' to explore the limits to certain kinds of variation in network structure. Milgram was interested in the fact that strangers are often able to identify mutual acquaintances or connections and will exclaim 'what a small world!' To explore this phenomenon he carried out an experiment in which he asked volunteers to pass a message to a named, but unknown, individual in another country. The volunteers were

instructed that they must pass the message only to a person known to them and that this second person must also pass the message to a known individual. The message must, therefore, be passed forward in the manner of a chain letter. Each person who receives the message is instructed, however, to pass it on to an acquaintance who they feel is likely to be able to get the message, directly or indirectly, to the target individual. Milgram found that messages could typically get from source to target through an average of six connections, or five intermediate individuals. This is the now-famous idea of 'six degrees of connection'.

Watts and Strogatz began to explore the mathematical properties of the networks in which these experimental conclusions hold. They showed that only certain kinds of networks have these small-world properties and that many of the measures used in social network analysis depended on their presence in the networks studied. Their focus of interest was, therefore, on variations in network structure and shifts of state from a small-world network to either more or less densely connected networks. Duncan Watts (1999; 2003) has shown that small-world properties exist in networks that are clustered into zones of relatively high density and by a differentiation between strong and weak ties. In such a network, the overlapping of connections is so great that the line distances between points are optimally low. A small-world graph contains many 'redundant' links such that points tend to be connected through multiple alternative paths. Watts showed that small changes in the connectivity of such networks can significantly alter their properties if these changes occur close to the threshold levels that define the small-world conditions.

Radical structural changes can therefore follow from minor local-level changes.

Structural change, then, is seen as resulting from the local-level making and breaking of connections and occurs as an unintended consequence of those actions. These kinds of change have been modelled in agent-based computational models that aim to simulate agent decision making and so to trace change over time. This work developed independently of work by physicists (see Snijders *et al.* 2010) but has rapidly been recognised as providing an essential element in the dynamic models proposed by the physicists. Tom Snijders's model depicts individuals as rule followers who make or break their social relations according to particular decision rules. Individuals act 'myopically', without awareness of the larger consequences of their actions (which are, typically, unknown and unpredictable to them). Individuals acting in this way produce incremental linear changes in the overall structure of the network. When their actions reduce the number of redundant links beyond a certain point, however, change may be radical and non-linear. At critical threshold points there is what Watts has called a 'phase transition' that disrupts the capacity of the network to continue developing as before. The diffusion of innovations and the flow of capital, for example, may be completely disrupted by such a transition. When local-level actions increase the number of redundant links beyond an upper threshold point, on the other hand, the network becomes so highly connected that ideas and resources can rapidly spread through the network at such a rate that all positional advantages are lost.

I have reviewed the history of social network analysis through tracing developments in relation to a number of specific

methodological approaches. The earliest of these was graph theory and the associated techniques of sociometry. This provides an intuitive modelling of social networks and allows a number of fundamental and advanced measures of network organisation to be calculated. The second mathematical approach I considered was the algebraic use of sets and matrices to uncover the structure of positions and roles within a network. While this approach is perfectly compatible with graph theory, it highlights quite distinct sets of issues. Next I looked at spatial models that emulate geographical mapping techniques to produce spatial configurations of points. These techniques allow a move away from the arbitrary configurations of sociometric sociograms and towards more visually meaningful arrangements. Finally, I considered some novel approaches to network dynamics that make it possible to build on the static models of graph theory, matrix algebra, and multidimensional scaling and to construct accounts of structural change and network development. In the chapter that follows, I will introduce the key concepts employed in these approaches, and in Chapter 4 I will look in more detail at some of the applications of those concepts in substantive studies.

Further reading

Scott, John 2012. *Social Network Analysis*. Third Edition. London: Sage. Chapter 2 gives a fuller account of the history of social network analysis.

Prell, Christina 2012. *Social Network Analysis: History, Theory and Methodology*. London: Sage. Chapter 3 provides an alternative account of this same history.

Freeman, Linton C. 2004. *The Development of Social Network Analysis: A Study in the Sociology of Science*. Vancouver: Empirical Press. The definitive and standard full-length history of social network analysis.

Bott, Elizabeth 1957. *Family and Social Network*. London: Tavistock Publications. A good example of a classic early study using network ideas.

Fischer, Claude S. 1982. *To Dwell Among Friends: Personal Networks in Town and City*. Chicago: University of Chicago Press. A more advanced middle-period study of personal networks.