Chapter 7 – The study of flow-form networks: an introduction to the methodological issues and challenges

7.1 Introduction: the challenges of studying flow-form networks

In this chapter I shall discuss how one may investigate flow-form networks, and the methodological challenges that they present. In particular, I shall deal with the study of flow-form networks in *human social* systems. Human networks have not often been studied from this perspective in the past, although, as I have discussed in earlier chapters, they have been extensively studied from a conventional network theory perspective. Unfortunately, conventional methodologies are likely to impede or otherwise affect the understanding of a flow-form network structure. This is because they are based on conventional theories that treat networks as entities that are constructed from interrelated *components*, rather than as systems arising as a result of *flow* processes. Conventional network analysis tools are based on the premise that a network is made from separate nodes (or actors) that make connections with others through explicit action. Examples of such conventional analysis tools include those that examine the *relationships* between actors (or nodes), and tools that measure levels of *interaction* between components of a network, or that identify *transactional* exchanges between nodes.

In flow-form networks however, communication does not take the form of discrete relationships, transactions or exchanges between nodes. Rather, communication is a *flow* that may be directed, diverted, accelerated, impeded or allowed to escape. The structure of a flow-form network is created by the flow itself, which is reciprocally coupled with a flow of contextual space that recedes and re-forms itself as material substance flows outwards. So to study a flow-form network, one must study *both* the flow within, *and* the dynamic flows of the space around it. Flow-form networks might be created by fluids, collective actions or movements of particles or actors (such as ants, people, cars in traffic etc.), or by thoughts, language and so on. Reciprocal flows of space that recede around a network as it develops are perhaps not so easy to identify, but they might be manifested in *contextual* changes.

7.2 Investigative tools that do not disrupt flow in networks

Unfortunately, investigative tools that treat networks as naturally evolved fluid systems are scarce, and there are not many prior examples of network studies that consider communicative flow as a continuous and non-transactional process. The only tool that I have encountered that deals with a network in a manner that does not disrupt its flow-form nature is a *fractal* measurement. The term "fractal" was coined by Benoit Mandelbrot (1983) and is a concept related to complexity theory. A fractal structure is one that looks similar at different scales of magnification. One example of a fractal structure is the British coastline. Regardless of whether it is viewed at a distance (say from an aeroplane), or closer when we walk alongside it, or closer still when we examine the shape of the rocks under our fingertips, at all these scales the coastline has a similarly jagged and irregular outline. Dendritic Networks may also be fractal, appearing to have similar forms whether they are viewed from a great distance, or greatly magnified. As well as introducing the concept of a fractal structure, Mandelbrot developed a way of measuring how "fractal" a structure is, which was effectively a measurement of the range of scales at which the structure looks similar. This measurement is known as the "fractal dimension". One interesting feature of the fractal dimension is that it may also be considered to be a measure of how "space filling" a structure is. A network that has a large fractal dimension has many levels of branching, and therefore one may magnify it greatly and it will still look to have a similar branching pattern. The branching pattern of a network with a small fractal dimension is less dense, so one couldn't magnify it much before the branching pattern disappeared. Effectively then, the fractal dimension of a network is a measure of its branching density, or of the space-filling quality of the network.

Several researchers have used fractal dimensions to investigate dendritic networks. For example, Family, Masters and Platt (1989) developed a method for measuring the fractal dimension of the network of microscopic blood vessels in the human retina, indicating the density of the network; while Boddy *et al* (1999), measured the fractal dimensions of various fungal mycelial networks and demonstrated that a fractal measurement was one way of identifying differences in network branching quality. Pelletier and Turcotte (2000) conducted a similar study, where they calculated the fractal dimension of leaf venation networks and compared them with those of river networks.

So, calculating a fractal dimension is one way of measuring networks that have dendritic structures, and of making comparisons between different types of networks that have apparently similar structures. This technique however relies on being able to *see* the structure and branching patterns of the network, as is possible in blood vessel networks, or river flow networks. In many human social networks, the network structure is not physically apparent, but *implicit*. I shall return later to the problems of making implicit social network structures explicitly visible. Suffice it to say here, that it is quite possible that the implicit, or hidden nature of flows within human social networks is one of the main reasons why human networks have not been studied using methods that reveal communicative flow. It is much easier to observe and quantify communicative *transactions* within a network, such as incidences of interaction between people, or of exchange of documents and so on. The problem is that the application of such transactional analysis in isolation, can *only* lead to a transaction-based understanding of network structure. The problem is exacerbated because transactional-based research methodologies endorse the conventional network theories that are currently so much in vogue, and hence have become hugely popular.

Nevertheless, it *is* possible to study flow-form networks by using transactional tools, despite the fact that it is not really what they were designed for. To be useful in the study of flow form networks however, these transactional tools must applied with an understanding of how a flow-form network may respond to such analysis, and ideally in conjunction with other kinds of tool. Transactional analysis *alone* will never reveal the true nature of any underlying flow-form network in a system.

7.3 The risks in unknowingly applying conventional tools to flow-form networks

The example that follows illustrates how using a conventional transaction-based methodology to study a flow-form network, *without awareness* that this is what one is doing can result in a grossly incorrect understanding of its structure. The example concerns the creation of a map of the Internet.

The Internet is often viewed as a system created entirely through human design. Huge amounts of resources are invested in the design of formally structured networks and in integrating them with the rest of the ‘net. The routing systems that handle and direct the traffic that flows on the Internet are subject to well-established protocols and are designed according to predictions of use and required capacity. Structurally, the Internet could be viewed as analogous to a human highway system (Gabor & Csabai, 2002). In terms of hardware and bandwidth, it is certainly the product of considerable human design effort. However, the growth of the Internet, the ways that it is used, and the patterns that these have generated are often less formally structured. Some have suggested that in overall system terms, the Internet is more akin to a living system (Chen, 1997; Heylighen and Bollen, 1996).

7.3.1 An example: Lumeta’s Internet map

Since the days of its inception people have created “maps” of the Internet. These maps have taken many different forms, and illustrate many different aspects of the net, from its topology, to its content, and its users. Figure 7.1 shows a map of the Internet created by Burch and Cheswick at an organization called Lumeta in 1997. This particular image was published in “Wired” magazine in 1998.

The map created by Lumeta shows the extent of the *connections* within the Internet. It was constructed through use of a network diagnostic tool called traceroute. Traceroute is a simple network command that shows the *route* that a “packet” of data takes through the Internet. A traceroute query is issued from a known start point to a defined end point, the object being to show the route that the query has taken from point to point, and how long it took to reach each stage. A typical response to a traceroute enquiry appears in Table 7.1.

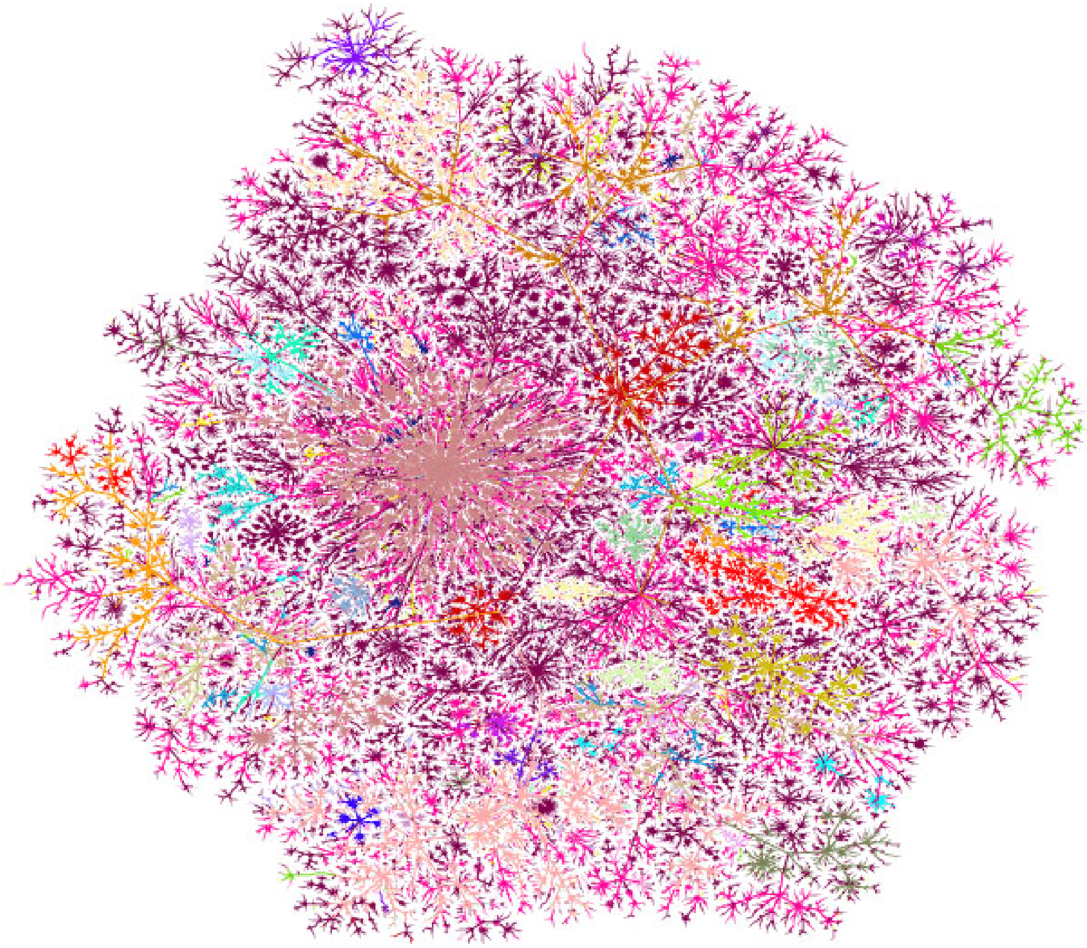

Figure 7.1 A map of the Internet created by Burch and Cheswick , Lumeta Corp., 1997.

To produce the visual map of the Internet, the Lumeta research group conducted thousands of traceroute enquiries. The addresses of the servers for the traceroute enquiries were gathered from the data tables of registered servers that are held on routers (traffic managing nodes) on the Internet. The results of these enquiries were then collated and transformed using a computer "spatialization" program to produce the visual map. Although the algorithm used to produce the spatial map is relatively simple, the enormous number of nodes that have to be arranged means that the production of each map takes several hours on a normal PC.

Tracing route to
pingu.bath.ac.uk
[138.38.32.5]over a
maximum of 30 hops:

1	16 ms	<10 ms	<10 ms	ata-bsl.router.bourne-steel.co.uk [62.49.84.105]
2	31 ms	31 ms	32 ms	bsl-ata.router.bourne-steel.co.uk [62.49.84.100]
3	31 ms	32 ms	31 ms	poole-adsl.router.bourne-steel.co.uk [62.49.84.97]
4	188 ms	62 ms	63 ms	thus1-hg3.ilford.broadband.bt.net [217.32.64.74]
5	47 ms	47 ms	63 ms	217.32.64.1
6	187 ms	78 ms	94 ms	217.32.64.106
7	47 ms	47 ms	63 ms	anchor-border-1-4-0-2-191.router.demon.net [212.240.162.126]
8	63 ms	47 ms	46 ms	tele-border-1-4-0-2-234.router.demon.net [195.173.72.49]
9	47 ms	63 ms	47 ms	linx-gw2.ja.net [195.66.226.15]
10	62 ms	47 ms	63 ms	gi4-0.lond-scr3.ja.net [146.97.35.129]
11	63 ms	46 ms	63 ms	po6-0.read-scr.ja.net [146.97.33.13]
12	63 ms	62 ms	47 ms	po2-0.bris-scr.ja.net [146.97.33.49]
13	141 ms	47 ms	109 ms	po3-0.bristol-bar.ja.net [146.97.35.150]
14	172 ms	62 ms	78 ms	brisc-2.swern.net.uk [146.97.40.102]
15	47 ms	62 ms	63 ms	bath-1-brisc-2-r2.swern.net.uk [194.82.125.158]
16	63 ms	62 ms	94 ms	bath-gw-1.swern.net.uk [194.82.125.198]
17	*	*	*	Request timed out.
18	63 ms	62 ms	63 ms	pingu.bath.ac.uk [138.38.32.5]

Trace complete.

Table 7.1 Typical response to a traceroute query.

7.3.2 The Internet map's inherent problems

Visually, the Lumeta map is striking. At first sight it appears structurally similar to some of the natural flow-form networks that I have discussed, as it has dendritically branching pathways, radiating from a source somewhere towards the centre of the map. Superficially, it looks similar to a fungal network, or perhaps to a blood capillary network.

On closer inspection however, it becomes evident that this map of the Internet has no cross-links between the branches; it lacks the anastomoses found in a healthy natural flow-form network. This kind of structure, without cross-linking branches, *is* found in the natural world, but in natural flow-form networks, it is a sign that the system is *dysfunctional*. An image of a dysfunctional fungal mycelial network is shown below (Figure 7.2). This mycelium is the dysfunctional offspring of a cross that was made between American and USSR strains of the same fungal species. Unlike a healthy fungal network, this unhealthy example has switched to a form of growth that lacks cross-links between its branches. As I explained in the previous chapter, in flow-form networks, anastomoses play a vital role in establishing resilience and fault-tolerance in a network. A fungal network that lacks anastomotic branches will be unable to communicate effectively within the system.

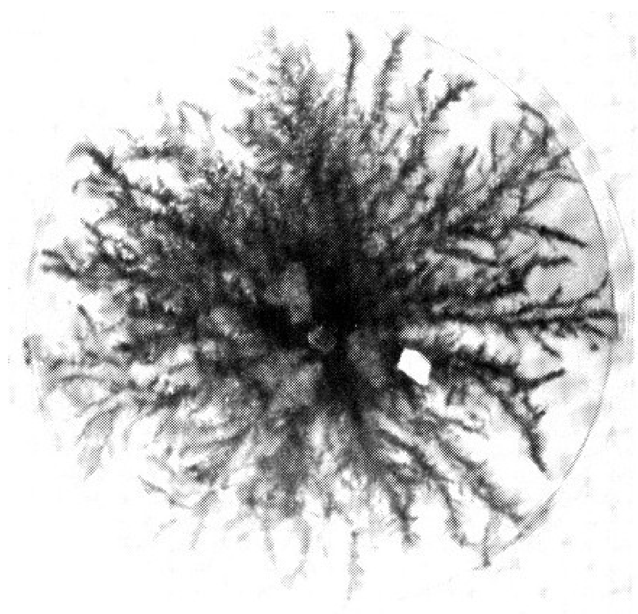

Figure 7.2 An unhealthy mycelial network. This mycelium is the offspring of a cross that was made between American and USSR strains of the same fungal species (Ainsworth *et al*, 1992).

So we have a paradox: the Lumeta map of the Internet that makes it look like a dysfunctional flow-form network. Yet it is well known that the Internet is a dynamic and thriving network, possibly even more so when this map was created in 1998 when the "dot com" boom was at its height. The Internet also exhibits, at least to an extent, a level of fault tolerance. If we try to access a U.S web site from the U.K., it usually doesn't matter if some of the lines between are down, as the traffic simply takes an alternative route.

The solution to this paradox lies in the nature of the tool that was used to create the Internet map. Traceroute is a discrete point-to-point tool. A traceroute query is issued from a known start point, to a defined endpoint. It indicates that a server exists at that endpoint, and shows the route that is taken to get there. So the image, created through use of traceroute, merely shows the server *connectivity* that existed within the Internet at a fixed point in time. Each branch on this network was created through a separate query from a fixed start point. So even if cross-branches do exist, between the connecting branches, this tool wouldn't find them. Furthermore, the tool provides no indication of the carrying *capacity* (bandwidth) of the Internet. It doesn't show which paths are used more, or which carry less data. It merely shows where there is a proliferation of branches, due to the presence of an abundance of servers at a particular location.

So two significant points emerge from consideration of this image. Firstly, the Lumeta map actually doesn't show a full picture of "what the Internet is like". The representation of the Internet in this map shows a small facet of how the Internet is organized, and it offers one *perspective* on this organization. Secondly, the reason that the Lumeta map provides this unilateral perspective is that this is what the enquiry tool used to create it was designed to do. There is no way that using the traceroute tool *alone* would result in anything other than a one-sided, target-based map of the Internet, that was unrepresentative of the whole system. This example therefore demonstrates to us the inability of inappropriate tools of enquiry to detect inherent connectedness, and highlights the need for appropriate tools and methodologies.

7.4 How conventional tools may be used to study flow-form networks

Given that the number of investigative tools that do not disrupt the flow in flow-form networks is limited, often the only network measurement tools available are those based on non-fluid models. Finding new tools to study natural networks is potentially a mammoth task, and was beyond the scope of this research study. Yet, although the lack of ideal tools presents a problem, we are not entirely prevented from studying flow-form networks in a manner appropriate to their form. I believe that we can use conventional tools, provided we remain aware of what we are looking at with them. To use an analogy: simply studying the properties of a cup of water will not tell us the properties of a river. If however we *compare* the behaviour of the water in the cup with that of the water in the river, we may learn much.

The focus of my own research was how the natural network metaphor might be studied in a human social context. So one of the principle challenges that I faced was finding how to use existing analytical tools to investigate flow-form networks in a human social context.

7.4.1 Multiple methods in one study

One way of tackling the problem is to use a multi-method approach. Using several contrasting methods for enquiring about a system could perhaps "fill in the gaps" that would be left if one were to use a single method on its own. Multiple method studies have been used often in the social sciences, where the approach is referred to as *triangulation*.

Ackroyd and Hughes (1992) explain that in the social sciences, triangulation provides a more complete picture of the system. They suggest that using several different methodologies in one study can encourage systematic continuity in the data, and overcome bias in the different data forms. They do point out however, that there are disadvantages to using several methods in a single study. One of these is the cost, the other is a theoretical issue: In the social sciences methods for collecting and analysing data are usually based on particular theories or models. Often as a result of this, a particular method cannot be combined with other methods that are based on different models. An example is discourse analysis, which asserts that every incidence of analysable discourse is but one "version" of an event; these versions stand as independent analysable accounts, but cannot be correlated with each other, or with any other form of data. So for example, a discourse study of a newspaper report could not be *correlated* with an eyewitness account, even if they are both about the same event, because discourse analysis treats each as an *independent* version. According to Silverman (2000), who also wrote about this problem, using data from multiple sources will not necessarily provide a more complete picture; it depends on whether the data can be related to each other, they may be making different assumptions about the world, and so cannot be correlated with each other.

According to Gomm (2004), triangulation has been used in the past to crosscheck different sources. For example, diaries or news reports may be compared with official records. In this case, the triangulation is done to check the *validity* of the data, not to get a clearer picture of a system. Ackroyd and Hughes (1992) suggest however, that in recent years, this approach has been largely rejected; the trend is now towards greater flexibility in methodological design and an emphasis on building up a picture from diverse sources.

7.5 Methods for study of human social networks

A principle concern in studying flow-form networks in human social systems is how one may go about finding what the flows *are*. What are the communicative media, and what is it that the flows are composed of? Potentially, the “fluid” (or flow medium) could be any number of things, both tangible and intangible, and both implicit and explicit. Flow may be represented by the collective movements of people (such as highway or footpath traffic), the spoken word (radio, face to face conversation, telephone conversation), the written word (letters, text messages, emails, internet chat), or intangible “qualities” such as trust, friendship, loyalty or respect. The potentials are virtually limitless.

A second problem is how one might *represent* these flows, visually or otherwise, to expose or reveal the network flows of the system. One would imagine that flow patterns in human social networks might be exposed by investigation of collective movements of people. Potentially one could construct maps of footprints, paths of people recorded by video tracking, or by using electronic tags to track the collective movements of people. However, although I have encountered research that uses electronic tags, video tracking and so on to monitor interactions between individuals (McCarthy and Meidel, 1999; McCarthy *et al*, 2001; Borovoy *et al*, 1997; Borovoy *et al*, 1996), I have not found any examples of researchers who have used them to study human communication as a network formed by *flow*, i.e. they have all focussed on *transactional exchanges* between individuals, rather than on communicative flow. This could be because, as I found in my own research, the development of tools that track *people* can be both costly and difficult, and is still in its infancy. It is also likely however to be a reflection of the popularity of conventional network theory, which has resulted in a focus on conventional methods that view *transactions* within a network as key to network structure, rather than communicative flow.

As I have already mentioned in an earlier chapter, social scientists were among the first to work on what has become conventional network theory, and in recent years a wide variety of human "networks" have been investigated. For example, Karathanos (1994) investigated the networks that are created through formation of coalitions and partnerships between people in organizations, while De Laat (2002) made a study of the networks created through the online discourse of the members of a Dutch police organization, focussing on how networks created online affected the sharing and construction of knowledge. Loosemore (1998) has looked at the influence of networks during crises in construction projects, while Cheng *et al* (2001) have made a more general study of the influence of communication networks in the construction industry.

7.5.1 Social network analysis

One of the most popular techniques used to analyse networks in human social systems is a method known as "social network analysis". Social network analysis is a technique for studying social interactions. It identifies and describes networks of people and/or other "actors" in a system and their relationships to each other. Social network analysis (hereafter referred to as SNA) has been applied in a wide variety of human social contexts, including analysis of family ties (Bien *et al*, 2001), studies of juvenile gangs (Baron and Tindall, 1993) and problem-solving networks in organizations (Stevenson, 1993). Social network analysis techniques have also been used to analyse computer networks (Ramaswamy, 2001), ecological relationships (Faust and Skvoretz, 2002; Corner *et* al, 2003), and even for conversation syntax analysis, where researchers were looking for how words were related to each other in texts (Brandes and Carman, 2003; Dooley *et al*, 2003). It has also been used extensively to analyse email and other online communication, in fact currently it seems to be used more for that than anything else (Reffay and Chanier, 2002;

Paolillo, 1999; Arenas *et* al, 2003; Huberman and Adamic, 2003; de Laat, 2002; Papakyriasis and Boudourides, 2001).

The principles of SNA are simple; one identifies a set of nodes or "actors", and then the relationships between them. So for example if one were looking at newspaper purchasing patterns, one could identify the people involved in buying newspapers, and then link the nodes according to the relationship "buys newspapers from".

In social network analysis, there are two generally accepted ways to display the data, as a *matrix*, or as a *graph*. A matrix charts the relationships in a tabular format. In the table below, "buys newspapers from" is identified by a 1, and "does not buy newspapers from" is identified by a 0.

	Ted	Joe	Bill
Ted	*	0	0
Joe	1	*	0
Bill	1	0	*

Table 7.2 Network matrix showing newspaper-purchasing relationships

In a graph format, the network actors are represented as diagrammatic nodes, and the relationships between them as lines connecting the nodes, as in the figure below:

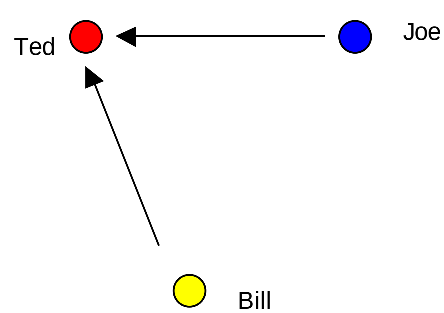

Figure 7.3 Network graph showing newspaper-purchasing relationships

For a simple network, such as this one that only has three actors, a matrix is easy to interpret. Indeed to conduct a full social network analysis, it is not necessary to plot the network in a graphical format. Should the network be much larger than the example here, however, a graphical format can make it easier to identify and visualise the relationships that exist.

Note that in the network in Figure 7.3, the lines connecting the actors have arrows. These represent the *directionality* of the relationships. In the example above, this indicates that Bill buys papers from Ted, but Ted does not buy papers from Bill; the link between them is *directed*. If Ted did also buy papers from Bill, the link between them would have arrows at both ends to indicate this, and the link would be described as *reciprocal*. These attributes are important in network analysis because they can affect the way that the data are subsequently analysed.

It is possible to make separate analyses for the various factors of influence in a social network. For example, one could construct one network that shows who the actors turn to for *advice*, and another that shows who they *trust*. These networks may have quite different structures, and hence might reveal an interesting facet of the social system.

7.5.1.1 Analysis of data in social networks

There is a whole set of specialized statistical analysis tools that can be applied to social networks. These tools can be applied to individual nodes, or to the whole network. For example, one measure that can be applied to the entire network is of its "density". This is a ratio of the number of *actual* links to the number of *possible* links in a network; it shows how densely interconnected a network is. Another such measure identifies "cliques" or clusters within the network, to give an indication of how coherent the network is, and whether it is subdivided into intercommunicating subgroups.

There are also a number of measures that can be applied to individual nodes in a network, giving an indication of the variations in roles that exist. These include "centrality", which is a measure of how well connected a node is to the network. Another is known as "betweenness", which is a representation of the extent to which a node acts as a "liaison" or connector between other nodes. There are many others in addition to these.

There are a number of computer programs that will analyse network data, including one titled UCINET (Borgatti *et al*, 2002), which has been specifically written for the task. There are also several software packages that will transform network data matrices into a graphical or visual format (Borgatti, 2002).

7.5.2 Using other methods in conjunction with SNA

The primary disadvantage of SNA is that it is based upon a notion that networks are *constructed* entities, composed of nodes interconnected by links that represent relationships or transactions between them. Social network analysis focuses on the transaction *points* within a network; it is a node-centred analysis. The relationships between these transactional points are analysed independently of their contexts, and indeed often independently from the *content* of the communication. Social network analysis emphasises the *structure* of a social network, without necessarily referring to *what* is being communicated within it, or why it is being communicated at all.

I would suggest that on their own, the results of SNA are of limited value. A network that is analysed in terms of structure alone will only confirm whether a network exists, and if so what form it takes. A structural analysis conducted in the absence of content studies and appreciation of context, will not provide answers to any of the “why” questions, or explain *how* the network came to be organized in that way.

7.5.2.1 Content analysis

A number of previously published studies have overcome this to a degree, through a dual approach to data collection on social networks, collecting both interaction data for SNA, and conducting content analysis of *what* was communicated (De Laat, 2002; Paolillo, 1999; Loosemore, 1998; Aviv *et al*, 2003).

De Laat's (2002) study concerned the network organization and discourse content of an online community. The community in question was a Dutch police organization, and the online vehicle was a pre-existing computer-supported collaborative learning (CSCL) environment that supported information exchange and work-related discussion. The data collected by De Laat consisted of log-files of online dialogue from the CSCL system. He used the interaction data gleaned from these to conduct a social network analysis, producing measures of centrality and betweenness. The UCINET software package was used to carry out the social network analysis. For the content analysis De Laat used a pre-existing quantitative coding scheme to code and analyse the discourse.

Aviv *et al* (2003) conducted a similar study. They also looked at transcripts from CSCL communities, this time the communities concerned were groups of students taking an Open University course. The methods here included various SNA techniques, using a commercially available network analysis software package to conduct the analysis. In addition to this, the transcripts were analysed for content, and like De Laat's study, employed a pre-existing coding scheme. The authors of this study were particularly interested in how actors form groups within networks, and used the SNA to identify "cliques" and "cohesion" within the network.

A study using similar methodological principles was conducted by Paolillo (1999). This study concerned the social network and language use of the participants of an IRC (Internet Relay Chat) community. Here, similarly to De Laat, the data consisted of log files containing the online conversations. These were used to glean both interaction details for SNA, and for content analysis. Paolillo devised his own coding scheme for the content analysis, which categorised statements according to whether they contained one of five linguistic features. The content analysis was summarised quantitatively, and correlated with the quantitative results of the social network analysis.

Finally, Loosemore's (1998) study focussed on the interactions of participants in a construction project when a crisis was encountered. He collected data in the form of letters, faxes, audio records of telephone conversations, notes from meetings and semi-structured interviews. With these he conducted both a qualitative content analysis of the communication, and a social network analysis of the interactions that occurred. Initially, the content analysis results were used to categorise the interaction data into three "phases", to produce three interaction matrices for SNA. The matrices were analysed using UCINET to produce a series of SNA outputs on features such as centrality and betweenness.

Like myself, Loosemore points out that a major limitation of SNA is that it does not show details of the information that was communicated. For example, in the final phase of the construction project, the SNA showed quite positive results, in terms of high levels of communication. Loosemore's content analysis however, indicated that the communication actually concerned the increase in problems arising on the project, and that the nature of the communication was becoming progressively more acrimonious. By using qualitative content analysis in association with the quantitative SNA, Loosemore identified the details of the communication content, and was thus adding depth to his results. To paraphrase his comments, the content analysis enabled him to answer some of the "why" questions about the SNA results.

7.5.2.2 Analysing use of artefacts

Some have further expanded on the benefits of a dual method approach, by using multiple methods to study networks. Sonnenwald (1996) took such a multi-method approach. She collected many different forms of data, from several different companies (all involved with design), over a considerable period of time. The data types included structured and unstructured interviews, documents, meeting notes, network interaction data, telephone transcripts, and other documentation. The interaction data were used to conduct an SNA, while content analysis techniques were employed on the other forms of data. Amongst these techniques were methods referred to by Sonnenwald as Event Sequence Analysis, and Concept or Thematic Analysis.

According to Sonnenwald, the benefits of this kind of study technique included the following:

- It allowed the designers' own perceptions and reflections and shared experiences to come to light
- It made use of many forms of data, so that more data could be collected
- Using data from different settings (companies) allowed patterns that might be more general than for one specific company to be shown

The method used by Sonnenwald to integrate all the different forms of data was qualitative, and unlike some of the dual method studies, she didn't quantitatively cross-analyse the content and structure studies.

Other authors who have chosen to use multi-method approach to studying communicative networks haven't specifically used SNA, rather they are using methods that are *like* SNA. For example, Perry and Sanderson (1998) studied coordination and dialogue within two collocated design teams. One was a team of engineers designing a pump, and the other a team of construction designers (architects, engineers etc.) designing an office block. The authors were particularly interested in how "artefacts" were used to coordinate the design work. Artefacts are documents, faxes, drawings, sketches etc., anything that represents and communicates the ideas of the designers. To collect data on the use of artefacts authors conducted interviews, observed meetings, observed the teams at work, and examined archived documents and artefacts produced by the designers. The analysis was qualitative, and the results discursive. They highlight the importance of artefacts as communicative tools, and the significance of collocation both as a means of sharing artefacts easily, and of facilitating team meetings.

In their paper, Perry and Sanderson highlight the joint significance of artefacts and social interaction, as well as the role that co-location plays in facilitating the use of both. They do not discuss the methodology they used, that is to say they do not mention any benefits or challenges to the way they collected their data. They do say that the two studies of the design teams were conducted by different people, and then the results compared for the paper. They suggest that this may help to identify patterns across organizations, and may encourage researchers to reflect on the differences they encounter.

Medway and Clark (2003) studied the design processes within two Canadian firms of architects. Their data collection methods included extensive field notes of observations, audio tape recordings, records of spontaneous explanations etc. offered by participants and copies of documents referred to or generated by the participants. As an initial means of investigating and coordinating the data, the authors produced “maps” of the “design streams”. Represented on these conceptual maps were participants, artefacts, conversations, meetings and so on. These were not strictly SNA maps, but they do show the flow of information and communication between participants, and over time. The authors made an extensive and qualitative content study of the spoken interactions that were recorded. In comment, they say that they like the maps they produced, as they “indicate the movement of ideas”… and they “provoke speculation and imagination”.

Ruhleder (1997) describes a video-based interaction analysis that she used to analyse communication within an organization. This analytic technique combined videotaping of interactions between people in an organization with participant observation, interviews and analysis of documents and technologies. The object was to analyse how people interact with one another, and with their physical environments, documents, artefacts and technologies. The videotapes were used as the basis of the analysis. The tapes were first logged for content, where a summary listing of the events on the tapes was created. Subsequently, interesting sections of the taped content were transcribed. Teams of researchers worked together to code the content of the transcriptions. They did not use a predetermined coding scheme; rather coding categories for the data were allowed to emerge from deep consideration of the data. As the video data are progressively analysed, the patterns that were found were cross-checked with the other forms of data that were collected, which included documents, field notes, interview transcripts, and so on.

7.6 A combined methodological approach to studying human social networks

These examples have indicated how some other researchers have used social network analysis to reveal structural aspects of human networks, while overcoming some of its shortcomings. The critical factor in conducting research of any kind, but particularly in the study of flow-form networks is to remember exactly what the methods we employ are actually telling us. SNA will give us an idea of the *transactional* relationships within a network, but it won't tell us *why* these relationships occur, or how they are related to the context of the system. It can however relate how people move within a system, and indicate whether they communicate with many others, or are non-communicative. It can also highlight incidences where people share contexts, such as in meetings. SNA might show that there was a gathering of people, and by combining this with contextual or content data, one could get an idea of *how* they were sharing contexts.

Meanwhile, content analysis (such as analysis of interviews, recorded dialogue etc.) will give an idea of *what* is communicated. Through content analysis, we can create *snapshots* of content, captured at a particular instance in time, and convey a static picture of what was communicated at that point.

Content analysis alone will not however show how the dialogue relates to the wider context of the system. This is where artefact analysis is appropriate. Analysis of how artefacts are used (to include computer documents, design sketches etc.) will show how people communicate the concepts in their minds to others in a tangible way, producing items that can be kept, referred to later and used as records. Analysis of the content of these artefacts will mean little without reference to the dialogue that surrounded them, or the contexts in which they were produced. Yet when data from artefact analysis are combined with SNA, they can indicate how people are communicating when they are not using dialogue, or how the artefacts *augment* the dialogue. Significantly, artefacts can represent *flow* of information within a system, a document may be passed from one person to another, two people may work collaboratively on a document, or a sketch may be used to convey the ideas of many people during a design meeting. The way that people use artefacts may bring meaning to some of the less clear relationships that emerge from SNA.

In all, while these analytical methodologies will never generate an entirely life-like model of the structure of a human flow-form network, the use of *multiple* analytical methodologies can provide a picture that is more comprehensive than analysis that relies on a single conventional method alone. Using several methods together, one can gain insights into a system from different perspectives, creating *snapshots* that can be combined, hologram-like to produce a multi-faceted picture of the entire system. By remaining aware of exactly *what* one is doing with a particular method, one can mitigate against the limitations of one method, by augmenting it with another. The challenge is to deduce from the alternative views of a network, SNA, content, artefact use etc., how they may reflect the *flows* within. By looking for correlations between the data, one can hope to find similar flow patterns. If the data correlate, one may have identified a pattern within a part of the network. If the data do not correlate with each other, perhaps there isn't flow, or perhaps it has been impeded. Alternatively, the lack of correlation between the different data sets might not indicate that there is no flow; it might exist, and the methods simply haven't detected it. The challenge then is to work out whether the lack of correlation results from a problem in the network, or from a problem with the methods.