The Network Turn

Changing Perspectives in the Humanities

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Catherine Nicole Coleman and Scott B. Weingart

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ABSTRACT: We live in a networked world. Online social networking platforms and the World Wide Web have changed how society thinks about connectivity. Because of the technological nature of such networks, their study has predominantly taken place within the domains of computer science and related scientific fields. But arts and humanities scholars are increasingly using the same kinds of visual and quantitative analysis to shed light on aspects of culture and society hitherto concealed. This Element contends that networks are a category of study that cuts across traditional academic barriers, uniting diverse disciplines through a shared understanding of complexity in our world. Moreover, we are at a moment in time when it is crucial that arts and humanities scholars join the critique of how large-scale network data and advanced network analysis are being harnessed for the purposes of power, surveillance, and commercial gain.

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KEYWORDS: network analysis, network visualisation, digital humanities, interdisciplinarity, complexity

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Introduction

In the days following the 9/11 terror attack, an FBI agent visited the Whitney Museum of American Art to see Mark Lombardi's 1996 drawing 'BCCI-ICIC & FAB, 1972–91 (4th version)' (Figure 1) (Hobbs, 2003: 11–12, 95–8). The web-like image comprises a meticulously researched diagram of individuals and groups with ties to a money-laundering organisation that operated under the name of the Bank of Commerce and Credit International (BCCI), which included Osama bin Laden and others associated with al-Qaeda. As Lombardi himself described, BCCI 'was used not only by drug dealers and con men but also by the governments of the US, UK, Saudi Arabia and the Gulf Arab states to funnel support to Afghan guerrillas fighting Soviet occupation, to pay off friends and adversaries alike and conduct secret arms sales to Iran' (Lombardi, 2001). In other words, in black and red ink, Lombardi traced a terrorist network that reached the centres of government. He had grasped the power of the network perspective to reveal conspiracy, adapting graphical traditions associated with the study of social networks developed in the first half of the twentieth century. Tragically, the significance of his research would be uncovered only after his death: in early 2002, a year after the artist's suicide, the FBI's Operation Green Quest raided the offices of several Virginia-based Islamic charities whose Saudi funders, including Mahfouz and prominent Bush backers, featured in Lombardi's work (Goldstone, 2015).

Three years after Lombardi produced his artwork, Albert-László Barabási and Réka Albert published a scientific article entitled 'Emergence of Scaling in Random Networks' (Barabási & Albert, 1999). It argued that a wide variety of seemingly heterogeneous networks, such as power grids, social networks, and the World Wide Web, exhibit nearly identical distributions of connectivity, and it offered an elegant model that explained how these distributions might arise.[1] This particular distribution of connectivity was different from those most scientists expected at the time.[2] The significance of Barabási and Albert's findings was that they provided a compelling case for analysing seemingly disparate systems and kinds of data using the same mathematical models and

[1] For the debate around this thesis, see Broido and Clauset (2019) and Holme (2019).

[2] For an earlier precedent, see Price (1965).

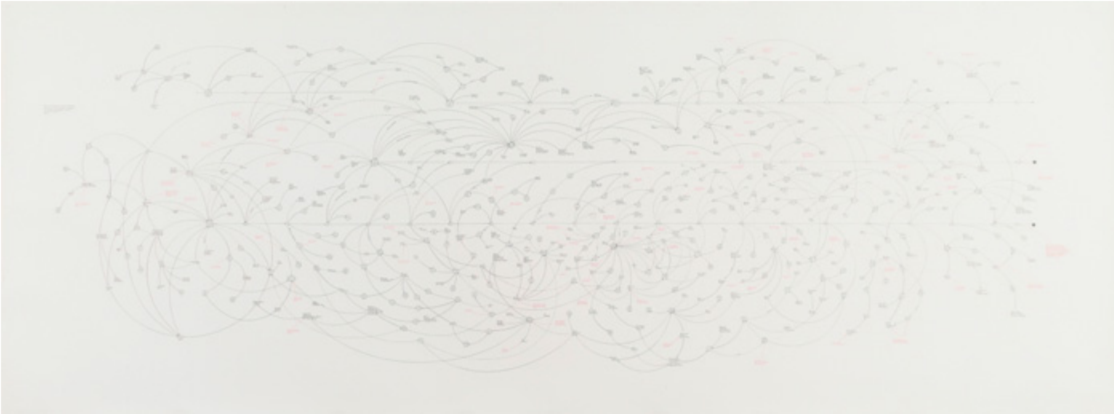

Figure 1 Lombardi, Mark (1951–2000), ‘BCCI-ICIC & FAB, 1972–91 (4th version)’ from the series BCCI, ICIC & FAB, 1996–2000. Graphite and coloured pencil on paper. New York, Whitney Museum of American Art. © 2019. Digital image. Whitney Museum of American Art / Licensed by Scala.

tools. For this reason, their article is regarded as one of the founding publications of the interdisciplinary field of modern network science. The argument for the application of analytical tools across domains was extended in Barabási's best-selling book *Linked*, in which he argued that many challenges in our world, such as managing the spread of epidemics, fighting terrorism, and handling economic crises, can be cracked by understanding these systems as networks (Barabási, 2002). As such, networks appear in Barabási's study as a kind of Rosetta Stone. This message reached 70,000 readers and thus played a small part in the rise of the 'network' perspective in the modern consciousness following the new millennium.

Lombardi and Barabási's work is part of what we call the 'network turn'. This turn cannot be attributed to either the artist or the scientist; they are but two examples of a whole host of converging thoughts and practices around the turn of the new millennium – the zeitgeist of the networked age. The World Wide Web had become available to the public only in 1991, but by 2004, the web-based view of relations manifested itself in an entirely new kind of communication platform when 'TheFacebook' was launched. The subsequent proliferation of social networking platforms has profoundly shaped the way we understand connectivity in the world today.

Another key driver of the network turn, highlighted by the FBI's interest in Lombardi's work, is terrorist activity – both in terms of the perceived threat of terrorist networks, and in the new technologies available to security agencies to mitigate against them. Following 9/11, using data-gathering approaches very similar to Lombardi's combined with computational analysis, Valdis Krebs used public information and newspaper clippings to produce a partial map of the social network behind the attack. His network analysis showed that all nineteen of the hijackers were within two email or phone call connections of two al-Qaeda members already known to the CIA before the attack. According to three common network analysis metrics, the network's most central figure was Muhammed Atta, who turned out to be the ringleader (Krebs, 2001). Krebs' findings raised the important question of whether the attack could have been predicted. Shortly after posting his analysis online, Krebs was invited to Washington, DC to brief intelligence contractors. The extent to which Krebs' insight about the power of network analysis fed into the existing methods that intelligence agencies employed is hard to gauge, but by

2013, as the leak by Edward Snowden brought to light, the National Security Agency was engaged in massive-scale network analysis using data from nine internet providers.

The study and critique of networks has predominantly taken place within the domains of computer science and related scientific fields, the military, and the tech sector due to the scale of digital data being analysed and the nature of the investigations prompting their study. This book not only argues that arts and humanities scholars can use the same kind of visual and quantitative analysis of networks to shed light on the study of culture; it also contends that the critical skills native to humanistic inquiry are vital to the theorisation and critique of our networked world. Network analysis, as we define it in this book, is a set of practices and discourses that sit at the interface of the natural sciences, humanities, social sciences, computer science, and design. We contend that networks are a category of study that cuts across traditional academic boundaries and that has the potential to unite diverse disciplines through a shared understanding of complexity in our world – whether that complexity pertains to the nature of the interactions of proteins in gene-regulatory networks or to the network of textual variants that can reveal the lineage of a poem. Moreover, this shared framework provides a compelling case for collaboration across those boundaries, for bringing together computational tools for quantitative network analysis, together with theories, discourses, and applied techniques from the social sciences, the humanities, visual design, and art practice.

The cases of Lombardi and Barabási provide an instructive way of grasping that shared framework because, superficially, their work has very little in common. Barabási and Albert explicitly cite the computerisation of data acquisition as essential to their research. By contrast, Lombardi's research process was analogue. He gathered his data on three-by-five notecards. There is no evidence that Lombardi read Barabási and Albert's groundbreaking work in statistics and physics; rather, his inspiration was panorama and history painting. He used the term 'narrative structures' to describe his hand-drawn webs of connection. Produced through an iterative process of refinement, the work is human in scale, legible visually in its entirety. Perhaps more importantly, it is his interpretation of a carefully researched but inevitably incomplete record. It does not pretend to objectivity. In stark contrast, Barabási and Albert's method is scientific: it proposes a model to predict the behaviour of systems and to understand complex topologies 'independent of the system and the identity of its constituents' (Barabási & Albert, 1999). Thus, where Lombardi is analysing past events, Barabási and Albert offer a predictive model; where Lombardi is visual, Barabási and Albert use algorithms designed to detect patterns in data sets too large or complex for the human eye to detect. These approaches seem to occupy two very separate worlds.

Nevertheless, Lombardi's art and the scientific approaches of Barabási and Albert have much in common. Lombardi distils the composition of relationships in history painting and the comprehensive 'at one view' of the panorama into a formal abstraction rooted in the conceptual art movement of the mid-twentieth century, and reflects the overlapping concerns, discourses, and methods of art and science. The artist and scientists use connectivity to make sense out of data: a representation of knowledge that relies on abstraction. Both produce results that are seductive in their elegance and simplicity. Networks are by definition an abstraction into a system of nodes and edges. Nodes are entities; edges are the relationships between them. Two examples can be seen in Figure 2. Such an abstract system is inherently intuitive. These two elements, nodes and edges, are the simple building blocks of an obviously abbreviated rendering, a malleable geometry that can range in complexity from a direct and declarative schematic to a dense, indecipherable web of connections.

The worlds from which the artist and the scientists emerge have their own long genealogies. The standard history we tell for network science traces its lineage back through graph theory to Leonard Euler's solution of the Königsberg Bridge problem in 1736. Similarly, we might argue that artists and humanities scholars have been engaging with network-analytic approaches for at least sixty years. However, these threads have visibly come together only in the past twenty years. In the first decade following the millennium, some pioneers began to apply the methods of network science to the study of cultural artefacts, but most scholars were still learning how to query web-based digitised archives without attention to the computer networks invisibly underpinning this virtual archival experience. However, since 2010 there has been a slow but steady increase in scholars in the arts and humanities employing network visualisation, social

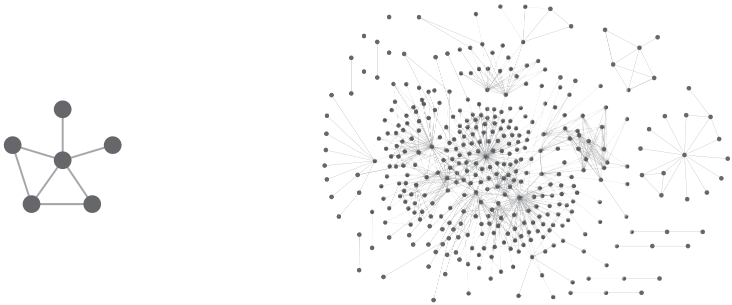

Figure 2 Networks consist of nodes and edges. On the left, a simple network of six nodes and seven edges. On the right, a more complex network (with several disjointed components) that depicts social relationships in a Protestant underground community during the reign of Queen Mary I of England (see Ahnert & Ahnert, 2015). Diagram by the authors.

network analysis theory, and quantitative measures from network science to address their research questions. In addition to a rise in the number of publications invoking these methodologies, the clear demand for workshops and training in network visualisation and analysis tailored to arts and humanities scholars is evidence of these approaches gaining traction. Such work still tends to be a fringe activity, though, and suspicion among more traditional elements within the disciplines who have interpreted the computational tools and methods associated with network analysis as part of the incursion of scientific method into their domain, which has sometimes been conflated with the neoliberal takeover of the university.

This book does not call for arts and humanities scholars to accept unquestioningly frameworks and methods developed in the field of network science. Rather, it argues that the discourse and analysis of networks can move forward only through collaboration and exchange at the interface of computational method, humanistic inquiry, and design practice. The case for scholars from the arts and humanities engaging with networks is compelling on a number of levels. The use of computational network analysis can lead to the creation of new knowledge, and to the corroboration of theories. It makes it possible, with relative ease and speed, to measure the relationships between many entities in multiple ways, allowing a rich, multidimensional reading of complex systems never possible before. It has proven to be an effective tool for understanding metric data on a very large scale. A seemingly infinite number of calculations can be run on the resulting network to filter and parse that large-scale data, giving a more nuanced understanding of both the local and the global. The ability to analyse data across scales has been rendered increasingly necessary in light of the ever-growing quantity of information made available through the digitisation of our cultural artefacts. Networks further offer the ability to contextualise the large scale with the small and vice versa, breaking the explanatory chasm between part and whole.

Moreover, scholars from the arts and humanities already have the conceptual framework to make this leap: they have been writing about networks for centuries, albeit from the metaphorical perspective, examining communities of practitioners, the dissemination of ideas, or the relationships between certain texts, images, or artefacts. Although researchers with standard humanities training will likely need to acquire some new skills to engage with the computational challenges of network visualisation and quantitative analysis, we contend that they already have a set of skills that are key to the development of the interdisciplinary practice of network analysis. This is not just about receiving wholesale methods and theories developed in the computational and social sciences; rather, the critical skills developed in the arts and humanities are needed to complicate and nuance the current ways in which data are collected, modelled, and queried in the field of network science. Finally, we are at a moment in time when it is crucial that arts and humanities scholars engage critically with both the potential and the pitfalls of technological advancements. By offering an understanding of how networks work, we provide a much-needed framework to articulate how companies and governments can exploit the harnessing of large-scale data and advanced network analysis for the purposes of power, surveillance, and commercial gain.

This book is not a how-to manual: it does not provide instruction in the basics of network analysis or the use of ‘out-of-the-box’ tools, or an introduction to programming, as a plethora of other resources already do this.[3] Our aim here is more ideological. We seek to open up a space for exchange between the humanities, arts, and sciences – a space that is genuinely collaborative, that is mutually beneficial, and that recognises that networks present a mode of inquiry that draws on knowledge and practices from all these domains. Its combined brevity and breadth mean that it is not the final word, but rather a provocation. We hope this book will be a starting point for debate: not just in the digital humanities community (who are already used to situating themselves at the intersections of disciplines), and not just in the arts and humanities, but also in the natural, social, and computer sciences. It is the desire to engage and debate that motivated us to offer this book open access. Our most basic aim is to persuade colleagues in the arts and humanities of the value of networks as a conceptual and methodological framework that supplements (but does not replace) traditional methods of inquiry. But our intentions are broader than that: we hope for a sharing across domains to deepen our understanding of networks. That deepening is gained by combining world views we might attribute on one hand to Lombardi and on the other to Barabási, the combination of careful research and a choice of parameters at the human scale, that is not only coupled with but iteratively developed in tandem with the power of computational analysis.

Part of the argument for multiple perspectives is manifested in the way this book has been written. It is the product of a collaboration between a scholar of English literature, book history, and digital methods, a physicist specialising in network science, a historian of science concentrating in digital humanities, and a digital research architect with a background in design and tool development. We have not split the chapters among different authors; rather the arguments are the product of ongoing debate among the four of us over a period of three and a half years. Such a process of creation, like much of the work going on within network analysis more broadly, necessitates co-authorship. This is something that remains relatively rare in the arts and humanities. We seek to demonstrate the benefits of co-authorship, the insights and perspectives it brings, which can rarely be replicated by a single-authored work. It is not a shortcut or a faster route to publication. The process of gaining understanding,

[3] For a useful overview of tools and tutorials, see http://historicalnetworkresearch.org/resources/external-resources/.

compromising, and iterating our arguments necessarily takes longer than writing a piece from a single viewpoint. However, we believe that process makes the work stronger. Genuine, deep sharing of ideas across disciplinary boundaries takes patience, goodwill, and a desire to learn and be challenged. We are therefore not simply arguing for a set of methodologies and discourses associated with the network framework. The network turn brings with it a set of research and publication practices that are inherently collaborative and dialogic.

The six chapters that follow are organised into three parts. Part I offers 'Frameworks' for understanding the methods developed in the natural, computational, and social sciences. To fully harness the analytical power of networks, we must first attend to the way a specific set of Western linguistic, disciplinary, and visual histories of networks frame the systems and phenomena we observe in the world, shaping, limiting, opening, and reorienting the questions we ask. Part II introduces 'Cultural Networks', giving an overview of the ways in which networks have already been used to examine cultural phenomena and artefacts, and the important role of design principles in both querying our data and communicating our research. Finally, Part III examines how network analysis provides a set of 'Manoeuvres': intellectual manoeuvres that refigure cultural objects in our minds as abstract systems of nodes and edges, mechanical manoeuvres that structure data and navigate input versus output, and manoeuvres between a landscape of abstraction and research questions that are steeped in contextual information. Taken together, these processes seek to dismantle the binaries between the 'humanistic' and the 'scientific' and, in so doing, create new norms of practice and inquiry. These new norms, however, are yet to be established. They must necessarily be shaped in ongoing collaboration and exchange. In the closing pages, we therefore suggest how different groups of scholars, practitioners, and professionals can direct the network turn as it becomes a standard part of our critical cultural apparatus.

Part I Frameworks

Networks represent more than a scientific method; they are a mindset shaped by a rich conceptual and visual history. To fully harness the analytical power of networks, we must first attend to the way these histories frame observable systems and phenomena in the world, shaping, limiting, opening, and reorienting the questions we ask.

1 Networks Are Always Metaphorical

In network science, researchers utilise networks as a formalised abstraction that permits computational analysis. In the humanities, by comparison, scholars largely employ networks as a metaphor. Despite these methodological differences, there are important continuities between the act of abstraction and use of metaphor. George Lakoff and Mark Johnson argue that metaphors are not just linguistic embellishment, but rather provide a conceptual framework that structures our most basic understandings of the world (Lakoff & Johnson, 1980). Lakoff and Raphael Núñez later applied the framework of conceptual metaphor to the domain of mathematics:

> Conceptual metaphor is a cognitive mechanism for allowing us to reason about one kind of thing as if it were another ... It is a grounded, inference-preserving cross-domain mapping – a neural mechanism that allows us to use the inferential structure of one conceptual domain (say, geometry) to reason about another (say, arithmetic). (Lakoff & Núñez, 2000: 6)

This is precisely how networks are used in the sciences. To the scientist a network is an abstract object, a collection of pairwise relationships (termed 'edges', 'links', or 'arcs') between defined entities (termed 'nodes' or 'vertices'). What receives surprisingly little attention in scientific network literature is the definition of those entities and relationships, or, in other words, the process of abstraction from the real world to the network representation. Network science as a field takes the abstract network as a starting point; the process of abstraction often belongs to another domain, namely that in which the network data originates. A historical correspondence network originates in the domain of history, a network of neurons in the domain of neuroscience. Because the process of abstraction leads us across disciplinary boundaries, both the original domain and network science often neglect it. To see the network as a metaphor, by contrast, we have to be fully aware of the process of abstraction: what information it prioritises and what the abstraction elides.

This chapter argues that researchers who employ networks as a metaphor (traditionally those in the arts and humanities) ought to be familiar with the mathematical formalisations. Conversely, scholars wedded to the computational power of quantitative network analysis should be aware that its power derives from its reliance on the metaphorical dimension and an act of interpretation. For this reason we sketch the Western cultural history of the network as a concept, tracing its etymology and its acceptance as an inferential structure that enables interrogation and discovery. Undertaking such a task, which spans centuries as well as disciplines, in just a handful of pages means that the resulting account is also necessarily an abstraction. Moreover, it relies on readily available sources such as the *Oxford English Dictionary* (*OED*) and the Google Books corpus, which bring with them their own set of biases – not least an anglophone focus. However, even with the partiality and brevity of our rendering, the shifting applications of the word 'network' chart a series of changing views on the organisation of our world and how we can begin to understand it.

Importantly, taking such an approach removes the narrative of novelty from networks. It is easy to think of the network as a modern concept, and it is certainly the impression we take away if we rely solely on the snapshot of the word's usage provided by Google Ngrams (see Figure 3). The Ngram shows limited usage in the nineteenth century, an upward curve beginning around 1920, and a sharp uptick after 1980; only isolated references occur before. However, the problems of the Google Books corpus for nuanced linguistic analysis are by now well documented, including the impact of optical character recognition (OCR) errors, the over-representation of scientific literature, messy metadata, the equal weight assigned to each book regardless of its literary impact, and the compounded bias of aggregated source libraries (Pechenick, Danforth, & Dodds, 2015). The latter means that a single, prolific author can noticeably insert new phrases into the Google Books lexicon, whether the author is widely read or not.

A complementary view is provided by the *OED* which lets us see some isolated data points from before 1800 in context. The earliest cited usage is in William Tyndale's 1530 translation of the Pentateuch: 'And he made a brasen gredyren of networke' (*OED*, 'network', n. 1.a). In this context the words describe a physical work, a gridiron ('gredyren'), which is constructed from

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Figure 3 Frequency of the word 'network' in the English Google Books corpus between 1800 and 2000, generated using the Google Ngrams tool, with smoothing parameter set to 3.

parallel bars, crossed or interlaced in the fashion of a net. Mail armour was formed as a network, and the term was also used to describe fabric during the early modern period. The component words, 'net' and 'work', are from common Germanic stock; the composite, however, seems to be an English coinage, although it has made its way into numerous languages including Danish (*netværk*), Dutch (*netwerk*), German (*Netzwerk*), Maltese (*netwerk*), Norwegian (*nettverk*), and Swedish (*nätverk*). The word for network in certain other languages carries the same lineage from the word for the material act of weaving nets. For example, the Italian for network is *rete*, which comes from the Latin *rete*, meaning 'net' (the same root as *red* in Spanish, *rede* in Portuguese and Galician, and *rețea* in Romanian). In English, the root 'ret' forms the basis of 'reticulation' (a pattern of interlacing lines) and 'retina' (the regular net-like arrangement of blood vessels in the eye). The etymology of 'network' in both Germanic and Romance languages, therefore, contains a set of assumptions about structure, pattern, order, and distribution. In many cases, a maker or designer is implied.

It is important to recognise these assumptions when we communicate across disciplinary boundaries because the kinds of complex systems the word 'network' is now more often used to describe do not necessarily share the ordered woven structural features of mail armour or gridirons. In the modern language of networks, these particular material forms might be referred to instead as *lattices*, a specific subcategory of networks. The development of the word 'network' as a metaphor for systems that have very different patterns of distribution from fabric or mail armour can be seen from at least the seventeenth century, when it was used to describe the system of arteries, veins, and capillaries in humans and animals – what we might describe as rhizomatic structures. Later, as people recognised these patterns in both natural and artificial systems, the word 'network' came to represent systems of interconnection in general.

The evolution of the concept to denote the physical infrastructures for the distribution of people, merchandise, and electricity to consumers follows the construction of those systems relatively swiftly. For example, the first purpose-built passenger railway, the Liverpool and Manchester Railway, was authorised by an Act of Parliament in 1826, and by 1836 nearly 400 miles of track had opened in England. During this period, competition emerged regarding different scales of gauge, in response to which Thornton Hunt published a tract in 1846 entitled *Unity of the Iron Network; Showing How the Last Argument for the Break of Gauge, Competition, Is at Variance with the True Interests of the Public*. 'Iron network' might be described as an allusive rather than descriptive metaphor (e.g. railway network). The decision to use this as the main title therefore suggests that the metaphor was already an established way of describing the rail system. Similarly, the idea of investing in a central plant and network to deliver electricity to customers was first acted upon in the late 1870s, and by 1883 references appear in technical journal articles to networks of conductors in the construction of street mains electricity (*OED*, 'network', n. 4.b.).

In the twentieth century, we see the emergence of domain-specific appropriations of the word, which happened in tandem with a long philosophical and cultural crisis surrounding the rise of secular and democratic societies. The 1934 book *Who Shall Survive?* that emerged from the research undertaken by Jacob Moreno and Helen Hall Jennings contains some of the earliest graphical depictions of social networks, known as sociograms (see Figure 4).[4] Moreno and Jennings were founders of the journal *Sociometry*, which was the venue for some of the earliest scholarly articles in this new field. Moreno and Jennings claimed that 'before the advent of sociometry no one knew what the interpersonal structure of a group "precisely" looked like' (Moreno [& Jennings], 1953: lvi). The sociogram can be seen as the precursor both to the graphical notation employed by the artist Mark Lombardi, and the network visualisation layouts now familiar to us thanks to the ubiquity of out-of-the-box tools like Gephi (discussed further in Chapter 4). For most of the remainder of the twentieth century, social network analysis followed in the footsteps of Moreno and Jennings, collecting small-scale social networks through intensive surveys of well-defined social groups, numbering typically fewer than 100 individuals, which can be rendered intuitively using the sociogram.

Social network analysis also produced a number of concepts and measurements that have crucially changed the metaphorical hinterland of the

4 Moreno was listed as the sole author of this book, although Jennings was credited with the authorship of a 'supplement'. Nonetheless, his acknowledgements do include the phrase 'I and my collaborator, Helen Jennings'. Linton Freeman contends that the completed research and the publications drew heavily on Jennings' contributions (Freeman, 2004: 35–6).

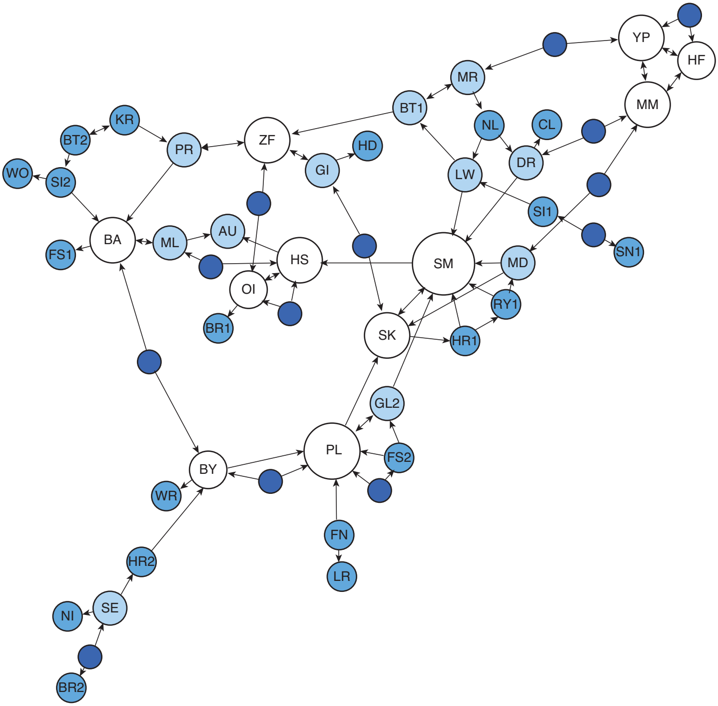

Figure 4 Redesigned network produced by Martin Grandjean based on Hall and Moreno's work in *Who Shall Survive?* showing relationships between children in a classroom (Grandjean, 2015, chosen due to original diagrams being in copyright). CC BY SA 4.0.

word 'network'. Central to this changing conceptual framework was the discovery that in social networks, two people are, on average, only separated by a small number of steps. In 1929, the popular Hungarian author Frigyes Karinthy wrote 'Láncszemek' ('Chain-Links'), a short story musing on the shrinking social world during a period of rich international trade in Hungary. In the novel, Karinthy's characters create a game:

> One of us suggested performing the following experiment to prove that the population of the Earth is closer together now than they have ever been before. We should select any person from the 1.5 billion inhabitants of the Earth – anyone, anywhere at all. He bet us that, using no more than *five* individuals, one of whom is a personal acquaintance, he could contact the selected individual using nothing except the network of personal acquaintances. (Karinthy, 1929)

Karinthy's game became reality in Stanley Milgram's research into the 'small world' phenomenon just over three decades later. Building on his earlier work with the mathematician Manfred Kochen and the political scientist Ithiel de Sola Pool, Milgram undertook a series of experiments that sought to determine the degrees of separation between people in real-world networks, which he reported in a 1967 issue of the popular magazine *Psychology Today*. Milgram invited members of the public to forward a parcel to close acquaintances in their immediate social (but not necessarily geographical) neighbourhood with the goal of eventually reaching a particular individual on the other side of the country. Although the methods and findings have since been disputed, Milgram claimed his study showed that 'only five intermediaries will, on average, suffice to link any two randomly chosen individuals, no matter where they happen to live in the United States' (Milgram, 1967: 66). Milgram's article generated enormous publicity, thereby connecting in a public consciousness the concept of the network and that of the small world.[5] More recently the findings have been popularised as the theory of 'six degrees of separation'. Conceptually this phrase makes sense only if you view the world in terms of the network. The network, then, is a pre-existing framework upon which the concept of six degrees of separation is drawn.

Interestingly, while the phrase is usually attributed to Milgram, it is more likely that John Guare popularised it through his 1990 play *Six Degrees of Separation*, which spawned a film of the same name in 1993.

[5] Milgram's experiments, it is now known, were plagued by high non-completion rates (Watts, 2004: 133–40).

What is helpful about approaching the sociological findings of Milgram's experiments via this play is that it captures the surprise Milgram's discoveries generated and what they might mean for lived experience. The character Ouisa Kittredge says:

> I read somewhere that everybody on this planet is separated by only six other people. Six degrees of separation. Between us and everybody else on this planet. The president of the United States. A gondolier in Venice. Fill in the names. I find that A) tremendously comforting that we're so close and B) like Chinese water torture that we're so close. Because you have to find the right six people to make the connection. It's not just big names. It's anyone. A native in a rain forest. A Tierra del Fuegan. An Eskimo. I am bound to everyone on this planet by a trail of six people. (Guare, 1990: 81)

The accessibility of the concept of six degrees of separation is shown by the way it has been seized on in popular culture. The parlour game 'Six degrees of Kevin Bacon' challenges players to find the shortest path between a given actor or actress and prolific actor Kevin Bacon (which is in turn referenced by the digital project Six Degrees of Francis Bacon). And the phrase has appeared as a title of two TV series (a drama about six New Yorkers, *Six Degrees*, and a comedy reality show, *Six Degrees of Everything*), songs by the bands Scouting for Girls and The Script and by country artist Miranda Lambert, and an episode in *Battlestar Galactica*. What is notable about Guare's monologue, and what seems to make the concept so appealing, is the invisibility of the connections, the difficulty of discovering them, and the sense of wonderment when they emerge.

That sense of wonder, however, is arguably a residue of the analogue era. By contrast, from the late 1990s onwards the rapid growth of both the Internet and computational processing power has made it possible to gather and analyse network data on an unprecedented scale. Now in a few lines of code we can construct and measure networks of various kinds and extract information about their global structure: how big they were, how densely clustered, and in the case of the small world phenomenon, how many degrees on average any randomly selected node was from any other node in a network. In the foundational 1998 publication 'Collective Dynamics of Small World Networks', Duncan J. Watts and Steven Strogatz showed how small world properties are not limited to social networks: the neural network of the worm *Caenorhabditis elegans*, the power grid of the western United States, and the collaboration graph of film actors are all small world networks (Watts & Strogatz, 1998). Together with the 1999 publication by Albert-László Barabási and Réka Albert discussed in the opening pages of this book, Watts and Strogatz's publication ushered in the field of network science. Whilst some of their observations had precedents in scientific scholarship, they shone light on the elegance of networks as an abstract framework, which opened the floodgates to natural scientists, computer scientists, and applied mathematicians working on network data.

The movement into the digital realm, however, does something to the way we think about networks. It seems to make scientists custodians of the knowledge we have about networks, even though the systems they are analysing are historically the intellectual domains of very different disciplines. By thinking of them as something that can be measured mathematically, they no longer seem metaphorical but real and knowable. However, science is not the saviour of these other disciplines; rather, these discoveries depend on the convergence of numerous disciplines that have zeroed in on one way of understanding the world. In the potted history outlined earlier, we see that the understanding of and public access to the concept of small world networks was shaped by novelists (Karinthy), mathematicians (Kochen, Strogatz), political scientists (de Sola Pool), social psychologists (Milgram), playwrights (Guare), sociologists (Watts), artists and archivists (Lombardi), and physicists (Barabási, Albert), amongst others. The network turn is a product of all of this work, and all of this work was fertilised in a world increasingly straining against its hierarchies of power amidst renewed pushes for decentralised infrastructures of transportation and communication.

However, among these many diverse disciplinary threads that converge in the network turn, the mathematical view is particularly amplified in the digital context, meaning that the metaphorical and human-scale issues of point of view, uncertainty, and exclusion have been sidelined in both the popular and the academic consciousness. We need to redirect attention to the metaphorical dimension because of the way it helps us pay attention to the role of human interpretation: the insights the metaphor provides also necessarily impose constraints on thinking. We must recognise how the etymological root of the word continues to shape research into the network phenomenon. When we employ the word 'network' now, we no longer think of physical woven nets or the regular lattice pattern it signified in the earliest known uses; yet the underlying assumption of systematic pattern still pertains to the extent that academic research into networks is still bound up with the task of accounting for those perceived patterns. One might argue that the way networks are imagined is irrelevant to their quantitative measurements, but ultimately such measures are always interpreted in terms of their meaning for the underlying network. And this interpretation is inextricably connected to our imagination of the network.

One of the main reasons Barabási's and Albert's 1999 paper became so foundational is because it confounded widespread assumptions regarding the connectivity of large real-world networks. Before information and communications technology made it possible to gather and analyse large-scale network data in the 1990s, such networks were often assumed to be simple random networks in which links exist with uniform probability. Barabási and Albert discovered that many real-world networks have a very different connectivity – one in which a small number of nodes are very highly connected, a larger number of nodes are reasonably well connected, and the vast majority are poorly connected. Moreover this distribution holds across different scales, making it *scale-free*. This means that in any specific region of the network, regardless of its size, we will also see a small number of relatively well-connected nodes and a large number of poorly connected nodes. Although the word 'network' no longer so strongly connotes the regularity it once implied, post-Barabási network science nonetheless operates on the foundation that physical, social, and biological networks are united by regularities in structure and form which allow for a combined science of networks that transcends traditional disciplines. Regularity is a thread still woven deeply into the fabric of networks.

Network measurements are also often conceived with a particular imagined network topology or visual paradigm in mind, and their quantitative rigour cannot entirely free them from this. The popularity of graph drawings to represent social relationships preceded measurements that focused on features like path and centrality. A 'community' in such drawings is most often defined as a network region that is more densely connected internally than it is to other network regions. Articles on these methods often feature artificial networks as test cases which have clusters of nodes with high internal connection density and few connections between them. As the field has discovered in the years since such methods were first devised, real-world network communities often do not match this simple imagined community structure. It has been shown that the dozens of different algorithms that grapple with the problem of defining and identifying varying notions of communities in fact demonstrate the *shortcomings* of the idea of defining network communities in the first place.

The metaphorical dimension of the network allows network scientists to imagine possible ways of navigating mathematical spaces that are both conceptually and topologically vast. The lens of metaphor, therefore, could be described as limiting, but this limitation is productive, giving researchers somewhere to begin their explorations. However, the moment we have identified as the network turn, around the new millennium, has yet to be self-reflexively theorised in this way, and as such the ways this metaphorical framework can be harnessed and challenged remain unexplored. In this gap lies an open invitation for arts and humanities scholars to add their expertise.

Moreover, by recognising that the quantitative approaches leveraged in network science rely on thinking we normally associate with humanistic inquiry, we can begin to break down the barriers between the two cultures of sciences and humanities identified in C. P. Snow's 1959 Rede lecture. This recognition undercuts the perception of a one-way movement of methods and theories that have been developed and tested in the sciences to solve problems in the arts and humanities. Rather, the interface between these two traditionally divided kingdoms allows greater self-reflexivity about the extent to which networks are what Lakoff and Núñez describe as 'a cognitive mechanism' that crosses conceptual domains. However, whereas Lakoff and Núñez see a one-to-one mapping in the most basic description of conceptual metaphors, networks cross multiple domains: from the material domain (of literal net-making), to the linguistic and literary domain (of words used to conjure a sense of complex systems of entanglement), to the graphical or visual sphere (of technical or medical diagrams and of graphics designed for navigating transport systems), to the abstract realm (of nodes and edges measured in mathematical space). Apart from the literal act of net-making, all other renderings of the network leverage at least one of these other domains to make sense of their own. This suggests that networks are inherently domain-crossing. However, although a small but consistent stream of historians have been engaging in interdisciplinary network analysis since at least the 1960s, relatively few arts and humanities scholars are currently involved in this cross-disciplinary exchange and collaboration. We must address this weakness if the field is to become self-critical.

4 Visual Networks

Visual networks are compelling, but are they effective? The conventional network graph of node and edge (points connected by lines) makes it possible to convey a tremendous amount of information all at once, in one view. Networks express an internal logic of relationships between entities that is inherently intuitive. But they also lack an explicit external spatial referent, whether the latitude and longitude of cartography, the scale and sequence of a timeline, or the categories and measures that mark the x-y axis of a statistical graph. They can represent relationships at human visible scale, or scale to dizzying, visually indecipherable complexity. The unbounded rhizomatic structure of the network has a malleable, infinitely re-orderable form that communicates in a way that is distinct from almost all other diagrams of data. This chapter addresses how that malleability can be harnessed for research and communication.

The sketch presented in Figure 10 is one of many drafts leading up to Mark Lombardi's work, 'BCCI-ICIC & FAB, 1971–91 (4th Version)', with which we opened this book. It is a rough, incomplete, marked-up draft with nodes outlined in blue, connections crossed out, and empty spaces awaiting more information. A comparison between this draft and the final version gives us some insight into the evolution of Lombardi's thinking. Externalising information and organising ideas spatially is not just a mode of presentation, it is an integral part of Lombardi's research into these complex financial systems. The story he finally shares has been refined through the process of sketching, editing, and redrawing. But it is not merely a cleaned-up version of the draft. It demonstrates Lombardi's command of visual rhetoric to lay out his argument for public consumption; to convince and persuade with his choice of colour, the quality of the line, the careful annotation, the apparent precision, the internal structure, and the overall shape. The fragments of evidence Lombardi originally collected on three-by-five notecards and arranged in notes and sketches do not speak for themselves; they are selected, edited, and enriched, using visualisation at stages throughout the process as a cognitive aide, a modelling activity, an argument, and a work of art in turn (see Tversky & Suwa, 2009 and Tversky, 2014). It is an iterative act of knowledge production that if executed in prose rather than in drawing would

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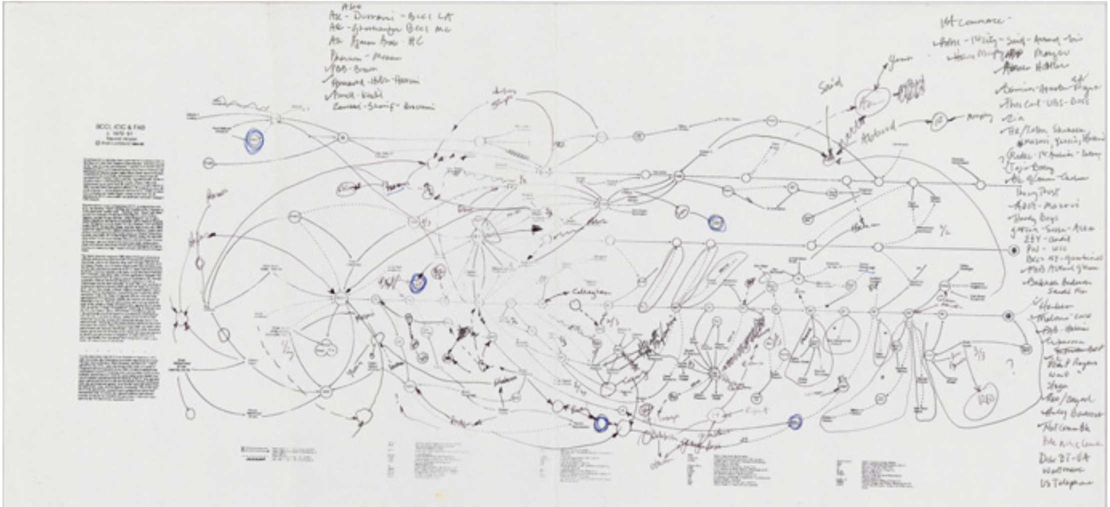

Figure 10 Lombardi, Mark (1951–2000): Untitled from the series BCCI, ICIC & FAB, 1996. Pen and ink and electrophotographic print on paper. New York, Whitney Museum of American Art. © 2019. Digital image. Whitney Museum of American Art / Licensed by Scala. figure 1

be very familiar to humanities scholars. This familiarity is an important point of reference when comparing hand-drawn visual networks like Lombardi's to those drawn with computer graphics software. Ben Fry, for example, points to Lombardi's work for lessons in a humanist view of data that uses visualisation as a story-telling medium requiring significant editing (Fry, 2016). Our contention is that handled in the right way, network visualisation can be both an important means of knowledge production and a powerful rhetorical tool.

The role of the visual in the production of knowledge is the thesis of Johanna Drucker's *Graphesis*. She opens the book with a comparison of two network visualisations: Athanasius Kircher's *Ars magna sciendi* (1669) and Barrett Lyon's 'Web Traffic Visualisation'. Both are networks depicted as nodes and edges (see Figure 11). Kircher returns us to the diagrammatic approaches to knowledge discussed in Chapter 2. It is a development of Ramon Llull's system published in his *Ars generalis ultima* or *Ars magna*: a method of combining religious and philosophical attributes selected from a number of lists, designed to engage Muslims in debate and win them to the Christian faith. Kircher's diagram forms a complete bipartite graph, where every node of the first set is connected to every node of the second. The Lyon visualisation, part of his Opte Project, is a computer-generated network graph intended to map the Internet. Nodes represent individual servers and hosts, and edges represent the fibre, copper, or other connections between them. Drucker's purpose in juxtaposing these two graphs is to draw our attention to their relationship to information. Kircher's work, she argues, '*produces the knowledge it draws*': the effect of combination is to generate insights. By comparison, Lyon's network visualisation of web traffic 'only displays information'. This distinction is an important one when thinking about how we employ visualisation in our work. Off-the-shelf graphics packages are employed in research as a means both of generating insights and displaying observed phenomena. However, the word 'display' is a potentially misleading term. As Drucker puts it, certain visualisations 'act as if they are just showing us *what is*, but in actuality, they are *arguments made in graphical form*' (Drucker, 2014). We need to recognise the rhetorical power of visualisation if we are to remain alert to the hidden agendas of the graphical forms we encounter.

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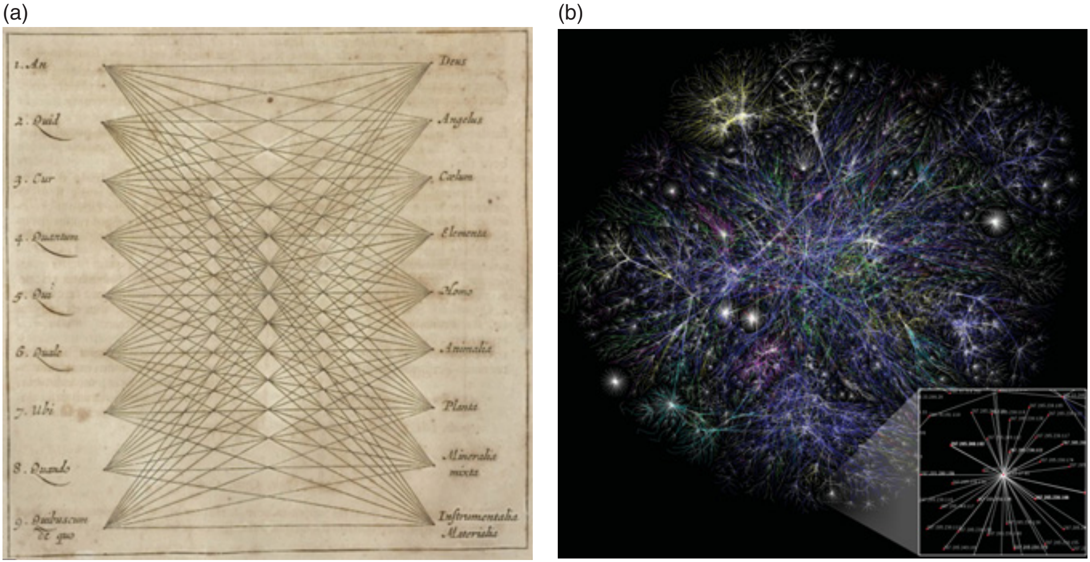

Figure 11 On the left, a combinatorial diagram entitled *Typus universalis, omnibus de quacunque re proposita questionibus formandis, aptus*, in Athanasius Kircher, *Ars magna sciendi* (Janssonius a Waesberg, 1669). Digital image. Max Planck Institute for the History of Science Library. CC BY SA 3.0. On the right, a visualisation from the Opte Project of the various routes through a portion of the Internet in 2005. Digital image. Wikimedia Commons. CC BY 2.5.

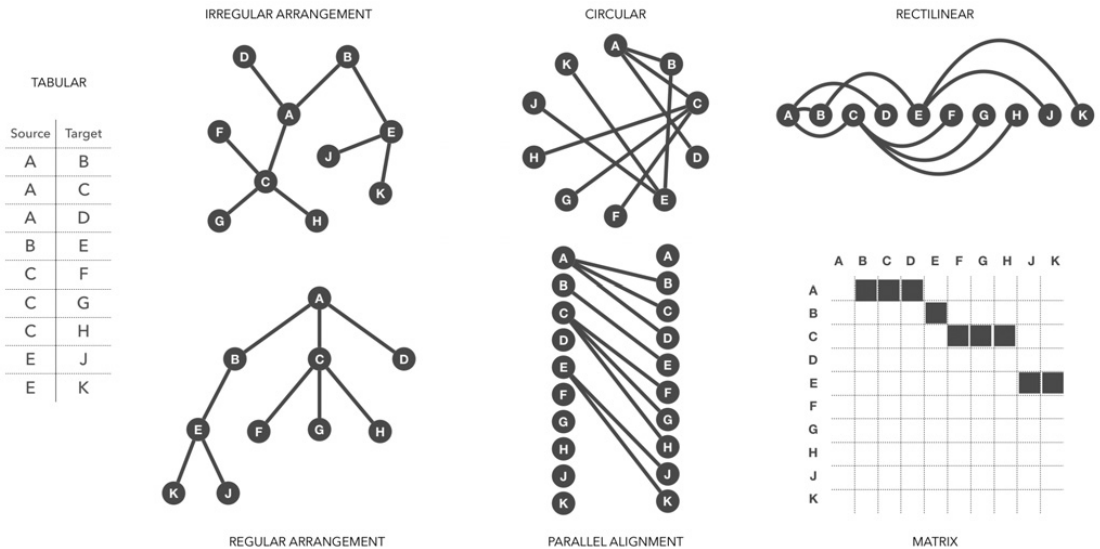

Figure 12 This figure shows a number of different ways to present the same network data. On the left is source–target pairs in a two-column table. The regular and irregular arrangement, circular, and rectilinear are all network layouts in Bertin's system. He distinguishes those node-link network graphs from the diagrams: parallel alignment and matrix. Diagram by the authors.