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Imag(in)ing Networks

Katja Mayer

Abstract:

Network cultures share imaginations of networks. Despite the lack of a consistent scientific network theory, a coherent trans-theoretical trend in today's network visualization can be observed: even if underlying data and purposes are very divergent, images of networks are similar. They are created from the same technical and graphical dispositives and produced by similar optimization algorithms for topological problems within the constraints of digital information visualization. For a concrete examination of the ongoing "viscourses" (Knorr-Cetina 1999) we need to focus on imaging practices and culturally and technically embedded standards that are easily overlooked. The suppositions to be presented are derived from the empirical observation of research practices in an institution specializing in Social Network Analysis and from several interviews with network and visualization experts conducted for my PhD.

Note:

As I do not hold the copyrights to most of the images that will be part of my presentation, I unfortunately cannot include them in this paper.

Thanks:

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Introduction

I am interested in the practice of scientific knowledge production. My background is in Science and Technology Studies (STS), where I examine means of legitimation of scientific knowledge with and through scientific images as images are conventionally not accounted as strict formal methods. The central question in my PhD is: What roles do images play in the knowledge production in the context of their production?

"Epistemic images" (Latour 1996) have been investigated for more than two decades in STS and history of science, but the practice of image production and their roles in the scientific community as well as the use of imaging technologies in social sciences and humanities are rarely objects of research projects.

With Social Network Analysis (SNA) I chose an interdisciplinary academic field and a scientific community where images play an important role in argumentation, knowledge production and diffusion, and where aesthetic criteria take an active part in imaging processes.

For my study of network visualizations I chose SNA for several reasons:

1. Visualization of social networks has been a core practice since software has become widely available.
2. There has also been a tradition of visualization in pre-digital times, so it would be possible to compare the features and styles without getting lost in densely engineered operative procedures.
3. It is still quite easy to have an overview of this relatively young and small discipline.
4. Parts of the community are actively and openly reflecting on their paradigms, methodology and strategies, especially at a time when *social software* and network analysis being used in many disciplines and contexts.
5. The community is accessible and has shown interest in my research project.

A wider discussion of quality standards of social network visualizations has recently emerged in this field. I have been able to identify several people in this debate and have asked them for an expert interview.

My suppositions derive from repeated empirical observations in an institution specialized in SNA in Vienna, Austria and from several interviews with network and visualization experts conducted for my dissertation. Participatory observation and several feedback discussions have provided additional insight into the image production procedure as well as into the personal positions and some of the collective attributions of the researchers in this field. With that I could establish an understanding of the role of network visualizations as transfer objects in the research process. I was only able to overview the various enactments and functions of network imagery when after analyzing the additional interviews I conducted with computer scientists, physicists, social scientists, and mathematicians, who all work on - or with the visualization of complex networks.

Another important source of my observations are meetings, method workshops and, most importantly, conferences. At the forthcoming conference New Network Theory in Amsterdam I am particularly looking for alternative stories, metaphors and imagery of networks that could open up new opportunities, new perspectives for SNA but also could serve as means for reflecting upon my own investigation.

In line with the concept of performativity, the underlying hypothesis of my project is that producing and representing knowledge are inseparable. My own research is generated from a "particular location" (Haraway 1988) but strives its research object as "multiplicities" (Mol 2002).

My presentation is subdivided into three sections:

1. Short overview to my investigation of epistemic images in Social Network Analysis with a special focus on the production of network visualizations by the pioneers in the 1930s.
2. The visual and formal culture of depicted networks.
3. The implications and paradoxes, that make it so hard for us today to imagine networks other than with nodes and edges, for a *New Network Theory*.

> "Thus: the strength of knowledge does not depend on its degree of truth but on its age, on the degree to which it has been incorporated, on its character as a condition of life. Where life and knowledge seemed to be at odds there was never any real fight; but denial and doubt were simply considered madness." (Nietzsche 1882, 110)

Epistemic Images

The roles of images in science have been contested for a long time. Their attributions range from representation to construction, from anthropology and semiology to phenomenology, from truth to emotion. Many scientists argued that truth can only be found in pure or abstract ideas and therefore have rejected the use of images. Not only were they convinced of the impossibility of mapping reality, they also pointed to the dubiousness and indeterminability of images and their creative distraction. Accordingly, images were unsuitable for use in scientific argumentation because of their aesthetic effect (which supposedly confounds scientific rationality). Since Freud there has been a debate (Mersch 2005) whether pictures evoke an affirmative tendency or if they can be negated in a logical sense.

Digital techniques as mathematical technology were regarded as trusted toolkits for scientific objectivity. With the rise of computer graphics within the last 20 years, new representational techniques have been developed along with new possibilities of simulations with new virtual spaces of potentiality. But with digitalization the boundaries between *allowed editing* and *tabooed manipulation and interpretation* become once again equivocal, especially since production, manipulation and interpretation are more inseparable then ever. (For further discussion see: Heintz 2001, Hessler 2006)

The wish to produce *realistic* images - from dinosaurs, nanolouse to colorful celestial bodies – have led to a claim for quality control or even aesthetic standardization. "Pictures must not be divorced from science and scientific plausibility", Ottimo writes in his widely discussed article in Nature (Ottimo 2003). The interesting term here is: *plausibility*. He is not arguing against an artistic approach, but he claims for a transparent justification of the used methods and demands for the compliance of scale. To connotate *realistic* directly with the *objective-natural* or with *puristic* or *abstract* representations of measurement is to forget that these modes of display are also aesthetic styles. Such an assessment of scientific images adopts a "principle of disjunction" (Bredekamp 2004) in the characterization of a scientific representation: the more natural an object appears in its display in reference to what we see, the more its picture has been constructed. In that sense visualizations of networks come with a strong natural appeal, because they are very complex assemblages projected on to a two-dimensional plane.

Making Images, Making Sense.

To investigate scientific images it is necessary to observe their process and context of production and their different "enactments (Law 2000). Latour and Woolgar referred to representational techniques in science as "inscription devices" (1979). Scientific graphs are very effective and persuasive form of inscription devices. Latour (1990) would even go as far as to suggest that the use of graphs is what distinguishes science from nonscience. And the historian Crosby (1997) traces the explosive development of all modern science back to two factors: Visualization and measurement.

With reference to Latour's article "Drawing Things Together" (1990) I expound on several functional qualities of scientific graphs/diagrams and therefore visualizations of social networks for the scientific research process. As an explicit elaboration and extension of Latour's specifications I include the diverse materialities, corporealities (Haraway 1991) and medialitites as horizontal dimension of analysis in my study.

1. Making structural data "visible" (Rheinberger 2006) transformes data into easily apprehendable icons.
2. Diagrams promote inductive abstraction from detail to general.
3. Diagrams can be superimposed and compared.
4. Scientific images function as apparati and results. "Diagnostic images" (Diebner 2006) faciliate exploration and they even help find errors in large datasets.
5. With conventional graphical forms of abstraction, diagrams remain sufficiently flexible so that the transfer of knowledge can take place.
6. Scientific images can be transported across contexts: they are "conscriptions" (Latour 1990) and mobilize consensus on data and evidence.

7. They are “mobiles” (Latour 1990) as they are transportable objects e.g. from laboratories to scientific conferences.
8. They provide material grounds for demonstrational purposes, maps for traveling fingers and metaphors.

The enactments of visualizations in the research process are also very dependent on the scientists experience and use of imaging technologies. Most social scientists have at least some expertise in dealing with statistical software and graphical output in form of diagrams. But dealing with social networks as concept in software and in images is still something that is at its inception, at least in Europe.

Structural Imaging

In the pioneering days of Social Network Analysis in the 1930s, before mathematicians became interested in real world graph problems, when “super-connectors” (Barabasi 2002) were called “stars”(Moreno 1953), and networks were drawn by hand, one can locate the basic assumptions that are still at work in scientific network visualization today. Interaction diagrams and later *sociograms* were originally developed for improvised theatre and psychodrama, before their application to social groups for intervention purposes.

The emergence of social network analysis results from many different influences. The idea of society as a number of individuals connected by interaction was introduced by Simmel in his formal sociology in 1908. Upon emigrating to the USA Lewin and Moreno brought and further developed interaction diagrams, *field theory* and *sociometry* in the 1930’s (Wasserman 1994). But one of the major influences for the visual dimension of the discipline was the work of Moreno, a psychiatrist and group therapist by training. Along with his co-author Jennings he developed sociograms for representing the interpersonal structure of groups and devised quantitative measures for network structures.

> “Before the advent of sociometry no one knew what the interpersonal structure of a group ‘precisely’ looked like.” (Moreno 1953, p. lvi)

Before the early 1930’s group structures were mainly displayed in matrices. Commonly the rows and columns (still) represent social actors and the values in the cells represent the connections. With the sociogram social actors are represented as points and connections as lines.

Moreno wrote about his research practice:

> “We have first to visualize … A process of charting has been devised by the sociometrists, the sociogram, which is more than merely a method of presentation. It is first of all a method of exploration. It makes possible the exploration of sociometric facts. The proper placement of every individual and of all interrelations of individuals can be shown on a sociogram. It is at present the only available scheme which makes structural analysis of a community possible.” (Moreno 1953, pp 95-96)

Above mentioned sociograms were drawn by hand and nevertheless Moreno claims high formal standards for his displays. But the most important task was to make structures evident and to allow exploration. That was more important than scientific reproducibility and falsifiability, scientific qualities that were claimed for the other methods, especially for the “sociometric test”, “sociometric experiment” (Moreno 1953) and the quantitative analysis of the interpersonal choice-making activity - choices with whom to interact, share time, space, energy and opinion. On another occasion Moreno (1953) emphasized the potential of sociometry in general and sociograms for social intervention and for the inducing of social change. With the help of sociometrists, participants of sociometric experiments could become active agents in matters concerning their life situation because they could see their embeddedness in social situations and groups and therefore, perform adaequate changes.

The sociograms of that time can be read as pictoral representations of (mathematical) graphs as they consist of a set of points along with a set of lines connecting pairs of points. Moreno does not refer to mathematical graph theory that was evolving around the same time, and so it can be stated that the sociograms “were ad hoc and their success varied with the insight and artistic skill of their creator”(Freeman 2000). So neither the sociometric drawings nor the *sociometric facts* - the analysis of the sociograms -

were derived from systematic calculation, but from systematic formalization, that was done *manually*.

The further development of sociograms by Moreno included directed relations represented by arrows, the use of colors to distinguish different attributes in relations for the creation of "multigraphs" (Freeman 2000), variations of shapes of points to "communicate characteristics of social actors" (Freeman 2000) and "variations in the locations of points (…) to stress important structural features of the data" (Freeman 2000). The question of locating the points on the plane led Moreno to place them in "positions that map to their actual locations in physical space" (Freeman 2000), similar to today's term *geomapping*. When there was "no specific basis for arranging points in one particular form or another" (Freeman 2000), they were arranged into a circle. With large datasets sociograms become less effectively readable due to an increased number of line crossings. It is still a widely used rule in network visualization, that "the fewer the line crossings, the better the sociogram." (Freeman 2000)

All of the features and rules mentioned above - although derived from insights of the manipulation of relatively small datasets - are still in use when it comes to visualizing (social) networks from large datasets today. These features are nowadays embedded in visualization software that theoretically make the image production obeying to the scientific laws of objectivity, reliability, validity, standardization and Occam's Razor.

Sociograms helped to in-form the sociometric facts. Manually. Diagrammatically.

They still do so but nowadays, automatically. So the models used in network analysis are basically topological, "their elements are defined relationally according to the pattern of ties that exist between them. There is no metric extension in this space (distance is calculated by the number of links separating two nodes) and no dimensional orientation (for example, up, down, right and left are undefined)." (Mohr forthcoming) But for their depiction as networks on a plane those models have to be projected onto two-dimensional space and mediated onto physical space.

Imaginations

Contemporary scientific network analysis studies interactions among a set of actors (e.g. persons, institutions, objects, molecules, etc.) from a structural perspective in a broad range of disciplines. Examples of (complex) networks under investigation are the Internet, the spread of diseases and social interactions, which are the speciality of SNA. Examples for such social interactions include: kinship, friendship, social movements, exchange of goods, work, capital, information etc.

To analyze a network (social or other) a finite set of actors has to be defined. For at least one type of relationship it has to be measured, which actors from the set are holding this type of relationship. In network analysis many very different scientific theories with specialized tools for data collection converge within a rather small formal methodological field that provides means for the measurement of relations and interactions. The mathematical theory of networks derives fundamentally from certain branches of topology and abstract algebra. Therefore, its tool set consists of elements from Boolean algebra, lattice theory, set and graph theory and combinatorial statistics.

The theory of graphs is often presented as general theory of networks because relational data is commonly organized in matrices or in graph drawings. The relational data used for both means of display are the same. In graphs actors are denoted as nodes/points/vertices and relations as edges/links/lines. In formal contexts the term network is used synonymously with the term graph.

To analyze social cohesion, the *density* of the network is measured. Density is derived from the number of links in a network, expressed as a proportion of the maximum possible number of links. Density is commonly measured in sub-networks, and not for the total graph. To gather knowledge about the relative importance of an actor in the network, *centrality* is calculated. "There are four measures of centrality that are widely used in network analysis: *degree centrality*, *betweenness*, *closeness*, and *eigenvector centrality*." (Wikipedia: Social Network Analysis) The degree of an actor/node is the number of direct relations/edges to the actor/node. Nodes that occur on many shortest paths between other nodes have higher betweenness than those that do not. Closeness is defined as the shortest path between two nodes. Eigenvector centrality assigns relative scores to all nodes in the network based on the principle that connections to high-scoring nodes contribute more to the score of the node in question than equal connections to low-scoring nodes. Those analysis techniques are among the first ones taught to students of network analysis and they belong to the field of graph theory.

The usage of tools from graph theory in SNA brings with it several problems. To name a few: Graph theory - developed in the context of relatively limited problems - rarely handles networks with several distinct types of relationships, each with its own configuration of links. It seems that such networks might be of most interest to sociologists. Nodes that have links back to themselves are neglected and not represented in full effect. Transformation relations are also mainly ignored as graph theory offers just a limited number of means for global analysis of networks. (Bender-deMoll 2006). There is nonlinear data that could better be represented with set-theory or categories as there is always a certain trope of causal hierarchy embedded in the network-node/edge worldview. The strong affinity of Rational Choice Theory with the network approach should also be mentioned here.

In highly acclaimed books from physicists presenting *the Network Theory*, original sociological concepts like *social structure* or *social capital* are laxly ignored or totally abandoned. What follows is a very formalized and pragmatic concept of the social, preferably projected onto socio-technical connections and systems of rational agents.

When looking at spatial metaphors used to describe networks, it is very interesting to see the problems we have when dealing with non-Euclidian topologic that is projected onto a two-dimensional plane, and therefore becoming geometric. „Most kinds of network data require transformation before they can be visually represented in a two-, three-, or n-dimensional social space because the properties of Euclidean distances measured in the coordinate frameworks we work with in the physical world (or in our electronic representations of it) may not hold true for network distances." (Bender-deMoll 2006)

It is also interesting to compare visualization styles to metaphorical concepts used to model networks. Rogers (Rogers 2007) showed how the depictions of link structures and issue networks on the internet related to concepts such as "pathways", abbreviated into the slogan: "Where do you want to go today?"(Microsoft advertisement 1996), how "virtual round tables" were envisioned as circle maps. He explained the trends towards "clusters", or "distributed geography" (Rogers 2007).

Until recently SNA and network analysis in general shared another deficiency: The impossibility or very laborious possibility of dealing with change in networks using static analysis tools and static images without a temporal axis. "The first common visualization approach plots network summary statistics as line graphs over time. (…) However, such summary statistics provide information on a single dimension of a network's structure. For example, one might find that a network reaches a given equilibrium transitivity level, but since transitivity is a single average for the graph as a whole, we cannot know if this - in itself - means the graph is now relationally stable. The second common visualization approach is to examine separate images of the network at each point in time. Unfortunately, such images are often difficult to interpret since it is impossible to identify the sequence linking node position in one frame to position in the next." (Moody 2005)

Dynamic visualization of longitudinal networks in the form of animations and simulations will force tools for graph layouts and other concepts to their limits, and it will bring a lot of changes in the modeling and comprehension of social networks. For a summary of ideas leading to Dynamic Network Analysis (DNA) please refer to: Carley, forthcoming.

Objectification

While observing the research practice in a SNA institution in Vienna, I could identify a nearly complete process from the formulation of the hypothesis, data collection to the analysis of the network that was densely intertwined with the production of visualizations. Network visualizations were produced AND explored, shaped AND showed. They helped realize cognition AND evidence. The analysis of the ongoing discourses had to be expanded to *viscourses* and with this the material dimension comes into focus. With the visualization of networks, objects are created in physical space. Materiality is given to values and algorithms that even can be touched and pointed at.

For the production of network visualizations the scientists come across at least 4 computer programs after the data was cleaned and manipulated to fit into a network matrix. With the software an uncountable number of algorithms for data analysis and for graph drawing is used on the formalized data. As far as the software is concerned, in all interviews conducted with persons involved into programming analysis and visualization tools, people complained about having to develop methods *on the fly* to answer pressing questions, not having the time to create an appropriate framework.

During image production many forms of media are transgressed: paper (for manual sketches and print-outs), computer, computer networks, projectors, walls, printers, fingers (to demonstrate). The analyst zooms in and out, compares features, different images, e.g., a network with a distribution graph, or the random distribution with the power law distribution. Screens are switched, data is in tables, rankings, or still in Google. Networks are flipped around in up to four (screen-) dimensions, manipulated with spring-embedders or multidimensional scaling.

> "Force-directed or spring-embedder algorithms are among the most common automatic network layout strategies. These algorithms function substantively on an analogy, treating the collection of nodes and arcs as a system of forces, and the layout as an "equilibrium state" of the system. Generally, edges between nodes are represented as an attractive force (a "spring" pulling them together), while nodes that do not share a tie are pushed apart by some constraint to help prevent overlap." (Moody 2005)

If the analyst is still not happy with the result, some features might be changed manually. This is done primarily because there are still too many edge crossings or the labels are not readable. When asked, the observed scientists told me that they wanted to make the images more efficiently understandable, first for themselves and, as soon as they knew more about the network, for the intended watchers. With manipulations as such, images are made even more *evident*.

Meanwhile the visualizations are shown to colleagues, talked about, pointed at and touched. In many SNA presentations idealtypical network patterns such as a triangle/triad mark the beginning of the visual analysis of the network. Then commonly graphs of whole networks (even if they are very complex and just a mesh of dots and lines) are demonstrated first, before it is zoomed into a special region.

The graphs are analyzed and described with metaphors like: "territory", "periphery", "hub", "frozen", and so on. Such enactments of metaphorical spaces are another important quality of network diagrams.

Trans-formation

Images of networks are complex assemblages themselves. Despite the mathematical impossibility of a unique layout and thus many possibilities of visualizing networks as mathematical graphs, most scientists adhere to the style of the node-edge diagram with its common iconography and basic shapes. They are produced from the same graphical dispositives, those nearly "naturalized" diagrammatic shapes, that already Moreno took advantage of. Our "complexity telescopes" (Nees 2005) stem from traditions of astronomy, biology, geography, transport logistics, or chemistry, just to name a few, such visual and scientific traditions that sometimes are forgotten by rather pragmatic network analysts.

From Indian mythology, Chinese maps to aboriginal sand drawings in Australia, the history of the net(work) metaphor is very well documented (e.g. Gießmann 2006). For example Donati (Gießmann 2006) proposed a netting metaphor both in his texts and his diagrams already in 1758, and Darwin just had to keep the tree-metaphor merely not to antagonize the Christian church that would not have been very fond of his coral-like diagrams (Bredekamp 2005) depicting models of evolution where God and mankind were no longer the apex of creation. In his letters he wrote about the beauty of infinite complexity. Also his modeling of the system of the species with the underlying Gestalt of a coral represent his search for a variability in nature, that is not mainly driven by the *survival of the fittest*. On the contrary his aversion of trees and genealogies resulted from his studies of diverse evolutionary strategies, such as choice due to favorable form and the anarchistic power of the ornament and the creative exuberance (Bredekamp 2005). Such rather ornamental imaging practices contrast with contemporary performances of formalization and operability.

Conclusion

A rising paradigm of strict aesthetic quality control that favors puristic displays in line with the principle of simplicity (*the simplest explanation tends to be the best*) inevitably leads to the scientific paradox of how to cope with complexity through simplicity.

Furthermore standardization efforts to facilitate a more effective data display that draw onto findings (Krempel 2005) of colorimetry, psychology of perception and cognitive sciences tend to blackbox imaging technologies even more. Such intentions contribute to the disjunction principle, which states, that the more natural an image appears, the more its picture has been constructed. Any such closures direct to the problem of methodological transparency. How do we treat apparati that are built upon prevalent conceptions of the human perception and cognition?

Ad hoc drawings seem to be rather cumbersome in times of very large datasets and the idea of representing complete networks. That is why such pictures are mainly produced in a qualitative research approach, e.g. during qualitative interviews or in few studies of ego-centered networks that operate more on a microlevel of analysis.

Depending on the research setting, network visualizations as cultural techniques can be seen as "boundary objects" (Star 1989) with a lot of different ascriptions particular to the needs from the material, but they also function as boundary when dealing with imaginations of networks. The generalized *look* shows the other side of network visualizations - as stabilized iconic entities. Common network visualizations (even if at some stages manipulated manually) result from highly normalized procedures. This paper argues for a deconstruction and decomposition of these procedures to shed light onto the many closures that are taken for granted. While observing scientific practice it could be exposed that such normalization is always accompanied by metaphorical enactments. It is evident that network visualizations obey rather strict theoretical and methodological conventions that are embedded in our imaginations. So here is another paradox: how can such normative images not count as strict and formal methods?

For a tangible examination of the ongoing viscourses we reverted to pre-digital image processing in SNA to demonstrate how symbolic forms and shapes – aside from innovative algorithms or new media developments - affect our thinking of networks. Those forms are still in full effect, but when deeply embedded in techniques, they are "dead metaphors" (Blumenberg 1999).

It was shown when examining the history of network visualization, SNA moved from a rather loose field to a rather normative framework. It is not a coincidence that in the last years there has been a strong opposition in the SNA community (reference: SOCNET mailinglist) against the appropriation of SNA by physicists and developers of social software.

Social scientists are experienced in the formalization of their disciplines but with network images a hidden normalization creeps also into cultural- and media studies. I am not arguing against the use of images in science, social science and humanities. On the contrary I think science should be performed deliberately with all our senses: I just want to show that the implicitness of highly constructed imaginary spaces is very hard to penetrate and overcome.

Can we find alternatives to depict a relation as line or arc? Are dots/nodes and lines/edges the boundaries we cannot transgress when modeling networks? And what does this mean for a theory that is so intertwined with its imaginaries?

With the perspective of network images as powerful "conscription devices" (Latour 1990) the question for a New Network Theory would be: how could we find new land with old maps?

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