Actor-Network VS Network Analysis VS Digital Networks
Are We Talking About the Same Networks?

Tommaso Venturini, Anders Munk, Mathieu Jacomy (Sciences Po médialab)

This paper discusses the differences and affinities among three types of networks (namely Actor-Networks, Social Networks and Digital Networks) that are playing an increasingly important role in digital STS.

In the last few decades, the notion of networks has slowly but steadily struck root across broad strands of STS research. It started with the advent of actor-network theory, which provided a convenient instrument to describe the construction work of socio-technical phenomena. Then came network analysis, and scholars who imported into STS the techniques of investigation and visualization developed in the tradition of social network analysis and scientometrics. Finally, with the increasing 'computerization' of STS, scholars turned their attention to digital networks as a way of tracing collective life.

Many researchers (not least at the Sciences Po médialab) have more or less explicitly tried to link these three movements in one coherent set of digital methods, betting on the idea that actor-network theory can be operationalized through network analysis thanks to the data provided by digital networks (Venturini 2012a/b). Yet, to be honest, little proves the continuity among these three objects besides the homonymy of the word 'network'. Are we sure that we are talking about the same thing?

> "Odi et amo. quare id faciam, fortasse requiris?
>   nescio, sed fieri sentio et excrucior."

Catullus 85 or Carmina LXXXV

Professor — you should not confuse the network that is drawn by the description and the network that is used to make the description.

Student — ⋯?

Professor — But yes! Surely you'd agree that drawing with a pencil is not the same thing as drawing the shape of a pencil. It's the same with this ambiguous word, network. With Actor-Network you may describe something that doesn't at all look like a network —an individual state of mind, a piece of machinery, a fictional character; conversely, you may describe a network —subways, sewages, telephones— which is not all drawn in an 'Actor-Networky' way. You are simply confusing the object with the method. ANT is a method, and mostly a negative one at that; it says nothing about the shape of what is being described with it.

Student — This is confusing! But my company executives, are they not forming a nice, revealing, significant network?

Professor — Maybe yes, I mean, surely, yes— but so what?

Student — Then, I can study them with Actor-Network-Theory!

Professor — Again, maybe yes, but maybe not. It depends entirely on what you yourself allow your actors, or rather your actants to do. Being connected, being interconnected, being

heterogeneous, is not enough. It all depends on the sort of action that is flowing from one to the other, hence the words 'net' and 'work'. Really, we should say 'worknet' instead of 'network'. It's the work, and the movement, and the flow, and the changes that should be stressed. But now we are stuck with 'network' and everyone thinks we mean the World Wide Web or something like that.

Student — Do you mean to say that once I have shown that my actors are related in the shape of a network, I have not yet done an ANT study?

Professor — That's exactly what I mean: ANT is more like the name of a pencil or a brush than the name of an object to be drawn or painted.

From conflation comes power

Say what you want, analytical dissection is not the only motive of science. Often, the desire to fit together concepts coming from different traditions and disciplines feels just as urgent. A good example of this movement is the conflation that in the last three decades has reunited three different meanings of the word 'network' in STS.

It all started in 1986 when Michel Callon introduced the term 'actor-network' as a conceptual tool to "describe the dynamics and internal structure of actor-worlds" (Callon, 1986a, p. 28). It is worth remembering that Callon's essay appeared in the collective volume "Mapping the Dynamics of Science and Technology". The book was intended to complement the traditional techniques of observation and narration employed in STS (mainly derived from historiography and anthropology), with new methods of computation and visualization derived from scientometrics and text-analysis.

Three ingredients of the network-conflation were already there:

1. The theoretical idea that collective phenomena are best described not by the substances, but by the relations that constitute them (actor-network theory).

2. The methodological appeal for new quantitative techniques to analyse and represent the connections between social actors (network analysis).

3. The intuition that the inscriptions left by collective actions (scientific publication in the specific case) could be re-purposed for social research (network data).

The ambiguity of the word 'network' – which can equally refer to a conceptual topology (the space of connections as opposed to the Euclidian space of forms), to a set of computation techniques (the mathematics of graphs) and to the hyper-textual organization of inscriptions (the relational datasets) – suggested that the conflation was possible and, indeed, desirable.

Conflating these otherwise disparate notions of 'network' was more than a conceptual trick. It involved wedding the ideas of Actor-Network Theory (ANT) to the methods of Social Network Analysis (SNA). Celebrated under the homonymy of their second letter, the marriage was particularly appealing for the STS, as it promised ways to follow socio-technical associations beyond the walls of scientific laboratories (to which STS were confined by the use of ethnographic techniques, cfr. Knorr-Cetina, 1995). But the

wedding coud also profit social network analysts, who could find the theoretical framework that they had missed (Granovetter, 1979 laments of a "Theory-Gap in Social Network Analysis" and Burt, 1980 argues that "the lack of network theory seems to me to be the most serious impediment to the realization of the potential value of network models in empirical research" p. 134).

Yet, for quite some time, the arranged marriage between ANT and SNA bred little progeny. The lack of relational data beyond those offered by bibliographic databases (which, at the time, did not extend much beyond the scope of what could be observed through the already succesful laboratory ethnographies) limited the interest in the conflation (though interesting work was done by scholars such as Cambrosio, Rip, Mogoutof).

The turn came with the advent of another type of networked data namely that originating from digital communication.

Speaking at the *Virtual Society?* conference (Woolgar 2002), Bruno Latour (1998) suggested that social connections become more material and thereby more traceable when flowing through digital infrastructures:

> Once you can get information as bores, bytes, modem, sockets, cables and so on, you have actually a more material way of looking at what happens in Society. Virtual Society thus, is not a thing of the future, it's the materialisation, the traceability of Society. It renders visible because of the obsessive necessity of materialising information into cables, into data.

In the audience were two young sociologists, Richard Rogers and Noortje Marres who, in the following years, developed a series of experimental tools and methods to put digital traces at the service of the social sciences (see Rogers, 2004, 2013, Rogers and Marres 2000 and 2002 and www.digitalmethods.net):

> Bruno Latour (1998), argued that the Web is mainly of importance to social science insofar as it makes possible new types of descriptions of social life. According to Latour, the social integration of the Web constitutes an event for social science because the social link becomes traceable in this medium. Thus, social relations are established in a tangible form as a material network connection. We take Latour's claim of the tangibility of the social as a point of departure in our search (Rogers and Marres 2002 p. 342).

It is important to notice that it is not the volume of digital data that made the difference (this is explicitly *not* a 'big data' argument), but its relational nature. As digital media are organized as networks both at the physical and content level (the Internet is the interconnection of computer-networks and the World Wide Web is the interconnection of online hypertexts), the inscriptions that they produce are *natively* relational. The TPC/IP (Transmission Control Protocol / Internet Protocol), the HTTP (Hypertext Transfer Protocol), the Relational Databases and all major protocols and formats supporting digital communication are relations-based.

 By generalizing the practice of citation beyond the scientific literature (Leydesdorff, 1998 and Leydesdorff & Wouters, 1999), digital protocols contributed to formalize collective life as a network of association. Both in the sense of extending the reach of the

network methods developed in scientometrics (cfr. for example, how Roth and Cointet, 2010 employed the exact same techniques to study the epistemic communities of the scientists working on the Zebra Fish and US political bloggers) and in the sense of encouraging collective life to organize in a network-like shapes.

This double movement is very clear in the most famous tool developed by Rogers and Marres – the IssueCrawler (www.issuecrawler.net). The IssueCrawler is a simple tool employing web crawling (a classic technique in digital engineering consisting in following and harvesting the hyperlinks connecting a series of websites) to investigate societal debates *as discussion networks*. By using this tool, Rogers and Marres not only extended network analysis to the study of public opinion, but also discovered that online public opinion is organized as a network:

> We took to the Web to study public debates on science and technology, but we found 'issue-networks' instead⋯ Following hyperlinks among pages dealing with a given issue, we found that these links provided a means to demarcate the network that could be said to be staging the controversy in the new medium (Marres & Rogers, 2005, p. 922)

It would be nice here to tell the story of social sciences revealing the nature of a new medium and repurposing its formats for research. Things, however, are more complex and while social scientists were striving to socialize web-networks, computer scientists were busy engineering sociological methods – and scientometrics in particular – into digital media (Marres, 2012a). The most famous example is contained in the article presenting the *Pagerank*, the algorithm that made the success of Google, where its inventors explicitly argue:

> It is obvious to try to apply standard citation analysis techniques to the webs's hypertextual citation structure. One can simply think of every link as being like an academic citation (Page *et al*, 1999, p. 2)

This explains why the network-conflation is so powerful: it is not just the meeting of two separate sociological schools; it is that this meeting takes place on the ground of one of the major technological (and economic) innovation of last century. If it feels more and more natural to think of collective phenomena in relational terms, it is because digital mediation is increasingly turning them into networks. Our professional sector resembled much more to a social network, since our colleagues invite us on LinkedIn. Friendship has literally become a matter of connection, now that it is mediated by Facebook. And when we look at our library we increasingly expect to see what other books "Customers Who Bought This Item Also Bought". The more it is mediated by network technologies, the more collective life can be read through the theory of networks, measured through network analysis and captured in network data.

> Sociologists of technology have long relied on methods of network and textual analysis in order to capture the unfolding of controversies⋯ Today the proliferation of digital technologies means that similar methods are deployed much more widely to analyse and visualise issues in digital networked media⋯ Indeed, network and textual analysis tools are now routinely deployed in digital culture (Marres, 2012b, p. 300)

The (con)fusion of the four meanings of 'network' (1. a conceptual metaphor; 2. an analytic technique; 3. a set of data; 4. a socio-technical system) is not just a product of

sociology; it is a product of society. This is why the network-conflation is so powerful – to the point that great is the temptation to argue not only that collective phenomena can be described and mediated through networks, but that society has in fact become a network (cfr. Castells, 2000; Van Dijk, J. (1999) The Network Society: Social Aspects of New Media, trans. L. Spoorenberg, Sage Publications, London., Barney, 2004) and even that everything has become a network (cfr. Barabasi, 2002). And this is why the network-conflation is so dangerous.

Networks are not networks

As the uncle of Spiderman used to say "with great power comes great responsibility" and the very same people who initiated the network-conflation in STS, the actor-network theorists, have always been wary about its use and abuse. In particular, they were afraid that, while offering an operationalization of their relational analysis, it also risked blurring important part of their approach. They were right.

The easiest way to answer the question asked by the title of this paper -"are we talking about the same networks?" - is with a simple "no, we are not". The networks captured by digital data and analyzed through the canon of graph mathematics do not resemble to the actor-network in at least *four* respects.

1. Partiality and bias of digital inscriptions

The first concerns the relational data that, as we said, catalyzed the fusion between actor-network theory and network analysis. It is obvious, but deserves to be reminded: digital traces (like any other type of inscription) are not always representative of the phenomena that we propose to study through them.

There are two main reasons for this: First, not all relevant collective actions are mediated by digital infrastructures: despite the growing extent to which digital mediation has infiltrated social life, there are still important interactions that fall beyond them. For instance, despite the advances in digitalization, the production of science and technology still relies on face-to-face interaction and direct manipulation. All the online journals and libraries will not replace the discussions in the corridors of conferences and all the computer simulations are no substitute for *in-vivo* measure and *in-vitro* experiments.

Second, digital technologies (as all communication media) do not just trace, but also translate the interactions that they support. Digital media are not the carbon-paper that trace our writing, they are the paper that replace the parchment, thereby substantially affecting the nature of the books we write and read (Eisenstein, 1979). This is not an abstract argument: working with digital traces entails a constant questioning of the findings obtained: what do I see when I examine the evolution of a hashtag? Public opinion, or Twitter (Marres & Gerlitz, forthcoming)? Digital inscriptions are not created

by or for the social sciences; they are the product of vast sociotechnical systems comprising online platforms, commercial startups, communication protocols, fiber cables, etc., and bring with them the influence of such system. This is not to say, to be sure, that digital traces are more biased than other types of inscriptions, but that the conditions of their production is always to be remembered (Venturini *et al.* 2014).

This first hitch concerns the catalyst (digital relation traces) that made possible the reaction between ANT and SNA, but other difficulties emerge when actor-networks and mathematical networks are closely compared. We will describe them in the next paragraphs by making reference to *conventional* graph mathematics. By *conventional*, we refer to the methods and tools that are implemented in network analysis tools and thus made easily available to social research. Though extensions have been proposed to overcome many of the limitations of graph theory (cfr., for instance, Everett & Borgatti, 2014 on negative connections and Chavalarias and Cointet, 2013 on dynamic clustering), their experimental character and mathematical subtlety have prevented them (so far at least) from entering the toolkit of social research.

2. Heterogeneity of nodes and edges

The first difference between graph mathematics and actor-networks was pointed out by Michel Callon (1985) in the very paper in which he introduced the notion of the actor-network:

> [an actor-network] is distinguished from a simple network because its elements are both heterogeneous and are mutually defined in the course of their association (p. 32).

One of the ideas that aroused most interest (but also most rejection) around ANT is its extremely broad definition of what a social actor is. According to ANT, collective action involves not only individuals (e.g. scientists and engineers), but also collective assemblages (e.g. laboratories and academic institutions), non-human actors (e.g. natural substances and technical devices) and even conceptual items (e.g. scientific theories and legal frameworks). At a first glance, this openness match well with the agnosticism of graphs, whose elements have been used to represent almost anything (from websites to neurons, from proteins to words). Yet while actor-networks allow and even prescribe the presence of items of different nature in the same network, graphs' nodes tend to be of the same type.

In network analysis, the heterogeneity of graphs is coupled with a surprising homogeneity within graphs. The reason is simple: graph mathematics is hardly capable of handling qualitative differences. The items in a graph can be quantitatively different (as they may carry different 'weights'), but they are all mathematically equivalent. It is possible, in other words, to build networks with nodes of different type (see for instance Cambrosio *et al.* 2004), but belonging to one type of the other will not affect what nodes can or cannot do.

This limitation is stronger felt for edges than for nodes. Conventional graph mathematics allows some nodes differentiation: for instance bi-partite graphs (Guillaume & Latapy,

2006) are composed of two types of nodes (and nodes of the same type cannot be directly connected). When it comes to edges, however, the homogeneity is highly imposing. The limitation is sometimes referred to as the problem of 'parallel edges': the difficulty to compute networks in which nodes can be connected by more than one edge at a time). Imagine a network of Facebook accounts. As long as the edges are limited to one type of connection (say friendship-links), graph analysis can deliver most interesting results (cfr. Rieder, 2013). But as soon as we try to project different types of relations *on the same network*, we stumble on the problem of weighting: how many 'likes' should count as equivalent of a comment? How much weaker does a friendship get when it is 'unfollowed' (removed from the user's news-feed)? Is posting a text stronger or weaker than posting an image? And, of course, putting together traces coming from different media compounds the problem.

Negative relations are especially complicated. Collective life is made of opposition as much as of alliances (and actors are defined by their enemies as much as by their friends), but conventional graph mathematics offers no convincing way to handle 'negatively charged' edges. In network analysis, therefore, opposition is generally operationalized as a lack of association (see the concept of 'structural hole' by Burt, 2005). In citation analysis, for instance, it is commonly accepted that 'there is no such thing as negative publicity'. Garfield, one of the fathers of scientometrics, makes it very clear: "If scientists tend to ignore inferior work that is of little importance, then the work that they do go to the trouble of formally criticizing must be of some substance. Why, then, should negative citations be considered a sign of discredit?" (1979, pp. 361, 362)

This workaround has been successfully used to exploit network analysis for controversy mapping (Venturini, 2010 and 2012) and produced interesting results when applied to digital data (see for instance Adamic & Glance, 2005). It often happens, however, that digital traces provide us information directly about opposition. For instance, studying controversies in Wikipedia, we can easily access 'reverts' and other antagonistic edits, but to exploit them to detect 'edit-factions' we need to turn the network around, according to the principle of 'my enemy's enemy is my friend' (Borra *et al*, 2014).

3. Reversibility of Actor-Network

The second glitch in the network-conflation has to do with the hyphen connecting actor and network in ANT. This little typographical character has a capital importance in actor-network theory and one that is often misunderstood. The wrong way to read the hyphen is as a pointer to the interactions between the social actors (that would constitute the atomic entities of collective life) and the system of relations that would connect them: "the idea was never to occupy a position into the agency/structure debate, not even to overcome this contradiction. Contradictions should not be overcome, but ignored or bypassed" (Latour, 1999, p. 15). Rather the hyphen stands for an equal: actor=network (*actores sive reticula*, if you prefer):

> To try to follow an actor-network is a bit like defining a wave-corpuscle in the 1930s: any entity
> can be seized either as an actor (a corpuscle) or as a network (a wave). It is in this complete

> reversibility—an actor is nothing but a network, except that a network is nothing but
> actors—that resides the main originality of this theory (Latour, 2010, p. 5).

The hyphen is not meant to connect the two halves of the expression (actor *and* network), it is meant to deny *both* (*neither* actor *nor* network). Paradoxical as it may sound, in the world of actor-network there are no actors (entities defined by properties independent from the relations connects them) and no networks (structures defined by patterns independent from the elements that they connect).

This reversibility is absent from graph mathematics, where nodes and networks are described by different properties and measured by different metrics. It is even commonly accepted that SNA techniques can be separated in two analytic toolkits: one to study the ego-networks (centered on a single node and its neighbors, see for instance White, 2000) and another to study global networks. Though such a distinction is more apparent than real (the two toolkits are based on the same graph mathematics), there is indeed a substantial difference in the way SNA conceives nodes (indivisible and impenetrable items) and networks (global and composite structures). And this difference allignse closely with the classic divides of social theory (micro/macro, interactions/structures, individuals/institutions, local/global etc. (cfr. Giddens, 1984 and Archer, 1995) that ANT has always rejected (Callon & Latour, 1981).

However, when looking at the actual techniques of network analysis, the separation between nodes and networks appears less significant. All the key properties of nodes (authority, centrality, betweens···) depend on the overall topology of the network in which they are located and, conversely, all the key properties of networks (diameter, modularity, clustering···) depend on the local arrangements between nodes. In graph mathematics, nothing can be calculated about networks without considering each and every node and little can be calculated about nodes without considering the network it its entirety.

Interestingly, this is more visible in the digital implementations of social networks than in their academic analysis (Latour et al., 2012). Consider, for instance, how Facebook's interface breached earlier WWW conventions by developing a website without homepage and without individual pages. Of course, there is much more to Facebook than the accounts of its users: among others, its employees, its stockholders and stakeholders, its advertisers, its servers, its cables···). Yet, none of this is visible in the online platform, which is made exclusively of its members' walls. And Facebook is no exception. All the homepages of the main Web2.0 platforms (Twitter, Flickr, Tumblr, Pinterest···) are remarkably empty and systematically deserted by their users (how many times have you visited the homepage of Wikipedia?). But what is most striking about Facebook's interface is that even the individual pages do not contain exclusive contents and do not have a fixed form. Yes, users can chose their name, edit their description upload a cover photo, but what really makes a Facebook profile is the 'wall' in which the user's posts are mixed with (often drown in) the contents published by their 'friends'. Facebook users are not the authors but merely the *curators* of their pages. The largest online social network, is not a global structure lodging an ensemble of indivisible and impenetrable atoms (actors *and* network). It is a constant flux of re-combinable contents relentlessly

clotting and dissolving (actor=network) (cfr. a similar analysis of Flick by Boullier & Crépel, 2012).

4. Dynamics of relational change

The last and possibly the most serious divergence between actor-network theory and network analysis concerns time. ANT is essentially a theory of change. Its focus is not the structure of associations, but on their dynamics. "Reality", writes Michel Callon in his seminal paper on the sociology of translations, "is a proces. Like a chemical body it passes through succesive states" (Callon 1986, p. 207). The difficulty to account for time in the graphical thinking associated with networks is not only a problem for actor-network theory. According to Mustafa Emirbayer (1997), time remain one of the main obstacles in the operationalizing relational sociology:

> Paradoxically (for a mode of study so intently focused upon processuality), relational sociology has the greatest difficulty in analyzing, not the structural features of static networks, whether these be cultural, social structural, or social psychological, but rather, the dynamic processes that transform those matrices of transactions in some fashion. Even studies of "processes-in-relations," in other words, too often privilege spatiality (or topological location) over temporality and narrative unfolding (p. 305).

The difficulty of graphs to render dynamics is probably the reasons why none of the diagrams appearing in the founding texts of actor-network theory are networks (see for instance Callon, 1986; Latour et al., 1992; Law & Callon, 1992). Most of the diagram employed in ANT papers contain a temporal dimension that would be difficult to render with conventional graph representation.

To be sure, it is not that graph mathematics is not interesting in dynamics. On the contrary, movement has always been one of the major preoccupations of network analysts. After all Euler (1736) invented graph mathematics precisely to solve the problem of how to move through the neighborhoodss of Konigsberg and the core application of network theory remains the management of flows (the routing of train first and of communication soon after). Yet, movement in graph theory is usually movement *through* networks and not movement *of* networks. Rooted deep in graph mathematics is the separation between what flows (ideas, goods, signals···) and what stays (the structure of connections that allows the flowing).

This separation is highly problematical for actor-network theory, which has always radically denied the existence of a 'context' in which action will take place. In ANT (which, if worth to remember, is a sociology of translation, not of transport – Callon, 1986), networks are *not* conceptualize as a system of routes through which actors drive their way. Quite the opposite: they are the maze of trails left by children running through the uncut grass. It is the run who makes the train, not the other way around. Actions is not what flows through networks, actions is what makes networks and actors altogether:.

This is yet another reason why actor-network theorists have always been uncomfortable with the graph topography and why, for instance, John Law and Annemarie Mol (Mol &

Law, 1994, Law and Mol, 2001) propose to replace networks with "fluid spaces" and "fire spaces", respectively caracterized by the constant transformation and the constant overflowing of boundaries.

Being sensitive to the difference in the density of association

So is this it? Should we declare the case closed, divorce network analysis from actor-network theory and renounce exploiting the traceability of digital networks? We think not. We believe that there is a more positive (though admittedly riskier) answer to the question posed in the title of this paper. To formulate it, one must gauge the potential equivalence among the three notions of 'network' in a less literal way. No, graphs do not resemble to actor-networks. Precisely as the pipe painted by Magritte does not resemble its referent (Foucault, 1983), the relations tying the Bush and bin Laden designed by Mark Lombardi or the Facebook connections designed by Paul Butler do not resemble the phenomena that they portray (see fig. 1).
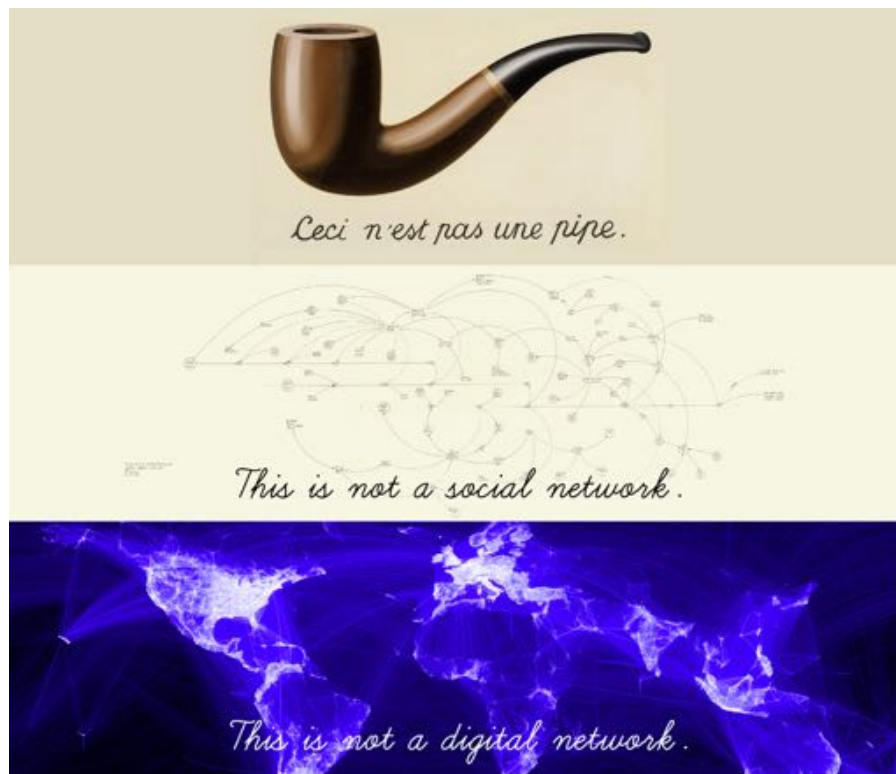

Figure 1. a. René Magritte, 1928, "La Trahison des images". b. Marc Lombardi, 1999, "George W. Bush, Harken Energy and Jackson Stephens, ca 1979–90"). c. Paul Butler, 2010 "Visualizing Friendship" (captions in b. and c. have been added by us).

Social networks are not made of lines on canvas; digital networks are not made of pixels and neither one nor the other are made of data. Collective actor-networks are made of flesh and fabric, of words and memories, of contracts and laws, of money and transactions and, increasingly, of cables and protocols. It is not surprising that graphs do not resemble them (and, by the way, have you ever seen a mathematical representation that resembles its object?). And yet, this does not mean that graphs cannot help us

understand collective topologies. If there is something that STS observed over and over, it is that scientific representations do not have to resemble to their referent to be useful. On the contrary: in order for them to travel they must sucessfully achieve the translations between referent and inscription.

Abandoning the benchmark of resemblance is important because it allows us to put aside (without forgetting or forgiving them, of course) the differences between graphs and actor-networks (we discussed heterogeneity, reversibility and dynamics, but other could be mentioned) and consider their similarities. To ask what analogy grounds network homonymy.

A first similarity is indirect and is to be found in their enemies. A first reason for SNA and ANT to be good friends is that they both fight the same assumptions of classic sociology. Their 'Ns' may not be synonyms, but their antonym is the same:

> Both of these approaches reject a priori reifications such as 'the social' or 'society'; instead, these notions are constructions out of social enmeshing and become only observable ex-post. Both resist reference to the representational or the symbolic; instead, they focus their empirical analyses on material reality and the meanings actors themselves ascribe to it in struggles and controversies. Both of these approaches consider the production of meaning as an activity of connecting/disconnecting and analyse how actors come to be created through collaborations of other actors in different contexts. The stories actors tell make the links between them explicit. For both approaches, the ties precede the nodes. (Mutzel, 2009, p. 878).

Actor-network theory and network analysis are both inspired by the same relational thinking (Emirbayer, 1997), whose first tenet is the refusal of any form of substantialism (Robinson, 2014). Both for ANT and SNA, associations (and dissociations) are the only things that matter. The nodes to which they are attached and the networks that contain them have little importance: their essence is defined by their connections – take the connections away and they will vanish in thin air.

John Law (1999, but see also Blok, 2010) describe this opposition by contrasting 'topographical' and 'topological' approaches and suggest to "imagine actor-network theory as a machine for waging war on Euclideanism: as a way of showing, inter alia, that regions are constituted by networks" (p. 7).

But there is more. The affinity between graphs and actor-networks is not only *negative* and it is not only *generic*. It is not just that SNA techniques captures some of ANT ideas, it is that specific graphs may reminds specific actor-networks – they do not resemble each other and yet they bear a distinct correspondence. To understand the difference between *resemblance* and *resonance*, consider geographical maps. Maps do not look like the territories that they represent. Yet they reproduce the same *pattern of differences* that exist in the corresponding territory:

> What is it in the territory that gets onto the map?" We know the territory does not get onto the map. That is the central point about which we here are all agreed. Now, if the territory were uniform, nothing would get onto the map except its boundaries, which are the points at which it ceases to be uniform against some large matrix. What gets onto the map, in fact, is difference, be it a difference in altitude, a difference in vegetation, a difference in population structure,

difference in surface, or whatever. Differences are the things that get onto a map (Bateson, 1972, p. 457)

The same the *un-resembling resonance* is what defines the relationshio graphs and actor-networks:

> A diagram of a network, then, does not look like a network but maintain the same qualities of relations – proximities, degrees of separation, and so forth – that a network also requires in order to form. Resemblance should here be considered a resonating rather than a hierarchy (a form) that arranges signifiers and signified within a sign. (Munster, 2013, 24)

But how, exactly, do graphs resonate with actor-networks? The easiest way to understand why networks do not resemble collective phenomena *and yet can represent them* is to consider the most literal expression of such representation: the drawing of social networks. Of all the techniques associated with graph analysis, the ones developed to *visualize* networks are those that most closely resonate with actor-network theory and in general with relational sociology. It is not a chance that, while graphs had been around for more than two centuries (Euler, 1736), it is only when sociologists seized them that visualization joined computation as an analytical tool.

It started with Jacob Moreno's (1934) analysis of the relations New York Training School for Girls. To explain why 14 pupils fled the school in less than two weeks, The Austrian-American social psychologists collected data on attraction and repulsions among the 500 girls in the school and, most importantly, visualized them in a diagram (or "sociogram" as Moreno called it):

> In Greek mythology Eros is the god of love and Eris is the god of discord. Less well known is the interesting brother of Eros, Anteros, the god of mutual love. That is how the Greeks accounted for the forces of attraction and repulsion among men. It is most beautiful Greek poetry that when love begins an arrow flies to the chosen. The symbol of the arrow has its counterpart in our symbol for attraction, the red line. The Greeks held that all the red lines are projected by Eros, all the blank lines by Eris, and all the mutual red one by Anteros, and that men had nothing to say about them. Instead of searching with a torch into the labyrinth of love and hatred, they had a mythical formula. We have tried to analyze this network. The forms taken by the interrelation of individuals is a structure and the complete pattern of these structures within a group is its organization. The expression of an individual position can be better visualized through a sociogram than through a sociometric equation (Moreno, 1934, p. 103).

The beautiful image of Eros's arrows turning into the red lines of the sociogram remind us of the importance that the father of SNA attributed to visualization. Visual metaphors are recurring in Moreno's writings, which seemed less interested in making social networks quantifiable than in making them *observable*. For example, interviewed by The NY Times, Moreno affirms:

> If we ever get to the point of *charting* a whole city or a whole nation, we would have an intricate maze of psychological reactions which would *present* a *picture* of a vast solar system of intangible structures powerfully influencing conduct, as gravitation does bodies in space. Such an *invisible* structure underlies society and has in influence in determining the conduct of society as a whole⋯ Untill we have at least determined the nature of these fundamental structures which form the networks, we are working *blindly* in a hit-or-miss effort to solve problems which are caused by group attraction, repulsion and indifference (The New York Times, 1933, emphasis added)

12

Interestingly this interview was titled "Emotions Mapped by New Geography", suggesting that geographical mapping (more than mathematical computation) might have been Moreno's main inspiration.

Much of the emphasis on visualization has been lost in the following works in social network analysis. The amazing developments of graph mathematics (pushed by the expansion of digital networks) seemed to have absorbed most of the attention of later social network analysts. As an indicator, a search in the *Social Networks* for articles containing "visual*" in their titles returns only 11 results over the 35 years of life of the journal.

But the interest for network visualization did not die out and recently surfaced again both in academic and popular culture. Thanks to the growing availability of personal-computer tools for network analysis (Pajek, NetDraw, Ucinet, Guess, Gephi, just to quote a few ones) *and* to the inclusion of visualization modules in such software, graphs have returned to being graphical. Recently, images of networks have started sprouting everywhere. They decorate buildings and objects; they are printed on t-shirts and posters; they colonize the desktop of our computers and the walls of our airports. Networks have become the emblem of modernity, the very form of its imagination. In part, of course, this is linked to the success of digital networks, but there is something else. Something connected to the *figurative power* of network visualization.

This *something*, we believe, is directly connected to the way networks are designed and in particular to the way nodes are positioned in space. Although several techniques for 'network spatialization' exist, a family of algorithms has progressively emerged as a standard for graph visualization: the so-called 'force-directed spatialization' (or 'force-vectors'). A force-vector layout works following a physical analogy: nodes are given a repulsive force that drives them apart, while edges work as springs binding the nodes that they connect. Once the algorithm is launched, it changes the disposition of nodes until reaching the equilibrium that guarantees the best balance of forces. Such equilibrium minimizes the number of lines crossings and thereby maximizes the legibility of the graph (according to a principle already enunciated by Moreno himself: "the fewer the number of lines crossing, the better the sociogram" 1953, p. 141).

There is, however, a most interesting by-product of such a visualization technique: not only do force-vectors minimize lines crossings, but they also give sense to the disposition of nodes in space. Before spatialization, the geometric distance between two nodes has strictly speaking no meaning. From a mathematical viewpoint, the only distance in a graph is the number of edges that have to be 'walked' to go from a node to another. In a force-spatialized network, however, spatial distance becomes meaningful: two nodes are the closer the more they are directly or indirectly connected (Jacomy et al, 2014). Force-spatialization delivers an amazing result – it re-materializes the notions of graph mathematics. Adreas Noak (2009) proved, for instance, that visual clustering in force-spatialized networks is directly equivalent to clustering by modularity algorithms. 'Centrality', 'betweeness', 'diameter' 'density', 'structural separation', all these concepts (and many others) recover their graphical meaning (Venturini, Jacomy & De Carvalho

Pereira, 2014). Not only can they be calculated, but also *seen*. This is where the figurative power of networks, their *un-resembling resonance*, comes from. This is also where the deepest bond between SNA and ANT is to be found.

Looking at a force-spatialized network provides a visual experience of *both* the metrics of network analysis *and* the notions of actor-network theory – thus revealing their *elective affinity*. Consider, for example, the notion of 'boundary'. Such notion has long been a puzzle for SNA and a source of criticism for ANT. In the practice of SNA, analysts have often found it difficult carve their network out of the proliferation of social relations (Laumann *et al.*, 1989).

> Networks are interesting but difficult to study because since real-world network lack convenient natural boundaries. When a network as a whole is impracticably large, the usual procedure is to arbitrarily delimit a subgraph and treat it as a representative sample of the whole network. Unfortunately, this procedure is hazardous not only qualitatively⋯ but quantitatively as well (Barnes, 1979 p. 416).

On the other hand, ANT has been often accused of dissolving all the classic distinctions of social theory (micro/macro, science/politics, science/technology, nature/culture, just to quote a few), without replacing them with any clear analytic framework. Though this accusation is not unmerited, the dislike for distinctions and frameworks does not make ANT a night where all cows are black. If it is true that following the actors (according to the ANT slogan) and their relations (according to the snowballing technique of SNA) researchers rarely encounter clear-cut boundaries, it also true that they do experience *variations in the density of association*.

In the 'small word' (Milgram, 1967; Watts & Strogatz, 1998) of our collective existence, everything is connected (by surprisingly few degrees of separation) and boundaries cannot be defined by the absence of connections. And yet, the density of association is not homogeneous in the social fabric. This *in*homogeneity is manifest when we observing force-spatialized networks: nodes and edges do not dispose orderly – some of them flock together, while others repulse each other. The visual space of graphs as the conceptual space of actor-network *is continuous but not uniform* (Venturini *et al.*, forthcoming). Exactly as in the Ikebana (the Japanese art of flowers arrangement), the beauty of network comes from the relative void that separates the clusters (the structural holes, as Burt calls them 1995). More crucially, 'empty' and 'full' in networks and actor-networks are never absolute, never positive, never emergent. Boundaries are always relative, relational and constructed by some form of boundary work (Gieryn, 1983).

So yes, in the end we might be talking about the same networks. Or, to be more precise, there may be important similarities that makes the use of graph convenient for the study of actor-network, *despite* the many differences that separate them. These differences should not be forget, but they should not block us either. After all this is not only true for graphs. No scientific representation of a social phenomenon looks exactly as the phenomenon itself - what good would they be if they returned a perfect copy of their

objet? There is no reason to turn our backs on networks just because they don't ressemble collective phenomena (in any case, neither did our texts or any other form we used to inscribe these phenomena). As long as we are aware of the risks of the network-conflation we can keep exploiting its power. Provided, though, that we acknowledge that we are not actually talking about the nodes or structures, the actors or the networks, the groups or the clusters, the edges or the associations. What we are talking about it the continuous but inhomogeneous fabric of social existence:

> Cooked rice (whose absolutely special identity is attested by a special name, which is not that of raw rice) can be defined only by a contradiction of substance; it is at once cohesive and detachable; its substantial destination is the fragment, the clump; the volatile conglomerate⋯ it constitutes in the picture a compact whiteness, granular (contrary to that of our bread) and yet friable: what comes to the table to the table, dense and stuck together, comes undone at a touch of the chopsticks, though without ever scattering, as if division occurred only to produce still another irreducible cohesion (Barthes, 1982, pp. 12-14).

References

Adamic, L. A., & Glance, N. (2005). The political blogosphere and the 2004 US election: divided they blog. In *Proceedings of the 3rd international workshop on Link discovery* (pp. 36–43). New York, New York, USA: ACM. doi:10.1145/1134271.1134277

Archer, M. S. (1995). *Realist Social Theory: The Morphogenetic Approach*. Cambridge: Cambridge University Press. Retrieved from http://www.amazon.com/Realist-Social-Theory-Morphogenetic-Approach/dp/0521484421

Barabási, A.-L. (2002). *Linked: The New Science of Networks. How Everything is Connected to Everything Else and What It Means for Business, Science, and Everyday Life* (p. 294). Cambridge Mass.: Perseus Books.

Barnes, J. A. (1979). Network analysis: orienting notion, rigorous technique, or substantive field of study. In W. P. Holland & S. Leinhardt (Eds.), *Perspectives on social network research* (pp. 403–423). New York: Academic Press.

Barney, D. (2004). *The Network Society*. Cambrdige: Polity Press.

Barthes, R. (1982). *The Empire of Signs*. New York: Hill and Wang (translation from the French 1970, *L'Empire des signes*).

Bateson, G. (1972). Form, Substance, and Difference. In *Steps to an Ecology of Mind* (pp. 454–471). doi:10.1007/978-1-4020-9650-1

Borra, E., Weltevrede, E., Ciuccarelli, P., Kaltenbrunner, A., Laniado, D., Magni, G., … Venturini, T. (2014). Contropedia - the analysis and visualization of controversies in Wikipedia articles. In *OpenSym 2014 Proceedings*.

Boullier, D., & Crépel, M. (2012). Biographie d'une photo numérique et pouvoir des tags : classer/circuler. *Anthropologie Des Connaissances*.

Blok, A. (2010). Topologies of climate change: Actor-network theory, relational-scalar analytics, and carbon-market overflows. *Environment and Planning D: Society and Space*, *28*(1), 896–912. doi:10.1068/d0309

Burt, R. S. (1980). Models of Network Structure. *Annual Review of Sociology*, *6*(1980), 79–141. doi:10.1146/annurev.so.06.080180.000455

Burt, R. S. (1995). *Structural Holes: The Social Structure of Competition* (p. 313). Cambridge Mass: Harvard University Press.

Callon, M. (1986a). The Sociology of an Actor-Network: The Case of the Electric Vehicle. In M. Callon, J. Law, & A. Rip (Eds.), *Mapping the dynamics of science and technology* (pp. 19–34). London: Macmillan.

Callon, M. (1986b). Some elements of a sociology of translation: domestication of the scallops and the fishermen of St Brieuc Bay. In J. Law (Ed.), *Power, action and belief: a new sociology of knowledge?* (pp. 196–223). London: Routledge.

Callon, M., & Latour, B. (1981). Unscrewing the Big Leviathans How Do Actors Macrostructure Reality. In K. Knorr-Cetina & A. Cicourel (Eds.), *Advances in Social Theory and Methodology. Toward an Integration of Micro and Macro Sociologies* (pp. 277–303). London: Routledge.

Cambrosio, A., Keating, P., & Mogoutov, A. (2004). Mapping Collaborative Work and Innovation in Biomedicine: a Computer Assisted Analysis of Antibody Reagent Workshops. *Social Studies of Science*.

Castells, M. (2000). *The Rise of the Network Society*. Oxford: Blackwell.

Chavalarias, D., & Cointet, J. P. (2013). Phylomemetic Patterns in Science Evolution-The Rise and Fall of Scientific Fields. *PLoS ONE*, *8*(2). doi:10.1371/journal.pone.0054847

Eisenstein, E. (1979). *The Printing Press as an Agent of Change*. Cambridge: Cambridge University Press.

Emirbayer, M. (1997). Manifesto for a Relational Sociology. *American Journal of Sociology*, *103*(2), 281–317. doi:10.1086/231209

Euler, L. (1736). Solutio problematis ad geometriam situs pertinentis. *Commentarii Academiae Scientiarum Petropolitanae*, (8), 128–140.

Everett, M. G., & Borgatti, S. P. (2014). Networks containing negative ties. *Social Networks*, *38*, 111–120. doi:10.1016/j.socnet.2014.03.005

Foucault, M. (1983). *This is not a pipe*. Berkeley and Los Angeles: University Of California Press.

Giddens, A. (1984). *Constitution of society: Outline of the theory of structuration*. Berkeley: University of California Press.

Gieryn, T. F. (1983). Boundary-Work and the Demarcation of Science from Non-Science: Strains and Interests in Professional Ideologies of Scientists. *American Sociological Review*, *48*(6), 781. doi:10.2307/2095325

Granovetter, M. (1979). The Theory-Gap in Social Network Analysis. In P. Holland & S. Leinhardt (Eds.), *Perspectives on Social Research* (pp. 501–518). New York: Academic Press.

Guillaume, J., & Latapy, M. (2006). Bipartite graphs as models of complex networks. *Physica A: Statistical and Theoretical Physics*, *371*(2), 795–813. doi:10.1016/j.physa.2006.04.047

Jacomy, M., Venturini, T., Heymann, S., & Bastian, M. (2014). ForceAtlas2, a Continuous Graph Layout Algorithm for Handy Network Visualization Designed for the Gephi Software. *PloS One*, *9*(6), e98679. doi:10.1371/journal.pone.0098679

Knorr-Cetina, K. (1995). Laboratory Studies, the Cultural Approach to the Study of Science. *Handbook of Science and Technology Studies*. London: Sage.

Latour, B. (1998). Thought experiments in social science: from the social contract to virtual society. In *1st Virtual Society? Annual Public Lecture*. Brunel University, London, 1 April.

Latour, B. (1999). On Recalling ANT. In J. Law & J. Hassard (Eds.), *Actor Network and After* (pp. 15–25). Oxford: Blackwell.

Latour, B., Mauguin, P., & Teil, G. (1992). A Note on Socio-technical Graphs. *Social Studies of Science*.

Latour, B. (2010). *Networks, Societies, Spheres: Reflections of an Actor-Network Theorist. In International Seminar On Network Theory: Network Multidimensionality In The Digital Age*. Annenberg School for Communication and Journalism, Los Angeles, United States.

Latour, B., Jensen, P., Venturini, T., Grauwin, S., & Boullier, D. (2012). "The whole is always smaller than its parts": a digital test of Gabriel Tardes' monads. *The British Journal of Sociology*, 63(4), 590–615. doi:10.1111/j.1468-4446.2012.01428.x

Laumann, E. O., Marsden, P. V, & Prensky, D. (1989). The boundary specification problem in network analysis. In L. C. Freeman, D. R. White, & A. K. Romney (Eds.), *Research methods in social network analysis* (pp. 61–79). Fairfax: George Mason University Press.

Law, J. (1999). After ANT : Complexity , Naming and Topology. In J. Law & J. Hassard (Eds.), *Actor Network and After* (pp. 1–14).

Law, J., & Callon, M. (1992). The Life and Death of an Aircraft: A Network Analysis of Technical Change. In W. Bijker & J. Law (Eds.), *Shaping Technology / Building Society: Studies in Sociotechnical Change* (pp. 21–52). MIT Press.

Law, J., & Mol, A. (2001). Situating technoscience: An inquiry into spatialities. *Environment and Planning D: Society and Space*, *19*, 609–621. doi:10.1068/d243t

Leydesdorff, L. (1998). Theories of citation? *Scientometrics*, *43*(1), 5–25. doi:10.1007/BF02458394

Leydesdorff, L., & Wouters, P. (1999). Between texts and contexts: Advances in theories of citation? (A rejoinder). *Scientometrics*. doi:10.1007/BF02457378

Marres, N. (2012a). The redistribution of methods: on intervention in digital social research, broadly conceived. *The Sociological Review*, *60*, 139–165. doi:10.1111/j.1467-954X.2012.02121.x

Marres, N. (2012b). On some uses and abuses of topology in the social analysis of technology. *Theory, Culture and Society*, *29*(4-5), 288–310.

Marres, N., & Gerlitz, C. (forthcoming). Interface Methods: On Some Confluence Between Sociology, STS and Digital Research. *Information Communication & Society*.

Marres, N., & Rogers, R. (2005). Recipe for Tracing the Fate of Issues and their Publics on the Web. In L. Bruno & P. Weibel (Eds.), *Making things public:* (pp. 922–935). Karlsruhe/Cambridge Mass: ZKM/MIT Press.

Milgram, S. (1967). The small world problem. *Psychology Today*, *2*(1), 60–67.

Mol, A, & Law, J. (1994). Regions, networks and fluids: Anaemia and social topology. *Social Studies of Science*, *24*(4), 641–671. doi:10.1177/030631279402400402

Moreno, J. (1934). *Who Shall Survive? (fist edition)* Washington, DC: Nervous and Mental Disease Publishing.

Moreno, J. (1953). *Who shall survive? Foundations of sociometry, group psychotherapy and sociodrama (second and expanded edition)* Beacon, N.Y.: Beacon House Inc.

Munster, A. (2013). *An Aesthesia of Networks: Conjunctive Experience in Art and Technology*. Cambridge Mass.: MIT Press. Retrieved from http://www.amazon.com/Aesthesia-Networks-Conjunctive-Technologies-Abstraction/dp/0262018950

Mutzel, S. (2009). Networks as Culturally Constituted Processes: A Comparison of Relational Sociology and Actor-network Theory. *Current Sociology*, *57*(November 2009), 871–887. doi:10.1177/0011392109342223

Noack, A. (2009). Modularity clustering is force-directed layout. *Physical Review E*, *79*(2). doi:10.1103/PhysRevE.79.026102

Page, L., Brin, S., Rajeev, M., & Terry, W. (1998). *The PageRank Citation Ranking: Bringing Order to the Web*. Standford University, technical report.

Rieder, B. (2013). Studying Facebook via Data Extraction: The Netvizz Application. *Proceedings of WebSci '13, the 5th Annual ACM Web Science Conference*, 346–355. doi:10.1145/2464464.2464475

Robinson, H. (2014). Substance. In E. N. Zalta (Ed.), *The Stanford Encyclopedia of Philosophy* (Spring 201.).

Rogers, R. (2000). *Preferred Placement: Knowledge Politics on the Web*. Maastricht: Jan Van Eyck Edition.

Rogers, R. (2004). *Information Politics on the Web*. Cambridge, Mass: MIT Press.

Rogers, R. (2013). *Digital Methods*. Cambridge Mass.: MIT Press.

Rogers, R., & Marres, N. (2000). Landscaping Climate Change: a mapping technique for understanding science and technology debates on the World Wide Web. *Public Understanding of Science*, *9*, 141–163. doi:10.1088/0963-6625/9/2/304

Rogers, R., & Marres, N. (2002). French scandals on the Web, and on the streets: A small experiment in stretching the limits of reported reality. *Asian Journal of Social Science*, *66*, 339–353.

Roth, C., & Cointet, J. (2010). Social and Semantic Coevolution in Knowledge Networks Epistemic networks. *Social Networks*, *32*(1), 16–29.

The New York Times. (1933). Emotions Mapped by New Geography. *The New York Times*, *3 April*.

Van Dijck, J. (2012). *The Network Society*. London: Sage.

Venturini, T. (2010). Diving in magma: how to explore controversies with actor-network theory. *Public Understanding of Science*, *19*(3), 258–273. doi:10.1177/0963662509102694

Venturini, T. (2012). Building on faults: how to represent controversies with digital methods. *Public Understanding of Science*, *21*(7), 796 – 812. doi:10.1177/0963662510387558

Venturini, T., & Guido, D. (2012). Once Upon a Text : an ANT Tale in Text Analysis. *Sociologica*, *3*. doi:10.2383/72700

Venturini, T., Baya Laffite, N., Cointet, J.-P., Gray, I., Zabban, V., & De Pryck, K. (2014). Three maps and three misunderstandings: A digital mapping of climate diplomacy. *Big Data & Society*, *1*(2). doi:10.1177/2053951714543804

Venturini T. et al. (forthcoming). An Unexpected Journey (how the médialab searched digital traces and found social continuity). In *Die Gesellschaft der Daten*. Berlin: Transcript.

Venturini, T., Jacomy, M, De Carvalho Pereira, D. (2014). Visual Network Analysis

(working paper), available at www.tommasoventurini.it

Watts, D. J., & Strogatz, S. H. (1998). Collective dynamics of "small-world"networks. *Nature*, *393*(6684), 440–442.

White, H. (2000). Toward ego-centered citation analysis. In B. Cronin & H. B. Atkins (Eds.), *The Web of Knowledge* (pp. 475–496). Medford: Information Today.

Woolgar, S. (Ed.). (2002). *Virtual Society?: Technology, Cyberbole, Reality*. Oxford: Oxford University Press.