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NETWORK BUZZ:

Conception and geometry of networks in geography, architecture and sociology

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Abstract

The idea of networks has in the recent decade rapidly risen to a top position in a long series of disciplines. Given that network is a key concept in space syntax theory and methodology, this paper investigates the origins and later development of network analysis in the adjacent fields of sociology and geography, not least since networks often are seen as a language that can connect and translate between systems and phenomena addressed in different disciplines. The overarching aim in the paper is to contribute to a more precise understanding of what network concept actually is in use in space syntax and, in extension, what this particular version has to offer the larger and more established disciplines of sociology and geography.

In sociology we find an initial discourse on networks already in Georg Simmel that to a certain degree challenged the conception of sociology strongly promoted by the more powerful Émile Durkheim, but was later lost. The concept of networks, however, remerged, not least in the work of John Scott that made direct references to the emergence of network analysis in geography. In geography we find networks to be an intrinsic part of the quantitative revolution in the 1950s and 60s, heralded by Peter Haggett and others, where networks were promoted as an alternative to the regional approach in geography. This opens for an exciting vista of geometric foundations of geography, with pertinent repercussions also for architecture.

However, this is clearly to move between distinctly different conceptions of networks; between what we can call social, physical, and cognitive networks. With this distinction in mind, there is a possibility to more precisely position networks as conceptualised in space syntax. Socially, networks in space syntax are representations of, what Durkheim referred to as, social morphology, which distinctly can never reach beyond the threshold of sociology but deals with "material substratum of society", which thereby offers a distinct identity and limit to the field of space syntax. Geographically, space syntax thus represents a peculiar form of network analysis demarcated by the physical fact of the city. Such ontology of 'regional networks' (cf. Jessop) is not unusual in geography, but fundamentally alien to the contemporary concept of networks found within sociology, emphasizing networks as an ontological alternative to such region-thinking (Latour, Scott). Finally, and possibly most originally, representations of networks in space syntax seem to develop a particular strand of advanced cognitive geometry that extends and complements the aims of behavioural and cognitive geography.

Keywords: *Networks, graph theory, regions, morphology, landscape*

Theme: *Spatial Analysis and Architectural Theory*

1. Introduction: spatial turns in the social sciences

Places are like ships, moving around and not necessarily staying in one location.
(Sheller and Urry 2006: 214.)

Places are not local things. They are moments in large-scale things, the large-scale things we call cties.
Places do not make cities. It is cities that make places. The distinction is vital.
We cannot make places without understanding cities.
(Hillier 1996: 151.)

In a certain sense, everything is everywhere at all times. For every location involves an aspect of itself in every other location. Thus every spatio-temporal standpoint mirrors the world.
(Whitehead 1926: 114.)

1.1 Introduction: critique of a static view of space

Recently, in the discipline of geography – generally considered *the* science of space – there has been a "mobility turn". "All the world seems to be on the move", Sheller and Urry (2006: 207) write and exemplify with asylum seekers, international students, terrorists, holiday makers, business people, prostitutes, commuters etcetera. "The scale of this travelling is immense" and as an effect they identify how a new paradigm is being formed in the social sciences: the "new mobilities" paradigm, including anthropology, sociology, cultural studies, geography, migration studies, science and technology studies, tourism and transport studies. This "mobility turn" is spreading into and transforming the social sciences, transcending the dichotomy between transport research and social research (ibid.: 208), thereby challenging the ways in which much urban social scientific analyses have been largely static, or "a-mobile" (ibid.: 207; 208).

The emergent mobilities paradigm undermines *sedentarist* theories present in many studies in geography, anthropology, and sociology. "Sedentarism treats as normal stability, meaning, and place, and treats as abnormal distance, change, and placelessness. Sedentarism is often derived loosely from Heidegger, for whom dwelling (or *wohnen*) means to reside or to stay, to dwell at peace, to be content or at home in a place. […] Such sedentarism locates bounded and authentic places or regions or nations as the fundamental basis of human identity and experience and as the basic units of social research" (Sheller and Urry 2006: 207f; see also Cresswell 2002, 12-15). Much of the representations of place and space in human geography – in the wake of the quantitative spatial science paradigm in the late 1960s – are characterized by sedentarism. As Yi-Fu Tuan wrote in 1977: "[Place] is essentially a static concept" (Tuan 1977: 179).

In sum, the mobility turn problematizes a static view on space and place. Space is not an unchangeable container within which objects are localized. Rather, space – or more correctly spacing (the act of making space) – is a dynamic process (MacCormack 2009: 279). The background is the larger "spatial turn" in the social sciences; an expansion of a constructivist approach to the world and our knowledge of it – an insight that frames knowledge as a social product (see Gregory 2000; Dixon et al., 2008: 2554). Space is no longer seen as something objective, unproblematic and eternal – an understanding that has given rise to a growing number of studies concerned with the discursive; that is, how we talk about and understand the world. Language and theories are important because they emphasize certain aspects of reality and hide others: they work as systems of preclusion that establishes historically and culturally contingent boundaries between the true and the false, normal and abnormal (Foucault 1993: 10f). The motivation behind these studies, it is often said, is a critique of power.

1.2 The critique is expressed in ordinary – not formal – language systems

This primacy of language and discourse is reflected in how the critique of spatial science and sedentarism – as a rule – is presented in *ordinary language systems* (basically: texts) rather than *formal language systems* (like geometry). The difference is that while the former is built on elements that have assigned meanings, the latter builds on elements that have unassigned meanings (in principle the points and lines and surfaces of geometry can refer to anything) (Gregory 2000: 768f).

This choice of representation is characteristic of the spatial turn as a whole, including the more recent mobility turn, and it typically takes the form of a rejection of more conventional geographical representation, such as maps, generally based in geometry. Geometrical representations are considered too abstract, too reductionist and too power-ridden to grasp man and his/her relation to space – a typical reference being Lefebvre's (1991) notion of *conceived space*. The conceived space of the scientist and/or planner is a power tool that subordinates the lived space of the ordinary man. Instead, new forms of representations are favoured (non-representational theory, various acts of performances, walking with the research subjects, borrowing from the humanities and including videos, sounds and other more artistic/poetic forms of representations etc.). A critical question addressed in this paper is to what degree this revaluation of the ways that scientists (ought to) represent space is political-ideological[1] rather than intellectual. Just as it is argued within the spatial turn, this is not only a technical question, but also a question with deep repercussion on how we conceptualise and communicate knowledge about space.

In the 1970s and 1980s humanistic geography – a subfield of human geography – struggled to overcome the deficiencies in spatial science, which by that time was becoming apparent and to instead understand places and environments "without accepting the analytical separation of subject from object" (Cosgrove 2000: 449). The phenomenological conception of the life-world became central in reconceptualising space, where life-world was taken to denote an "opposition to the more distant, analytical and manipulative approaches of spatial science and planning spatial organization or behaviour. Thus, from the person-centred perspective of the life-world, place is more important than space, and geographical investigation is required to honour the experiences, imagination and attachments of intentional human subjects." (Ibid..) At the same time, the new mobilities paradigm represents a critique against the tendency in humanistic geography to take this conceptualisation too far and essentialize human experience, identity and place, arguing instead "in favour of more fluid notions of selfhood and place identity" (Pile and Thrift 1995).

1.3 What about geometry?

Without necessarily arguing with this debate, we want to raise another question: Does either of these turns (the spatial and the new mobilities turn) by necessity imply a rejection of geometrical representation? Almost fifty years ago, as part of an argument for more scientific approaches in geography, Peter Haggett (1965: 15f) asserted that there is a "neglect of geometrical traditions in geography". We suggest this to again be the case.[2] Or more correctly;

1 For example, the critique against spatial science in the 1970s mainly came from Marxist and feminist geographers.

2 Or more correctly; there is a tradition of representing space geometrically (GIS, Mike Batty, Portugali) in geography, but there seems to be very little rapport between this more applied branch, on the one hand, and the more critical-cultural branch, on the other. As noted by Pacione (1999: 1) 'Applied geography is concerned with the application of geographical knowledge and skills to the resolution of real-world social, economic and

what we see is a divergence running straight through the social sciences concerning the conceptualization of space, where we, on the one hand, find a successful continuation and updating of the spatial science paradigm, dramatically augmented by GIS techniques, exemplified, for instance, in applied geography and spatial modelling, where geometry is essential to spatial representations, and, on the other hand, a rapidly expanding critical-cultural direction, where the explicit or implicit rejection of geometric representations of space to a certain degree is part of the program. While the more fundamental difference here concerns the nature of the questions asked in these directions, we raise the question whether the extraordinary lack of rapport between the two only is due to differences in research agendas or whether it is enhanced by the different *choices of representations* in the two camps, creating a situation where the two speak different languages.

The geometrical tradition was fundamental to the original Greek conception of geography, just as it was central in the attempt to turn geography into a spatial science. "Geometry"[3], Peter Haggett (1965: 15f) says, "not only offers a chance of welding aspects of human and physical geography into a new working partnership, but revives the central role of cartography in relation to the two". However, as a consequence of the critique of spatial science, the study of spatial patterns, the use of quantitative methods and the search for laws of spatial organization play a much smaller role within the discipline of human geography than was the case in the 1960s and early 1970s, "when they were presented as geography's entrée to, and niche within, the social sciences" (Johnston 2000: 466). Today, "the search for 'spatial order' as set out in Haggett's pioneering conspectus […] barely rates a mention in contemporary presentations of the discipline's contents" (ibid.: 467).[4]

Briefly put, the discipline of geography, in the 1970s, moved from "[a] place among the natural sciences" to "[a] place among the social sciences" (Gregory 1978). "[T]he nub of the argument" of the critique against spatial science and geometrical representation, is, as Gregory says (ibid.: 172), "that spatial structures are implicated in social structures and each has to be theorized with the other." Today, with countless publications on the spatial turn behind us, we can, however, raise the question whether the theorization of social structures have been prioritized at the expense of the theorization of spatial structures, or, put differently, to what degree the social construction of space has come to hide the spatial construction of society. How are spatial structures to be theorized together with social structures in a genuine sense, if its primary language (geometry) is abandoned in favour of the primary language of the social sciences (text).

The paper does not argue for a return of the separation of man and space, but attempts to acknowledge that man not only constructs and is constructed by the form of conceptual space best captured in texts, but also a creature who constructs and is constructed by physical space best captured by geometry. In other words, man is an experiencing subject, but s/he is a

environmental problems, yet the approach has been the subject of criticism from Marxist and […] postmodern theorists.'

[3] As Cole and King (1968: 70) say, one should talk about geometries in plural, since there are at least five different types of geometry: 1. Euclidean, 2. Affine, 3. Projective, 4. Topological, 5. Point set theory. "Topology […] is altogether more flexible than the foregoing geometries, or perhaps 'elastic', for it is referred to as the *rubber sheet geometry.* Imagine a rubber sheet pinned on a surface to form the square ABCD. When this is deformed, ABC and D are still in the same order" (Cole and King 1968: 71).

[4] In geography in recent years, there has been an increased interest in mathematics and geometry, although in a different form than during the era of spatial science. Focus is no longer on "the mathematics of geography," to borrow Elden's (2008: 2645) expression, but rather on "the geography of mathematics." Or with Simonsen's (2004: 1336) words: "[T]he kind of geometry put forward in the new metaphorization is very different from the one known from spatial analysis. It is much more unstable, messy, nonlinear, and open-ended."

physical object too, and in order to capture these different, yet intertwined, aspects of man-in-space we need not only ordinary language systems, but formal language systems as well.

1.4 Geometrical representations in architecture: network analysis

In this paper we want to challenge the perfunctory assumption that geometrical representations of space are inherently less adapted for the representation of man-and-space, or man-in-space, or space-through-man. To do this we will make a shift in “science of space” from geography to architecture, a shift that reflects what we deem a fundamental neglect in discourse on space in the social sciences, the fact that it is not only conceptual space that is constructed by man, but physical space as well, a fact, we will argue, that geography with its heritage in description of natural space has problems to handle, treating physical space created by man as given rather than constructed. This challenge, on the contrary, is exactly what is naturally dealt with in the other “science of space”, architecture, that is, how to represent man made space.

Architecture has an equally long tradition as geography of representing space and the built environment geometrically. More specifically, we will draw on the architectural theory of space syntax[5], and attempt to show by this example that there can be fruitful ways of representing also more fluid and dynamic – and realistic – notions of space *geometrically*, notions that exactly set out to represent “man-in-space” and therefore can be said to be in accordance with many of the arguments put forth in the new mobilities paradigm. The discussion will focus on the axial map, a geometric representation developed in space syntax as an approximation of the experience of being in the city. More precisely, it constitutes a form of *network analysis* based in graph theoretical descriptions that we also find proficiently in certain directions of both spatial modelling in geography (Batty, 2005) and social network analysis in sociology (Scott, 2013). This opens for fruitful comparison of how similar geometric representations are applied and interpreted in the different disciplines.

A basic assumption in this paper is that all representations – not only geometrical/quantitative representations – are reductions of reality. Natural language, what we above have called texts) are to equal degree reductions. There is no a priori “good” or “bad” representation, only more or less suitable for what one wants to convey. “You cannot think without abstractions; accordingly, it is of the utmost importance to be vigilant in critically revising your *modes* of abstraction” (Whitehead 1953: 73).

2. Geometric representations

It has become a truism that in any scientific endeavour to study some set of phenomena we are by necessity forced, first of all, to construct some kind of representation of these phenomena, that is, we can not study ‘reality’ as it is, but only through representations of this ‘reality’. We will not dwell on this tremendous discussion, but clearly state that we generally agree, and instead immediately move on to the assumption for a long time held as true that the primary

[5] “The foundations of space syntax analysis originate in a field of mathematics known as graph theory that deals with the study of topological relationships. In order to apply graph theory to architecture, a range of mapping or abstraction techniques are required to convert complex spatial environments into a set of topological relationships. The three most common forms of abstraction, which precede analysis using space syntax mathematics, produce convex spaces, axial lines and visibility graphs.” (Dawes and Ostwald 2013: 1.)

form of representation of space is geometry; that geometry is the language of space. (e.g. Harvey, 1969; Tabak, 2004). As outlined above, this is not true in the same sense anymore and what we rather see is a divergence within the social sciences when it comes to the issue of space, where we find both a continuation of the spatial science paradigm where geometric representations are essential and a expanding critical-cultural direction where geometric representations of space to a large degree are rejected. Our central question is whether this is a rejection for ideological or intellectual reasons and whether there is the possibility of geometric representation of space that to a greater degree avoids the subject-object dichotomy that hampered spatial science.

This echoes the attempt that characterises *behavioural geography* and, more precisely, the development of the notion of *cognitive maps* (e.g. Golledge and Stimson, 1997). […]

However, speaking most generally, these attempts have so far not delivered any conclusive results when it comes to the geometric character of cognitive maps, why it so far has not led to any distinct methodologies about how to represent how people cognize space, rather there is a rich but inconclusive debate (Ibid.).

While the progress in behavioural geography is of central interest, we will here turn to a more easily isolated case found in, what we would like to call, the other major discipline of space, architecture, and more particularly the research tradition *space syntax* (Hillier and Hanson, 1984). Here we exactly find a methodology that aim to represent space geometrically but based in human cognition, that is, most deliberately trying to overcome the subject-object dichotomy typically found in spatial science. As such, the representations developed in space syntax have great affinity with the attempts in behavioural geography and the concept of cognitive mapping elaborated above (Seamon, 1994).

Central for the research in space syntax is exactly to take an analytical approach to the cognitive dimension of architectural and urban space, specifically aiming to develop knowledge that can support architectural and urban design. Sustaining the system perspective of spatial modeling but adding more imaginative geometric description from urban morphology, space syntax merges both traditions into an analytical urban morphology, focusing on space. Instrumental for space syntax analysis is the invention of the *axial map*, which is a geometric representation of urban space based on graph theory, constructed from the point of view of a cognitive subject, i.e. an experiencing and acting human being (Hillier and Hanson, 1984). The axial map is made up of the least amount of straight lines that cover all accessible urban space in the area of analysis, where each straight line (here called *axial line*) in the map represents an urban space that is possible to visually overlook and physically access (Ibid.). Of great importance is the development of axial analysis into segment analysis (Hillier and Iida, 2005), where the axial map is broken down into a network of street segments. Based on this, different properties of the network can be analysed, such as, *integration* and *choice*, where different distance measures can be calculated, such as topological (axial steps), geometric (least angular deviation) and metric (metric distance) (Ibid.). Integration and choice are very similar to what is known as *closeness centrality* and *betweenness centrality* respectively in general network analysis (see below; Newman, 2010).

It is from this clear how space syntax methodology share both representational techniques as well as measurements with general graph theory based network analysis. Network analysis, however, is an extremely generic form of analysis that to equal degree is found in sociology, biology and computer science for instance (Newman, 2010), why the devil here is found in the details. It is exactly the negligence to discuss geometric representations, such as network analysis, in detail, we argue, that has lead to premature rejection of such representations of space in several recent directions of the social sciences. The critical issue, rather, is how, for instance, network analysis is applied, that is, what more precisely is it that is represented; from what perspective are the representations made, that is, where is the subject in these representations; how are these networks described and compared more precisely, that is, how are the properties of the networks measured?

We will in the following, therefore, conduct a close comparison of certain aspects of how network analysis typically is applied in spatial modelling, social network analysis and space syntax respectively, in an effort to from this comparison glean the possibilities of geometric representations of space that overcome the unduly separation of subject and object and fruitfully captures 'man-in-space'.

3. Network analysis in spatial modelling, sociology and space syntax

In his impressive opus Networks (2010), Mark Newman sets out the idea of Network analysis by simply stating that: "There are many systems of interest to scientist that are composed of individual parts or components linked together in some way" (Ibid.: 1). While some study the components and some the connections or interactions he continues, there: "is a third aspect to these interacting systems, sometimes neglected but almost always crucial to the behaviour to the system, which is the *pattern* of connections between components" (for anyone working in space syntax this rings most familiar) and such patterns: "can be represented as a network" (Ibid.: 1-2). More specifically: "A network is a simplified representation that reduces a system to an abstract structure capturing only the basics of connection patterns and little else" (Ibid.: 2).

Formally, such representations consists of components represented by points and connections represented by lines, where: "In the jargon of the field the points are referred to as *vertices* or *nodes* and the lines are referred to as *edges*" (Ibid., 1). This extremely simple set of geometric notation clearly opens the possibility to represent a wide range of phenomena as networks. As mentioned earlier, we find network analysis in such disparate disciplines as biology, sociology and computer science. These simplified descriptions are, moreover, taken as the point of departure for different kinds of analyses and measurements of their properties. Typical among such properties that can be measured in networks are different kinds of network centrality, such as *closeness centrality* and *betweenness centrality*, which, as we saw, in space syntax jargon are known as *integration* and *choice* respectively.

However, such a generic approach to representation leaves a great deal open for interpretation in the individual discipline, something that hope to make apparent by a comparison of network analysis in the different but related disciplines of spatial modelling, sociology and space syntax. Of particular interest here is how the fundamental critique delivered against spatial science, where network analysis and graph theoretical representations of space was first introduced to geography (e.g. Haggett, 1965), is dealt with, that is, how: "the analytical separation of subject from object" (Cosgrove 2000: 449) and the fact "that spatial structures are implicated in social structures and each has to be theorized with the other" (Gregory, 1978: 172) is dealt with. We will try to accomplish this through a close comparison of some central aspects of how network analysis or, more specifically, the graph theoretical notations used to geometrically represent networks in network analysis, are applied in spatial modelling, social network analysis and space syntax respectively. The three main questions asked are: What, more precisely, is represented by the fundamental components of vertices and edges in the different cases; how is the subject-object relation represented; and how is the fundamental property of distance in networks represented and measured in the different disciplines?

3.1 Network representations in spatial modelling

We are inclined to understand the world as a sequential development. In the case of space in the social sciences, for instance, we easily come to subscribe to the story how 'spatial science' by the 1980s was overtaken by a 'spatial turn', in short replacing *space* with *place*, which in turn seems to currently be overtaken by a 'mobility turn', replacing *space* with *movement*. Now, as beautifully argued by Doreen Massey, this is only true as long as you do not account for space (2005). The fundamental mystery of space is how it allows for several parallel trajectories of time, why there is no simple sequence, but rather several simultaneous developments. Therefore, spatial science was never simply overtaken by a spatial turn, but has most successfully continued its general program, however, not unaffected by other developments concerning space in the social sciences. Most prominently we find such a continuation in the fields of applied geography, for instance in spatial analysis and urban modelling, which comprise dimensions of both traffic modelling and regional science, represented, for example, by the work of Mike Batty (2005) and Juval Portugali (2011). While this field make use of a wide range of more novel modelling methodologies, such *agent-based modelling* and *cellular automata* (e.g. Batty, 2005), network analysis is found at the bottom of a lot of this work.

There is a long history of application of graph descriptions in the analysis of urban form (Hansen, 1959; Nystuen and Dacey, 1961; Kansky, 1963; Haggett and Chorley, 1969; Wilson, 1970), where: "urban form usually is represented as a pattern of identifiable urban elements such as locations or areas whose relationships to one another often are associated with linear transport routes such as streets within cities. These elements can be thought of as forming nodes [vertices] in a graph, the relations between the nodes being arcs [edges] which represents direct flows or associations between the elements" (Batty, 2004).[6] On the detailed level that concerns us here we can be more specific about how urban form is represented as graphs. Typically, what is represented on this scale is the street network, where street junctions are represented as vertices and the street segments in between junctions are represented as edges. In most cases this gives rise to a planar graph, meaning that there are no edges crossing each other, which can become the object of analysis of its different network properties.

Turning to our questions listed above it is, first, quite clear that what the graph represents here is the space of the physically defined street network, where each street junction is considered a vertex and each segment in between junctions is considered an edge. As such it distinctly represents a physical entity, that is, an object outside the subject using the network for traveling, for example. Second, if we are to consider the presence of a subject in this representation, the definition of junctions as vertices and segments as edges, creates an inclination to identify the subject in the street junctions rather than in the segments in between. This fits well with how models of this kind, for instance in traffic panning, are co-joined with theories about decision-making, such as rational or discrete choice models (Becker, 1965; Winston, 1982). That is, it is at the junctions a subject is introduced to an alternative and therefore forced to make a decision.

In extension, we here also see how this in particular fit the modelling of car traffic, where such street junctions typically present the driver to a rather distinct set of choices, while the travelling mode of walking, in principle, present the pedestrian both to a richer set of choices

[6] The terminology varies in different disciplines applying graph theory. Generally speaking, *node* and *vertex* refer to the same thing and *arc*, *link* and *edge* refer to the same thing.

and in a more continuous manner not limited to street junctions. Tram-traffic, on the other hand, presents the driver of trams to few alternatives as well, which, moreover, are not identical to street junctions, why a graph representation of a tram-line typically will turn out differently than one representing car-traffic, even though covering the same street system.

In general terms we can conclude, that the application of the geometric representations of networks as graphs in spatial modelling represents the object of the physically defined space of street networks in cities, and if there is a subject present in this representation it is found at the street junctions as a situation of rational choice. An interpretation of this conclusion concurs with the general critique directed at spatial science, that is, that it typically separates subject from object and aim only to represent the object of the physical network. When, however, we still find a subject inscribed in this representation, it is a highly simplified subject represented, so to say, on the objects terms. This is stressed by the abstract measures of distance in the network, normally used in spatial modelling. Whether, metric, topological, temporal or monetary, they typically lack deeper foundations in human behaviour or cognition. In sum, what is represented and measured is the physical object, the technology, rather than human action, behaviour or cognition, that is, the subject.

This does not by necessity imply a general rejection of the approach to network analysis in spatial modelling; rather it is quite well designed for particular purposes. The problem enters when such models are stretched beyond their limits, for instance, when going from understand them as models of limited description to models of general prediction. Moreover, it is easy to see how network models of this kind are far from adequate for the aims inherent to research programs as those generally found within the spatial turn, for instance.

3.2 Network representations in social network analysis

In social network analysis a network usually is a network of people or groups of people. The most prominent advocate of network analysis in sociology is John Scott (e.g. 2013). Scott sees the need for network analysis in sociology from the point of view of the different types of data the sociologist work with. He identifies two major types, *attribute data* and *relational data*, where the first concerns “the attitudes, opinions and behaviour of agents” (Scott, 2013: 3) and the second: “the contacts, ties and connections, and the group attachments and meetings that relate one agent to another” (Ibid.:3). His argument is that while there has been extensive methodological development concerning the first type of data, little attention has been given to the second kind, which he deems as paradoxical, since: “relational data are central to the principal concerns of the sociological tradition, with its emphasis upon investigating the structure of social action (Ibid.:5).

However, there is a tradition of social network analysis that Scott roots in the development of German *gestalt* psychology in the 1920s, but which in its more recent form parallels the development of network analysis in spatial modelling in the 1950s. This tradition explicitly addressed relational data in sociology from the very beginning (Scott, 2013: 13-19).

Returning to our questions, it is, first, immediately obvious how graphs are made to represents something completely different in sociology than in spatial modelling. What is represented here is social networks, where vertices typically are made to represent individuals, or groups of individuals, and edges represents relations between individuals or groups of individuals. It, therefore, clearly concerns the representation of a social entity, in stark contrast to the physical entities represented in spatial modelling. Concerning, second, the subject-object relation this means that what is represented are subjects, arguably objectified due to their limited qualitative description. However, these subjects can, generally speaking, be augmented by attribute data both concerning the subjects themselves and the character of their connections.

What is more problematic, in our current perspective, is the character of what can be considered the object in these descriptions, that is, how the spatial dimension of social networks is dealt with. This is a problem generally acknowledged also in sociology:

> "McGrath et al. [1997] conclude that if a researcher wishes to infer something about the actual sociometric properties of a network then the physical distance between points should correspond as closely as possible to the graph theoretical distances among them. This conclusion reinforces the long-standing desire of social network analysts to move away from metaphorical and illustrative diagrams and to produce more rigorous maps of social structure that, like geographical maps, retain the mathematical properties of the graph and allow new features to be discovered." (Scott, 2013: 148)

This clearly illustrates how networks are inherently spatial objects, but that the character of space here typically varies from discipline to discipline. The ontology of social networks is typically mixed and their properties, hence, more vague and difficult to define and measure. While such representations form the basis also in social network analysis for typical measures of the graphs such as the variation of connectivity or centrality for the different vertices, the problem here is not so much the measures in themselves as the mixed character of space in social networks. Most generally, we could say that they are constituted by social space, that is, social relations of different kinds, as developed for example by Mark Granovetter in his highly influential notion of strong and weak ties (Granovetter, 1972). However, social space in this meaning is typically influenced by physical space, an idea that goes back to the very origins of sociology (Liebst, 2012). Our point here, however, is to distinctly point out the, maybe obviously, different character of space in social network analysis from similar descriptions in spatial modelling.

Concluding, we can say that what is mapped in social network analysis is individuals or groups of individuals, which clearly bring a subject into the analysis while rather aiming the character of the object indistinct. If the object in this respect is identified as space, it clearly takes on a quite abstract quality in social network analysis. Once again, to capture the nature of the structure and strength of different social relations, abstracted from notions of spatial relations in physical space, and how these form different kinds of networks and clusters, is naturally exactly what is aimed at in social network analysis. As such they seem, in principle, much closer to the general intentions in the spatial turn of a more morphic and socially constructed concept of space that on a deep level understand space as an entanglement of subject and object and, furthermore, theorises space together with the social. However, network analysis is not the descriptive technique favoured, generally speaking, in the spatial turn. Moreover, with its weak relation to physical space it generally find little applicability in urban studies.

4. Discussion: Network analysis in space syntax

With these discussions of network representations in spatial modelling and sociology respectively, it seems highly interesting to return to network representations in space syntax. When it comes to our first question that concerns what actually is represented, we can say, as in the case of spatial modelling, that what is represented is physical space and, in a quite similar manner to spatial modelling, most often defined as the street system of cities. The great difference is found in how, quite in contrast to spatial modelling, street junctions are represented as edges and street segments as vertices. This seemingly simple shift in descriptive technique, however, has quite great implication, we argue. From the point of view of spatial modelling this shift has been acknowledged and discussed by Mike Batty (2004). He demonstrates how the graph typically drawn in space syntax simply represents what is called the dual graph, which is inherent in any graph as its simple inversion. However, the dual graph carries a lot of complications, such as for instance the fact that it not is a planar graph. This is quite obvious for anyone applying space syntax technique where the fact that an axial line simultaneously can connect a large set of other axial lines is a bit mind-boggling. However it could also be argued that this is exactly what makes axial maps so lifelike and the reason that they have proven successful in capturing human use of street systems.

If we move to our second question about how the representation deals with the relation between subject and object, we can say that in axial maps the subject has typically been located in quite a different location than in spatial modelling, that is, not in the street junctions and not even in the street segment but in the axial line, which most often is constituted by several street segments. This is quite extraordinary if one tries to imagine this realistically; the subject is here represented by a linear component of quite large extension, often several hundred meters, which furthermore simultaneously connects several other linear components. The subject, if this is taken literally, is extended into a quite vast space that it is designated to fill simultaneously. One could argue that this basically is an odd notion, that has all to gain from being corrected, which is the implicit argument of Mike Batty in his comment (2004), or it could be taken as something highly original, that opens new doors to geometric representation of space.

Our argument is that space syntax here, at the core of its contribution to spatial analysis, offers something highly fruitful. In contrast to spatial modelling, where we concluded that it represents the subject on the object's terms, we can argue that in space syntax, through a small shift in descriptive technique, the object is suddenly represented on the subject's terms. While this clearly is a hasty conclusion that needs further investigation, we do want to argue that this can show how geometrical representations of space still are far from exhausted in the social sciences.

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