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Mapping the Field of the New Brain Sciences: methodological, conceptual and technical dimensions

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'The world is complex, dynamic, multidimensional; the paper is static, flat.
How are we to represent the rich visual world of experience and measurement
on mere flatland?'
Tufte (1990)

- This paper examines the many dimensions associated with 'mapping' from the metaphorical and rhetorical to the more conceptual and methodological aspects. The paper focuses on the technical or practical mapping of techno-scientific fields including biomedical and some specialized areas related to the brain sciences[1].

- The concept of 'mapping' has been widely used and abused as a metaphor, theoretical, conceptual or even technical device. The literature abounds on 'mapping', it seems everything can be mapped from change, crime, culture, feminism, homosexuality, ideology, and modernity, to populations, the mind, the subject, the unknown, vulnerability, and security.

- There is an extensive literature on the historical uses and meanings of maps, and their associated claims such as scientific precision, accuracy and 'objectivity', prediction and usefulness in visualizing large-scale and heterogeneous datasets. Maps are viewed as practical, synoptic, and useful tools in documentation, orientation and navigation. In addition, they can mediate or help in breakthrough discoveries from John Snow's 1854 maps of the London cholera outbreak (Tufte 1997) to the wiring diagram of the worm *C. elegans*[2] in the 20th century. They can visualize large-scale datasets from the geographic representation of the Earth or our galaxy, to the web mapping of the French presidential elections[3] or the recent mapping of the Iranian cultural and political blogosphere[4]. Maps are widely used in science because they frequently 'catalyse' the discovery process; like Poincaré's maps or Einstein's thought experiments, a map or diagram can be used to make a practical point be it 'philosophical or physical' (Galison 2003). Reductionism is seen here as an advantage: maps reveal by concealing the 'messiness of the world'.

- Another important attribute of maps is their power to predict. Thus their widespread use in policy-making; to track trends, emergence and spread of epidemics in health policy, or in crime-prevention policies (through 'crime-mapping technologies'). Brain maps, diagrams, and techniques which are as diverse in meaning and implications as their genetic counterparts are also pervasive. Brain mapping projects abound: The Allen Institute for Brain Science's map of the brain of an adult mouse; The Human Brain Project (HBP) launched in 1993 by the National Institute of Health (NIH); The Blue Brain Project which consists in 'reverse-engineer the mammalian brain' by designing a 3-D brain through which simulations can lead to the understanding of brain function and dysfunction. These attempts fulfil to some extent what Sydney Brenner referred to in his Nobel lecture as 'CellMap'[5], the architecture of which will facilitate 'computation' but most importantly 'prediction'.

- Maps also have what Callon (1998) refers to as a 'performative' dimension specifically their power to act on and mould the world we inhabit by creating new identities, categories and 'grids of specification'. Mapping and maps are thus never *just* metaphorical. From empires and nation building to geopolitical wars and conflicts, maps are used as an 'institution of power' (Anderson 1983), as a proof or disproof for any claim of possession or dispossession, legitimacy or illegitimacy. Since colonial times, they have been used as a powerful grid to classify, label,

[1] This paper summarizes the conclusions of a longer paper. A copy of the full paper is available on request.
[2] The neuronal mapping of *C. elegans* has earned Sydney Brenner a Nobel.
[3] Observatoire Présidentielle 2007 www.blogopole.fr (Accessed June 2008)
[4] Harvard's Berkman Center for Internet and Society. Mapping Iran's Online Public: http://cyber.law.harvard.edu/publications/2008/Mapping_Irans_Online_Public (Accessed June 2008)
[5] Nobel Lecture, December 8, 2002 'Nature's gift to science'.

regulate and control populations. The visualization of the hegemonized human landscape relies on two assumptions: the power of the grid and the belief in 'serialization' that is 'the assumption that the world was made of replicable plurals' (Anderson 1983).

- Maps have been criticised not only for being reductionist (a mere representation of the world) but also because of the 'fictions of homogeneity' they create (Gaudillière and Rheinberger 2004). In addition, these maps have social, moral, political, and economic implications when they are used to define, categorize, objectify, standardize, and homogenize issues and notions such as normalcy, identities, ethnicities e.g. the 'Genographic project' launched by National Geographic or the appropriation of genetic data with the Icelandic Decode Initiative[6]. It is not a coincidence if the philosopher of science Stephen Toulmin (1953) writes that one draws consequences by merely drawing lines.

- Recently we have seen the development of diverse computer-assisted tools that facilitate the visualization and navigation of complex techno-scientific fields in multi-dimensional levels such as the 'Blogopole', 'WebAtlas Navicrawler', the 'Issue Crawler', and Boyack and Klavans's (2005) use of bibliometric approaches to produced a 'Map of Science'. On the basis of a detailed examination of diverse and sophisticated visualizing tools, we can note some key points:
    a. Expertise or at least a thorough knowledge is needed to make use and analyze the resulting maps in a substantial and meaningful way;
    b. The internet or web-platform is a new 'social' terrain to be explored by social scientists. They are social in the sense that they can gather communities, mark a 'presence', advocate political beliefs etc.; political issues are created, discussed, circulated, mobilized;
    c. The Issue Crawler for instance has been used to map events, issues and debates (Marres 2004; Marres and Rogers 2005), to localize the various actors involved in an event, issue or controversy and those who are supposed to be involved but are not 'visible'. In that sense the Issue Crawler has been used as an instrument for 'critique' and not only for 'empirical analysis' (Rogers 2007);
    d. Websites and the blogosphere involve different types of actors including citizens and leaders, militants and disinterested parties etc. a pool of heterogeneous and complex actors and actants;
    e. Analyzing the web in snapshots allows to archive and stabilize a very plastic and changing milieu;
    f. The web offers a 'democratic' platform whereby everyone can have a say and everyone counts for one;
    g. The web is at the same time a platform that offers 'ethnographic material' and an object of study;
    h. Though still not widely used in the social sciences, the Issue Crawler is attractive in terms of its power to crawl all the web and thus unveil the connections (or their lack) between the different actors involved in the 'field' under scrutiny;
    i. The Issue Crawler and similar technologies allow these questions to be explored: What does it mean to be more 'visible' on the web? Does the reality of the web matches the reality outside the web (online vs. offline mapping 'realities')?;

- Despite some limitations such as language limitation and the web's plastic nature, social researchers have started to make use of the Issue Crawler to map controversies as they are being discussed, circulated, and mobilized on the web, for instance:

[6] See further Gaudillière, J.-P. and H.-J. Rheinberger (2004). From molecular genetics to genomics : the mapping cultures of twentieth-century genetics. London, Routledge.

a. McNally (2005) suggests using the Issue Crawler 'to map, monitor and engage with the global proteomics research network'. The crawler is used as a means to follow globally the dynamics of all actors involved in proteomics;
b. Holm and William-Jones (2006) ask whether it is relevant to talk about a coherent homogeneous field of 'Global bioethics' given the 'clustering' (thus dispersion) of the field;
c. Marres and Rogers use the Issue Crawler to trace the 'fate of issues and their publics on the web' (Marres and Rogers 2005), from the Narmanda Dams and Ferghana Valley (Marres and Rogers 2008), to climate change (Rogers and Marres 2000) and 'eco-homes' (Marres 2007). In a recent article, Marres and Rogers (2008) use the method to address the particular question of the role of Information and Communication technologies (ICTs) in the globalization of NGO practices based on three case studies mapped by the Issue Crawler. Their study shows how the global civil society network that emerges on the web is not only an 'artefact of the medium' but a reflection of the broader politics of NGO dynamics in terms of the documentation of issues and how they are rendered 'visible';
d. Further, actor-network theories view these issue-networks as a feature of a social-technological assemblage and therefore approach them as the sites where the articulation of objects of knowledge are being formed. The technology here plays an active role and is not merely instrumental. Moreover, web-analysis which is based on an actor-network configuration, changes the definition of what the 'global' and the 'local' amount to. It actually views those two notions as deriving from the circulation (mobilization, enrolment, effacement) of these heterogeneous elements and entities in networks. In their study of the web-practices of NGOs, Marres and Rogers conclude that globalization is in the end 'an instrumentalization of networks and issues'.

- We can also identify approaches that map the dynamics of science and technology through a triangulation of qualitative or traditional ethnographic tools and quantitative metrics dubbed 'qualitative scientometrics' (Callon, Law et al. 1986), 'semi-quantitative methods' (Cambrosio, Keating et al. 2004) or 'quali-quantitative tools'[7]. Bourdieu can be considered in that sense an avant-garde of 'empirical sociology' with his extensive use of 'correspondence analysis' in the mapping of any field or social space, be it culture, academia, literature, science or the socio-economic fabric. The combination of 'quali-quantitative' tools has been frequently adopted in recent years particularly with the introduction of sophisticated computer-assisted softwares (such as Réseau-Lu) and the refinement of bibliometric approaches.

- The rationale behind such a triangulation of methods and methodologies is that techno-scientific fields can not be grasped either by reason alone or the context in which they emerge. Rather, they are a hybrid medium, made of heterogeneous agents and agencies, that mobilize various actors to sustain the field and remain visible. This mobilization leads to a series of 'translations'. Hence the need to trace back those translations through 'inscription devices' (Callon, Law et al. 1986) such as scientific 'texts', documents, and other publications which become strategic tools in the hands of their authors. It is only when these diverse elements are *inscribed* in some worded medium that they become durable and reflect a world-view in process (Callon, Law et al. 1986).

- Scientometrics and 'quantitative maps' have been used for many reasons:
    a. Their capacity to handle massive and heterogeneous data (Leydesdorff 1995; Cambrosio, Keating et al. 2006);

[7] To quote Bruno Latour on 'Mapping Scientific Controversies' http://www.macospol.eu/streaming2/ (Accessed June 2008)

b. Their capacity to visualize 'science' through citation mapping (Small 1999); the first to articulate the need for such maps was Doyle (1961);
c. As a heuristic tool for historical reconstructions of events, such as the historical reconstruction of the development of DNA research (Garfield, Sher et al. 1964) and AIDS research (Small 1994);
d. As a tool to map scientific networks; recent articles have focused more particularly on mapping collaborative initiatives, interdisciplinarity (Cambrosio, Keating et al. 2004; Bourret, Mogoutov et al. 2006), and the nature of scientific research fronts (Price 1965);
e. Their capacity to reflect the structure of thought (Mccain 1986);
f. Their capacity to analyze research trends (Duplenko and Burchinsky 1995), and identify the ever-changing frontiers of science (Garfield and Small 1989);
g. As a reflection of a certain vision of the world, e.g. the world as perceived by technoscientists and engineers (Callon, Law et al. 1986);
h. As a reflection of the interaction between authors, their role in science through citation patterns (Hjorland and Albrechtsen 1995), and their participation/contribution to field formation e.g. in the emergence of nanotechnology (Rueda, Gerdsri et al. 2007);
i. To inform policies for the allocation of resources among disciplines (Boyack, Klavans et al. 2005) and for other policy and managerial decisions (Noyons 2001);
j. To assess the quality of research e.g., psychiatric biomedical research (Lewison, Thornicroft et al. 2007) and research performance (Ingwersen, Larsen et al. 2001)
k. As a means to understand the scope and structural pattern of science (Small 1976; Small and Garfield 1985; Boyack, Klavans et al. 2005), scientific knowledge (Griffith, Small et al. 1974; Small and Griffith 1974) and research fields (Duplenko and Burchinsky 1995);
l. As a measurement of science communication (Goffman and Saracevic 1977; Leydesdorff 1995; Leydesdorff and Hellsten 2005), 'maps represent semantic fields' (Leydesdorff and Hellsten 2005);
m. As a way to 'navigate' through citation networks (Small 1995; Borner, Chen et al. 2003) and the 'spatial representations' of the different research fronts in the 'scientific publications' (Borner, Chen et al. 2003);
n. To analyze the dynamics of techno-scientific interfaces and the movement of academic and industrial researchers between institutions (through patents and publications) (Schmoch 1997).

- Different types of maps have been produced by scientometrics and bibliometric approaches specifically to map complex biomedical fields. An example is the mobilization of specialists in the development of AIDS-related therapeutic tests; the first study (Dodier and Barbot 2000) to combine ethnographic work and Réseau-lu, a software developed by Aguidel. A few other examples are examined: the mapping of the emerging biomedical platforms and players such as 'translation' in cancer research (Keating and Cambrosio 2003; Cambrosio, Keating et al. 2004; 2006) and the few bibliometric approaches used to map some aspects of the field of the brain sciences, such as consciousness (Maasen 2007), memory research (Schwechheimer and Winterhager 2001), and the growth of the 'neurosciences' (Sengupta 1989).

- Some social scientists make use of such sophisticated softwares combined with traditional ethnographic tools for the following reasons:
    a. They allow visualization of the emergence of new platforms or players e.g. biomedical player in the case of translational cancer research (Cambrosio, Keating et al. 2006) through a review of a large and complex amount of data. In Cambrosio et al the database contains a review of 121 journals specializing in cancer;

b. They show the relations between heterogeneous data and account for all actors involved; 'human and non-human' (Dodier and Barbot 2000; Cambrosio, Keating et al. 2004; Cambrosio, Keating et al. 2006);
c. They avoid 'two pitfalls' of traditional sociological analyses: (i) 'A thick description of selected sites descriptions of selected sites' that misses the figurational dimension of the collaborative network and (ii) a simplistic account that misses the complexity because the few quantitative indicators can not fully account for the massive amount of information thereby 'destroying…the very phenomena under investigation' (Cambrosio, Keating et al. 2004);
d. They validate the findings. Bibliometric analysis is validated by peer review of the field. And vice versa quantitative maps may sometimes 'reveal' unidentified or unknown features.

- The theoretical and conceptual dimensions of mapping are examined in particular the relation between field theories and mapped fields. This is demonstrated in Bourdieu's field theory, more particularly his notion of 'homologies' between fields which is probably inspired from the concept of 'symmetric joint maps' used in correspondence analysis (de Nooy 2003).

- A slightly different approach to mapping derives from Bourdieu's (2001) extensive use of 'correspondence analysis'. Though available since the mid 1930s, it has not been frequently used in social science research in both the UK and the USA. This is in striking contrast with its popularity in France, for instance, where it was originally developed in the 1960s to provide a mathematical analysis of contingency data sets in linguistics. It is one way among a wide set of other alternative methods to handle and represent the relationships between categorical data. Bourdieu drew heavily upon it, he used it to support for instance his critical analysis of French socio-cultural life (Bourdieu 1979) and French academia (Bourdieu 1984).

- Many sociologists are attracted to correspondence analysis (CA thereof) for the following reasons:
    a. Some see it as a tool for visualizing multiple coordinates and various data, or visualizing the relations between categorical variables. Visualization not for the sake of it but to understand the 'content' of the associations (de Nooy 2003);
    b. Others consider it a tool to handle 'complexity' and reflect a 'filmic representation of dynamic change' (Byrne 1999);
    c. Still others (Gatrell, Popay et al. 2004) use it because the technique reflects the structural landscape of the social world as Bourdieu envisaged it. He (1992) writes, 'If I make use of correspondence analysis, in preference to multivariate regression for instance, it is because correspondence analysis is a **relational techniques** of data analysis whose philosophy corresponds exactly to what, in my view, the reality of the social world is. It is a technique which "thinks" in terms of relations, as I try to do precisely with the notion of field.'

- Another mapping method en vogue is "Social Network Analysis" (SNA). Bourdieu preferred CA over SNA for theoretical rather than technical reasons. Social network analysts and Bourdieu have different understandings of the structure of society (de Nooy 2003); the former focus on interaction and exchange while the latter focus on different kinds of capital. The former views interaction as a 'manifest' phenomenon, Bourdieu views the background characteristics or structure of society as a latent 'objective' reality that can be unveiled or extracted through CA. The former focuses on the 'present' state of affairs of interactions thus implicitly denying the past, Bourdieu on the other hand considers interactions (perception, behaviours etc.) as the product of a long process of socialization.

- Nonetheless de Nooy (2003) provides strong arguments as to why SNA is still better equipped to capture the dynamics of 'objective relations' (such as the differential possession of capital). Contrarily to what Bourdieu claims, objective relations may actually influence 'interactions' within a field which may then change the distribution of capital (the defining or characteristic structure of society). Viewed this way, interactions become an important actor capable of modifying the distribution of 'properties'-a determinant of interactions. This is why de Nooy considers that SNA has a crucial role in 'unravelling the process in which a field is being restructured and symbolic values are (re)produced.' Many social network analysts have in fact tested Bourdieu's social capital based on SNA and as de Nooy argues basically both methods can adequately capture the notion of 'capital'.

- On the basis of this examination of approaches to mapping, we conclude that there are reasons why it might make sense to map a field, and that mapping is not merely a figure of speech. However it is important to ensure that the problematic to be explored in the mapping process is clearly articulated. Without such a clear formulation maps are doomed to be trapped in a 'semantic' loop (Lopez 2006) and be vulnerable to any 'deconstruction' attempt (Harley 1989).

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