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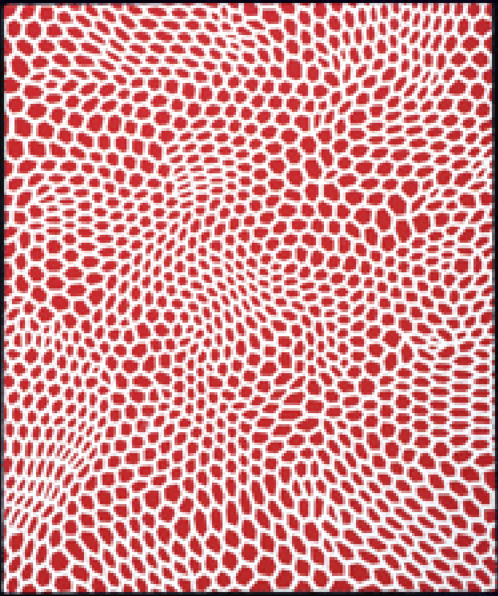

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Introduction: The Becoming Topological of Culture

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Abstract
In social and cultural theory, topology has been used to articulate changes in structures and spaces of power. In this introduction, we argue that culture itself is becoming topological. In particular, this 'becoming topological' can be identified in the significance of a new order of spatio-temporal continuity for forms of economic, political and cultural life today. This ordering emerges, sometimes without explicit coordination, in practices of sorting, naming, numbering, comparing, listing, and calculating. We show that the effect of these practices is both to introduce new continuities into a discontinuous world by establishing equivalences or similitudes, and to make and mark discontinuities through repeated contrasts. In this multiplication of relations, topological change is established as being constant, normal and immanent, rather than being an exceptional form, which is externally produced; that is, forms of economic, political and cultural life are identified and made legible in terms of their capacities for continuous change. Outlining the contributions to this Special Issue, the introduction discusses the meaning of topological culture and provides an analytic framework through which to understand its implications.

Keywords
change, comparison, continuity, models, networks, topological culture

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Introduction

In his studies of the mass culture of the Weimar Republic (1995), Siegfried Kracauer famously identifies a 'turn to the surface'. In developing his description of this turn, Kracauer pays special attention to the objects, media and practices that 'display an elective affinity' with the surface such as the hotel lobby, arcades, and dance troupes as well as newspapers, photography and cinema. So, for example, he describes the dance displays in popular revues where troupes such as the Tiller girls performed, as ornaments made out of bathing suited bodies. The attraction is the display of 'girl clusters whose movements are demonstrations of mathematics'. Kracauer focuses on the penetration of cultural forms by a ratio: 'The ornament, detached from its bearers, must be understood rationally'. He describes the reason at work as having a mathematical logic – a 'Euclidean geometry' – that organizes the masses. Cultural forms obey the logic of a 'linear system', and the 'elementary components' of physics, such as 'waves and spirals', training 'the broadest mass of people to create a pattern of undreamed-of dimensions'. For Kracauer, the mass ornament is the 'aesthetic reflex of the rationality to which the prevailing economic system aspires' (Kracauer, 1995: 79). But, so we will suggest here, a new rationality is emerging: the moving ratio of a topological culture.

This ratio can be identified in the significance of a new order of spatio-temporal continuity for forms of economic, political and cultural life today. This ordering of continuity emerges, sometimes without explicit coordination, in practices of sorting, naming, numbering, comparing, listing, and calculating. The effect of these practices is both to introduce new continuities into a discontinuous world by establishing equivalences or similitudes, and to make and mark discontinuities through repeated contrasts. The topological cultural forms (or constantly changing deformations) of lists, models, networks, clouds, fractals, and flows proliferate. In the movements of these dynamic forms there is a multiplication of relations of equivalence and difference and a radical expansion of the possibilities of establishing comparisons (Heintz, 2010; Riles, 2011). Ordinal rankings or ratings, for example, are increasing in number and importance not only in the economy but also in education, health, and popular culture, as they are used to derive and justify the allocation of resources (Guyer, 2010). More widely, the operationalization of listing has provided powerful tools for sequencing, linking and connecting activities in many contemporary calculative infrastructures, including, for example, credit rating agencies (Leyshon and Thrift, 1999).

In this multiplication of relations, change is established as constant, normal and immanent, rather than as exceptional or externally produced; that is, forms of economic, political and cultural life are identified and made legible in terms of their capacities for change. There is an ongoing expansion of the present (Nowotny, 2002), and a problematization of events in terms of the potential they offer for change, for what could be and for what might have been. Change is normalized as it becomes a shared condition: everyone is, variously, implicated, even if only as those whose exclusion is required for change to happen. The claim this introduction is making, then, is that culture is increasingly organized in terms of its capacities for change: tendencies for innovation, for inclusion and exclusion, for expression, emerge in culture as a field of connectedness, that is, of ordering by means of continuity, and not as a structure based on essential properties, such as archetypes, values or norms, or regional location.

The influence of topology in social and cultural theory in recent decades is immense. Topological ideas have been a significant source of inspiration across many social science disciplines, including philosophy, sociology, political science, psychology, anthropology, geography and economics. Topological ideas have fed into and transformed multiple specific fields of study. So, for example, as Marres (2012) observes, in the field of social studies of technology, topological ideas have helped dismantle the view that technology and society occupy different domains, contributing instead to the concept of a heterogeneous 'assemblage', which is heterogeneously composed of social, technical and natural entities (Latour, 1987). In economic sociology they have contributed to an understanding of markets as emergent in the activities of firms that continuously and jointly construct a market interface (White, 2002; Stark, 2009). In relation to studies of globalization, topological thinking has fed interest in processes of de- and re-territorialization, networks, flows and assemblages (Castells, 2006; Appadurai, 1990; Ong and Collier, 2005; Lash and Lury, 2007) and is deployed by those geographers and political theorists who seek to describe dynamic relations and mobilities that cannot be contained by scaled spatial entities, such as territory (Balibar, 2009; Elden 2009). In all these approaches it is *relationality* that is important, and topological concepts have enabled social theory to move beyond a reliance on the mechanical and organic to include transductive and transitive modes of relating (Simondon, 1992), and helped turn space and time from 'a priori' into 'a posteriori' categories (Lash, 2009).

But what is proposed in this introduction is not simply the transposition of topological ideas onto the field of culture. Instead we are interested in teasing out an epochal transformation in the intersection between the form and content of cultural expression. In other words, the becoming topological of culture does not simply correspond to how culture imagines topology; instead, our proposal is that topology is now emergent in the practices of ordering, modelling, networking and mapping that co-constitute culture, technology and science. In short, a distributed, dynamic configuration of practices is organizing the forms of social life in ways that supplement and extend those of Euclidean geometry. The latter relies upon 'lower level' principles of invariance or constancy (rotation, symmetry, scale and translation) and enable movement – or transformation only in relation to external metrics of time and space. In contrast, in a topological society, we no longer live in or experience 'movement' or transformation as the transmission of fixed forms in space and time but rather movement – as the ordering of continuity – composes the forms of social and cultural life themselves. This is not, of course, a matter of one rationality displacing the other, but of their overlapping and mutual implication such that the continuity of movement – or the continuum – becomes fundamental to contemporary culture.

At the same time as making this epochal claim, however, we – and our contributors – do not wish to jettison the conceptual vocabulary afforded by theoretical understandings of topology. The introduction will thus outline both what is involved in the becoming topological of culture, by describing the topological forms of culture that emerge in processes of continuity and ordering, *and* discuss topological thinking insofar as it informs contemporary debates. This approach – the combination of the claim that culture is becoming topological with the use of topology as a way of analysing culture – is, we suggest, not a mere doubling or mirroring, but a slide along a möbius strip, from the outside-in of cultural theory to the inside-out of culture becoming topological. The introduction will thus contribute to what might be called cultural topology (see Shields in this issue for an account of what this might involve) as well as establishing the claim that culture is becoming topological.

In order to illustrate this topological twist, we will focus on the problematic of relationality as it emerges in cultural topology by outlining two key approaches to the problem of the continuum as they are found in mathematics. We organize our account in this way because of the significance we attribute to the mode of ordering based on continuity in contemporary (topological) culture, and because different approaches to the problem of the continuum have been developed in social and cultural theory. In this theory, there is often direct and indirect reference to divergent mathematical understandings of topology, including differential topology and point-set topology, and thus we discuss these approaches later in this introduction. We see this development of topological concepts in cultural theory as part of a dialogue with mathematical (and other) thought that seeks to address the contemporary historical conjunction in which culture is becoming topological.

The structure of the introduction is thus as follows: first we will describe the emergence of topological culture through a discussion of processes of mediation. This involves showing how relations of continuity and discontinuity are being made and unmade by describing the emergence of new kinds of connectivity, ordered-ness and limits, and exploring their role in the creation of the infinity variety of 'Escher-like system[s] of exclusion and inclusion' (Gregory, 2004: 125) that characterize contemporary culture. The second part of the introduction describes further the developments that have contributed to the coming into being of topological culture, including the expanded role of indices, the formation of meta-models and the proliferation of networks in practices of auto-spatialization. The third part is an exploration of topology in mathematics insofar as it is relevant to social and cultural theory, explicating the significance of the problem of the continuum for understandings of relationality. The fourth part considers issues of control and critique in relation to the operations of method in topological culture, while the final, fifth, part returns to the question of what it means to describe the becoming topological of culture in terms of a moving ratio.

Topological Media-tions

There are many different origins identified in histories of topological thinking (see Shields, 2012) but we choose to start with the work of mathematicians Karl Friedrich Gauss and Bernard Riemann in the second half of the 19th century who developed methods that allowed the study of n-dimensional surfaces without any reference to a supplementary embedding space-time – that is, surfaces that are spaces in themselves (DeLanda, 2005). Put simply, a surface that is a space in itself is not fixed by way of external co-ordinates but is, rather, organized from within itself; it has intrinsic rather than extrinsic dimensions. Mathematicians were not, of course, alone in their explorations of the continuum in this period, and by the turn of the century there were parallel concerns emerging in physics, biology (notably in the work of Jakob von Uexküll),[1] architecture, urban planning, art and literature (among many possible accounts of such developments see Kwinter, 2002, for a discussion with an explicitly topological focus) as well as in social and cultural theory. The notion of the boundary – not only dividing but also joining – was, for example, central to Simmel's conception of sociology: he wrote about the importance of its 'infinitely variable placement' (Simmel, 2007b) in establishing relations between individuals and between individuals and groups. Indeed, he describes the human being as 'the bordering creature' whose situated embodiment shapes and is shaped in every dimension by the spatial and temporal boundaries of existence (Kemple, 2007). In 'The Transcendent Character of Life', one of his last essays, he comments on the double aspect of the human condition both to contain and to surpass itself: 'we are bounded in every direction, and we are bounded in no direction' (1971 [1918]: 355, quoted in Kemple, 2007: 4).

Heidegger, too, can also be seen as a thinker of the continuum. Such an interpretation is proposed by Peter Sloterdijk (2012) through an explication of Heidegger's existential analytic of the 'in' in Being-in (*In-Sein*). Sloterdijk argues that this must be understood in terms *not* of 'being-in something', with its presumption of a homogeneous container space (as water is 'in' the glass, or the suit is 'in' the wardrobe), but in terms of Heidegger's allusion to the Old German verb *innan*: 'What he calls being-in-the world meaning nothing other than to ''inn'' the world in the verbal-transitive sense: to dwell in the world and to enjoy its openness through an initial attunement (*Einstimmung*) and expansion (A*usgriff*)'. According to Sloterdijk, Heidegger does not present *Da-sein* as 'a sort of a being, which is free from being-in, but which at times is in the mood to take up a ''relation'' to the world'. Rather, 'taking up of relations to the world is possible only because, as being-in-the-world, *Da-sein* is as it is'.

As the exploration of the constitutive role of the continuum begins to emerge across disciplines, the mathematical field of topology develops through the study of the properties of examples of such surfaces, including, notably, the manifold. Riemann himself proposed a general theory of continuous manifolds or open-sets to define the curvature of space. This manifold geometry of continual spatial relations was understood by Riemann in terms of a multiply-extended magnitude capable of different measure relations, independent of the three-dimensional ambient of Euclidean coordinates. It was used to demonstrate that spatial structures may change from point to point on a curve, and thus provided the basis for a mathematical understanding of a continuously changing curvature of n-dimensions. What was of interest to mathematicians was how to define the invariance – that which stays the same – in such spaces of continuous transformation. As we noted above, the operations of invariance in topological geometry – ordering and continuity – are, by contrast with Euclidean geometry, more general. Crucially, they mean that invariance and intrinsic change (understood as deformation) are not incompatible; rather they are rigorously inter-related. Put another way, topology is the setting up of spaces of different kinds of order and continuity in such a way as to enable deformation or change, what Massumi (2002) calls the continuity of transformation. Alternatively, we can describe a topological surface as 'a relational field of emergence' (Parisi, 2012; Manning, 2009).

Our claim in this introduction, however, is not simply that topological thinking develops in the arts, humanities, social and natural science alongside mathematics. Rather, it is that contemporary culture is itself coming to display a proliferation of surfaces that *behave topologically*.[2] To support such a claim we might point to 20th-century developments in the gridding of time and space, the proliferation of registers, filing and listing systems, the making and remaking of categories, the identification of populations, and the invention of logistics, all of which Nigel Thrift (2004) identifies as contributing to what he describes as movement-space. As he and other commentators have also observed, software is now so substantially integrated into the dynamics of contemporary culture and society that it is routinely involved in the reformulation of processes, ideas, institutions and cultural objects (Fuller, 2003; Galloway and Thacker, 2007). Thrift describes movement-space as a pre-individual, post-social substrate of guaranteed correlations, assured encounters and unconsidered anticipations, which brings new 'awhereness' into the world.[3] In terms of the account we are presenting here, it is this maximization of relations that makes the analysis of the becoming topological of culture a pressing concern; the imperative is to ask: how are capacities for change being rendered legible, how are they being mobilized, and with what effects?

To do this it is helpful to begin to augment this historical account of the emergence of topological culture. Alongside the tendencies listed above, we would want to propose the increasing significance of practices of mediation (Serres, 1995; Latour, 2005). We can start, for example, by considering the changes befalling the various kinds of 'borders' or 'frames' (window, screen, mirror and interface) that mediate social and cultural experience. A basic definition of the frame in media theory is 'a window that opens onto a larger space that is assumed to extend beyond the frame' (Manovich, 2001: 80); alternatively, the frame may be said to connect and separate 'two absolutely different spaces that somehow coexist' (Manovich, 2001: 95). One of the key implications of Deleuze's work on cinema, however, was to consider the frame itself as dynamic, that is, as a constantly changing articulation of the continuum. As Deleuze and Guattari put it: 'Frames or sections are not co-ordinates; they belong to compounds of sensations whose faces, interfaces, they constitute' (1994: 187). In this view, the 'borders' or 'frames' of mirrors, windows, screens and interfaces have become surfaces of sensation themselves by operating the opposition between inside and outside in a dynamic re-making of relations to each other. In this framing there is a loss of the fixity, distance and perspective that went with the classical division between subject and object, as Scott Lash (2012) makes clear.

Let us give some more examples of how the frames of mediation have come to produce topological spaces. In Beatrice Colomina's (1996) discussion of the use of the horizontal window by Le Corbusier, for example, she argues that whereas the vertical window produces an impression of a complete, three-dimensional external space from the inside-out by giving a sense of perspectival depth, the horizontal or landscape window frames a new space, a planar projection 'sticking to the window'. Any building that Le Corbusier might create in relation to the space of such a window could be understood as a mechanism for classification since a building designed to have horizontal windows, as Colomina observes, is a building that 'collects views and, in doing so, classifies them. The house is a system for taking pictures. What determines the nature of the picture is the window' (Colomina, 1996: 311). As she notes, for Le Corbusier, 'to inhabit' the inside-out space of the building produced through the frame of the horizontal window was equivalent to inhabiting a camera.[4] In this way, Colomina places the shift in architecture associated with Le

Corbusier in relation to the ways in which one of the cultural forms identified by Kracauer as having an affinity with the turn to the surface, photography, contributes to a representational and epistemological break with perspective. Photography, Colomina suggests, makes everything contiguous and equivalent (see also Lury, 1996).

Along the same lines, the art critic Rosalind Krauss (1972) describes the pictorial frontality of Le Corbusier's drawings of buildings in terms of the wedging together of objects in a space of pure extension. Rather than edges being used to indicate the depth and discrete separateness of objects, continuity is established between them through what the Purists called a 'marriage de contours'.[5] This 'marriage' – in which one object is brought into relations of contiguity with another in a dynamic framing – is also to be found in television. Mary-Ann Doane (1990), for example, argues that television's 'greatest prowess is its ability to be there', by which she means 'both on the scene and in your living room', and that this '"being-there and here" goes on at the same time, in that quasi-simultaneity to which I have referred'. In this view, the television screen is a 'covering' of the split between here and there, of the outside of the world and the inside of the home; a surface that, nevertheless, does not refer back to a separation between reality and appearance. On the contrary, the television screen is a covering or surface that, as Doane remarks, gives 'shape, contour and figure' to the separation.

Television is conceptualized here as a function, a mapping, or relation of connection, hence a space of topological mediation.[6] If, for William Uricchio (2005), '[t]he idea of the medium, explicitly, invoked in terms like "television" and the German word for television, "Fernsehen", was about the extension of vision in real time', for Samuel Weber (1996) television confounds the points of reference that allow the viewer's determination of what is near and what is far, what is now and what was then, what is connected and what is disconnected. In their place, the television screen is an active surface of coverage or co-ordinatization: television does not extend vision in the sense of capturing the object of sight and then transmitting it (re-presenting it); rather, it is a space in which object-images are animated or brought to life in continuous movement, the continuously changing space of the screen. Indeed, this is only another way of describing television's widely recognized spatio-temporal organization, that is, its articulation of presence, contingency and immediacy, or 'liveness' (Williams, 1974; Marriott, 2007; Auslander, 2008). In this conception, television is a regime of image that is not static but continuously regenerated in cycles of scanning (Parikka, 2011). This allows, as Maurizio Lazzarato puts it, 'sets of elements, affects, organs, flux and functions . . . [to] operate on the same level' in such a way as to cause "subjectivity" . . . [to find] itself simultaneously on the side of the subject and on the side of the object' (Lazzarato, 2006; see also Lury, 2007).

This spatio-temporal configuration of liveness is by no means limited to television, but is, rather, characteristic of contemporary media more generally, contributing to the rise of what Eva Horn has called the *'medial a priori'* (2008: 8). Katherine N. Hayles refers too to 'the movement of computation out of the box and into the environment' (Hayles in Gane et al., 2007: 349), while Parisi writes that 'information is not transmitted between the environment, body and machines, but an entire ecology of information sensing is at play in the movement of transmission between channels' (Parisi, 2009: 188). This increasingly pervasive – ubiquitous – organization of liveness has significant implications for how politics is being reconfigured. Consider, for example, Judith Butler's description of the ways in which the spatio-temporality of politics is being re-constituted in the 'occupy and assemble' movement of 2011. The relation between the 'scene' of action and the media is not only one where the media give visibility to the scene, but one where the media are part of the scene and action, indeed *are* 'the scene or the space in its extended and replicable visual and audible dimensions' (Butler, 2011). For Butler, mediation not only extends the scene visually and audibly but also participates in the 'delimitation and the transposability of the scene' within a new continuum that spans and connects multiple locations, producing a relationship between the local and the global as the recursive unfolding of a surface of connection. In this context, the bodies carrying the camera, audio-recorder or cell-phone become the frame or border between the scene and the media, included and excluded at the same time and because of this vulnerable to the violence of the state.

But our argument does not presume that the emergence of topological culture is confined to media of communication alone. Our proposal is that it is also emergent in the un-co-ordinated or rather, not externally co-ordinated, activities, relationships and mobilities of multiple actors, infrastructural systems, and networks. We acknowledge here the work of political theorist Etienne Balibar (2002), who argues that borders are no longer to be found only at the edges but also in the middle of territories. And this is the argument taken up by Mezzadra and Neilson (2012): they argue not only that borders are in the middle – in and of mediation – but also that borders do not operate only through the binary opposition 'open and closed'. Borders, they say, are 'parameters that enable the channeling of flows and provide coordinates within which flows can be joined or segmented, connected or disconnected'. In describing the operation of such borders, Mezzadra and Neilson further identify the creation of a constituent excess of inclusion over belonging, an excess which, they suggest, contributes to the proliferation of subject positions, including that of the so-called 'irregular' migrant. Neither fully insiders nor fully outsiders, irregular migrants are, they argue, included in the space of labour markets and citizenship but are not able 'to share the ''belonging'' (the legal status) to which a whole set of rights correspond'.

In Penny Harvey's (2012) description of large-scale road construction programmes in Peru, we can similarly see how diverse practices of relationality and connectivity are mobilized in the production of state space, in this case though by way of the infrastructure of roads rather than through the operation of borders. Harvey's analytical framework calls particular attention to the ways in which the differences and discontinuities in the spatio-temporal relations of roads can be considered as 'intervals' that both separate and connect across time and space. What she is able to show with this framework is that 'state-space' and 'territory' are not co-terminous, but, rather, are put in multiple relations with each other. In Harvey's analysis, as in Mezzadra and Neilson's, state space is found to be organized in terms of variable openness, that is, it is simultaneously grounded and mobile, continuous and discontinuous, specific and generic.

In Harvey's contribution, topology is mobilized as a framework of analysis. This is also how Mike Michael and Marsha Rosengarten (2012) begin their contribution to this issue. Identifying three characteristics of topology, they suggest, will help them describe two enactments of HIV – the UN's AIDS clock and clinical trials for an HIV biomedical prevention technology – pre-exposure prophylaxis (PrEP). These topological characteristics are: space and time are not external frameworks but are emergent; points (which might be entities or events) that are distant can also be proximal (categorically as well as spatially and temporally); and transformations of the relations between points are not causal or linear, but open and immanent. As they observe, topology understood in this way affords a number of supplements to the conventional sociological accounting of globalization processes. In the particular case of their examples, a topological conceptual framework enables them to show that while the HIV interventions they describe are enacted in global terms they are met with, and become mediated by, localizing contingencies which themselves draw from globalizing resources. At the same time, however, as their contribution proceeds, they also point to the ways in which a topological sensibility 'allows for a more complex relation to such an analysis – one which reflects upon (or rather inflects with) the enactment of the very categories (of global/local) that the analysis purports to topologize'. Thus, they begin to explore how topology is never simply either the object or the means of study, but is always folded into itself. Indeed, it is this dynamic, recursive onto-epistemological relationship, so we suggest, that is one of the characteristics of the becoming topological of contemporary culture. It provides the basis for the view that topological culture is a form of practical abstraction (Toscano, 2008).

In another exploration of topological dynamics, Evelyn Ruppert (2012) argues that the use of 'joined-up' databases in government policy transforms government logic and the conception of the subject. Thus, in contrast to a national imaginary of state and society informed by a topographic logic (in which, for example, the census produces the fiction of the nation as a finite, unified, homogeneous whole in terms of the addition of discrete households or individuals: $1 + 1 + \cdots$), Ruppert shows how New Labour's Transformational Government strategy aimed to identify individuals in terms of open-ended categories such as 'poverty plus'.[7] The ambition was to be able to place individuals on a continuum of needs, which in turn was to be mapped onto 'responsive services'. It was held that it was only by connecting and recursively integrating individuals, needs and services in this way that, for example, a child in need or potentially at risk could be made visible. While Ruppert is keen to show the ways in which this transformation was contested, she also argues for the significance of an imagined topological configuration of state and society in which the imagined collective or 'whole' is neither homogeneous nor unified but is, rather, produced as heterogeneous, as internally differentiated and always changing but somehow still finite.

In these and many other cases, we suggest, a topological ratio can be seen to be emerging in processes of mediation. The effect is to produce a continuum that not only enacts the scalar entities of the 'local', the 'national' and the 'global' but also puts them in multiple relations to each other. In the terms introduced by Sloterdijk, the multiplicity of relations does not simply happen *in* the in-between but rather operates a topological continuum *of* the in-between.

Auto-spatialization

To develop further our analysis of the topological forms of contemporary culture, this section seeks to develop a notion of auto-spatialization. This is a term we take from the work of philosopher Gilles Chatêlet (2006), who describes a renewal of the notion of indexation in what he describes as graphic reason.[8] Auto-spatialization refers in Chatêlet's work to a changed relation between indices and that to which indices are supposed to point. In 'classical' mathematical calculation, he argues, a set of indices was neutral: indexation remained external to the development of calculation. Indices were operated as if notation was completely indifferent to that which it noted. In 'contemporary' calculation, he proposes however, notation is becoming concrete: indexation is no longer determined by an external 'set' (of numbers or data) but by a process of deformation in a surface that is itself in motion. Indexation is no longer reduced to the external evaluation of a collection or set, he says, but becomes 'the protagonist of an experiment which secretes its own overflow' (Chatêlet, 2006: 40).

What this suggests to us is that it is important to look at changes in the semiosis of contemporary culture, that is, changes in processes of abstraction and translation, of proportion and participation, ordering and valuing, sensing and knowing. Our suggestion is that there is currently a transformation in the operation and significance of the indexical in contemporary culture (Lury, forthcoming). So, for example, in relation to the inter-related processes of making of science, state and society, a wide variety of commentators have argued that the use of indices in metrics has historically been supported in various ways, by complex sets of social relations and technologies, often enabling the entities they produce to travel great distances in stable form (to be transmitted as immutable mobiles in Latour's (1987) terms). The movement of such entities – or the transmittability of what was indicated – has historically required the use of indices in ways that enabled them to make references in relation to objects as if they were indifferent to those objects. In contrast, many of today's indices, such as the derivatives of the financial market, the indicators of behaviour employed in the joined-up databases of government, and the algorithmic operations of the software programs that help comprise Facebook and Google, are implicated in transitive relations to an active or dynamic object or environment.

This is a relation in which epistemology and ontology are re-configured. The usefulness of one of the most important capacities of indices – to point, to indicate 'here' and 'now' – a usefulness that has been limited by the grounding, stabilization or territorialization of the fixity of the co-ordinates of the relations they have been used to enact, is now being deliberately animated. This animation, in for example, 'live' data', is a consequence, in large part, of the introduction and operation of dynamic feedback loops, and the extension of their significance by their use in diverse, iterative and automatic information processing systems, supported by multiple sensory memory systems (Thrift, 2008). The transformation of indexation described by Chatêlet thus follows, we suggest, the movement of information and communication technologies into wider circulatory practices of ordering and coding, of representing and regulating difference. Indices in such feedback loops refer to and produce not static or inert space in which fixed, closed objects move or are transported, but a space in movement.

For C.S. Peirce, indices are signs that use some physical or existential continuity with their objects to direct attention to that object. This capacity draws on the two components that are necessarily part of any act of signifying for Peirce: the sign-object relation and the sign-interpretant relation. The indexical act of signifying, he says, consists of a sign that signifies its object by using some physical or existential continuity (sign-object relation), and generates a further sign to signify that object (sign-interpretant relation). That the interpretant need not be a person but can be another sign is obviously significant in relation to the proliferation of the automated recursive systems mentioned above, and to the possibility that the ordering of sequences of indexes afford for the emergence of what might be called epigenetic surfaces (Kwinter, 1992). What is perhaps most significant here, however, is that, in the dynamic surfaces that are spaces in themselves, indexical continuity need no longer operate only extensively (that is, in terms of extensive distance, of nearness or farness) but may also take place intensively, as they are, for example, put to work in the three topological operations that Michael and Rosengarten describe.[9]

The notion of auto-spatialization as we invoke it here is thus an attempt to point to the new productivity of the storage, transference and relay of metonymic traces in time and space. To explore this further we take inspiration from Steve Brown's (2012) discussion of the importance of understanding memory in terms of mathematical space. Brown discusses the limits of the concept of the virtual in terms of its inability to account for memory in terms of spatio-temporal actualities. To make good these limits he focuses on the potential of Kurt Lewin's use of topological space for a psychological understanding of memory. However, we see this mathematical understanding of memory, defined by thresholds of transition and two-way relations, as also relevant to an understanding of the expansion of the capabilities of the index and the resurgence of the archive in contemporary culture. That is, the topological space of memory outlined by Brown helps describe how the digital archive has become an operative construct whose recursive connections produce a range of experiential spatio-temporal actualities. In such archives, data storage, organized by way of addresses, need no longer be physically located, grounded in a fixed space, but instead is constituted in indexical processes of de- and re-attachment of data, a continuously changing surface of searchability (Parikka, 2011). In relation to archives and other memory spaces organized in this way, the expansion of the actuality of the present described by Helga Nowotny (2002) emerges, variously, as now-ness, anticipation, the predictability of the present, and real-time.

As a second example of auto-spatializing processes, we would point to transformations in the relation between models and physical objects that take place within the calculative background described by Thrift. In this case, there is also a move away from the simulation of existing physical space towards the deployment and exploration of the continuous and changing surface that is space itself. More specifically, the shift towards interactive algorithms, evolving software, responsive and affective computing has opened up the operation of axiomatics – that is, statements that do not derive from or depend upon other statements, which may be mathematical but may also be social and technical, including for example, contracts and protocols. For example, by gathering data from physical space and letting a program run, computational design has shown that space may engender itself through the continuous interaction of variable parts. The axioms of such programs are, as it were, directly responding to the environment.

Far from being projections within the grid of Euclidean coordinates, computational models are instances of the auto-orderings of matter, as the model takes material contingencies to transform its set values and adapt to new ones. In such models, points, as philosopher and designer Bernard Cache (1995) suggests, deflect from linear trajectories and rotate on themselves like a dancer, whose body continuously swerves in order not to fall. Using this kind of modeling process, Cache has designed and built not objects but objectile structures generated through the rotation of lines. In such models, the space of change is a plane of continual variation in which the model is merged with matter. The computation of urban data provides another example of an algorithmic mode of planning defined by 'an extended apparatus of prediction able not only to establish the condition of the present through the retrieval of past data, but also, and significantly, to change these conditions according to data variations immediately retrieved from the environment' (Parisi, 2012).

Indeed, instead of models, it may be more useful to speak of what Felix Guattari (1977) called 'meta-models'. Arguing against the notion of the model as a structure of representation defined by prototypes, inherited patterns or blueprints, Guattari devised the notion of meta-models to acknowledge the auto-gestation of signs and objects of a non-verbal or non-discursive kind. Examples include practices of auto-modeling, appropriating parts of a model to construct new cartographies of invisible connections and diagrammatic conjunctions. Connections here are not only relations between objects that already exist, but also connections between possible (but not yet existing) objects, described by the invisible contacts established between deterritorialized indices. In her contribution to this issue, Parisi suggests that, far from establishing a continuous feedback or irreversible function whereby software takes command over urban behaviour or the latter acts back on the program, the sequential running of algorithms instead exposes an incomputable quantity of rules to an infinite quality of behaviours, leading to un-provable and un-applicable spatio-temporalities. In Parisi's view, the digital design of time and space is not only controlling or pre-empting the emergence of events, but also unleashing random events or unlived worlds into urban design. From this standpoint, the topological surface of contemporary culture does not simply enliven or generate connections, but, rather, is defined by auto-spatializing algorithmic patterns.

For Guattari, meta-models point to the invention of transdisciplinary methods that are able to borrow ideas and things from non-unified fields so as to produce novel concepts that have the capacity to change the understanding of existing problems. In other words, meta-modeling is not only a concept but also a method, able to address the changing conditions of problems without having to refer to subsisting dimensions. For Guattari, meta-models deploy an auto-generating topological surface equipped with its own system of reference and its own variations.

A model is merely the partial image of an auto-productive space that signs and things can create beneath and through the system of representation. Meta-modeling therefore can also be understood through another of Guattari's concepts: the notion of the diagram that he borrows from Peirce, perhaps the fundamental trope in Chatêlet's graphic reason (see also Rotman, 2012).

Diagrammatics stands for the a-signifying or signal-ectic semiotics that describes the processuality of signs and not their position on a structural grid. For Guattari, mathematics, computer encoding, economic functions, art and music are all instances of diagrammatics. They are processes in which ideas, intensities, functions are transmitted without having to pass through a structure of (symbolic) signification. Diagrammatics indeed establish a direct connection between form and matter, signs and objects (Guattari, 1977: 281): an immanence of relations that creates curves in the surface of spaces in themselves. The reciprocal relation between material fluxes and the semiotic machine (Guattari, 1977: 281) therefore corresponds to an auto-modelling surface. This is precisely a topological space in that it is a space defined by relations or the infinitesimal points running between objects. This relational space is not, however, constituted by voids or gaps but is rather a constantly changing space whose movement is described by infinitely small particles occupying what looks like an empty interval, but is in reality a threshold of change, at which one geometrical surface is knotted into another and another: a möbius strip of invariants transforming lines and points into curves and joints linking one plane to another.

A third example of auto-spatializing processes is networking. In this case, the links with topology are obvious. Networks typically deploy a branch of topology that draws graphs composed of two elements: nodes and connections between nodes, or edges. In such graphs, linking is a recursive and nonlinear process that produces emergent patterns or forms of organization. When applied in computing, network topology is essentially concerned with classifying patterns of interconnections between computers, but it is by no means so restricted: it has found rich potential for application not only in informatics, but also in biology, warfare and the social sciences (Wuchty et al., 2006; Arquilla and Ronfeldt, 2001; Christakis and Fowler, 2009). In other words, the space in itself that is constituted in network topology is the space that increasingly defines the cultural dynamics of hyper-connected societies.

In this regard, networks may perhaps be considered as a special case in the becoming topological of culture. While social and political theory first singled out network topology as the defining form of the complex organizational changes affecting the composition of capital and labour at the turn of the 21st century (Castells, 1996; Hardt and Negri, 2000), it soon became clear that it did not only mark a re-organization of economic production. As a result of the exponential socialization of personal computing, diagrammatically governed by internet protocols (Terranova, 2004; Galloway, 2004; Galloway and Thacker, 2007) and, more recently, by means of the extension of internet connectivity to a wide range of devices endowed with micro-processing and communication capabilities such as internet TV and radio, tablets, and smart phones (Raychaudhuri and Gerla, 2011), digital social networks are increasingly coming to determine the formation of what Bernard Stiegler (2008) calls 'new relational circuits of transindividuation'. These circuits comprise one of the most glaring examples of topological space in contemporary culture.

In his contribution to this issue, Richard Rogers (2012) identifies four distinctive spatializations, or what he terms political geometries, produced in the mapping practices of the web over the last 20 years. In the 1990s, or as he calls it, the 'web as hyperspace' period, 'links on websites propel so-called cybernauts into other dimensions'. The mapping of hyperlinks highlighted the importance of the politics of association within network topologies and demonstrated that they could no longer simply be assumed to correspond to the early typology of centralized, decentralized and distributed networks. On the contrary, selective link-making 'creates space ... as demarcated and shaped by limited acts of association'. During the second period, the 'public-sphere or neo-pluralistic period', the web is conceived as a 'great conversation' to be mapped thematically. Websphere analysis, however, had to face new auto-spatializing processes emerging from the increasing centrality of search engines in organizing the political geometries of the web – and their limits in mapping alternate spaces such as those generated by practices of commenting, tagging and so on. In these practices, spheres were increasingly co-constructed by engine algorithms and site owner behaviour, enacting the web as a series of sub-spaces such as, for example, the websphere, the blogosphere, the newssphere or even the tagosphere (folksonomic spaces). As Rogers put it, the study of the politics of web space became cross-spherical. In the third period, the web is mapped as a set of social networks or as a space 'that could show a social network'; 'clusters of actors' are linked with 'issue spaces', revealing their co-constitution, while in the fourth and current period, we are witnessing a mutation in web topology introduced by the diffusion of locative technologies. This is not the 'grounding' of users in physical space, but the construction of network actors as always only temporarily based, 'travelling physically from event to event' (Rogers, 2012; see also Mackenzie, 2010).

Across all these periods, net-mapping practices construct a range of possible topologies in which form (the pattern of relations between points) enables function (the speed by which certain elements flow from point to point, the kinds of actions that networks find easier to perform, including evaluations of how different networks can be 'punctured' or cut) and function dynamically defines the qualities of relations in terms of, for example, density and direction of connections within a centre/periphery polarity (Christakis and Fowler, 2009). Digital social networks, then, are topological actualities in which culture is increasingly defined and produced out of the in-betweens of digital databases that are themselves continuously being remade within the multiple relational circuits of technical-geographical milieus. From this point of view, digital social network topologies exceed the common representation of networks as two-dimensional graphs composed of nodes and edges and instead are continually taking shape in a variety of topological forms, such as the globes, spheres and foam described by Sloterdijk in his account of the processes of techno-social trans-individuation. The dynamic recursiveness of processes of sharing, linking and modifying of internet objects (text, video, sound and software), the circulation of the social quanta of beliefs and desires (Tarde, 1903), and their implication in processes of subjectivation constitute the multiple spatio-temporalities of contemporary culture through their ordering in topological continua.

Network topology further confounds the distinction between inside and outside by folding into the subjective techno-bubble which human subjectivity (or the anthropological stratum of the human) keeps drawing around itself. From the folded interiority of the hyper-connected, multiply-screened homes of US suburbs described by Nicholas Mirzoeff (2005) to the mobile, tethered, psychological bubbles drawn by cell phone and digital social networks enveloping the affluent US teenagers described by Sherry Turkle (2011), network subjectivities emerge as split between the discrete and the continuous. On the one hand, the social appears to be constituted by individuated, infolded envelopes, enclosing the world of social relations from a specific point of view, and relating to each other only through the mediation of (internet) objects. On the other hand, there is the production of foam-like forms of sociality, a cavernous social world of interconnected, open monads, trans-individuated by diffuse, differential processes of imitation and invention. *More geometrico*, then, the web maps charted by Rogers open onto a new kind of hyper-Spinozist topological ethics of affective composition, which is at the same time a neo-monadology of trans-individuation. If the ‘common’, as Hardt and Negri have recently argued, is the framework through which to break the ‘epistemological impasse between the universal and the particular’, then we could argue that it will be ‘common notions’ emerging out of this networked topological ethics of composition that will determine the trans-individuation of the ‘revolutionary assemblages’ opposing neoliberal capital today (Hardt and Negri, 2009: 120, 340–4).

Mathematics, Relations and the Problem of the Continuum

What understanding of mathematics is at issue in the account we have been giving in this introduction? For some, most notably for Alain

Badiou (2005), mathematics is itself ontological, or better it is the purest form of ontology to the point where he can claim that mathematics is ontology and ontology is mathematics. In contrast, in this introduction, we are suggesting that rather than being equivalent to ontology, topology is a socio-technical field of practical abstraction in which the possibility of new relations between ontology and epistemology are emerging. And such relations – to be found in, for example, the changing role of indices or movement of models into the social world – are what is producing a topological culture: surfaces that are spaces in themselves are not only self-organizing and emergent, but their self-organization brings being and knowing, ontology and epistemology, into new kinds of relations. Indeed, this is the transitivity described by Sloterdijk in his discussion of Heidegger above. For this reason – to acknowledge some of the problem-spaces of this transitivity, but also to indicate the variety of approaches to topology within mathematics – what follows now is a brief overview of some of the developments in mathematical history that have been significant for both social and cultural theory *and* the practices in which the continuum emerges.

This short overview is thus not intended as a summary, but is, rather, a sketch, a pathway, organized – initially at least – by reference to the problem of the continuum. We believe this problem is a useful focus here since, as we note above, it is a locus for the question of how to think – and do – relations. Indeed, we would suggest both that the theorem of the continuum is at the core of topological thinking, and that the becoming topological of culture provides the terrain for some of the most interesting thinking about the problem of the continuum today. This theorem can be presented in terms of the question: what does it mean to think the space between two points as a continual surface of relations? Then, should we think of the continuum as the space of relations either as a differential that exceeds the entities it relates in the direction of the infinitesimal (that is, the smallest points between terms) or as being decomposed into set-points? The first approaches the problem of the continuum in terms of relations of differentiation and integration, while the second deploys an understanding in terms of the relationality associated with discrete point-set topology. The former explores the possibilities of relations of transformation, continuity or continuousness in terms of continual variation. The latter develops a notion of the continuum through the explication of 'pure' discreteness as expressed, for example, by the concept of the whole number. In this second approach, it is the very distinct-ness or discrete-ness of objects (of points, numbers or entities) that is what allows for general relations of invariance to be established. In this section, we chart a way through the complex mathematical field of topology by mapping these two tendencies, since they are of special relevance to the understandings of topology in social and cultural theory.[10]

As previously mentioned, a topological surface can be seen as an instance of Riemann's manifold, a non-standard geometrical figure that he defined in terms of spatial relations and not by reference to points in space (see Boyer, 1989: 545–7). More precisely, Riemann's continuous manifold explained how space was a kind of patchwork of local spaces. He thus provided a framework by which to map the locally Euclidean structure of neighborhoods without an a priori global Euclidean map. On the contrary, each point in a surface has a small neighbourhood, which can correspond to a Euclidean space, but the manifold of which the point-neighbourhood is part, does not. The Riemannian manifold thus describes the multidimensionality of a curved – or constantly curving – space specified by way of its relationship to other spaces. Importantly, for our argument, the Riemannian manifold is the mathematical description of the dimensions of a space that is not reducible to the physical arrangement of points according to fixed coordinates. Alternatively put, in this understanding, space is described in terms of differential continuity, the specification of which results in the mathematics of a variety of continuous or discrete manifolds. Indeed, so conceived, the space of the manifold anticipated the field of algebraic topology which approaches the continuum theorem by way of a concern to describe all possible continuous relations between sets.

If this tendency within the mathematical history of topology approached the theorem of the continuum by emphasizing the infinite and differential character of the relation, the other tendency we discuss here explains the problem of the continuum in terms of empty sets. For instance, Cantor's *Contribution to the Theory of Manifold* (1878) sought to establish a formalization of the mathematical invariance of dimensions (Crilly and Johnson, 1999: 8). Cantor rejected Riemann's infinite-dimensional topology, according to which a function could possess an infinite number of points of discontinuity that could nonetheless be integrated, starting from the general level of differential relations. Instead he worked with the hypothesis that a different type of infinite sets could exist in a higher dimensional space or plane (Crilly and Johnson, 1999: 5). Cantor was looking for topological invariance determined by infinite sets as opposed to the general continual variations of manifolds as spatial curvatures.

Of particular interest to the cultural and social theoretical articulation of the continuum is Cantor's notion of the 'limit point'. Cantor defined every infinite set of points in a bounded region of n-dimensional space as possessing at least one limit point. According to Cantor, the limit point (or accumulation point) is internal to the set but is not the same as the set: it is a point that can never be reached but nevertheless can be mathematically described as being internal to the set. A limit point so defined can thus for example correspond to a variable that, despite being indeterminable in an absolute sense, can be determined as existing within a set of given values. It is thus central to how the border or boundary is to be understood (in terms of inclusion and belonging, and also in terms of internal and external relations) in mathematical terms. For example, Sha (2012) describes the limit of the open set as being undefined and yet a margin. In his account, the restriction of access to a movie theatre for people aged between 13 and 17 becomes a flexible edge, which nonetheless can establish that people almost 13 can be included as 13.

In other words, for what has come to be known as point-set topology, the continual relation between points does not depend on the differential ratio of the relation, but is instead conceived as another set of points. Against all forms of experiential intuition, point-set topology, derived from Cantor's actual infinities, defines curvatures – or manifolds – as sets of ordered n-tuples of numbers.[11] Cantor's set theory therefore defined a way in which operations on discrete entities (discrete sets of numbers) could be used to explain continuousness. More specifically, continuity is granted by the empty set – a discrete void – that is divorced from any specific instances of the set. From this standpoint, as Badiou has made clear, there can be no over-arching one, totality or whole that can explain or contain all. For Badiou (2005), within this empty one, there is, however, multiplicity to the extent that a proper name can never exhaust the infinity of the set. In this way of thinking, defining, for example, a group of people as multiplicity (in terms of, for example, inclusion and exclusion) cannot be done by categorization or reference to the specific characteristics of its members, but must be achieved by the operation of the group as an empty set.

But this is to jump ahead. At the turn of the 20th century Henri Poincaré, who famously claimed that set theory was the disease of the 19th century, put set-topology or the problem of the mathematical formalization of the continuum, into question.[12] His study of combinatorial topology focused on the intrinsic qualitative aspects of spatial configurations that remained invariant under continuous one-to-one transformations. So, for example, a circle is said to be topologically equivalent to an ellipse insofar as the dimensionality of their space is a topological invariant. Alternatively put, Poincaré was able to show how a function of continual deformation from a spherical into an oval form could be described without the need for puncturing or tearing, that is, without the necessity of making a cut or establishing a finite point or the operation of discrete entities. According to Poincaré, topology could and should thus be concerned with the qualitative rather than quantitative aspects of mathematics: the qualitative integration of differential equations, he argued, would define a topological continuum more effectively than discrete set-topology.[13] Indeed this is the position outlined by Rotman (2012), who argues, in implicit contradistinction to Badiou, that point-set topology remains restricted within its own ontological premises in mathematics. For Poincaré, the uniform continuity of 4-D manifolds was to be explained in terms of qualitative transformation and infinitesimal connectedness of the sets or states of experience rather than by discrete spatio-temporal sets isolated from one another.

Poincaré's topology re-introduced the study of qualitative properties and continuity into the theory of discrete or finite groups. In this way of thinking, the relation is not defined by finite points of determination or integration (nodes, dips, focal points and centres), but is, rather, determined at another level, where these points are part of a field of vectors (continual tendencies of a line) that encompass them all. Among other contemporary writers, Manuel DeLanda (1991) has used this notion of a vectorial field of forces to describe the quasi-historical relations that led to the birth of capitalism as well as to explain how the military machine embraced the calculation of the movements of a target on the battleground in terms of vectors. More recently, DeLanda (2006) has adopted this topological understanding to discuss 'the social' in terms of assemblages of differential relations.

Yet, as already suggested, the necessity of discrete entities to the explanation of the relation and the mathematical theorem of the continuum remains contested in contemporary mathematics. Indeed, the articles included here adopt different positions in relation to the mathematical problem of the continuum. For Xin Wei Sha (2012), for example, topology is not a tool for measuring social relations but a poietic articulation of cultural dynamics, a materially situated articulation of culture. He proposes that topology itself needs to be understood as a mathematical index of lived experience, of a mathematics unwilling and unable to dissociate liveness from culture. This is a mathematics 'even more primordial than counting' (Sha, 2012).

Through a close reading of point-set topology, Sha argues that behind the notion of the open set is the concept of openness. A topological space defined in relation to the notion of openness is, he suggests, able to articulate changes of states by way of vector spaces or spaces of transformation, without reference to metric numbers and dimensionality. One of the examples Sha uses to demonstrate this is the flow of people through the US Bureau of Immigration Center at Ellis Island, New York. In his terms, this flow is an infinite set of life courses clustered around a limit, in this case, the event of passing through Ellis Island. The topological concept of openness, he suggests, can be used to colour 'the life courses that run before and extend beyond this event according to some particular grouping'. For Sha, it is connectedness that explains how transformation can occur from one set or group of people into another, and it is connectedness that underpins the notion of topology, which he deploys to account for the felt experience of continuity. For Sha, topology is simultaneously both a concept of continuity corresponding to a quality of lived experience and a (mathematical) description of this experience. It is a method of cultural analysis that exposes mathematics to a non-metric and non-discrete articulation of experience: a poiesis of matter.

Brian Rotman (2012) also shares Poincaré's view of topology, but for different reasons than does Sha. Against the discontinuity inherent to digital models, Rotman argues for a mathematical view of topological space based on analog transformations. He rejects point-set topology and instead suggests another mode of conceiving the mathematics of topology. Through a close investigation of categorical thinking, Rotman appeals to the diagrammatic language of arrows and configurations of arrows. For Rotman and others, diagrammatic thinking is diametrically opposed to the purification of formal language carried out by the 1930s Bourbaki group. With the intention of cleaning mathematical language from paradoxes, this group purged notation, definition, construction, diagram and ultimately any processual thinking from mathematics. Against this Puritanism of mathematical thought, Rotman asks: how does language understand mathematics? In other words, what are the categories that subtend formalism? Far from being defined in terms of discrete objects, Rotman conceives of categories in terms of objects and arrows, or composition and equality between arrows.

As is Sha, Rotman is thus critical of the static structuralism of set theory, but he puts forward a contrasting alternative. Sha rearticulates the notion of openness in the open set to maintain a rigorous yet anexact mathematical method: a poieis that articulates cultural dynamics and experience. In other words, Sha reinvigorates mathematics from the point of view of the openness of open sets. Rotman instead does not seek to rescue set theory but rather takes arrows to be the primitive terms of schemes or dynamic structures, clearly defined by external relationality. In this way of thinking, it is the outside that *produces* the inside and thus there is no recognition of any sense of belonging to a primordial set, even an open one. Rotman's categorical thinking aims here to expose the limits of mathematical thought as an autonomous enterprise. Instead he suggests that mathematical objects 'are never isolated individuals' because they 'are structurally akin' to other 'species or families of related objects' (Rotman, 2012). Ultimately Rotman is proposing a diagrammatic thought of things in movement. Whilst sharing with Sha the desire for topology to be understood in terms of dynamics, Rotman more explicitly argues for a structuralism of becoming that is a step away from mathematical definitions. His antipathy to mathematical formalism leads him to argue that (mathematical) topology is but a mode of thought in which multiple interconnected levels are being deployed in the service of an analytic physics of culture.

As these examples suggest, despite our identification of two tendencies in mathematical topology, any simple opposition between a topology of continuity and a set-topology of discontinuity or between discrete and continuum, digital and analog, can only be misleading. Indeed, the opposition is put forward here, not as a fixed contrast, but as a way of pursuing the problematic of the continuum, with the aim of understanding what is at stake in modalities of relations, of inclusion and belonging, and the constitution of entities. For us, what the internally divided mathematical field of topology offers for social and cultural theory is the possibility of describing a double condition in which the maximization of relations constituting topological culture may be at once experienced and not experienced. This is also the argument of Lash (2012), who discusses topology in terms of set topology, the infinity of infinity, or the openness of the open set. More specifically, Lash (like Brown, 2012) suggests that unlike Deleuze's notion of the virtual, which is beyond experience, topology can be understood in terms of figures, which enable the analysis of the deformation of one actual entity into another in terms of particular topological properties. Topology is thus at the twisted intersection of the mathematical and the empirical realms for Lash. With topology, he suggests, it is possible to explain how the lived experience is able to go beyond itself: a lived deformation.

Lash, like Rotman, embraces the critique of formalism, but, in contrast to Rotman, suggests that both set-topology and Poincaré's manifold continuum offer a defense of the figure. However, whilst Badiou's appeal to set theory and indirectly to set-topology ends up proposing an infinite temporality, a trans-infinity beyond experience, Lash instead insists that topological figuration deals with experience or empirical surfaces (Lash and Lury, 2007; Adkins and Lury, 2009). From this standpoint, Lash complicates our reading of topology by arguing for a transcendental-empirical double, which at once includes mathematics and experience, a form of practical abstraction, constructing its own space-time. And while Rotman insists upon the importance of the diagram, so the notion of the imaginary is important to Lash, who uses it in contrast to both the symbolic and the real. The imaginary describes 'something invented' (Castoriadis, 1997: 127), whether this refers to a 'sheer' invention ('a story entirely dreamed up'), or a slippage, a shift in meaning in which available symbols are invested with other significations than their 'normal' or canonical significations. Above all, the imaginary is 'the capacity to see in a thing what it is not, to see it other than it is' (Castoriadis, 1997: 127).[14]

Deformations of Control and Critique

In relation to the becoming of such a topological imaginary, the issue of what a number of contributors to this issue understand as method becomes important. Importantly, attention to this issue does not fail to address what Allen calls 'topologies of power', that is, the ways in which the abstract materiality of topological rationality is itself 'imbued with power', since, as Allen says, 'proximity, distance and reach are inseparable from the practices of power which define them' (Allen, 2011).[15]

In their advocacy of the border as method, for example, Mezzadra and Neilson (2012) explicitly challenge the view that method is 'a set of pregiven, neutral techniques that can be applied to diverse objects without fundamentally altering the ways in which they are constructed and understood'. They assert that border as method is more than methodological, and argue that it is a matter of politics: 'To put this differently we could say that method for us is as much about acting on the world as it is about knowing it. More accurately it is about the relation of action to knowledge where many different knowledge regimes and practices come into conflict'. Noortje Marres also provides a discussion of topological method, what she calls the topological expansion of the frame as method. She too is interested not only in how it is that topology may be used to perform the epistemic work of rendering legible relations among entities and the ontological work of actually bringing about such relevant relations but also, like Mezzadra and Neilson, with the politics of how both these kinds of work – epistemological and ontological – may be brought together in method. Thus she is concerned to explicate how it may be that the frame as method may be developed – or topologically expanded – as an *empirical* mode of critique. In her case, this mode needs to be 'invested in capturing and dramatizing the contingent, dynamic and non-coherent unfolding of the times and spaces of issues'.

To develop this approach she takes two contrasting examples of the use of frame as a topological method in relation to an instance of environmental politics: the use of smart meters in green homes. In the first expansion of the frame Marres describes, there is an invocation of both the dynamic nature of technical and social arrangements, and the interrelatedness of different levels of orders, namely technology, society and the environment. However, in this first expansion of the frame, the invocation is, she says, only half-heartedly topological: the topological imagination is not extended either to the social itself, which continues to be framed in scalar terms, or to the relation between technological and social change, which she says continues to be defined as a causal one, however minimally speaking. The second way of expanding of the frame Marres describes is more radical. It involves not only the inclusion of more actors in a space of debate or controversy, but also the recognition of the necessity of changes in the shape of the space itself brought about by the inclusion of more – and more heterogeneous – actors. For Marres, this second use of the frame as topological method recognizes the capacity of controversy to produce variations in the spaces and times of issues: 'rather than defining controversy in terms of actors taking positions, it here entails the articulation of heterogeneous – social, technological, environmental, political, economic – concerns. A particular object is thus seen, by way of this topological expansion of the frame as method, to be constituted in particular 'states of issuefication' (see Rogers, 2012).

In their exploration of contemporary processes of mediation, Fuller and Goffey (2012) explore the forms of life that are brought into relation with each other in the continuum of 'Don't/Be Evil'. In relation to one of the examples of the 'machines' that produce this continuum, the relational data-base, they observe what we might call the use of 'the normal' or normalization as method. As they point out, normalization is technically understood as part of the 'optimization' of the design of a database: it involves the stripping away of unnecessary hierarchies or other structures within data, resulting in the treatment of each piece of data and each relation as a separate entity. This means that as data is updated, deleted or inserted, it does not carry with it any dependencies on other data or structures, but is characterized only by its discreteness. Normalization is thus described by Fuller and Goffey as a method that has the capacity to produce neutrality as to the relative importance of one datum compared to another. So how is this neutrality to be understood politically?

On the one hand, we can be critical, as are Fuller and Goffey, of the ways that entry into a network is sometimes constrained so as to obviate the neutrality of normalization; on the other, we can also be a little apprehensive (as are they too) as to what, if anything, could *not* be encompassed in this mode of reasoning and its operational imaginary of the 'infinite comprehension of a concept'? In the face of this expansion of reason, some of our contributors, such as Harvey, call attention to what she believes to be the inevitability of 'invisible trouble' within complex relational spaces. Fuller and Goffey themselves propose the adoption of a strategematic approach to 'expand' this trouble, an approach which they explain by reference to the micro-politics developed by Félix Guattari. This politics operates on the basis that the development of the analysis of experience is one with the process of its production. The proliferating concepts that result in this process may become, they suggest, practical elements in ongoing and diverse processes of experimentation, a kind of onto-epistemological reverse engineering.

The Limits of Reason

We started this essay by suggesting that the turn to the surface identified by Kracauer is entering a new phase. Kracauer argues that the ratio he describes negates human reason in the promotion of an abstractness that is not attached to the exercise of human self-understanding: abstractness, he says, is 'the expression of rationality grown obdurate'. Capitalism does not rationalize too much for Kracauer, but rather too little: it does not encompass 'man'. On the one hand, this view might be taken to imply that the limits of rationality can and should be overcome by its extension, but on the other, it also suggests that the nature of the reason or ratio he describes is at issue in any attempt by humanity to exercise self-understanding.

The topological culture that we have described in this introduction goes beyond that which Kracauer observes in relation to both these understandings; that is, it involves both an immense extension of the reach of rationality and an intensive transformation in reason itself. On the one hand, in today's topological forms of culture rationalism is no longer a limited form of language, but is rather an implementation of an infinity of reason that precludes any contagion with sensuality, the visceral or feeling. There is a new formalism, which is beyond direct sensation; this reason is not challenged by either the semiosis of language or a feeling body but, rather, is extended beyond any category or specific body. On the other hand, the rise of topological culture is not only about more and more efficacious abstraction, more calculation and control: insofar as the indices, meta-models, networks and experiments of topology are not detached from the material, from the body, language or the senses, but rather work in and through them, topological rationality participates in and renews the specificity of the material and the sensuous. Topological rationality is thus not obdurate, in contrast to that described by Kracauer, but rather is dynamic, soft and tractable, both precise and vague, able to operate the physical and sensual horizon of experience beyond and beneath the law-like symbolic system of signification. As such, the radical incompatibilities at the heart of topological culture do not simply encompass 'man' but rather actively engages the limit modes of the human in forms of practical abstraction that produce humanity both with-in and with-out the self-understanding of experience. Just as the rationality of culture is becoming co-extensive with the globe, the globe itself is simultaneously being brought into existence as a topological space.

Notes

1. Sloterdijk is only one of a number of topological philosophers who have drawn on the work of von Uexküll, whose work drew attention to the significance of border maintenance for organisms, especially in relation to immunity. Others influenced by von Uexküll's thinking include Heidegger, Merleau-Ponty, Agamben, Cassirer, Deleuze and Guattari as well as contemporary biologists including, notably, Herbert Maturana.
2. Indeed, we would further suggest that one of the characteristics of a topological culture is that subjectivity is being rendered intelligible as behaviour through the ways in which change is organized at both sub- and supra-individual levels.
3. Sloterdijk's sphereology can be seen as an attempt to answer the question of 'where' in new ways (Borch, 2008: 548–9). Borch quotes Sloterdijk's claim that Tarde's monadology suggests that societies or associations are 'scales calling for space' that can be adequately described only 'thanks to an analysis

of expansion, a topology, a dimension theory and a ''network'' analysis' (in Borch, 2008: 557).

4. Sloterdijk too is interested in Le Corbusier and in particular in the idea that the house is a machine to live in. He argues that this notion of the house-machine prepared the way for new flexible architectures that dissolved the connection between a house and its stationary place-specificity (Borch, 2008: 558). In this regard, Sloterdijk also discusses the architect Buckminster Fuller who developed mobile buildings that were adaptable to various air conditions.
5. She writes, 'First, the object is registered as pure extension, as flat shape which never breaks rank with the picture's frontality to suggest a turning of one of its facets into depth. Second, the constellation of objects wedge together in that insistent continuity of edges which the Purists called mar-riage de contours. Third, colour and texture are handled in a manner that calls attention to the inherent superficiality of these ''secondary qualities'' – so that distance or depth in the painting becomes no longer a matter of representing the space separating one object from another in the real world. Instead distance is transformed into a representation of the caesura between the appearance of the object and the object itself' (Krauss, 1972: 52–3).
6. The school of German media archeologists has drawn particular attention to the ways in which 'technical media is defined by its capacities to make continuous signals in discrete series, through, for instance, the Fourier trans-formation' (Parikka, 2011: 59).
7. Commercial '1 + ' devices which have the capacity to go beyond addition include Google Plus and Nike Plus.
8. Brian Massumi speaks to some of the same issues in his description of a vector space that is not containable in metric space, a qualitative space of variation referenced only to its own movement, what he calls a space 'run-ning on autopilot'. For him, this is 'an intensive movement, occurring in place (as at a work-station, or with rolled-up eyes) – or more accurately out-placed, in the event. This is an abstract movement on an abstract surface' (Massumi, 2002: 187).
9. In an intriguing account of Peirce's thinking, Pape (2008) claims that the index is fundamental to the achievement of continuousness. Thus he quotes Peirce: 'A tap on the door is an index. Anything which startles us is an index, in so far as it marks the junction between two portions of an experience' (CP 2.285, 1893, quoted in Helmut, 2008: 7). This interpretation of Peirce's thinking suggest that, for Peirce, the two-place relations of indices are always parts of other two-place or n-place relations.
10. We recognize that it is only one possible mapping.
11. On set-topology see Boyer (1968: 621–2).
12. One of the most basic problems in topology is to determine when two topo-logical spaces are the same, that is, when they can be identified with one another in a continuous way. This has been called the 'Poincaré Conjecture', marking the beginning of algebraic topology (Eynde, 1999: 82–87, and Rotman, 2012).
13. Poincaré, inspired by the theory of continuous groups, re-articulated the problem of the continuum in terms of Julius Plucker's equivalence principle. The latter stated that it is possible to construct an infinity of different but

equivalent spaces by choosing different primary elements, such as lines, planes, conics, so as to develop a ''relativistic'' view of dimensions in spatial geometry (Crilly and Johnson, 1999: 7–14; Bell, 1986: 538–40, 604).

14. For Castoriadis, the imaginary stems from the 'originary faculty of positing or presenting oneself with things and relations that do not exist.... This is, finally, the elementary and irreducible capacity of evoking images' (2005: 127).
15. In this respect, it is interesting to note that Michel Foucault approached the notion of neoliberalism in his last courses at the Collège de France by paying attention, as Stephen Collier (2009) observes, to the topological dimensions of technologies of power. For Collier, 'the identification of advanced liberalism as a diagram of power or a form of govern-mentality' makes visible what is most general and abstract about 'a new class of governmental forms across a range of cases', thus constructing neoliberalism as a kind of topological invariant unfolding through a series of deformations. Indeed, Collier suggests that a 'topological analysis is now required to show how styles of analysis, techniques or forms of reasoning associated with ''advanced liberal'' government are being recombined with other forms, and to diagnose the governmental ensembles that emerge from these recombinations' (Collier, 2009: 99).

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Nearness and *Da-sein*: The Spatiality of Being and Time

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Abstract

This paper focuses on the latent spatial philosophy in Heidegger's 'Being and Time', highlighting a key aspect of the Heideggerian oeuvre that has mostly been overlooked by commentators. It outlines the concept of an original spatiality of being that is opposed to the philosophies of space in both physics and Cartesian metaphysics. Through an elaboration of the essentially relational character of *Da-sein*, it is argued that Heidegger's vocabulary in 'Being and Time' yields an onto-topology that shows Da-sein's primary spatial embeddedness in the world. Finally, the paper argues that Heidegger's concept of spatiality remained cursory due to its residual existentialist focus. In this context, it attempts a re-evaluation of its intellectual trajectory within the realm of the Spheres project.

Keywords

Heidegger, space, spatiality, *Da-sein*, Sloterdijk, spheres, Spheres project

> An essential tendency toward nearness lies in Da-sein. (Heiddegger, 1996: 98)

Only very few commentators on Heidegger have noted the nascent but revolutionary treatise on being and space that underlies the sensationally programmatic study of *Being and Time*. Under the spell of Heidegger's existential analytic of time, it has mostly been overlooked that the former is grounded in a corresponding analytic of space and that both are fundamentally rooted in an analysis of movement. Therefore, we can find entire libraries filled with studies of Heidegger's onto-chronology, his doctrines of Temporalizing (*Zeitigung*) and Historicity and read various

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treatises on his philosophy of movement, or onto-kinesis. Concerning his attempts at a theory of an originary 'making-room' (*Einräumen*) of space or onto-topology, however, we find nothing but scattered, unciteable and pietistic paraphrases.

Heidegger's analysis positively delineates the spatiality of *Da-sein* as Approaching (*Näherung*) and Orientation (*Orientierung*) through two destructive steps. The spatial concepts of both, 'vulgar' physics as well as metaphysics, must effectively be cleared away before the existential analytic of Being-in (*In-Sein*) can be elaborated.

> What does being-in mean? Initially, we supplement the expression being-in with the phrase 'in the world,' and are inclined to understand this being-in as 'being-in something.' With this term, the kind of being of a being is named which is 'in' something else, as water is 'in' the glass, the dress is 'in' the closet.… Water and glass, dress and closet, are both 'in' space 'at' a location in the same way. This relation of being can be expanded; that is, the bench in the lecture hall, the lecture hall in the university, the university in the city, and so on until: the bench in 'world space.' These beings whose being 'in' one another can be determined in this way all have the same kind of being-that of being objectively present-as things occurring 'within' the world.… In contrast, being-in designates a constitution of being of Da-sein, and is an existential. But we cannot understand by this the objective presence of a material thing (the human body) 'in' a being objectively present.… 'In' stems from *innan*-, to live, *habitare*, to dwell. 'An' means I am used to, familiar with, I take care of something. It has the meaning of *colo* in the sense of *habito* and *diligo*.… Being as the infinitive of 'I am': that is, understood as an existential, means to dwell near … to be familiar with. (1996: 50–51)

By alluding to the Old German verb *innan*, to inhabit, Heidegger quickly reveals the crux of the existential analytic of spatiality. What he calls being-in-the-world means nothing other than to 'inn' the world in the verbal-transitive sense: to dwell in the world and to enjoy its openness through an initial attunement (*Einstimmung*) and expansion (*Ausgriff*). Because Da-sein is always already a completed act of inhabiting – the result of a primal leap into dwelling – spatiality and existence are inseparable. To speak of dwelling in the world does not mean to presuppose a domestic relationship between existing beings and vast, unbounded space: it is exactly this concept of being-at-home in the world that must be questioned, as to simply accept this condition as a fact would mean to fall back into the logic of container-physics that needs to be overcome. All holistic philosophies and teachings of mother's-womb-immanence fail at exactly this task and are thus reified into pious forms of half-baked thought. Nor is the house of Being a simple cubicle that existing beings enter into and exit out of. Its structure is more akin to a globe of care (*Sorge*) in which Da-sein has spread in its ex-stasis (*Außersichsein*). Heidegger's radical phenomenological attention delegitimizes both the century-old realms of container-physics and metaphysics alike. Man is never simply an animate creature in its environment or a rational entity in the house of heaven. Nor is he the devotional being of God's creation. Consequently, the ecological chatter that emerged in the 1920s is just as much subjected to a phenomenological critique: Biology thinks just as little as any other standard science. 'The saying used so often today, "Human beings have their environment", does not say anything ontologically as long as this 'having' is undetermined' (1996: 54). But what is meant by the 'environ' of environment (*Umhaften der Umwelt*)?

> According to what we have said, being-in is not a 'quality' which Da-sein sometimes has and sometimes does not have, without which it could be just as well as it could with it. It is not the case that human being 'is', and then on top of that has a relation of being to the 'world' which it sometimes takes upon itself. Da-sein is never 'initially' a sort of a being which is free from being-in, but which at times is in the mood to take up a 'relation' to the world. This taking up of relations to the world is possible only because, as being-in-the-world, Da-sein is as it is. This constitution of being is not first derived from the fact that besides the being which has the character of Da-sein there are other beings which are objectively present and meet up with it. These other beings can only 'meet up' 'with' Da-sein because they are able to show themselves of their own accord within a world. (1996: 53–54)

Conventional thinking's existential blindness to space manifests itself in the old worldview that integrates man more or less seamlessly into an all-encompassing realm of nature, thought as cosmos.[1] In modern thought, Descartes' division of substance into a thinking and an extensive part gives the clearest example of the unwillingness to question the place of their coincidence. Because Descartes reduces spatiality to the aggregates of 'body' and 'thing' that become the only bearers of extension, the question of the meeting-place of thinking and extension cannot arise. The thinking thing remains a worldless entity that appears to have the capacity to occasionally enter into relations with things in extension. The *res cogitans* thus seems akin to a ghostly hunter who goes on the prowl in the land of cognizable extension just to withdraw again into his worldless fortress of no extension. Heidegger counters this with an originary being-in of Da-sein in the sense of being-in-the-world. Even cognition is only a specific mode of dwelling in the spaciousness (*Geräumigkeit*) of the world that is opened through circumspect heedfulness (*Besorgen*):

> In directing itself toward . . . and in grasping something, Da-sein does not first go outside of the inner sphere in which it is initially encapsulated, but, rather, in its primary kind of being, it is always already 'outside' together with some being encountered in the world already discovered. Nor is any inner sphere abandoned when Da-sein dwells together with a being to be known and determines its character. Rather, even in this 'being outside' together with its object, Da-sein is 'inside', correctly understood; that is, it itself exists as the being-in-the-world which knows. Again, the perception of what is known does not take place as a return with one's booty to the 'cabinet' of consciousness after one has gone out and grasped it. Rather, in perceiving, preserving, and retaining, the Da-sein that knows remains outside as Da-sein. (1996: 58)

In his positive statements on the spatiality of Da-sein, Heidegger specifically highlights two of its characteristics: de-distancing (*Ent-fernung*) and directionality (*Ausrichtung*):

> De-distancing means making distance disappear, making the being at a distance of something disappear, bringing it near. Da-sein is essentially de-distancing. . . . De-distancing discovers remoteness. . . . Initially and for the most part, de-distancing is a circumspect approaching, a bringing near as supplying, preparing, having at hand. . . . *An essential tendency toward nearness lies in Da-sein*. (1996: 97–8; emphasis in original)

> In accordance with its spatiality, Da-sein is initially never here, but over there. From this over there it comes back to its here. (1996: 100)

> As being-in which de-distances, Da-sein has at the same time the character of directionality. Every bringing near has always taken a direction in a region beforehand from which what is de-distanced approaches. . . . Circumspect heedfulness is a directional de-distancing. (1996: 100)

> Letting innerworldly beings be encountered, which is constitutive for being-in-the-world, is 'giving space'. This 'giving space,' which

> we call making room, frees things at hand for their spatiality.... As circumspect taking care of things in the world, Da-sein can change things around, remove them or 'make room' for them only because making room – understood as an existential – belongs to its being-in-the-world...the 'subject,' correctly understood ontologically, Da-sein, is spatial. (1996: 103)

Who at this point would have expected a main argument to follow this mighty prelude remains gravely disappointed. The existential where-analysis abruptly gives way to an existential who-analysis without any further mention of the thread that Heidegger had only begun to unravel. Following this thread further would have inevitably revealed the manifold universes of existential spatiality that gain a renewed thrust through the terminology of spheres. The inhabitation of spheres, however, cannot be fully explicated as long as Da-sein is understood as having an essential tendency towards solitude.[2] The analytic of the existential 'where' demands that all suggestions of and allusions to essential solitude are bracketed in order to gain reassurance of the deep structure of an accompanied and complemented Da-sein. In the face of this task, the early Heidegger problematically remained an existentialist. His hasty turn towards the who-question leaves us with a lonely and weak hysteric-heroic subject that always believes itself to be the first to die and that remains miserably ignorant concerning its embeddedness within relations of intimacy and solidarity. Such a hypertensive 'who' in an uncertain 'where' can indeed experience unpleasant surprises when it tries to bind itself to the next best nation it finds.

When Heidegger's imperial enthusiasm sought fulfilment and grandeur in the 'national revolution', it became clear that an existential authenticity (*Eigentlichkeit*) that doesn't radically clarify its position easily turns delusional. From 1934 onwards, Heidegger knew, if only implicitly, that he had been carried away in his engagement in the national-socialist awakening. In it, time had effectively turned into space. Whoever enters into this vortex lives in a different sphere, on a different stage in an impenetrable inner space while he appears to be right here in the present. Heidegger's later work discreetly draws the conclusions from this lapse. The betrayed *völkisch* revolutionary does not expect much of lived history anymore; he retires from the worldly game of powers. Instead, he seeks salvation in more personal exercises in self-intimacy. With tenacity, he remains in his anarchic province and hosts organized tours through the house of being and through language – like a magical concierge equipped with heavy key chains, always ready to give Daedalean advice. In emotional moments he conjures up the Parmenidean holy globe of being as if he tired of historicity and returned to the eleatic. Heidegger's late work continues to repeat the ever-same wary figures of an original deepening of thought without ever again reaching the point from which the question of an originary, always already shared making-room of the world could have been fruitfully posed.

The Spheres project can be seen as an attempt to salvage from oblivion a certain element of the project of *Being and Space* that remained trapped in Heidegger's early work. We hold the opinion that through a theory of couplings, of genius and of complemented existence, we can save all there is to save from Heidegger's interest in rootedness. To have established a ground in the existing duality: this much nativity or anchorage in the real must be kept even if philosophy intently pursues its indispensable separation from the empirical community. The contemporary task for thinking, then, is to rework the tension between autochthony (*ab ovo* or starting from community) and release (starting from death or infinity).

Translated by Peer Illner

Notes

1. In his analytic of place, Aristotle had already fantastically approached the problem of an existential topology even if for him being of 'something in something else' couldn't have been addressed as an existential problem. In *Physics Book IV*, we find the following explanation of the eight different significations of 'in': 'The next step we must take is to see in how many senses one thing is said to be "in" another. (1) As the finger is "in" the hand and generally the part "in" the whole. (2) As the whole is "in" the parts: for there is no whole over and above the parts. (3) As man is "in" animal and generally species "in" genus. (4) As the genus is "in" the species and generally the part of the specific form "in" the definition of the specific form. (5) As health is "in" the hot and the cold and generally the form "in" the matter. (6) As the affairs of Greece centre "in" the king, and generally events centre "in" their primary motive agent. (7) As the existence of a thing centres "in" its good and generally "in" its end, i.e. in "that for the sake of which" it exists. (8) In the strictest sense of all, as a thing is "in" a vessel, and generally "in" place. One might raise the question whether a thing can be in itself, or whether nothing can be in itself – everything being either nowhere or in something else' (Aristotle, 1930: 56).
2. This remains the case in Heidegger's most significant lecture course in Freiburg, from the winter term 1929–30. On a notice-board of the institute, Heidegger had written 'Singularisation' (*Vereinzelung*) instead of Solitude in the title (Heidegger, 2001).

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Cultural Topology: The Seven Bridges of Königsburg, 1736

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Abstract

In an example of Enlightenment 'engaged research' and public intellectual practice, Euler established the basis of topology and graph theory through his solution to the puzzle of whether a stroll around the seven bridges of 18th-century Königsberg (Kaliningrad) was possible without having to cross any given bridge twice. This 'Manifesto' argues that, born in a form of cultural studies, topology offers 21st-century researchers a model for mapping the dynamics of time as well as space, allowing the rigorous description of events, situations, changing cultural formations and social spatializations. Law and Mol's network spaces, Serre's folded time, Massey's 'power geometries', Lefebvre's 'production of space' and 'rhythmanalysis' can be developed through a cultural topological sensitivity that allows time to be understood as not only progressive but cyclical, relationships and the 'reach' of power can be understood through 'knots', and a topology of experience to model the 'plushness of the Real' via extra- and over-dimensioned time-spaces that capture nuance while drawing on systematic conceptual resources.

Keywords

cultural topology, engaged research, networks, social spatialization, space, time

Topology has existed as a mathematical discipline for little over 80 years. However, as early as the 18th century Leonhard Euler discovered the first topological property: the 'Euler characteristic' establishes the genus of shapes (such as 'circular' or 'linear' or 'cubic'). Regardless of how they are deformed (e.g. by stretching or folding the space they are in), the sum of a particular shape's vertices, edges, and faces remains the same.

This idea was established through a discussion of the Seven Bridges of Königsberg (Euler, 1752 [1741]): Euler solved a problem which had been set by the inhabitants and provided the basis for a more general method

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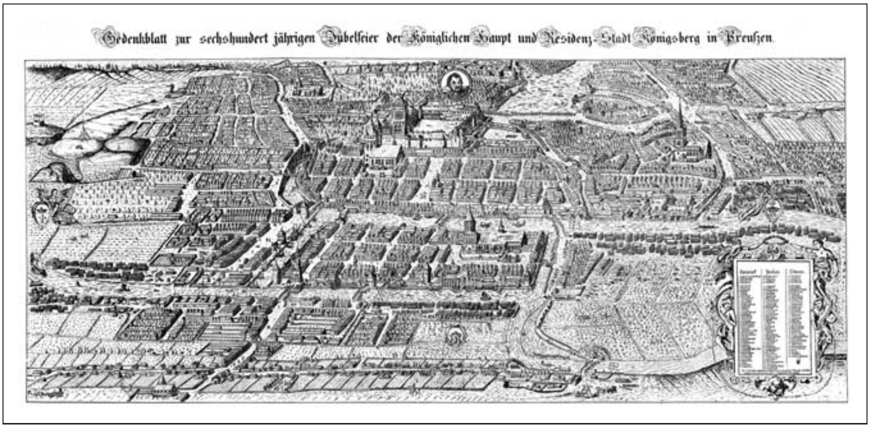

Figure 1. Engraving of Königsburg in 1613.
Source: Wikimedia, Joachim Bering 1813.

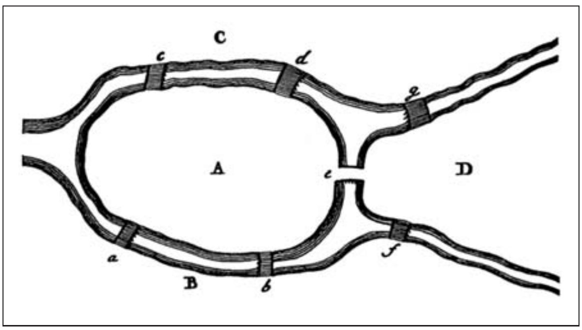

Figure 2. Euler's 1736 diagram of the Bridges of Konigsberg c.1736 (after Mallion, 2008: 26 and Faculty of Science University of Kragujevac, 2007).

of choosing routes efficiently. The old capital of East Prussia was built at a fork in the river Pregel (now named the Pregolya) and a strategic island crossing. Seven bridges connected four areas of the city on the point, each bank and the island (see Figures 1 and 2). Could a person go for a stroll, crossing each bridge once? An acquaintance, the mayor in nearby Danzig (now Gdansk), wrote:

> You would render to me and our friend Kühn [a local mathematics professor] a most valuable service, putting us greatly in your debt, most learned Sir, if you would send us the solution, which you know well, to the problem of the seven Königsberg bridges, together with a proof. It would prove to be an outstanding example of the calculus of position [*Calculi Situs*], worthy of your great genius. I have

> added a sketch of the said bridges . . . (letter from Ehler, 9 March 1736)

This is a topological problem in that connectivity is at issue, not the size of any one bridge or its distance from another bridge. Euler 'understood that the problem did not depend on the precise map of the city . . . it was not a problem of geometry. . . . Euler establishes the new nature of the problem by using the term ''geometry of position'', an expression introduced for the first time by Leibnitz' (Kantor, 2005) as *geometriam situs*, or *analysis situs*, 'another kind of analysis, geometric or linear, which deals directly with position, as algebra deals with magnitudes' (Leibniz and Clarke, 2000; Letter to Huygens, 1679). Euler presents his argument in 21 numbered paragraphs, beginning by saying:

> 1. Hence, when a problem was recently mentioned which seemed geometrical but was so constructed that it did not require the measurement of distances, nor did calculation help at all, I had no doubt that it was concerned with the geometry of position – especially as its solution involved only position, and no calculation was of any use. I have therefore decided to give here the method which I have found for solving this problem, as an example of the geometry of position.
>
> 2. The problem, which I am told is widely known, is as follows: in Königsberg . . . (Euler, 1752 [1741]: 128).

And so begins one of the foundational papers of modern mathematics, in a problem of *urban cultural space and leisure* – an historical example of engaged scholarship and research – and the importance of public curiosity to innovation. This is to assert a methodological claim on cultural studies and a theoretical claim on topology. Against the usual stereotypes of Enlightenment methods and scholarly practice, we see an engagement that is thoroughly 21st century in its responsiveness. It ties topology to culture and to the complexity of everyday experience rather than the formalism of social laws in a manner that prefigures the stress on relationality in later cultural studies research, for at issue is the way the town is put together in two and three dimensions and how the bridges connect its island (see Figure 2). It is not the exact shape of an object that is of interest but the way objects are put together – how parts relate to wholes or how a shape divides a plane by containing an inside separated from an outside.

Euler showed that it was impossible to find a route through the town that would cross each of its seven bridges across Pregel exactly once. 'If there are more than two areas to which an odd number of bridges lead, then such a journey is impossible' (Euler, 1752 [1741]: 139, para. 20). Euler develops a technique of assigning each area a capital letter A–D and each bridge a lowercase letter a–f and then asking about the path necessary to connect the areas, crossing each bridge only once. How many times does the letter for a given bridge appear when one connects the areas? 'A path signified by n letters corresponds to crossing n-1 bridges, so a solution to the Königsberg problem requires an eight-letter path' (Hopkins and Wilson, 2004: 204). One can perform a similar calculation for any given arrangement of areas or objects joined by bridges or links. This sums up the number of bridges required in any path that doesn't have to re-cross a bridge (Euler, 1752[1741]: paras 8–12).

The strategically-located town and most of its bridges were destroyed by aerial bombing and heavy fighting in 1945. After the Second World War, the town was used as a key military base and was closed to foreigners for 50 years. The area bordering eastern Poland along the Baltic Sea, now separated from the Russian Federation by the independent republics of Lithuania and Belarus, is both an exclave of Russia and an enclave within the European Union countries of Poland and Lithuania. Of the few buildings that survived, the Cathedral with the grave of the philosopher Emmanuel Kant is still standing. To mark the tercentenary of Euler's solution, a number of mathematicians re-surveyed the original location, now Kaliningrad, and concluded that 'Eulerian Walks' are still possible but not a perfect 'Eulerian circuit' as the bürgers dreamt of. Despite the war-time destruction, a new Kaiserbrücke footbridge was rebuilt in 2005 and a motorway now spans Kneiphof Island but allows pedestrian access to the island. Bailey adds:

> War, ironically, has led to the solution of the problem of the Seven Bridges. The case of Koenigsberg/Kaliningrad shows how politics affects spatialization: what was once an abstract mathematical problem concerning space is completely altered due to politics. The city teaches an important lesson about how space is not simply a static, apolitical, mathematical entity, but rather a dynamic entity that is constantly changing due to natural, economic, social and political forces. . . . To this day Kaliningrad remains a Russian 'island' and is now situated within the EU, sandwiched between Poland and Lithuania . . .
>
> Kaliningrad Oblast is a living palimpsest, which complicates spatial questions concerning nationality, identity and homeland. Vesiland and Chamberlin describe Kaliningrad as haunted: 'The Russians and others who came here after World War II for a new life

> moved into the shell of a nation, into other people's homes and farms, to use other people's furniture and pots and pans' (1997). The Russians living in Kaliningrad occupy a space with a German past, from which they are disconnected; a space which is at the same time disconnected from their motherland. (Bailey, 2010: online)

Writing on the mathematical history, Mallion makes the speculative statement: 'if the 1542 Honigbrücke [bridge *e* in Figure 2] had never been built, Euler would never have been asked to look at this problem at all.... And if Euler had not intervened, topology and graph theory might have developed along different lines' (Mallion, 2008: 34–5). Bailey's point is that Königsberg/Kaliningrad continues to provoke questions of relations between areas and cultural spaces as a type of what Blackwell calls *cultural topology* (Blackwell, 2004; Shields, forthcoming).

Non-Euclidean Topological Spaces, Surfaces and Mobilities

Early proto-topologists such as Euler accepted the existence of an absolute space as a real medium needed for the determination of absolute rest and motion and for a law of inertia. But what if M.C. Escher were to paint an imagined Königsberg in which one could find a Eulerian walk, crossing each bridge only once? This would require a weird painterly space in which the ground and bridges warped back on themselves to allow a strolling *flâneur* to never cross their own path.

Non-Euclidean 'topological spaces', a term introduced by Felix Hausdorff in 1922, are behind the visual tricks of Escher's paintings. However, they are studied as geometric wholes. Changing the parameters of spaces reshapes them by continuous stretching and bending much as a potter could change their mind mid-creation to reshape an object. Topology focuses on spatial properties of these object-spaces that do not change under such 'homeomorphic' continuous deformations. For example, any object with one hole is 'homeomorphic' with any others with one hole. Similarly the angles of a triangle on a flat plane add up to 180 degrees, but laid onto a sphere one can still discern a triangle with three points. But because of the curvature introduced into its sides, the sum of the angles of a triangle will be greater, altering one of Euclid's *Laws*. So topology includes not only strict shape invariance but also fuzzier, yet mathematically rigorous, 'shape consistency' under deformation.

This can usefully be compared to other things that change yet are held to remain the same, such as a family or community or group – virtualities, that is, intangible-but-real-entities that remain despite turnover in membership. Other examples include objects that age (e.g. a corroding automobile) yet are still referred to as the same object. The virtual builds beyond a social constructionism to a post-structural empiricism that acknowledges the realism of entities such as a group or a mathematical set independent of the elements (e.g. the set of prime numbers versus the numbers that make it up – see Shields, 2006b).

Topology can shed new insight into familiar social science objects of research by mapping out how such objects change and how they relate, in this process, to other changing objects in multiple, relational spaces. Topology sets aside the privilege granted to Euclidean space in lay understandings of the social to problematize even the spatio-temporal ironies and anomalies we do recognize in everyday life. That is, topology allows us to systematically adopt a critical stance to how notions such as a 'shrinking' or more closely tied world is represented and understood. For example, how is it that the rapid changes introduced in only half a century by technologies of mobile computing, communications and travel are construed as unremarkable entwinings of distant places into a new spatialization of the world as distinct but normatively de-differentiated?

Topology provides methodological and conceptually precise frameworks for conceiving not only of relationships or the structure of activities or tasks such as crossing bridges. Topology also allows one to rigorously approach situations where the order of things is deformed by any given force. That is, it provides the mental hand-holds for working with situations where relationships are changed, distanciated, collapsed or distorted, reshaping the 'diagram' one might draw of the situation. Typically, diagrams are projections of multi-dimensional processes onto the two-dimensional topology of the page. Complexity is strategically visualized in a reduction of overall relations and transformations. In general, topology spatializes variables as the respective dimensions or parameters of 'manifolds' (what popular complexity theory has called 'phase spaces'). Within manifolds, 'neighbourhoods' of relative predictability may be related to neighbourhoods with different qualities. Independent variables are referred to as 'dimensions' that operate on the manifold as a whole rather than on objects or specific points within it. For example, theories of relativity popularized the notion of everyday life as a three-dimensional spatial manifold, operated on by a further, fourth dimension: time.

Dimensions can also be understood as degrees of freedom: the point has zero, the one-dimensional knot one; two-dimensional surfaces can be stretched on two axes. Similarly, if a manifold has a boundary, it is one dimension lower: string tied in a knot has two boundaries at either end that are points (zero dimensional – unless its ends join [a circle], in which case it would have no boundaries); the boundary of a two-dimensional surface is a line (one-dimensional), that is, an edge, and so on. Such topological axioms of connectivity, relationality and dimensionality already operate in spatial data sets and the algorithms of Geographical Information Systems. However, they deserve more political-economic and sociological critique as they tend to operate normatively with institutional and governmental effects.

Taking a more social example, anthropologists have long posited a spatial aspect to rites of passage where a liminal zone of initiation is counterposed as a threshold zone in which the rules of the usual social environment do not apply but are suspended; young initiates are removed from the tribe to be initiated and instructed, then 'reborn' back into the social world of the tribe as adults. The differential relationship between centres and peripheries is a second geographical commonplace, so much so that one could speak of a liminal spatialization of the periphery (e.g. historical seaside Brighton compared to London; Shields, 1993).

Massey has called these social spatializations (Shields, 2006a) 'power geometries' (Massey, 1999). Power geometries are located, not stretched, and refer to capabilities as potentials. But Massey is more obviously topological when she considers the remolding of the Earth by tectonic forces and the rapid transformation of the relationships between distant places entailed by globalization as a virtual 'shrinking' of the world achieved through closer ties and communications (cf. Shields, 2003, 2006b). Other examples could include Giddens' time-space distanciation as the stretching out of social relations, or Harvey's time-space compression as a metaphor for theorizing globalization, or Virilio's emphasis on acceleration and the speed of travel and communications as having the effect of 'shrinking' our world (Virilio, 1986). How is it that these transformations in not only our understanding of but our practices in space seem so commonplace? The implications of these theories have not been systematically understood, thereby cutting short critique. Virilio, for example, goes on to assert: 'The reduction of distances has become a strategic reality bearing incalculable economic and political consequences, since it corresponds to the negation of space' (1986: 133). However, it is not a matter of negation of space but a change to conventional understandings and practices of space, a topological shift which involves both time and space: a new cultural topology. These are questions of not just a single era's experience but of cultural topology in general which asks further – how is that such global connectivity is mapped onto a local neighbourhood in which Euclidean and Cartesian rules of engagement and embodiment apply? More than a changing spatialization, this appears as a multilayered topology with different spatializations applied at different scales. A topological sensibility generates these sorts of novel and non-totalizing hypotheses which shed light on the dynamism of experience and perception, norms and practice. What are the topologies of capitalism, and could this not be a better framework for comparative insight than the nervous shifting from foot to foot that has marked two decades of critique, grasping at organizing rubrics such as postfordism, hypercapitalism, late capitalism and neoliberal globalization?

Even critical approaches to time and space would benefit from topology's accommodation of multiple dimensions of both at once. This constitutes a dramatic change from organizing metaphors of surface and depth. Furthermore, it offers a basis on which one might reassess the binarisms of the tradition from Hegel through Heidegger and on to Lefebvre, Virilio and more recent writers that accepts the language of the 'negation' of space – that is, that time as instant or point is the antithesis of space (and only a certain, European notion of space as *spatium*) as unbounded field. This 'black-boxes' both time and space as opposed singularities. While elegant, it is only one diagrammatic reduction when there are many possible time-space relationships between spatialities and temporalities.

For example, the common experience of duration stretching out like eddies in the flow of time can be mapped as extra-temporal dimensions. These have been compared to the many loops of thread that make a 'terrycloth' towel. Lower dimensional temporalities may be insignificant under most conditions but become the site of emergent psycho-political change (see Randall, 2001). A prototype for this approach might also be found in the anthropology and psychology of time (respectively e.g. Lomnitz, 2001, and Csikszentmihalyi, 1990; see also Kubicek, 2008, on the history of the scalar concept of 'deep time' in geology). What difference does this make to critical practice? It allows new practices of 'thick description' (Ryle, 1968; Geertz, 1973). It reminds us to relate, trace and contest the relationships between these multiple dimensions and to wonder at the priority given to the time-space relations between all these dimensions that make up the 'plushness' of the real (see Shields, forthcoming).

A *topology of experience* may be strategically sketched as a diagram of what happened or what happens, but the contingencies of the embodied flow of experience, and its knotting of the past as 'experiences' and the present as experiencing, suggest more multidimensional models of happening than a two-dimensional diagram would conventionally capture. As Vannini (2011) illustrates, travel and other mobilities are more complex than a mere line between departure and destination. That is to say that mobilities not only indicate the contours and dimensions of a topology, but are traced on or in topological surfaces that delimit the degrees of freedom of any movement: 'In truth, to change the world, one must change space' was Lefebvre's 'strategic hypothesis' (1974: 220, my trans.).

The itinerary that threads back and forth across Königsburg's bridges and island also has the quality of knots or of a cat's cradle game. Familiar knots are embeddings of a one-dimensional space or manifold, such as a loop of string, into more dimensions, such as a three-dimensional physical space. We know that the string can be unknotted and re-tied into a different type of knot, making some knots equivalent to others. A geometrical solution would be confined to one dimension – pulling the string out of the knot bit by bit. A topological solution would consider how to untie the knot as a manifold set in extra dimensions. By extension one might consider the knots of everyday life in even more dimensions: adding historical time is already a topological move, but considered in the varying tempo of time and virtual temporalities such as, for example, Braudel's *longue durée* or Benjamin's flash of *Jetz-zeit*, now-time, or Lefebvre's 'moment' that displaces the steady march of clock time. These variations to the rhythms of everyday life are only a few established examples that use 'over-dimensioned' representations of experience to sound and probe relations.

Knots have been the basis for cross-cultural conceptions of complexity, from Piranesi's labyrinths, to fishing nets to children's games. Because topology offers the insight that it is possible to analyze systematically relationships and configurations themselves, it shows us that knots are more than metaphors: knots describe topologically not only complex networks but the twisted path a document might take through a bureaucracy, or that a decision-making process might follow. Topology maps across boundaries and interfaces where 'translations' that may recode, warp or recast objects, such as a document or terminology that is understood in different ways on either side of this border, a topological fold, held in place by power, that reorients the internal sense of a message. One might thus trace the experience of boundary-objects that have these qualities (Bowker and Star, 1999) as well as discursive sleights of hand in which meanings are realigned according the interpretation of different groups and their interests. For example, Stark, Vedres and Bruszt show how discursive meaning can be shifted to allow divergent local and transnational interests to engage in shared projects and narratives amongst groups in civil society (Stark et al., 2006).

From Spatial to Topological Turn

These itineraries or mobilities are a fundamental aspect of the topological shift which moves away from relatively static or intersecting spatializations to the dynamism and tensions amongst objects set in conflicting spatial orders or spatializations that recast those objects and their qualities and powers or reach (in very different ways). Topology thus accounts for both the proper and improper, the legitimate and the out-of-place. Building on the so-called 'spatial turn', a 'topological turn' in cultural studies is foreshadowed by proto-topologies such as Arjun Appadurai's description of globalization as a series of 'scapes' of sectoral flows such as information, bodies or capital (Appadurai, 1996). Theorists such as Deleuze, Mackenzie, Delanda and Massumi have also mobilized topological insights, for example the role of 'attractors' as 'catastrophe' points in the 'bifurcation' or sudden phase change of complex systems (Delanda, 2002; Deleuze, 1986; Mackenzie, 2005; Massumi, 2002). On the social science side, the tendency has been to exploit only the metaphorical richness of topology. A cultural topology promises to allow generalization across cases by drawing on the rigorous language and classification system already developed in mathematics. On the natural science side, no non-algebraic primers are available (but see Barr, 1989; Blackwell, 2004) and the tendency is to discuss the mathematical intrigue of the science (Delanda, 2002; Mackenzie, 2005).

For example, the geographers John Allen and Allan Cochrane describe topological models of power as an alternative set of metaphors to those that structure the thinking of power as either vertical hierarchies or horizontal networks. Rather than these 'extensive' relations, topology suggests 'intensive' relations whereby the state makes itself felt within policy and decision processes as 'reach': 'proximity and reach play across one another in a variety of intensive ways to bridge the gap erected by the physical barriers of distance' (Allen and Cochrane, 2010: 1075). But the topological is in fact not directly addressed: their model is topological in that they describe ways that the central state in the UK is implicated institutionally in regions and thus peripheries are brought close to the centre – space shrinks and warps dynamically as an institutional creation that is re-conjured and re-actualized by different interests and constituencies in a process of permanent struggle.

> What is politically at stake in favouring topology over topography, spatial intension over spatial extension, is that such an approach is able to show how the state's hierarchical powers have not so much been rescaled or redistributed as reassembled in terms of spatial reach. Equally, a topological understanding of the politics involved also reveals what lies behind the opening up of authority in the more complex institutional arrangements unfolding. (Allen and Cochrane, 2010: 1073)

There are more questions and possibilities to this topology: How does the spatial interleave with the time of the state – of election cycles, parliamentary sittings, budget years, bureaucratic work-plans, policy events and news media deadlines – and the time of crises, of people's needs and events?

Giaccaria and Minca build on Agamben's discussion of Schmidt's contrast between the topological and topographical (inside/outside, far/near and so on) in describing Nazi concentration camps such as Auschwitz as not 'outside' of the Nazi social system but imbricated within it as an internal 'threshold, or a zone of indifference, where inside and outside . . . blur with each other' (Agamben, 2005: 23–4 cited in Giaccaria and Minca, 2011: 4). It is not a simple space of confinement but of indeterminacy that breaks the linkage between location and identity (Agamben, 1998: 19–20). Solzhenitsyn describes the Soviet Gulag system in similarly evocative terms as an 'archipelago' within the doorsteps of everyday life (Solzhenitsyn, 1977), suggestive of a topological rationality deployed in the service of power that analysts continue to struggle with, for example the case of the CIA's extraterritorial network of holding cells, 'black sites' and flights, and program of 'extraordinary rendition' after 9/11. This 'topological' informs but escapes the topography that spatializes a set of policies as an actual environment. An overlapping communication or tension is thus set up that potentially destabilizes the self-consistency of ordered space.

It is worth recalling a well-known attempt to draw on topology builds on Bachelard's phenomenological consideration of experience and experiment. Law and Mol consider the deformation of networks, developing the example of the colonial Portuguese sailing ship, an unreliable vessel that required constant repair and is thus itself a manifold of changing parts, mobile within a further manifold of the space of the oceans. Thus the analysis stages the confrontation between shape invariance of a stable network of components of the vessel – its hull, rudder, sails and so on – and its mobility and displacement in the water. Their work moves on to fluidly changing and intermittent, flickering topologies and the inter-topological effects between them, but more can be made of topology itself as an organizing trope for unpacking the concept of immutable mobile. It is worth rereading the insight that topology lends to the analysis of this case and of the methodological workings of actor network theories. For Law and Mol:

> In fact to talk about 'immutable mobility' is to play a double game . . . the immutable mobile achieves its character by virtue of participation in two spaces: it participates in both network and Euclidean space. And such is Latour's trick. To talk of an 'immutable mobile' is to elide the two. The immutability belongs to network space: to a first approximation the vessel doesn't move within this. If it did, it would stop being a vessel. But it is that immutability in network space which affords both the immutability and the mobility in Euclidean space. To put it more strongly, it is the interference between the spatial systems that affords the vessel its special properties. We are in the presence of two topological systems, two ways of performing shape invariance. And the two are being linked together . . .
>
> . . . In this looser locution it is *relationality* that becomes important, the possibility of thinking in terms of (broadened) forms of

> connection – rather than the network metaphor which links an appreciation of relationality to a specific image of connectivity. . . . More complicated visions of spatiality are required. . . . The challenge, then, is to inquire into the possibility of other, non-Euclidean, non-network, spatialities. (Law and Mol, 2000)

By suggesting analysis move to the level of interacting spaces or manifolds, they argue that success may depend on this interaction (in this case, stability and fixity of the vessel-network allows mobility in the ocean space). This may include disturbances of the stability of objects, such as Law and Mol find in another case: the Zimbabwe bush pump. This village hand pump can be a mash-up of jury-rigged elements such that the form changes to achieve constancy in the function of the water pump, and because of this fluidity its usage spreads. Law and Mol note that graduate change and modification allow entities in a 'topology of fluidity', adaptation and resilience allows continuity in their functions. The punchline must be added: as the manifold or network-space of the object warps, the relationships of the object remain constant within the manifold. But seen from 'outside' its workings, improvisation and repair, from the vantage point of everyday Euclidean space as it were, the entire object-network morphs together with its manifold. It is the topology that is fluidly changing, not the object.

The Topological Turn and Cultural Studies

Bachelard himself comments in other works on knots as a potential model of consciousness (Bachelard and Flocon, 1950). These and the previous cases of nested manifolds illustrate a knotting of spaces that itself requires a *topological sensitivity*. This would extend beyond the geometries of single objects and even the performative dramas centred around them. Rather than actual objects, the less tangible but still real threads of relations and the ways in which these can be interwoven with other, more or less systematic sets of relations to produce complex patterns of behaviour and function as outcomes are the focus. This might be imagined as the weaving of warp and weft, two ordered sets of thread or yarn, to produce patterns on a loom.

These precedents suggest the potential of a topologically-informed cultural studies, but in fragmentary fashion. While describing what topology is, the purpose here is neither to systematically critique nor to establish an agenda for what a cultural topology can do. Topology offers cultural studies a new 'dimensionality' and level of precision regarding spatial and temporal relations. As Massumi shows, the political is as much in the dimension of anticipation – that is, in the structuring of futures in the form of anticipated outcomes, normalized desire and the governance of choice – not in a topologically Euclidean present.

The strangeness of everyday life is precisely its disequilibrium as a knotting of topologies that entwine local with global, present with past and future, rather than its banality, presentism or constrained domestic space.

Rather than solely relating to situations of ongoing or marked change or deformation, knotting, multiply-imbricated spatial and temporal orders, a cultural topology exposes the complexity of the everyday, the settled. In setting the static or routine if not in motion, then in an orbit that becomes a wobble of becoming, a cultural topology is as much about mobility as about the emergence of what is taken for granted as the actually real.

The topological turn suggests a reconsideration of themes of relationality not well addressed in English-language social science writing since before the Second World War (cf. Sorokin, 1937–41). As the comments above suggest, cultural topology holds promise for cultural studies and the analysis of power. Cultural topology advances studies of social spatialization by including dynamic changes over time in space itself rather than only the relative relations of objects and entities in a static space. As entities move or relations change it is the space, field or manifold which is understood to also undergo topological changes: folds, stretching, shrinkage and warping. This approach to cultural studies also has methodological and pragmatic implications for research itself. It folds up academic social science into a new relation between the disciplines of space, time and the social and brings this into a new relationship with communities and with public curiosity – a precedent set by the historical case of Euler's topological response to the burger's puzzle of Königsberg's bridges. The implications of cultural topology for knowledge projects and institutions such as the university should not be underestimated.

This brief overview finds in the early beginnings of topology as *analysis situs* of the bridges of Königsberg a model for the relationship between theory and public curiosity. A rigorous analysis of connectivity and relation contributes to major themes in the social sciences. The analysis of change and transformation, the knotting of inter-topological effects and the specification of degrees of freedom of movement, that is, of the relations that can be effected actually or virtually in a time-space, implies a topological approach. If unacknowledged, it leads analysts to miss the broader time-space conjunctures that are at play in everyday life, in cultural formations and regimes of governmentality. This is advanced both economically for neoliberal capitalism and culturally as in social spatializations. Not 'connecting up' time-space insights is compounded by assumptions such that space is simply negated rather than warped by new, suddenly impinging dimensions, perhaps catastrophically.

Although political geographers in particular have advanced topological models of power and sovereignty to ask what is at stake politically, spatial naivété in the social sciences has allowed the persistent assumption of a Euclidean and absolute space-time despite the inclusion of virtualities operating with their own separate topological qualities as objects of analysis. Topology offers not only a rigorous language but is already incorporated, untheorized, in the mathematical algorithms of spatial statistical computing. Moving beyond spatial critique, this challenges us to rethink organizing metaphors of both time and space and to bring critical attention to bear on the intersecting topologies that contribute to the complex knotting of everyday life and the plushness of the real. A topological sensibility deserves to be put on the agendas of social science theory and method.

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Between Inclusion and Exclusion: On the Topology of Global Space and Borders

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Abstract
The research hypothesis that we call *border as method* offers a fertile ground upon which to test the potentiality and the limits of the topological approach. In this article we present our hypothesis and address three questions relevant for topology. First, we ask how the topological approach can be applied within the heterogeneous space of globalization, which we argue does not obey the dialectic of inclusion and exclusion. Second, we address the claim of neutrality that is often linked to the topological approach. Our point is that in mapping a space of flows and porous borders, the topological approach must be grasped in its ambivalence; it can become a tool for control as well as a tool for the expansion of freedom and equality. Finally, we argue that it is useful, perhaps even necessary, to locate the topological approach on the border, investigating concrete practices of border crossing that challenge the very possibility of a neutral mapping.

Keywords
borderzones, cultural theory, migration

The research hypothesis that we call *border as method* (Mezzadra and Neilson, 2008) offers a fertile ground upon which to test the potentiality and limits of the topological approach. In recent years this approach has provided an extremely rich series of theoretical and empirical elaborations that blur the boundaries between humanities, natural sciences

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and social sciences. Crossing mathematical insights with philosophical investigations, proponents of the topological approach have questioned the binary between transformation and invariance. This has allowed an analysis of emerging operations of control that account for new relations of connectivity across discrete spaces and organizations of data. From architecture (Massumi, 1998) to research on networks and virtual space (Terranova, 2004) to social and cultural theory (Lash and Lury, 2007), the topological approach has occasioned a rethinking of questions about the constitution of disciplines, the uses of knowledge and the changing status of research objects. The topic of borders and boundaries is crucial in these investigations, even if this question is not explicitly theorized by proponents of the topological approach. No matter how much topology draws our attention to unexpected forms of connection and continuity, it must also account for processes of partition, filtering and hierarchization. The image of topological space has been particularly useful for grasping some of the characteristics of the so-called space of flows associated with globalization as well as with neoliberal social *milieus* reshaped by market rationality (Collier, 2009; Terranova, 2009). Our analysis points also to the usefulness of topology for understanding the mobility and elusiveness of spatial formations within geographies of globalization that are marked as much by differentiation as by connection. We try to grasp this predicament by developing the concept of the heterogeneity of global space. This means at once thinking through the dynamics of flows and focusing on violent processes of articulation, division and interruption that cross contemporary elaborations of space and subjectivity. We are particularly interested in the political implications of this predicament.

Our approach to borders seeks to trace and track the relevance of their current proliferation from the point of view of the articulation of global processes. This means we do not see borders as devices that obstruct or block global flows. Rather we see them as parameters that enable the channelling of flows and provide coordinates within which flows can be joined or segmented, connected or disconnected. It is important to consider the world-making function of borders, as a number of important scholars from Carl Schmitt (2003) to Étienne Balibar (2002) have emphasized. Once we see borders as making a world rather than dividing an already-made world, their topological functioning becomes clear. Traditional images and theories of borders are predicated upon a methodological nationalism that at one point held a monopoly on different and even conflicting branches of social, political and even cultural thought. The existence of a bounded space was taken for granted and the border was the line that established the limits of extension while also defining the perimeter within which intensive interactions could be observed and compared to those occurring in other supposedly bounded spaces. When we speak of 'border as method' we take stock of the material and epistemological endgame of such methodological nationalism and of the related image of borders. This has strong resonance with the emphasis placed by proponents of the topological approach on moving beyond the surface of the Euclidean plane and the Cartesian grid to introduce a new spatial thinking that identifies fields of relation rather than discontinuous points and lines. The bordering processes that we investigate criss-cross the apparently bounded and discrete spaces that borders were once considered to establish through processes of exclusion and division. This opens up the possibility of new 'fields of relation', such as the virtual proximity of borders that are separated across geographical space or different kinds of folding and filtering that challenge the rigidity of the distinction between inclusion and exclusion. The calculus of these relations is played out against a political edge. The analysis we pursue thus pushes the topological approach to come to grips with some of the most challenging problems in contemporary political debates, from the ongoing crisis of citizenship to the rethinking of political representation, from the changing valences of territory to the invention of new forms of political action.

In this article we ask how border thinking and the material confrontation and proliferation of borders in today's world invites a rethinking and reconfiguration of topological figures, properties and arrangements. When topological relations are held to the political edge of the border the strange forms of recursion, correlation and invariance that they generate must be interrogated in ways that reach beyond the importation of a mathematical heuristic into social thought. At the border there is a certain intensification of political and even existential stakes that crystallize relations of domination and exploitation, subjection and subjectivation, power and resistance. Looking through this crystal implies a different optic of analysis, one which shows how these complex relations are invested with clashes and dissonances, manipulations and deceptions that leap off the surface of the topological manifold no matter how it is submitted to deformation or curvature. From this point of view we argue that it is useful, perhaps even necessary, to locate the topological approach *on the border*, investigating concrete practices of *border crossing* that embody the elements of constituent excess present in every scene of border making or border contestation. This is why we focus on the subjective dimensions of migration and the ways in which bodies in motion challenge border regimes across diverse geographical scales. It is also why we emphasize the making and unmaking of social worlds.

The Challenges of Contemporary Migration

Whether or not it is possible to define our age as 'the age of migration' (Castles and Miller, 2003), it is a matter of fact that migration posits fundamental challenges that are signal of our times. This is particularly the case in a situation such as the one we are living in, which has been deeply shaped since 2007/8 by the global economic crisis. The inquiry into the multifarious ways in which migration has figured in the genealogy of this crisis, into how the crisis has affected the condition of migrants worldwide, and into migrants' reactions to this economic turmoil seems to us one of the most urgent tasks we are confronted with as critical migration and border scholars. Movements and struggles of migration have in any case been central to the production of new transnational social spaces (Rouse, 1991), which have greatly contributed to the cultural, economic and political shape of globalization. The specific angle from which we investigate these emerging transnational social spaces is that provided by the relations between migration, citizenship and labour markets.

Many scholars and activists have analysed, in the last decade, movements across borders and border struggles that are profoundly changing both labour markets and the shape and composition of citizenship across diverse global spaces. 'Precarious employment', 'differential inclusion' and the 'proliferation of borders' are some of the concepts that have been crucial to both our individual and collective research and political engagement with migration. These are also notions that have echoes within topological discussions that move beyond familiar figures of spatial and social stability. Focusing on movements across borders and border struggles opens up an original and productive perspective on the debates on the constitution of labour markets, the social composition of workforces as well as on the production and reproduction of the very fabric of citizenship. One important strain of these debates has focused on 'precarity', which has been a particularly virulent political concern in continental Europe in the last decade but has also emerged as an important topic of debate in other locations (Neilson and Rossiter, 2008; Ross, 2009; Vosko, 2006). Movements and struggles of migration highlight the tensions, subjective claims and conflictual dynamics that criss-cross the field of precarity, contrasting the tendency to provide anodyne and neutral sociological descriptions of the 'neoliberal' flexibilization of labour markets and the disarticulation of citizenship.

In a general sense, precarity refers to the explosion of the dyad citizen-worker that after the Second World War assumed dominance – whether in the Stakhanov moment of the USSR, the heyday of US industrial towns such as Flint, Michigan, or the disciplined working subject of the Nehru plans in India. Soon after the Second World War, T.H. Marshall (1950) provided a kind of formal conceptualization of this dyadic figure of the citizen-worker, conceiving the social rights of citizenship to be intimately connected to the dynamics of the national labour market. It is not that now this connection has been fully ruptured. There is still, undeniably, a nexus of citizenship and labour, whether manifest in paths to citizenship that pass coercively through the labour contract, regular forms of collective bargaining and arbitration that are still practised through nationally organized trade union systems, or the newer forms of Anglo-Saxon 'mutual obligation' that mandate third-way schemes such as 'work for the dole'.

What has changed is that this citizenship–labour nexus can no longer be fully captured by the dyadic subject citizen-worker and the gendered division of labour that sustained its reproduction. Both citizen and worker have been invested by diffuse processes of division and multiplication; and migration has played crucial roles within these processes. Consequently, the subjective positions of both citizens and workers need to be rethought outside the dyadic structure of citizen-worker that can no longer be taken for granted and which underlies the construct of the national labour market. What we would like to emphasize here is that the specific connection between labour and citizenship that culminated in social citizenship has played a very important role in shaping the whole imaginary of western sociology, including its 'methodological nationalism' and basic sociological concepts that were formulated in ways that take for granted the existence of bounded social and political spaces. We understand topology as an attempt to come to terms with the problematic undoing of these bounded spaces. This is what makes the topological approach particularly challenging and productive from the point of view of our research perspective of *border as method*.

Immanent Outsiders at the Border

The processes of the proliferation of borders and the multiplication of labour that we analyse in our work are crucial to the disarticulation of the dyad citizen-worker and to the production of new, flexible and mobile assemblages of labour markets and citizenship. Contrary to the dominant tendency in border studies, even more pronounced after September 11, to stress dynamics of *exclusion*, we focus on the changing shape of *inclusion* that can be analysed assuming the perspective of the border. It is from this point of view that we share one of the basic points of the topological approach to social and cultural processes. As Celia Lury writes, the topological thinking of multiplicity maintains that 'the parts that comprise the whole (in relations of multiplicity) are always more than the elements in which it consists'. This leads her to pick up an evocative phrase from Alain Badiou, and to explain that in the topological space 'there is an excess of inclusion over belonging' (Lury, 2009: 80). This fits nicely both with our emphasis on the constituent excess evident at the border and with our attempt to move beyond the binary inclusion/exclusion, pointing to the proliferation of subject positions that are neither fully included nor fully excluded from the space of citizenship and from labour markets, of subjectivities that are neither fully insiders nor fully outsiders. So-called 'irregular migrants' are a perfect illustration of the condition described by Badiou, since while they are included in the space of labour markets and citizenship, and indeed contribute to the production and reproduction of those very spaces, they do not share the 'belonging' (the legal status) to which a whole set of rights correspond.

Observing these conditions, Anne McNevin suggests the term 'immanent outsiders' to describe 'irregular' migrants (2006: 141). Such a definition clearly points to a process that blurs the very existence of a clear-cut border between inside and outside. Taking account of this process entails a critical questioning of the basic condition around which the history of the modern state, the global political geography it organized, as well as sociological imaginary it generated revolved. Far from considering such figures as the 'irregular' migrant as 'marginal', we approach them as central to the fundamental transformations that have reshaped citizenship and labour, culture and space over the last two decades. We agree with Étienne Balibar when he draws his own conclusion from an analysis of these transformations and contends that one of their most important consequences is that processes of bordering proliferate across political space. As he says:

> Whereas traditionally and in conformity with both their juridical definition and 'cartographical' representation as incorporated in national memory, they should be *at the edge of the territory*, marking the point where it ends, it seems that borders and the institutional practices corresponding to them have been transported *into the middle of political space*. (Balibar, 2004: 109)

In this important and often discussed quote we can say that Balibar pursues a kind of topological approach to contemporary political space. Borders, in his perspective, could be said to work as topological functions, which at once connect and divide, cross and cut political space, include and exclude.

The approach we call *border as method* has been developed taking these transformations and analyses such as the one proposed by Balibar as points of departure. More generally our engagement with borders acknowledges and reflects the growing relevance borders have acquired in research, political and artistic practices in recent years. One of the reasons for this heightened interest can definitely be found in the fact that borders nowadays are what Achille Mbembe (2003) would call 'necropolitical' sites *par excellence*. Wendy Brown writes in her recent book on new walls that in the past 13 years there have been at least 5000 deaths along the US–Mexico border (Brown, 2010: 91). According to independent assessment, since the fall of the Berlin wall in 1989 at least 17,738 people have died along the so-called 'external frontiers' of the European Union.[1] Needless to say these figures would be higher once unreported deaths on the way to borders (for instance in the Sahara) were added. While we share with many scholars, activists and artists rage and indignation about this permanent war against migrants staged at borders, we take our distance from the widespread reading of contemporary borders in terms of a unilateral emphasis on 'exclusion', conveyed for instance by the use of metaphors such as 'Fortress Europe' and by the reference to the iconic image of the wall. Such an image of the border seems to us precisely to discount the insights that can be gained from the topological approach. The image of the wall, for instance, tends to pose a form of invariance that resists the operation of transformations, deformations and modulations.

We are much more interested in an analysis of the multifarious struggles and tensions between practices of border crossing and practices of border reinforcing (Vila, 2000) that constitute the border as a social institution. Our point is that the violence that plays itself out at the border must be understood and criticized from the point of view of these struggles and these tensions. The topological approach is close to our own research practice since it facilitates a mapping of the shifting configurations of space and time that result from such conflictual encounters. However, the emphasis we put on tensions and struggles challenges any possible neutrality of analysis. It further brings us to stress not only the elements of connectedness that are so crucial to topology, but also the multiple factors of disconnection associated with the very existence of borders. More generally, we are convinced that connectedness and disconnection have to be taken and reflected upon together if we are to gain an accurate picture of the emerging heterogeneity of global space.

Border as Method

A further important aspect of our project needs to be highlighted. While we emphasize the strategic importance of borders in the contemporary world, we do not intend to join the chorus that in recent years and from many different points of view has celebrated the 'return' of the nation-state on the world stage, dismissing the debates on globalization as mere ideological distortion. To the contrary, one of our central theses is that borders, far from serving simply to block or obstruct global flows, have become essential devices for their articulation. Just as Wendy Brown (2010) reads the proliferation of walls across diverse geographical scales as a sign of the 'waning of sovereignty', so we take the proliferation of borders as a distinctive feature of contemporary globalization. From this point of view the border becomes for us a strategic angle on *actually existing global processes*. We contend that, rather than organizing a stable map of the world, the processes of proliferation and transformation of borders aim to manage the 'creative destruction' and constant recombination of spaces and times that lie at the heart of contemporary capitalist globalization.

The multiplication of borders in the global world implies deep transformations in their very nature. From the path-breaking work of Eyal Weizman (2007) on the wall between Israel and the Palestinian occupied territories (that is, precisely on the most intimidating wall that is often taken as example of the rigidity of borders), we draw the idea of a fundamental flexibility of contemporary borders and of the territories they are meant to circumscribe. Allowing Weizman's analysis to resonate in other 'borderscapes' (Perera, 2009), without losing the sense of the peculiarity of each instance, we trace processes of the doing and undoing of borders and boundaries, for instance analysing the new border regime that is emerging in Europe (Hess and Kasparak, 2010). We also try to map from the point of view of subjects in motion the elusive geography resulting from these processes. The deep instability of the traditional 'geopolitical' border requires, moreover, a careful analysis of the new configurations that emerge from its intertwining with other lines of distinction, with internal social and cultural boundaries.

Our aim is to bring into view a series of problems, processes and concepts that allow us to elaborate a new theoretical paradigm that differs from that constructed about the image of the wall or the theme of security. But we also depart from the classical paradigm of border studies (Kolossov, 2005), which tends to proceed by the comparison of discrete case studies, assuming clear and distinct differences between the various situations and contexts under investigation. Our primary interest is not in comparing different instances or techniques of bordering but rather in interlacing, juxtaposing and superimposing the practices, techniques and sites in question, highlighting their mutual implications and consonances as well as their differences and dissonances, their commonalities and their singularities. The result is a different means of knowledge production, one which resonates again with topological thought, highlighting the fact that geographical distance does not necessarily separate different practices and experiences of bordering in the conceptual or political sense. Part of our approach involves discerning these kinds of propinquity between various material instantiations of borders, keeping in mind that these instantiations are themselves made possible by the cognitive operation of border devices.

It is important to note here that borders are also essential to cognitive processes, since they allow both the establishment of taxonomies and conceptual hierarchies that structure the movement of thought. In so far as it serves at once to make divisions and establish connections, the border is an epistemological device, which is at work whenever a distinction between subject and object is established. As again Balibar notes, this is the reason why it is so difficult to provide a *definition* of the border, since 'the very representation of the border is the precondition for any definition' (2002: 76). Furthermore, borders establish the scientific division of labour associated with the sectioning of knowledge into different disciplinary zones. Cognitive borders, in this sense, often intertwine with geographical borders – just think for example of comparative literature or of so-called area studies (Chow, 2006). In any case, it should be clear that cognitive borders have great philosophical relevance, since they describe a general, perhaps one could even say a universal, dimension of human thought.

A thinker who has for many years studied the violence and border conflicts in regions such as the Balkans and the Indian subcontinent, Rada Iveković (2010), has recently proposed rethinking the 'politics of philosophy' in relation to what she calls *la partage de la raison*. The French term *partage*, which combines the sense of both division and connection, has no straightforward English translation. Nominating at once the act of division and the act of connection, the two actions constitutive of the border, *la partage de la raison*, in Iveković's formulation, highlights the crucial role of translation as a social, cultural and political practice that enables the elaboration of a new concept of the common. Here, the reference to Iveković's work allows us to clarify the somewhat paradoxical sense in which we write of *border as method*. On the one hand, we refer to a process of producing knowledge that holds open the tension between empirical research and the invention of concepts that orient it. On the other hand, to approach the border as a method means to suspend, to recall a phenomenological category, the set of disciplinary practices that present the objects of knowledge as already given, and to investigate rather the processes by which these objects are constituted.

Just as we want to question the vision of the border as a neutral line, then, so we also question the notion that method is a set of pre-given, neutral techniques that can be applied to diverse objects without fundamentally altering the ways in which they are constructed and understood. At stake in border as method, however, is something more than what John Law (2004) calls the performativity of method. That is to say, while we accept that methods tend to produce, often in contradictory and unexpected ways, the worlds they claim to describe, the question of border as method is for us something more than methodological. It is above all a question of politics, about the kinds of social worlds and subjectivities produced at the border and the way our work plays into and intervenes in these practices. To put this differently we could say that method for us is as much about acting on the world as it is about knowing it. More accurately it is about the relation of action to knowledge in a situation where many different knowledge regimes and practices come into conflict. Border as method involves negotiating the boundaries between the different kinds of knowledges that come to bear on the border and, in so doing, aims to throw light on the subjectivities that come into being through such regime conflicts. For all of these reasons, the border for us is not so much a research object as an epistemological viewpoint that allows an acute critical analysis not only of how relations of domination and exploitation are being redefined at the present time but also of the struggles that take shape around these changing relations.

Differential Inclusion

We can now return to our discussion of what Lury, following Badiou, calls 'an excess of inclusion over belonging'. It is again from the point of view of migration that we would like to develop this important insight. 'Porous boundaries and multiple identities', Stephen Castles and Alastair Davidson wrote at the turn of the century, 'undermine ideas of cultural belonging as a necessary accompaniment to political membership. There are increasing numbers of *citizens who do not belong*' (2000: viii). It is important that Castles and Davidson refer here not merely to 'irregular migrants' but to citizens who do not 'belong'. We see the analysis of the production of such subjectivities that are included but do not 'belong' as strategic. On the one hand, it provides a new angle on mechanisms of exclusion. On the other hand, it facilitates a critical approach to programmes of social inclusion, which are almost always seen as unambiguously benevolent but which also function as devices of hierarchization and control. What we need is a new theoretical framework capable of coming to terms with the shifting modalities of this elusiveness and the myriad systems of *differential inclusion* that we see taking shape in various borderscapes across the globe. Contrary for instance to Chantal Mouffe (2005) and Ernesto Laclau (2005), who argue that it is only through exclusion that a society can construct itself as a totality, the analysis of the multifarious mechanisms that filter and stratify subjects in motion leads us to rethink political processes and conflicts *on the border* between inclusion and exclusion. It is within this framework that we wish to rethink the topological approach.

The concept of differential inclusion has a complex and multiform genealogy that crosses the borders of migration studies and feminist thought. Although it has assumed many names, this concept has long provided a means for describing and analysing how inclusion in a sphere or realm can be subject to varying degrees of subordination, rule, discrimination and segmentation. More recently, the concept of differential inclusion has been deployed in an attempt to move beyond what we consider to be the blind spots in the widespread notion of Fortress Europe, which fails to account for the prodigious and increasing presence of migrants in the European space (Mezzadra, 2011). In this context, the concept was introduced to account for the actual operation of the migration regime in the making in Europe. Quite interestingly, an important point of reference for the deployment of the concept of differential inclusion was ethnographic analyses of the ways in which the US–Mexican border is managed (De Genova, 2002). In both the European and US instances, there is a legal production of illegality and a corresponding process of migrant inclusion through illegalization that creates the conditions under which a racial divide is inscribed within the composition of labour and citizenship. From this perspective, the devices and practices of border reinforcing shape the conditions under which border crossing is possible and actually practised and experienced. From a topological point of view one could say that the concept of differential inclusion points to a substitution of the binary distinction between inclusion and exclusion with continuous parametric modulations – that is, processes of filtering and selecting that refer to multiple and shifting scales, ratings and evaluations.

This is a point of view that emerges from the angle of subjects in motion and an attempt to point out the multifarious tensions that criss-cross contemporary practices of mobility far beyond the so-called global North. The analysis of the *hukou* system of household registration in contemporary China (Pun, 2005), the investigation of the complex systems of bordering that internally divide the Indian labour market (Samaddar, 2009) as well as of the vast panoply of South–South migration (Malecki and Ewers, 2007; Oishi, 2005; Xiang, 2008) – all highlight similar devices and regimes of selective filtering of labour mobilities. In each of these cases, despite the many empirical and geographical differences that must be taken into account, the border provides a nodal point of crystallization where tensions of labour and capital, as well as transformations of citizenship and the potentialities inherent in them, become visible. This is the optic provided by the border.

To fully understand the processes of differential inclusion, however, it is useful to mention a couple of technical devices of changing border and migration regimes that make the selective filtering of mobility possible. The first of these is externalization, which involves the displacement of border control and its technologies beyond the territorial edges of formally unified political spaces. This is evident in the management of the 'external frontiers of Europe' as well as in Australia's 'Pacific Solution' (Byrne, 2004; Geiger and Pécoud, 2010; Hess and Kasparak, 2010). In both cases, third countries are involved in the border regime, whether this implies the offshore outsourcing of detention facilities, cooperation in deportation procedures, visa policing or the surveillance of routes and so-called carriers of migration. What tends to emerge, as we argued above, are different degrees of internality and externality, which substitute and blur the clear-cut distinction between inside and outside that was produced by the traditional border of the nation-state. These techniques and measures of externalization facilitate the processes of filtering and differential inclusion by creating waiting zones through which the timing and tempo of migration can be more precisely regulated. At stake is also a certain folding of space, which brings remote and forgotten locations – islands, deserts, metropolitan peripheries, hidden parts of airports and ports – into topological proximity with the conspicuous and visible heartlands of nation-states and political regions. Migratory and refugee movements are thus channelled through holding zones and funnels, where the procedures of selection can be exercised, whether in entirely technocratic ways or through violent interventions (Bigo and Gould, 2005; Cuttitta, 2007; Neilson and Mitropoulos, 2007; Rigo, 2007).

These complex transformations of border regimes correspond to the dream of a 'just-in-time' and 'to-the-point' migration that is increasingly shaping migratory policies across diverse geographic scales (Xiang, 2008). Confronted with the unpredictability and 'turbulence' of contemporary migratory movements, this dream is compelled to come to terms with the impossibility of its full realization. This is the gap between dream and reality that produces the nightmare we mentioned above; that is, the deaths that are continuously occurring across borderscapes worldwide. Nevertheless, the fantasy of eliminating the gap between dream and reality continues to spur innovations in migration policies that attempt to react to the crisis of traditional quota systems, which are increasingly recognized as inadequate to the new flexibility and interpenetration of labour markets and economic systems.

It is to confront this crisis that points-based-systems of migration control have experienced a revival and a great diffusion in recent years. These highly technocratic but also quite arbitrary means of instituting differential inclusion involve the submission of migratory subjects to different and ever more highly calibrated parameters that purport to measure their worthiness and suitability to enter certain political spaces: education, health, religion, language, savings and readiness to 'integrate' figure prominently in these systems, alongside classical economic criteria such as labour skills. These systems tend to multiply and increasingly stratify the legal statuses of subjects inhabiting the same political space, while at the same time allowing an effective policing of the borders and boundaries between these different subject positions.

Despite this multiplication of control devices, there appear tensions and contradictions within points-based migration systems, not least due to the increasingly complicated landscape of transnational migration. The fault lines within such migration regimes are opened up not only by the inventiveness of migrants themselves, who continuously find tactics to negotiate and move through the hierarchized terms of these systems, but also by myriad other actors including labour brokers, migration agencies and middlemen working along the boundaries between legality and illegality. The question of what constitutes 'labour skills' is one that is particularly pressed by these actors at a time when 'grey zones' between 'skilled' and 'unskilled' labour proliferate within contemporary regimes of flexible production, especially in the cognitive and service sectors (Anderson and Ruhs, 2008). Here we see a proliferation of borders not as the separating lines between discrete spaces but as the production of multiple parameters that in combination determine the vectors of movement across an increasingly heterogenized social space. This can be considered as a kind of topological network of control. But the forms of flexibility and modulation involved in the two examples of externalization and points-systems are no less violent or discriminating than more traditional forms of topographical bordering. Moreover, they are criss-crossed by practices of struggle and contestation in each and every node of the network.

Mapping a Shifting Political Landscape

The blurring of patterns of internality and externality implicit in the increasingly prevalent migration regimes of differential inclusion also has important ramifications, as we already stressed, for the issues surrounding political subjectivity, not least the changing nature and forms of citizenship. Behind the rapid diffusion of points-based migration policies there is a fast-growing worldwide competition for skilled migrants. Such systems allow a preferential path to permanent residency and eventually to citizenship for subjects who perform appropriately in the intricate obstacle race instituted by these measures. The consequences for traditional theories of citizenship are huge. Ayelet Shachar discusses the spread of such 'talent-for-citizenship exchange' as well as its 'mirror image' in emigrant-sending countries, which increasingly encourage dual citizenship, investments in the national economy and return migration. This involves manifold processes of the flexibilization of citizenship as well as the overlapping and alteration of the traditional nation-state logic of political membership and identity with a 'more market-oriented and calculated rationale' (Shachar, 2006: 199).

Here we see another manifestation of the multiplication of citizenship statuses, but it is important to note that its effects are not merely restricted to an elite of globally mobile talented workers. Citizenship, under these circumstances, is not only a site of multiplicity but also of conflict. Unskilled workers too have a multiplicity of citizenship and residency statuses, among them the condition of being undocumented or clandestine. Taken together these transformations exhibit a disarticulation of the space of citizenship. Not only does 'Who is the citizen?' (Isin and Turner, 2008: 8) become an increasingly problematic question for contemporary theories of citizenship, but it is also necessary to ask 'What makes the citizen?' (Isin, 2009: 383). Under these conditions, Saskia Sassen (2006) argues, a full understanding of the tensions and conflicts that mark contemporary citizenship can emerge only from an analysis that works from the edges of the space of citizenship and not from one that operates from the legal plenitude of its center. That political subject who is 'unauthorized yet recognized' (Sassen, 2006: 294) or, in other words, the 'irregular' migrant, the 'immanent outsider' we considered above, is not only subject to exclusion but also becomes a key actor in reshaping, contesting and redefining the borders of citizenship.

The multitudinous claims articulated by movements of undocumented migrants, including the *sans papiers* in Europe and an important element of the US Latinos movement of 2006, attest the potentialities of such citizenship conflicts and practices (Suárez-Navaz et al., 2008). Contrary to the usual tendency in migration studies to place a firm border between analyses of skilled and undocumented migration, we contend it is necessary to take account of both of these, as well as of the overlappings and grey zones between them, to arrive at an adequate analysis of the contemporary contours of citizenship. Border struggles such as the ones we evoke in this article are to be understood as a flipside of the processes of flexibilization of migration management and citizenship we have also been describing. They challenge our imagination to invent new models of political action and a new theoretical language beyond the dyad of the citizen-worker.

To conclude: the image of the wall could not possibly explain the new processes of border construction. Nonetheless the factors that make it necessary to question this dominant image of the border as a wall do not signal the disappearance of processes of hierarchization and control. On the contrary, they point in many ways to the proliferation or multiplication of walls and borders of various kinds, not merely to mark the distinction between internal and external spaces, but also within the space and time of global capital and the borders of differential inclusion. The image of flows has been key both to the development of the topological approach and, more generally, to the discussion of globalization (Castells, 2001). It has also shaped (and continues to shape) projects of mapping that are part and parcel of the establishment of new assemblages and regimes of control. To get an idea of this one has only to look at the 'interactive map' developed by the International Centre for Migration Policy Development (ICMPD) within the framework of the so-called 'Dialogue on Mediterranean Trans-Migration'. The aim of this map is to track the increasing unpredictability and autonomy of migration in the Mediterranean area (Tsianos, 2008). Scholars trained in the topological approach (but also activists) can easily recognize in this map, which has multiple points of entry and does not represent a stable geography of mobility and control, a cartographic language and gaze they have concurred to produce.

In recent years, the prevalence of the image of flows in critical analysis of the making of global space has been challenged by several anthropologists, who have pointed to the importance of the 'carving of channels' (Tsing, 2000, 2005), of 'zoning technologies' (Ong, 2006) as well as of 'enclaves' and 'global hops' that can efficiently connect 'the enclaved points in the network while excluding (with equal efficiency) the spaces that lie between the points' (Ferguson, 2006: 47). Our own work is consistent with these approaches, which do not mean to disqualify the image of flows as such, but rather to deepen our knowledge of the actual processes of production of and conditions of possibility for flows themselves. We think that the ‘continuity of transformation’ with which topology deals (Massumi, 1998) has to be understood against this background, following both the lines of channels that ‘striate’ the ‘smooth space’ of flows and the movements of subjects that struggle on a daily basis against the new hierarchies and domination devices that the multiplication of borders produces in the global present.

Note

1. See: fortresseurope.blogspot.com (accessed 19 September 2011).

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The Topological Quality of Infrastructural Relation: An Ethnographic Approach

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Abstract
This article seeks to address how topological approaches to cultural change might be combined with ethnographic analysis in order to suggest new ways of thinking empirically about the dynamic political and moral spaces that infrastructural systems create and sustain. The analytical focus is on how diverse notions of relationality and connectivity are mobilized in the production of infrastructural systems that sustain the capacity of 'state-space' to simultaneously emerge as closed territorial entity and as open, networked form. The article seeks to establish that the differences and discontinuities inherent in all spatio-temporal relations might productively be considered as 'intervals' that both separate and connect across time and space. The notion of an infrastructural system as an interface that conjures both topological and topographical space is the idea that I set out to explore.

Keywords
connectivity, infrastructure, Peru, relationality, state-space, topological approaches

In this article I consider how topological thinking might inform a critical ethnographic analysis of how infrastructural systems come to constitute state-space, both as material relational form and as abstract potential. Infrastructural projects such as the large-scale road construction programmes that I have studied in Peru[1] are clearly linked to the territorializing practices of state-making and the study of the emergence of such systems offers a vantage point from which to explore the ways in which

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particular spatial configurations facilitate the exercise of power. As ordering projects these infrastructures open up the possibility for thinking through the specific ways in which 'state-space' and 'territory' are conceptually conflated, as suggested by Brenner and Elden (2009), and by Brighenti (2010) in their respective reflections on the work of Henri Lefebvre. Lefebvre (1991 [1974]) was interested in challenging the 'transparency' or taken-for-grantedness of state-space, and called for a critical analysis of the specific practices and processes through which an acceptance of generic or abstract space is achieved. There are many ways in which this agenda has been taken up in recent years, in what Brenner and Elden refer to as a 'veritable outpouring of innovative theoretical and empirical work devoted to denaturalizing the historical and contemporary geographies of state power' (2009: 355). But they also note that less attention has been paid to the ways in which 'territory' signals a historically and geographically specific form of political organization and political thought' (2009: 355). Brighenti's work on the 'territory effect' takes up this challenge and demonstrates an important theoretical and descriptive commitment to 'reveal the permanent tension between, on the one hand, procedures of stabilization, order, consensus, hegemony, preassignment and, on the other, the irreducible plurality of each territory, necessarily mirrored in every territorial constitution and regime' (Brighenti, 2010: 53).

The irreducible plurality of infrastructural spaces has been explored by scholars of science and technology studies interested in the multiple material, financial, technical, political and social relations that infrastructural spaces 'bundle together' (Collier, 2011). The memorable accounts of the unexpected consequences and contingent effects of state-sponsored infrastructural projects which such scholarship have produced exemplify how these complex relational spaces carry 'invisible trouble' within themselves (Star and Lampland, 2009) and register the inherent instabilities and fluctuations that their multiple components entail.[2]

The idiom of the topological offers a language for articulating the instabilities and fluctuations of state territory in explicit contradistinction to the topographical or metric idioms deployed to conjure more static notions of state-space. Topographical idioms mobilize the coordinates and metrics of fixed spatial geometries that allow the size of a territory to be measured or the distance between centre and periphery to be calculated, giving singular and absolute depictions of the space in question. In topographical mapping, the boundaries of state power appear as commensurate with a clearly defined territorial boundary, and such categorical mappings are echoed in the spatially nested structures of administrative divisions (in Peru these would be departments, provinces, districts and communities). Topological idioms, by contrast, focus on how 'power relationships are not so much positioned in space or extended across it, as compose the spaces of which they are a part' (Allen, 2011: 284). The topological approach thus draws attention to the spatial figures where insides and outsides are continuous, where borders of inclusion and exclusion do not coincide with the edges of a demarcated territory, and where it is the mutable quality of relations that determines distance and proximity, rather than a singular and absolute measure.[3]

The move to topological thinking in the contemporary social sciences has come by diverse routes. Mathematical explorations of non-Euclidian geometry have provided some of the concepts, and the empirical world of continuous calculation has prompted the current interest in the ways in which 'number-work' shapes contemporary life beyond any stable sense of metrics. My core interest here concerns the question of how material infrastructures of state participate in the enduring contradictions and controversies over how state-space is imagined and produced. However, the historical entanglements of modern states with calculative practice is self-evident when considering the development of infrastructural systems – whether we think of roads, railways and canals, or of information networks, transactional data or the multiple sensors built into the fabric of modern cities. Sloterdijk (2009) has argued that the 20th century was marked by an increasing and recursive awareness of relativity and perspectival difference. Such awareness heralded an increased strategic attention to the productivity of such difference, which has been mobilized in forms of warfare, of trade, of political and economic life, relational modes of action, or 'environmental thinking' that have transformed the conditions of modern life in dramatic ways. The background material conditions of such transformations are also the subject of Thrift's (2004) analysis of how the world of continuous calculation might be producing new kinds of spatial awareness. Thrift's analysis has suggestive implications for those interested in the spatial dynamics of infrastructural systems. The growth of calculation marks the emergence of the modern state, from early state interest in 'synoptic facts' (Thrift, 2004: 588), statistical methods (Porter, 1995) and the topographical 'gridding of time and space' (Thrift, 2004: 589; see also Pickles, 2004). The contemporary state, while still utterly reliant on its calculative powers, is of course also thoroughly engaged in 'environmental thinking' in Sloterdijk's terms. Quantitative methods are now routinely used to engage, rather than resolve, ambiguity and uncertainty. Thrift argues that this move, which we might describe as the emergence of a more pervasive topological orientation, involves the recognition of a more plastic sense of space and time, of relative space, of constant mobility and of perpetual change. Such recognition does not displace the centrality of calculative reason. On the contrary, Thrift argues that 'relative space' relies on 'absolute space' for its existence (2004: 597), and that 'the fine grid of calculation' has made the intrinsic multiplicity and differentiation of absolute space explicit (see also Brenner et al., 2010).

In this article I set out to fold these discussions of shifting spatial imaginaries into an analysis of how it is that state-space is apprehended in daily life in places where the tensions between absolute and relative space have become evident in the confrontations over resource extraction, and in the dramatic reconfiguration of value that global markets in minerals and hydro-carbons have brought to previously marginal rural areas. I am especially interested in the particular ways in which the contemporary commitment of the Peruvian state to neoliberal values has drawn attention to the 'variable openness' of state-space and in how it is that state-space is apprehended as both grounded and mobile, simultaneously continuous and discontinuous, specific and generic.

To approach these questions, I draw on current ethnographic work on state-space and road construction in Peru, and more particularly on the relationship between the notion of state-space as an abstract, future-oriented relational ordering and the road system as a network form that is designed to integrate state-space across different scales. I have found that a 'topological' approach to road systems offers some interesting possibilities over the idea of road systems as imposed grids which integrate state-space through the connective force of a network (see Knox et al., 2006). This latter more topographical understanding underpins the most common approach to road networks, which tend to be considered primarily in relation to a model of change as exception and as technologically driven.

'Roads' are not very promising topological objects, they do not conjure the image of plasticity and continual change that topological approaches are generally concerned with. And while those who attend to roads as sites of ethnographic enquiry certainly recognize their intrinsic multiplicity, they are not usually thought of in this way (e.g. Campbell, 2004; Dalakoglou, 2010; Harvey, 2005; Kernaghan, 2009; Klaeger, 2009, Moran, 2009; Thévenot, 2002; Sinclair, 2003). Roads are practical spaces, background spaces indeed that we trust to hold their form and leave us to go about our business. Road systems are infrastructures that are explicitly constructed with a view to stabilization, to the fixing of unstable terrains, and to the demarcation of specific routes between points. They are built to connect places and, in large-scale public works of the kind I study in Peru, they are built to draw together otherwise disparate spaces and populations. In this sense they might be imagined as overcoming rather than manifesting difference. And yet such a description of what roads do relies on a very static notion of state-space, and a very singular and linear understanding of what and how a road network integrates. In what follows I present four ethnographic perspectives on roads as controversial and unsettling state-spaces. Taken together these perspectives challenge the self-evident plausibility of a topographic orientation to infrastructural systems and show how a topological approach might reconfigure how we imagine such infrastructures in relation to the exercise of state power.

Longing for Connection – Roads as Social Generics

In 1999 President Fujimori of Peru had signed a new Forest Law as part of an ongoing strategy to promote bilateral agreements with Brazil, particularly with respect to the search for oil and the development of hydro power. Within this agreement there was a commitment to the improvement of the transport infrastructures, which included provision for the asphalting of a stretch of existing road which would extend the transcontinental network and ultimately offer Brazil a route to Peru's Pacific ports (Harvey and Knox, 2008). But Fujimori never followed through on this commitment. His priorities were focused elsewhere as he struggled to alter the constitution to secure himself a third term of office (Crabtree, 2006). By 2000 he had fled the country and an emergency interim government was trying to stabilize a volatile situation of deep-seated corruption in a country only recently emerging from over a decade of war between the state and the Maoist guerrilla movement of the Shining Path. It was only after Fujimori had left the country that the people of Ocongate (a small town in the southern Peruvian Andes where I have been working on and off since 1983) found out about the legal provision for a road. The agreement was about to expire. A few key local actors began to petition the government and eventually on 11 September 2001 – when the eyes of the world were turned elsewhere – they managed to gather around 4000 protesters and occupy a bridge not far from the highland city of Cusco, effectively blocking one of the key arterial highways of southern Peru. Their demand was that the new government commit the funds and build the road. The protest was effective. The government agreed to extend the timeframe of the Forest Law and funds were committed to the building of the Inter-Oceanic highway.

I do not pretend to know how much effect their demonstration had on those empowered to fund such projects. But the demonstration left its mark on those who participated. When people told me about the occupation of the bridge the event was framed as a heroic claim on the state – they stressed their determination and their success in working to ensure that the new road would not bypass their town. They spoke of their passionate longing for this road as a way to improve their everyday lives. They talked about the dust that they were forced to swallow, and of the risk to their lives every time they travelled. Their accounts of the demonstration graphically described how they had chained themselves to the bridge, how they slept in the open air without food, how they mustered the support not only of the other communities along the route but also of the powerful miraculous Christ figure whose shrine is located in the sacred mountains that dominate the landscape in this region

The passionate desire for the road seemed to align local interest to a general enthusiasm for road construction – embraced not just by the governments of Brazil and Peru, but supported by multilateral lenders such as the World Bank. All these agencies, local and global, mobilize a thoroughly topographical justification for road building programmes, repeating the idea that political and economic stagnation stem from a missing relation, a gap, that is felt to impede progress. In this mode of reasoning, networked connectivity, economic progress and democratization are understood to be mutually constitutive. The formula has driven investment in Latin American road construction programmes since the 1920s, when roads emerged as the technology of choice for the consolidation of the modern state, whose resources and capacities for action were tightly tied to US ambitions to expand markets and export cultural and political orientations beyond its own sovereign territories (Salvatore, 2006).

In Peru the road building programmes were played out as a technological confrontation with the natural world, a drama enhanced by established (topographical) imaginaries of a divisive and racialized national geography (Orlove, 1993): a narrow coastal strip, divided from the resource-rich Amazon forest by the huge barrier of the Andean mountain range. The new roads were designed to cut through these barriers, meeting the interests of banks, governments and local people, all equally invested in the idea of connectivity as public good, a way to increase the circulation of raw materials, commodities, people and information for the benefit and progress of all.

In the first decade of the 21st century, the Inter-Oceanic highway was also justified in these terms (Llosa, 2003; Paredes, 1992). However, road construction projects exceed single scales of integration, with political and moral consequences that are highly disruptive of the ambition to use such systems to create integrated and homogeneous social space (Thévenot, 2002). In Ocongate the ways in which a need for a new road surface was imagined had little to do with the macro-economic ambitions of Brazil, the development of the Amazon region or the integration of the Peruvian state. From the perspective of the campaigners their protest for the road was a bid to change their conditions and expectations of life, to reconfigure how they connect to others. Their protest was not radical. They were calling on the state, as righteous citizens, to remember their condition and to fulfil the constitutional obligation to ensure parity of inclusion through the provision of a stable and reliable 'state-space'. Their pasts and their futures were at stake, and in this grabbed space of opportunity their demand was for an engineering solution: they wanted a fast, reliable, asphalt road which would address *their specific condition* of geographic isolation and marginality *and* make their space continuous with and equivalent to other spaces in the more developed regions of the country to meet an imagined generic standard. Ultimately, they were looking for transformations in their daily lives and were less invested in the logics that drove the move, at another scale, to develop market potential by ensuring networked connectivity. In fact they were somewhat sceptical about the integrative capacity of the road, schooled in the experience of differential inclusion. They knew that their town was not remote to those with expensive vehicles, they knew that the engineers could get back to the east coast of Brazil in less time than it took them to travel a few hundred kilometres down the road in old trucks and buses. Nevertheless, it was clearly politically expedient to play up the image of a homogeneous and bounded isolation to bring the much desired road their way – by packaging the problem in the right way, as an instance of topographical exclusion, they could get a solution to other problems that nobody else is interested in.

What I want to draw out from this account is the way in which the road operates as a social generic that overcomes the historical and geological specificity of place in two distinct ways. First, in relation to the ways in which roads appear as standard forms, as social generics of the one-size-fits-all variety. But they are also social generics of another kind, that rather than taking standard form are more virtual, under-specified, not-yet specific. They thus appear as both solution and open-ended possibility, a technical fix and an opening to the contingent effects of environmental thinking.

In accounts of networked connectivity it is common to find that the ways in which connectivity is achieved matters less than connectivity itself – in network thinking the relation itself is not what's interesting. And since the relation is taken for granted, there is a tendency to think of networks via an inventory approach – the connection is either on or off – you are in the loop or out of it. We are familiar with this trope from Castells' work on the network society (Castells, 1996, 1997, 1998) and from the ways in which this framing has been rhetorically adopted by the World Bank and by governments and local councils across the world eager to enhance their own connective presence, or to get their citizens to join up to the market, to e-governance, to community building (Green et al., 2005).

Notwithstanding the innovative connections that such networks have enabled (and to which I return shortly), the preoccupations that this emphasis on connectivity produces tend to play into the notion that the absence of a specific connection is somehow tantamount to an absence of relationality per se. This attitude was certainly characteristic of campaigners for the road in Peru, who were terrified of being left out of the loop. Tremendous effort was put into trying to find out exactly where the new road was going to go – with many people deeply concerned about the possibility of further marginalization should the road not run more or less past their front door!

By contrast to the standard one-size-fits-all and fixes-all generic produced in response to the perceived gaps in the network that have to be bridged to ensure appropriate participation – there is the other social generic which is not 'empty' but merely 'under-specified'. This under-specified generic is similar to Marc Augé's (1995) notion of the non-place. Augé's non-places are spaces of transit in which no lasting social relations are established. Non-places are the spaces of super-modernity such as airports, motorways, hypermarkets, designed to maximize circulatory flows. And while some complain of the impersonality of such environments, Augé points out that it is their generic qualities that open up the promise of utopian futures, for, as non-places, they are also cast as spaces of potential, in which relations are not yet prescribed or symbolized – free zones for adventure and creativity.

Roads as Topological Spaces

One of the attractions for me of topological thinking comes from the way in which the topological figure can hold the under-specified generic and the specific together, as exemplified by Bernard Cache's (1995) topological description of Lausanne. In his description of the emergence of this city Cache tracks the ways in which the urban space takes shape and transforms over time. He describes the multiple vectors, the intersecting architectural framings, and the mutating, relational, social spaces – the folding of material and symbolic space, of geology and history, of past and present. In this way he conveys how urban spaces have geological, social and temporal specificity in relation to the durational abstract potentiality of Lausanne's topology.

I had been alerted to these kinds of relations from my work with civil engineers working on the roads of Peru. They taught me about the dynamic tension in their work between generics and specifics as they deployed various standard techniques of transformation in relation to specific material worlds. Engineers engage the dynamic properties of material spaces. On the one hand they seek to stabilize materials through the deployment of metrics – materials are gathered, tested, modelled, retested, their material properties all carefully measured defined. But this work of definition then becomes a future-oriented speculation – the capacities of materials are calculated with respect to less certain measures – starting with the available time and money for the realization of the project – but extending also to all the possible conditions which the asphalt surface might engage in the future. In this sense it is self-evident to an engineer that roads are provisional structures – they require constant attention and repair – their construction and maintenance is a balancing act and their resilience will depend on many things which are carefully taken into account when they are built – and others which are entirely unexpected and to which the road surface has to adapt. Engineers thus constantly work between the one-size-fits-all generic of the technical fix – deploying standard formulas, techniques and materials, and the specificity of the material and social conditions that constitute the grounds of possibility for their work (see Harvey and Knox, 2010).

It is important to note here – following Cache – that the road has a virtual quality that exceeds any particular configuration. The specificity of a site will be integral to the infrastructure that emerges, but this actualization is a singular and provisional end-point, the outcome of an intervention that manages to fix things for the moment, by limiting or reducing the scope of other possible mutations. But if we follow a more topological approach and hold to the notion of road systems as open mutating structures – we are left with the question of how it is that these now apparently fluid spaces are so compelling as the means to integrate social entities such as states or regions. My argument thus far has suggested that while roads might connect things up, this connection does not necessarily involve any particular sense of integration.

Confrontation and Territory Effect

In 2009 a group of indigenous people near the Amazonian town of Bagua blocked a road to draw attention to the fact that the state had failed to consult them about the sale of oil concessions granting (foreign) oil companies the right to explore on their territories. International laws, to which Peru is a signatory, require the state to ensure indigenous participation in the re-designation of their territories. At the same time the state is the legal proprietor of the subsoil and had enacted specific decrees in parliament to open up the subsoils to international capital. In 2009 the President was determined to further his politics of free-market liberalism and refused to negotiate with local people. The army fired on protesters from the air and protesters attacked police on the ground. There were deaths on both sides. As in the previous example, protesters had forced their presence on the state, making themselves visible by the blocking of a road. But this time the response was brutal. The road effectively corralled the protesters, making them visible to a vengeful state that refused to engage in the discussion of who has the right to make a living from this place and how. The President of Peru, Alan Garcia, argued that the nation could not be held back by the selfish acts of a minority. He declared the categorical identity of Peru as that of a mining nation, and articulated his responsibility to enable the nation to realize its potential (Drinot, 2011). The killings provoked an international outcry. Images of the desperately uneven confrontation circulated from cell phones to computers and all kinds of media outlets. Garcia's attempts to impose a mining identity on the complex and variegated space that we call Peru was challenged and the integrity of the national space became less obvious, momentarily de-stabilized. It was not simply that the protesters had been discounted – treated as disruptive criminals, rather than as organized citizens. It was also that the Amazon forest was seen as a space that counted for many other people around the planet who were anxious both about the expansion of mining interests and the effect of extractive capital on a shared ecosystem.

It is clear from this example that connections are not that straightforward. Here there is already a road and it is causing problems. The connection has not simply failed to bridge the gap, if anything it has exacerbated it. And in the process it is clear that the gap is not constituted by a missing relation but by a tension in the network. The connection is threatening, drawing in unwelcome modes of integration. Not everything in the network is of a kind, flows are disrupted and the state moves in to clear the way. But it is not that clear any more who is inside and who is outside the network or rather which network. Interior and exterior perspectives fold into each other, intersecting and challenging any stabilization of value. As in the first example, the local confrontation plays out the complex dynamics which inflect Peru's international relations, extending possibilities for both capital growth and for ecological futures, while at the same time insisting on sovereign rights to allow and/or to curtail such flows.

In short, taken together, these two ethnographic perspectives show that the confrontations taking place on these roads are not fights over pre-existing territories as configured in models of competing interests. They are more importantly confrontations over what these places might become, specific struggles in which the future is folded into the present, and where anticipated futures bring forward past experience in ways that conflate the specific and the generic. The collaborations and collusions entailed in these movements are important. There are no clear lines of differentiation. State actors, engineers and local people all know (through specific relational dynamics) that roads are not simply delivering state-space in the sense of a stable topographic network. For all the planning and the blueprints, road construction only partially delivers a transparent territory effect. In fact, the idea that roads are built to fill in the gaps between places can only figure as a plausible account after the event. Rather than plug gaps, or create gaps, what these infrastructures do is transform relational fields. Thus, if we approach roads topologically we begin to identify relational scenarios where the plugging of a gap does not bring closure but opens other relational possibilities.

Material Politics – A Relational History

My third ethnographic figure is drawn from the Huayllaga region of central Peru described by anthropologist Richard Kernaghan (2009). The road that Kerhnaghan describes was originally built as part of an ambitious infrastructural state initiative to connect the diverse regions of the Peruvian Amazon to coastal urban markets. During the 1980s the Huallaga region became an important stronghold of the Maoist guerrillas as a strategic space from which they could disrupt the flow of goods from the guerrilla-friendly illegibility of the Amazonian frontier. The road was the only way into this region and so the guerrillas systematically undid the road. Those who did travel the road were liable to be taken hostage and forced to help them dig it up, scar its surface, dismantle the many bridges. Their sabotage mounted an effective challenge to the power of the state to maintain its interconnected territory. They used the road to show that the state was a spent force, unable to act. Some years later, when the war had played itself out, the state demonstrated its recovery by repaving the road – a gap was plugged. But this act of repaving opened new possibilities. The wonderful flat surface of the new road proved ideal for drug traffickers to land their small planes. It allowed them to appear and disappear in the coca-producing regions using state-space in ways that evade state control. Again the state responded. The challenge was to think of a way to keep the road open while closing it to aircraft. The solution was to build short concrete walls at regular intervals along the straight stretches of road. Cars can zigzag round these walls (although not without considerable danger and subsequent loss of life) but the planes could not negotiate them. The drugs trade fell off – and the region reverted to one of abandonment and poverty, open to the possibilities of new politics of integration and still one of the most volatile regions in the country.

From the perspective of the Huallaga region, marginality no longer appears as a function of a missing physical connection but invokes the contentious relational value of specific connections or the lack of them. As in Bagua, where the state's intention to open a connection for capital was disrupted by the fact that the land was already occupied by citizens supported by international social movements from across the world, here too international vectors threaten the precarious self-image of the state as an identifiable and singular entity. The combined presence of transnational corporations and indigenous peoples unhinges the smooth relation between capital flow and public good. What is left now of the notion of an infrastructural system?

Blockage, Stagnation and Emergent Positioning

Road construction on the new Inter-Oceanic highway linking the highlands of Peru to the Brazilian border was well under way when the Ocongate protest happened. Indeed the progress was what brought the problem to light. After much debate it had been agreed that the new road would not cut through the centre of the small and densely populated Andean town. Instead it would run around the edge, opening up a new space between the houses and the river, ensuring that the town square remained intact. Some agreed that this was the only way. Others were disappointed. They knew that even this minor detour would effectively preclude the traffic from stopping. There was little advantage to them. Nothing would change. And this was the problem. The road was supposed to change things. In the campaign to bring the road to the town much had been made of the ways in which asphalt concrete would put a stop to the dust – the dust that they had to swallow when they travelled, the dust that swirled in clouds around moving vehicles and, in particular, the dust that the school children were forced to inhale in and around their playgrounds. The schools lie to one end of the town and became a focal point for local protest. The townspeople asked the construction company to asphalt an extra stretch of road – the stretch that ran past the school. This short stretch had come to index a future that teetered between progress and stagnation – it had always been assumed that the new road would come this way. The company refused. From their perspective, they had to work to a tight budget and a tight schedule. The works that they were contracted to deliver could not be diverted to deal with every local concern along the way. Ocongate was just one point along a 700 km stretch of a route where the affective force of deprivation and expectation would constantly generate demands. But their refusal made no sense to local people. The construction company was there. They had the materials and the machinery. The short stretch would hardly detain them and people knew that in other circumstances deals were struck, other modes of compensation or equivalence were conjured to allow the works to proceed. And so the director of the school organized the parents to march on the construction camp demanding that the engineer in charge of the works negotiate with them. There were hundreds of people and from inside the camp it felt as if they were under siege. Inside they were scared. Outside people were angry but they had no real sense of being on a demonstration – they wanted to talk. They were told that the engineer had gone to the city but that he was on his way back and would speak to them when he arrived. What actually arrived were bus loads of special forces, armed police who dispersed the crowd with tear gas and batons – pursuing the parents along the streets and into their homes. The protesters clung to their designation as parents in their accounts, to emphasize that they had protested, as before, as citizens, family members, women and children alongside the men. But this time their blockade was treated as an attack. The police force was brought in to protect the public works and the private company contracted to deliver them.

Fortunately nobody was killed. But the incident was hugely significant in the unfolding relationship between the company and local residents. From that point on the construction camps were patrolled by armed guards. The local police were formally subcontracted to protect the company. The lines of protection and of threat were articulated in ways that located public interest firmly on the side of the corporation. As in Bagua, the road that they had longed for and campaigned for so ardently had opened them to capital in ways that they had not anticipated. The new connectivity turned out to involve a militarization of their immediate environment, a closing off of rights to peaceful protest, and a closing off of expectations of protection from the local police. The road and its promise of productive connectivity had become a space that amplified social discontinuity. The anxieties about the future folded back into the present and provoked both the demonstration and the armed response.

In this folding the road also emerged as a site through which an implicit politics of scale became explicit. From the beginning the expectations for this road configured the space as a site of convergence, where the slippage between the ambition for intercontinental connectivity seamlessly morphed into the site of local development and improvement. But the 'win-win' formula collapsed as, in the process of construction, the company felt itself compelled to explicitly impose a scale at odds with that which would enable local people to feel that this project might, in the end, have something to do with them.

Conclusions

The article has explored the ways in which shifting perspectives from the roadways of Peru offer us a way of thinking about how infrastructural systems create and sustain dynamic political and moral spaces. The idea has been to look in detail at the specific relational discontinuities that roads (as state-spaces) actualize. I have argued that it is not sufficient to think about such discontinuities as simple gaps, or breaks in a network. Rather, I have argued that such discontinuities might more productively be approached as intervals, a space-time that marks difference rather than absence. In such spaces of difference and ambiguity movement becomes visible, and plasticity is made explicit.

My account also raises questions about how such awareness emerges. Thrift's (2004) argument about the effects of continuous calculation on contemporary spatial awareness resonates with Sloterdijk's (2009) recent work on environmental thinking. Both authors are concerned to trace a material history of unfolding uncertainty, ambiguity and destabilization as internal to the development of modern technological rationalism. The perspectives presented here support these accounts, but they also question the conditions under which the productivity of difference becomes explicit. Notions of movement-space are themselves open and multiple, and have histories that are not confined to 'encounters' with continuous calculation. They might equally emerge through other modes of disruption and consequent controversy, and topological understandings of movement and of multiple perspectives are thus as relevant to Cache's (1995) history of Lausanne or my studies of the roads of Peru as they are to the effects of contemporary computing capacity.

The power of topological approaches in this respect lies in the attentive orientation toward the specific relations in play and to the specific transformations between generics, abstractions and particulars through which open-ended topological dynamics become, albeit momentarily, actualized as topographical arrangements or a territory effect in which difference loses its sense of dynamic potential. It is important to emphasize that the terms of this continual movement between the topological and the topographic holds no intrinsic value. States, protesters and people going about their everyday lives all engage with and reproduce notions of absolute and of relative space. My particular interest in state-space emerges from the ways in which this tension, or point of ambiguity around the folding of topographical and topological imaginaries, is mobilized in particular circumstances and with specific effects.

Infrastructural systems offer a way into these debates, as Star (1999; see also Lampland and Star, 2009) has long argued. Road systems are state infrastructures that simultaneously occupy specific and generic space, transcending local conditions, yet only ever engaged through local conditions; designed with an eye to the future but grown on established relational terrain and thereby carrying forward both the strengths and limitations of where they came from. In this respect we might think of the infrastructural qualities of roads as pertaining to how they make up and undo state-space through the ways in which they both posit and unsettle territories and populations, work across local, national and international spaces of law, history and aspiration, bringing past and future, interior and exterior together in ways that topological approaches help us to identify.

Notes

1. The article draws on ethnographic fieldwork conducted in 2005–6 with Dr Hannah Knox. The research project 'Roads to Development? Uneven Modernities and the Politics of Knowledge' was supported by the ESRC and by the ESRC Centre for Research on Socio-Cultural Change (CRESC).
2. Salient examples include: Bowker and Star (1994), Edwards (2004), Goddard (1994), Graham and Marvin (2001), Hughes (1983), Latour (1996), Mukerji (2009), Star and Lampland (2009) and Thévenot (2002).
3. Notions of the topological have been adopted by social scientists from mathematics, but also appear in the social science conceptual tool kit via Deleuzian approaches (Deleuze and Guattari, 1987). For an overview of the diverse possibilities that this topological turn affords, the ATACD project from which this special issue derives has much to offer.

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Article

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HIV, Globalization and Topology: Of Prepositions and Propositions

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Abstract

In this article we explore how two enactments of HIV – the UN's AIDS Clock and clinical trials for an HIV biomedical prevention technology or pre-exposure prophylaxis (PrEP) – entail particular globalizing and localizing dynamics. Drawing on Latour's and Whitehead's concept of proposition, and Serres' call for a philosophy of prepositions, we use the composite notion of pre/pro-positions to trace the shifting topological status of HIV. For example, we show how PrEP emerges through topological entwinements of globalizing biomedical standardization, localizing protests against PrEP trials and globalizing ethical principles. We go on to examine how our own analysis manifests a parallel topological pattern in which we deploy a globalizing argument about the localizing of the globalizing found in the AIDS Clock and the PrEP trails. Finally, we consider how the movement of 'topology' into the social sciences might itself benefit from a topological treatment.

Keywords

globalization, HIV, prepositions, propositions, topology

If topology can be defined in the simplest of mathematical terms as a study of 'the properties that are preserved through deformations, twistings, and stretchings of objects',[1] there are clearly numerous ways in which it can be unpacked in its relation to social scientific inquiry (e.g. DeLanda, 2002; Lash and Lury, 2007; Mol and Law, 1994). For immediate purposes, we note three points that typify our use of topology: space and time are not external frameworks but are emergent; points (which might be entities or events) that are distant can also be proximal (categorically as well as spatially and temporally); and transformations

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of the relations between points are not causal or linear, but open and immanent.

In this article, this characterization of topology affords a number of interesting supplements to the sociological accounting of globalization processes. First, and most obviously, we would argue that it facilitates exploration of the relation between global and local without tacit recourse to an external framing or parametization of one by the other that is found in much social science. Instead of accounting for the local in terms of the global or vice versa, topology resources an analysis in terms of their mutual emergence. We illustrate this through a consideration of the AIDS Clock on the United Nations Population Fund (UNFPA) website[2] that registers the increasing number of people living with HIV worldwide, and the randomized clinical trials (RCTs) of an HIV prevention technology commonly referred to as pre-exposure prophylaxis or PrEP (with its accompanying ethical problematique). Both of these interventions – the clock and the clinical trials – are instantiated or enacted in global terms, that is, on a global register. In part our aim is to trace the topological space in which these interventions, in being enacted as global, are met with, and become mediated by, localizing contingencies which themselves draw from globalizing resources. Here, we make use of Latour's and Serres' respective notions of proposition and preposition because together they are particularly helpful in unravelling the topologies of the AIDS Clock and the PrEP RCTs. By enabling us to see the myriad of entities (e.g. drugs, bodies, algorithms) that are topologically connected in the AIDS Clock and the PrEP RCTs, these concepts also allow us to address how the clock and the trials opened *locally* to particular potentialities, notably their own continued globalization.

Thus, our 'first-order' argument is that the globalizing enactments of HIV can be usefully illuminated through a topological analysis that charts how divergent spatio-temporalities can co-emerge (to open up particular potentialities). Over and above the implications for social scientific understanding of globalization, this argument suggests that existing conceptions of a 'global' epidemic are often ill-equipped to respond to the topological contingencies that comprise 'their' dynamic.

However, a topological sensibility also allows for a more complex relation to such an analysis – one which reflects upon (or rather inflects with) the enactment of the very categories (of global/local) that the analysis purports to topologize. In a 'second-order' argument around our own analytic engagement with the two forms of HIV intervention, we set out how our own analysis displays topological features parallel to those we unpick in relation to HIV intervention. On this score, again via the work of Serres and Latour, we draw upon and develop the interconnected notions of propositions and prepositions as a means of articulating these complex topologies across 'what is being analysed'

(HIV interventions) and 'what constitutes the analysis' (a topological accounting).

Moreover, we go on to situate this point in relation to a proposed 'third-order' argument, namely that we should also consider the application of topology to the relation between the 'disciplines' of social science and topology. This move sensitizes us to the complex dynamics of the interdisciplinary enactment of the global and local, specifically the application and applicability of concepts across disciplines. In other words, we argue that we need to be topologically sensitive to the ordering and disordering entailed in such conceptual exchanges between these disciplines, not least those involving the concept of 'topology'.

In what follows, we begin by separately presenting our two core empirical cases: the AIDS Clock, and accounts of standardized randomized clinical trials and their accompanying ethics, or ethical problematique. We then consider how their attempted global reach weaves into various local contingencies, particularly localizing critiques that emphasize the conditions of infection and death, and local political protest against the clinical trials. We argue that there are topological interconnections among these globalizing and localizing enactments.[3] However, we also go on to note how our own critical commentary upon these interconnections is itself topologically related to its subject matter. In the process, we suggest a series of linked conceptual tools for thinking the topological relations enacted both in these empirical relations and in our analytic enactment of them. Finally, we draw out some implications for the response to the HIV epidemic but also for the topologies of 'doing of topology' in social science.

Gloablizing Registers of HIV

The AIDS Clock

On visiting the AIDS Clock at United Nations Population Fund (UNFPA) website, one is met with a large digital readout at the head of the page. To the left of this scroll two texts: 'Every 16 seconds, another person dies of AIDS', then 'That leaves...'. The readout (standing at around 35,400,000) changes upwards by one every few seconds. To the right is the text: 'People living with HIV'. Beneath this is a map of the world divided into countries, and in the top right-hand corner of the map is a small panel divided into three bars. On the uppermost is the text: 'RESIZE THE MAP'; the middle reads: 'All countries resize relative to number of people with HIV'; the bottom simply says 'Play'. On pressing 'Play' the map morphs from the familiar projection of countries into a configuration in which, as the accompanying texts states: 'The area of a country now represents the number of people living with HIV'. As the cursor is moved over each territory, a figure appears along with the name of each country. Most immediately prominent are South Africa

(5.7 million), India (2.5 million) and Nigeria (2.6 million), though these numbers do not seem to be proportional to the resized national territories (for instance India and South Africa take up roughly the same area). In addition, with the pressing of ‘Play’ a drop-down menu appears which lists such options as ‘Regional Info’, ‘Relative to Population’ and ‘About HIV/AIDS’. Following the ‘Relative to Population’ option allows one to see the percentage of people infected with HIV for each country (where data is available), for example, Swaziland, 26.1 percent. At the bottom of the webpage is a section providing further resources: Fast Facts, links to the 2008 Report on global AIDS epidemic, a Media Kit, a Download of Fast Fact Powerpoint slides, for instance.

The AIDS Clock described above is a relaunch of a clock originally unveiled in public lobby of the United Nations in New York in 1997. This travelled as an exhibition (e.g. to Toronto, the Hague) before being redesigned as a web-based advocacy tool in 1999. The current incarnation entailed a recalibration in accordance with the new epidemiological data presented in the UNAIDS (2006a) *Report on the Global AIDS Epidemic*. A press release from the UNFPA[4] states that the clock’s mission is: ‘to present the world with a powerful symbol of the epidemic’s scale and the urgent response it demands’. Moreover, ‘“The AIDS Clock reminds us of how pressing our work is”, said UNFPA Executive Director Thoraya Ahmed Obaid. “Behind each number is a face, a family and a circle of loved ones who are also affected. Our goal is to slow down, and eventually turn back the AIDS Clock. Preventing HIV is the key.”’ As ‘a multimedia advocacy tool’ the clock also ‘links to regional figures, fact sheets and epidemiology trends, based on information provided by UNAIDS. It also provides links, amongst others, to some of the major campaigns that work to spread awareness of the issue and mobilize effective responses’. As we have noted, clicking on various sections of the map reveals more complex epidemiological accounts of how and where infections occur and which, in turn, generates a significantly resized map. Yet, crucially, all this (partial) difference feeds into a single clock figure that, as with the original clock, aims to allow people ‘to comprehend, in a visual and visceral way, the scale of the epidemic’.[5]

Randomized Clinical Trials and their Ethical Problematique

The epidemiological mapping depicted in the AIDS Clock aims to trigger a heightened sense of urgency regarding the issue of global prevention, drawing attention through the menu embedded in the map to how different epidemiological groups experience higher HIV incidence. Since the introduction of antiretroviral HIV drug therapies and their capacity to slow viral replication and therefore the onset of AIDS (acquired immune deficiency) resulting from HIV infection, randomized clinical trials (henceforth RCTs) have been conducted to establish the efficacy of using the same drugs for prevention purposes (Padian et al., 2010). As in other areas of the biomedical sciences, RCTs are generally seen as the gold standard in testing pharmaceuticals in general, and HIV treatments/ pharmaceutical prophylactics in particular (Padian et al., 2010).[6] Indeed, RCTs are regarded as ethical in themselves as the following quote, from leading practitioners in the field, illustrates:

> In clinical medicine, the randomized controlled trial is considered the best way of measuring the efficacy of interventions because of its ability to minimize bias and avoid false conclusions. Random assignment of individuals to different treatment groups is the best way of achieving a balance between groups for the known and unknown factors that influence outcome. This may seem to run counter to the traditional medical model of the doctor deciding which treatment is best for each patient, but it is considered ethical only when there is genuine uncertainty about which treatment to offer. By the same token, failure to tackle genuine uncertainty about treatments through randomized controlled trials can be considered unethical because it allows ineffective or harmful treatments to continue unchecked. (Stephenson and Imrie, 1998: 611)

The trialling of antiretroviral drugs for prevention follows many years of testing their efficacy against viral replication in HIV positive populations (thereby preventing the onset of acquired immune deficiency syndrome and inevitable death) and, importantly, evidence of their efficacy in preventing vertical transmission of the virus from mother to baby in pregnancy and during birth (Padian et al., 2008: 586). Of the trials under way, we want to focus on those assessing the efficacy of an orally ingested, systemic form of pre-exposure prophylaxis – a daily pill – that operates over the entire body via the bloodstream. This sort of microbicide stands in contrast to topical microbicides, for example, a gel containing the same drugs but applied to a specific body surface (vaginally or rectally).

PrEP trials – in the same manner as other HIV biomedical prevention trials – depend on the likelihood that a high number of participants will be exposed to HIV (usually through unprotected sexual intercourse) during the course of the trial.[7] This means that most trials are conducted where HIV prevalence and incidence is high, features of the epidemic that are prominent in low- and middle-income countries where effective forms of non-biomedical prevention (promotion of the male condom) has either not been instituted or instituted inappropriately for the specific cultural context (Piot et al., 2008). Without rehearsing the complexities of HIV prevention, it is possible to state that the conditions giving rise to HIV vulnerability and hence attractive for conducting randomized clinical trials are also the very conditions that may be exacerbated by such trials. Inadequate health and medical infrastructure that has contributed to poor prevention and insufficient HIV treatment, in particular, may be burdened by the presence of an HIV biomedical trial that incurs, as one example, unwanted adverse effects after the trial is completed (MacQueen et al., 2007). Even during a trial and in the presence of state-of-the-art technologies for testing the intervention, it is well recognized that 'offshore' trials cannot provide the same quality of care as that available in the national context of the trial sponsor (Craddock, 2004: 241; MacQueen et al., 2007: 554). Hence, it is apparent that the conduct of an RCT poses what are recognized as bioethical concerns. In recognition of these, international normative agencies such as UNAIDS/WHO (2007) provide guidance on issues of participant consent, provision of other forms of prevention (at present, counselling and condoms) and provision of medical care. Indeed, bearing in mind debate within the HIV field as evidenced in reports by UNAIDS/WHO (2007) and UNAIDS and AVAC (2007), it could be argued that HIV biomedical prevention RCTs are considerably more ethical than their counterparts in other areas of biomedical and, specifically, pharmaceutical research. With the exception of HIV vaccine trials, pharmaceutical companies have no direct involvement, and arguments about the use of offshore 'experimental populations' and their likely lack of access to a drug intervention developed as a result of their risky labour contribution (Petryna, 2005; Sundar Rajan, 2007: 78, 80) can be readily countered. Funding for the trials comes from philanthropic sources or public monies and the research itself is conducted by scientists employed within the academy or by large non-government not-for-profit organizations. Further, such organizations may – as part of their research or, more aptly, as an expected extension of their research – engage in ongoing activities about access to the intervention if it is found effective.[8]

Nevertheless, the trials have not been without controversy (as we note below), and given that critical engagement from within the HIV social science field is, with a few exceptions (see Craddock, 2004; Kippax, 2008, 2010; MacQueen et al., 2007), remarkably limited, it is our contention that by relying on the code of practice set out by international bioethics, little is done to redress the conditions that provide justification for such trials. Moreover, resort to bioethics with its requirements for participant consent, weighing of benefit over risk and reciprocity in the form of later access to the intervention under trial detracts from a more comprehensive account of ethics (see Michael and Rosengarten, forthcoming; Rosengarten and Michael, 2009). Despite the goal of achieving more effective prevention, it is often the case that state-of-the-art science is directed solely toward testing the efficacy of the intervention and not whether it will be effective in practice (Kippax, 2010).[9] The following quote exemplifies this while providing insight into how the relations between the global and local are configured in the world of a non-capital-driven science. As such, it highlights the need for a critique of RCTs that encompasses the problematic nature of interests that are not only attached to the pursuit of market gain (Petryna, 2005; Sundar Rajan, 2007) but also to 'scientific standards'. As one leading (publicly funded) scientist has written, the *ethical problem* is of providing trial participants with the best standard of prevention:

> To comply with ethical guidelines, we have reduced our ability to assess new prevention methods by comparing them to the best available prevention standards of care (eg, limitless sexually transmitted infection treatment; frequent, individualised, and *expensive* [our emphasis] condom counselling). Such strategies are not representative of the standard of typical prevention services in the community and are not sustainable after completion of the trial. (Padian et al., 2008: 593)

It is apparent in the above statement that ethics is seen as a potential hindrance to accomplishing a statistically significant outcome through the achievement of a substantial number of HIV infections. It is also apparent that prevention counselling, referred to as expensive, is an obstruction to the gold standard of the trial. But even more startling is the way in which the RCT is dependent on access to a community enacted as not having good prevention services. Here we see that the goal of achieving a biomedical prevention technology may transcend the goal of prevention. Arguably, we are returned to the concerns set out by Petryna and Sundar Rajan about accessibility but not, as they discuss, accessibility to the trial-engineered intervention. Rather, the need for the intervention has become subordinated to the scientific project of testing. So, both in relation to RCTs and their related ethics, there are putatively universalistic clinical research standards being enacted *which are simultaneously* subject to a range of generic ethical questions – what we might call, an accompanying 'ethical problematique'.[10]

Localizing the Globalizing

In the cases of both the AIDS Clock and the PrEP RCTs and their accompanying ethical problematique, a particular sort of spatio-temporality is played out. This is a smooth spatio-temporality where the meanings of clock and PrEP RCT/ethics can move uninterruptedly. The AIDS Clock and PrEP RCT/ethics remain unchanged any place, any time: the clock will always and everywhere impress the urgency of the task of preventing HIV; the PrEP RCT/ethics will always and everywhere generate robust clinical knowledge in ethically reflexive and, hopefully, ethically sound, ways. In both cases, external systems of 'measurement' are applied: an algorithm that extrapolates a global number of people living with HIV on the basis of epidemiological statistics based on UNAIDS (2006a) *Report on the Global AIDS Epidemic*; a set of clinical research principles and ethical techniques determine what can 'count', clinically and ethically, as a valid trial. This is a Euclidian space-time – or rather, more accurately, a Euclidian spatialization-temporalization – where the particular events of deaths and trials can be converted into general values and effects (a click of the digital AIDS Clock and its impact upon a generic viewer; the validity of a trial and its implications for the generic implementation of PrEP programmes).

Yet both clock and trial are profoundly local. In relation to the AIDS Clock, we have a global estimated count that is meant to serve as a constant reminder of the constantly increasing number of HIV infections across the world. While the symbolism is undeniably powerful, such a measure necessarily diffuses the specificity of, and differences among, infections. Behind such a number there is huge complexity. Indeed this is conveyed, if only in a very partial way, by those responsible for the AIDS Clock when they state: 'Behind each number is a face, a family and a circle of loved ones who are also affected.' The number rests on an abstraction of 'infection' from the 'local' where different rates and qualities of infection take place. Even the additional web links, which, for example, show differences in numbers of infections in different countries, do not convey the particularity of local, national and regional differences in the social phenomena that enable or inhibit HIV transmission (see for example: Hirsch et al., 2009; Kalipeni et al., 2004; Kippax, 2010). Nor do they convey the quality of life and life expectancy of those infected, the varying implications for relatives, and so on and so forth (see for example: Biehl, 2007; Fassin, 2007).

But further, and perhaps more crucially, we must ask who can access the AIDS Clock? Despite being on the web, it seems to be accessible by relatively few, and even fewer who can respond productively to it – who can be inspired by its affective qualities to develop and implement 'viable' clinical responses, for example. Put another way, the AIDS Clock is an assemblage entailing numerical estimations, algorithms, public relations, institutional positioning, website media, design choices and so on and so forth. It is an ordering device for what is ultimately a particular and delimited audience comprised of scientists, policy-makers, clinicians, activists, etc.

In relation to the PrEP RCTs/ethics, the initial implementation of these met with considerable resistance – forms of resistance that had not previously occurred in relation to other HIV biomedical prevention trials, such as those for vaccines or topical microbicides (GCM, 2008a, 2008b). In this context, PrEP trials generated a more public community resistance, with demonstrations at an international conference that led to widespread international media coverage. With PrEP, one of the first

RCTs – and the only one to target injecting drug users – was challenged as being unethical because of the lack of provision of clean needles and syringes. Clean needles and syringes provide 100 percent protection against HIV infection and, therefore, would remove the need for a biomedical prevention technology such as PrEP (Jintarkanon et al., 2005).

Protests against this PrEP trial conducted in Thailand, and others in Cameroon and Cambodia intended to test PrEP against sexual exposure,[11] suggest that PrEP RCT/ethics are viewed as mediating particular interests.[12] Even where local support for trials is pursued and gained, ethical-seeming RCTs do not address the specificities of localities which might affect trial participation and outcomes. In the Thai example mentioned above, for instance, it has been said that although the trail organisers provide bleach to enable the 'safe' re-use of needles and that clean needles can be purchased legally in Thailand, a context of fear and poverty affects the everyday livelihood of injecting drug users and others, and it is this culture which needs to be addressed in order to achieve safe and effective prevention. In 2001, the Thai government implemented a 'war on drugs' that was represented as targeting drug traffickers. However, a report by Human Rights Watch (2004) states that by 2004, over 2000 people, including some with no connection to drug use and certainly no involvement in trafficking, had been killed by sections of the police who were paid accordingly. The same report notes that a culture of terror was created and many people still fear that purchasing needles could lead to them being accused of trafficking, with life-threatening consequences. At the same time, in some cases, protests against the trial draw on principles that are claimed to have global applicability, notably the bioethical principle set down by the Declaration of Helsinki that a new treatment or technique should only be tested against the best current prophylactic (in this instance, clean needles and syringes), diagnostic or therapeutic methods (The Thai AIDS Treatment Action Group TTATAG, 2004).

Further, some practitioners have also queried the validity of HIV biomedical prevention RCTs/ethics, raising concerns about the fact that while contexts where there is HIV vulnerability, high HIV prevalence (existing infections) and poor prevention provide the best research conditions, the research itself can exacerbate these conditions (MacQueen et al., 2007: 559). In contrast to what is available in the home country of the trial sponsor and lead researchers, a trial participant in a low- or middle-income country is likely to have significantly less access to health care and medical resources. In turn, their trial-incurred needs may place more pressure on already inadequate familial, local and national resources. On top of this, the very possibility of a new prevention technology against HIV may provide some communities with a diminished sense of transmission risk, thereby undermining existing prevention practices and leading to new infections (see AVAC, 2008; Grant et al., 2005; Vernazza, 2009).

Ironically, then, trials may reinforce the local conditions which make those localities so technically attractive for conducting trials.

In order to address this problem of the potentially negative impacts of RCTs – as framed by international bioethics regulatory bodies – a complex set of procedures is carried out by those responsible for undertaking RCTs. These include the provision of 'objective' ethical oversight, whereby the trial protocol is monitored by an independent group of researchers, the provision of follow-up medical care for adverse events, the obtaining of informed consent from participants prior to their enrolment, plus the provision of 'state of the art' methods of protection, for example: male and female condoms, sterile injecting equipment, treatment for other sexually transmitted infections, counselling, possibly access to male circumcision, PEP (post-exposure prophylaxis). However, the recognition that 'state of the art' methods must be provided is itself subject to criticism by scientists (Padian et al., 2008): as such methods are made locally available, so 'partial' protection is likely to increase, and thus it becomes more difficult to assess the statistical significance of efficacy of the particular intervention that is being trialled (in this case PrEP). In other words, the bioethical problematique is itself open to criticism on the basis that it interferes with the science.

In sum, RCTs (e.g. those in Thailand) are locally problematized, ironically by the sometime recourse to a globalizing discourse (Declaration of Helsinki); similarly, the ethical problematique (which insists on the local provision of 'state-of-the-art' methods of prevention) also faces criticism by scientists fearful that their local trials will be unable to attain statistical significance. Here, we see how the globalizing of both the AIDS Clock and RCTs/ethics is localized in various ways, but also how such localization draws on ostensibly globalizing resources (Declarations and statistics).

The Topos of (Our) Critical-analytic Story

So, the argument here is that the standardizations enacted by the AIDS Clock and PrEP RCT/ethics create a smooth spatiotemporal space where seemingly distant categories, spaces and times – HIV infections, HIV trials, ethical problems – that appear highly divergent can be topologically assembled, brought into contact with one another, shown to share an identity. And yet, we have also seen how the globality of the AIDS Clock and PrEP RCT/ethics can be problematized – they do not quite describe a smooth spatiotemporal space where anyplace, anytime their meaning remains assured. Rather, we find that these are enacted in profoundly localized ways, even if part of that localization might be grounded in the globalizing.

The foregoing comprises our 'first-order' argument, but this is related to another concerning the form of our own argumentation. In key respects, our own account of HIV, ironically, amounts to a standardized critical-analytic story about how the performance of standardization is compromised by local variability. That is to say, our arguments in relation to globalizing or standardizing aspirations of PrEP RCTs/ethics and the AIDS Clock are themselves no less globalizing or standardizing. This analytic has long been exercised in sociology, which has examined the ways in which technical standardization presupposes a particular, often inappropriate, local social world – that is to say, practises what Brian Wynne (1989) calls 'a naïve sociology' which might nevertheless be highly sophisticated in its productivity, as we find in relation to the standardization wrought by audit.[13]

Despite all these lay, political and academic critical responses, these global standards nevertheless remain durable insofar as they are constantly reiterated: the clock will apparently always and everywhere count HIV infections, however inappropriately generic those infections might appear; and standardized RCT/ethics will always and everywhere apply in the production of the best ethically derived, clinically robust knowledge despite their 'subversion', or at least problematization, by local contingencies.

But notice, arguably the counter-examples and counter-arguments seem to be following these standardizations, always and everywhere. It would seem that critique (including our analysis) fits into the same formal globalizing categories enacted in the AIDS Clock and PrEP RCTs/ethics themselves. And this present reflection is itself a re-localization as we point to the local pecularities of this standardizing critique: does it always apply (given the durability of some of these standardizations, perhaps something else is needed?) or apply equally across the two cases of the AIDS Clock and and PrEP RCTs/ethics?

This is our 'second-order' argument: that a topological analysis of this form does not escape the topological patterns of globalizing and localizing practices – indeed, it exemplifies them. Moreover, just as these map onto patterns of ordering and disordering for the AIDS Clock and PrEP RCTs/ethics (e.g. standardized trials are implemented locally but resisted locally by using standardized principles), so too our standardized analytic argument is undermined by its localization which, ironically, reinforces the self-same globalizing argument.

Topology, Prepositions and Propositions

In this section we attempt to theorize further this topological analytic, drawing especially on the work of Michel Serres, Bruno Latour and Alfred North Whitehead. Arguably Michel Serres is a topological thinker. Very simply put, Serres (e.g. 1982a, 1982b, 1995; Serres and Latour, 1995) has always been fundamentally interested in heterogeneous relations – between science and art, subject and object, and the material and the semiotic. Serres is concerned with how such connections take place to render patterns of order and disorder. In the process he has developed various figures that might enable us to grasp the mediation of these exchanges between humans and non-humans, arts and sciences: the north-west passage; the parasite; Hermes; angels. In all this, he is pursuing a 'philosophy of prepositions'. Instead of such commonplace prepositions (such as 'between', 'above', 'inside') that typically denote physical relations, Serres' vocabulary is one of prepositional figures (Hermes, parasite, etc.) that attempt to capture heterogeneous relations and exchanges. Things that are seemingly distant – the semiotic and the material, the arts and the sciences, pasts and futures – turn out to be far more promiscuous and can be shown to be in far closer proximity than one might initially imagine. This perspective is particularly well-expressed in his topological model of time. As he puts it:

> [Time is] not laminar [flowing smoothly]. The usual theory supposes time to be always and everywhere laminar. With geometrically rigid and measurable distances – at least constant.... No, time flows in a turbulent and chaotic manner; it percolates ... this time can be schematized by a kind of crumpling, a multiple, foldable diversity. (Serres and Latour, 1995: 59)[14]

He continues:

> If you take a handkerchief and spread it out in order to iron it, you can see certain fixed distances and proximities. If you sketch a circle in one area, you can mark out nearby points and far-off distances. Then take the same handkerchief and crumple it by putting it in your pocket. Two distant points suddenly are close, even superimposed. If, further, you tear it in certain places, two points that were close can become very distant. The science of nearness and rifts is called topology, and the science of stable and well-defined distances is called metrical geometry.... Admittedly, we need the latter for measurements, but why extrapolate from it a general theory of time? People usually confuse time and the measurement of time which is a metrical reading on a straight line. (Serres and Latour, 1995: 60)

So, here we have a topological world of promiscuous, rhizomic (e.g. Deleuze and Guattari, 1988) mixing. The measure of relationalities that make up those mixings is not an external one, but topologically internal to the process of mixing.[15] Serres' call for a philosophy of prepositions is thus a simultaneous call for a topological sensibility, and in what follows, we will draw especially on the concept of a preposition in order to trace the relations enacted in the topologies of both our two case study examples and our analysis of them.

Before we do this, we supplement the notion of preposition. Here, we draw on Bruno Latour, whose work, especially in relation to Actor-Network Theory (ANT), and his later ironic reformulation of this as 'actant-rhizome ontology' (Latour, 2005: 9), certainly points to a topological sensibility, not least insofar as seemingly 'distant' actors are very 'close' by virtue of the circulation of intermediaries or the translations of mediators (also see, for example, Blok, 2010; Mol and Law, 1994). However, in the present article, we make use of another aspect of his work – his thinking on 'proposition' – which reflects a different topological feature, namely, that the relations between points, or entities, unfold in ways that are open, immanent, emergent. For Latour:

> Propositions are not statements, or things, or any sort of intermediary between the two. They are, first of all, actants.... What distinguishes propositions from one another is not a single vertical abyss between words and the world but the many differences between them, without anyone knowing in advance if these differences are big or small, provisional or definitive, reducible or irreducible. (1999: 141)

If propositions emphasize the divergent hybridities of actants, prepositions address the 'how' of this hybridity – how 'this' has gone with 'that' in this or that event. However, additionally, propositions are dynamic insofar as they are not stable but are 'occasions given to different entities to enter into contact. These occasions for interaction allow the entities to modify their definitions over the course of an event' (Latour, 1999: 141). On this score, Latour reflects Whitehead's (1978 [1929]: 185–6) own characterization of a proposition as 'a hybrid between pure potentialities and actualities'. Propositions thus are ontologically heterogeneous both in their admixtures of the human and the non-human, but also in their embodiment of the actual and the potential (see Halewood and Michael, 2008). Put simply, the term 'proposition' indicates that an emerging entity propositions particular relations with other entities, that is, proposes a particular future for 'itself'.

In sum, pre-positions and pro-positions together reflect the 'how' and the 'what' that goes into the emergence, content and potentiality of an event (or entity).[16] Crucially, what neither concepts does is specify externally, or at the outset, the 'what' and 'how' that comprise an event and its potentiality.

PrEP RCTs/ethics and the AIDS Clock both entail the particular bringing together of a series of entities: risks, drugs, measures of effectivity, ethical issues, HIV-infected people. But the 'how' of this bringing together involves, as we have seen, particular forms of standardization. The result is a potentiality for both PrEP RCTs/ethics and the AIDS Clock that can be distilled as 'more of the same': both will remain durable through a continuing 'deformation' of 'what' it is that can enter into the process of their emergence.

To detail these pre/pro-positional processes we can draw on the two topological categories that can serve, albeit tentatively, as pre/pro-positional figures.[17] These are forms of classification or equivalence: the stricter or narrower homeomorphic criteria of similarity in which belonging to the same set means having the same general features (in the case of classifying capital letters of the English alphabet, this might involve criteria such as numbers of holes and tails, thus $A = R$); and the more liberal or broader homotopic categorization (in which criteria of similarity allow for some forms of deformation, such as 'squishing' features such as tails out of view, thus $A = R = P = O$).

Thus we might see the durability of the AIDS Clock and PrEP RCT/ethics as a homotopic mediation: forms of deformation of infections that allow for particular forms of equivalence. In the case of the clock, the local details of infections are stripped away to produce a 'generic infection'. The 'generic infection' is, it might be argued, a major 'deformation' that is linked to a particular reformation – that of the AIDS Clock and international research, policy, programmes and so on generated with the production of a generic number that globally instils a sense of urgency. The preposition that classifies together – genericizes – a vast diversity of infections and their conditions of emergence propositions the prospect of global urgency and global action. In the case of PrEP RCT/ethics – its formation as globally relevant goes hand in hand with prepositional deformation into generic at-risk bodies, drug effectiveness and ethical problematique that propositionally opens out onto its own continuing universal relevance. This suggests, though we cannot pursue it here, that one implication is that the pre/pro-positions entailed in both the AIDS Clock and PrEP RCT/ethics are as much concerned with the 'continuation of research' as with the prevention of HIV.

In contrast, a homeomorphic equivalence might be seen to apply in the classification of the two key local–global enactments that we have described above. There is a basic similarity between, on the one hand, the deformations of local specificity enacted by the globalizing AIDS Clock and PrEP RCTs/ethics and, on the other, the deformation of that local specificity into the form of a 'principle' (everything is local) to resource a globalizing or standardizing critique of the globalizing or standardizing aspirations of the AIDS Clock and PrEP RCTs/ethics. As noted immediately above, homotopic equivalences between infections are drawn in order to enact the AIDS Clock and PrEP RCTs/ethics. However, in parallel, homotopic equivalences are rendered in our critical-analytic account whereby different specific locals which might, as we saw, lay claim to universalist principles such as those promoted through, say, the Declaration of Helsinki are genericized for the purpose of establishing a critique of global reach. The preposition that classifies together – genericizes – a vast diversity of local cases 'propositions' the prospect of globalizing critique on the ironic basis that *everything* is local, globally. As such, there seem to be two parallel, homeomorphically equivalent types of homotopy enacted here which share prepositional and propositional forms. However, where the AIDS Clock and PrEP RCTs/ethics deform the local to accentuate the global, our critical-analytic account accentuates the local to critique the global, thereby globalizing this form of critique.

In essence, then, topology might serve as a source of pre/pro-positional figures for (social scientifically) grasping the complex circuits of identification and differentiation, or emergence and prospect, that characterize cases such as the AIDS Clock and PrEP RCTs/ethics, and their critique. And yet this move itself raises topological issues about the pre/pro-positional relations among disciplines, especially in relation to the migration of concepts from topology and sociology.

Complexifying the Conclusion

Thus far we have treated the AIDS Clock and the PrEP RCTs/ethics as separate (topological) events, yet, of course, there are links between – they are pre/pro-positionally related to one another. As we have documented, the AIDS Clock serves as a symbol to motivate efforts to decrease numbers of infections, and in this respect we might say that it is part of the affective mechanisms behind such efforts. Yet PrEP can best be clinically trialled in situations where the incidence of HIV is relatively high, and where there are 'sufficiently' impoverished prevention mechanisms in place to enable the effects of PrEP to be clinically detectable and generalizable. Put another way, the cumulative sum displayed on the AIDS Clock is what the PrEP RCT/ethics partially affectively 'depends' upon as a spur to action, a call to arms. While the AIDS Clock standardizes infections, its impact through specific interventions such as treatment and prevention programmes but also RCTs is highly localized – affectively impacting on those in a position to react (most relevant in the present case, researchers and ethicists).[18] Simultaneously, PrEP RCT/ethics partially technically depends on non-generic infections in the most deprived areas, namely impoverished conditions which elevate the risk of infection and thus facilitate the capacity of RCTs – because of their standardized RCT/ethics procedures – to generate 'useful' data. But a trial's very presence, by virtue of its particular instantiation of RCT/ethics procedures, may both reduce participant risk of infection (through prevention counselling) *and* precipitate behavioural disinhibition (e.g. lead to more infections, say through increased non-use of condoms).[19] The increased infections, born out of the specificities of a situated implementation of standardized RCT/ethics procedures, eventually become translated back into the generic infections of the AIDS Clock. The AIDS Clock serves as a symbol to motivate efforts to decrease numbers of infections . . .

In sum, we move from the globalization enacted by the AIDS Clock, through the localization of its impacts on medical researchers and their ethics fellow-travellers, who apply the globalized standards of RCTs and the accompanying ethical problematique, which requires and therefore does not act to prevent local infections, which translate into the generic infections of the globalizing AIDS Clock. What seems to be happening here is a switching of generic and non-generic status, globalization and localization, the standardizing and the situating. The AIDS Clock propositions a particular constituency (researchers) that is prepositioned with an ethical problematique to proposition itself in terms of universal scientifico-ethical technique which generates local infections that are generically prepositioned in the ongoing emergence of the AIDS Clock. Or, to draw on that topological cliché, the Moebius strip: if one's thumb is on the globalizing, genericizing 'side', and forefinger on the localizing, diversifying 'side', a little travel soon reverses these contacts.

At the practical level, the topological forms traced here suggest there is no simple way to 'turn back the AIDS Clock'. For example, if RCTs (that have been facilitated by the AIDS Clock) show that PrEP works, this could affect the development of a vaccine which becomes more difficult to test if risk of HIV infection is statistically reduced by PrEP.[20] Any turning back of the clock is unlikely to be an unalloyed good, and any triumphalism is likely to generate its own topological challenges.

However, as the paragraph above hints, the topological accounting presented in this article is inevitably partial. The pre/pro-positions we have explored are very particular ones, and certainly other topological trajectories could have been followed (say, in relation to interactions between vaccine and prophylactic research programmes, or to the pattern of local protests and movements). What the foregoing has illustrated, hopefully, is an outline of a means – or a sensibility – for exploring, analysing and narrating forms of complex and sometimes surprising connection, emergence and prospect, that also addresses those very processes of exploration, analysis and narration.

But lest we finish on too comfortable a note, it should also be pointed out that this very accounting has its own topological dynamics, this time between disciplines (broadly, social science and topology). In keeping with the sensibility outlined above, and as a part of our 'third-order' argument, we might ask what are the pre/pro-positions that best capture the relation between topology and social science? Is there perhaps too much of a one-way traffic – from topology (homeomorphism, homotopy, Moebius strip) to social science? Ironically, thinking topologically might mean de-privileging topology as a discipline (or multi-discipline). As noted elsewhere (Michael, 2009), we might discover topologically interesting pre/pro-positional figures within the social sciences (and social theory): Simmel's 'stranger', de Certeau's idle walker, Benjamin's angel of history are three intriguing candidates. Conversely, armed with an ontology of a 'multiple, foldable diversity', and following the by-ways of Serres' North-West passage, we might find that topology itself echoes social scientific analytics. Thus, for example, might it be the case that the concepts of the homeomorphic and homotopic resonate with 'membership categorization devices' in conversation analysis or the Protagorean dilemmatic thinking of rhetorical social psychology?

In any case, a topological analytic sensibility needs to be flexibly iterative, and among its giddy folds we find that the topologizing of topology pre/pro-positions its partiality, while topologizing topologizing topology reasserts its centrality, or global reach.

The preceding topological convolution points the way to our last twist. The article has been structured around three 'ordered' arguments. We have placed inverted commas around these because we wanted to connote neither hierarchy nor, indeed, an easy distinction between them. Rather, we would argue that our arguments about the topologies of HIV, critique and interdisciplinarity can themselves be regarded as topologically entwined. Thus, the three 'orders' should be regarded not in terms of external parameters (for example, a spatialization in which the empirical, analytic and interdisciplinary are nested one inside the other) but as immanent in, and emergent from, the complex topological conjunctions entailed in this empirical-analytic-disciplinary space.

Notes

1. 'Topology', Wolfram MathWorld, URL (consulted 12 May 2011): http://mathworld.wolfram.com/Topology.html.
2. See: http://www.unfpa.org/aids_clock/ (consulted 9 April 2010).
3. Our particular topological account of RCTs differs from Szerszynski's (2012). He illustrates his Agambian topology of inclusive exclusion with reference to Cooper's (2011) analysis of how the mainstream usefulness (inclusiveness) of RCTs has rested on the exposure of marginal (excluded) groups to incalculable risk. Of course, this topology partially applies to our case study: the 'excluded' are the subjects based in the offshore sites of India or East Asia or southern Africa, However, these 'marginal subjects' are included not only through their role in the production of biomedical knowledge, but also through complex topologies of ethics (through which they are afforded a degree of protection) and the ethical and political challenges that they (or their representatives, at least) launch. Over and above this, this article is mainly concerned with the topologies entailed in particular globalizations of HIV, but also with the topologies of topological analysis.
4. UNESCAP, Social Development Division, Social Policy and Population Section, 'AIDS clock ticking ...', URL (consulted 2 June 2010): http://

www.unescap.org/ESID/psis/population/popheadline/312/art8.asp. All quotes in this paragraph are from this press release.

5. See: 'AIDS Clock: About the AIDS Clock', URL (consulted 9 April 2010): http://www.unfpa.org/aids_clock/about.html
6. This does not mean that there are no criticisms of RCTs, not least among certain practitioners (see Will and Moreira, 2010).
7. The randomized clinical trial is regarded as a fully scientific objective form of evaluating drugs. It involves comparing two groups, one subject to the intervention while the other is not but using a method where those directly involved – the researchers and the trial participants – do not know who is receiving the drug and who is receiving a placebo.
8. According to reports from Centers for Disease Control, responsible for some of the PrEP trials, discussions have been conducted with the public health authority in Botswana to determine how PrEP might be delivered if found effective. The author Rosengarten has attended discussions on the design of social research to facilitate effective use of PrEP, held by the iPrEX triallists. It's also worth noting that a more nuanced understanding of the role of the HIV pharmaceutical industry may be in order, in contrast to a more overt set of operations carried out by the pharmaceutical industry described by Kaushick Sundar Rajan (2007) and Adriana Petryna (2005). Gilead Sciences Inc., manufacturer of the drugs used in PrEP, has stated that it will provide no-profit pricing access to PrEP by 97 low- and middle-income countries (see Gilead Sciences Inc., 2011).
9. In general, these trials are ethically justified in light of international bioethics principles and guidelines established within the HIV field on the grounds that those recruited to the trials are in urgent need of the intervention and that sufficient safety monitoring is undertaken through an independent Safety Monitoring Board. The World Medical Association Declaration of Helsinki 'Ethical Principles for Medical Research Involving Human Subjects' includes the following in its statement on ethical medical research: 'Populations that are underrepresented in medical research should be provided appropriate access to participation in research.' However, this argument also results in what has been identified as a paradox for HIV biomedical research, resulting in debate within the HIV field on what form of care should be provided alongside the trial for adverse events. The debate turns on the question of whether the level of care should be equivalent to that provided in the trial sponsor's home country (for instance, in the United States or United Kingdom) or be equivalent to the best standard of care available within the country location of the trial, although not necessarily within the actual locale of the trial (see MacQueen et al., 2007).
10. We use the term 'problematique' because it connotes the framing of a problem, not simply the problem itself. Thus when we refer to an ethical problematique we are signalling that a particular biomedical intervention is not merely associated with a particular set of ethical problems, but with a specific way of formulating issues as ethical problems of a particular sort.
11. In 2004, Cambodian and Cameroon groups representing female sex workers targeted for the first round of PrEP trials claimed that the trials were unethical because they did not provide sufficient information, they did not guarantee medical care for adverse events, and there was no provision of

anti-HIV drugs for those who became infected during the trial. These claims have been disputed by those responsible for the design and implementation of the trials (Mills et al., 2005). Nevertheless, these claims can be said to reflect the lack of trust that arises in response to 'standardist' claims – whether these be around clinical trials, instructions for the use of pesticides or innumerable forms of audit. In any case, the two trials were closed.

12. Trial sponsors and scientists now invest considerable effort in gaining community support for RCTs. The achievement of support is taken as an endorsement of the trial as ethical. But it is also something of a guarantee against further trial closures, costly in terms of dollars and for scientific research (UNAIDS, 2006b; UNAIDS and AVAC, 2007).
13. On this score our analysis falls in line with a standard constructionist critical analytic which shows how claims for standardization, universality or globality are undermined by the contingencies of the local. Ironically, it is through the flexibility and adaptability of the local that these standards are rendered workable (see, for example, Bowker and Star, 1999; Power, 1999). On another level, our analysis might be said to suffer from a lack of symmetry: we claim that the global is 'constructed' while the local is real (e.g. Ashmore, 1989; Woolgar, 1988). Of course, we see both these registers as heterogeneously emergent.
14. While Serres is here specifically developing a topological model of time, the points he makes apply more generally.
15. For an example of prepositional analysis where 'roadkill' is understood in terms of the divergent relational patterns – perpendicularity and frottage – between cars and animals, or rather automobility and animobility, see Michael (2004).
16. Or, in Whitehead's (1978) terms, we might put it thus: prepositions address how an actual entity or occasion is concresced from prehensions, while propositions address how an actual entity or occasion becomes a prehension that concresces with other prehensions to generate novel actual entities or occasions.
17. See, for example, 'Topology', Wolfram MathWorld, URL (consulted 12 May 2011): http://mathworld.wolfram.com/Topology.html.
18. As a prehension, the AIDS Clock is affective insofar as the actual occasion or entity of a potential trial can accommodate it. For some events, it is an irrelevance. In any case, there is always an element of local teleology in the process of affecting, or, more generally, becoming (Whitehead, 1978).
19. Padian et al. frame the concern about the capacity for HIV RCTs to demonstrate efficacy in terms of providing 'enhanced' prevention packages in excess of what is already provided within a community. They state:

    > The ethical issues of offering enhanced HIV prevention services in the comparison arm must be weighed against the ethical issues of lengthy and expensive prevention trials that provide the control group with an unsustainable level of prevention services that does not reflect community standards. (2010: 631).

20. In detail, should PrEP be found to be sufficiently efficacious, what should be given to placebo group participants in other ongoing and future prevention

trials? Could PrEP trials continue to be 'ethical' with a placebo arm if PrEP is found to reduce the likelihood of infection? Moreover, would trials for other prevention technologies such as vaccines be required to offer PrEP to all participants (AVAC, 2008: 9)? If so, potentially more efficacious vaccines might be delayed because the effects of the vaccines would be masked, and because, with reduced risk of infection and therefore to compensate statistically, higher numbers of participants will be required. In other words, the HIV toll may be slowed but the specific dynamics comprising it are likely to become more complex. The chances of better interventions for dealing with the virus may, as a consequence, become increasingly encumbered by the affects of the clock, PrEP and RCT/ethics currently in existence.

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The Governmental Topologies of Database Devices

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Abstract

In business and government, databases contain large quantities of digital transactional data (purchases made, services used, finances transferred, benefits received, licences acquired, borders crossed, tickets purchased). The data can be understood as ongoing and dynamic measurements of the activities and doings of people. In government, numerous database devices have been developed to connect such data across services to discover patterns and identify and evaluate the performance of individuals and populations. Under the UK's New Labour government, the development of such devices was part of a broader policy known as 'joined-up thinking and government'. Analyses of this policy have typically understood joining up as an operation of adding together distributed data about subjects, which can then be used in the service of government surveillance, the database state or informational capitalism. But rather than such technical or managerialist analytics, I argue that topological analytics capture what these database devices enact and do: they materialize the 'individuality' of subjects in intensified, distributed and fluctuating ways and materialize and intensify a logic of what Deleuze describes as modulating controls. Through examples of UK New Labour social policy initiatives over the past decade, I argue that topological analytics can account for these as immanent rather than exceptional properties of database devices and, as such, part and parcel of a governmental logic and ontology of subjects.

Keywords

control, database, digital devices, government, metrics, topology, transactions

Most government departments keep records, often in electronic format, that contain identification data about people and the services they have received. New information and communication technologies (ICTs) have

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advanced the digitization of these government records and the storing, maintenance, sharing and searching of large volumes of personal data. The UK public sector is estimated to have held some 300 million personal contact detail records in 2005 (Office for National Statistics, 2005: 7). Such identification databases are by far most advanced in the commercial sector where 'informational capitalism' has become a prime generator of knowledge (Thrift, 2005). Walmart, for example, holds 460 terabytes of consumer data and Tesco has two years of purchasing data for 14 million households (40% of the UK population).[1] Individuals also compile databases about themselves through a variety of applications and software for monitoring and tracking everything from dietary habits, training programmes, levels of happiness and spending practices to children's sleeping patterns (Wolf, 2010).

In all of these examples, various analytic devices are used to discover patterns and reveal things about who we are as individuals and populations based on patterns in transactions, activities and conduct recorded in different databases. At the policy level this has more generally come to be known as 'joined-up thinking and government' and 'connecting the dots' in databases (Amoore, 2009). Under New Labour, the UK government developed and implemented several databases based on this logic: one report identified some 46 databases – from law enforcement and child welfare to e-Borders – many of which involve data sharing across government agencies (Anderson et al., 2009). For this reason the report called the UK a 'database state'. Some of these databases developed out of New Labour's 'Transformational Government' strategy, which envisioned technology as an 'enabler' of policy and service delivery change:

> Twenty First Century Government is enabled by technology – policy is inspired by it, business change is delivered by it, customer and corporate services are dependent on it, and democratic engagement is exploring it. Moreover modern governments with serious transformational intent see technology as a strategic asset and not just a tactical tool. Technology alone does not transform government, but government cannot transform to meet modern citizens' expectations without it. (Cabinet Office, 2005: 3)

Some of these database initiatives have been more fully developed and implemented than others, and under the Conservative-Lib Dem coalition government they will likely be reconfigured or perhaps abandoned.[2] To be sure, database government constitutes a science-in-the-making and is to varying degrees delivering the objectives of joined-up thinking. It is also subject to intense scrutiny. Academic reviews of databases are quite damning. In the field of social policy, child welfare databases are possibly 'not fit for purpose' (Shaw et al., 2009) and leading to many versions of the population as practitioners variably interpret, record, and understand instructions and categories (Pithouse et al., 2009). Because these databases depend on diverse and complex socio-technical arrangements – of professionals, computers, software, forms, and all of the many actors involved in long chains of relations – their operation is highly variable and contingent, resulting in multiple actually operating systems in practice. But many of these criticisms have been lodged against central government programmes, whether or not databases are deployed as a solution or as a support. Through many devices central governments have long sought conformity, coherence and consistency in programmes and to tame the unruliness of local discretion and idiosyncratic practices through standards, forms, rules, tick boxes, procedures, reporting requirements and so on. Databases are just one such device introduced as a solution for taming and dealing with such multiplicity.

Notwithstanding this variability, others have argued that child welfare databases are the culmination of developments over the past 30 years which have involved a shift in the practice of social work from a narrative to a database 'way of thinking', with the result that social work now operates less on the terrain of the 'social' and more on the terrain of the 'informational' (Parton, 2008). Furthermore, the effects of databases are said not only to be reconstituting how social work is practised, but also reordering and regulating workflows and monitoring practitioners and their engagements (Garrett, 2009). They are not only surveilling workers but also designed to follow and watch people (Anderson et al., 2009). This interpretation is most often the point of criticism and resistance:

> Concerns about state-sponsored ICT systems in children's services raise issues about inappropriate surveillance and net-widening, threats to citizen privacy, data security and quality, and the unreflective assumptions within policy about universal technology systems, such as CAF [Common Assessment Framework], to engage effectively with the complexity of child and family needs. (Pithouse et al., 2009: 601)

Yet, despite their claims about the rise of an all-knowing panoptic state, it is safe to say that, while the UK state has lots of data, it is struggling under the weight of myriad non-interoperable and often incomparable and conflicting datasets. Indeed, numerous database initiatives have stalled or have been significantly redesigned as a result (e.g. the NHS National Programme for IT).[3] Rather than an all-knowing state, what we have instead is a plethora of partial projects and initiatives that are seeking to harness ICTs in the service of better knowing and governing individuals and populations. There are technological, economic and political reasons for this, especially in relation to data privacy and confidentiality. Be that as it may, efforts abound to create standardized, interoperable and dynamic databases to support evidence-based policy, enable individually tailored and targeted services, reduce costs, and provide robust population statistics for analysis and research.

In this article I take a different approach to thinking about these database initiatives. The critiques outlined above typically interpret the joining up of data as a simple operation of connecting information about subjects compiled at different government locations, which can then be used in the service of government surveillance, the database state or informational capitalism. These can be understood as technical and managerialist analytics of what joined-up databases do in relation to knowing and governing individuals and populations.[4] Failures can be explained as the result of technical challenges, and operational variations and complexity can be explained as either indications of system failure or success in adapting to local circumstances and the idiosyncrasies of practice.

Rather than thinking of complexity, variation and uncertainty as effects of joined-up databases, I argue that these properties are immanent to the government logic and conception of the subject that joined-up databases advance. To start, I adopt an ontological rather than epistemological framing as put forward by Law and Singleton (2005). An epistemological framing posits that these different analytics produce different perspectives on an object, which can be 'flexibly interpreted', and consequently objects are 'interpretively complex'. Complexity is thus a product of diverse analytics and multiple interpretations, rather than a quality of the object in question. Instead, an ontological framing understands objects as already and always multiple and complex, and 'moves us from multiple interpretations of objects to thinking about multiple objects themselves' (Law and Singleton, 2005: 334).

The problem then is that social science analytics (such as technical and managerialist ones) typically cannot account for such multiplicity and complexity. For this reason Law and Singleton propose topological analytics to understand how complex realities are 'enacted into being'. It is with this understanding that I engage topological analytics to interpret the conception of the subject and government logic that joined-up databases enact. I argue that, rather than being technologically determined, these databases are bound up with a particular ontology of the subject and governing logic, and that there is not a determinist but a dynamic relationship between the two (Agar, 2003). It is this conception that I explore through examples of policies developed by the UK New Labour government, which signal a changing relation to data as well as relation to quantification in social, commercial and governmental domains. It is a relation that is part of a technocratic infrastructure for knowing subjects and populations, not so much in relation to pre-defined categories of identity but in relation to what people do, their interactions, transactions, performance, activities and movements in relation to government.[5]

In the first section I specify a set of presuppositions about topological analytics that I then use to analyse social policy databases. I argue that these databases do not simply add up data about subjects but materialize ontologically different subjects in relation to what they do. While in social policy behaviour and conduct are generally constitutive of identity, I argue that joined-up databases materialize the 'individuality' of subjects in intensified, distributed and fluctuating ways. Second, such operations also materialize and intensify a neoliberal logic of control whereby enclosed spaces of governing give way to what Deleuze (1992) describes as modulating controls. It is this materialized and intensified individualization and logic of control that topological analytics open up and which I explore through examples of UK New Labour social policy initiatives over the first decade of the 21st century.

Topological Analytics

I first conceive of these databases as 'devices' as they are government schemes devised to both calculate and intervene in the performance of individuals and populations, and consist of an ensemble or system of relations. That is, they are oriented to a governmental purpose and, as such, the terminology is most closely aligned with what Foucault defined as *dispositif*:

> a heterogeneous ensemble consisting of discourses, institutions, architectural forms, regulatory decisions, laws, administrative measures, scientific statements, philosophical, moral and philanthropic propositions – in short, the said as much as the unsaid. Such are the elements of the apparatus. The apparatus itself is the system of relations that can be established between these elements. (Foucault, 1980a: 194)

In this light, database devices consist not only of inscriptions but *strategic orderings* and relations between many governing actors and elements. Actor-network theory (ANT) is helpful in specifying and advancing this understanding of relations by attending to the role of 'immutable mobiles' in enabling such arrangements to 'hold' in some relational or functional manner between sites, and to form more or less stable networks (Law and Singleton, 2005). But what often happens is that devices (their elements or relations) tend to change and the network 'fails'. A solution that is often advanced is to explore how a network struggles to maintain the stability of its devices. But this means that invariance becomes only a principle because in practice devices can be mutable and multiple (Mol and Law, 1994).[6] Topological analytics provide a way of thinking of devices that accounts for such instabilities of devices and the mutability of their elements, relations and boundaries.

Rather than a given theory, social scientists generally identify a few key properties of the topological from mathematics and have then taken these up to study social phenomena. One property is a non-Euclidean and non-topographical conception of space, which Celia Lury (2009) has described as follows:

> Topology in mathematics does not start with a space but starts with a problem (an equation) then explores the space in which it has a solution. So while geometry had classically been understood as the perception and organisation of a static, homogenous space that might be projected reliably into the future, topology offers a way of thinking about processes of actualization in n-dimensional spaces in terms of probabilities, not certain futures. To put this another way, space, problem and solution are co-constituted in topological mathematics. If this is indeed so, then it suggests that what is involved in thinking topologically across disciplines is neither induction nor deduction but abduction. And abduction does not involve either metaphors or tools – but speculative reason or reasonable guesses.

Thus, rather than static and predictable, a topological space (or object or subject) is mutable, its boundaries changeable and modulating in unpredictable ways giving rise to probabilistic rather than predictive reasoning. Law and Singleton (2005) state this differently: that objects have no clear boundaries and are made up of heterogeneous mixtures of variable elements with unstable relations that can be discontinuous, unpredictable and generate varying patterns of absence and presence. Yet, as Law (2002) notes, while some properties are changing others are continuous and retained. The challenge of a topological analytics is to identify the possibilities and properties of different forms of continuous transformation, that is, ways of deforming objects while securing their continuity.

Drawing on these understandings, I conceive of topological analytics as involving a series of interrelated presuppositions: the co-constitution of a space, problem and solution resulting in varying rather than fixed boundaries and a logic of abduction or reasonable guesses; and invariance alongside varying and heterogeneous elements and relations that can be folded and reordered and generate shifting patterns of present and absent elements. These properties form the analytic starting point for conceptualizing the ontology of the subject and governmental logic of database devices. To start, I specify the content of government databases as being made up of transactional metrics, and then I take up these topological analytics in relation to a number of social policy initiatives and database devices.

Population Metrics: The Stable and the Transforming

Government administrative databases constitute a particular kind of measurement and data on subjects. They consist of past, current and ongoing measurements of conduct recorded through established means of data collection (e.g. tax, national insurance or school records). The databases track the transactions of individuals in relation to government services: their registration of life events, income earned and taxes paid, licences obtained, schools attended, cars purchased, borders crossed, visas acquired, benefits received, visits made to hospitals and so on.[7] They also contain records of 'encounters' with governments and log changes in individual lives. The data is generated as a by-product of everyday administrative transactions with government and is deemed 'better information' in part because it is considered dynamic measurements of what people 'actually' do and need, which change over time and space and thus require constant monitoring and evaluation.[8]

To be sure, transactions have long been the basis of government administrative systems and the mainstays of government record keeping, monitoring and evaluation, and, in social policy, conduct and behaviour have been key indicators and registers of identity. What is new is the digitization of these records, the possibility of real-time tracking of transactions and the potential to join up transactional data distributed across government sites and functions. In other words, digitized data are transforming government knowledge practices.

Administrative databases and the identification of correlations and patterns in transactions across governing sites constitute particular kinds of operation and measurement that I call population metrics – measures that identify and evaluate the performance of individuals and populations (Ruppert, 2010). Population metrics work in much the same way as metrics operate in business, government and academia, to evaluate and compare the performance and progress of people, groups and things. For example, in education, league tables and scores evaluate schools, in universities, bibliometrics measure academic performance and in health care, standards such as wait times evaluate service delivery. The same logic applies to how transactions are used in government to identify individuals and populations and evaluate their performance.

But before transactions can be combined, reassembled and correlated, 'identity management' is required to confirm, verify or authenticate identities, prove eligibility and entitlement to public services and benefits, trace and track transactions and movements, and join up databases across sites and functions. In addition to assigning a unique identifier or code, identity management involves recording what are considered relatively stable biographical identifiers and locators that can include name, date and place of birth, gender, and address and biometrics. Identity management thus involves the stabilization of a set of biographical and/or biometric classifications or 'single source of truth' about individuals that is kept up to date (Varney, 2006: 38).

For the UK government, identity management is achieved through the use of unique identifying numbers and codes. There are numerous such identifiers in circulation: national insurance, pupil, health, and driver licence numbers.[9] Once identities are managed in this way, then individuals and populations can be known in relation to their multiple transactions and movements.

Identifying: Multiplicities and Singularities

Identity management constitutes an understanding of individuals as being made up of a set of unchangeable and stabilized identifications. Once identity management is in place, then it is possible to track, trace and infer knowledge about individuals and populations through the linking of multiple transactions, which become the dynamic and relevant metrics to be measured, monitored and analysed. This understanding of individuals was most comprehensively laid out in the UK Labour government's 'Transformational Government' strategy, which sought to use new technologies to transform the 'business of government' by joining up and sharing data and services rather than duplicating them. Multiple sources of information are deemed necessary to provide complete pictures of customer needs and behaviours, which are multiple and complex (Varney, 2006). People do not fit into the usual group categories (the elderly, the student) but rather – from the governing point of view – have changing and multiple needs that require 'responsive services' (Cabinet Office, 2006b: 8).

It is this conception that informed many specific UK social policy initiatives.[10] The Social Exclusion programme was based on the understanding that relative disadvantage is caused by linked, multiple health and social problems and risk factors that sometimes 'interact' to multiply their overall effects (Cabinet Office, 2006a). A key solution promoted was the joining up of databases to identify individuals at risk of social exclusion, such as those who are 'poverty plus' or have 'chaotic lives and multiple needs' (2006a: 76). Database devices that materialize this conception of the joined-up subject have been most significantly advanced and implemented in two key areas: child welfare and youth justice. I will thus focus on these examples in the remainder of the article.[11]

The Integrated Children's System (ICS) – an e-social care record system and database for managing information on children who are or may be in need – is designed to collect and record a great amount of detailed information from different practitioners (social workers, head teachers, counsellors, police, health care workers and so on) and to predict children who may be at risk of abuse or potentially in need (Department for Children, Schools and Families, 2007). The data are recordings of transactions and interactions between practitioners and children and their parents, including contact information, assessments, service planning and service review. The logic is that, by joining up data, children can be identified in relation to a combination of needs, an understanding that no one practitioner could ever possibly attain because the subject's relations and interactions are distributed among several service points. It is only by connecting and integrating the data that a child in need or potentially at risk of abuse can be made visible. Each child's combination of singular transactions with government agencies, when categorized (e.g. failing grades, non-attendance at school, criminal record), produces a metric or measurement of needs along a continuum from no additional needs, additional needs to complex needs.

The Youth Justice Board Management Information System (MIS) involves a similar conception of young people. Each local authority in England and Wales has a multi-agency Youth Offending Team (YOT), with representation from the police, the probation service, social services, the health service and education.[12] YOTs enter cross-agency individual-level data into the system and the data is then used to assess children and young people (10–17 years of age, what I will refer to as 'youth') and their likelihood of (re)offending. The MIS assembles biographical and transactional data (evaluations, assessments, interventions, judgments, sentencing) of young offenders compiled across distributed government sites: schools/colleges, police, general practitioners, health service providers, social services, housing, voluntary organizations, courts and so on. The data includes case-level information compiled by myriad practitioners (police, housing officers, social workers): offences details, court data (charges, sentencing), intervention records (e.g. assessments, plans, dates of contacts, outcomes), assessments of assets at various stages of contact (12 dynamic factors that are scored, such as living arrangements, education, lifestyle, substance use, emotional health), indicators of vulnerability and risk (based on a series of questions), restorative justice interventions, parenting interventions (meetings) and mental health and substance abuse interventions (referrals, assessments, treatments).[13] Collectively, these constitute a series of metrics that measure the performance of youth in relation to myriad government services.

The two programmes and their related database devices are based on the logic that the subject is made up of unique combinations of distributed transactional metrics that reveal who they are and their capacities, problems and needs. An individual is not simply a child or youth, but rather a combination of needs and services. The population to which they belong is thus based on associations not so much with others but patterns in their transactions. Existing disadvantage, for example, is detected in relation to combinations of transactions for benefits, employment support, health care, mental health services, alcohol services, housing and supported housing, homelessness services, policing, prisons, courts and drug services. Children and youth are discovered through combinations of multiple transactions that vary and change. In other words, new and emergent subjects can be discovered and made up by these technologies: the youth at risk of (re)offending or the child with complex needs. While similar kinds of subjects may have been previously identified, database devices introduce a change in criteria, detection and reporting that capture new people as part of these populations. Furthermore, they intensify individualization by assembling ever more and diverse metrics to specify subjects while identity management secures their continuity within their transforming and changing constitution.

Thus, rather than abstractions or disembodiments, these constitute particular materializations of both subjects and populations. The transactional metrics of subjects and their performance in relation to practitioners constitute a kind of 'surface' rather than determinist or causal understandings (Savage, 2009). But it is through the assembling of data distributed across distant government sites that patterns and associations in the performances of subjects are detected. Government sites and their contained data are thus 'folded' and brought closer together by and into the database device. Additionally, rather than transporting immutable mobiles to different sites to stabilize forms and relations and exert control from a distance (as conceived by ANT), it is an assembling device that gathers diverse and distributed elements constituted by heterogeneous arrangements and practices.

As such, the boundaries of government databases become permeable and what is assembled – included/excluded, present/absent, inside/outside – of the database device can vary and change. What 'makes up' the subject and the population, or what could be called the boundaries of the social, is thus mutable as varying metrics can be joined up, arrayed and correlated across sites and databases. Such arrays do not assemble all data but do so selectively and thereby create unstable patterns of absence and presence. Yet the biographical metrics of identity management provide a 'core of stability' (Law and Singleton, 2005) that enables governing sites to be brought close together. What then is mutable is the transactional metrics and relations between performances that make up the subject, and for social policy these are key matters of concern.[14]

In this regard, database devices are materializations of what Latour (1998) has called a traceable social that is rendered visible, not by extracting it from something else but by making it observable. ICTs are usually depicted as communicating information stripped of the encumbrances of social relations and location (Strathern, 2000). Rather, ICTs do not abstract and detach from the social only then to be put back into it but are part and parcel of the very relations that get materialized in data. Rather than occupying a 'space of flows' or a virtual informationalized world, data is itself a materiality that can be assembled in multiple ways by folding in heterogeneous data from distributed sites.

Such traceability does not reveal an overarching society but a multiplicity of links and orders made up of aggregations of individuals. In relation to populations such materializations are of course not new. Governments and social scientists have long produced materializations, from censuses and maps to other inscription devices. As such, the point is not that materializations are becoming more abstract but that social orders are being materialized in new ways and in specifically more traceable ways that are enabling the making and identification of new connections and the capacity to see populations being made and remade, to see populations as being composed and recomposed.

But so too is the individual subject being materialized in intensified ways, as a monad, a being composed of a 'vast crowd of elements' (Latour, 2010: 10) that only joined-up databases and their visualizations can identify.[15] Both the individual and the population are beings beyond human perception and thus database devices are required to mediate and make them visible. What are those elements? They are the interactions and transactions of a child with government agencies and her/his identification as a child in need – that is, each child is an interiorization of a whole set of relations, interactions, assessments and evaluations, or what I have called metrics. The child does not occupy one subject position nor multiple subject positions but, in relation to government, is a multiplicity. And the population is an aggregation of individuals who are themselves also aggregations of multiple elements. What is assembled then is not the product of any one relation or performance but numerous ones such that the enactment of both the subject and population is more precarious, indeterminate and unpredictable.

This conception of the individual as a monad is suggested in the Transformational Government agenda (Cabinet Office, 2006b). It advanced the understanding that people rarely fall neatly into categories and associate themselves with different groups at different times depending on their particular needs, and so interventions must be responsive to their unique needs (Cabinet Office, 2005). Each person is conceived of as a singularity; not a member of a group or having a generalized group identity, but made up of a singular composition of performances that need to be guided and shaped. Database devices both materialize and intensify this composition while at the same time enabling it to mutate and change.

Governing: Singularities

In sum, patterns among transactional metrics are measures of the relative performance of children or young offenders who are not placed into categories of normality or abnormality. Categories are the disciplinary techniques that Foucault first described, which generally operate through classification schemes and statistics that categorize and organize individuals into populations – the poor, the criminal or the delinquent – and govern through what Deleuze (1992) also described as spaces of enclosure such as the school and prison. However, as Foucault (2003, 2007) argued in his later lectures at the Collège de France, such technologies of discipline that concentrate and enclose give way to a positive power and technologies that expand, where '[n]ew elements are constantly being integrated: production, psychology, behavior', 'allowing the development of ever-wider circuits' which 'lets things happen' (Foucault, 2007: 45).[16] It is an inventive power that works by inclusion and enables transformation and innovation through the interplay of coexisting government interventions (education, welfare, police and so on) that get materialized by the database device and 'whose effect will be greater than the sum of its component parts' (Deleuze, 1992: 3). That is, rather than a simple operation of addition, the database device is generative of new and emergent subjects and populations.

Importantly, it is through 'fine-grained' individualization and what Foucault described as 'a series of fine and constantly observed differences' (2003: 46) that differential normalizing is achieved. This is the ontology of the subject that the database devices materialize, as a monad made up of complex, unique, dynamic and always varying metrics. While children can still be generalized into patterns of likeness or similarity, immense detailed data on them is maintained and linked to a pattern. In this regard there is multiplication and complexification rather than simply the generalization of the individual into a category. Rather than a series of categories, children are located along a continuum of need where various services and interventions can be said to 'co-exist in one and the same modulation' (Deleuze, 1992: 5). Amoore and de Goede (2008) develop a similar argument in relation to security practices where transactional data is used to classify people not in relation to categories but according to degrees of differential risk. At the same time, such devices seek to 'hold' the individual in relation to the whole population by maintaining his/her specificities and variations, and making these traceable and visible. The population is the aggregation of these specificities and variations, such that each child occupies a singular point within the pattern of needs of the 370,000 children in England and Wales (statistic cited in Shaw et al., 2009).

These devices thus work vitalistically – they aggregate individuals to assess the relative health of a population (the number of children with different degrees of need or the number of youth at risk of (re)offending). This is of course the general problematic of governing, which is to know the nature and then govern and regulate the forces of the whole, that is, the population, the referent object of biopolitics (Foucault, 1997). It requires specific totalizing procedures – that is, techniques that can constitute an entity out of various individual parts – all the rates, profiles, patterns and probabilities necessary to manage, regulate and maximize the potential of a changing population (Dillon and Lubo-Guerrero, 2008). The social policy programmes mentioned above and the database devices in question seek to do so and to maximize populations: to identify and target a population of people who are socially excluded or at risk of being so; and to protect children by sorting them into categories of need and intervening in their development. Such identifications are then the basis of governing which seeks to prevent an increase in the number of certain kinds of people (socially excluded, abused child, teenage mother, youth offender).[17] That is, once identified as a probability – children at risk of abuse or youth at risk of (re)offending – then individualizing interventions can be defined. In this regard, susceptibility is not identified following a logic of induction or deduction but instead abduction: through patterns in joined-up data probabilities, reasonable speculations and precautionary principles lead to the identification of possible kinds of people.

In this way biopower and governing are integrated: the former track, regularize and manage populations and the latter guide and shape individual bodies (Foucault, 1980b). For while identification is based on a person's metrics, interventions consist of tailored and individualized rather than collectivized strategies. The individual may be generalized to become part of a population (totalizing) but at the same time her/his singular identification or 'fine-grained' individuality is maintained, thus opening her/him up to singularized governing interventions (individualizing).

This is the logic of 'modernising of public services', which involves defining personalized packages of public services (Office for National Statistics, 2005). People are conceived as passive recipients of packages of services formulated from distributed data about them and targeted to meet their needs but not seen by them.[18] It is multiple transactions and their performances in relation to government services that reveal their problems and needs. Metrics are not based on a causal model but on patterns, regularities and a surface of interfaces and connections between measurements of what people do.

But targeted government interventions further generate varying and unstable relations. Metrics are a 'species of nominalism' (Hacking, 2007: 294) whereby being classified and named a 'child with complex needs' is only part of the dynamic. In addition to the experts and technologies of identification and their diagnostic practices, bureaucratizing practices then intervene to guide and shape and sometimes 'correct' people. Ian Hacking, in his many writings, has argued that both processes are involved in 'making up people': a new metric can bring into being a new conception and experience of a way to be a person. Furthermore, there is a 'looping effect', a process by which a metric may interact with the people through governing interventions that reinforce the 'identity' of a person so discovered (Hacking, 2007).[19] Because of these two processes, people are moving targets: metrics interact with people and change them and since they are changed they are not quite the same kind of people as before. Thus as people change metrics also change and become modulating such that populations are in a constant process of differentiating. Database devices thus also evolve alongside the performances of individuals and are not separate from them such that the technique and people are co-constituting. Hence, rather than a fixed shape and pattern of social structures and differentiations, populations are modulating differentiations. This challenges the usual way that population is understood, as consisting of people with different traits and behaviours that can be identified, categorized and governed. But this also means that governing interventions must also modulate and change in relation to 'moving' people. Not only must interventions be personalized and individualized, they must also change in relation to the changes that they have in part constituted.

Governmental Topologies

The foregoing is a conception that does not simplify but constitutes what Deleuze called a 'complicating machine' (Rajchman, 2000). But it is not complicating because of the availability of large volumes of digital data, the computational power of computer technologies and the myriad socio-technical relations that make them up. Rather, it is complicating because database devices materialize and intensify a conception of subjects and populations as always coming into existence through sets of modulating transactional metrics and relations where change is immanent in conduct. It is transactional metrics that differentiate and are productive of who people are and it is through their performance, or doing, that individuals and populations are registered and identified. The usual categories of sociological and social policy interest such as 'group identifications' or 'backgrounds' (e.g. ethnicity, religion, class, gender) and causal and depth models give way to 'surface' phenomena such as descriptions of patterns, links and regularities in conduct (Savage, 2009). The former are relatively fixed (date of birth, place of birth), or change slowly and predictably (age), or can be captured in subjective identifications (ethnicity) and constitute the relatively immutable elements of identity management. However, transactions change, and so metrics modulate as they track, measure and evaluate performance. The transactions of individuals dynamically constitute population, and it is relations between rather than detailed descriptions of transactions that matter. The object of interest is thus not the substantive elements of culture but their links and transformations, not some essential properties but instead relations (Lash and Lury, 2007). So while capturing identity preoccupies techniques such as censuses, joined-up administrative databases locate differences in relation to multiple registers of conduct that define both who people are and who they are possibly becoming. In this regard, population metrics are akin to what Rogers (2009) has called 'post-demographic'.

In the introduction I specified a set of properties of topological analytics for understanding the database devices described above and the subjects and logics that they enact. With these analytics I argued that they constitute a social space by assembling and folding in dispersed data to generate heterogeneous and changeable mixtures of varying metrics and relations. At the same time, they enact individuals as sets of stable properties or identifiers such that subjects can be traced and tracked and understood as always in the process of changing and becoming. Transactions are the transforming and informing of who people are and their joining up constitutes metrics that evaluate and measure the performance of individuals and populations. But metrics and governing interventions are also dynamic and redefined and reformulated and deformed as a consequence of the looping effect between names and the named.

But rather than being 'new' it is an ontology of the subject and governmental logic that perhaps only now can be materialized and intensified through and with a database device. For Latour (2010), it is the ontology of individuals and the social that was advanced by Gabriele Tarde in the 19th century. While Durkheim sought to understand the individual in relation to the whole of a society and structuring social laws, Tarde sought to follow individual monads and their formation into aggregates and multiple social orderings. Latour argues that it was in part a lack of information and the incapacity to grasp the multiple and complex qualities of individuals and their aggregations that resulted in the dominance of the Durkheimian understanding rather than the Tardean conception of the social. Now, with the proliferation of digital data and devices, he argues that Tarde's conception can be realized. I am not interested in the Durkheim versus Tarde debate, nor in recovering Tarde for sociology, but rather how this understanding is useful for interpreting the relation between devices and governing logics. Database devices make it possible to materialize a conception of population as a space of relations consisting of multiple aggregates of individuals with fixed metrics (biographies) along with complex and always-varying ones (transactions, conduct). This is not a conception determined but rather intensified and materialized by information technologies. Similarly, it is a materialization and intensification of what Foucault called the 'fine grain of individuality' and the singularity of the case (2003: xxii) and of a government logic elaborated by Deleuze (1992) as modulating control.

To conclude, by deploying topological analytics I have argued that database devices enact and advance a particular conception of subjects and governmental logic. Other analytics are certainly possible.

For example, in relation to youth justice database devices structuralist analytics advance the argument that risk assessments obscure and aggravate existing social inequalities; actuarial analytics identify the problems of individual interventions based on inferences and population-wide probabilities; managerialist analytics establish the shortcomings and failures of risk criteria and scales; and political analytics identify discriminatory and human rights consequences of risk assessments based on what youth might do.[20] I have also noted different social theory analytics such as Foucault's *dispositif* or Latour's actor-networks. But rather than offer topological analytics as an alternative perspective, I adopted an ontological stance to argue that different reals are enacted by different analytics. It is a stance that understands phenomena as already and always multiple and complex, and does not deny other possibilities but positions these as questions of 'ontological politics' (Mol, 1999). All analytics order and enact the world in ways that make some elements and relations present while absenting others (Law and Singleton, 2005).

What elements and relations do topological analytics make present? Principally, they emphasize variable, unstable and modulating relations, uncertainty, permeable boundaries and abduction as *immanent* rather than *exceptional* qualities of database devices. While there have been numerous critiques of neoliberal strategies, little attention has been paid to how databases and new analytics are advancing an ontology of subjects and populations as sets of unstable, transforming and generative transactional relations, and likenesses and identifiers of who they are and 'of a potential future person yet to come' (Amoore, 2009: 18).[21] Instead, social science analytics remain fixed on categories of identity and techniques of better knowing and governing the subject. However, not only government but also commercial, social and political practices involve the enacting of multiple forms of association and identification that are more variable, unstable and modulating than 'older' forms of identity. This is what topological analytics capture. Government database devices intensify these qualities through what Foucault described as dividing practices that extend through 'ever-wider circuits' (2003: 45) and 'series of fine and constantly observed differences' (2003: 46). Such differential practices are materialized and intensified by database devices, which are constituted by and generative of uncertainty and instability in both how the subject is known and governed.

To conclude, if managerialist analytics attend to how governing practices are deterministic and aim to stabilize forms and relations, then topological analytics start with the assumption that 'the world is messy' and that 'we cannot know it by insisting that it is clear' (Law and Singleton, 2005: 350). Or, as Mol et al. have stated in relation to care practices, 'we do not bracket *failure* and *fragility*, but face up to them' and learn to live 'with the erratic' (2010: 10, emphasis in original). By adopting these presuppositions I am not claiming that topology offers a better analytic (and indeed I have emphasized that analytics are not perspectives on but enactments of objects and subjects). Instead, it makes qualities such as fragility and uncertainty present and thereby opens up a different line of inquiry and set of questions about the governing consequences of database devices. Here I will suggest a few. If complexity, uncertainty and instability are understood as intrinsic rather than indications of system failure, then what does this mean for practitioners who must take decisions? Do these qualities demand more rather than less human judgement and intervention? If the identity of people is mutable then does this open up or close down the capacity of subjects to intervene in their identification? Are they rendered more passive or does uncertainty afford them opportunities to challenge or confound identification?[22] In other words, topological analytics turns our attention to questions of how practitioners and subjects work with rather than seek to tame complexity and instability and the possibility that these elements are not exceptions but givens and part and parcel of a governmental logic and ontology of subjects.

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Notes

1. Wal-Mart estimate from Hays (2004) and Tesco estimate from Andrew Fearne, presentation at the 'New Populations' workshop, Open University, Milton Keynes, 30 April 2009.
2. At the time of writing, the Conservative-Lib Dem coalition government had scrapped Identity Cards and the ContactPoint children's database.
3. NPfIT started in February 2002, with the goal of replacing all NHS computer systems with a new centralized system. Since April 2005, it has been run by an agency of the Department of Health called Connecting for Health (CfH). According to some assessments, 'NPfIT is in serious trouble with systems being delivered years late or not at all', and there are many 'public concerns about the safety, privacy and functionality of a number of systems' (Anderson et al., 2009: 12). In August 2011, after a major review by the Cabinet Office, which found progress to be 'dismal', the project was taken over by the central government's IT team with the objective of shifting 'elements of NHS IT into the ''common ICT infrastructure'' envisaged for the whole public sector' (Cross, 2011).
4. The terminology of 'technical and managerialist' analytics is from Law and Singleton (2005).

5. See Savage and Burrows (2007) and Amoore and de Goede (2008) for discussions of how transactions have become key registers of identification in commercial and border management security practices.
6. Law and Singleton (2005) cite several examples of empirical case studies that have shown how such stability does not hold in practice, such as de Laet and Mol's (2002) study of how a water pump used in the villages of Zimbabwe is a mutable mobile.
7. Government records can contain data on a person's history of bankruptcies, tax liens, civil judgments, criminal background, civil litigation histories, outstanding warrants, professional licences, records of property and land ownership, marriage, birth and divorce records, and business licences.
8. For examples, see arguments in Cabinet Office (2005) and Department of Health (2008).
9. Under New Labour, the UK government began to consolidate these into a single government identifier through the Identity Card and National Register. However, the Conservative-Lib Dem coalition government scrapped the programme and alternatives are being investigated, such as joining up identifiers used by the Identity and Passport Service (IPS), Department for Work and Pensions (DWP) and the Driver and Vehicle Licensing Agency (DVLA).
10. For comparison to joined-up databases used in border management see Amoore (2006).
11. Versions of these database devices are continuing under the Conservative-Lib Dem coalition government.
12. The most common version of the MIS is the electronic Youth Offending Information System (eYOIS), which is used by almost three-quarters of YOTs and designed by the software company CACI. The eYOIS enables data exchange between independent systems, electronically and in 'real time'. It assembles data on multiple events, relations and transactions of youth with distributed justice and social welfare offices to manage interventions and evaluate their risk of (re)offending.
13. See Youth Justice Board (2010) *YOT Data Recording Guidance*. In 2009/10, there were 157 YOTs: 139 in England and 18 in Wales (Youth Justice Board, 2010). On 14 October 2010 the Coalition government announced the Youth Justice Board would be abolished and its functions moved to the Ministry of Justice. The practices and uses of the MIS have been retained.
14. For example, Bateman (2011) notes how a youth justice database device called Asset assembles different metrics about youth to establish categories of youth at risk of (re)offending. Minor adjustments to the metrics can significantly change the numbers of youth falling into different categories of risk and thus the assessments are 'sufficiently loose' and alterable.
15. This understanding of monads draws from Leibnitz's formulation as taken up by Bruno Latour (2005, 2010) and Chunglin Kwa (2002).
16. See Amoore and de Goede, who take up this distinction in relation to a security practice that 'preempts, visualises and opens to circulation' (2008: 174).
17. See Ian Hacking (2007) on the making up of 'kinds of people'.
18. As described in Sir David Varney's report on service transformation (Varney, 2006).

19. Through examples such as autism, obesity, child abuse and multiple personality disorder, he argues that a number of practices constitute 'engines of discovery' in the making up of people. These include practices of counting, quantifying, setting norms and establishing correlations.
20. These critiques have been made of youth justice risk-led practices that tailor sentencing to fit with the unique circumstances of the individual (also referred to as the 'scaled approach') and outlined by Bateman (2011). Rather than what youth have done, risk assessments are based on what they might do. Risk assessment is carried out through a database device called Asset, which assembles different metrics (or what is called 'ratings') about youth such as their living arrangements, family and personal relationships, education, training and employment or substance misuse. By adding up these metrics an overall risk score rather than the seriousness of the crime committed is used to determine a corresponding sentence.
21. For examples of arguments about the neoliberal logic of government databases see Bellamy et al. (2005) and Henman (2010).
22. See for example the discussion in Ruppert (2011) with regard to how database devices render subjects interpassive.

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Memory and Mathesis: For a Topological Approach to Psychology

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Abstract

The 'mathematical imaginary' at work in psychology is central to the contingent history of the discipline, but is also responsible for considerable confusion and ambiguity around the ontological assumptions of psychological theories and models. Rather than reject the mathematical altogether, this article argues for an alternative form of mathematical description in psychology through the use of topology. Drawing on DeLanda's topological account of the virtual, the relationship between psychology and ontology is progressively questioned in relation to memory. Henri Bergson's conception of duration and the pure past is juxtaposed with the topological psychology of Kurt Lewin and its notion of life space as a manifold with *n*-dimensions. Using a diagrammatic strategy developed by Mullarkey, an actualist account of the virtual is used to hold these distinct bodies of work together. Psychological events may be given a 'thick description' through the identification of topological relations and invariants. The interplay between the actual entities that are afforded in experience can be seen to be virtualized as planes of irreality. A topological approach to psychology offers the opportunity of replacing the taxonomy of essences common to the discipline with a dynamic account of invariance through homeomorphism.

Keywords

Henri Bergson, Kurt Lewin, social memory, topological psychology, virtuality

> [T]he determination of topological relationships is the fundamental task in all psychological problems. (Lewin, 1936: 87)

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Origins

By 1967, Herbert Simon once predicted, the majority of psychology will take the form of computer programs (see Newell and Simon, 1963). This expression of what we might call the ‘mathematical imaginary’, shared by a particular type of psychologist, neatly encapsulates an entire historical trajectory traced by the discipline. Psychology separated itself from philosophy by applying the logic of differential calculus to the study of mind. The earliest forms of psychological experimentation (e.g. Wundt, Ebbinghaus) established a relationship between rates of the presentation of stimuli and the rate of some response made by the experimental subject. The mathematical function that is thereby obtained was considered to directly represent a psychological operation that would then be postulated by theoretical deduction. Ebbinghaus (1913 [1885]), for example, derived a function that he dubbed a ‘forgetting curve’ by calculating the differential between the presentation of sequence of random numbers and the subsequent serial recall of the stimuli.

If one were to unpack what Isabelle Stengers (2010) calls a ‘contingent history of science’ in the case of psychology, then this practical application of differential calculus deserves to be considered as an ‘event’ – an intensive, symmetry-breaking threshold where novelty emerges in the thinking of the psychological and its rendering as a scientific object. The psychological subject is transformed into a mathematical space in which a huge variety of functions can be plotted (e.g. rates of forgetting, diminution of attention, levels of anxiety). In fact the only constraint on the number of functions that can be produced through this process is the limitation of the empirical creativity of the experimentalists concerned. Small wonder that William James – who was responsible in part for the establishment of one of the first experimental psychology laboratories in North America – spent much of his *Principles of Psychology* attempting to produce a cohesive theoretical framework around the burgeoning range of data produced in this mathematized space of the subject.

By the time Simon made his prediction, this mathematical space had undergone numerous revisions. The behaviourist or ‘empty organism’ approach had attempted to purge subjectivity altogether by recourse to the positivist procedure of treating the derived functions as law-like regularities that did not require further specification. However, progressively, it was realized that for any psychological act of sufficient complexity, the functions were inaccurate and required further modification to be plausible, usually in the form of nesting differential relations of stimulus–response rates within one another. These were expressed as massive algebraic expansions that quite literally transformed psychological research into mathematical puzzle-solving, albeit of a mundane and time-consuming sort (a movement known as ‘informal behaviourism’). The difficulty here is that the algebraic formulation of even a basic psychological act reaches such a byzantine level of intricacy that it appears wildly implausible – the function seems to disintegrate into symbolic dust. The elegant solution to this difficulty was to inject reflexivity into the mathematical space. If we continuously feed the outcome of a given calculation back into the formula to create new starting conditions then dynamism returns to the otherwise inflexible regularity. And if it is then assumed that the psychological subject itself engages in just this kind of continuous feedback, the mathematical space is transformed. The subject is no longer the referent of a mathematical *operation* but is rather itself a mathematical *operator* which is continuously (re)tracing its own mathematical coordinates. In this way the declaration that psychology is reducible to a kind of computational modelling, by way of Simon's analogy with the program, is curiously a kind of empowering of the subject, which is granted its own autonomy for self-calculation, since it is now recognized as a self-governing cybernetic system (see Dupuy, 2000).

This brief and crude history of psychology is designed to illustrate the extent to which mathematics and mathesis plays a crucial yet also ambiguous role in the shaping of psychological thinking. Much effort has been expended both inside and outside the discipline in the critique of the kinds of statistical assumptions that psychologists make in the generation of quantitative data, especially data from experiments (see Cohen, 1994, for a very precise statement). The myriad epistemological problems that arise from placing statistical norms at the centre of psychological research have been thoroughly exposed (see Rose, 1989, 1996). But what is less discussed is the particular way in which numerical reasoning – the 'mathematical imaginary' – directly structures ontological assumptions within psychology. Number dominates not only the way psychologists tend to generate knowledge, but also how they typically conceive of the very object given to their studies.

But let me immediately make some caveats. Not all psychology is entirely in thrall to number. Historically, there are dialects within the discipline that have been in dialogue with phenomenology and have attempted a sustained non-mathematical effort at thinking subjectivity (see Brown and Stenner, 2009; Curt, 1994; Shotter, 1993; Tolman, 1994). Similarly, alternatives to experimentation (so-called qualitative methods) have been well developed, such that in some areas, such as social psychology, the range of philosophical, practical and sometimes ideological divisions between researchers are simply glossed as 'quantitative vs qualitative psychology' (see Willig, 2012). When this division is entrenched, two apocalyptic visions of the future of psychology are afforded. Coming from one side, quantitative research is the guarantee of objectivity, scientificity and, ultimately, of a unity of knowledge that is threatened by an immature return to a pre-scientific notion of the subject that will dissolve the discipline into politically-oriented squabbles that will destroy its professional standing. And from the other, there is the corresponding idea that premature quantification of the subject, in the form outlined in Heidegger's (1993) famous description of mathesis, is a project which is corrosive to the adequate thinking of Being and will ultimately reduce psychology into an instrument of social administration (or 'the police' as Canguilhem, 1980, had it), unless the discipline can be re-founded on more appropriate conceptual and methodological grounds.

Tempting as it is to replay these debates once more, in this article I will deliberately ignore this particular division. I will neither simply reject nor affirm quantification as the basis for psychology, but will instead seek to examine the ontological implications of different mathematical assumptions as they are played out in psychological research. The strategy I will pursue here will be to explore what a particular branch of modern mathematics – namely topology – can offer to psychological thinking. Here I will orient to Manuel DeLanda's description of topology as 'the least differentiated geometry' (2002: 26); that is, a set of descriptions of invariance in a relatively undifferentiated, non-Euclidean space. Such a mathematical space can be seen as prior to and in some sense implied by the Euclidean space of subject–object transactions typically posited in psychology.

Invoking DeLanda's work immediately brings with it an engagement with the question of the 'virtual' and the merits of this term for social scientific analysis. Part of the difficulty of addressing this question is that in Deleuze and Bergson's work, upon which DeLanda draws, the distinction between virtual and actual is premised upon a further distinction between psychology and ontology. Here the topics that are usually treated as defining psychology, such as memory, emotion and perception, are raised to the status of ontological questions by forcing them beyond the limits of any given experience. That is to say that an adequate treatment of a topic such as memory necessarily departs from a concern with the particular experiences of any given person in favour of a questioning of the impersonal conditions of memorial experiences *as such* (as in Ansell Pearson's 2002 treatment of 'the time of life' as the basis for approaching memory). I am acutely aware that making such a Bergsonian 'turn beyond experience' may render psychology obsolete for many thinkers, with its questions better posed in formal philosophical terms. However such ontological elevation risks mystification if it does not supply the means by which ontological terms (such as 'virtual' or 'duration') can be translated back into notions which allow purchase on mundane experience, even if they necessarily challenge and expand what may count as such experience. Here DeLanda's (2002) call to identify the processes through which actualization takes place can be heeded by drawing on topology to describe how invariants taken in an ontological sense may either persist or be transformed as they are expressed in psychological terms.

There is, in fact, an existing attempt to use topology for just this kind of philosophical renewal within the discipline – Kurt Lewin's *Principles of Topological Psychology* (1936). This work will be discussed at some length as we proceed. I will argue that juxtaposing Lewin's work with that of Bergson lends weight to an 'actualist' interpretation of the virtual, where topological abstraction can offer a thick description of psychological events. The juxtaposition will be conducted using a 'diagrammatic' strategy proposed by John Mullarkey (2006). This involves an attempt at a visual representation of a conceptual argument. Mullarkey argues that in circumstances where we are confronted with 'systems of reference' that are fundamentally opposed, a diagram can serve as a subtractive or condensed presentation of a theory. The diagram is affirmative – it offers no critique, no suggestion of synthesis. It allows the implicit contradictions of a theory to be visually unfolded in the diagram itself. My intention in using diagrams to juxtapose markedly different approaches in this way is to ask what kind of space would be required for two or more seeming opposed diagrammed theories to be compossible.

For the most part, I will use the psychology of memory as my source of examples. In part this choice is because memory is central to both Bergson and Deleuze's Bergsonism, and hence is thoroughly implicated in the question of the virtual. But as an area, memory has always captured the mathematical imaginary of psychologists, given the peculiar combination of quantities (rates of forgetting) and qualities (distinctions between memory processes) that are debated here.

Where better, then, to mobilize a different kind of mathematical imaginary in psychology, one that is hopefully better equipped to address the ontological difficulties that have beset the discipline.

Boxes

The psychology of memory is one of the defining areas of research within the discipline. Its progress stands as a good exemplar for the discipline as a whole, with its shift from rudimentary experimental attempts to measure the power of recall quantitatively, through speculative attempts to model the cognitive architecture that defines the executive and storage functions in remembering, to the current preoccupation with seeing memory as the ongoing reconstruction of the past in multilayered cognitive-neural networks of brain mental activity (see Draaisma, 2000; Schacter, 1996). For the most part, research in this area uses traditional forms of psychological experimentation that involve manipulation of external stimuli to explore the effects on responses, taken to indicate the workings of cognitive processes. Theoretical work starts from the assumption that memory can be treated as a system whose boundaries and limits are defined by the overall cognitive architecture of mind, which

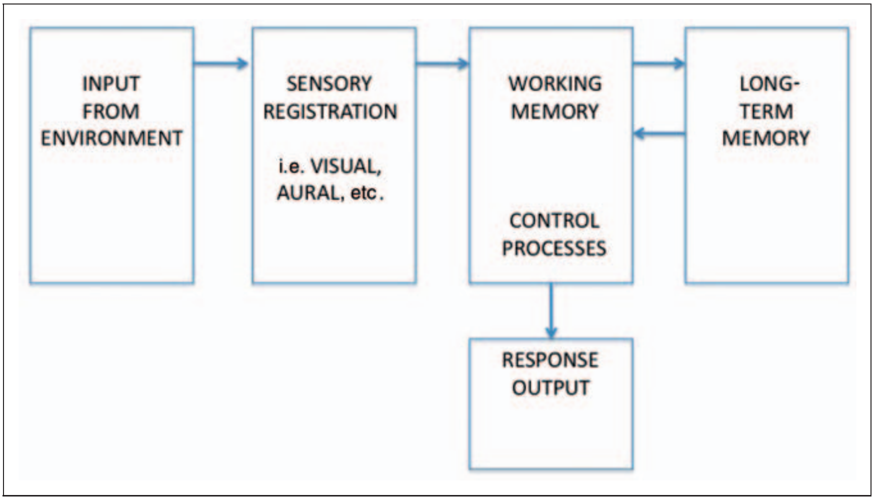

Figure 1. Simplified model of memory (after Atkinson and Schiffrin, 1968).

will at some point in the future be mapped clearly on to the neural structure of the brain.

Figure 1 shows a 'classic' organization of some of the cognitive processes involved in memory. The logic of this diagram is deceptively straightforward. The first box depicts an input of some kind, which is received by the perceptual system denoted by the second box. The perceptual sensations generated by receptors are then transmitted onwards to a set of central or 'executive' control processes (the third box), which have at least two general roles: they temporarily prolong perceptions such that they can be subject to further processing and also store these same perceptions by forwarding them to the final box – long-term memory. Processing may further involve the summoning of relevant contents back from long-term memory, which may be blended with the 'new' perceptions to arrive at an output, shown here as the final additional smaller box.

This is, of course, a ridiculously simplified model of memory. There is considerably more complexity and subtlety in recent work such as Conway's conception of autobiographical memory (see Conway and Pleydell-Pearce, 2000), Lansdale's (2004) studies of acropetal memory and current ecological approaches to remembering (Manier, 2004; Sutton, 2009; Winograd et al., 1999). Nevertheless the simplified model encapsulates much of the default or standard assumptions that define cognitive approaches to memory. The very representational form this model takes is telling and begs a series of questions. What do the boxes and arrows actually denote? Their form suggests that they are substances and processes. The boxes are stable entities of some sort, and the arrows are functional relations denoting an exchange (either unidirectional or bidirectional) between these entities. But this is not the case. The first box – 'environmental input' – must have some entitative status, not least because contained within it is the whole causal universe that the subject might perceive. Similarly, the fifth box – 'response output' – can only really refer in entitative terms to the embodiment through which this output is enacted. But the remaining three boxes are best understood as bundles of processes, although the third – 'long-term memory' – sounds markedly more thing-like than the other two. The very division into boxes suggests an implied Cartesian subject/object distinction, but it is unclear where the boundaries are drawn. The diagram seems to show a subject who has equal standing to the 'environment' – but should not, properly speaking, boxes 2–5 be contained within box 1? And for that matter should not boxes 3 and 4 (as the 'cognitive' bits) be contained within boxes 2 and 5 (as the 'embodied' bits)? The same kinds of difficulties arise when we think about the arrows. The arrow between boxes 2 and 3 is a 'perception', but what is the arrow between boxes 3 and 4? Is it still a perception or is it already a memory? If the latter, then how did this transformation occur? But what then is the reverse arrow coming back from box 4 to 3? It might be a memory, or a memory in the process of becoming restored to the status of a perception or something else entirely. Finally how are we to understand the blank space outside the boxes? In what kind of space is this set of relations placed? How are the temporal dimensions of this space to be understood, given the nominal impossibility of thinking memory outside of time?

Leaving aside the actual theoretical postulates of given cognitive models of memory, by itself the diagram reveals a number of difficulties. There is an implicit dualism, where the subject is given far greater weight than the environment. Differences in behavioural output are functionally related to something in the broader world that serves as input, but appear ultimately to be determined to a far greater extent by what happens 'within' the subject itself. The whole process of remembering appears to occur in a space that is outside of any particular context or historical contingency. In other words, memory unfolds in a space that is never anywhere in particular, that is, as a form of pure transcendence. Allied to this is the lack of any specification of a time function, leading us to assume that Newtonian or reversible time is implied. This would mean that running the model backwards would make no difference to the key properties that are expressed. However, if the model is applied repeated to a series of episodes of remembering, long-term memory (box 4) would expand quantitatively. There would be more placed 'in it' with each iteration. This means, in turn, that over time there is a greater likelihood of a 'match' between the contents of long-term memory and incoming perceptions – as we get older, more situations resemble those we have previously experienced – and correspondingly that the processing and outputs would be qualitatively different as time progresses. Time matters for this model, yet nowhere is it described.

To sum up, the problem with this model is not that it is a mechanical image of an organic process. Nor is it that it offers a reductive mathematical approximation (the differential between input and output rates) to describe human action. Rather, *it is neither sufficiently mechanical nor properly reductive*. It fails to properly clarify the entities and processes that it claims are at work, and it gives no description of the mathematical space in which these points and vectors are distributed. These type of models are often critiqued for suggesting a 'container' view of memories (Middleton and Brown, 2005), but here we have little sense of what is contained and what is doing the containing, nor of basic features of the space–time in which all this is thought to occur. What we have here is an ontological incoherency based on a lack of mathematical specification.

Cones

Much of the critique of the psychological model of memory described above is derived from Bergson's *Matter and Memory* (1991 [1908]). In this key work, Bergson elevates certain aspects of memory to an ontological category – 'pure memory' – that grounds a unique account of the mechanisms underpinning recollection in the form of the actualization of memory-images. What is of interest to us here is the manner in which Bergson points towards a different mobilization of the mathematical in relation to memory, one that enables us to think the outside of the boxes we encountered in Figure 1. As I will go on to show shortly, this thinking ultimately leads us toward topology.

Matter and Memory famously delivers a version of the psychological that bypasses subject–object dualism. In place of the bounded perceiving subject that stands over and against the world of objects, we have a monist account of a plane of images – including that image we call our body – acting upon one another. Perception, on this account, is not the passive reception of an object (or its copy), but rather a process of reflection and refraction as images communicate movement through one another. What we perceive is selected aspects of an image – a 'virtual image' – that are structured by the potential they offer for our own actions: 'our needs are... so many searchlights which, directed upon the continuity of sensible qualities, single out in it distinct bodies' (Bergson, 1991 [1908]: 198). Perception is then a relational process that is subtractive; out of the multiple possible virtual images that might be reflected in the encounter between my 'body-image' and another image, the one that offers the most to my ongoing needs is selected. In respect to the account of the psychological that is unfolded here, what Bergson does is to de-throne consciousness by arguing that it adds nothing in representational terms and that, crucially, reflection is not a property of the subject as such but rather a relational process where perception is never singular (see Massumi, 2002).

Bergson's account of the spatial plane in which communication between images occurs stresses something like a physics of perception – terms such as 'refraction', 'vibration' and 'resonance' dominate. We can address a great many memory issues by treating remembering, with respect to this plane, as the prolonging of a virtual image within an action. For example, our ability to remember how to write or to drive – usually referred to as 'procedural memory' in psychology – can be considered as a mechanical problem involving the body's capacity to prolong the movement of a virtual image within the effectors of its nervous system (termed 'habit-memory' by Bergson). We might extend this description to recuperate some aspects of the model in Figure 1, on condition that these processes are 'de-subjectified' and treated outwith a bounded consciousness that is managing reflection.

However, when it comes to the more complex question of the modes through which we remember distinct aspects of our past experience – so-called 'episodic' and 'autobiographical' memories – we must turn towards Bergson's conception of time as 'duration'. Here Bergson famously describes time as qualitative flow, an intensive 'continuous variation' that does not in itself contain portions or instants. This is contrasted with the notion of 'clock time' or the division of time into passing instants, which is, for Bergson, a secondary spatialization of time that is accomplished by the organism to serve its own survival needs and interests. If the temporal character of memory is fashioned after duration, then it may be described in the following way:

> Duration is the continuous progress of the past which gnaws into the future and which swells as it advances. And as the past grows without ceasing, so also there is no limit to its preservation. Memory, as we have tried to prove, is not a faculty for putting away recollections in a drawer, or of inscribing them in a register. There is no register, no drawer; there is not even, properly speaking, a faculty, for a faculty works intermittently, when it will or when it can, while the piling up of the past upon the past goes on without relaxation. In reality the past is preserved by itself, automatically. In its entirety, probably, it follows us at every instant; all that we have felt, thought and willed from earliest infancy is there, leaning over the present which is about to join it, pressing against the portals of consciousness that would fain leave it outside. (Bergson, 1998: 4–5)

This passage from *Creative Evolution* (1998 [1911]) summarizes much of what is at stake in viewing memory from the perspective of duration.

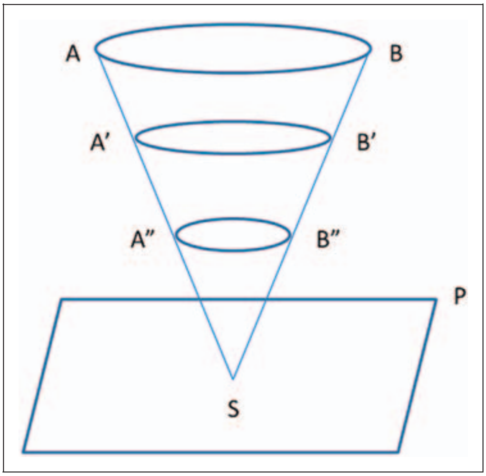

Figure 2. The cone of pure memory (after Bergson, 1991 [1908]: 162).

If there are no divisions, as such, within duration, then the idea of memory as the effort to preserve discrete episodes of lived experiences is nonsensical. There are never any gaps in experience to fill, no break between my current perception and the totality of my past. Everything is already there 'preserved by itself'. And yet this preservation cannot be thought of as a container or an archive, since duration, by definition is not spatialized as such. There is no need to add the box marked 'long-term memory' found in Figure 1.

What, though, is the status of this 'past' that 'follows us at every instant'? There is a significant interpretive divergence here. Deleuze's (1991, 1999) reading of Bergson claims that 'only the present is ''psychological''; but the past is pure ontology; pure recollection has only ontological significance' (Deleuze, 1991: 56). Which is to say that, insofar as we are considering the act of recollection itself, we remain within psychology. But if we attempt to account for the necessary grounds through which these acts are performed, we pass to ontology. This, for Deleuze, is the more significant intellectual project, since 'we can see that... psychology is now only an opening onto ontology, a springboard for an ''installation'' in Being' (1991: 76). The pure past has no direct psychological significance; it concerns instead an impersonal time, a virtual plane of Being which may actualize itself in the form of mundane, concrete personal experiences, and is therefore the creative engine that affords the psychological.

But in contrast to this 'virtualist' reading of pure memory, we clearly see in the excerpt cited above that there is a crucial psychological dimension in Bergson's account. What matters is 'all we have felt, thought and willed from earliest infancy'. It is not the totality of the past as such that is significant, but only that portion of it that I can call ‘mine’. John Mullarkey (2004, 2006) presses this point to advocate an ‘actualist’ reading of the pure past. He argues that recollection – those psychological processes Deleuze sees as a mere ‘springboard’ – require no further grounding in anything outside of themselves. If perception is already divided, such that the present into which duration ‘gnaws’ is already imbued with the power to creatively differ from itself, then no further engine of novelty and transformation is required. We do not need a concept of the virtual to think of change and difference in the psychological, since it is already dynamically produced in the exchange or ‘endosmosis’ between duration and perception.

Settling this important debate in Bergson studies is far beyond the scope of this article. But we can note that it raises an important concern for the ‘mathematical imaginary’. Consider the famous diagram of the cone that appears in chapter 3 of *Matter and Memory* (Figure 2). Bergson was well aware of the irony of demonstrating the concept of duration through words and images that necessarily spatialized time (see Lawlor, 2003). This diagram then schematically, and problematically, attempts to visualize how duration – sketched as the cone with the points A·B·S – is inserted into the concrete spatially distributed plane of images that is depicted as the rectangle P. The point S is where the duration and space meld into one another. It is very unfortunate that Bergson’s choice of denotation – the letter ‘S’ – seems to suggest to us that this meeting point is a bounded psychological subject. This is, of course, not the case. If S denotes any ‘thing’ in particular then it is the body-image, or rather a nervous system that is capable of slowing down and reflecting movements from other images in such a way that it creates an interval in the otherwise ceaseless play of images acting upon one another. It is this interval into which the past is thrust. In this way, as Worms (1999) has it, the body is the ‘and’ in ‘matter AND memory’, the lynchpin around which the endosmosis of time and space is to be thought. We might extend this further by speculating that we need not even think in terms of an individual body, but rather of assemblies of bodies whose nervous systems are sufficiently affectively correlated so as to act in concert as a collective body-image.

Irrespective of how we define S, what counts at this point is how pure memory is inserted into space in its most condensed form. Bergson describes this as occurring through twinned processes of contraction and rotation, whereby the past presents those aspects of itself that are most useful to infuse current perceptions:

> memory, laden with the whole of the past, responds to the appeal of the present state by two simultaneous movements, one of translation, by which it moves in its entirety to meet experience . . . and the other of rotation upon itself, by which it turns toward the situation

> of the moment, presenting to it that side of itself which may prove most useful. (Bergson, 1991 [1908]: 77)

Now it is this notion of an intrinsic utility to the manner in which the pure past (whether understood in ontological or psychological terms) is inserted into the interval S that is critical. In a fine summary of Bergsonism, James Burton glosses the process in the following way:

> Pure memory cannot be experienced as such, for it marks the limit of experience; yet it remains virtually present in that any aspect of the past existence of the body-image may in theory be produced in the form of memory-images, by the contracting and filtering of that past that is the body-image's continuous activity. (Burton, 2008: 329)

Burton follows the logic of the virtualist interpretation of Bergson in making the claims that 'in theory' since everything that is psychological is already a priori installed in pure memory, or, in other words, that any given present is virtualized and subsumed within the pure past, then it follows that 'any aspect of the past existence of the body-image' may be recollected as 'memory-images'. It is at this point that the difficulty of sorting out the ontological from the psychological becomes apparent. As an ontological claim, this is entirely consistent with what Mullarkey (2004) calls the Manichean promotion of the virtual as the source of change, transformation and creativity. 'In theory' everything must be possible. But as a psychological claim this is deeply problematic. Why would our memories be structured in such a way as to always present those aspects of themselves that are most useful? And why, for that matter, would our perceptual processes operate along the same lines? How is it possible that we could – again, in theory – recollect every aspect of our past experience? To assume such an instrinsic utility to memory would be to subscribe to a certain kind of normativity in remembering, where the tendency of memory processes is to organize our prior experiences in such as way as to promote vitality, creativity and transformation. Those instances that do not fit with this tendency – memories that are painful, awkward or simply inconvenient to us in our daily affairs – must be deemed pathological or special cases. But if we begin with psychology rather than ontology, what is rapidly apparent is that the supposedly pathological is considerably more common than the normative. Our capacities to recollect often seem to refuse to fulfil our needs, whether that be in the cases where we simply fail to remember a name, an event or a story that would have made a difference on a particular occasion, through to the more significant experiences where we are dogged by memories of things that we would far rather forget, where we cannot help but be overwhelmed by a past that will not be kept outside the 'portals of consciousness' (see Haaken and Reavey's 2010 collection for illustration).

The difficulty here is with the purity of 'pure memory'. If it is treated as beyond further specification then inevitably these psychologically derived questions will receive only the most abstract of answers. However, within the virtualist version of Bergson there is to be found the basis for a fruitful mathematical response. Ansell Pearson (2002) lays great emphasis on the distinction between quantitative and qualitative multiplicities that can be read from Bergson (notably in *Time and Free Will*). DeLanda (2002) reframes this, in Deleuzian terms, as the difference between the intensive and extensive expressions of a given multiplicity, where the latter is to be treated in terms of Euclidean space, while the former needs to understood in terms of vector space. Finally, Bergson himself indicates that there is an organization, of sorts, to be divined within duration, as denoted by his division of the cone into section (A'·B'; A''·B'', etc.). To recapitulate our conclusions at the end of the previous section: if we are to advance further in our understanding of the relation of psychology to ontology we must embrace rather than reject this mathematical description as the means of going forward.

Regions

Topology is a comparatively under-used resource in psychology. Modelling tends to be performed using statistical techniques such as factorization or regression to produce mathematical spaces of covariance. These reveal extensive structures that can be visualized using techniques such as clustering. However, these structures can often be conceptually incoherent, raising significant concerns as to the ontological claims on which they are premised, as we saw in our brief consideration of Figure 1. Following DeLanda (2002), we might envisage a further set of mathematical operations that would be required to understand the emergence of these extensive structures. This would consist of mapping intensive processes (e.g. perceptual and memory processes) in the form of vectors, and then subsequently of defining the topological space in which something of the long-term tendencies of these vectors can be grasped. For DeLanda topological space, in comparison with two other kinds of space (vector space, extensive structures), is 'ideally continuous and relatively undifferentiated' such that it is a 'counterpart of the virtual' (2002: 69). To put this in terms of Bergson's cone diagram, we might say that the plane P refers to extensive structures, the point S marks intensive processes, and the cone itself denotes a relatively undifferentiated topological space.

How then are we to think this topological space in such a way that the tension between ontology and psychology can be made productive? I will now turn to discuss the single most sustained attempt to demonstrate the

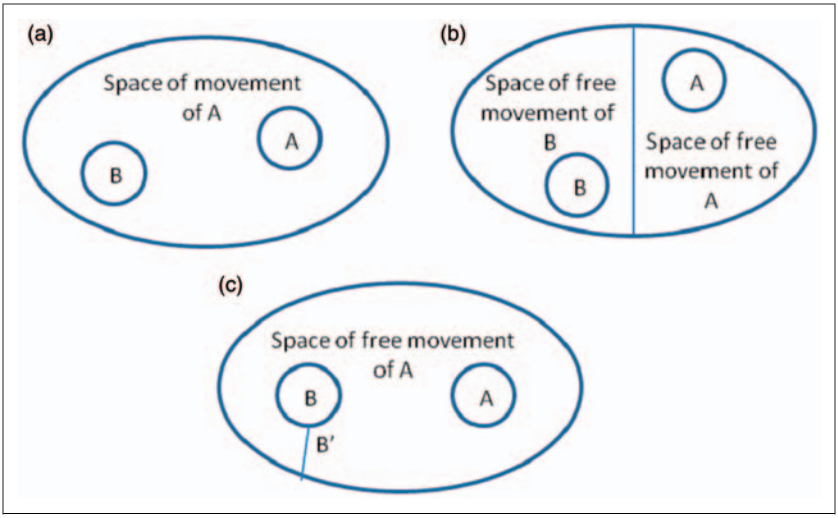

Figure 3. Three topological versions of children in a bathtub (after Lewin, 1936: 43).

power of topology for psychological thinking – Kurt Lewin's *Principles of Topological Psychology* (1936). Lewin's work grew from the Gestalt tradition in the 1920s and 1930s, which attempted to establish a closer dialogue between psychological research and theoretical physics.[1] In *Principles*, Lewin proposes that topology serves to ground the specification of all other psychological processes: 'the determination of topological relationships is the fundamental task in all psychological problems' (1936: 87). This is so because, for Lewin, an adequate account of a psychological event, or situation (S), requires an estimation of the behaviour (B) that defines that situation. Behaviour (B) is a vector that can be calculated by positing a manifold with at least two degrees of freedom, which Lewin refers to as person (P) and environment (E):

> Every psychological event depends upon the state of the person and at the same time the state of the environment, although their relative importance is different in different cases. Thus we can state our formula $B = f(S)$ for every psychological event as $B = f(PE)$. (1936: 12)

As we saw with the model of memory in Figure 1, if we do not think through the mathematical space in which elements that make up the differential relation are plotted, then we rapidly descend into ontological confusion. The notion of manifold is then essential if we are to 'find methods of representing person and environment as common terms in the same situation' (1936: 12) such that their vectors can be established. In later work, Lewin would concern himself more fully with the calculation of such vectors (see Lewin, 1946), but here he engaged in using topology to rethink the mathematical-ontological grounds of psychology. Lewin refers to the required manifold as 'life space'. This he defines as the 'totality of possible events' that might be experienced by a given person, or more precisely as the 'total of possible and not-possible ways of behaving' (1936: 15). What Lewin ultimately intends is for this seemingly inconceivable range of possibilities to be expressed by adding further *n* degrees of freedom to the life space manifold. His ambitions are then cognate with those of Bergson – an adequate account of living, psychological processes needs to invoke the totality of lived experiences.

Life space is a topological space of relation and connection. The fundamental question grounding psychological events is of the constitution of parts and wholes and whether any two given points plotted in the space may be connected or separated. Take a simple example used by Lewin of two children sat in a bathtub. This is illustrated using the diagrams a–c in Figure 3. In all three diagrams, the bathtub can be treated topologically as a region (see Lewin, 1936: 105–6), meaning a set of points enclosed by a Jordan curve, such that every point within can be connected to any other without crossing the curve. If A and B mark the position of the children relative to one another, then in the situation shown in Figure 3a, the bathtub is a 'space of free movement' in a simply connected region. The size or shape of this space is not relevant – merely that it is possible to move from any point to any other within the region defined by the Jordan curve. In Figure 3b this region is divided. If child B draws their hand across the water to indicate a 'cut' or border making out a part of the bathtub that they claim as their own, then the region is divided into two separate regions (i.e. it is no longer possible for every point to be connected to every other without crossing the borderline). Lewin refers to this drawing of boundaries within a region as the constitution of a 'power field'. However, in Figure 3c if child B merely places their hand on the side of the bathtub to form a barrier B', this does not have the same effect, since it is still possible for connections to be drawn merely by passing around the other (unblocked) side. In this case the region is still considered to be whole, but it is doubly rather than simply connected.

The example described in Figure 3b abstracts topological invariants from the psychological event in the form of regions. What is depicted is a relatively undifferentiated space that is prior to a Euclidean or geometric definition. It does not really matter whether the children are in a bathtub, a playground, or relating to one another through the internet, so long as their movements do not cross the boundary defining the region. It is the boundary that distributes the possible and the non-possible consistently through any set of transformations during which topological invariance is preserved. While the space can be further metricized, by plotting

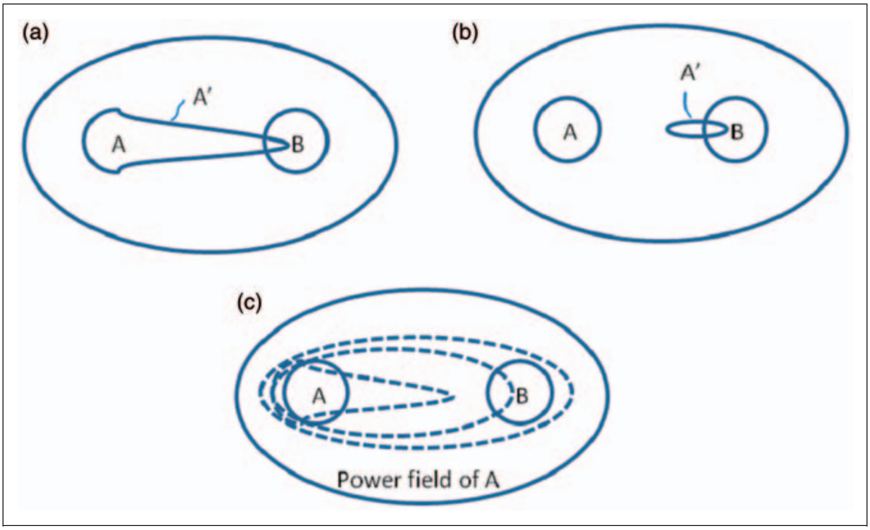

Figure 4. Three ways of diagramming a 'look' (after Lewin, 1936: 128).

vectors, or qualified, through phenomenological exploration, it is prior to the definition of either extensive structures or subjectivity – that is to say, prior to the application of either quantitative or qualitative methods as these are usually understood in psychology.

The status of this abstracted set of invariants bears comparison with the Bergsonian 'virtual'. Lewin uses the phrase 'what is real is what has effects' (1936: 19) to describe the topological properties of life space. The sense of this is close to Deleuze's formulation of a Bergsonian pure past where 'the possible has no reality (although it may have an actuality); conversely the virtual is not actual, but *as such possesses a reality*' (1991: 96). We might reformulate this to state that topological invariance has effects in terms of distributing what may be actualized as possible and not-possible so long as it persists through the transformations it undergoes. This does not mean that we should consider life space as some overarching mechanism that directly drives psychological processes. It is rather a description of psychological events from the perspective of the distribution of potential experiences. Take the following example used by Lewin of a mother who 'looks her child in the eye when she is trying to induce him to carry out a certain action or to emphasize a command' (1936: 127). There are several different ways of conceptualizing this look between mother (A) and child (B) topologically (see Figure 4).

In Figure 4a, the gaze is diagrammed as something akin to a 'quasi-physical' action. The mother, treated here as region A, extends herself (A') towards the child (B) in such a way that the two regions overlap to form a new connected region (A + A’ + B). It does not matter that there is no actual physical contact – it suffices that the gaze captures the attention of the child for a new region to be formed. Alternatively, it might be more appropriate, as illustrated in Figure 4b, to map the ‘looking at’ as a glance (A’) that is thrown toward the child ‘like a ball’ without there being continuous contact with A. The child is aware of having been looked at by the mother, this glance having a reality and a set of ongoing effects on the child that merits the event of the ‘looking at’ being rendered as a region (A’) that the child now has to negotiate in their subsequent actions (for example, averting their eyes from their mother or turning their back to ensure they cannot be directly ‘looked at’ again). Finally, the dynamic nature of the glance as a form of reproach or boundary setting might be emphasized in Figure 4c as a ‘change of the position and intensity’ of a ‘field of forces’ (Lewin, 1936: 129) that radiates from the mother around the child. This has the merit of indicating that the field of forces extended by the gaze might set very particular boundaries, involving specific implications for the child should they choose to cross the boundaries.

These differences in the topological mapping of an event as mundane as ‘being looked at’ indicate that Lewin’s topological-abstractive procedure is able to recover a range of potential experiences that might be afforded without a shift in overall topological invariance. More importantly, it demonstrates that we do not need to posit a Cartesian dualism to grasp these psychological dynamics between mother and child. In all of the three mappings it is as though ‘the mother controls the infant by her will in a way which is only slightly different from the way in which she controls her own body’ (Lewin, 1936: 179). The unit of analysis is then not the emotional attachment between self-contained individuals, but rather resonances and tensions across nervous systems that can be treated analytically as defining a region.

So far we have considered psychological events that are comparatively straightforward (although, as we have just seen, even an act as simple as a gaze can be topologically unfolded in numerous ways). The following example is more elaborate:

> A woman stands at the loom in a big noisy factory, next to the last in the eighth row. A thread is broken. She is about to stop the machine to see what has happened. It is shortly before the lunch hour. She has accomplished very little during the morning. She is annoyed. (Lewin, 1936: 22)

Lewin stresses the relationship here between physical qualities of the factory (the space, the noise) and the apparently subjective experiences of the worker (frustration, annoyance). However, unlike the Cartesian division in Figure 1, where the former would be packaged together as 'the environment' and the latter as 'cognitive processes', here this relationship is between 'quasi-physical facts' plotted as points within a region. As Lewin puts it, 'these facts are to be included in the representation of the psychological life space only to the extent and in the manner in which they affect the individual in his [sic] momentary state' (1936: 4). The question is then of what is and is not possible given this arrangement of points. For example, if the woman stops the loom, this will have consequences for the operation of the machines in the other rows. Would this act amount to crossing the boundary of the region? Or can it be accomplished within the existing connections and relations that define this psychological event?

Lewin continues the description of the loom operator by adding the following details:

> She has been married for three years. For a year and a half, her husband has been unemployed. The two-year old child has been seriously ill, but today seems somewhat better. She and her husband have been quarrelling more and more often recently. They had a quarrel this morning. Her husband's parents have suggested that she send the child to them in the country. The woman is undecided what to do about it. (1936: 22–3)

These details are treated as 'quasi-social' facts. This is to say that their relevance does not come from some causal force they exert on the woman's behaviour, but rather the extent to which they can be plotted as part of the manifold of possible and non-possible events. For example, if stopping the loom is a boundary-crossing event, it may cascade into a further boundary-crossing event in the manifold that includes the relations to her family (it is not possible for the child to remain at home and for the woman to be unemployed). DeLanda (2002), drawing on complexity theory, calls these linked series of boundary crossings 'symmetry-breaking events'. That is to say that some topological invariance is lost across the life space manifold.

In this example, there is a topological expansion of the psychological event. We – and indeed the woman herself – are able to conceive of a very large series of potential topological expansions. Perhaps there is a region where the child being sent to the country is compossible with a revolutionary event where the workers take charge of the factory. Insofar as a region where these connections are possible can be conceived from within the psychological event itself, then it has effects as what Lewin calls a 'quasi-conceptual fact'. In topological terms this can be expressed by adding a further degree of freedom to the manifold, which can be visualized as a further dimension. Lewin notes that any point in a region can be treated as intersecting with an additional dimension, such that a

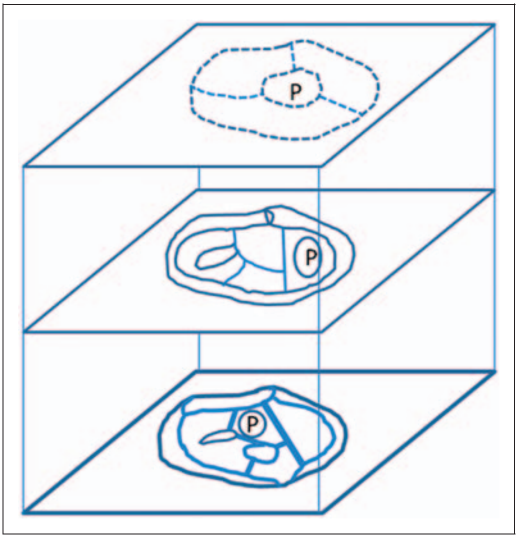

Figure 5. Degrees of irreality (after Lewin, 1936: 200).

further coordinate is added to its distribution. The addition of dimensions is termed 'degrees of irreality' by Lewin:

> Action itself can be of very different degrees of reality. Processes which concern strong needs of the person and in which he had to surmount strong physical or social barriers have usually a high degree of reality. Among the quasi-conceptual processes one can for instance distinguish carefully planned consideration of the ways and means which lead to a certain goal from free play of phantasy, which is more irreal. (1936: 196)

What Lewin describes here is an ongoing procedure of topological abstraction. There are, ultimately, *n*-dimensions that might be psychologically relevant to a given event. But the further this abstraction – or, we might equally say, *virtualization* – proceeds, the further we depart from concrete actuality towards the relative indifferentiation of life space considered as the 'totality of possible events'. In an attempt to visualize this procedure, Lewin offers the following diagram (Figure 5):

Like many attempts to visualize *n*-dimensional space, this diagram is not entirely successful. We must think of each plane as intersecting such that it adds a further coordinate to the plotting of point P, where this latter denotes a psychological event. If it were possible to continuously add further planes in this way, we would ultimately end up with a diagram that approximated life space as such, that is to say with an image of the virtual. This would be of a piece with extending the Bergsonian cone in Figure 2 to its limit.

To summarize, Lewin argues that psychological analysis typically starts from an incorrect unit of analysis – usually reducing behaviour to either subject or environment. In order to understand a psychological event we must first treat it as relative to an intensive process that is reducible to neither subject nor environment and which can be mathematically described as a manifold with at least two degrees of freedom (or 'life space'). This manifold can be expanded to encompass the totality of possible and non-possible experiences by adding further degrees of freedom. Doing so recovers topological invariants that allow for an adequate description of a given psychological event – it situates the event as emerging from a virtual space of potential. Lewin goes on to argue that there is a psychological reality to 'quasi-physical', 'quasi-social' and 'quasi-conceptual' facts. Perception self-divides, such that what is apprehended is not just concrete actualities, but also virtual connections, regions and boundaries that inhere in these actualities. Finally, change and creativity in and through psychological events is relative to the degree of abstraction (or 'irreality') that the event affords.

Dimensions

Lewin, like Bergson, attempts to ground psychological processes in an ontology that tends towards undifferentiation and continuity, but which can nevertheless be visualized in terms of its dynamic relation to discontinuous, discrete episodes in which experience is actualized. Clearly there are significant differences between the thinkers. On the one side, we have a philosopher whose concern is to develop 'fluid' philosophical concepts that do justice to the change and mobility he sees as characterizing an 'indefinite' reality (see Bergson, 1992: 211). On the other, a psychologist seeking a theoretical renewal of a discipline that has cut itself off from the emerging visions of reality expressed in modern physics. The argument has been that, despite these differences, the juxtaposition of these thinkers progressively realizes a different kind of 'mathematical imaginary' in relation to psychology. While critics inside and outside the discipline typically see quantification and the use of number as pure reductionism, I have described how the abstractions proposed by Bergson and Lewin enable a more fluid and mobile account of the dynamic relation between psychological processes and virtualization which destabilizes the otherwise implied Cartesianism in psychological models.

In this penultimate section I want to show – quite literally – how topology is the means by which these two thinkers can be held together, despite their differences. The form of my argument thus far has been shaped by what Mullarkey (2006) calls 'diagrammatology' – the perspectival presentation of systems of reference. I have tried to allow the

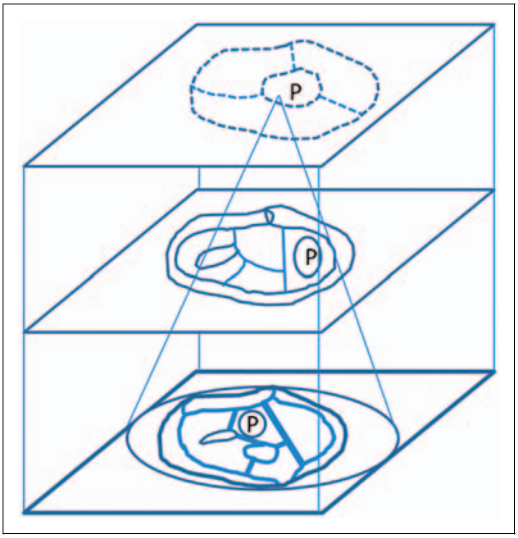

Figure 6. Bergson's cone combined with Lewin's levels of irreality.

diagrams themselves to pose the problems in an attempt to affirm rather than simply critique each position I have reviewed (cognitive models, Bergsonism, Lewin's topological psychology). This is not to say that each position does not have shortcomings, but my preference throughout has been to allow these difficulties to unfold from the diagrams. How then can we attempt to hold together these various positions? I offer Figure 6 as a partial attempt to do so.

The first thing to note is that it appears that Figure 1 is absent from this juxtaposition. In fact I think we can say that the 'input' and 'sensory registration' boxes have exploded into the movement of images and points on the uppermost plane. Furthermore, that the 'response' and 'working memory' boxes are now located at the point of the cone – where they mark the interval opened up by the nervous system for the insertion of duration and the virtualization of actual experience. And finally, that the 'long-term memory' box is now dissolved into the entirety of the cone itself.

What does the superimposition of the Bergsonist cone on Lewin's levels of irreality suggest? Lewin's planes of irreality denote an open set of topological abstractions that are equivalent to adding a new dimension successively to a given point. Any given psychological event can then be expanded by adding a further degree of freedom, such that its corresponding space of movement may be plotted through adding a further set of coordinates. The topological mapping of the event then appears to be stretched across the planes such that 'P' marks a manifold with *n*-dimensions. For Lewin, these abstracted planes do not all have the same level of reality, meaning that the movements possible along these planes are quasi-physical, quasi-social or quasi-conceptual – which is to say, they are comparatively more virtualized than one another.

The juxtaposition with the cone assists in viewing the successive dimensions added to the event as progressive virtualizations. But it also raises a number of problems. If the point of the cone marks the actual – what becomes rendered as 'lived experience' – then what is the psychological status of the planes? For Lewin they are clearly expansions of the psychological event that can be apprehended as such from within the event (note that we are leaving indefinite who or what it is that is doing the apprehending, whether it refers to a person or a collectivity, a single nervous system or an assemblage of affectively correlated bodies). This places the account at odds with Deleuze's Bergsonism, where the virtual has ontological rather than psychological standing – virtualization takes us 'beyond experience', actualization is what affords experience.

It is the immobile appearance of the diagram itself that is partly to blame. Lawlor (2003) suggests that Bergson's cone ought really to be visualized in a dynamic fashion, such that cone rotates with downward and upward movements, corresponding to actualization and virtualization. In a similar fashion, we might think of the planes of irreality as in a process of continuous transformation, which can be visualized for analytic purposes as passing through a series of visual forms while maintaining topological invariance. Adding further dimensions does not simply add complexity but also visualizes moments of symmetry breaking, where invariance is lost before re-settling around a new distribution of relations. In Lewin's terms, this could occur through a quasi-conceptual movement (i.e. thinking) approaching or crossing a boundary resulting in a transformation of the structure of a region. If it is possible from within the psychological event to conceive of a passage beyond an apparent boundary, then this has 'real' transformative effects on the movements that are then possible in the region in which the event is defined. Crudely put, if we can think, feel or recollect our way beyond the concrete actuality of our circumstances, this brings about a new actuality.

Accounting for the juxtaposition in this way makes it necessary at this point to choose between the rival interpretations of Bergson. The cone cannot be stripped of its psychological relevance. It denotes virtualizations that are relative to a psychological event, and not a pure ontological/mathematical space from which the psychological event is extracted. Mullarkey (2004) argues that this 'actualist' reading is supported by reference to the numerous occasions in which Bergson gives a psychological rendering of duration – the past is in some sense 'our past', it is 'for us'. Moreover, the processes of reflection and refraction, through which images communicate movement through one another, already generates an actual that divides itself up, that is never singular.

It is these multiple, intersecting self-created actualities that are virtualized, this being the 'flip-side of this act of self-creation: that is, what strings along (or ''condenses'' or ''dominates'' or ''synthesizes'') the various presents we call one individual's own breadth of experience' (Mullarkey, 2004: 478). On this account, the psychological is not the residue of a superior movement (ontologically speaking) by which the virtual begets the actual. It is instead the case that:

> the virtual is grounded by a play of actualities: the virtual for Bergson becomes a well-founded perspectival and psychological phenomenon – an emergent product formed through the interplay between a multiplicity of actual entities (including spatial and temporal continuities and discontinuities, identities and differences, quantities and qualities). Being 'well-founded' here means that the virtual, while a function of the actual and an emergent product, has real effects on the actual rather than being merely epiphenomenal. (Mullarkey, 2004: 471)

To put this in Lewin's terms, the psychological event is defined by topological relations that are continuously virtualized through quasi-physical, quasi-social and quasi-conceptual means, equivalent to the addition of further *n*-dimensions at any point. The 'play of actualities' can then be understood as an open series of transformations that are extended and prolonged as virtualizations, and which may in turn exert real effects when they are brought back in to play through recollection.

Bergson uses the term 'attention to life' to refer to the effortful attempt to produce 'cohesion' between the movements and sensations passing between the body-image and other images, and the recollections that are condensed and contracted in remembering (see Bergson, 1991: 173). Attention to life is a seizing of actualities, the establishing and expanding of a 'foothold' among the world of images, the constitution of a perspective, such that the 'mass of accumulated memories' now seems to stand on the 'sensations and movements of the present hour', as if they were a 'pyramid which should stand upon its apex'. The woman standing before her loom, in Lewin's example, is involved in an expanding attention to life when the region which defines the relationship between the broken thread and her son is transformed by quasi-conceptual operations that create a new region where her leaving the malfunctioning loom and her son remaining at home are compossible. The remaking of the region occurs through a conjugation of movements that involve actual entities (the woman, the factory, the home, her son) and virtualizations (the use of recollection and imagination to produce a world where non-possible events become possible). But we could equally imagine the failure of such compossibility in this psychological event, since it depends upon the topological invariants that structure each intersecting dimension of the manifold. Perhaps, right now, there is no conceivable way of crossing the boundary through quasi-conceptual means. And since we are now considering the virtual as the series of virtualizations of the actual defining the topological features of a life space (the totality of possible events), then it makes it plausible to consider that there may be invariance in the present and in the breadth of past experience. Rendering the pure past as a perspectival product of actual psychological experience (albeit experience outwith a bounded subject) intensifies the stakes of self-creation: not everything may be possible, the past may not afford transformation of the present.

Lines

I began with a proposition that borders on the heretical for critics of mainstream experimental psychology – that the 'mathematical imaginary' of the discipline is actually the route to its renewal. The diagrammatic juxtaposition of Bergson and Lewin's models has attempted to make that peculiar proposition thinkable. What then might be accomplished through the topological approach to psychology that emerges from this juxtaposition? It suggests that, in principle, every psychological event can be mapped by surfacing the topological relations that define this particular instance of life space. The movements that can be traced in this topological space do not necessarily imply Cartesian distinctions. As we saw earlier, the mapping of something as fleeting as a glance can be performed in numerous ways. Topological description effectively operates here as 'thick description' (as with Ryle's famous example of a winking gesture), a means of demonstrating that several different actualities can emerge from the same topological space.

Tracing the invariants that persist through the transformations of topological life space may succeed in producing 'affective universes' of psychological events (see Brown and Stenner, 2009). This would have the advantage of substituting a dynamic homeomorphism for the tendency of psychologists to categorize on the basis of taxonomic distinctions of essential qualities. For instance, rather than personality types, we would have a thick description of tendencies, boundaries, relations and thresholds of transformation (i.e. symmetry breaking).

Such a topological approach would shift the unit of analysis for psychological analysis beyond the individual. Let me briefly offer three examples of problems drawn from my own work:

In a secure forensic mental health unit, how is the management of sexuality bounded by the literal and practical boundaries of the unit? To what extent is a sense of the 'loss' of sexuality required by formal patient–staff interactions? (Brown et al., forthcoming)

How do the objects and design of a reminiscence museum in a home for the care of elderly people connect past and present for elderly clients and their families? Which objects appear to afford 'disruptive' connections? (Bendien et al., 2010)

Why are adoptive parents unable to dispose of objects (e.g. toys, clothes) that link their adoptive children to difficult or traumatic pasts? Ought they to engage in efforts to fictively reconstruct a past that affords a different future life trajectory for the child? (Brown et al., forthcoming)

What is common across all three sets of problems is a concern for the virtual aspects of psychological events (e.g. openings to a broader domain of impersonal experience through affective and recollective means) as a constituent part of inhabiting concrete, actual relational settings.

The attempt to think Bergson and Lewin together diagrammatically favoured an actualist reading of the pure past/duration. This sidesteps the tendency in Deleuze's Bergsonism to see in psychology merely a 'springboard' to ontology. That is, the view that actual experience is extracted from an undifferentiated virtuality upon which its intelligibility depends. However it still preserves some of the resources that this virtualist reading of Bergson offers. For instance, DeLanda's (2002) effort to make the pure past knowable through topological abstraction is retained when virtualization is seen, with Lewin, as the adding of planes of irreality. Furthermore, we have a vocabulary in the form of quasi-physical, quasi-social and quasi-conceptual operations in which to understand how psychological events automatically virtualize and self-divide in themselves, and in so doing accomplish a form of autopoiesis. This can be subsumed under Bergson's notion of 'attention to life', the efforts at producing coherence from movement, which we can here see as the process of distributing what is to be counted as subjects and objects. It is the glance itself as the expression of attention to life that distributes the possible actualities of mother and child vs. child incorporating part of the mother vs. single mother–child assembly. But most important of all is the recognition of topological invariance, within certain thresholds, as a fundamental principle of psychological life. We do little justice to the difficulties, struggles and resilience that make up a significant proportion of life space by referring the capacity for transformation to a conception of the virtual that is purely ontological, that is shorn of any psychological relevance. To see psychological events as epiphenomenal residue of a creative movement that is, by definition, beyond experience tends to leave us mute when it comes to accounting for mundane, difficult experiences. Why does recollection often leave us feeling that our lives are without value? How is it that we can be locked into ways of being that we are well aware are less than ideal? What is the holding power that certain images, people or things have over our thinking? Why can we not conceive of ways beyond our current experience? A topological approach to psychology might have no immediate answers to these kinds of questions, but it would at least supply a set of descriptive tools with which to make them tractable.

Note

1. The history of the Gestalt movement offers an instructive counterpoint to the kinds of psychological thinking discussed in this paper. Ash's (1998) detailed account of the movement points to the way the Gestaltists opposed the reductionist and mechanistic tendencies in the psychology of the time, and the broader place of the movement within the political tensions of 1930s Germany, resulting in the emigration to the USA of its major figures (e.g. Wolfgang Köhler, Max Wertheimer, Kurt Koffka). Lewin's own trajectory is similarly complex, with an equal attention to innovation in theory (e.g. topological psychology; vector psychology), method (e.g. film and visual methods) and practical intervention (e.g. action research) – see Marrow's (1977) detailed account.

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Digital Design and Topological Control

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Abstract

At the turn of the 21st century, topology, the mathematical study of spatial properties that remain the same under the continuous deformation of objects, has come to invest all fields of aesthetics and culture. In particular, the algebraic topology of continuity has added to the digital realm of binary information, the on and off states of 0s and 1s, an invariant property (e.g. a continuous function), which now governs the relation between different forms of data. As this invariant function of continual transformation has entered the field of automated computation, the culture of binary digits has shifted towards a new level of calculation derived from the introduction of temporal quantities into finite sets of algorithmic instructions and parameters. This new level of topological computation, it will be argued, defines new operative procedures of control, constantly adding axioms at the limit of calculation through an invariant function that establishes a smooth or uninterrupted connectivity between distinct data. The establishment of a continual function between distinct forms of data is based on homeomorphism or topological isomorphism between data objects, of which parametricism, as the new global style for architecture and design, is a perfect example.

Keywords

mereotopology, parametric architecture, postcybernetic control, topological continuum

Topological Urbanism

At the turn of the 21st century, topology has led to a new mathematical formalization of the relation between space and time (e.g. the instantaneous communication of ubiquitous computing), perception, cognition and memory (e.g. the automation of orientation, navigation, and mapping) and between model and matter (e.g. digital design

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and construction). In sum, topology has introduced relations to the programming of culture.

This article will place this topology of continuity[1] within the field of computational architecture, in particular the digital design of urban space. Software design has turned the Euclidean grid of discrete points into a morphogenetic form of relations changing over time. The computational programming of urban settings has substituted the urban plan with a topological schema of variations directed by the capacity of algorithms to evolve and to be affected by external contingencies in *real* time. For instance, urban software for modelling water in the city (from sewer systems to storm water drainage systems and water distribution systems) or the more general digital design of prototype systems that include data and models for land use (e.g. geographic information systems, GIS), transportation analysis, cost estimation, energy usage, water, noise, airflows, etc., responds to changing conditions or calculates according to a potential urban behaviour under certain circumstances. Software applications, such as navigation systems, have most commonly been described as modes of tracking movement and orientating spatial perception. The computation of topological invariants has instead opened new conditions of interactivity between software and actual behaviour, which are included in the programming of an infinite series of scenarios. Recently, Benjamin H. Bratton has argued that the iPhone and similar handheld devices are radically changing the possibilities of spatial interaction by eclipsing the physical city, now overcome by a geo-computational space in which digital objects will be able to see, hear and comment on our interactions with them (Bratton, 2009). For Bratton, urbanists and architects should stop designing new buildings and rather focus on building new software programs to improve the use of existing urban structures and systems. As the city has become the meta-data environment of digital media, digital networks have come to share data with our nervous systems, while our bodies have become one with 'the extensional networks of the living city, both controlling its machinery at a distance... and [being controlled] psychologically by that machinery in the course of our movements' (2009: 93).

The continuous smooth feedbacks between software programming and urban behaviour is here condensed within handheld devices to suggest that data are continuously animated and transformed into maps, which control and connect with the immediate and remote environment. This direct relation with ambient information, provided by software interfaces such as the iPhone, according to Bratton, points to a spatial network made not of icons but of real conditions of connection. Bratton explains that digital urbanism is not about designing a new network of connections but requires a way to capitalize upon 'the computational mechanisms that formulate the nodal and edge conditions and the interface'. This involves a 'systematising of the possibility of particular event[s]' and a 'geo-computational program... that calculates conditions of appearance' rather than scripting beforehand what can emerge at the end (2009: 94).

What topology has brought to urban design is the capacity of long-term planning to become open to revisions, updates, real-time inputs and contingencies. As the computational power of managing and calculating data has become extended to the design of urban scenarios, real-time variations have been included within software programs so as to anticipate the emergence of potential changes. The computation of urban data will be taken here as an example of an algorithmic mode of planning defined by an extended apparatus of prediction able not only to establish the condition of the present through the retrieval of past data but also, and significantly, to change these conditions according to data variations immediately retrieved from the environment. From this standpoint, topology has also meant that the cybernetic logic of control has disclosed its mechanisms of value and measure to non-quantifiable conditions so as to capture qualitative changes *before* their emergence. But these mechanisms of anticipation or of pro-programming scenarios are not simply defined by the mathematics of division and addition, and similarly do not just rely on off and on states of 0s and 1s.

What is new here is that these mechanisms now seem to rely on the topological calculation of the continuous function, an invariant property that fills the gap between binary digits. This article suggests that this continuous function now characterizes the computational design of the urban space in the form of parametric aesthetics. In particular, parametric aesthetics serves here to suggest that the topological approach to urban design is based on the introduction of qualitative variations and temporal evolution in the predictive calculation of data, which account for potential urban scenarios. This is why topology implies a transformation in strategies of control, whereby the software interaction with the real data of the environment has become constitutive of a postcybernetic logistics. Far from simply reducing biophysical variables and contingencies to sets of binary codes, which are unable to process the grey areas between sequences, the topological approach to digital design coincides with the integration of differential relations, or intensive data within the generation of spatio-temporal connections. The introduction of the invariable function in computational planning also reveals that cybernetic control now relies on the calculation of differentials and uncertainties. In the computation of urban design, this is evidenced by the use of growing algorithms or open-ended instructions that respond and adapt to the external environment, thus including contingencies into programming.

Parametric aesthetics is thus a mode of computational control relying on the capacities of algorithms to create the perception of space as a relational field of emergence. From this standpoint, parametric aesthetics also suggests that computational control has developed its own aesthetic form, which has been associated with folds, morphologies, smooth surfaces and real-time evolving structures. In other words, control as the topological computation of space has acquired a sensuous skin, turning all points, corners and lines into planes of relations, short-circuits of immediate connection or speedy paths of variations. Here there is no core, no end point and no individual response: only the continuous fluctuation of a total form enveloping all parts.

The article also discusses how topology implies an ontological concern for the mathematical formalization of the relation between finite and infinite sets. In particular, the article will briefly address the mathematical formalization of the continuum problem and the systematization of infinitesimals leading to the development of topology. The Leibnizian quest for infinitesimals, together with Deleuze's concept of differential relations, will be specifically considered as crucial to the ontological constitution of topology, resulting in a computational design based on contingent variabilities or temporalities. Parametric aesthetics, however, inherits the onto-mathematical diatribe between extension as a field of continual variations (determined by an underlying infinitesimal series) and extension as a sequence of spatio-temporal actualities able to connect and disconnect. This diatribe will be here discussed by emphasizing the contrast between topology and its aesthetics of smooth control, and mereotopology, offering us an aesthetic of discontinuous relations between control and events.

Parametric aesthetics indeed reveals that the topological mode of calculating relations, where all parts become incorporated into one evolving whole, is not exhaustive of all relations, and of the algorithmic sequential relations in particular. On the contrary, parametric aesthetics precisely involves the quantification of data as parameters, which cannot be overlooked and simply become dissolved into continual qualities. Instead, parametric aesthetics rather points at the persistence of parts and of the relations of parts to whole without parts being always already subsumed into a whole. These parts, and in this case, parametric and algorithmic quantities, are discrete entities that may enter into a relation thanks to their capacity to select not only data coming from the environment but also to predict data that is not possible to compute. This other face of parametric aesthetics will be explained through Alfred N. Whitehead's notion of mereotopology, insofar as the relation between parts and wholes is central to a study of the relation between infinite and finite entities. Whitehead's mereotopological schema rejected the Leibnizian infinitesimal series and questioned Henri Bergson's predilections for temporal continuity by arguing that what connects points are actual entities on an extensive continuum. However, the Whiteheadian case of mereotopology and its schema of discontinuous relations are not simply alternative instances set against the topological aesthetics of power, using vectorial tools as instruments of control. The mereotopological schema serves here to suggest that there is no equivalence between the topological architecture of control and spatio-temporal events. With mereotopology, in other words, control and events are not in a reciprocal presupposition: topological continuities are expressions of large assemblages able to incorporate discontinuous events into a stream of infinitesimal variations, but events are not definable by infinitesimal or temporal continuities.

From this standpoint, parametricism is an example of the operative system of control defined by the computation of infrastructural networks: the smooth architecture of continual variations changing the values of parameters by responding to real data from the environment. Here parametricism deploys how control operates as a prehensive apparatus of spatio-temporal futurities. In other words, control, as Brian Massumi (2007) has brilliantly explained, is a mechanism of anticipation, whereby the *apprehension* for unknown variables indirectly works to determine the reality of the present. If topological control works, it is because what can be anticipated corresponds to what actually has to happen, foreclosing the conditions of uncertainties into pre-set probabilities in the present.

The mereotopological schema, however, offers another understanding of parametric relations, showing how parameters can themselves be conceived as actual entities entering a nexus of spatio-temporal events, whose relations are discontinuous. The very strategy of anticipation of spatio-temporalities in digital design inversely contributes to the diffusion of unintended algorithmic actualities into computational culture. These actualities are here understood as computational events. Events, according to Whitehead, involve the capacity of any actual entity (organic or inorganic) to select and become affected by pure data-objects (or eternal objects in Whitehead's terminology), which define how the indeterminate becomes determinate in an actual entity.

Alfred N. Whitehead's mereotopological schema implies that events come first: the summation of actual entities in a nexus that has selected pure data and has brought them together for the first, unique and unrepeatable space-time. From this standpoint, the article will contrast the topological view of parametric aesthetics, which assumes that variations are to be derived from the relational or infinitesimal space of contingencies lying outside the system (which are then pre-programmed in the urban model for instance), with the mereotopological insistence that parts, quantities, discontinuities exist not only at the level of actualities, but also at the general level of formality. This means that Whitehead's mereotopological schema forces us to revisit the computational significance of formal hierarchies in relation to actual contingencies. No longer are contingencies to be conceived as being external (a mere factor of extrinsic force) to the formal schema but, as this article attempts to argue, contingencies or chances are instead internal to the logical condition of any formal processing. This means that patternless structures are internal to any logic of computation and, as a result, they define any mathematical, physical or biological organization of matter as incomplete.

The article suggests that contingencies are to be found first at the level of computational processing, because it is at this level that algorithms encounter the indeterminate conditions (patternless data) for which they can become eventful. This idea of computational contingency is based on recent findings in information theory that argue for a mathematical logic (and not the statistical notion) of randomness (i.e. lack of structure), meaning that 'something is random if it can't be compressed into a shorter description. In other words, there is no concise theory that produces it' (Chaitin, 2001: 18). Chaitin's algorithmic information theory sets incompleteness and undecidability within his axiomatic system to show that it is impossible to calculate randomness, or what he defines as the uncomputable: maximally unknowable and irreducible data. Since it is impossible to calculate the size of the smallest program, as Turing and Gödel demonstrated, Chaitin concludes that computational logic implies a program-size complexity, whereby it is the program (the software, the theory) and not just its application that shows the existence of patternless infinities at the limit of actual sets of algorithms.

From this standpoint, this article does not use the example of parametric aesthetics to claim that novelty in computation is to be derived from external factors, or, for instance, by the way a discontinuous relation between software and hardware becomes an opportunity for explaining novelty in digital urbanism. This is not what is argued here. Instead this article's argument is driven by the possibility offered by the mereotopological schema of finding the conditions for novelty in digitality in the discontinuous architecture of eternal objects – uncomputable quantities – that are or are not selected by actual entities. This forced juxtaposition of the formal level of uncomputable data with the formal schema of eternal objects is in this article another way to point out the incompleteness of computation as the very condition for novelty. The article suggests that this condition is intrinsic to computation and irreducible to any interactive relation between software and hardware. In this way, mereotopological discontinuity is not an alternative to the topological form of power, which is, as argued in the first part of this article, ontologically grounded in relational continuity. If anything, the mereotopological schema of discontinuous data can help us to reveal that the predictive machine of control, which now involves, as Brian Massumi (2007) has brilliantly explained, a pre-emptive mode of power foreclosing futurity into actualities, is not the same as the uncomputable machine of the event. The latter instead, unlike control, requires that indeterminate data become determined in the cumulative processing of non-equivalent actualities.

To put it in another way, the introduction of topological invariants in computation points to an apparatus of power operating by pre-empting change and re-programming the event before this can happen, thus flattening control and novelty (or event) onto a topological matrix of continual co-evolution. On the contrary, borrowing from Whitehead's mereotopological schema of relation, it is possible to suggest that parts cannot become a whole but rather a whole can be a part that connects to another. This is also to say that if the parametric aesthetics of topological control anticipates events in its own morphogenetic body, mereotopology reveals that events are cut-bringing novelties that characterize the becoming of the extensive continuum. Events therefore do not grant continuity between entities, but, on the contrary, are the occasions for the discontinuous becoming of continuities. This explanation, however, only helps us to describe the actual level of novelty. Actual novelty instead does not come from nowhere and does not exclusively concern the physical realm. Novelty must also be explained at the level of abstract formalism. The mereotopological schema of eternal objects and actual entities proposed by Whitehead contributes to metaphysically support what in information theory is increasingly becoming unavoidable: the presence of the uncomputable in logic. The formal reality of uncomputable random data is here taken as the condition that makes any mode of computation (analogue or digital) possible.

This condition has to be found within the computational processing of algorithms, at the formal and axiomatic level. It is here suggested that uncomputable data can reveal a strange contingency within form, chance within programming. From this standpoint, uncomputable algorithms interrupt the topological co-evolution of urban software and urban behaviour. Far from establishing continuous feedback or reversible function whereby software takes command of urban behaviour or the latter feeds back on the program, the sequential running of algorithms will instead expose an uncomputable quantity of rules for an infinite quality of behaviours, which are un-provable and un-applicable spatio-temporalities. Here control becomes as random (or patternless) as the uncomputable data it tries to compress into axioms. The uncomputable triggers contingent rules within computational design. It is this new dominance of contingency within programming that demarcates the unquantifiable reality of events and the impossibility for control to incorporate and neutralize them. In particular, digital urbanism points at computational events at once discovered and constructed by the software programming of unlived spatio-temporalities. From this standpoint, this article takes parametric aesthetics as a case in which the digital design of time and space is not only controlling (or pre-empting) the emergence of events, but is instead unleashing random events or unlived worlds in urban design.

Before the case of parametric aesthetics, the article will address the mathematico-geometric and ontological notion of relational space in digital design. This discussion will contribute to the analysis of the 5Subzero's design of the responsive environment, *Topotransegrity*. The last section draws on Alfred N. Whitehead's notion of mereotopology to explain how novelty in parametric aesthetics is to be found in the uncomputable order of relations or the infinite quantities invading digital programming.

The Invariant Function

The invariant function of continual transformation has entered the field of automated computation. It has shifted the culture of binary digits towards the calculation of temporal quantities and into finite sets of algorithmic instructions and parameters. This topological computation involves operative procedures of control, constantly adding axioms at the limit of axioms through an invariant function that establishes a smooth (uninterrupted) connectivity between distinct data. The establishment of a continual function between distinct forms of data is based on homeomorphism or topological isomorphism between places or objects, of which parametricism,[2] as the new global style for architecture and design, is a perfect example.

Parametricism is here taken as an example of algebraic topology as it understands space as a field of relations and not discontinuous points (Boyer, 1989).[3] Metric distances between points are substituted by neighbourhood proximity, which, computationally speaking, include vague or incomplete quantities (at the limit of 0s and 1s) in the calculation of probabilities. For example, the introduction of indeterminacies into the source code of parametric programming has transformed the binary logic of yes and no into the fuzzy states of the logical conditions defined by *maybe* and *perhaps*. These are not merely qualitative renderings of digital binarism, for which a certain sequence may correspond to a certain shade of colour. Fuzzy states are instead to be understood as involving new processes of quantifications. The spatial architecture of points and lines, of discrete and finite states, has been superseded by topological methods of measuring infinitesimal quantities and establishing neighbourhood proximity through the function of the constant invariant. Paradoxically, however, it will be argued, the topological culture of continual variations forecloses the potential intrusion of discontinuity, unforeseen change, in the efficient continuity of cause and effects.

From this standpoint, topological thinking as a new method of quantification of uncertain states also corresponds to an operative power of control based on topological computations (i.e. the adding of invariant functions between axioms and between formal models and material implementations). Here control works not to prevent the future but to add a link to it by using the invariant function as a protocol for uncertainties. In other words, the introduction of invariant functions in computation points out that the gap between 0s and 1s is instead a relational space composed of infinitesimal points of continuity.

In the early 1990s experimentations with computational programming had already embraced the topological turn in digital design. Architect Greg Lynn (1993: 9), for instance, famously observed that each pure element of quantity, for instance a binary algorithm, was determined in a qualitative form by neighbouring forces, the vague space around the point, which unravelled the topological complexity of the generative form. These qualitative forces were, for instance, defined by the physical stress caused by environmental forces on the genetic elements of a form. Physical forces were here equivalent to the infinitesimal points of any point, turning the degrees of separation between one form and another into gradients on a curve. For Lynn, these relational points had to be included in the generative computation of form.

The inputting of physical gradients into computation, however, did not correspond to the representation of intensive quantities (the qualities of the physical stress points between terms) reduced to 0s and 1s binary states. If Leibniz admitted that the space between undivided monads was not a void, but a full texture of micropercepts and microaffects, Lynn's topological architecture suggested that these points were included in the process of computation itself: the generative movement from one set of algorithms to another exceeded the binary function. In other words, computational abstraction surpassed the representation or simulation of space. As Kipnis argued, the architecture of Deformation showed that computational techniques stimulated investigations towards a non-representational space. Computation thus involved:

> the study of camouflage methods experimenting with computer 'morphing' programs that smoothly transform one figure into another, or employing topological meshing techniques such as splines, NURBS, etc., that join surfaces delimited by the parameters of disjoint two-dimensional figures into a smoothed solid. (2009: 112)

Lynn's neo-Baroque aesthetics of a folding architecture directly responds to the continuum problem posed by Leibniz's infinitesimal or differential calculus (Boyer, 1989: 216).[4] Leibniz used the calculus as a way to solve the question of infinity: is a line between two points another point or an infinitesimal aggregation of points (increasingly small quantities that cannot be mathematically counted)?[5]

Leibniz concluded that if a line was an aggregation of points, infinitely divisible parts, then a continuum could neither be a unity nor an aggregation of unities. In other words, continua were *not real entities* at all.

Continua were 'wholes preceding their parts' and had a purely ideal character (i.e. non-physical). For Leibniz space and time, as continua, were ideal, and anything real, such as matter, was discrete, compounded of simple unit substances or *monads*.[6] But to explain the transition from finite, discrete reality to infinitesimal, transcendental magnitudes, Leibniz resorted to the philosophical law of continuity, emphasizing the role of the ratio between differentials (differential calculus), the infinitesimal differential quantity or the curve of transition between two orders of magnitude or quantities (infinite and finite series) (Boyer, 1989: 399–407).[7]

Leibniz's 'labyrinth of the continuum' described the paradoxical condition of transcendental infinities and actual finitude: how could the infinitely divisible yet be constituted by discrete unities (Leibniz, 2001).[8]

At the core of Leibniz's topological conception of space is the differential calculus as the calculation of derivatives or differential relations, describing the infinitely small quantities between two quantities (the quantity of the ordinate x and the quantity of the abscissa y).[9] Lynn's neo-Baroque aesthetics builds on the computation of infinitesimal relations to animate digital design away from the coldness of binary codes. However, as Lynn also suggests, this topological turn is not simply part of a technical and/or aesthetic movement, but more precisely addresses the metaphysical primacy of relations and processes over points and results. Folding in architecture indeed deploys the intricacy of technicality and aesthetics with metaphysics as a way to describe the cultural tendency of an epoch. The bending and twisting of lines into complex structures that loop and auto-reflect on their irregular trajectories reveals nothing other than a sense of spatiality in computational culture.

Just as Leibniz insisted that there is a transcendental ideal order of infinitely small quantities, Deleuze conceived of infinitesimals as the differential relation that supersedes actual terms. As the terms cancel each other out, the relation remains. This is a third term, which Deleuze (2004: 217–20) identifies with the tangent of a curve, a straight line that touches a curve at only one point.[10] But the infinitesimal gap between two points was no longer governed by a transcendental infinity (determined by the principle of sufficient reason). According to Deleuze, as non-standard analysis reintroduced the infinitesimal as a non-exact numerical quantity, it also provided a new axiomatic formula of differential relations. In short, the formalization of differential relations coincided with the systematization of the intuition of continuity by means of non-standard axioms (Fletcher, 1989).

From this standpoint, the differential relation was formalized as the function of an invariant, a constant x through which the continuum between discrete entities became a mathematical expression of relational continuity itself. According to Deleuze, however, the algebraic determination of indeterminate differentials (or infinitesimal dy or dx) was not simply an axiomatic solution. On the contrary, it also meant that the differential relation could not correspond to a discrete number or finite quantity (an axiom). The finite result (the invariant x) instead could only be determined by the immanence of the relation with the infinitely small: the tendency of the differential relation to vanish but of the relation to tend towards the limit z. According to Deleuze, the integration of the differential relation resulted not in a determinate point, or discrete axiom, but involved the sequential arrangement of points generating not a straight line but a curve. This curve was a function in the neighbourhood of the given tangential point: the limit of the function. The introduction of differential relations into digital design thus exposes the integration of infinite qualities as a computational limit expressed by the curve.

Parametric Aesthetics

The computation of infinitesimal relations has come to describe not only, as Lynn would have it, the neo-Baroque aesthetics of a folding architecture, but also the postcybernetic control of the continuum itself. Topology as the ultimate mathematics of smooth space now corresponds to the aesthetic of postcybernetic control based on curvature or continual variation: differential relations have become the curving space of control itself.

Let us take one example that particularly addresses the computation of topological relations as a generalized instance of postcybernetic control. Parametric design,[11] for example, can be said to underpin many forms of topological operationality as it specifically works to programme mathematical relations between data sets. As the term ‘parametric’ implies, a parameter is a variable to which other variables are related. Hence sets of variables and their relationships determine the changes of a spatial form. While the initial conditions of the parametric design are still programmed through a binary logic of 0s and 1s, these conditions are open to change through the evolutionary processing of parameters, when new variables are at once generated from and added to the set of initial values. Hence, the continual relation of programmed variables is more important to the parametric design of urban space, for instance, than the digitalization of physical variables into sets of 0s and 1s. This means that while, on the one hand, parametric relations order variables into sequential binary sets, they are also determined by the qualitative level of topological functions, where differential relations explain how the transformation of one value is equivalent to the continual variations of the whole space.

Nevertheless, the determination of a continual correspondence between data variables and the form of space is not specific to parametric design. As Sanford Kwinter (2008: 37) points out, design has always been a highly advanced form of rationality. Design is a rational technique, which breeds and mutates infrastructures: from knowledge to cultural and urban infrastructures. Thus parametric design is just another instance of design as a logistics of operations, where algorithmic information and data structures are now 'oriented to performative environments, to protocols, and, *in extremis*, to psychological operations' (2008: 39). According to Kwinter, as architecture has turned into 'experiments in design logic, research and potential' (2008: 51), so has the computational paradigm extended concepts of materiality, society, economics and nature into the incorporeal field of intensive manifolds, turning spaces into 'shapes of time' (2008: 53). As the qualitative level of relations (or topological continuity) has become central to computational design, so time, intended as lapses of evolution, growths, adaptation of initial values, has come to determine the final shape of spaces.[12]

This has also meant that with parametric design, modifications of values can be performed almost in real time, compared to the time-consuming re-drawing required by the traditional AutoCAD for instance. Before the advent of parametric design, buildings were modelled using computer drafting programs, such as industry standards AutoCAD or MicroStation, and then analysed by engineers using their own software, and ultimately sent to environmental engineers using yet another software program. Parametric design affords the engineering of the overall levels of a spatial form to be manipulated at the same time. Through the altering of specific parameters that are able to automatically adjust by building on data such as the total gross area, total building height, total number of floors, the various levels of engineering are integrated into one topological software program. Parametric design offers the modulation of variable relationships between entities, where the alteration of properties results in different outcomes of the overall form.[13] Parameters can be established from a vast list of possibilities; they could be taken from data on wind speed or rainfall for example. These variabilities can also be directly related to costs on a spreadsheet ultimately ensuring a smooth direct relationality between architectural and economic changes. This direct relation between financial costs and spatial form partakes of a topological regime of immediate convergence – or algebraic invariant – between variables of forms and economic value.[14] To establish continuity between discontinuous groups of values, one part of the design has to respond to transformations in another, or the entire design can respond to changing conditions, such as light, airflow, but also weight distribution and gravitational pressure. In general, any output or variable from the outside is pre-included in the list of possibilities of the algorithmic architecture, defining space as a topological engine of potentialities. Results can be instantaneously fed back into the system through a recursive loop of algorithms, tested and played again to evolve different results.

As Michel Hensel and Achim Menges (2009: 212) argue, parametric architecture needs to be conceived as a system with a set of finite internal relationships and external forces that inform it and to which it responds. These relationships are constructed by the computational capacities to envisage the material characteristics and behaviour of locally specific and yet dynamic environmental conditions, which for instance produce microclimatic levels of differentiation in a geographic field. In general, the shift from computational programming as ‘design-defining’ (e.g. design based on pre-set algorithms) to design as ‘program-evolving’ (e.g. design derived from the interaction between parameters that become generative of other levels by responding to real-time inputs) explains how design now relies on continual relations rather than digital fixing.[15] It is precisely this emphasis on the evolving relation between parameters of interaction that now characterizes computational architecture in terms of real-time adaptation, emergence and change. From this standpoint, program-evolving urbanism includes the design of smart infrastructures that are able to monitor, respond to and/or anticipate the transport logistics of a city (including roads, rail, water and air) for instance. As parameters have become evolutionary variables that enter and exit relations with other parameters, urban design is set to include time-related data in the programming.

The integration of wireless sensor networks into large-scale engineering systems, such as, for instance, networks of pipelines, tunnels and bridges, relies on the parametric programming of engineering systems that directly respond to sensor networks.[16] The generative programming of parameters, whereby each parameter includes temporal variations, now animates the design of urban infrastructures integrating differential relations between systems (rail, road, air, water systems) into one smooth machine of continual variation. Here the monitoring of real-time data, central to software-enhanced infrastructure, is only another facet of a program-evolving urbanism where smooth, speedy and cost-efficient systems are integrated into an evolving meta-system including all infrastructures.

The scope of program-evolving urbanism is not dissimilar to computer devices offering us new possibilities of navigation, which then become part of our saved favourite paths, presenting us with set solutions, which we have previously selected or added to the navigation program. In other words, in the same way as your smart phone works as a monitor device for tracking your location, which then becomes data used to construct the profile of your movement, so the monitoring procedure of smart infrastructures collects data which then become part of the programming of new infrastructural systems. As data become recorded so they evolve into predictive scenarios aiming not simply at pre-setting your movement but generating its future conditions through the evolving interaction of parameters with real-time data. Ultimately, the goal of parametric design is *deep* relationality, the *real-time* integration of the evolving variables of a built environment in software systems able to create scenarios by responding to or pre-adapting data. As Neil Leach (2009) has observed, parametric architecture needs to be conceived as marking a third phase in digital design, where the use of algorithms to experiment with forms and the tectonic application of digital software are being superseded by the software evolution of urban space.[17] This means that software is no longer a tool for design, but it has become one *with* design and its form of rationality, now seemingly operating through the generative parameters of continual variation.

In sum, parametric design is an instance of the general tendency towards topological control, where changes, or the evolution of parameters, are already pre-programmed through the invariant function between parameters. The aesthetic appeal of smooth control is precisely the continuous curvature of the straight line, the rounded shapes of a folding urbanscape of temporal variations and real-time responsiveness.

From this standpoint, change is intrinsic to the operative logic of control to the extent that it is pro-actively programmed or actively programmed within the codes that guarantee continuity of form and function. The invariant connection between the distinct levels of networks is instantiated in parametric urban models, which are based not on geometric planning but on the mathematical variables of evolutive urban software. As *R&Sie(n)* architect François Roche (2009: 40) recently suggested, the new parametric programming of digital cities resembles less a binary grid of finite sets (0s and 1s) than a biostructure that develops its own adaptive behaviour, based on growth scripts and open algorithms. This is a new bio-computational design whose programming capacities are stretched to calculate potential conditions of relationality and intensive change, rather than writing scripts of what can eventually emerge. These design programs are meta-protocols constituting an urban ecology of software continuities between many discrete infrastructural systems integrated into a single envelope – an intensive manifold whose interior and exterior sites can be activated in any number of ways. From this standpoint, parametric design may become an example of how urban infrastructures are co-evolving with urban software such that the invisible architecture of topological computing is no longer set to represent but to programme the development of physical space.

Temporal Qualities

The introduction of temporal qualities into parametric design characterizes the aesthetics of curvature. Here relations between parametric quantities shape parts into an architecture of the whole.[18] The topological approach has substituted the function of digital sequencing with the composite function of relations, so that changes at one level of parametric value effectuate changes at another level. From this standpoint, parametric design has given way to a plethora of morphogenetic

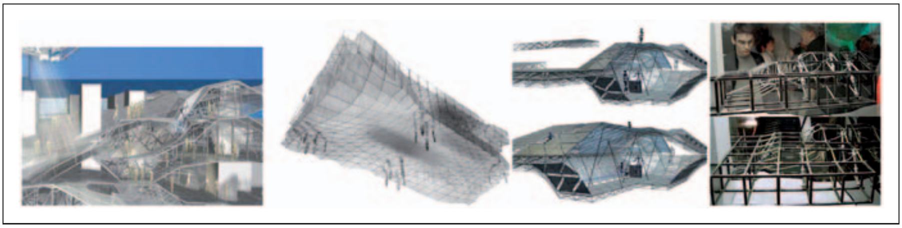

Figure 1. *Topotransegrity*, 2006.
Source: 5Subzero (Delphine Ammann, Karim Muallam, Robert R. Neumayr, Georgina Robledo).

architectures, where the whole stems from the relations between mechanical, physical and algorithmic parts.

For instance, *Topotransegrity*, an award-winning responsive and kinetic architecture designed by 5Subzero,[19] shows how the spatial organization of public space can derive from a topological design of continual adaptation between software programs, mechanical parts and real-time physical movement. *Topotransegrity* brings together surfaces through pneumatic space frame structures that can be manipulated either through an automated control mechanism, through real-time feedback or by software programs. In particular, the programming of the structure relies on external and internal parameters defined by the environment influencing different parts of the structure. The continual relation between the parameters and their changing mode of operation affords a series of emerging user-dependent spatial configurations.

As a whole, *Topotransegrity* is a kinetic structure, sustained by three sets of pneumatic pistons designed by Festo. The pistons are equipped with responsive software, which evaluates the surroundings and reconfigures the structure according to changing conditions. *Topotransegrity* extends across existing buildings at the Barbican complex in London to form a topological surface of connection. This surface constitutes a generic responsive structural system ready to adapt to distinct spatial requirements. The structure is capable of various transformations, which range from small-scale surface articulations to large surface deformations, working as temporary enclosures. The introduction of contingent elements from the environment into the parametric programming of its different parts is here used by the 5Subzero group as a trigger that allows the responsive structure to multiply, intensify and vary the potential uses of public spaces. According to the 5Subzero group, *Topotransegrity* is therefore not simply a pre-programmed structure, but has to rely on external real-time feedback to generate new internal configurations. For instance, sensors, input devices and wireless networks are integrated into existing building materials transforming the architectural space of the Barbican into a complex continuity. This is determined by invariant functions deploying the topological relation between the program mode (parameters automating the basic functions of the structure by adding new levels of connection), the crowd mode (parameters determined by real-time responses of the structure towards movements and behavioural patterns of visitors) and the memory mode (parameters that record on a long-term basis the paths and motion patterns chosen by users). These three parametric modes of operation run simultaneously, interacting with visitors in a permanent feedback loop: local reactions to spatial adaptations are fed back into the system of parameters, which in turn specifically re-designs the built environment according to changing patterns of use.

It could be argued that the crowd or any other external data constitute those contingencies that are somehow controlled or directed by the program, which then spatializes the qualities of temporal variations. It may be true then to say that *Topotransegrity* is unable to create the conditions for a radically novel reconfiguration of space to the extent that contingencies serve the software system merely to find optimal solutions to emerging problems. On the other hand, however, *Topotransegrity* is precisely an instance of a topological aesthetics of control turning discrete points and finite lines into a mesh of infinitesimal points of variations governed by invariant functions, which integrate distinct actual parameters into a continual surface of configurations. This is less about the software hierarchical mastery over hardware or modes of behaviour than a form of control defined by the differential integration of the temporal qualities of software programming, kinetic mechanics and real-time interaction. *Topotransegrity* therefore points to topological aesthetics as a dominant form of spatial experimentation in postcybernetic culture. But can this aesthetics be traversed by cut-bringing events irreducible to the pre-emptive program of parametric control?

Eternal Quantities

Alfred North Whitehead's notion of mereotopology (1978: 294–301)[20] proposed that space is composed of actual entities that connect.[21] These are atomic occasions or discrete events explaining how the becoming of continuity and not continual change occurs. Zeno's paradox of discrete units and infinitesimal divisibility is here not addressed through the Bergsonian metaphysics of a continual duration, or *élan vital*, where all quantity amounts to a difference in kind.[22] A mereotopology of atomic spatio-temporality instead explains that potentials break the continuity of connection. According to Whitehead, Leibniz's infinitesimal divisions, which Poincaré defined as topological invariants, could not explain the reality of events on the plane of continuity (or the continual chain of cause and effect determining the sequential relations between actualities), because the distance between actualities could not be filled by the infinitesimal continuity of percepts and affects (Whitehead, 1978: 332–3). On the contrary, the distance between actual entities had to be considered as such: a space of connection, overlapping, inclusion, juxtaposition, disjunction and intersection defined by the points and lines of finite actualities. In other words, there are always actualities amid actualities.

According to Whitehead (1978: 328), the relations between actual occasions need to be compared not to the infinite lines of the Euclidean parallel axiom, but to finite segments. Each actual occasion is finite. It does not change and does not move. Actual entities, like the parameters in *Topotransegrity*, are real potentialities, determined by what Whitehead (1978:169) calls causal efficacy, the sequential order of data defined by the physical prehensions of past data from one entity to the next. From this standpoint, the continuity between parameters is explained by the connection between entities, which are not geometrical points but 'spatial regions' with semi-boundaries (e.g. volumes, lumps, spheres) (1978: 63, 121–5, 206). Hence, continuity is not explained by infinitesimals or the convergence of two parallel infinite lines touching infinity, but by the relation between these spatio-temporal regions of objectified real potentialities (actual entities) that are slices of time, atomic durations (1978: 77).[23] Instead of infinitesimally divisible points of perceptions and affections, Whitehead believes that there is an infinite number of actual entities between any two actualities, even between those that are nominally close together. This is why Whitehead rejects Zeno's paradox of infinitesimal small points and argues that continuity is not a ground to start from, but something that has to be achieved as a result of actual entities' extensive connections (1978: 96–7, 294).

From this standpoint, the mereotopological relation between distinct sets of parameters deployed in *Topotransegrity* corresponds to the real potential of each actual entity to become the datum of another parameter. In other words, since the topological relation between parameters implies that a change in a parameter has an effect on other parameters and a generalized impact on the whole architectural structure, each parameter can be considered to have a real potential to become data for change for another. On one level, the extensive subdivisions (the parametric connection between software, crowd and memory modes) and the topological relations of the points and lines between the physical space, the digital software and the kinetic pistons compose the *real potential* of actual entities (finite quantities or parameters). This actual level of parametric quantification and relationality describes the real potential of extended continuity, where the relation between finite entities is intersected by other finite entities and not by the phenomenal qualities of perception and affection. The parametric design of *Topotransegrity*'s project therefore deploys a nexus of actual entities or events, which, according to Whitehead, stems from a series of sequences constituting a 'historic fact' (the objectified real potentials of software, crowd and memory parameters at each spatio-temporal connection) relating occasions to occasions (1978: 66). Data are what has been in the past, but also what might have been, and what might be of the spatial configurations: a software program, the real-time movements of a crowd, the reshaping of the pistons. All these data are always actuals, and their specific potentiality is always a real possibility that affects the next series. Following the logic of cause and effect, the relation between parametric data involves a movement from past to present and future spatio-temporalities.

The parametric software of the adaptive structure, determined by constant feedback loops with the movement of the crowd and the kinetic configuration of the pneumatic pistons, operates in the same repetitive fashion of physical, organic and inorganic, matter. Here the invariant function of the topological continuum corresponds to the physical, extensive connection between actual entities, the overlapping and intersection between parts (as defined by mereology). This is only the topological level of parametric design. But a mereotopological reading of *Topotransegrity* will have to include another level of relationality, an abstract set of infinite relations, which cannot be defined exclusively in terms of physical qualities. *Topotransegrity* in fact operates on two levels of potentialities, which may correspond with Whitehead's distinction between the real potential of each actual entity to become the datum of another and the pure potentials (or eternal objects) which ingress actual occasions in many points (1978: 23). But the level of pure potentials in *Topotransegrity* is not explicitly unfolded although it constitutes the modes of partition, separation or quantification of qualities of movement and response. From the standpoint of mereotopology these modes imply at least two orders of magnitude, the order of actual quantities and the order of infinite quantities.

A mereotopological view of *Topotransegrity* indeed can be taken as an example of parametric control, precisely involving the constraints of these two orders of relational quantities, not only corresponding to the continual programming of contingencies but to the discontinuity between control and events. For mereotopology is a symmetry-breaking schema of real and pure potentials that explain how the continuous connection between actualities is infected with abstract objects, whose indeterminate reality adds new character to actual relations. This is not an eternal geometry operating on contingent physics. Despite the fact that the order of eternal objects, as pure relata, is not open to be modified by eventful actualities, the objects themselves become nonetheless part and parcel of events. In particular, it is the way that these otherwise non-communicating objects are selected that allows them to acquire unity in actual entities. This new unity reveals how eternal objects undergo eventful changes and are indeed intrinsic to actualities. This also means that events are at once disjunctions of actual data and conjunction of eternal objects.

The topological model implies a continual ground by which events are such only when it becomes possible for actualities to jump out of the spatio-temporal grid into the infinity of virtual time. The mereotopological schema instead suggests that events are the cumulative order of spatio-temporal actualities hosting an unrepeatable togetherness of eternal objects. Therefore it is not the formal hierarchy of eternal objects that determines actual events. Events instead are the result of the actual accumulation of physical data, whose causal chain is interrupted by the ingression of eternal objects. These are not simply selected by actualities to manage orders of behaviour or action, but are prehended for the pure chance or potentialities that these objects offer. Actualities therefore do not simply operate a probabilistic calculation about which eternal object to select. On the contrary, selection is a *feeling* for non-actual ideas, involving the ingression of chance for what has happened, what may happen and what could have happened. This is how contingency becomes intrinsic to the speculative power of eternal objects: a process by which existing relations can change character and become anew. This means that the indeterminacy of eternal objects is felt like the reality of chance, pure potentialities, determining the atomic (and eventful) character of actual relations.[24]

There is no undifferentiated pool of eternal objects constituting a continuum of temporal qualities, divided or spatialized by actual entities. On the contrary, each eternal object uniquely contributes or adds indetermination to each set of actual entities in so far as each eternal object 'stands a determinateness as to the relationship of *A* [an eternal object] to other eternal objects' (1978: 160). Eternal objects explain internal relations as 'a systematic mutual relatedness' where each eternal object has a status (1978: 161). Eternal objects are not temporal forms of relations but are permanent and infinite sets of eternal objects, isolated from their individual essences. They are relata in the uniform schema of relational essences, where each eternal objects stands internally within all of its possible relationships (1978: 164). Whitehead explains that there is a uniform scheme of relationships between the infinite sets of eternal objects, which acquire a togetherness of their individual essence once they are included in an actual entity. This means that for any actual occasion 'a' there is a group of eternal objects ingredient in that actual occasion. Since any given group of eternal objects may form the base of an abstractive hierarchy of relation, there is an abstractive hierarchy associated with any actual occasion 'a'. This associated hierarchy is 'the shape, or pattern, or form, of the occasion, insofar as the occasion is constituted of what enters into full realization' (1978: 170).

Each actual parameter is then infected by a multiplicity of eternal objects and becomes related to other parameters by means of their potentiality to be selected by an infinite number of actualities. And yet, eternal objects do not add intensive temporalities to parameters. On the contrary, actual parameters are the point of selective limitation or constraint of these infinite objects, and as such they are general determinations applied to the spatio-temporal continuum. 'Thus primarily, the spatio-temporal continuum is a locus of relational possibility, selected from the more general realm of systematic [and abstract] relationship' (1978: 161). Once eternal objects are selected they add a new level of determination to the spatio-temporal sequence of parameters, a novel character to the actual relations between quantities of systematic length, weighted with the individual peculiarities of the relevant environment. For Whitehead, the mereotopological schema explains how novelty involves a discontinuity of continual relations. Any parameter, insofar as it is an actual entity, corresponds to the prehensions of physical data of past, present and future actualities. But a parametric value is also a conceptual prehension of the abstract relata or eternal objects, which are included in the actual parameter as gradients of determination.

If Bergson's *élan vital* is a virtual continuum each time divided by perceptual selections or material actualities, Whitehead seems to claim that this correlation between one time (the topological invariant continuum of indiscernible, undifferentiated duration) to many spaces precludes any event ever occurring on the extensive continuum of actualities. Like Henri Poincaré's view of an infinitesimal curving space or a topological continuum of uncut forms, Bergson (1991: 133–78) was seeking a temporal invariant between events. From this standpoint, only *virtual* time (uncoordinated intensive time) can *amodally* link two causally connected actualities (or parameters). Such virtual time is a real interval, exposing the plenitude of cosmic time, which has no intrinsic measure except a continual variation of differential relations. Instead, Whitehead's mereotopological schema defines the relationship between actual entities as marked by the cut that the abstract infinity between eternal objects adds to the physical chain.

A parameter is not only the transduction of physical qualities (such as the volume of a space, gravitational forces, the circulation of air, the movement of people, the shades of lights, the sonic frequencies, the electromagnetic vibrations, etc.) into finite quantities, but an actual object itself. There is, however, an abstract potential within parameters that cannot be grasped at the level of sequential sets but needs to be explained as the infinite quantities of eternal objects that infect and add novelty to actual parameters. This means that the invariant function of topological continual relations, grounding the ontological dominance of the aesthetics of curvilinearity, is only one way of articulating the relation between control and events. The mereotopological schema of eternal objects and actual entities offers another way.

The dominance of the invariant function determines relations between parameters in terms of vectorial qualities. As demonstrated by Greg Lynn's calculus-based architectural forms, it is the qualitative relations of vectors that constitute space as a fluid environment of forces. But this qualitative inflection of parametric design has become a dominant post-cybernetic procedure of connecting entities through a temporal flux of continual variations. For instance, the aesthetic appeal of morphogenetic forms defined by the continual variation of points into temporal vectors, has become equivalent to the aesthetic power of control transmuting actualities into supple lines of convergence, compatibility and uniformality.

One cannot deny that parametric design includes non-exactly measurable qualities into programming, thus conferring a qualitative transformation of the geometrical form as a whole, specifically resulting from the operations of a differential relation encompassing all points on a curve. What is suggested here, however, is that the qualitative dimension of the differential relation has become central to the topological view of the postcybernetic logic of control, whereby prediction is no longer based on the calculation of finite probabilities, but on the inclusion of potential qualities. Brian Massumi (2007) has defined this shift in terms of the mediatic power of pre-emption, whereby the indeterminate qualities of the future are incessantly foreclosed into sets of probabilities in the present. The ingression of topological invariants into cybernetic systems precisely allows automated processes to constantly transduce temporal qualities into quantities, by developing an aesthetic of continual variability of quantities.

And yet, one cannot overlook the process of quantifications of which parametric design is an instance. To argue that this mainly entails a transduction of qualities into quantities in a fluctuating geometrical shape is to deny that quantities could ever be more than finite sets of instructions. Whitehead's mereotopological schema instead adds an abstract schema of discontinuous objects to the actual continuum, so that infinite relations between pure quantities can ingress actual qualities. Points of connection are not only finite parts that overlap, the process of overlapping also includes the selection of abstract quantities that add a new quantitative character to overlapped parts. To put it in another way, parametric relations are not only transductions of qualities into quantities. They are infected with abstract non-denumerable relations of pure quantities, eternal objects: discrete yet permanent relations adding novel character to existing parametric relations. From a mereotopological point of view, each parametric extensive relation is hosting another order of quantities that cannot be contained by the number of its actual members.

If the topology of parametric design implies the calculation of variables through the invariant function, Whitehead's mereotopology always exposes actual events escaping any form of overall continuity. Mereotopology then suggests that underneath continual morphogenesis, there lies a holey space of abstract quantities, infinite relations of numbers that cannot be counted as such. These are the black holes of probability and statistical calculation, remarking the occurrence of *something* travelling beneath and throughout actual regions. These holes in parametric design define the intrusion of parasitic quantities, non-isomorphic functions unable to unite all finite quantities into a morphogenetic continuity.

The topological view of the digital processing of physical data has already unleashed these abstract quantities into culture through the parametric design of buildings, cities, environments, animate and inanimate objects. This design indeed involves not simply the algebraic manipulation of physical data, but the computation of the extensive continuum of actualities (physical and digital parameters) involving their irreversible encounter with abstract quantities, adding uncomputable chance to actual relations. Parametric design is then also an instance of an aesthetic of discontinuity between abstract objects and between actual sets. This discontinuity explains how the spatio-temporal continuum can become other than the actual relations composing it. Here, the introduction of novel configurations of space is not derived from the continual variations of form, but from a universe of discontinuous potentialities abducting the actual relations of data and thus exposing parametric aesthetics to the infinite quantities accompanying any set of probabilities. If topological continuity is the aesthetic design of postcybernetic control via the continual variation of qualities, mereotopological discontinuities expose the aesthetics of irreducible quantities defining the event of computational relations beyond the smooth surface of pre-emption. Since parametric design deals with different orders of quantification (finite and infinite relations), it cannot but become a channel for the proliferation of uncomputable realities within the programming of extensive relations. The parametric aesthetics of *Topotransegrity* therefore does not simply offer a formal system of relations between the software level of programming, the hardware level of the kinetic pistons, the level of physical movement, the level of circulation of air and access. On the contrary, mereotopology exposes this formal system to indeterminate, uncomputable and contingent potentialities of urban programming, where indeterminate quantities invade existing parametric relations. It is this abstract quantitative order of relations that needs to be accounted for in debates about the significance of topology for the aesthetics of digital design.

Notes

1. Henri Poincaré is considered to be the originator of algebraic topology and of the theory of analytic function. In 1895, he published *Analysis Situ*, one of the earliest systematic theorizations of topology. In particular, Poincaré's use of 'homotopy theory' contributed to reducing topological questions to algebra by associating topological spaces with various groups defined as algebraic invariants. Poincaré introduced a fundamental group to distinguish different

categories of two-dimensional surfaces. He was able to show that any two-dimensional surface, having the same fundamental group as the two-dimensional surface of a sphere, is topologically equivalent to a sphere. He conjectured that the result held for three-dimensional manifolds and could be extended to higher dimensions. Yet up to the present there still is no list of possible manifolds that can be checked to verify that they all have different homotopy groups. The invariant function, as a property of non-change, explains change as the morphological transformation of the whole, rather than as parts breaking from the whole. See Boyer (1989: 599–605).

2. Patrick Schumacher recently claimed that parametricism is the dominant style of today's avant-garde and insists on the power of large-scale urban schemes. See Schumacher (2009).
3. In the mathematical field of topology, a homeomorphism or topological isomorphism or bicontinuous function (from the Greek words *Ὅμοιος* [*homoios*] = similar and *μορφή* [*morphē*] = shape, form) is a continuous function between two topological spaces that has a continuous inverse function. Homeomorphisms are the isomorphisms in the category of topological spaces (e.g. the mappings which preserve all the topological properties of a given space). Two spaces with a homeomorphism between them are called homeomorphic. From a topological viewpoint they are the same. If topological space is a geometric object, for instance, homeomorphism defines a continuous stretching and bending of the object into a new shape. Thus, a square and a circle are homeomorphic to each other, but a sphere and a donut are not. In other words, topology is the study of those properties of objects that do not change when homeomorphisms are applied. As Henri Poincaré famously said, mathematics is not the study of objects, but instead the relations (isomorphisms for instance) between them. See Boyer (1989: 603–4).
4. Calculus stems from the manipulation of very small quantities or infinitesimal objects that can be treated like numbers but which are 'infinitely small'. On a number line, infinitesimals have not location zero, but have zero distance from zero. Such quantity corresponded to a single number. As Boyer (1989: 216) explains, only after the development of a general abstract concept of real number was it possible to interpret the differential calculus in terms of the limit of an infinite sequence of ratios or numbers.
5. Infinitesimals have been used to express the idea of objects so small that they cannot be seen or measured. An infinitesimal number is a non-standard number whose modulus is less than any non-zero positive standard number. In mathematics, an infinitesimal, or infinitely small number, is a number that is greater in absolute value than zero yet smaller than any positive real number. An infinitesimal is a variable whose limit is zero. The development by Abraham Robinson (1960) of 'Nonstandard Analysis' conferred new significance on infinitesimals and brought them closer to the vision of Leibniz (1646–1716), who introduced the dy/dx notation for the derivative and perceived infinitesimals more like small but constant quantities. Infinitesimal or differential calculus is an area of mathematics pioneered by Gottfried Leibniz based on the concept of infinitesimals, as opposed to the calculus of Isaac Newton, which is based upon the concept of the limit. See Boyer (1989: 391–5, 519–22).

6. Monads are 'substantial forms of being'. They are eternal, indecomposable, individual, subject to their own laws, un-interacting, and each reflecting the entire universe in a pre-established order. Monads are centres of force, while space, matter and motion are phenomenal. In 1960, Abraham Robinson worked out a rigorous foundation for Leibniz's infinitesimals, using model theory. With non-standard analysis, Leibniz's mathematical reasoning was also revised. See Martin and Brown (1988).
7. The law of continuity is based on the principle that between one state and another there are infinite intermediate states. A continuous entity – a *continuum* – has no interior 'gaps'. On the contrary, to be discrete is to be separated, like the scattered pebbles on a beach or the leaves on a tree. Continuity connotes *undivided* unity; discreteness, divided plurality. Repeated or successive division gives the fundamental nature of a continuum. The process of dividing a continuous line into parts will never terminate in an *indivisible part or atom* that cannot be further divided. One of the first formulations of the law of continuity is the famous Zeno's paradox, a set of problems devised by Zeno of Elea. To support Parmenides' metaphysical doctrine, that 'all is one' contrary to what we perceive, Zeno's paradoxes demonstrate that plurality and change are illusions. Parmenides rejected pluralism and the reality of any kind of change: all was one indivisible, unchanging reality. Another formulation of the law of continuity is offered by Leibniz (see his preface to *New Essays on Human Understanding* (1981 [c. 1704]). The law of continuity in Leibniz also refers to the principle of pre-established harmony, according to which each event occurs when it does because it was pre-programmed to do so by God. See Boyer (1989: 74, 399–407).
8. However, Leibniz is thought to have resolved the paradoxes of continuity by arguing that there are no jumps in nature and thus no discontinuities. He believed that any change passes through some intermediate change and that there is an actual infinity in things. Similarly, he used this principle of continuity to show that no motion can arise from a state of complete rest. See Leibniz (1981, 2001).
9. A derivative is the quotient of two differentials, a differential relation such as dy/dx, where dy and dx are infinitely small quantities whose relation to x (or the quantity of the ordinate) and y (or the quantity of the abscissa) is equal to zero. But, whereas the relation between the actualities x and y is equal to zero, the relation between the two infinitely small quantities (dx and dy) is not zero. This means that these infinitely small quantities are of another existing order compared to the actualities x and y. These infinitely small quantities persist as they vanish by approaching zero ($dx/dy = 0$).
10. Gilles Deleuze's reading of Leibniz's infinitesimal calculus explained that the relation between x and y could not but correspond to another kind of relation describing the differential distance between dx and dy. While dx and dy cancel each other out in the form of vanishing quantities (infinitesimals), the differential relation between them remains itself real. From this standpoint, both Leibniz and Deleuze link the mathematical problem of infinity to the geometrical problem of deriving the function of a curve (the relation between x and y quantities) from the given property of its tangent. See Deleuze (2004: 217–20).

11. 'Parametric' is a term used in a variety of disciplines from mathematics through to design. Literally it means working within parameters of a defined range. Within the field of contemporary design, it refers broadly to the utilization of parametric modelling software. In contrast to standard software packages based on datum geometric objects, parametric software links dimensions and parameters to geometry, thereby allowing for the incremental adjustment of a part, producing effects on the whole assembly. For example, as a point within a curve is repositioned the whole curve comes to realign itself. Parametric software therefore lends itself to curvilinear design as in the work of Frank Gehry, Zaha Hadid and other formal architects. However, it would be wrong to assume that parametric design is concerned primarily with form-making. On the contrary, parametric techniques afford design new modes of efficiency compared to standard approaches, and new ways of coordinating the construction process (e.g. Business Information Modelling), as in the case of Digital Project, an architectural version of CATIA customized for the building industry by Gehry Technologies. See Meredith (2008).
12. The correspondence between qualitative change, temporality and movement is evident in the use of computed animation in the design of spatial fields of relations as well as in the design of real-time interactive architectures, where environmental factors and users can become inputs that change the programmed structure of parameters and algorithms. On the notion of time-like architectures see Lynn (1999: 9–41); see also Grosz (2001), Spuybroek (2004) and Senagala (2001).
13. For example, a line has two parameters – its length and its direction – and altering one of these factors gives you a different form. A polyline has the previous two factors plus the positioning of its vertices and, if any of these is altered, a different form is given, and so on.
14. For example a tower that has a vertical rotation of floor plates can be seen in terms of cost: a very twisted form costs more than a not so twisted form.
15. Among some of the most recent experiments with designing program-evolving architectures, the work of artist Casey-Reas on software processing particularly engages with the evolving capacities of variables exploring the microdynamics of emergent form out of complex levels of urban interaction. See 'Intensive Fields – New Parametric Techniques In Urbanism', USC Conference, Los Angeles, 12 December 2009. See http://parasite.usc.edu/?page_id=28 (accessed May 2012).
16. The Infrasense Laboratory at Imperial College, London, has recently started a research project called 'Smart Infrastructure: Wireless Sensor Networks for Condition Assessment and Monitoring of Civil Engineering Infrastructure'. This form of smart infrastructure wireless sensor networks is here used above all to monitor changes and collect data that software can analyse so as to look for new solutions to emerging problems, such as the flow of water due to leaking pipes, for instance. See: http://www2.imperial.ac.uk/infrasense/SmartInfrastructure.php (accessed April 2011).
17. Leach defines the first instance of digital architecture as the phase of virtual reality, defined by early experimentation of digital forms. In 2002–3, a

second phase of digital design opposed to the earlier phase of form-making produced an emphasis on the notion of tectonics because the materials of architecture had become increasingly informed by the worlds of the computer. In particular, he refers to the computational programming of the British Museum roof. A third shift in digital design is marked by the current use of computation at an urban scale, defined by the development of parametric techniques in the design of cities. See Leach (2009).

18. One can take as an example of the aesthetics of the curvature Zaha Hadid Architects' design of the BMW Central Building, where the primary organizing strategy of the building lies in the scissor-section that connects ground floor and first floor into a continuous field: two sequences of terraced plates (like giant staircases) step up from north to south and from south to north. See: http://zahahadidblog.com/projects/2007/06/11/bmw-central-building (accessed October 2010).
19. See: www.5subzero.at (accessed October 2010).
20. The analysis of parthood relations (*mereology*, from the Greek *mero*, 'part') was an ontological alternative to set theory, which dispensed with abstract entities and treated all objects of quantification as individuals. As a formal theory, mereology is an attempt to set out the general principles underlying the relationships between a whole and its constituent parts, just like set theory is an attempt to set out the principles underlying the relationships between a class and its constituent members. Mereological reasoning, however, cannot by itself explain the notion of a whole (a self-connected whole, such as a stone or a whistle, as opposed to a scattered entity of disconnected parts, such as a broken glass, an archipelago, or the sum of two distinct cats). Whitehead's early attempts to characterize his ontology of events provide a good exemplification of this mereological dilemma. For Whitehead, a necessary condition for two events to have a sum is that they be at least 'joined' to each other, that is, connected (be they discrete or not). These relations, concerned with spatio-temporal entities, cannot, however, be defined directly in terms of plain mereological primitives. To overcome the bounds of mereology, the microscopic discontinuity of matter had to be overcome since the question of what characterizes objects that are all of a piece required topological analysis. Two distinct events can be perfectly spatio-temporally co-located, they do not *occupy* the spatio-temporal region at which they are *located*, and can therefore share it with other things. The combination of mereology and topology contributed to Whitehead's articulation of the notion of the extended continuum. See Whitehead (1978: 294–301).
21. Whitehead used the notion of mereotopology to address the problem of abstraction and spatial measurement without equating abstraction to infinitesimal points. He used the logic of non-metrical spatial relations of extensive parts and wholes, thus starting with concrete actualities or occasions of experience. Since all metrical relations involve measurement and to measure or quantify is the ultimate method of abstraction, Whitehead developed the notion of extensive abstraction. This notion was intended to problematize the general theory of relativity and the theory of measurement, which seemingly collapsed physics and geometry, ignoring, according to Whitehead, the distinction between the abstract and the concrete. For Whitehead it was

instead necessary to separate the geometrico-mathematical order for the physical world so as to formally be able to explain their relations, thus making measurement as determinate as possible. According to Whitehead, the general theory of relativity equates the relational structures of geometry with contingent relations of facts and thus loses sight of the logical relations that would make cosmological measurement possible. This is why Whitehead's mereotopological approach insists on the spatialization of extension and the temporalization of extension, whereby 'physical time is the reflection of genetic divisibility into coordinate divisibility' (1978: 289). Whitehead argued that the solution to this problem was to separate the necessary relations of geometry from the contingent relations of physics, so that one's theory of space and gravity is 'bimetric', or is built from the two metrics of geometry and physics. See Whitehead (1978: 283–7, 294–301, 327–9).

22. In particular, and contrary to Whitehead, Bergson's theory of time, the qualitative time of the *élan vital*, is opposed to the metric time of scientific epistemology, thus identifying the necessity of abstraction with the imperatives of the scientific enterprise. Whitehead, on the contrary, seeks a divergence between geometrico-mathematical abstraction and physical actualities in order to propose a more rigorous metaphysical schema of relations. See Bergson (1994: 358–65, 374–80).
23. As Whitehead explains, each actual entity is atomic as it is spatio-temporally extended (1978: 77).
24. As Whitehead specifies: 'In the essence of each eternal object there stands an indeterminateness which expresses its indifferent patience for any mode of ingression into any actual occasion' (1997: 171).

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Mapping and the Politics of Web Space

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Abstract

This article concerns efforts to see politics in web space. It is a network-topological approach in which the mappings of web space over the past decade have resulted in specific political geometries (roundtables, spheres, lists, etc.). In the web as hyperspace period, random site generators invited surfers to jumpcut through space. Mapping was performed for sites' backlinks, showing distinctive 'politics of association'. In the web as public sphere period, circle maps served as virtual roundtables. What if the web were to decide who should sit at the table? As ideas about the shapes the web accommodated shifted from public spheres to networks, the maps displayed 'issue spaces' – clusters of actors engaged in the same issue area, but now central or marginal. Finally, in what is dubbed as the revenge of geography, in the current locative period, maps show the distributed geography of engagement. Actors are temporarily 'based' and travelling physically from event to event, with tracing and other social software showing their routes. The article treats the shift in focus away from the 'metaphysics' of software-enabled spaces online (the 'virtual' topologies) to critiques of the new 'trace routes' (followed by mobile network actors) now that cyberspace is grounded.

Keywords

internet, politics, space, web

The Death of Cyberspace and the End of Cybergeography

The symbolic end of cyberspace may be located in the lawsuit against Yahoo! in May 2000, brought before the Tribunal de Grande Instance de Paris by two French non-governmental organizations, the French Union of Jewish Students and the League Against Racism and Anti-Semitism. The suit ultimately led to the ruling in November 2000 that called for software to block Yahoo's Nazi memorabilia pages from web users located in France (Goldsmith and Wu, 2006). Web software now

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routinely knows a user's geographical location, and acts upon the knowledge. You are reminded of the geographical awareness of the web when in France you type into the browser 'google.com' and are redirected to google.fr. Whilst it may be viewed as a practical and commercial effort to connect users with languages and local advertisements, the search engine's IP-to-geo-location handling also may be described as the software-enabled demise of cyberspace as place-less space. With location-aware web devices (e.g. search engines), cyberspace becomes less an experience in displacement than one of re-placement – you are sent home by default.

The announcement of the death of cyberspace through the revenge of geography, which virtual ethnographers also have sounded, has consequences for any theorizing of the history of web space (Miller and Slater, 2000). The web's location-awareness could be described as a redrawing not only of space online but of its cybergeographic study (Dodge, 2000). The online 'realm', once routinely thought of and mapped as placeless, now foregrounds location, spelling an end, in a sense, to cybergeography as topological approach to online shape- and space-making, as I argue. In the following I periodize or at least distinguish chronologically between a number of overlapping conceptions of space online over the past 15 to 20 years. Prior to the grounding of the web for the search engine user according to a geography of location, or what is conceived as the current locative period, the internet offered shapes, or space arrangements, that were not based on the coordinates of a locality. From hyperspace in the early 1990s over spheres in the early 2000s and later to networks, these space arrangements, or topologies, draw upon a video game, a social theory and an analytical method for their conception as well as the work they do, as I come to. The heterogeneous list of the hyperspace button in an Atari game, Habermas's public sphere theory and social network analysis have served to conceive of space, navigate it as well as map it, however disparately. Indeed, as has been pointed out, the mapping of the web for the user is perhaps less concerned with the territory (however cyber-) than with navigation (November et al., 2010). Consider the names of the browsers from the 1990s and early 2000s: Netscape Navigator, Microsoft's Internet Explorer and Apple's Safari, all inviting navigation of the sea of information, uncharted space and the jungle. More recently, in keeping with the demise of cyberspace, these cybergeographical devices have given way to browsers (or browser names) less concerned with navigating per se, as Mozilla's Firefox and Google's Chrome.

Mapping space online, however, has not been merely for conceiving of cyberspace as space, and navigating through it. Rather, the mappings are also efforts to see politics online, and enable their study, by new media. The analysis that follows is concerned with the kinds of politics sought online, both in the shapes that have provided space for the politics but also in their mappings, whether manual, semi-automated or automated. Making a link to associate with the like-minded, joining a webring (of interlinked sites) or setting up a crawler and graph visualization machine to show the size (of the interlinked) movement or issue network all do and map politics (without relying on coordinates and location), as I come to.

Prior to the discussion of how space online and its politics have been conceived, I would like to point out that certain projects (prior to the current locative period) have deployed the coordinates of the geographical map. The internet's basic root server infrastructure as well as traffic flows through it have been points and lines respectively on Mercator maps. The maps may be made to show politics. For example, internet traffic maps may be made to display political economies of network engineering. Traffic is routed by peering arrangements that are often more economic than efficient. Run trace routes between Amsterdam and Zimbabwe and note that the packets travel via the United States, instead of in a 'more direct' line from north to south. In another example of political geography online, notice the locations of the 13 root servers. A root server location map would show north-south divides, and the control of the internet by the United States and its allies. They 'rule the root' (Mueller, 2004). Digital divide cartograms show countries resized according to percentages of the online populations per country. Another digital divide cartogram has country sizes inverted to show what the world would look like if it were mapped, not in the progressivist *Wired*-style, where worldwide connectivity and useage only appear to expand, but rather in its inverse. The disconnected world map is a world upside-down, if you will, with countries sized according to non-usage (see Figure 1). In a sense, the geographical mappings that see politics online are more an exception compared to the politics seen by (linking) association, however that tie is defined, as I show. Indeed, the focus lies in the mappings that would show politics in the non-infrastructural internet and particularly the web. In other words, I discuss what could be called political web topology.

In particular, I discuss approaches to the study of the politics of web space that I made in parallel to developing a series of political web mapping devices.[1] Instead of placing my own mapping software projects in the foreground, I would like to describe, periodize and critique the ideas encountered during the course of 15 years of that work that have informed the theorizing of the politics of web space.

Starry Nights: Tethering Individual Websites to Each Other (by Inlinks) in the Hyperspace Period

Generally, thinking in terms of the web as a universe (to be charted) coincided with early ideas of the web as a hyperspace, where one

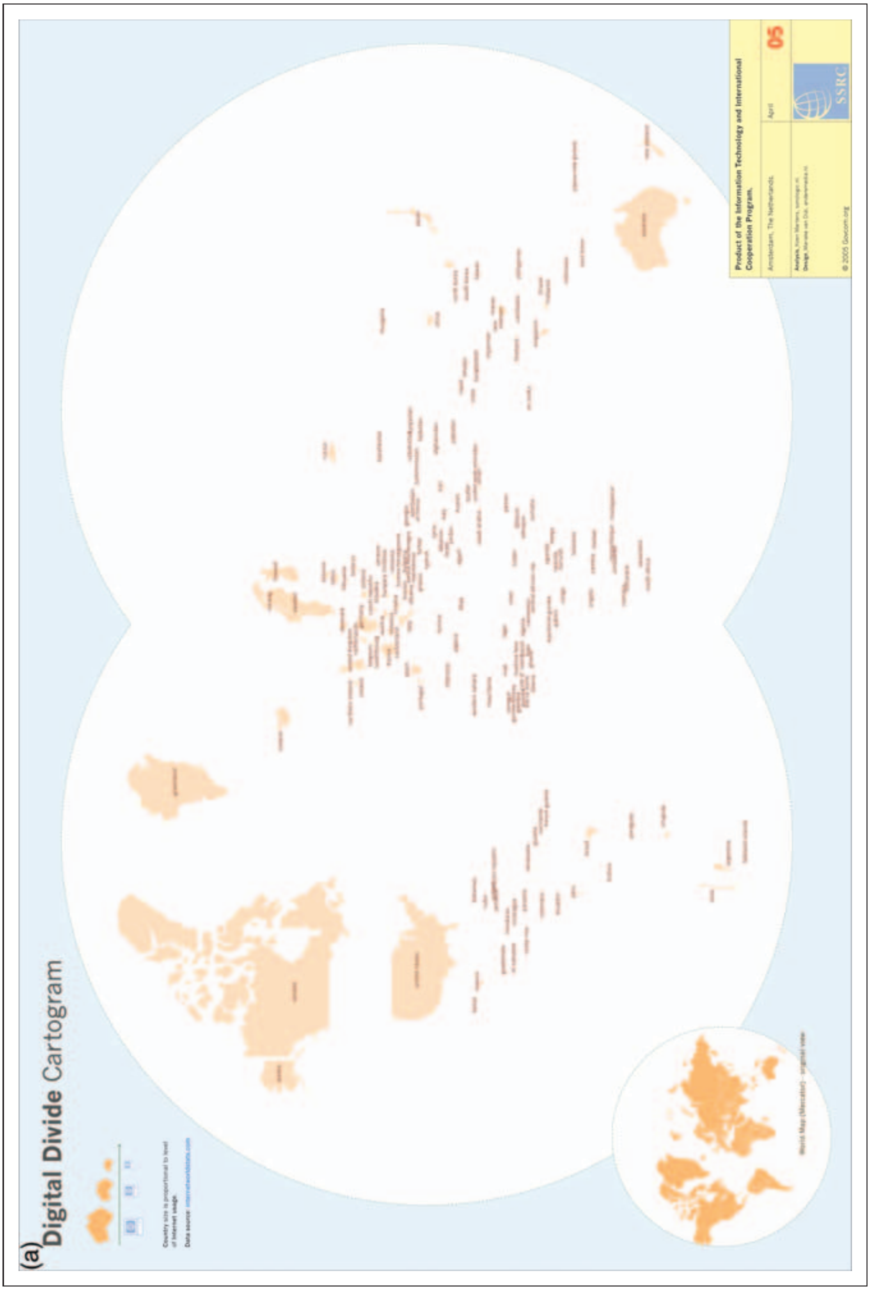

Figure 1. (a) Digital Divide Cartogram, WSIS Tunisia Series, Govcom.org, 2005. ©Govcom.org Foundation, Amsterdam, 2005; (b) Digital Divide Cartogram (Inverted), WSIS Tunisia Series, Govcom.org, 2005. ©Govcom.org Foundation, Amsterdam, 2005.

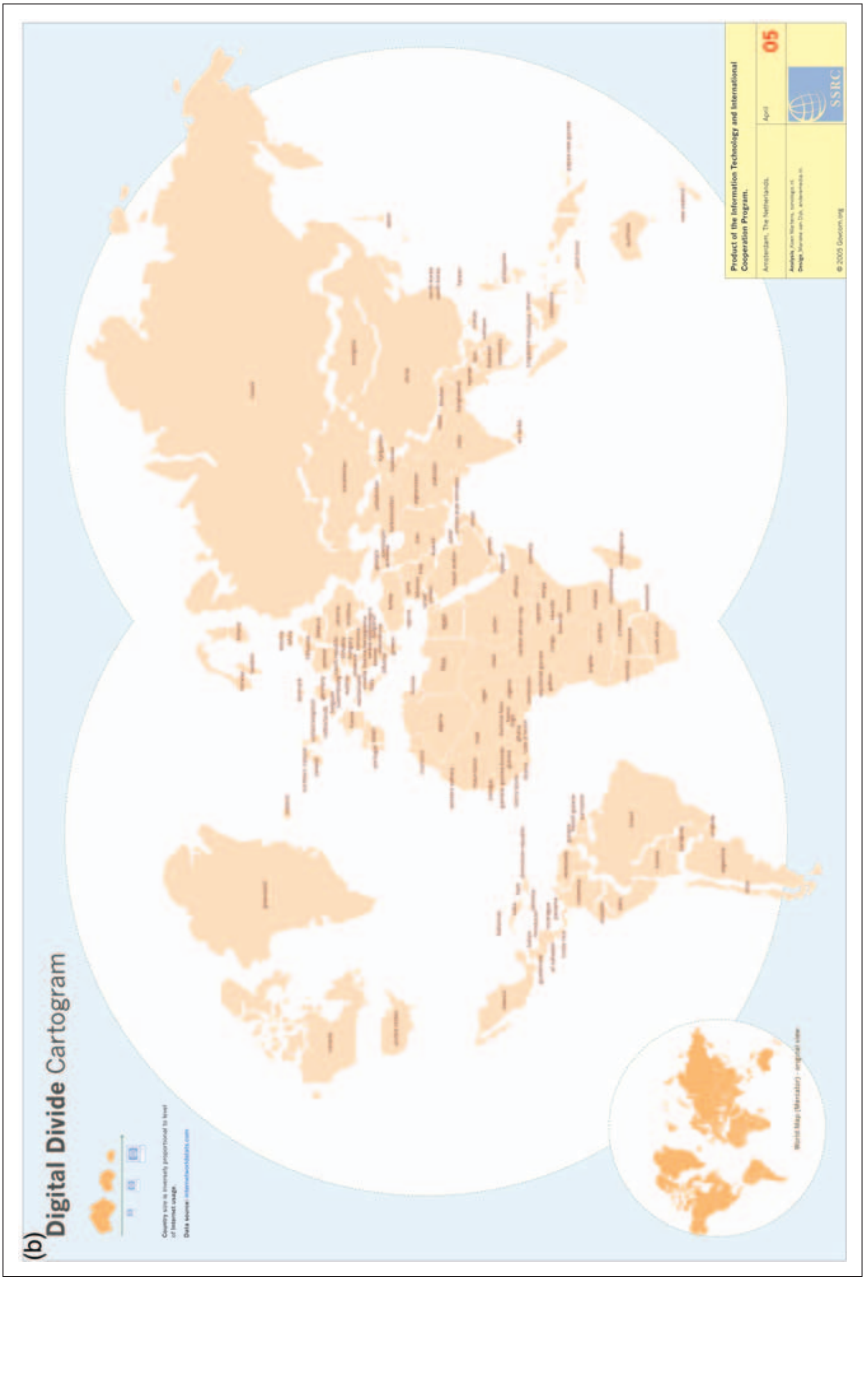

Figure 1. Continued.

would *jump* from one site to another at some great, unknown distance. With starry night site backdrops in abundance, the early web looked as if it would '[bring] us into new dimensions' (Lialina, 2005). The popularity of random site lists, or generators, is another case in point. They found their most well-known expression in Google's 'I'm feeling lucky' feature, built into the first online version of the engine in 1998. It arguably played upon the famed hyperspace button (from the Asteroids arcade game by Atari). 'Randomness' as a selection or recommendation mechanism is still in evidence, as with the 'next blog' button on blogspot.com sites. That current web applications occasionally still build in a jump-to-unknown-site feature, which also could be interpreted in the blogger case as a variation on a web ring, shows that vintage ideas about how one may wish to navigate web space remain.

Besides traffic and server location maps, the study of hyperlinks would come to root web space, at least initially, prior to the placement of sites in spaces and networks, and to the grounding of users in geographical space, discussed below. The important insight of the 1990s was that websites (or webmasters) hyperlink selectively as opposed to capriciously. There is a certain optionality in link-making. Making a link to another site, not making a link, or removing a link may be viewed, sociologically or politically, as acts of association, non-association or disassociation, respectively. A Georgia Tech University study on world wide web usage, published in 1999, found that hyperlinks are matters of organizational policy, especially for corporations and government (Kehoe et al., 1999). Such a 'professionalization' of hyperlinking, it may be observed, is to be seen in how domain types tend to link (Park and Thelwall, 2003; see also Figure 2). For example, governments tend to link to other governmental sites only. Corporations tend to link only internally, to themselves. Industry alliances, business-organization NGOs, or front groups do the web outreach work for corporations, providing 'public interest' links.

With the 'randomness' of linking yielding to the purposeful, 'mapped' inlinks between *individual sites* became telling. The web could be made to show associations – links between sites as professional, organizational and cultural as meaningful ties. In this pre-network mapping, individual sites were 'evaluated', singly, for reputational purposes as well as for the associations they put on display. For example, in a mapping of genetically modified food, researchers and I provided actor profiles according to the *specific* links received and given between organizations and organization types (Marres and Rogers, 2000; see Figure 3). A poignant finding concerned the hyperlinking behavior of Novartis, Greenpeace and a series of governmental organizations. Novartis linked to Greenpeace; Greenpeace did not link back. Both Novartis and Greenpeace linked to the governmental sites, and no governmental sites linked back to them. In other words, when mapped, the particularities of relationships

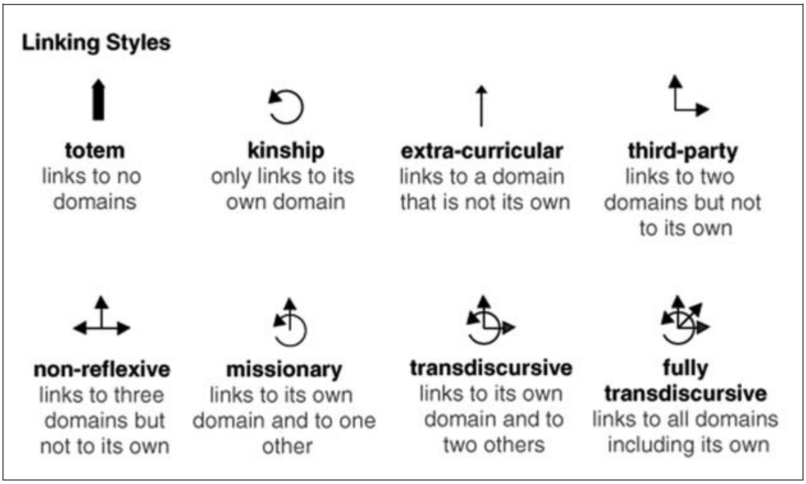

Figure 2. Actor Hyperlink Language, Govcom.org, Design and Media Research Fellowship, Jan van Eyck Academy, Maastricht, 1999. ©Govcom.org Foundation, Amsterdam, 1999. Reproduced with permission.

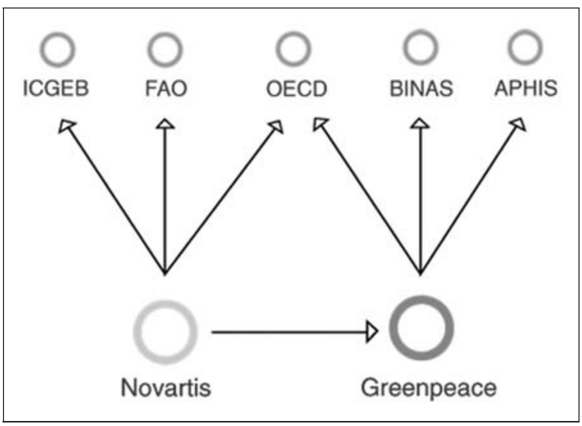

Figure 3. Aspirational linking in the GM Food Issue Space. Novartis links to Greenpeace. Greenpeace does not link back. Greenpeace and Novartis link to government. Government does not link back. Govcom.org, Design and Media Research Fellowship, Jan van Eyck Academy, Maastricht, 1999. ©Govcom.org Foundation, Amsterdam, 1999. Reproduced with permission.

between three individual actors came into view. The work was expanded to look into linking between site types, and how linking may serve more generally as reputational marker for a site type. Three corporate sites were compared; the sites' respective standings differ according to the types of links received, and sites' respective displays of endorsement

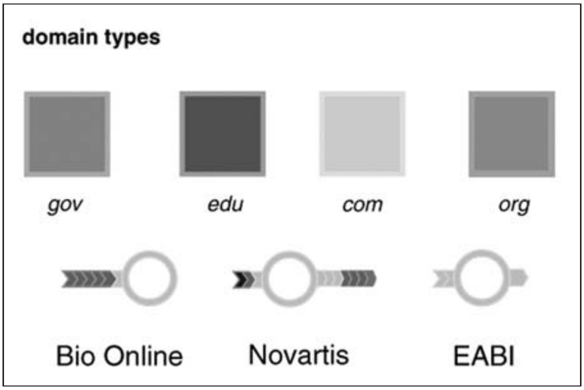

Figure 4. Actor reputational profiles by inlink and outlink types. Govcom.org, Design and Media Research Fellowship, Jan van Eyck Academy, Maastricht, 1999. ©Govcom.org Foundation, Amsterdam, 1999. Reproduced with permission.

according to types of links given. One corporation has a different standing by virtue of receiving links from non-governmental organizations and government, as opposed to from other corporations only (see Figure 4).

In keeping with the view that not all links are equal, researchers have explored the delicate sociality and temporality of link-making (Beaulieu, 2005). In exploring what researchers and I called ‘hyperlink diplomacy’, links were classified as cordial, critical or aspirational (Rogers, 2002). Cordial links are the most common – to project partners, affiliates and other friendly or respected information sources. Critical links, largely an NGO undertaking, have faded in practice, and aspirational links are made normally by smaller organizations to establishment actors, often by those desiring funding or affiliation. For example, the Soros Foundation, the philanthropic funding organization active, among other areas, in public health issues in Russia (in the late 1990s and beyond), received links from Russian HIV-AIDS actors and did not link back (see Figure 5).

Crucially, with or without maps, these associations formed by hyperlinks came to be known as ‘spaces’, e.g. the ‘hate space’ on the web (Sunstein, 2001). In other words, selective link-making creates space when one conceives of space as that demarcated and shaped by limited acts of association. The demarcationist, space-making approach had another important consequence. It performed an important break with cyberspace by suggesting that hyperlinking behaviors dismantle the ‘open-ended-ness’ of cyberspace, an idea that informed ‘placeless-ness’ and led to what one may call ‘place-less space’.

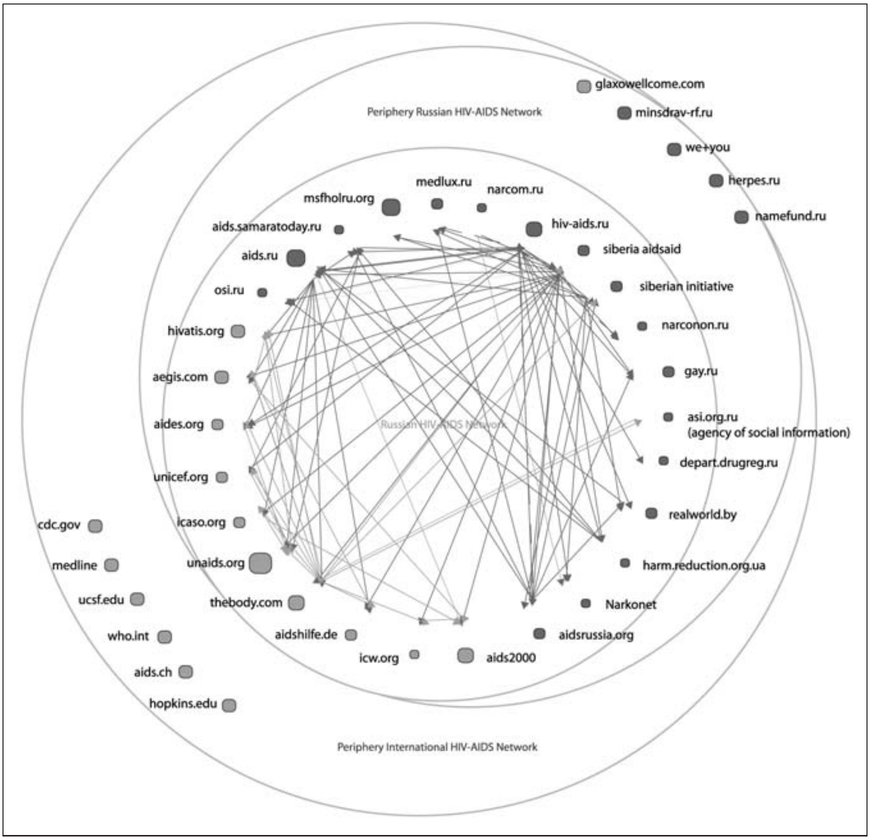

Figure 5. Russian HIV-AIDS virtual roundtable construct, with disproportionate attention from and to the Soros Foundation. Govcom.org, Design and Media Research Fellowship, Jan van Eyck Academy, Maastricht, 2000. ©Govcom.org Foundation, Amsterdam, 2000. Reproduced with permission. Colour version available at: http://www.govcom.org/TCS/rogers_colour_images.zip.

From the Politics of Surfer Pathways to List Politics

How do hyperlink spaces showing associational politics differ from other conceptualizations of web space from the early years and beyond? What could be the shapes of the spaces demarcated by link associations that inform thoughts about the politics of the web? To take up the first question, in the late 1990s and early 2000s the leading visualizations colleagues and I discussed were Plumb Design's ThinkMap Visual Thesaurus as well as the I/O/D's WebStalker, followed shortly thereafter by TouchGraph's Google Browser as well as Theyrule.net by Josh On (Altena, 1999). All are non-directed graphs, without arrowheads, which is to say that the items or nodes (synonyms, site pages, board members and companies) are associated (and lines are drawn between them), without specifying a uni- or bi-directional association. Undirected graphs, arguably, derive from a path model of the web, also built into browsers (with the forward and backward arrows), and lead to ideas about every link being a two-way link (Berners-Lee, 1999; Nelson, 1999). They also lead to ideas about the web as 'small world', where there are measurable distances between sites, described as degrees of separation (Watts, 1999). Link maps, thus, would be thought of as surfer pathway maps, or pathfinders, and the politics in them concerned the distance between official and non-official sites, or between the serious and the salacious.

Seeing the web in terms of paths is not farfetched, since one may surf from page to page, and use the browser buttons, or the browser history, to retrace one's steps and also move forward again. However, on the web, two-way links, it may be observed, are less frequent than one-way links. Whichever ways the links were directed, writers found politics in pathways. Viewing any hyperlink as a bi-directional association, we learned at the time, also has its infamous cases, whereby for example a German ministerial site was accused of 'being linked' to a call boy network (Marres, 2000). The Bundesministerium fuer Familie, Senioren, Frauen und Jugend hyperlinked to a women's issues information site, and that site linked to a call boy network. To the popular German newspaper, *Bild Zeitung*, this web path implicated government. Indeed, it is precisely the perceived political implications of surfer pathways that lead governmental and other sites to place a disclaimer on external links. To government, the surfer should be informed that she is leaving a site, and the outlink that enables the departure should not be considered as an endorsement.

From the point of view of dominant device algorithms, outlinks are endorsements rather than stepping stones in a path. Even more strikingly, outlinks are seen, collectively, as website authority measures. Thus much of the work that would order the web (the Yahoo! Directory and its counterparts like the Open Directory Project, as well as Google and the other major engines that picked up on its PageRank method) parted ways with the great pioneers of hypertext (and hyperlinks), and the random site generators, who viewed the web as pathway space for the surfer to author a journey, a story or an adventure (Bush, 1945; Nelson, 1965; Landow, 1994). With directories and engines, the web became a space of expert and device-authored lists, where the politics of 'making the list' became the concern. In the case of search engines, the lists are generated on the basis of hyperlinks between sites, and ranked according to the sites with the most (authoritative) links in (Brin and Page, 1998). For engines, the question reads: which sites are towards the top and liable to be seen and clicked, and which are buried? For directories, the question becomes: why are particular sites not listed in a given category? By asking these questions, researchers took up the politics of inclusion and exclusion. They left behind the story-telling, pathway web from hypertext and literary theory, and entered the study of information politics (Elmer, 2001). The politics of search engines (and, less so, directories) became a dominant line of inquiry (Introna and Nissenbaum, 2000; Rogers, 2004; van Couvering, 2004).

As links increasingly ordered the web, leading to questions of directory and device-authored source reputation and inclusion towards the top, it is important to recall how one was able to find the links in the first place, in order to read between them, and eventually map sets of them. Also, how would one map the politics of search engine space made possible by counting inlinks? In the late 1990s links into sites, referred to as 'inlinks' or 'backlinks', were not clearly visible. As is well-known, a site's outlinks, most readily in the form of one or more link or resources lists, are viewable to a site visitor. To gain a sense of a site's inlinks, however, requires the use of the advanced search of an engine, access to the referrer logs of a site, or a crawler. Engines that encouraged Boolean queries, like Alta Vista's advanced search of old, enabled sophisticated inlink research (Wouters et al., 2004). For example, one could query the domain-specific inlinks to a particular site, and manually create the organizational profiles discussed above, showing who links to whom in the tradition of the study of the micro-politics of association. A site's log files, once considered a promising avenue of internet studies research, are now routinely out of public view (Jones, 1999). The 'trick' of adding stats to the end of a host name, and subsequently harvesting one or more sites' log files, including the referrers (showing traffic from inlinks), is no longer workable. Most content management systems have public viewing of site statistics turned off by default. Researchers may turn to marketing company databases, as Neilsen's BuzzMetrics, or to Alexa's top and related site features. 'Deep log analysis' generally requires permission from site owners and is fruitful for single site analysis, or the comparison of a limited number of sites (Nicholas et al., 2005).

Until the creation of 'trackback', a feature implemented in the Movable Type blogging software in 2002 that shows the links into a posting, inlinks in the late 1990s and early 2000s were not an everyday research concern. Apart from network science researchers and algorithm-makers, only the occasional political web researchers with specially constructed crawlers made use of them. Inlinks were found by crawling sets of sites. As in scientometrics, one site's outlinks (the references) are another set of sites' inlinks (the citations). Large populations of crawled sites in a particular topic or issue area, as in the work on the Zapatista case, and in other information science efforts with affinities to a social science approach to the study of hyperlinks, yielded network maps, discussed below (Garrido and Halavais, 2003; Thelwall, 2004).

Nowadays, on the web and especially in the blogosphere and in online news, devices recommend pages routinely by counting inlinks, e.g. 'most blogged' stories at the *New York Times* and the *Washington Post*. They also count most emailed stories and most searched for (and found) stories, providing further types of authority measures and privileging mechanisms. Concern with inlinks as a marker of page relevance marked a major shift in the underpinnings of web space. Arguably the period of making Mappi Mundae of cyberspace and creating the browsers to navigate the sea, the uncharted space and the jungle came to an end (Dodge, 2000; see Figures 6 and 7).

For information retrieval, counting inlinks addressed the site authority problem. To those more concerned with the politics of web space, counting inlinks, and especially how they are counted, raised questions beyond inclusion and exclusion in search engine returns (Introna and Nissenbaum, 2000). To take up the first point, previously, in the mid-1990s, the foremost issue concerning search engine developers related to how to separate the 'real name' from the borrowers of the name, e.g. to return Harvard University at the top of the list when Harvard is queried, and not a deli or a health clinic with the same name. In leading search engine results (AltaVista's), the 'eminent scientist and the isolated crackpot [stood] side by side', as one leading author put it more generally about search results spaces (Rheingold, 1994). In their ranking logics,

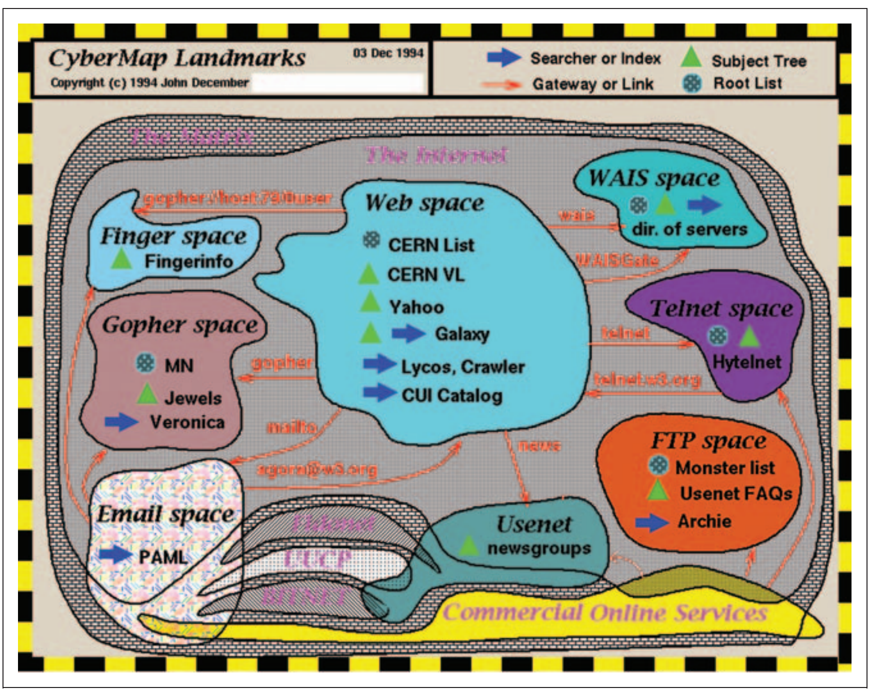

Figure 6. CyberMap landmarks. ©John December 1994. Reproduced with permission from John December.

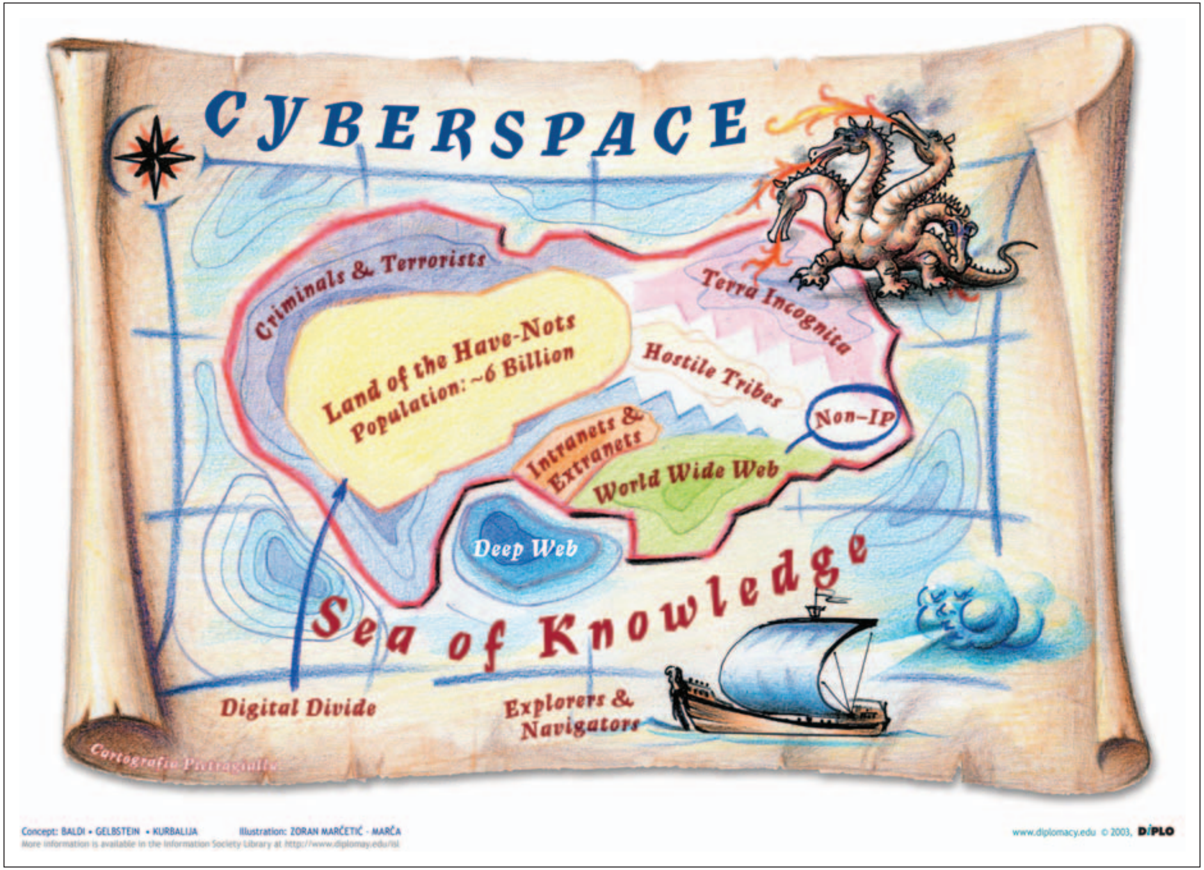

Figure 7. Cyberspace. ©DiploFoundation, 2003. Reproduced with permission from DiploFoundation, www.diplomacy.edu.

AltaVista granted site owners the authority to describe the content of their sites (in metatags) and their descriptions became the basis for the engine returns. The web became a space displaying 'side-by-side-ness', fitting with contemporaneous ideas about its pluralizing potential (Barbrook and Cameron, 1996; Rogers, 2004). Institutional hierarchies of credibility were challenged; non-institutional actors found their place towards the top of engine returns.

Google, conversely, granted other sites that authority (hyperlinks and link pointer text). Counting inlinks and having other sites grant authority through linking (and naming their links well) form the basis for most search engine algorithms these days, including Yahoo's as well as Microsoft's. Once a major competitor to automated search engines, the directory has declined. The demise of the directory can be viewed (at archive.org's WayBack Machine) by noticing how it has been placed deeper and deeper in Google's search hierarchy – from front page tab to two, and now three clicks away, if it can be found at all by clicking. The politics of search engine tabs here lie in setting the work of web librarians in relative darkness. Even Yahoo's much heralded web 'library science' of the 1990s, the Yahoo directory, is no longer its default engine. Thus web space, if conceived as ordered by engines, is no longer expert-vetted. (It is problematic, however, to think of web space ordered by engines as unvetted at all. Engine companies hire 'optimizers' (often a student job) to check results per query. They back-check samples of query results to determine whether they match expectations.)

Search Engine Space and the New Politics of the Sphere

The 'sphere' from public sphere theory has reverberated for some time in thoughts about web space (Dean, 2003). The blogger who coined, or recoined, the term the blogosphere had in mind rational argument among bloggers (Quick, 2002). Prior to the growth of networks of the like-minded, and the neo-tribal school of thought for interpreting web 'spaces' like the hate space outlined by Cass Sunstein, the idea of the sphere rested on the web as 'great conversation' (Reno vs. ACLU, 1997; Sunstein, 2001). Mapping conversations (for example, in Usenet) coincided with assumptions of the neo-pluralistic potential, the rich content of public debate online, and the deliberative democratic spirit (Sack, 2002; Kahn and Kellner, 2004; Turner, 2006).

Conceptions of web space, and how it is ordered, now must take into account how engines are demarcating spheres, and how site owners must cooperate with engines to be well included in a sphere. 'Websphere' analysis, initially, did not refer to search engine space but rather to a meticulous collection of thematically related sites for further analysis (Foot and Schneider, 2002; Schneider and Foot, 2004, 2005). Nowadays, spheres are increasingly co-constructed by engine algorithms and site owner behavior. Searching Google for recent news items, or for recent blog postings, is done by searching Google News and Google Blog Search, respectively. The web has separate spheres.

Of course when site owners link improperly, i.e. many (suddenly) name their links with terms in their pointer text as ‘miserable failure’, the engines no longer work, if by working is meant the maintenance of real name (official) results returned from real name queries (Tatum, 2005). ‘Miserable failure’ is not supposed to place the White House page for George W. Bush’s political biography at the top of engine returns, as it did in Google between October 2003 and January 2007. Google-bombing and other forms of lack of cooperation revealed how Google and other PageRank-like algorithms would like site owners to link. Engine considerations of proper site owner as well as user behavior have consequences for thinking about the politics of web space. The implications go beyond the study of how Google fixes its engine, and what that may mean generally for the critique of any organic search engine returns, as the non-advertising search engine results are called in the industry (Cohen, 2007).

Rather, the consequences of site owner and user behavior have to do with the multiplication of web spaces. As a case in point, commentators in the blogosphere (those leaving comments on postings) do not tend to name their links in a fashion ultimately digestible for dominant engine ranking algorithms. Comment links are routinely not counted by search engines, meaning that there is a hierarchy in what counts as a link. When a web search engine is unable to handle site owner and user manners in a new space (in this case, comments in blog postings), the web becomes a series of sub-spaces, as one may interpret the rise of notions of separate spheres, e.g. the websphere, the blogosphere, the newssphere or even the tagosphere (folksonomic spaces). Each is searched separately – web search, blog search, news search, social bookmark search. Each sphere engine also has different source privileging mechanisms, with different combinations of authority and freshness. The study of the politics of web space becomes cross-spherical. How does a source fare for the same query across each sphere? Questions of new media effects arise that go hand in hand with the web’s neo-pluralistic potential from public sphere theory. Is one more knowledgeable, or exposed to more points of view, when primarily searching and reading in the websphere, the newssphere, the blogosphere, or the folksonomic tagosphere?

Apart from the observations made above about the hierarchies of sites found in inlink counts and in search engine returns, now across spheres, the idea of the perceived equality of sources continues to politicize web space. Arguably each new space or sphere stakes claim to more source equality than preceding spaces. Concern with the under-representation or absence of a large portion of sources the web has its roots in research into the dark or hidden web (Lawrence and Giles, 1999). Such thoughts about under-representation are reflected in the so-called French viewpoints in the literature as well as in the Google counter-project, Quaero (Jeanneney, 2006). It is not so much the public spirit over the commercial that informs the idea of a Google counter-project as it is US source dominance. In Google and the other currently dominant search engines no single French site is in the top 50, according to PageRank (Govcom.org, 2006). Of course the French would not use google.com, but google.fr, which itself is of interest to scholars of media concentration. In country after country the national engines (e.g. free.fr) have small market shares compared to Google. When arguments were presented for funding the counter-project, in France Google commanded approximately 90 percent of the market, in the Netherlands over 95 percent (Journal du Net, 2007). National webs, if understood as those organized by national engines, have grown darker. Thus whilst Google may wish to organize the world's information (as its slogan goes), it is increasingly organizing at least major countries', and major language spaces'.

Network Mapping and Multiple Site Analysis

That the web would come to be thought of in terms of a network space, as opposed, for example, to a virtual sphere, relies initially on a change in its mapping. Indeed, when network mapping, it is important to point out that the analysts' focus is no longer on mapping the online space of special status such as new public sphere, and seeing that form of politics. Web network analysts tend to leave behind approaches that are informed by cyberspace and the virtual. They have more in common with infrastructural mapping (nodes and lines). But unlike server maps or traffic and click analysis with log files, the work relies on discrete or massive multiple-site analysis. Why map multiple sites as networks, and which politics could be shown? There are largely two kinds of political network mapping that make use of multiple-site analysis, the social and the issue-professional. In the more popular 'social' way of thinking, network mapping on the web has as its goal to make the covert visible, to reveal the deep structure of relationships, to dig for ties and, often, dirt (Krebs, 2002; Hobbs, 2003; Bureau d'études, 2003). Where the dirt is concerned, a search engine query resulted in the newspaper headline: 'UN weapons inspector is leader of S&M sex ring' (Rennie, 2002). Indeed, there is a brand of web political work devoted to 'outing' and scandalizing, which could be described as a light form of info-war. Put differently, understandings of the web as space that could show a social network, together with the return of the informality of the web (particularly through the blogosphere and more recently social software), have given rise to an investigative outlook. The impulse relates not only to projects to reveal old boys' networks (strong ties with consequences) but also to the web's street proximity, its closeness to the ground, including the 'fact-checking', evidential spirit of the political blogosphere. Digging up information, data-mining, and checking up are forms of digital traces mapping.

In network mapping it is important to emphasize the reliance on the web's capacity to display configured, professional and publicized political culture. Such work also leaves behind the hopeful public sphere and deliberative democratic approaches, discussed above for example in notions of the web as 'great conversation'. Noortje Marres prefaces her PhD dissertation with the following remark: 'When we [took] to the web to study public debates on controversial science and technology, we [found] issue networks instead' (Marres, 2005). Notions of the web as debate space, as great conversation, with the virtual roundtable construct, did not fit with the empirical findings. Even when research endeavored to *make* the web into a debate space, by harvesting text from organizations' specific, issue-related deep pages, often only statement juxtapositions were found – comments by organizations on a particular statement, but scant inter-organizational exchange (see Figures 8 and 9). Organizations would release views on an issue on their websites, but forums and other dialogue spaces were not used by what could be construed as the parties to a debate. The web could not stand in for a building – or an event where debating parties could gather. The alleged deliberative, conversational and non-hierarchical spirit of the web could not be found (Dean, 2002).

With the demise in commitments to deliberative approaches to understand web-political spaces came an appreciation for forms of network politics, especially those that could be seen as configurations of transnational, highly mobile actors, who are, in a sense, based in networks (Keck and Sikkink, 1998; Riles, 2001). Especially global issues may have typical discursive homes, as at (recurring) conferences, summits and other gatherings. Web mapping became a means to pin down the locations of mobile actors in issue networks, and also ask questions about commitment and attention span (see Figure 10). As a part of the circulation of people, things and information, do networked actors move from issue to issue, or do issues move from network to network? Previously, in social movement research, the idea was mooted that there is free-floating movement potential, in the sense of a given collection of publics able to form a movement, with particular conditions (Rucht, 1999). That is, movements are not spontaneous uprisings as in the notion of a smart mob, but rather more an infrastructural phenomenon (Rheingold, 2002). The question of organizational structure may be put to networks. Are networks simply there, like websites under construction, waiting for political content? In a case study over an 18-month period on the media

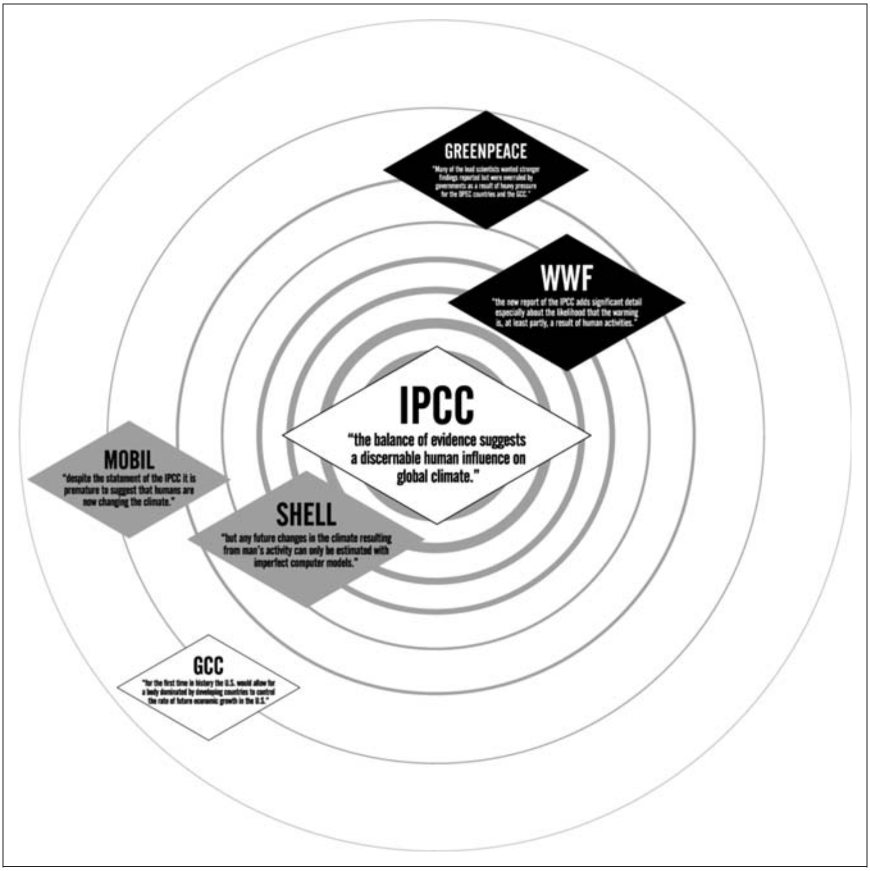

Figure 8. Key statement in context map. Discursive affinities (or non-affinities) between organizations in the use of the Intergovernmental Panel on Climate Change's finding: 'The balance of evidence suggests a discernible human influence on global climate', Noortje Marres, Richard Rogers and Noel Douglas, 1998. ©The authors, 1998. Reproduced with permission.

justice network in the United States, a core and durable network of approximately 20 media justice actors more than doubled its size when funding was announced (Rogers, 2007). More critically, the notion of actors being based in networks, as opposed to institutions or other rooted settings, raises the question of whether they remember what is happening on the ground. The challenges in the political network mapping of web space currently concern how the maps of where issues are based (networks) stand in for what is happening not so much off-line, but off-network. In all, in the neo-cartography, the web becomes a space to map actor movement from issue (network) to issue (network), and critique commitment.

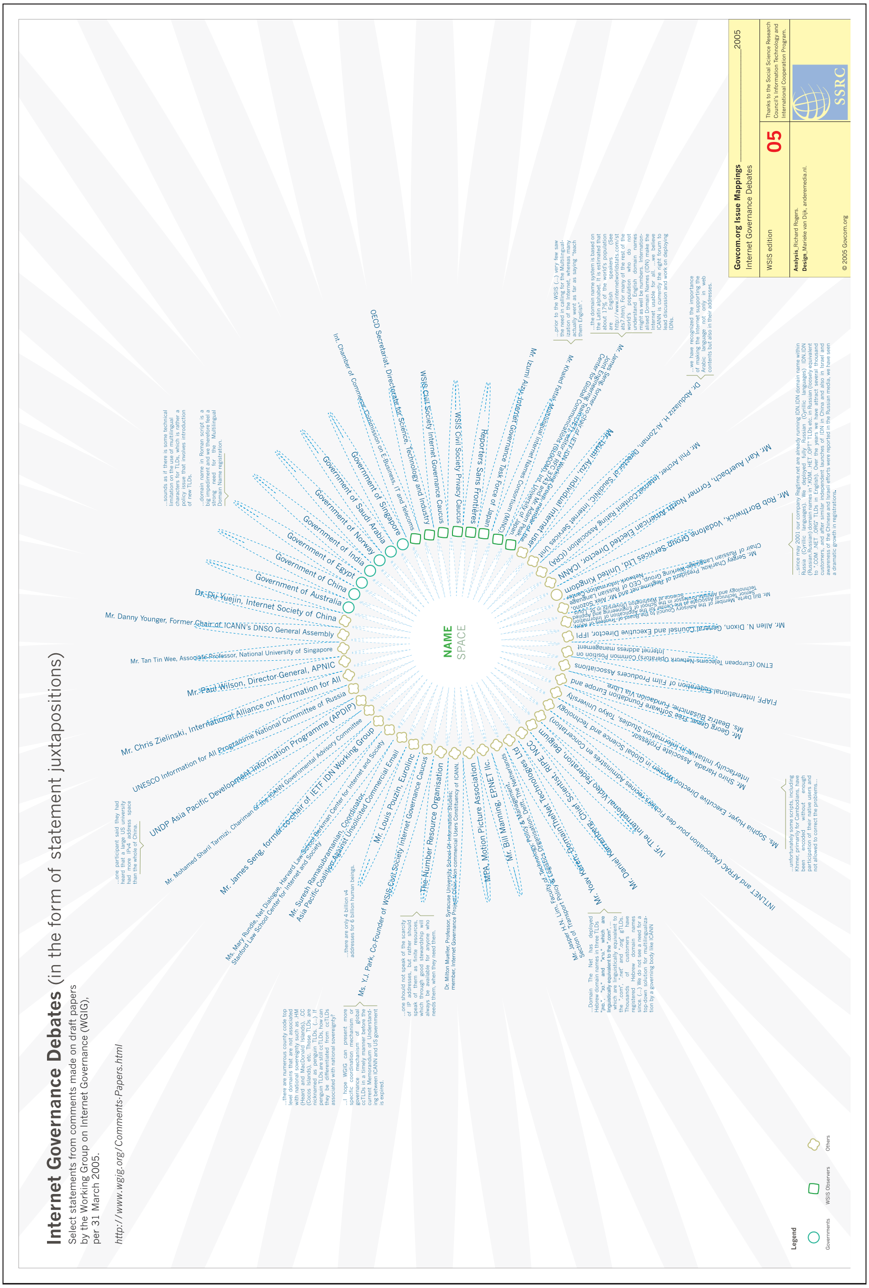

Figure 9. Internet governance debates (in the form of statement juxtapositions): Name Space, WSIS Tunisia Series, Govcom.org Foundation, May 2005. ©Govcom.org Foundation, Amsterdam, 2005. Reproduced with permission.

Figure 10. The base of an issue. Issuecrawler results plotted to the Issuegeographer, Govcom.org Foundation, 2005. ©Govcom.org Foundation, Amsterdam, 2005. Reproduced with permission.

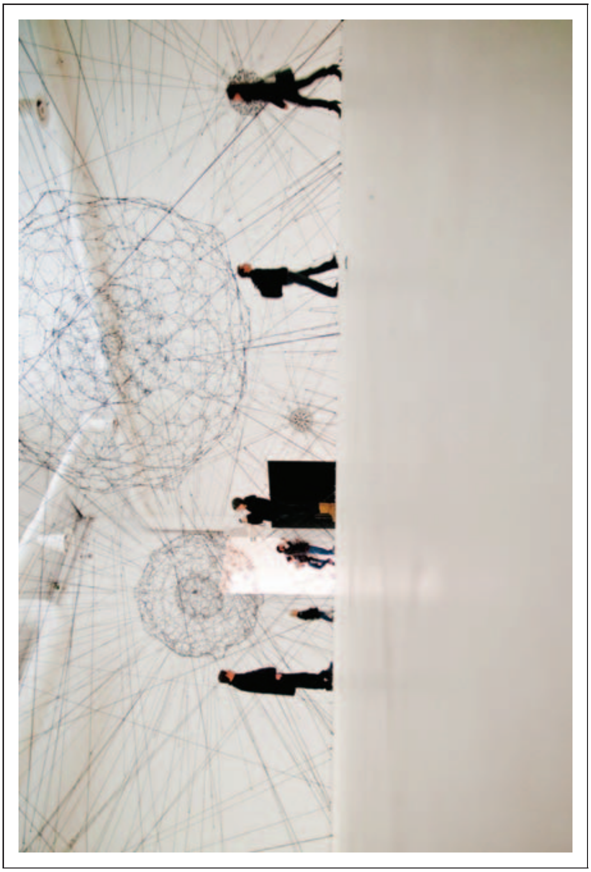

Figure 11. 'Galaxies Forming along Filaments, like Droplets along the Strands of a Spider's Web', by Tomás Saraceno, Venice Biennale, 2009. Photo: ©Anne Helmond, 2009.

Conclusion: Questions for the Study of the Politics of Recent Web Space

One could consider the web as a network space to be mapped. The (mapped) spatializations I refer to, however, are not ones that are auto-generated by software or given by algorithm or physics, at least not all of them (see introduction to this issue). Rather each redoes network space in ways that are often distinctive from the infrastructural topologies that preceded them, namely the centralized, decentralized and distributed networks of communications theorist Paul Baran (1962), or the chain, star and all-channel networks of the security studies scholars John Arquilla and David Ronfeldt (1993, 2001). Each spatialization also reconfigures the network as spaces to do work that is more than communication flow (maintaining it robustly), or command and operations (keeping up the fight).

I am describing the web historically as in spaces in the making. They are often in the making both in their political potential ('great conversation', etc.) as well as in their mapping. They have relied not only on the physics of the network map but on the metaphysics of the non-geometrical sphere.

The purpose of the analysis also has been to periodize these conceptions of web space. With the first period, hyperspace, a time that predates search engines, links on websites propel so-called cybernauts into other dimensions by virtue of random links or later offerings called 'next blog', a feature still present on blogspot.com sites. With the first mappae mundi of cyberspace, in the cybergeographical turn of the mid to late 1990s, the network gains more contours, with multiple borders inside it, as well as inhabitants (cyberians). It is no longer primarily depicted as matrices and corridors but as territories and islands, including topical ones, where there is a melding of tree maps and coastal drawings. Auto-spatialization occurred when network mapping software entered web space, initially with a search engine that performed a kind of network scientometrics. Google's ascendency could be viewed a triumph of network science over other approaches in information and library science embodied by Yahoo!'s directory (for example), but the introduction of the graph also interfered with the plotting of circle maps and the virtual roundtable construct. The information equality associated with alphabetical listings, and the egalitarianism of the activists' circle and the NGOs' roundtable, became entangled in link networks and so-called power laws. Here one could think of the art work by Tomás Saraceno, the sphere enmeshed in the network, shown at the Venice Biennale in 2009, as capturing a specific historical moment in web network topology prior to the geoweb or the locative (see Figure 11) (Latour, 2010). The network's more recent locative turn, in the mid-2000s, saw the end of both cyberspace and the virtual as a political space competing for *status aparte*. With cyberspace all but grounded, efforts at retaining its sovereignty were pushed off-shore to data haven undertakings, such as Metahaven's sealand project (van der Velden, 2004).

The current locative period, referred to in the introduction as the death of cyberspace and the revenge of geography, has seen methods built into tools for outing and scandalizing; it also has seen the return of questions about equality and demographic concentrations in web space. For example, the Wikiscanner, which through IP-to-geo lookups outs the anonymous editors of Wikipedia articles, prompted a royal scandal in the Netherlands (Verkade, 2007). The *NRC Handelsblad* newspaper reported they discovered that a computer at the Dutch royal family's household had made an anonymous edit and embellished an entry about one of the princesses. The case concerned the scandal in 2003 where a Dutch prince renounced his claim to the throne because his princess provided 'incomplete and false' information about her relationship with a drug lord. The royal edit on the Wikipedia page removed the word 'false', leaving only 'incomplete'. In another example of the return of well-known politics, researchers have pointed to the reinforcement of class structures in the differing populations of users of Facebook and MySpace (boyd, 2007). In one instance, in the US military, MySpace (which was said to be used by enlisted personnel) was banned and the officers' Facebook was not. Researchers also see a treasure trove of data in the profiles and linked friends to be harvested from these spaces so as to enable the study of existing as opposed to online-only social networks.

The question here no longer concerns media and analysts' projections of politics onto web space (the great conversation, public sphere and deliberative debate) and how to historize, empirically support or debunk them. Rather, the web is increasingly grounded with geographical and linguistic specificity per platform and space. Indeed, how to approach the study of the sub-division of the web into separate spaces? Which politics are in view per online space? Does the domestication of what was once cyberspace bring us back to the classic questions and approaches (class structures in social media)? Is the imaginative association between the internet and new politics in decline? Are the topologies becoming only more and more traditional?

Generally, inquiries over the past decade and a half into the politics of web space have shifted from the extent to which the online world provides new hierarchies to how they reflect and re-create them. As scholars continue to disaggregate the online (as search engines already have done in providing separate sub-engines per sphere), the concerns shift away from the study of internet and politics in general to the politics of separate spaces.

Note

1. The Issuecrawler (http://www.issuecrawler.net) is server-side web network location and analysis software. Input URLs into the Issuecrawler, and the

software crawls the URLs, captures page/site outlinks, performs co-link analysis, and outputs the results in lists as well as visualizations. The software was conceived in the mid-1990s at the Department of Science and Technology Dynamics, University of Amsterdam, and funded by the Soros Foundation in 2000. It has a forerunner in the Netlocator, also known as the De-pluralizing Engine, built in Maastricht during the Jan van Eyck Design and Media Research Fellowship, 1999–2000.

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Topology and Morphogenesis

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Abstract

One can use mathematics not as an instrument or measure, or a replacement for God, but as a poetic articulation, or perhaps as a stammered experimental approach to cultural dynamics. I choose to start with the simplest symbolic substances that respect the lifeworld's continuous dynamism, temporality, boundless morphogenesis, superposability, continuity, density and value, and yet are independent of measure, metric, counting, finitude, formal logic, syntax, grammar, digitality and computability – in short, free of the formal structures that would put a cage over all of the lifeworld. I call these substances *topological media*. This article introduces elementary topological concepts with which we can articulate material and cultural change using notions of proximity, limit, and change, without recourse to number or metric. The motivation is that topology furnishes us with concepts well-adapted for poietically articulating the world as stuff, rather than objects with an a priori schema. With care, it may provide a fruitful approach to morphogenesis and cultural dynamics that is neither reductive nor anthropocentric. I will not pretend any systematic application of the scaffolding concepts introduced in this article. Instead, I would see what fellow students of cultural dynamics and cosmopolitics make of these concepts in their own work.

Keywords

continuity, cultural theory, individuation, poiesis, process philosophy, transformation

Mathematics as Poetic Material and Material Mode of Articulation

At a symposium on Deleuze and Whitehead[1] I proposed that one could use mathematics as poetry rather than as instrument or measure, or a replacement for God, or a conceptual battering ram. (I must confess, however, to some pleasure in Alain Badiou's fearless and fierce polemic maintaining that mathematics = ontology.) Regarding mathematics as

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substance, and not merely a description of substance, shaping mathematics as poietic material in fact differs in kind from using mathematics to describe the universe as physicists see it. Part of the charm of FoAM's responsive environment TRG (Kuzmanovic and Boykett, 2006) is its attempt to make palpable a concept of the world (recent quantum field theoretic cosmology) by forcibly identifying it with the perceptual field – a cosmic ambition. The artists could only begin to approximate this by restricting TRG to a very compact physical duration and place in Kibla, and by making allegorical simulations in software. Allegory makes the world of difference between depiction and enaction, perception and phenomenology. Allegory is allied with depiction because it makes a picture and a necessary gap between the picture and what the picture homologously represents; therefore it always implicates questions of knowledge, which devolve to questions of sense data. In that case, however, we are dogged by all the epistemological problems of language as representation raised since Wittgenstein and Debord to the present day.

This article is part of a larger experiment to use mathematics not as representations or models of some aspects or strata of the world, but rather as modes of articulation, especially poetic material modes, that consequently are adequate to life. It could be sharply different sorts of poetic matter: continuous topological dynamics, geometric measure theory, or even fancier stuff like non-commutative algebra and étale cohomology. But I propose to start with the simplest symbolic substances that respect the lifeworld's continuous dynamism, change, temporality, infinite transformation, morphogenesis, superposability, continuity, density and value, and yet are free of or at least agnostic with respect to measure, metric, counting, finitude, formal logic, linguistics (syntax, grammar), digitality and computability, in short of formal structures that would put a cage over all of the lifeworld. I call these substances *topological media*. Simplicity is not a requirement of the theory (no Occam's razor here) but merely an acknowledgement that I do not understand enough about the lifeworld to bring out fancier stuff yet, of which there is so much more up the wizard's sleeves.

The fundamental difference in this approach is to use mathematics as substance in a workmanlike way, patching here and there to see what values ensue. I regard mathematics as a trellis for play, rather than a carapace, always sensitive to whether the poetic material accommodates transfinite, incommensurable, immanent passion. Totalizing carapaces like Stephen Wolfram's computational equivalence principle, which at bottom is a transcendental atomic metaphysics founded on making counting sacred, would hammer us into a very sparse ontology. And to a hammer everything is a nail.

This article introduces modes of articulation with which we can articulate substance and infinity using notions of proximity, convergence, limit, change and novelty, without recourse to number or metric. For the moment, I will label these fields of concepts very loosely as: topology, and topological dynamics.[2] These concepts should honour the full density, richness and felt meaning of living experience. Mathematicians will note that for the sake of concision I am using these terms mildly but responsibly loosened from the contexts in which they traditionally have been defined. I will elaborate them more accurately as we proceed.

The motivation for this work is that topology furnishes us with concepts that are well adapted for alternatively articulating the world as plenum and stuff. Continuous topological dynamical systems are useful for articulating morphogenetic process. I should say that I will introduce more and less than what mathematicians call 'topology' – as introduced by Henri Poincaré (1892, 1899, 1902a, 1902b, 1904), L.E.J. Brouwer (1910, 1911, 1912, 1976) and Felix Hausdorff (1965) (see also James, 1984). More, because I will refer to fields of articulation and shared experience considerably more extensive than the mathematical purview of point set topology, such as cigarette smoking, songs and social migration. Less, because in this article we will spare the schoolbook approach and take a high road more akin to Gilles Châtelet's (2000) treatment of mathematics via essential intuitions. Like Châtelet, I will respect the intuitive essences of the concepts and their derivations, which in mathematics take the form of logical (but not formally mechanized) proof.[3] Also, mindful of the problematic misunderstanding of earlier work by, for example, René Thom (1989, 1990), let me dissuade would-be scientists from enlisting topological theorems for mathematical modelling in its instrumental sense. And finally, I wager that the modes of articulation I introduce in this article for their poietic potential have implications for art, philosophy and engineering beyond the scope of the particular motivating applications in this article. However, I will *not* pretend to make a systematic application of all the scaffolding concepts introduced in this article. In fact, I should like to see what fellow travellers make of these concepts in their own work. (For a more adequate elaboration of some applications of this approach to a particular set of work in the confluence of media and performing arts, computational technologies of performance, and philosophy of process, see Sha, forthcoming.)

A Non-reductive Morphogenesis

I discuss the process of cultural dynamics always accounting for the radical entanglement of observer with the observed. This implies that descriptions of a situation or a process are always situated. (As Maturana and Varela said in *Tree of Knowledge* [1992]: everything that is said, is said by somebody, somewhere; [see also Maturana, 1987].) So, descriptions are articulations. Therefore, the mode of articulation matters. Topology provides an *anexact* (in Deleuze's sense) mode of articulation, that does not need numerical measure, equations, exact data, statistics.

Speaking of human experience, one of the central challenges to anthropology and social sciences has been the contest between 'quantitative' and 'cultural' methods. Forty years ago, R. Duncan Luce, David Krantz, Amos Tversky and Patrick Suppes published a three-volume *Encyclopedia of Measurement* (Krantz et al., 1971; Luce et al., 1990; Suppes et al., 1989) for the social sciences that epitomized significant approaches to 'measuring' cultural and social dynamics, across a much more ample range of techniques than the statistical or numerically based models that typify quantitative discourse. Despite such an ample and encyclopaedic project, we can still advance the hypothesis that any sufficiently thick account of a human phenomenon, especially as a dynamical process, would be too dense to be adequately modelled by numerical models alone. This seemingly simple hypothesis evokes incompatible and equally certain responses. The incompatibility of those responses marks this as a proposition worth investigation. Against this hypothesis about the inadequacy of quantitative methods, techno-scientifically powered rationality demands rigor, prediction and generalization. Cultural, literary and historical approaches are rigorous in their domains, but compete with difficulty against the rhetorical and political strength of the predictive and general powers afforded by a system of quantitative measurement. Let's call this debate about the adequacy of quantitive vs. qualitative methods the *social scientific measurement problem*.

In 2010, a European Union Framework-supported project called 'A Topological Approach to Cultural Dynamics' (ATACD) closed its three-year course with a conference in Barcelona with a very large range of responses to the challenge of understanding cultural dynamics, with techniques ranging over quantitative modelling, computational physics and design, and literary and historical methods. The diverse and energetic response demonstrated a wide recognition of the need for fresh approaches to the measurement problem, between absolute mutual rejection, or absorption of one by the other, which in the present age largely means absorption by quantitative and computational models.

This article introduces a handful of the most elementary concepts of topology as a contribution toward more generous articulations of cultural dynamics without number or metric, respecting the material and contingent features of social and cultural phenomena.

What is the methodological significance of such an approach? Rather than begin with a complex schema and observational apparatus, we can try to take a minimally scaffolded approach to the phenomena: minimal in language, and minimal in formal schema. As we dwell in the phenomena, site, event, we can successively identify salient features of the phenomena, and then successively invent articulations that trace the phenomena. We do not pretend at any stage to completely capture what we articulate. Indeed, as I wrote at the beginning of this article, I introduce these topological concepts and theorems not for the purpose of providing a truer model of reality or even of perception, but as a mode of articulation and, on occasion, poetic expression.

The most minimal mode of articulation available to us is the mode of collectives, sets. But bare sets are too bare and in fact offer grip to Russellian paradoxes in their bareness. The next simplest mode of articulation is the notion of proximity, the motivating notion for topology. In fact it is scaffolded by the more primordial notion of 'open' set, augmented by the set theoretic notions of intersection and union. Along the way, we avoid metric, numerical measure, for several reasons. A practical one is that, far from Galileo's claim, most phenomena in the world come to us without numerical measure or metric. In fact, the move toward 'data-driven' applications confuses number-measure for the numbered thing, which is a desiccating move. We propose to try the topological as an anexact mode of articulation that retains as much as possible the wet, juicy messiness of the world, without the desiccating moves of metrizing, or premature orthogonalization.

There is a much stronger methodological potential: topological concepts can provide adequate grip so we can apply *theorems* as an artful propositional procedure, as Isabelle Stengers characterized Whitehead's speculative philosophy fashioning out of concrete ontology 'abstractions [that] act as "lures", luring attention toward "something that matters"' (2008: 96).[4] The fundamental point is that, typically, a mathematical theorem's hypotheses do not need to be calibrated by numerical measure, nor in fact any 'empirical truth', and therein lies its potential for supple adequacy. In fact, the vast majority of mathematics avoids explicit numerical constants and explicit equations, and this is especially true of topology, as should be clear from the exposition I have given earlier in this essay. What this implies for future work is that we can make arguments that are *both* qualitative and definitive. For example, under adequate, qualitatively expressed conditions, we may be able to rigorously establish 'qualitative' phenomena such as periodicity, convergence and existence of maxima or minima, all significant in articulating cultural, sociological, historical dynamics.

The Case for Continua

Exploring the implications of a topological approach to a plenist, unbifurcated ontology, I am concerned with the question of how things emerge and dissolve with respect to their background. I use 'thing' mindful of several notions: (1) Latour's (and science studies') things, such as controversies that have left the lab and have entered into public discourse, not unrelated to (2) Heidegger's 'thing', performing, gathering the fourfold: earth and sky, divinities and mortals; and (3) computer science/machine perception's notion of an object that can be 'inferred' from sensor data. A topological dynamic approach offers a processual perspective complementary to these notions. A processual approach to experience calls forth memory and anticipation and, in a technologized world, mechanical analogues known as machine learning and machine perception. The holy grail of machine perception is to recognize a pattern with no a priori distribution, model, taxonomy, or context. This is analogous to upholding Derrida's (1989) negative answer to the origin of intuition in geometry.

Continuous Topology, Topological Manifolds

Writing of speculative philosophy and art, the challenge is always to describe the notions in just the right degree of detail or concreteness. It's not only the *what* but the *how* and *why* that we're concerned with. It takes some judgement to estimate at what level of detail we need to stop, giving enough to offer the reader the conceptual grit and grip needed to make his or her own concepts, but not too much to obscure the essential ideas. Some editors may not recognize that, with technical concepts such as concepts of mathematical objects and related morphisms, one can err on the side of too much explanation. More detailed descriptions aimed at students (of all ages) of mathematics typically would stop the reader at the wall of notation. That said, Klaus Jänich's (1984) uniquely vivacious book on basic topology could serve as a second reference for some of the articulations I propose. In mathematics, the *how* and *why* require us to go through the actual proofs. Understanding a proof may require years of meditation on a paragraph of mathematical writing. That said, I will present a proof only in order to advance and thicken the argument, rather than demonstrate the truth and force of a theorem.

Before we begin, I should emphasize that topology as mathematicians have developed it over the past hundred years comprises an enormous range of spaces, mappings, properties and concepts, immeasurably richer than the discrete, graph topology cited by computer scientists and their clients. (For example, B.C. Smith uses 'topological' in a typically loose way: 'By "topological" I mean that the overall temporal order of events is dictated, but that their absolute or metric time-structure (e.g., exactly how fast the program runs) is not' [1999: 6].) Graphs are a particular and relatively uninteresting class of topological spaces, but the vast majority of topological spaces are not graphs. For the purposes of this article, when I say 'topological' I will mean the general properties of the class of topological manifolds and *not* the special properties of discrete graphs. In fact, one of my strongest technical reasons for introducing the topological is to provide an alternative to all the figures in discrete sets and graphs. Topology is (much) more than graphs.[5]

Examples

It may be helpful to keep in mind some working examples in which you, the reader, can check your developing intuitions about the topological concepts that I am about to describe. For each example, the fundamental question to think about concerns proximity: what do you consider to be a neighbourhood, without necessarily appealing to any numerical quantitative means.

Example: The Earth

One example comes from considering the geophysical boundary of our planet: where does the Earth end and space begin as one ascends into the atmosphere? One could apply all sorts of criteria. The point at which one loses consciousness in a rising high altitude balloon? The barometric pressure? The flux of ultraviolet light or cosmic rays intersecting a meter held in the hand? The visibility of the people waving goodbye? Take the atmospheric resistance, for example. A macroscopic body intersecting the atmosphere at extremely high speed (tens of thousands of miles per hour) and at a shallow enough angle may even glance off the atmosphere the way a rock can skip off the surface of a lake, but the same body brought slowly through the atmosphere will easily penetrate the atmosphere. So the manner in which one approaches the planet certainly affects the boundedness of the planet.

Of course, where the Earth ends and space begins is conventional, but the conventionality underlines the material fact that there is no sharp atmospheric boundary around the planet Earth.

Flows

A flow can be regarded as a set of trajectories, where each particular trajectory of a particle, $\gamma[s]$, is a mapping from a scalar parameter into a given manifold $\gamma : R \rightarrow M$. A second, less explicit, way is to consider not individual trajectories of flows but a model of how all possible trajectories are generated from a much more concise set of *differential* equations describing the flow as a whole, whose 'solutions' are the trajectories. In other words, the set of differential equations yields not specific numbers but equations as their solutions. So we move from the actual to the potential in a concrete way. In fact this mode of thinking is a germ of the intuition behind the paired concepts: actual/potential. Systems of ordinary differential equations are the heart of the theory of dynamical systems, which in turn provide notions constituting complexity theory, systems theory and cybernetics.

Now, even this description, however flexibly it unchains us from an unwarrantedly explicit description of material dynamical experience, is still too explicit, and subject to reification error, or what A.N. Whitehead called the 'fallacy of misplaced concreteness' (Whitehead, 1978: 21). In the absence of any concrete data about the 'physics of materials', that is, the constants of the model, analogous to constants of thermal or electrical conductivity, or the gravitational constant G, or the speed of light in electromagnetism, what can we say with rigor and warrant that on the one hand does not make unreasonably 'concrete' demands on description, yet on the other hand honours the phenomena in question? If we dispense with explicit equations also at this potential level of ordinary differential equations (ODEs), we can still, nonetheless, make provably certain statements about the behaviour of the possible solutions to a given system. Some qualitative but rigorously treatable features or aspects include periodicity, or the existence and uniqueness or structure of periodic trajectories (also called 'orbits').[6]

We can articulate rich physical phenomena using notions like the wash of ripples along the banks of a river, the accumulation of leaves in the eddies trapped in the crook of a tree trunk fallen into the water, or more symbolic entities like the destinations of lanterns set out to float on the current, or the origins of a river and all its tributaries. The destination(s) and origins of a trajectory, regarded as limits as trajectory-time goes to infinity or negative infinity, can be regarded as limit events of dynamical processes.

Where's the Smoke?

Stand a group of people in a room; ask someone to light and smoke a cigarette. Ask each person to raise a hand upon smelling the smoke. This seems like a reasonable way to empirically define where the smoke is. But notice several features about this experiment. The extent of the smoke changes with time. The extent is determined physiologically, situationally, phenomenally: different people have different sensibilities and each person may be more or less sensitive to smoke according to how much s/he thinks about the smoke. In fact, just asking people to smell for smoke primes their sensitivities. Therefore the smoke's extent is an amalgam of the physical particles in motion, the people's physiologies, and the phenomenological expectation set by the asking.

Songs

Imagine the set of all songs, alternatively defined as (1) performed live, with contingent warble, glide and rubato; (2) transcribed to a formal system of notes in a normalized and regularized set of pitches and durations; (3) paralleled and labelled by words: titles and lyrics; (4) as variations in air pressure – time series of acoustic amplitudes over time. Each of these characterizations enables quite different ways of considering what songs are similar to what. Consider yet another interpretation: (5) songs as a set of social practices whose cultural and micro-local meaning and value are inherited from local as well as non-local histories. A performance of one song also conditions other performances. In his history of Arab musical performance on the eve of the introduction of European notational, recording and distributional economies, El-Mallah (1997) describes how the recording and transcription of a particular performance freezes-in a canonical representative of a family of related song performances whose boundary is constantly re-negotiated by social practices. A key point here is that those social practices, however categorized, unfold boundlessly and endlessly in ways that I suggest are *non*-computable in essence. (To argue this fully would take us too far afield, so I refer to Penrose [1991] as one starting point.)

From Demographics to Events

Imagine the set X of all the life courses of people through time. (For this example, think of time conventionally as a unidimensional index of processes.) This is, in principle, a space of boundlessly many dimensions. Each point or element of this set X is itself a whole life course, a trajectory that could be arrayed along a literally boundless number of features: geography, wealth, bio-matter, movement, historical context, class, social fields and so forth. It is difficult to imagine how to compare lives against one another, and in fact one could well argue that any attempt to metrize the set of life courses unavoidably desiccates the experiences they singly and intersubjectively trace. Consider the flow of peoples into the United States over the past century, and consider how the state has attracted, admitted or excluded people along its borders. The life courses of all these immigrants vary infinitely, and we cannot follow these lives in their dizzying contingent crenulation. Indeed, how could we begin to think what lives are proximate, or related to which, and how some lives cluster or intertwine, while others remain forever distinct? In what senses can we understand 'intertwine', 'cluster' and 'remain distinct'? How, aside from resorting to literary means of Dantean scale, can we articulate the set of all life courses, the 'space of lives'? This example and the smoke example suggest a material, morphogenetic approach to sociocultural dynamics. We will come back to this example, after we have absorbed some topological concepts.

Point-set Topology

The basic axioms of set theory include the notion of inclusion (membership), subset, intersection and union. What is already enormously powerful at this level of description is that there is no comment on the nature of a *set*, whether it is material or abstract, finite or infinite. There is no restriction at all on how a set may be defined. In a most fundamental difference with computer engineering, a set does not have to be defined by explicit enumeration. Much of the imaginary of the computer scientist is delimited by the notion of a finite, denumerable set $\{x_1, x_2, x_3, \ldots, x_n\}$ where n is some explicit, finite integer. But a set can be defined by a rule, such as 'set of all real numbers', or 'the set of all moments of introspection', or 'the set of all pleasures'. It is set theory's lack of structure (mass, dimension, colour, emotion, race, class, gender, religion, history, etc.) that makes it such an ample notion: anything can be in a set. And it is this very omnivorous nature of the concept of set that gave rise to the most significant crisis in the foundations of logic and mathematics in the early 20th century, instantiated by Russell's paradox and the paradox of the set of all sets. But here I stop since my concern is not to explicate or repair set theory, but to pass on to fields richer than bare sets. In fact, the very enormity and brilliance of Badiou's effort to construct a neo-Platonist ontology on set theory testifies to the sparseness of the theory which necessitates the effort. Just one step up from bare set theory takes us to point-set topology, the next sparsest set of concepts in mathematics, built from the raw material of sets, but now admitting more structure.

It may appear marvellous how what seems like the barest whiff of structure yields such a powerful set of concepts and theorems. But this should not appear any more surprising than Galileo's Renaissance observation that the book of Nature is written in mathematics, if one regards mathematics from a Latourian perspective as a relatively high-level machine for the inscription of material processes (Latour, 1988).

In this article, we can only touch on the most elementary concepts and theorems, but even these seem fertile for our interests in philosophy of media, art and technoscience.

Point-set topology is one of the most primordial modes of articulation available to us, the open set is its most fundamental notion. *It is even more primordial than counting*. Primordial does not mean foundational, however: it means that no other compactly articulated concepts are ready to hand from which to construct an argument, in the given scope of reasoning.

We begin with point-set topology, not set theory, because, *pace* Badiou, I believe that set theory is too sparse to accommodate being in the world without severe distortions of our felt experience. Two observations to substantiate this belief:

(1) Russell and Whitehead took hundreds of intricate, technical pages to establish from set theory alone the integers: 1, 2, 3,... as sets built out of the empty set: (ø, {ø}, {ø, {ø}}, {ø, {ø, {ø}}}...}. They prove theorem *102, that $1 + 1 = 2$, after about 1000 pages of work.

(2) In a *tour de force* effort, for which he received the Fields Medal, Paul Cohen established the independence of the *Continuum Hypothesis* from the *Axiom of Choice*. In our context, this

> demonstrates that the continuum is ontologically distinct from even the transfinitization of ordination, number, count.

Point-set topology provides articulations of these notions: *open* (*closed*) set, *extent*, *neighbourhood* (proximity), *connectedness*, *convergence*, *limit* and *continuous transformation* (or mapping), all without relying on numerical measure or metric. Yet, as we will see, we can make more certain statements about qualitative, that is, topological, behaviour than any that can be made with numerical measure. Moreover, having such primordial structure means that topological arguments start with less conceptual machinery, which appeals to the minimalist taste. Readers who have slogged through epsilon-delta proofs will appreciate a notion of continuity built only out of the elementary notions of open set and inverse map.

The open set captures the notion of a set that welcomes members, and does not have a sharp litmus test for membership. In fact its most fundamental characterization is the following: If x is in the set O, then there is some complete neighbourhood of x entirely contained inside O. What are some examples of an open set? A mundane one would be from demographics. Say that we are restricting access to a movie theatre to people ages 13 to 17. At those boundary ages, disputes inevitably emerge: how close to the 'edge' may one be and still be admitted? If we were to say 13 and older, someone who is 12 years, 364 days, 23 hours, and 59 minutes old may argue that they are really already 13 up to the precision of clock technology. Let's say we restrict to those who are strictly older than 13 and strictly younger than 16. Then one would have a margin, but an undefined sort of margin: any margin will do, so long as that margin is not nil. For example, one test could be for the putative theater-goer to pull someone who is younger, but provably older than 13. That would suffice.

A more nuanced example comes from the political economy of pharmaceuticals in Mexico. Anthropologist Cori Hayden (2007) has studied the complex and ever-shifting taxonomies of pharmaceuticals in Mexico, ranging from brand-name 'originals' to 'generics', interchangeable generics, and 'similar' drugs. She identifies brand-name originals (the 'originator' holding the initial patent), generic medicine (same compound, no brand name, not proven bioequivalent), branded generic (same compound, branded by generics manufacturer, not proven to be bioequivalent), interchangeable generic (same compound, bioequivalent), and 'similar' (non-bioequivalent copy). The last category is recognized by the World Health Organization, but not by Mexican health regulations. Indeed, a chain of pharmacies has been built along this last category, Dr. Simi's Similares™. Hayden considers how similarity and equivalency are contested in Mexico among transnational pharmaceutical corporations, other retailers, advertisers and the public (itself a contested set of sets), where the norms of similarity are heterogeneous and politically contested. Numerical measurement is inadequate to the shifting but definite and perhaps overlapping regions of similarity in the world of these pharmaceuticals.[7]

The rigorous concept of open set concretizes the notions of similarity and comparison from such examples. The conceptually deepest aspect of the concretization is that it leaves behind the concept of number, or, even more deeply, the very concept of in-principle-numeric measure. In other words, one does not need to measure anything using some metric (a distance, whether physical or 'abstract') or number in order to apply this test for openness. This concept of openness underlies the rigorous characterization of *open set*.

Especially in this article I qualify certain concepts or arguments as 'rigorous', meaning that they admit definitions that are sufficiently precise and arguments sufficiently verifiable to be accepted by mathematicians. Such concepts and arguments enjoy a particular mode of portability, shareability and re-usability similar to that shared by the perspectivally approached, aperspectival entities (objects and processes) of mathematics. I use such concepts not to box thought, but to sustain articulation, perhaps poietic articulation.

The open set is the most basic notion in point-set topology, but a set is never definable as open in itself; it is always defined relative to a topology, which is a set X of which U is a subset, together with a family of the subsets of X that are declared to be open. Which sets are declared to be 'open sets' is up to you, the designer of the topology, provided only that the subsets in this family satisfy the following.

Axioms of Topology

1. If A and B are open, then the intersection of A and B (notated $A \cap B$) is open.
2. The arbitrary union of open sets is open.
3. The total set X, and the empty set, denoted ø, are both open.

I wish to underline the openness of the concept of open set: given a set X – a universe – there is not necessarily a unique topology. More than one topology may be defined on a given set X. Every set X has at least two topologies. The coarsest topology is the one where the only open sets are X and the empty set ø. And the finest topology is the one in which all the subsets are declared to be open.

By definition, a subset C of X is *closed* if its complement is open in X.

An arbitrary subset U of X may be neither open nor closed. Take, for example, the set of points in the cone of half-open segments based at the origin of $x_i \geq 0$, but whose distance from the origin is strictly less than 1: $(x_1)^2 + (x_2)^2 + \cdots + (x_n)^2 < 1$.

The main lesson here is that the art of a topologist, even at this elementary level, contains a great deal of creative flexibility, that there is no transcendental principle determining a unique topology for every set X.

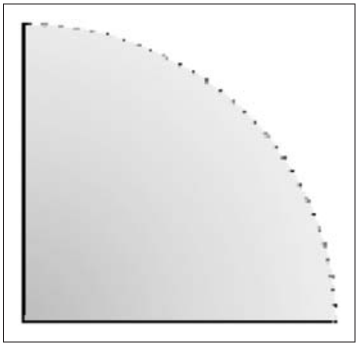

Figure 1. Half-open cone in R^2: it includes points on the vertical and horizontal rays. Figure by author.

A topology is always a choice relative to a universe-set, satisfying some light conditions that enable a conversation built upon provable theorems. Note that the full space X and the empty set ø are both open and closed.

Certain kinds of topologies are more amenable than others to most intuitions. For example, you may expect that given any two distinct points a, b in X you ought to be able to find two open sets around each that do not meet, that is, that they can each be contained in their own bubble. But it may be that the elements (points) of a topology are all entangled in some way (e.g. if they are the rays that meet at the origin) and the set of sets declared 'open' is too sparse to separate these elements. One example of a very sparse topology would be the one in which the only open sets are the empty set ø, and the entire space X. No two distinct points are separated according to that pathologically sparse topology. (Mathematicians call such unpleasant and complicating situations 'pathologies', but have various ways to deal with them by construction and definition.)

Separability and Topological Spaces

To exclude such pathologies, we use the following

> Definition: A space X is *Hausdorff* (separable) if any two points a, b, are contained in disjoint open neighbourhoods U, V; denoted: $a \in U$, and $b \in V$, $U \cap V = \emptyset$. (See Figure 2.)

Although this may seem hardly contestable, not all topologies are Hausdorff.

An Example of a Non-separable (non-Hausdorff) Space. Define a topology on subsets of R^n, called the Zariski topology, by looking at the zerosets of polynomials. For a polynomial P(z) there are only finitely many points z in R^n, for which $P(z) = 0$. Call this set Zeroset[P]. A discrete set of points is closed in R^n, so its complement is an open set. But any two complements of discrete sets of points meet as subsets of R^n, so no pair of points in R^n can be separated by disjoint open sets in the Zariski topology, the family of sets that are defined to be open with respect to the Zariski topology of complements of zerosets of polynomials. (As an exercise, consider the space of all songs that are fixed by a finite set of word-positions, or named-pitches in fixed positions in the melody.)

Inducing a Topology: Revisiting Ellis Island

Consider again the flow of peoples into the United States over the past century, but consider an iconic slice through the flow of peoples at the event of their entry through the US Bureau of Immigration center at Ellis Island, New York. Consider the event of being examined by the state and given some status as an immigrant to the nation. In terms of topological dynamical systems this amounts to taking a *transversal slice* through the flow. This slice is called the Poincaré section (see Figures 3 and 4). (There is a constellation of concepts in differential topology and dynamical systems with which we can make this as fruitfully rigorous as any mathematical theory.)

And imagine some groupings that make sense in such a transversal section to the flow of lives through that place and event. Groupings could arise from one of any number of features: with whom one rubs shoulders in the waiting room, religious practice, exhibiting a medical syndrome, wealth or class, and so forth. Each choice associates the people into different collections of

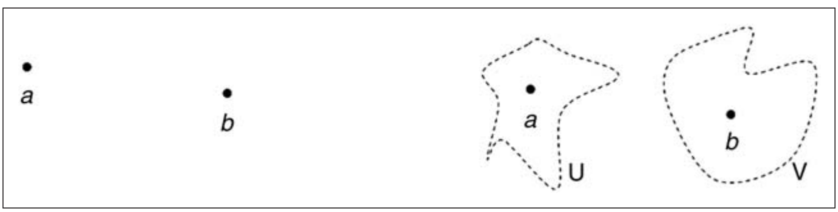

Figure 2. Hausdorff separability: any two points a, b, are contained in disjoint open neighbourhoods U, V, $a \in U$, and $b \in V$. Figure by author.

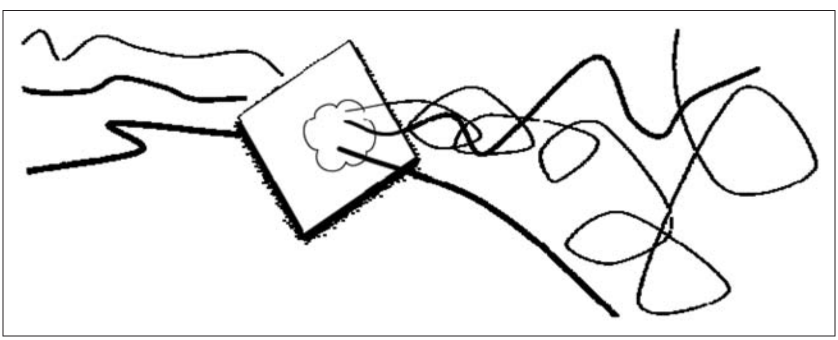

Figure 3. A Poincaré section through life courses as paths. Figure by author.

groupings and proximities, by no means spatial or metric. Consider colouring the life courses that run before and extend beyond this event according to some particular grouping. We can in principle colour the life courses by how they grouped on a particular day on Ellis Island. In the words of a student of topology, a topology on people intersecting the Immigration intake facility *induces* a topology on the set of life courses (see Figure 3).

Definition: A point z is a *limit* of an infinite sequence of points z_1, $z_2, \ldots$, if for every neighbourhood U containing z, there is some

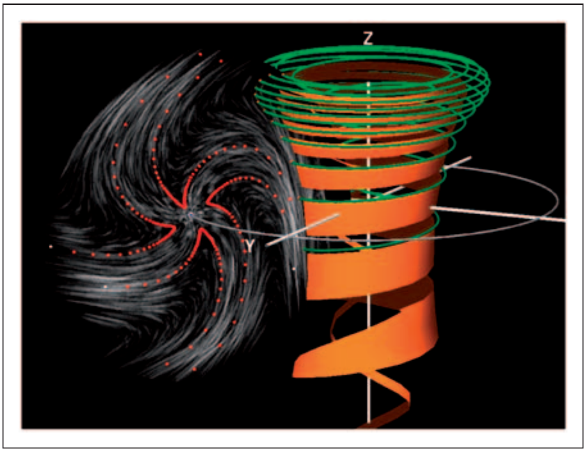

Figure 4. A Poincaré section through the flow of a dynamical system.
Source: H. Löffelmann, T. Kucera and E. Gröller, 'Visualizing Poincaré Maps together with the Underlying Flow'. Available at: http://www.cg.tuwien.ac.at/research/vis/dynsys/Poincare97/yellow.1024x768.fc.jpg (retrieved 24 May 2012).

Figure 5. Tree – arboreal; roots – rhizomatic; dirt – substrate.
Source: Available at http://upload.wikimedia.org/wikipedia/commons/6/60/Tree_roots_cross_section.jpg (retrieved 1 June 2012).

integer N, for which z_i are $\in$ U, for all $i > N$. In other words, no matter how you restrict attention around this point z, after ignoring finitely many points in the sequence, the remaining members of the sequence are all contained in the neighbourhood U.

Theorem: Limits in a topological space X are unique if and only if X is Hausdorff.[8]

Proof. We prove one direction: *X is Hausdorff implies that limits are unique*. Suppose x and x' are each a limit of the sequence $z_1, z_2, \ldots$. Let us suppose that x and x' are *distinct*. We will show that this yields a contradiction. Since X is Hausdorff, we can find *disjoint* neighbourhoods U containing x, and U' containing x. Consider U. By definition, there is a 'tail' of the sequence $z_1, z_2, \ldots$ entirely contained inside U. In other words, there is an integer N such that *all* z_k, for $k > N$ are contained in this neighbourhood U. But the same is true for U': there is a tail with an associated threshold index N' of the sequence $z_1, z_2, \ldots$ that is entirely contained in U'. Looking far enough out along those tails, we arrive at points z_k that must lie in both U and U'. (Just choose the index k greater than both N and N'.) But then U and U' are *not* disjoint. This contradiction shows that the hypothesis that x and x' are distinct is untenable. So limits are unique. QED.

Notice we proved that limits are unique, but not that a limit necessarily exists for any particular infinite sequence. Despite the most committed beliefs in a god, or an ideal communist or market economy, or Whiteheadean eternal object, the *existence* of a limit is a separate matter from its putative *qualities*. For example, we can say X is a closed curve whose tangent vector sweeps out a total signed angle of 7π (pi). However, one can prove that every closed curve's tangent vector sweeps out a total angle of 2π, so there are no such curves.

Returning to our demographic example, one could have a topology on the space of life courses that is not Hausdorff. This means that no two distinct life courses are contained in their own, disjoint neighbourhoods. For example, some ethical theories could amount to arguing that each open set of life courses overlaps with every other set of life courses. However, if the topology is Hausdorff, then *if* an infinite (or practically infinite) sequence of life courses has a limit – if there is some particular life course around which an infinite (boundlessly many) set of life courses cluster – then that limit is unique.

Notice that we can use the proof of the theorem in fact as the sketch of an argument, because the concept and the proof are quite supple and general. They rely on no notion of metric, no numerical measure, *no data*. Most significantly we have a mode of articulation of changes of state with no requirement that change be arrayed according to a unidimensional index called time, nor any dimensional index at all. Therefore the argument can be used in a great many material dynamic situations.

Covering, Basis

Given a subset Ω of the topological space X, a covering of Ω is a collection of open sets in X such that their union contains Ω. It is key that the sets be *open in X*. A covering does not have to be finite (or even countably infinite). For example, any subset S of a metric space, no matter how pathological (imagine a monstrously heterogeneous cloud of shards and dust like the set A in Figure 6), has a covering. Just take for the covering a set of epsilon balls centred on the points of S: $S \subset \cup_{z \in S} B_i(x)$. There are as many balls as there are points in S, so if S contains an uncountable number of points, then this covering has an uncountable number of balls. It does the job, but extravagantly, transfinitely.

A *basis* for the topological space X is a family of the open sets in X such that every subset of X has a cover comprising elements from that family. There can be more than one basis – usually an infinite number of bases – for a space X relative to a given topology.

Examples

> *Exercise*: Consider the topology T1 generated by open discs. Compare it with the topology T2 generated by infinite strips. In other words, is every set that can be covered by an open set in T1 also covered by an open set in T2?

It is not true that any family of subsets of a topological space V can be extended by arbitrary unions and intersections into a topology for V, even if the initial family itself contains an infinite number of sets and the union of the family has unbounded extent. Regarding the x–y plane as a subset of R^3, consider the family of sets generated by (countable)

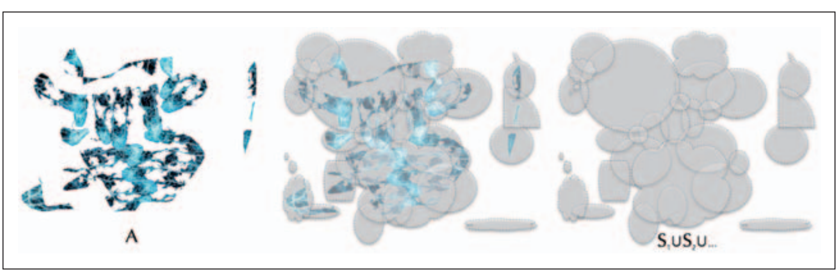

Figure 6. Covering a set A with a family of open sets $S_1 \cup S_2 \cup \ldots$. Figure by author.

intersections and arbitrary unions of subsets of the x–y plane P (the points <x, y, z> in R^3 such that $z = 0$). Any union or intersection of two subsets of P will be another subset of P. Now take a 'thick' subset of the full R^3, say the unit ball B centred at <0, 0, 1/2>, which intersects the plane P, but most of whose points are not in P. No union or intersection of planar subsets in P can cover the ball B.

Notice that these notions of openness and covering do not require any notion of dimension, so they are more primordial than dimensionality. *A topological space does not have to have the property of dimension!* But in the case that our topological space is indeed dimensional, in particular if it has the structure of a vector space like R^3, then we see that there is some deeper relation between a set's characteristic of being an open set and its dimensionality. Two-dimensional, in particular planar subsets of R^3 cannot be open in any topology on R^3.

Topological Vector Spaces

A vector space V is a set that has the structure of R^n, in other words its structure is isomorphic to the product of n copies of the real number line R. Therefore any element of such a space V can be indexed by an n-tuple of real numbers, that is, a vector of dimension *n*: $<x_1, x_2 \ldots x_n>$. Although a vector space may seem canonical in man-made parts of our world – witness the prevalence of table-based relational databases in our informatic technology – in fact, the ubiquity is itself an artifact of the convenience of a particular form of linear algebraic thinking.

Not All Topological Spaces Are Vector Spaces

A set (space) may not have any features that resemble a vector space. Christopher Alexander (2002: 143–242) identified 15 fundamental properties that appear over and over again in built spaces that have vitality. The more shape-oriented of these patterns include: *interlock*, *border*, *good shape* and, most importantly, *centre*. Of course, the space of features that build vitality is infinite and infinitely nuanced, and much more specific in every concrete instance, so how can we interpret Alexander's 15 patterns? One way is to see them as a basis in a subspace of the topological space of patterns of built structure. Certain patterns are indeed geometrical, or more accurately have to do with spatial relations such as degree or diversity of spatial rhythm, or the propensity to develop centres of tension or attention. Notice that, as is clear with the 'smoke' example, these patterns intrinsically intertwine the observer with the observed. Moreover, we do not necessarily have any notion of scaling a pattern, for example, a way to multiply the number of centres by some numerical constant, or otherwise numerically quantify a pattern.

So, while Alexander's 'space' of patterns does not seem to have the structure of a vector space (e.g. a structure of patterns naturally homomorphic with a notion of addition and of scalar multiplication), we can still interpret the foundational character of Alexander's 15 patterns in the sense of a covering generated by a particular family of patterns (subsets) in the space of all patterns of living in the built environment. But in order to articulate such a topological approach, we would need to articulate the intersection and union of two patterns. One obvious interpretation would be to logically combine them; for example, a design configuration that exemplifies both 'good interlock' and 'no two parts the same'. But another interpretation could be to first apply the *operation* of making a design have more interlock, and then to further individuate series. Indeed, given that Alexander emphasizes that his patterns are actually *transformations* rather than particular forms, the second interpretation could be a more plausible approach to topologizing an Alexandrian space of patterns. In that case, an open set of patterns would actually be an open set in the topology of transformations that can be applied to a built structure at a site. Again, recalling that there can be many topologies depending on the situation, we can retain a more supple approach to architectural design.

This emphasis on transformation, rather than 'things themselves', plus our previous discussion of dynamical examples, motivates the notion of mappings of topological spaces as a mode of articulation of material dynamical processes.

Mapping

Given topological manifolds X and Y we can define maps (aka functions, mappings) from one to another, f: $X \rightarrow Y$, as an association of elements of X and elements of Y: to every element x in X (written $x \in X$), we associate an element labelled f(x) in Y. The only condition is that the result of applying the mapping f is well defined; that is, that the result is determinate and unique for the given x. A rigorous test: if $f(x_1) \neq f(x_2)$, then $x_1 \neq x_2$ for any x_1, x_2 in X.

Given two topological manifolds M and N, consider the set of all mappings that in some sense respect the topological structure of these spaces. Approximately put, such mappings should carry open sets in the domain space M to open sets in the range space N. We call such mappings *continuous homomorphisms*, and we label the set of such mappings Hom(M,N). One particularly interesting, infinite dimensional subspace of Hom(M,N) is the set of differentiable maps Diff(X,Y) of differentiable maps from X to Y. (To define that requires some calculus, but for now, we will say that in the case X and Y are vector spaces, a differentiable function, at every point x, has some local approximation by a *linear mapping*.)[9] On top of Diff(X,Y), we can define further a mapping defined not on the base spaces X and Y, but on the function space Diff(X,Y). We'll call such a mapping an *operator* to help us remember that it maps a mapping to a mapping. An important example would be a differential operator like ∇ that maps a function *f* to its *differential*, a linear mapping ∇f from TM to TN. This provides an enormous expressive range to any analysis of transformation and functional change. You can see that this allows us to lift the discussion of mappings to a tower of structures, or to higher order operators.

Computer engineers, cognitive scientists and their clients in cultural studies or social sciences are typically quite cavalier about the domain or range of a mapping. But in order to make sense of a map *f*, it is necessary to ask: What is the domain of f? What is its range? For example, following George Lakoff one could define metaphor as a 'structural homomorphism' from one cognitive domain to another. But what does that mean? What is the structure? What is a cognitive domain? Is it like an open set in a topological vector space? If this metaphor is supposedly a map called, say, f, is this map non-trivial: $\mathrm{Image}[f] \neq ø$? Is it even well defined: $f(x) \neq f(y) => x \neq y$? One expects that a metaphor, if indeed it can be regarded as mapping, can certainly associate one entity to two or more entities, therefore such an association is not a well-defined mapping. So it is not clear what space, domain, mapping, or homomorphism mean, but it could be a fertile exercise to pursue this question furnished with topological concepts.

Continuous, Connected, Simply Connected

Gottfried Wilhelm Leibniz, one of the authors of the view of matter to which I am subscribing in this work, introduced a material law of continuity, which he described in a letter to Fontenelle in 1699:

> the law of continuity that I believe I was the first to introduce, and which is not altogether of geometric necessity, as when it decrees that there is no change by a leap. (Leibniz, 2006: 137)

This expresses an axiom about the fullness of the world, a world not atomic, but *plenist*. One way to introduce this idea is via a related concept of a simply connected set. Intuitively, we can say the set is simply connected if we can draw a curve between any two points in that set without having to lift the pen. But this is a *gedanken* test, a quasi-physical action to be imagined in order to determine some quasi-physical property. If the curve is broken, then one imagines there is a point at which the pen must be picked up off of the paper and set down somewhere else to continue the drawing of the curve – Leibniz's leap. But there are vastly different sorts of sets, not just curves, many for which it does not make sense to speak of dimension and which cannot be modelled by a two-dimensional sheet of paper. For example, consider the clouds in the sky, or the aroma of smoke, or the set of all metaphors. For such sets, we would need some concept that articulates the intuition of continuity more generally. Look more carefully at a (bounded) curve segment, broken at (at least) a single point. A disconnected curve is also the union of two open sub-intervals, or sub-arcs. It is this criterion that we can generalize to arbitrary sets: Can the set be decomposed into two *disjoint* open subsets? If each of the two covering sets is open, then we imagine that we can slip a boundary – a 'leap' – into the gap between them. So, a set is connected, by definition, if and only if it *cannot* be covered by two open subsets. The feature of connectedness has nothing to do with the unidimensionality of the curve. Notice that the set in question may or may not be open or look anything at all like an ordinary shape that you can draw; it could be rather messy, even pathological, as some mathematicians like to say.

This prototype criterion of connectedness induces in the imagination a transformation, a mapping, from one set, the interval, into another set, a curve that may be broken or unbroken. It is a subtle and profound shift of conceptual register to turn our attention from sets to the transformations of sets, to what is called a space of mappings. To articulate continuity, we really are asking a question not about a set (*an object*) $U \subset X$, but a mapping (*a transformation on objects*) between topological spaces, say φ: $X \rightarrow Y$. In this case, we say that a mapping φ from topological space X to topological space Y is *continuous* if and only if the pre-image of any open set in its range space Y is open in its domain space X; mnemonically, 'φ^{-1}[open] is open' – the pre-image of an open set is open. This is a considerably more expansive and supple test than trying to draw a curve in your imagination. This was one of the more subtle conceptual moves in the

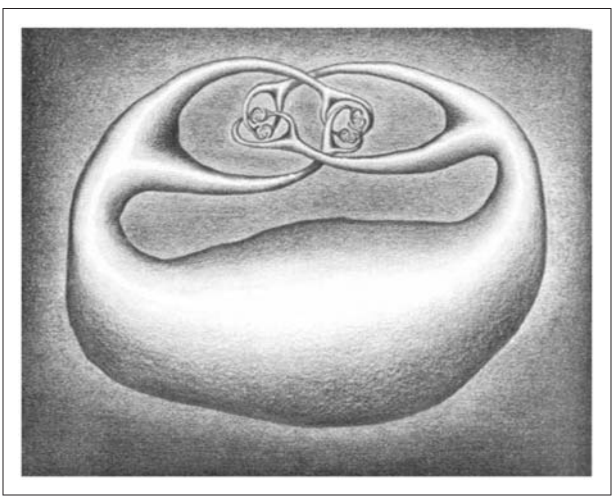

Figure 7. Alexander's Horned Sphere, defined by an infinite nest of ever-finer pincers, cuts R^3 into two components, one of which – the exterior – is not simply-connected. Source: *Notes on Algebraic Topology*, by Andries Brouwer, aeb@cwi.nl,v1.0, 991111, http://www.win.tue.nl/~aeb/at/algtop-5.html (retrieved 24 May 2012).

history of 20th-century mathematics, whose philosophical consequences we are just beginning to consider with this article. Such a concept of continuity offers us a way to begin to articulate continuity in the full extent of felt experience of the world without any recourse to metric or dimension.

Nonetheless, this notion of continuity agrees with the more familiar, restricted, metric concepts of continuity. For example, in the case of the real line R, a classical formal way of describing continuity is to use the ordinary Euclidean distance derived from absolute value on R. Here is a definition of continuity for functions of the real line that uses the notion of a metric: f is *continuous* at a point x_0 if for all $\varepsilon > 0$ there is a $\delta > 0$, such that $| x - x_0 | < \delta => |f[x] - f[x_0] | > \varepsilon$. (Glossing this more fully in English: If a point x is within distance δ of the fixed point x_0, then the value of f at x is within distance ε of the value of f at x_0.) The function f: $R \rightarrow R$ is called a *continuous mapping* if it is continuous at every point $x \in R$.

We can apply what mathematicians colloquially call an 'epsilon-delta' characterization of continuity to any function of the real line, but this requires at least some way of measuring the distance between any two elements of the set. You should draw some diagrams and convince yourself that this epsilon-delta definition of continuity agrees with the more purely topological notion of continuity. In other words, if a function mapping R to R is continuous in one sense, then it is continuous in the other sense as well, and conversely.

However natural this has become since Newton, a metric measuring the distance between any two elements of a set is often not evident in social and cultural phenomena. Moreover, demanding or imposing a metric introduces artifacts with political implications. Topology does not require a metric.

> *Theorem*. The image under a continuous map f: $X \rightarrow Y$, of a connected set K is connected.
>
> Proof: Suppose not. Then there are two disjoint open subsets of Y, call them V and W, such that the image under f of K is a subset of the union of V and W. (Written in more contemporary concision: $f[K] \subset V \cup W$.) Since f is continuous, by definition, the *inverse* images of V and W with respect to f – $f^{-1}[V]$ and $f^{-1}[W]$ – are both open subsets of X. We'll prove that these are disjoint, and cover K, which will contradict the hypothesis that K is connected. To show these two pre-images are disjoint, suppose p is a point in their intersection. But then f[p] is in both V and W, which cannot be the case, because V and W are disjoint. Therefore, their pre-images are also disjoint. Next, take any point *m* in K. By our hypothesis, the image point f[*m*] must be in either V or W. Therefore *m* is in the pre-image of V or of W with respect to f – $f^{-1}[V]$ or $f^{-1}[W]$. In other

words m is in the union of $f^{-1}[V]$ and $f^{-1}[W]$. We've shown that K is covered by these two pre-images, which are disjoint, open sets. This contradiction implies that our hypothesis must be false. Therefore f[K] is a connected subset of Y. QED.

Toward Topological Dynamics as an Approach to Social and Cultural Morphogenesis

Let us pause to see where we are and where we are headed. Based on some primordial concepts of open set, topology, basis, mapping, continuity, we have built up a miniature theory that allows us to describe phenomena in qualitative terms and make definite statements about them. These statements, being axioms and theorems, hold in all the situations where we have checked that the three basic conditions for a topology are satisfied. They are propositional in Isabelle Stengers' sense. Now we head toward building a trellis for describing dynamical systems, which are usually introduced as systems of differential equations, using such qualitative articulations. On one hand, we will be able to give a more delicate and concrete nuance to flow, change and becoming than what Deleuze and Guattari explicitly described, and on the other hand, we do not bind ourselves to numerical empiricism or to reductive forms like graphs. We are not furnished yet with the concepts to articulate these intuitions in detail, so we will defer this for a more complete description of dynamical systems and process another day. At the very least, we should recognize that the classical figures of the line, the circle, and the sinusoidal wave are not adequate to the temporality of human experience and phenomena. To more adequately address this takes us to a forthcoming work.[10]

So what, in sum, have we encountered from the beginning of this journey? (It is only a beginning.) We have a non-ego-based, number-free and metric-free account of experience that respects evidence of continuous lived experience but does not reduce to sense perception or ego-centred experience. We have an essential concept of continuity both as a quality of lived experience and as a mode of description of such experience. We have here the seed of an approach to poiesis and expressive experience that is 'non-classical' in the senses of quantum theory and measure theory, avoiding recourse to stochastic methods, statistics and informatic sweepings of the lifeworld under the rug. Yet because topological articulations admit metric measures as special cases, we can commensurate dynamical processes with metric, numerical measure when it is warranted, justified and practically feasible. Furnished with a topological alternatives to, or thickenings of, quantitative methods, we can, through particular studies such as the other contributions in this issue, build a new set of methods for cultural analysis that on the one hand mesh analytically with quantitative methods and on the other are more adequate to qualitative change, multiplicity and complex dynamics in culture. Consequently, we have the possibility of a radically de-centred, de-anthropomorphized concept of experience and cultural dynamics. This avoids methodological and critical problems with reductive modelling and the more canonical interpretations of phenomenology. And it provides a conceptual trellis for the condensation of subjectivity in the endless exfoliation of experience in the world.

Notes

1. 'Deleuze, Whitehead and the Transformations of Metaphysics', with Isabelle Stengers, James Williams, Mick Halewood, Steven Meyer and about 20 other philosophers, Royal Flemish Academy, May 2005. See Sha (2005).
2. As a term in humanities and social sciences, 'theory' lumps together a heterogeneous assortment of philosophical, historiographical, analytical, critical, psychoanalytical and other conceptual studies. But such a set of reflections, representing divergent and even incommensurable approaches to the diverse objects of literature, art, history and human experience, seems to create a set of all sets, that is, in fact an impossible object, a reification error. To a mathematician, the word 'theory' by itself has no meaning, it is always a theory of something: of Lie groups, of Riemannian manifolds, of currents and varifolds. There is no impermeable ontological or epistemic distinction between the objects and the modes of articulation of mathematics. This porosity implies a material continuity consonant with Badiou's lemma 'mathematics is ontology' (Sha, 2000).
3. A mathematical mode of articulation like topology or any field of mathematics is much more than merely a descriptive scheme. One can say surely and supra-individually what will follow from the given conditions. This additional expressive power of a mathematical mode of articulation derives from its structure as proof. But what mathematicians regard as proof is not what logicians or foundationalists call proof, because mathematicians rely on the accumulated body of intuition acquired in continuous streams of face-to-face apprenticeship together with not-necessarily computational calculations which fill in the potentially infinite gaps in between the steps of a mathematical proof. Mathematical proofs combine deductively, effectively and supra-individually.

   Gödel's Incompleteness Theorem does not invalidate this point because it does not contradict the correctness of a correct proof, or the collective truth of interdependent theorems relative to an axiomatic system. Gödel proved something far more radical than a simple – and naively untenable – refusal to acknowledge the validity of mathematical proofs. He demonstrated that in any mathematical theory that contains the logic of arithmetic one can construct a statement that is provably true, and provably false in that theory!
4. Isabelle Stengers writes:

   > In order to think abstractions in Whitehead's sense, we need to forget about nouns like 'a table' or 'a human being', and to think rather about a mathematical circle. Such a circle is not abstracted

> from concrete circular forms; its mode of abstraction is related to its functioning as a lure for mathematical thought – it lures mathematicians into adventures which produce new aspects of what it means to be a circle into a mathematical mode of existence.
>
> This is why Whitehead could write, in *Modes of Thought*, that 'The aim of philosophy is sheer disclosure'.... The aim of the abstractions that Whitehead designed is not to produce new definitions of what we consensually perceive and name, but to induce empirically felt variations in the way our experience matters. (Stengers, 2008: 96)

5. It should be unnecessary to say also that topology is not topography.
6. A much more powerful way to understand such trajectories is to regard them as orbits of points under the action of a Lie group acting on the given space M. Or, even more flexibly, as orbits under the action of a homeomorphism mapping M to M, h: $M \rightarrow M$.
7. Hayden prefaces her review of the technics and politics of similarity with an anti-Similares slogan: '¿Te curaste o te sientes similar? (Are you better, or do you feel similar?) (2007: 481–2).
8. When we say 'X is a topology', more precisely we mean X and a particular family of subsets of X that we declare to be open. Different choices of family yield different topologies on the same point set X. X could be (Hausdorff) separable with respect to one topology, but not with respect to another.
9. For vector spaces X and Y, over the scalar field R, a map f: X -> Y is *linear* if

$$f(u + v) = f(u) + f(v)$$

and

$$f(k * u) = k * f(u)$$

for any u, v in X, and any scalar k in R.

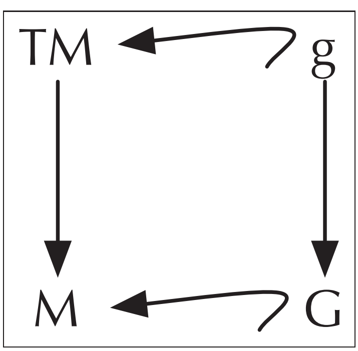

Figure 8. Lie group action on manifold M, lifting to their respective tangent spaces TM and Lie algebra g. Figure by author.

10. This project is the subject of a forthcoming book, entitled *Poiesis, Enchantment, and Topological Matter*.

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Topology, Algebra, Diagrams

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Abstract
Starting from Poincaré's assignment of an algebraic object to a topological manifold, namely the fundamental group, this article introduces the concept of categories and their language of arrows that has, since their mid-20th-century inception, altered how large areas of mathematics, from algebra to abstract logic and computer programming, are conceptualized. The assignment of the fundamental group is an example of a functor, an arrow construction central to the notion of a category. The exposition of category theory's arrows, which operate at three distinct but deeply interconnected levels, is framed by a comparison with the language and outlook of set theory founded on the concept of membership; sets and their theorization having provided, famously through the Bourbaki initiative, the basic ontological and epistemological vocabulary for defining and handling all mathematical entities. The comparison with sets emphasizes how categories offer a form of diagrammatic argument and thought against set theory's fidelity to syntax-based proofs; how categories invert set theory's priority of objects and their attributes over relations by making the relations of an object to others of its kin primary; and how categories replace identity, that is, equality, between objects, by the weaker notion of isomorphism, restricting equality to identity between arrows. The article concludes with a return to topology and some remarks about the question of its possible use in articulating/characterizing cultural dynamics.

Keywords
algebraic, arrows, categories, diagrams, sets

> Diagrams . . . for those capable of attention are the moments where being is glimpsed smiling. (Châtelet, 2000: 10)

What is a topological space? Two responses: one, palpable and familiar examples, the other abstract and alien.

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The first response visualizes movement in material space, bodies, concrete contours of shapes and figures: discs, circles, a Möbius strip, the surface of a sphere, a cylinder, a torus, a sphere with holes; a braid, a spiral, a knot threading through Euclidean space, perhaps a Klein Bottle. Topology studies the properties of spaces left unchanged by continuous deformations – stretching, twisting, folding, bending and so on. Two spaces are topologically identical – *homeomorphic* – if each can be deformed into the other. For example, the surfaces of a sphere, cube, pyramid are homeomorphic; a coffee cup is homeomorphic to a donut, a coffee pot to a donut with a tunnel (equivalently a sphere with two tunnels). Topology offers mathematical models of continuous analogue transformation in contrast to the discrete changes and discontinuities of digital models. Deforming one space into another exemplifies a fundamental fact: mathematical entities in general, not just topological spaces, are never isolated individuals: they belong to types or species or families of related objects to which they are structurally akin (of which more later) and their study involves the transformations between them that preserve their species kinship.[1]

The second response is the official, axiomatic definition. A topological space is a set X together with a family of its subsets – open sets – defined by the property that any finite intersection and infinite union of them is open; and a continuous deformation of spaces is a function f(x) from X to Y such that if f(S) is an open set in Y, then its inverse image $f^{-1}(S)$ is an open subset of X. This point-set formulation of an abstract or general topological space is the universally accepted mathematical definition of the concept. The definition is of maximum generality. It assumes nothing about the elements of X – they could literally be points in material space, or algebraic structures, or vectors, and so on – and nothing about the nature of the open sets beyond their definition. Moreover the 'space' is simply a set, a naked or featureless multiplicity: one cannot visualize it, nor does it make any reference to bodies or material space or physical movement. The idea of 'space' it offers, then, is unconnected to our palpable relation to curves and surfaces. It encompasses spaces with n dimensions and strange properties, spaces with an infinite number of dimensions, abstract spaces of functions such as Hilbert space, and so on.

Abstract Sets

The mainstream picture we have (have been given by the mathematical community) of mathematics since the early decades of the 20th century is couched in the language of abstract sets. By the late 19th century, Cantor's theory of a hierarchy of infinite sets with different infinite magnitudes had been accepted as legitimate mathematics, but not without the presence of paradoxes, such as 'Is the set of all sets which are not members of themselves, a member of itself?', which demanded an answer to the question: What exactly – rigorously – is a set?

In response, mathematicians axiomatized the concept by constructing a system of axioms whose intended objects were sets and whose only primitive, undefined relation was 'is a member (element) of'. The axioms posited the existence of certain sets – the empty set, an infinite set – together with ways of producing new sets from existing ones (power set, choice set) and conceived equality between sets extensionally: regardless of any intensive differences, sets are equal if every member of one is a member of the other. The axioms freed mathematics from the taint of paradox associated with the idea of 'set' and allowed mathematicians to extend the foundational project (already initiated by Weierstrass's arithmetization of a limit in terms of sets of points and Dedekind's definition of the continuum of real numbers as subsets of the rational numbers) to the whole of mathematics (Gowers, 2008: 771–2, 776).

A collective of mathematicians writing under the pseudonym Bourbaki initiated the project in the 1930s to do just that, producing over the following decades thousands of pages of rigorously re-written mathematics in which every mathematical object and relation is a set and every mathematical argument, construction and definition is translated into the language of sets subject ultimately to Boolean apparatus of logical quantifiers ranging over a universe of sets.

Ontologically, the enterprise successfully realizes a late 19th-century foundational desire, parallel to the contemporary atomism in physics, to identify the fundamental '*Dinge*' of mathematics. But its authors enclose it within an extreme, puritanical interpretation of mathematical rigour, according to which nothing – no notation, definition, construction, conjecture, concept, theorem or proof – is allowed to refer to or invoke or rely on any attribute, body or process of the physical world, not least any reference to the mathematician's corporeality. An interdict that – significantly, for reasons to emerge – applies to drawing diagrams but does not – how could it? – extend to writing, to the physical inscribing of material symbols by mathematicians. As a result, contrary to normal (naïve, unformalized) mathematical practice, which is rarely free of figures, not one of their thousands of pages, Bourbaki proudly declare, contains a single diagram.

Certain features of this set-based characterization of mathematics stand out. First, objects are primary, relations between them secondary. Although ontologically every mathematical entity whether an object (a number, group, topological space, vector, ordered set, matrix and so on) or a relation (a connection between objects, a function) is translatable into the language of sets, the ontology is not flat: the two are not imagined to be on the same level. Conceptually – epistemologically, definitionally – objects have a prior status: one defines a structure (a group, a space) as a set together with an operation on its elements or subsets, *then* one considers how, as an entity, it might be related to entities other than itself. The idea of a primacy of objects resonates with a recent initiative in contemporary philosophy, associated with Graham Harman (2005: 187–9), which he dubs 'a weird realism'. This is the project of 'object-oriented ontology' that 'features a world packed full of ghostly real objects signaling to each other from inscrutable depths, unable to touch one another fully'. Rejecting the doctrine that being and thought are the same, adhered to by many from Parmenides to Badiou, Harman is obliged to revive the problem of causation and 'reawaken the metaphysical question of what relation means'. The result is a post-Heideggerian phenomenology having little to do with set-theoretical mathematics.

Second, set-theoretic onto-epistemology is entirely intrinsic: objects are self-contained, isolated entities ultimately specifiable as structures of sets, their specific content an interior knowable without reference to that of any other object; a Platonic universe of ideal abstract multiplicities without histories or any relation to bodies. Translating the entire corpus of mathematics into the language of sets is an impressive and highly influential meta-theoretical achievement of 20th-century mathematics. It has dominated theoretical discussion of mathematics as well as the norms for 'correct', 'rigorous' presentations of the subject for a better part of the century. It is reproduced within contemporary philosophy beyond its purpose of securing a rigorous ontology for mathematics. For Alain Badiou it settles the question of ontology as such, ontology in general, by virtue of 'the equation that "ontology = axiomatic set theory", since mathematics alone thinks being, and it is only in axiomatic set theory that mathematics adequately thinks itself and constitutes a condition of philosophy'.[2]

The claim is contentious. Elaborating it would take us too far afield. Instead, we might note, by way of contrast, various examples of *extrinsic* relational approaches to the onto-epistemology of objects. Outside mathematics, in structural linguistics, the rejection of intrinsic content is precisely Saussure's turn from a referential understanding of language with 'positive' terms to one in which the value of an item consists of its differential relations with other items. On a different terrain, the shift from internal psychological structure to external social relations lies behind the varied formulations of the individual 'I' by Vygotsky, Voloshinov and Mead. In mathematics, before set theory's instauration, external relations (movements) govern Klein's *Erlanger Programm* of 1872, which classifies geometries not in terms of the intrinsic properties of the objects, the figures they study, but through external movements, the symmetry groups the figures conform to. In Poincaré's understanding of science it is the excision of the Kantian *Ding an Sich*: 'The things themselves are not what science can reach ... but only the relations between things. Outside of these relations there is no knowable reality' (1905: 2). I'll describe below a final, far-reaching example of an extrinsic epistemology of objects (one that arose in the wake of Poincaré's study of topological manifolds) provided by categories (see the section on 'Functorial Thought and Algebraic Topology').

Third, set-theory's foundational remit, its task of securing mathematics' ontology, is inherently formalistic. The signifier-driven Bourbaki programme of ensuring that 'naïve' mathematics be translated into a first-order logic and vocabulary of sets and membership assures its fidelity to a severely abstract, linear, logico-syntactical language and style of exposition, a language that obviously excludes diagrams. If one understands diagrams pictorially, as visible icons of ideas, their exclusion reveals an essentially iconoclastic dimension of Bourbakist 'rigour' that lies deep in Platonist suspicion of images. But, though visually apprehended, diagrams operate in a gesturo-haptic register, which points to another aspect of their absence from the Bourbaki pages. As we'll see later (see the section on 'Topology and Embodied Space') diagrams, according to Gilles Châtelet, play a pivotal role in mathematical ontogenesis, operating in the space between the body and the written – in the present case set-theoretically framed – symbol. From this perspective, the exclusion of diagrams both protects the purity of mathematical objects from any kind of physical or corporeal contamination and cannot but be silent regarding mathematics' becoming.

N-dimensional Spaces

Set theory's formal – a-spatial – definition of a topological space cited earlier proves to be powerfully suggestive. It allows one to abstract the spatial nature – extension and orthogonality – of the three axes of Euclidean space and treat them simply as independent variables, replacing three by n to produce an n-dimensional topological space that, in its natural formulation, is a *manifold*, meaning it is locally Euclidean – any small enough region of it can be continuously mapped onto a region of Euclidean space. An important subspecies of manifolds, *differentiable manifolds* (introduced earlier in all but name by Riemann), occurs when the mapping functions are not merely continuous but infinitely smooth, when they are differentiable in the sense of calculus, and so allow its techniques to be deployed in modelling the behaviour of material systems in time measured along the continuum (a one-dimensional differentiable manifold) of real numbers. Thus, given a dynamical system, it will have a number of degrees of freedom, independent ways it can vary, whose values are taken to constitute a full description of its state. For example, a bicycle has a number, say six, degrees of freedom, so its behaviour in time, the smooth changes in its state, can be understood as the path of a single point in a six-dimensional differentiable manifold whose topological structure is given by the differential equations and vector field which the degrees of freedom satisfy. In this way, the dynamic behaviour of any physical process can be modelled as the path of a point in an n-dimensional space. According to Manuel DeLanda (2002), such a topological account of material change, coupled with symmetry-breaking discontinuities, offers a precise working out of the dynamic underlying Gilles Deleuze's (1994: 214ff.) account of becoming, of the ontogenesis of the actual, the material world of bodies and physical processes, from the virtual.

The topological vocabulary of n-dimensional differentiable manifolds – orbits, attractors, basins of attraction – bundled together with the (quite different) theory of chaos and fractals is widely evoked. But one can ask two questions about the appropriateness and cultural utility of this approach. First, how suitable is the concept of independent 'degrees of freedom', derived from modelling the dynamics of purely mechanical systems, for theorizing the modes of variation of *cultural* apparatuses? Second, does the approach go beyond a physics of culture, a science of its material forms? Even if one assumes its total success in capturing physical dynamics, why should the topological vocabulary on offer, based as it is entirely on differential equations and the techniques of calculus – the science of extensive, material change – have more than a limited relevance for the *intensive* phenomena and their dynamics operating in the socio-cultural universe? Certainly, one doesn't, except within quantitative forms of sociology (statistics, sociometrics), physical geography and so on, find much use for models based on numerical or metric concepts, let alone calculus, in the literature of social and cultural theory. What, in any event, do infinitely smooth functions and the discrete infinity of numbered points on the one-dimensional continuum have to do with social time and cultural temporality? And why should time be modelled as a set of points along a line?[3]

Functorial Thought and Algebraic Topology

But topology, the mathematics of continuous transformations, is inherently indifferent to questions of measurement (differentiable or otherwise). Its interest is with shape, with the spatial characteristics of a topological space. Presented with a surface, for example, it asks: Does it have one or more holes? Does it have an edge, a boundary? What curves if any can be drawn on its surface? What are its formal properties? For surfaces of dimension higher than two – because they can't be visualized as objects in familiar three-dimensional sensory space – answering such questions requires new methods, methods pioneered by Poincaré for the case of manifolds. Manifolds are a fundamental species of topological space. All the familiar curves, knots and surfaces we began with are one- or two-dimensional manifolds. Poincaré, investigating the properties of three- and higher-dimensional manifolds, introduced in 1895 a radically new concept, the *fundamental group* of a manifold, initiating what came to be called algebraic topology, a field joining algebra and topology at the centre of contemporary understanding of the concept; and the field, as we'll see, wherein the set-theoretical understanding of mathematical objects is revealed as conceptually inadequate.

Because they are locally Euclidean, one is able to define 'paths' in manifolds. Poincaré's invention was to construct an algebraic object, namely a group, from classes of closed paths – loops – in a manifold. One picks an arbitrary point p in a manifold M and then considers all loops starting and ending at p. If a loop can be continuously deformed into another loop the two are identified as members of a single class. This leaves a set S of classes of loops through p not deformable into each other. A binary operation, composition of loops, is defined on S making it into a group – the *fundamental group* G(M) of M.

The assignment of the fundamental group to a topological manifold (akin to the 17th-century assignation of an algebraic equation to a geometric curve) allows manifolds to be conceptualized in terms of group properties. This is because G does more than assign a group to a manifold; it assigns group homomorphisms to continuous functions and it preserves the latter's connections: if two functions compose, then so do their corresponding homomorphisms.[4] This means that topological properties and relations can be *systematically* translated into those of groups, which was Poincaré's intention, namely, thinking topology algebraically.

Poincaré's approach – finding invariant aspects of a space alive to algebraic formalization – is surely suggestive. Invariants are as important to transformations of social and cultural space as they are within mathematics and their dynamics will likewise exhibit structural features. Thinking algebraically, then, might be a fruitful route into the topology of sociocultural phenomena. Whether this is so is an open question since algebra, at least so far, is a little used resource in the toolbox of the social sciences.

The question arises as to whether the systematicity of this translation, a higher-level phenomenon that emerges from the interaction between algebra and topology, can be articulated within the set-theoretical language which defines and circumscribes them. A negative answer to this question – the recognition that a new language was needed – crystallized in the 1940s when Samuel Eilenberg, a topologist, observed to Saunders Maclane, an algebraist, that the latter's calculation of a certain algebraic structure looked identical to a calculation in topology of a well-known homology group. Out of their joint attempt to say why this might be and to understand what mathematical moves were common to the two calculations, they formulated a language of what they dubbed 'categories' – a diagrammatic language of arrows and configurations of arrows that in the 60 or so years since its formulation has more than accomplished what they had in mind, leading not only to a re-writing of algebra and topology and their relation but to a radical impact on the theory of programming as well as a geometrical reformulation of mathematical logic.

What is a category? A category is a collection of objects A, B, ... and arrows or *morphisms* A → B from a source object A to a target object B, obeying a few simple axioms, namely, arrows A → B and B → C can be composed to form a new arrow A → C, the operation of composition is associative, and every object has an identity arrow which leaves any arrow with which it can be composed unchanged.[5] Each axiom can be expressed equivalently as an equation or as a commuting diagram of arrows. The components of a category are objects, arrows, composition of arrows and equality between arrows. It is widely believed that these four concepts are sufficient to encompass all mathematical structures in the following sense: 'To each species of mathematical structure, there corresponds a category whose objects have that structure and whose morphisms preserve it' (Goguen, 1991: 3). Some examples are: the category SET has sets for its objects and functions on their elements as arrows; the category GP of groups has objects, groups and arrows as homomorphisms; the objects of the category TOP are topological spaces with arrows continuous transformations. Any kind of mathematical entity – a function, relation, graph, geometrical object, a family of sets, and so on – can, with appropriate arrows, serve as the objects of a category.

In particular, and importantly so, the objects of a category can themselves be categories. In this case, the arrows of the larger category of categories are called *functors*. Functors, arrows between categories, are functions of two variables, sending objects to objects and arrows to arrows in such a way that composition relations between arrows are preserved.[6] The originating concept of algebraic topology, the assignment of a fundamental group of a manifold, is a functor from the category MAN of topological manifolds to the category GP of groups. Functors are the nuts and bolts of category-theoretic thinking, and relations between them are important, prompting them to be considered as objects in a category of functors. Relations between them, the arrows in this new category, are called *natural transformations*.[7]

Categories contrast to set-theoretical framing of mathematics in two respects. First, prioritizing arrows over objects mandates an exterior epistemology in contrast to the interior version built into set theory. Unlike the set-based version, an object in a category is understood relationally, through external difference, not as an autonomous, internally structured entity; it is known and constituted entirely in terms of the arrows entering and exiting it from other objects. In other words, categories think a mathematical object from the outside, in a 'bio-social' register from species to individual, and not as an isolated, self-contained entity whose relations to others proceed from the inside out. In this categories echo the external, sociologized epistemologies of Saussure and others, mentioned earlier.

Second, in contrast to the fixity of sets and the membership relation, arrows and composition connote movement or transformation.

Categories deliver a dynamic logic through schemes of arrows that allow mathematics to be understood and practised as diagrammatic thought. Diagrams, interdicted by the Bourbaki enterprise as un-rigorous and extraneous to mathematical content, are not only a legitimate constituent of categorical language but are the means of definitions and proof. Categories also constitute, in their operation as an algebraic formalism, a species of structuralism. Not in the dominant mid-20th-century sense associated with Lévi-Strauss who derived it from the linguist Roman Jakobson. For Jakobson speech is constituted from pairs of binary oppositions (vowel/consonant, acute/grave) that operate together to form triangular phonological structures. Lévi-Strauss transferred this schematic from phonology to anthropology producing, for example, from the binary oppositions culture/nature and normal/transformed applied to food the triangle of the raw, the cooked and the rotten. Not, then, the structuralism founded on oppositions between yes/no properties compatible/complicit with the set-theoretic thinking of the period, with its ontology of identity and pure unchanging 'being' wedded to a binary logic of excluded middle. Rather, a mobile structuralism of n-ary relations and transformations, a mathematical universe of things-in-formation.

The language of categories has successfully colonized large areas of contemporary mathematics, including the study of topology. The two contrasts with set theory indicate why categorical language might be a more relevant and interesting way of thinking for social and cultural theory in relation to topological spaces than that offered by the set-theoretical model of point-set topology. One can add a programmatic point. A category is a multiplicity, a family or species of kindred objects understood relationally and not as isolated individuals. It would be surprising if the theory's success as a transparent language of mathematical structure had no transfer or application to questions of structure and relationality within social and cultural multiplicities One possibility: adapt Poincaré's approach and formulate functors assigning algebraic structures – invariants – to the topological transformation of multiplicities. But again, given the dearth of algebraic thinking within socio-cultural theory (a reaction perhaps against the crudity of set-theoretic structuralism), it is difficult to evaluate the feasibility of the suggestion.

Topology and Embodied Space

That categories deploy diagrams in a substantive way differentiates them from set theory, but conveys no hint of a deeper sense of diagrams, namely, the pivotal role they play in mathematical ontogenesis.

According to Deleuze, there are two poles of mathematical activity: what he terms the axiomatic, articulated here as the translation of mathematics into axiomatically based structures of sets; and the problematic pole, according to which mathematics is produced in response to problems (inside and outside mathematics) whose solutions account for the ontogenesis and character of these very structures. For Châtelet, diagrams coupled with gestures are the very means of ontogenesis, a principal strand in the becoming of mathematical ideas, objects and relations. Refusing the Aristotelean division between movable matter and immovable mathematics, Châtelet insists that mathematics can neither be divorced from 'sensible matter', from the movement and material agency of bodies, nor from the contemplative, a-logical and intuitive operations of thought: it combines them as 'embodied rumination'. He offers a material/corporeal account of mathematics, wherein gestures – which arise from 'disciplined distributions of mobility' of the body – are the physical vectors of mathematical thought. A gesture is not referential, it doesn't 'throw out bridges between us and things' and it doesn't operate along predetermined routes – 'no algorithm controls its staging'. Gestures are not conscious, intentional acts: 'One is infused with a gesture before knowing it.' Gestures are not communicative acts by an individual 'mind': they are outside – before – the domain of signs, not subject to a pre-given signifier/signified code of interpretation. The gesture's mode of meaning is enactive, it performs: it is a material event that engenders mathematical substance by virtue of occurring. It *expresses* thought, as Deleuze would say.

Diagrams arise in the wake of gestures, and they facilitate other gestures. A gesture arrested in mid-flight creates a diagram, a movement captured ahead of itself: 'A diagram can transfix a gesture, bring it to rest, long before it curls up into a sign.' And it is the source of – 'it cuts out' or 'alludes to' – another gesture. Gestures and diagrams are inseparable. Diagrams/gestures operate in a pivotal space: they are embodied acts that bridge the gulf between thought and the sign. On one side: intuition, a-articulated images, and rumination; on the other: syntax, representation, symbols. Observation in the mathematics classroom reveals the impulse to gesture and to draw diagrams as ever-present in learning and solving problems. This being so, one would expect a Châtelet/Deleuze account of embodied ontogenesis to provide useful insights for pedagogical research. Such proves to be the case; a contemporary study concludes that students' diagrams are 'precisely what Châtelet found in historical developments in mathematics: inventive "cutting out" gestures that interfere and trouble assumed spatial principles . . . and [which show] the emergence of new perspectival dis-symmetries within the given surface'.[8]

Gestures of the body, disciplined mobility in space, figures and their deformations, lie at the origin of topological thought. Châtelet's work suggests the possibility of accessing the intrinsic corporeality of topological ideas through a kind of reverse engineering: retrieve the gestures that have been operationalized/internalized into symbols, make the problems they respond to and the intuitions guiding them physically explicit within a material context. Of course, many kinds of artwork incorporate topological and geometrical ideas in material form, but they do so implicitly in the service of aesthesis and not as an explicit retrieval of an abstract, operationalized gesture. There are, however, conceptually motivated rather than artistic examples that might be noted. Here are two.

The hyperbolic plane is an abstractly defined mathematical object, a non-Euclidean surface whose curvature, opposite to the everywhere positive curvature of a sphere, is everywhere negative. A recent project shows how negative curvature, 'the geometrical equivalent of negative numbers', occurs naturally within the process of crocheting: if one increases the number of stitches in successive rows the resulting crocheted object curls inward and exhibits a negative curvature; one materializes in crocheted form the topology of a hyperbolic plane.[9] Alternatively, rather than manually produced material objects, one can materialize a mathematical concept through physical performance. For example, as we have seen, the commuting diagrams of category theory are patterns of arrows that capture mathematical concepts. Interpreting arrows topologically, as movements of bodies in space, together with suitable physical correlates of composition and equality of arrows, delivers a movement scheme for a dance. Even simple concepts – counting and the ordinal numbers it produces – have interesting enough diagrams of arrows for the idea to work, as was recently demonstrated by the performance of a movement piece, *Ordinal 5*, based on the commuting diagram for the number five conceived in category theoretic terms.[10]

Observe in conclusion that locating topology in relation to the sensory modalities and activity of bodies is where we came in, with a picture of topological spaces as palpable spatial entities – Mobius strip, sphere, Klein Bottle, knots and so on. All known and studied in the period before set-theoretical thinking rigorously excluded the body. If, with Châtelet, we accept the corporeal dimension of mathematical concepts, we might return to these palpable – gesturally accessible – origins and seek to extract topological concepts from them, hopefully ones of interest to social and cultural theory.[11] For example, knots (and one is reminded of crocheting), which are an object of much contemporary research, offer a rich and heterogeneous site of topological complexity.[12]

It would seem that simple one- and two-dimensional surfaces are surprisingly useful sources of topological, culturally interesting insights. Thus, as Sloterdijk has demonstrated in his study of sphericity, even the sphere, as banally familiar and simple a surface as one can imagine, can give rise to a topologically framed, philosophical anthropology, an existential account of spatial being, in terms of enclosures, containers, bubbles, globes and foam.

Notes

1. In algebra, homomorphisms. For example, if A and B are groups with an operation of +, a homomorphism is a function f from A to B that preserves the operation, that is, f maps x + y onto f(x) + f(y). For vector spaces, functions from one space to another which preserve addition of vectors and scalar multiplication are linear transformations; and so on.
2. See Smith (2004: 78), where Badiou's 'meta-ontological' claim is exposited in relation to Deleuze's opposing view of multiplicities.
3. The question is outside the topic here, so a brief response by way of two ways of challenging the one-dimensional continuum model of time. Far from infinite smoothness, the time-line might be discontinuous, infinitely un-smooth, composed of ever-smaller bits, its dimension a fractal, so that 'linear', successive time could have a fractal dimension that hovered (perhaps indiscernibly) around 1, or at a perceptible difference from 1. Or, abandoning a line entirely, time could be conceptualized as a surface, a fully two-dimensional temporality yielding non-linear space-like possibilities of 'succession'. For example, time might be imagined, Michel Serres suggests, as a 'crumpled handkerchief', thus opening the possibility of distant moments being in close temporal proximity to each other. There are two philosophical concepts of time: metric time, the one-dimensional irreversible medium in which all material and immaterial processes take place. Virtual time, expounded by Deleuze, as that from which time is expressed, a becoming inseparable from these very processes. Fractal time and two-dimensional models of time differently problematize the dimensionality of the former.
4. In other words, G is a particular kind of function from topological spaces to groups which preserves composition of continuous functions, meaning that the image G(f * g) of a composite of continuous functions f and g is the composite G(f) * G(g) of their images G(f) and G(g).
5. Axiom 1: Composition. If f: $A \rightarrow B$ and g: $B \rightarrow C$ then there exists a composite arrow g * f from A to C. In other words, categories are closed with respect to concatenation of arrows.

   Axiom 2: Identity. Every object A has an identity arrow idA such that idA * f = f * idA = f for any arrow f. In other words, idA is to the operation * what 0 is to addition and 1 is to multiplication.

   Axiom 3: Associativity. The operation of composition is associative. If f: $A \rightarrow B$, g: $B \rightarrow C$ and h: $C \rightarrow D$ then f * (g * h) = (f * g) * h. In other words, the two possible paths from A to D are the same.
6. The double action of a functor G from a category C to category D goes as follows. G maps objects X and Y of C to objects G(X) and G(Y) in D. G maps arrows f: $X \rightarrow Y$ and h: $Y \rightarrow Z$ in C to arrows G(f): $G(X) \rightarrow G(Y)$ and G(h): $G(Y) \rightarrow G(Z)$ in D such that composition of arrows is preserved. That is, the G-transform of a composite G(h * f) is equal to the composite G(h) * G(f) of G-transforms (Figure 1).
7. As an arrow between functors, a natural transformation must satisfy two objectives. If G and H are functors from C to D one needs to compare their images, that is, relate G(X) with H(X) and G(Y) with H(Y) as X and Y range over C. And one needs to compare the action on the arrows between

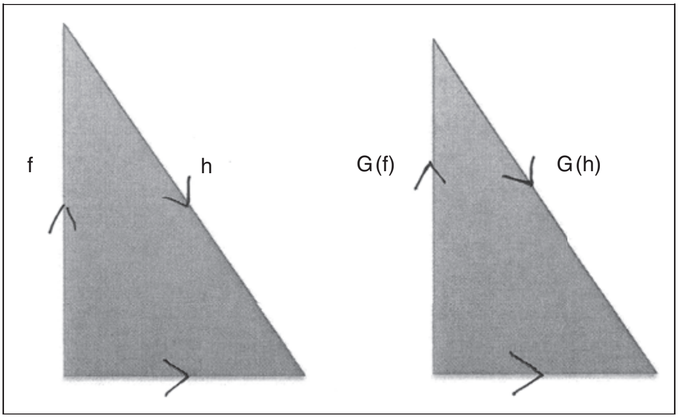

Figure 1. A functor G from C to D.

the objects of C. We can only do this via a family of arrows in D – an arrow μX from G(X) to H(X) for each X in C. But G and H as functors also assign arrows in D to those in C. The naturality condition ensures that the two assignments of arrows are compatible. Functors can go in opposite directions. G might assign a group to a manifold and H a functor in the reverse direction, assigning a manifold to a group. In general such functors will not be opposites or inverses of each other but various conceptual versions of these; the concept of adjointness captures such an idea. A basic example: if G is a forgetful functor then F, a functor which produces the freest structures possible that could have been forgotten by G, is adjoint to G.

8. See de Freitas and Sinclair (2011: 18). This is an empirically based study of Châtelet's ideas framed within Deleuze's conception of mathematical thought. It is elaborated in the context of communication in de Freitas (to appear).
9. There are now large-scale, communally produced crocheted artifacts, fashioned after naturally occurring surfaces such as coral reefs (Wertheim et al., 2004/5).
10. Conceived by the author. Performed at the Tate Modern, 19–20 November 2011. See Julian Henriques (2012) for a full report of the event and the topological sound art that accompanied it.
11. The impulse here to return topology to a founding material and spatial intuition is pursued very differently in Richeson (2008), who presents the subject as growing out of and responding to Euler's formula connecting the vertices, faces and edges of polyhedra.
12. Lacan, for example, who incorporates topological concepts throughout his work, advocates a knot-based model of psychic structure based on the Borromeo knot. See Ragland and Milovanovic (2004).

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Deforming the Figure: Topology and the Social Imaginary

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Abstract

Topology is integral to a shift in socio-cultural theory from a linguistic to a mathematical paradigm. This has enabled in Badiou and Žižek a critique of the symbolic register, understood in terms of pure conceptual abstraction. Drawing on topology, this article understands it instead in terms of the *figure*. The break with the symbolic and language necessitates a break with form, but topologically still preserves a logic of the figure. This becomes a process of figuration, indeed a process of 'deformation'. Badiou/Žižek will then presume a break with the symbolic for 'the real'. But topology entails the centrality of not the real but the *imaginary*. With Castoriadis, this imaginary is understood as productive and social, and with Sloterdijk as spatial. In our times this is a self-organizing socio-technical imaginary. For Niklas Luhmann these socio-technical systems engage in coupling. They structurally couple with other social imaginaries. Their self-organization, going beyond pure functionality, operates through semantic excess: an excess that organizes the system and is their structure. Such structural coupling entails semantic exchange, consisting of not just information but also of images.

Keywords

figure, form, social imaginary, structural coupling, symbolic, topology

In what follows I want to address *topology*. It is widely agreed that topology is, in the first instance, less temporal than spatial. Topology takes us beyond the classical object and indeed beyond the classical subject. The classical object that we encounter – as most forcefully and powerfully delineated by Kant – is a form in something like a 'container space'. As such it is 'topographical'. Topology will take us beyond this classical object and form. Yet it will remain geometrical and spatial and

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as such does not take us beyond the *figure*. It will indeed give us a new paradigm of figure and object that is beyond form: a process of figuration, an object that is constantly in *deformation*. As spatial, as figural, topological objects seem most prone to relate to, to 'couple' with, a particular mode of subjectivity. This is a mode of subjectivity in which the *imaginary*, rather than the real or the symbolic, is the most prominent dimension. If the symbolic and the real work most pronouncedly in the register of time, it is the imaginary that is the most spatial of our faculties. It is the imaginary that encounters the object in its spatiality.

Many contemporary cultural thinkers, most notably Alain Badiou and Slavoj Žižek, as well as a number of conceptual artists, suggest that contemporary subjectivity engages with objects that are beyond experience. These authors take us beyond experience to an infinite temporality. They understand what is at stake here as a multiplicity of the *real*. I will insist, to the contrary, that topological thinking, and the topological character of so much of contemporary culture features not the real, but instead the *imaginary*. Let me make two preliminary points about the imaginary. First, if Emile Durkheim introduces culture as a question of the *social* symbolic, then as we will see below, it makes just as much sense to talk about a *social imaginary*. Second Durkheim's symbolic functioned primarily to more or less stabilize and reproduce social relations. Such is also the case in Lacan's psychoanalytic theory, both of the symbolic and the imaginary. In what follows I will identify two imaginaries: on the one hand, a 'reproductive' imaginary that is ensconced in the functioning of capitalism and the dominance of the commodity, and, on the other, a 'productive imaginary'. This article will focus on this topological and productive imaginary, which is, I will suggest, at the heart of contemporary subjectivity. This imaginary is social and technological, and is engaged with topological objects. It is at the same time experienced and beyond experience.

At this juncture I need to be clear about my aims in the following. I am not making primarily an argument for the priority of space over time. Indeed the sort of self-organizing and co-evolutionary topology described below is also profoundly temporal. Topological objects do not, I will maintain, exist in time and space. Through their own energetics, they drive their own space and time. Topological space in its own self-transformation must be simultaneously temporal. My aim in this article is thus not to separate space from time, but to use notions of space to better understand the figure – or process of figuration – that is at the heart of topology, which, in turn, is tightly bound up with the imaginary, the social imaginary and its empiricist or *a posteriori* mode of operation. The complex of keywords in this is topology, the social imaginary, the figure and their, not rationalist but consistently inductive, empiricism. These elements work largely spatially, but a metaphysics of space is not at all at the centre of my argument. Indeed, though I will use the notion of the imaginary in a predominantly spatial and hence figural sense in this article, I am well aware of the temporality that is also driving the productive imaginary. Indeed this productive imagination *is* time in Heidegger's *Being and Time*. Heidegger spends the entire second half of *Being and Time*'s companion volume, *Kant and the Problem of Metaphysics*, explicating this. But I want to break with the rigorous *a priori* of Heidegger's imaginary for an empiricist imaginary: one that works less through some kind of transcendental argument than through imagings, mirroring, imitation – an imaginary that is fundamentally thus figural.

Topology: Mathematics and Figuration

Why 'topology'? Topology is integral to the 'mathematical turn' in cultural and social theory. In cultural theory this is associated first and foremost with Badiou's (2006) focus on post-Euclidean mathematics. As human beings begin to think in abstractions, they do so not just linguistically but mathematically. This is the case not only in the West, starting from the Pythagorean School, but also in Indian thought and the Arab world. Thought has thus historically been mathematical, linguistic and religious (Collins, 1998). Now, once again, we do not want to think, culturally or social scientifically, via only language or linguistic symbols but also via mathematical and religious symbols. Badiou (2004) has famously rejected what he sees as the 'sophism' of 'linguistic' thought for the truth instead of the mathematical. At the same time he has addressed the religious and the universal in his book on Saint Paul (Badiou, 2003). The point for us is that Paul's strongly ontological Christianity most fully breaks with experience. The Synoptic gospels, Matthew, Mark and Luke, focused on the evidence, the miracle-based experience of possible redemption. In contrast, the Gospel of John and the thought of Saint Paul were focused on the beyond-experience, the Christian infinity of Death and Resurrection. For Badiou mathematics, since Georg Cantor's scientific revolution, is important because it addresses infinity in nature: that is, it addresses natural infinities. These natural infinities take Badiou beyond an ontology and a politics of experience. When he addresses the religious, he does so to better engage with the infinite.

A half-century ago there was a similar turn of theory towards the realm of mathematics. Then, Cornelius Castoriadis and Jean François Lyotard, as well as Gilles Deleuze, were involved in debates in the context of the Bourbaki group in French mathematics. Again at stake was post-Cantorian mathematics. In *The Critique of Pure Reason*'s transcendental aesthetic, Kant understands time and space in terms of objects of experience. Thus knowledge depends on an experience of time in terms of algebra, in which numbers are the objects of experience, and space in terms of a Euclidean geometry, in which forms are the objects of experience.[1] Cantor's set-theoretical revolution brings us to an encounter with a not theological but natural infinity: an infinity of infinities. Thus mathematics can be understood as beyond experience and beyond the object. This is the basis of Badiou's critical theory. But its focus is temporality. Similarly with space there is the development of Riemannian geometry and topology, which takes us beyond Euclidean form into what Manuel Delanda (2002) has understood as 'intensive science'. Thus mathematics leaves the realm of social science positivism and instrumental rationality and becomes also a basis for critique.

We also see the importance of mathematics in cultural theory in the Kabbalistic thinking of Benjamin, of Gershom Scholem and indeed of Kafka. The messianic, the eschatological, of early Christianity is beyond experience. We encounter such Kabbalistic as well as Gnostic thought in Scholem and Hans Jonas (Handelman, 1991). Benjamin, through his breaking with (Kantian) experience, notably in 'On Language as Such and on the Language of Man' (1996b) and 'Critique of Violence' (1996a), developed such a critical eschatological politics. Benjamin, aware of his own effective innumeracy, deferred to his friend Scholem's mathematical eschatology. In Kafka's 'angelology', Benjamin observed there is hope, but not for us: there is hope only for the angels. Michel Serres' angelology (1995), which is at the same time a theory of information, has its roots in his own mathematical thinking (Serres, 1968). As in Scholem, so in Serres, mathematical thought is not just very different from the more instrumental quantitative positivism of most of social science, it also is explicitly a critique of Newtonian and Kantian experience. Thus we can understand Serres' magisterial Doctoral d'Etat dissertation on Leibniz's mathematical models: if Newtonian mathematics were epistemological, then Leibniz's calculus was *ontological*. For Leibniz and Serres, mathematics deals with the very structure of being.

This said, topology does not repeat the Deleuzian prism of virtual and actual. In this model we experience an actual which is generated by the virtual. Thus in the calculus-modelled process of differentiation and integration in Deleuze's *Difference and Repetition* (2004) we encounter the virtual and the actual. Similarly, in Friedrich Kittler's (1997) media theory, the algorithm generates what we experience on our screens. In topology, the virtual does *not* generate the actual. Instead there are topological surfaces and the topological figure. You cannot speak of a virtual figure or virtual surface because the virtual is not experienced and, on the contrary, generates the figure (surface). Topological entities instead *deform* into one another. I will want to define the topological object thus as a *space of deformation* (Günzel, 2007: 21). For example, a circle and a square are topological equivalents. They are not topographically equivalent, yet they belong to the same topological set. This is the set of their shared properties, such as being planar and having an inside and outside separated by a boundary. By definition, topological objects can be stretched or twisted into one another, but they cannot be torn or cut, as in the famous example of the donut that deforms into a coffee cup. So, unlike the virtual, which is beyond experience and the experienced actual, topological figures cut across the distinction of the virtual and actual. The movement, the process at stake is not the generation of an actual by a virtual, but the deformation of, as it were, two actuals into one another via their topological properties. For our purposes, then, the topological, unlike the virtual, is constitutively figural.[2] The topological object is a process, a space of figuration. This point is at the heart of this article. Because the virtual is beyond the actual that it generates, the virtual must belong to a problematique of the real. Because the topological objects are figures in deformation, they must belong to a paradigm of the *imaginary*.

Equally as important, topological space must be understood as not *topographical* space. A topographical object is a form, a fixed form. The topological object is anti-form, in-form, *de*-form. Topographical objects are located in, move in (topographical) space. Topological objects are not located *in* space at all. Topological objects *are* spaces. Topological objects do not move in space. They are instead spaces of movement. Topographical objects are forms that move in space. Topological objects are not forms, but themselves spaces: spaces of deformation. Here the single and three-dimensional as it were 'container space' of Newtonian physics and Kantian experience splinters into the multiplicity of spaces (Günzel, 2007: 23). In Kant's Transcendental Aesthetic, space is exterior to – and time is interior to – subjectivity: to the unity of apperception. In this context, topological space is the form that intensifies, that infolds into the figure. For its part, the transformation of time works on the lines of McLuhan's sensorium that is externalized into the global media environment. Thus time exteriorizes from the inside of the subject: the single Newtonian time of Kant's subjective unity splinters into a multiplicity of temporalities.

So topology is a challenge to today's temporalization of thought, from Deleuze to Badiou, from Derrida to Heidegger, from Žižek to Negri. This temporal dominance in cultural theory breaks with the unitary subject of the symbolic for a multiplicity that is rooted in the real. Topology's geometric paradigm will also give us a subject as, this time spatial, multiplicity. As such it must deal in the register of the image, with the figure.[3] As such its deconstruction of unity must privilege the imaginary, the productive imaginary as itself a multiplicity. In as much as subjectivity is cognitive or moral it engages the world in a mode foregrounding the symbolic and the real. Inasmuch as it deals with art, media and urban space, it will foreground the imaginary.[4] Topology, while a systematic critique of form, is still a defence of the figure. Badiou gives us a critical theory of capitalism through an infinite temporality that subtracts from, that is beyond experience. Topology, as Lury (2012) insists, is a question of surfaces, of empirical surfaces. To start from such surfaces is to shift out of *a priori* modes of thought. Yet these surfaces infold (Deleuze, 1988). Topology is thus at the same time experienced and beyond-experience. Topology is like Foucault's 'man': it is a transcendental-empirical double. It is at the same time finite and infinite. In this chapter, the sort of critical social topology we are addressing is thus, on the one hand, a method, and on the other a set of processes emerging in cultural and social life. In the culture industries and in technological media, and in the East, perhaps more than the West, social life itself is becoming more topological.

The Topological Animal

Sloterdijk's Philosophical Anthropology

The entirety of Peter Sloterdijk's *Sphären* is a cultural theory of space. If for Heidegger after the *Kehre*, language is the house of being, for Sloterdijk being itself is a house. Or better the house, or the sphere, is the space in which subjectivity is constituted and ontologically exists. The three volumes of *Sphären* are: *Blasen* (Bubbles) (1998), a 'micro-spherology; *Globen* (Globes) (1999), a 'macro-spherology'; and *Schäume* (Foam) (2004), a 'plural spherology'. Volume 2, *Globen*, is largely concerned with the topographical: it addresses the single Kantian container space, which is the space of metaphysics, of onto-theology. Volume 3, *Schäume* (Foam), is explicitly topological. It makes sense to see volumes 1 and 3 as critiques of *Globen*, of the macro-spherology. They are critiques of metaphysics, which Sloterdijk understands, in large part, in terms of Plato's Academy with its primacy of classical geometry.

Already in Sloterdijk's first and massively influential book, *Critique of Cynical Reason* (1988), the figure of Diogenes the Cynic was dominant. Diogenes was excluded from the metaphysics and geometry of Plato's Academy and de facto constituted hiss critique from the outside. Now volume 1 of *Spheres* is a critique of the assumptions of 'the One' of Plato's metaphysics and the topography of *Globen*. This critique is launched in terms of a (proto-) inter-subjectivity of the intimacy of 'the two'. This intimate inter-subjectivity works through its own characteristic media and micro-spheres. Here we see not so much 'the One' of the Beautiful (the Good) in Plato's *Republic* as the micro-sphere of inter-subjective intimacy of erotic love between man and boy in the *Phaedrus* and *Symposium*. Here the Old Testament's Genesis is re-read not in terms of the One of God as Yahweh, but instead as the intimate communicative inter-subjectivity of God and Adam. Here the intimacy of the couple dominates. There is no God without Adam (Sloterdijk, 2011: 42–3). Volume 3, for its part, is a critique of the Academic geometry of

Platonic metaphysics from the point of view of a plural spherology: a critique of 'the One' from the standpoint of the modern multiplicity of today's topological geometry.

Spheres is at the same time Heideggerian and a critique of Heidegger. It is not so much *Sein und Zeit* (Sloterdijk, 1998: 345) as *Sein und Raum*. *Dasein* for Sloterdijk (2001) is first and foremost *da*, it is there; it is spatial. Even in *Being and Time* we are in a seemingly spatial world with *Dasein* before we move to the more temporal character of 'thrown-ness' and 'anticipation'. Heidegger is a rigorous *a priori* thinker; Sloterdijk breaks with the *a priori* for a philosophical anthropology and a psychology. Where Heidegger talks about the condition of existence of ontological subjectivity, Sloterdijk is focused on what distinguishes humans from other animals. In *Sein und Zeit*'s famous chapter on Being-In, the key opposition is *Vorhandenheit* and *Zuhandenheit*, present-at-hand and ready-to-hand. For authentic *Dasein* we need the ready-to-hand. For Sloterdijk (2004: 364–5), what counts instead is the *hand*.

As animals with hands, we throw stones to keep enemies at bay. We build enclosures. We make tools. Crucial in this is the enclosure. Humans are the enclosure-building animals. Our building of enclosures echoes our original enclosure in the womb. This incubator and the early incubators of domestic living spaces give us humans a uniquely extended period of incubation. In classical philosophical anthropology, in Arnold Gehlen, the human *differentia specifica* is our *Instinktarmut*, a poverty of instincts (Sloterdijk, 2004: 229). This absence, this lack must somehow be filled. Human lack means we need security in a way that animals do not. Sloterdijk understands this security in terms of what he calls an 'immunology'. But this lack is also a space of indeterminacy.

In mainstream sociology Peter Berger (1990) was a philosophical anthropologist. He addressed the security side of human *Instinktarmut* and suggested a sacred canopy to provide this security. For Sloterdijk in the age of onto-theology or metaphysics of volume 2 of *Sphären*, this security, this immunology, works through a cosmology of the One, based on the Platonic Good or the Judaeo-Christian God. But all of this security disappears when we are thrown into the multiplicity, what seems to be the void of modernity. In this void, in this ontological insecurity, what takes the place of the sacred and Platonic canopy is instead technology itself. The first of these pluri-spheres, the first case of immunology through foam and technology, is the greenhouse of London's Crystal Palace, from the first International Expo of 1851 (Sloterdijk, 2004: 332).

Psycho-topology: Intimate Space and Unmediated Communication

The problem for Sloterdijk (1998: 343) is that in Heidegger's *Dasein* there is no intimacy.[5] So we have human being and intimate space, its intimate protector/incubator. And like Gaston Bachelard's *Poetics of Space* and Rachel Whiteread's houses, it is the nooks and crannies of the house that are the object of the investment of desire (Sloterdijk, 1998: 9). Indeed, Sloterdijk begins the first volume of *Spheres* with a quote from Bachelard, one that rejects Platonic Academic geometry for the roundness of intimacy. The subjects and objects of Platonist metaphysics are rejected for what are the *media* of intimacy. With Thomas Macho (1993) Sloterdijk (2011: 291–5) disagrees with Freudian object theory. Before the oral, anal and genital phases of the Freudian proto-subject who is attached to, respectively, the breast, faeces and the mother as objects, are three more primordial stages. In the first of these, the foetus and mother connect through the placenta and the medium of blood. In a second phase the newborn connects with the world not through the mother's breast but through the medium of breath. In the third stage through the medium of the newborn's voice. In each pre-oral phase what is at stake is not objects but media spaces. As the 'open animal', only humans are topological. Only humans have worlds. Animals, even mammals, are born. Humans 'come into the *world*'. As topological entities, human beings must be spaces of deformation. The lack – the space which the instincts do not fully determine – becomes topological.

Sloterdijk (2004: 388–9) draws on John Bowlby's theory of attachment. Bowlby was an evolutionary psychologist and biologist. In this context we can understand humans as topological animals: as a highly evolved species (see Holmes, 1993) with high levels of neuro-plasticity (Malabou, 2004). Attachment and prolonged incubation may be tied to the development of such plasticity. To be the enclosure-building animal entails plasticity and incubation. In Sloterdijk's philosophical anthropology, man is the enclosure-building animal. Other animals adapt to their environment, while humans build their environment. So other animals evolve in a process of adaptation to the environment. Because each of us builds their own environment, we do not evolve in this simple Darwinian fashion: instead humans co-evolve. Topological beings co-evolve. At a certain point in the evolution of species, we emerge as the *co-evolving* animals.

Lacan's psychology also was influenced by philosophical anthropology (Jay, 1994). In the Mandarin editions of Lacan's writings on the 'mirror phase', the imaginary is translated as the *xiangxiang* (想象). Here the first graph *xiang* (想) indicates thought and the second *xiang* (象) means appearance or image: the imaginary is a thought-image. This *xiangxiang* is the ideal ego of Lacan's reproductive imaginary that reproduces capitalist relations of domination. This is an ideal unification of the subject, as 'the One' that all of Lacan's work is directed against. Now there is another term in Mandarin for the imaginary, or the imagination, and this is the *xiangxiangli* (想象力). It is the same thought-image with a *li* (力) added on. This *li* means power, force, strength: both physically and spiritually. This second imaginary is not the reproductive but instead the *productive* imaginary. It is central to the late Lacan's (2000) topological paradigm of subjectivity. This is to be found in the 'Rings of String' essay from the Twentieth Seminar. This late Lacan of the real is the mathematical and topology-influenced Lacan. In 'Rings of String' Lacan focuses on a familiar topological figure: the Borromean Knot. Borromean rings consist of three topological circles whose linkage forms a Brunnian link, in which the removal of any ring results in two unlinked rings. The Borromean Knot is comprised for him of rings of string. One of these rings – none of which is removable – is symbolic, one imaginary, and one real.

If Badiou's mathematical multiplicity is rooted in the algebra of number, of post-object number, then Lacan's is rooted in post-Euclidean geometry. The imaginary now is no longer identical with the ideal ego. Instead it inhabits a space of topological deformation. If the knot is a figure comprised of rings of the real, the symbolic and the imaginary, then subjectivity as multiplicity is not grounded solely in the real. This late Lacanian subjectivity is just as much symbolic and imaginary. It is a topological multiplicity of all three registers. The rings are topological equivalents. As such they must share properties and belong to the same set: the set of, not the real, but of the topological.

Socio-topology

Once we are in the realm of philosophical anthropology, it follows that the human's 'world' is just a variant of the environment of all biological beings. Being in the world is one mode of being-in-the-environment. For Sloterdijk in our plural modernity of '*foam*', Heidegger's being-in-the-world is displaced by system-in-the environment. This move – from phenomenology to nonlinear systems – is widespread in socio-cultural theory. Thus Luhmann has drawn on Maturana and Varela to reconstitute Husserl's time consciousness as a system–environment relationship. And Bernard Stiegler has drawn on Gilbert Simondon to reconstitute a phenomenology with roots in Husserl, Heidegger and Derrida as a technological phenomenology. In Sloterdijk this seems to hinge on phenomenology's '*horizon*' being reconstituted as topology's *atmosphere*. If Husserl, Heidegger and phenomenology give us a horizon on which subjectivity constitutes meaning, then co-evolutionary topological systems give us *atmospheres*.

The horizon, like the 'world', is metaphysical. The atmosphere is physical *and* metaphysical. In topology we have (self-built) environments and atmospheres. In Renaissance painting there was a perspectival horizon.[6] The visitor experienced this from the outside. In contemporary art, for example Olafur Eliasson's 2003 *Weather Project* in Tate Modern's

Turbine Hall, the sun and this weather is experienced by the visitor (from the inside) as an atmosphere. Signally, the 2006 Shanghai Biennale on Hyper Art and HyperDesign was one of the first major contemporary art events in China in which Mainland Chinese visitors started to outnumber westerners. While western visitors mostly looked at the show's installations from a critical distance, large numbers of local visitors entered into the inside of the installations, crawling under and about them and taking photos. In a sort of architectural turn in art led by Gordon Matta Clark and now Beijing artist Liu Wei, nature and culture, the physical (cf. load bearing-ness in both Matta Clark and Liu Wei) and metaphysical are merged. With, again, McLuhan, we are inside the media, inside the object.

For Heidegger, death was the horizon on which we constitute the meaning of our beings. In our topological modernity this horizon of our finitude has exploded: it is shattered into an infinity of atmospheres, in which we must constitute our fragile and plural meanings. In these atmospheres we both breathe and constitute meaning. The effective afterword to *Spheres*' three volumes is Sloterdijk's (2006) *Im Weltinnenraum des Kapitals: Für eine philosophische Theorie der Globalisierung*: if capital has for centuries effectively accumulated extensively as *Globen*, now it must accumulate intensively. Hence globalization, *außenweltlich* process, has now become *innenweltlich*. So we move from a topographical to a topological regime of capital accumulation. Here capital accumulates as atmospheres themselves. Topography may give us two-dimensionality, actor-networks and the network society, but now we move to the *épaisseur* of atmospheres as capital accumulates intensively. In the plural spherology of contemporary foam we are individuated into our own bubbles and those very bubbles mediate our communication. We move from a psychology to a sociology, and now it is these topological spaces that communicate with one another. Our capsules separate us from one another, but they also make us multiple as subjectivities. They cut both ways: they open and close and burst.

We are these topological systems we construct. Communication takes place, when it does, not in a topological space but between topological spaces. These are atmospheres of isolated individuation. Yet atmospheres can also be shared. Thus pivotal for Sloterdijk (2004: 342) in the transition to modernity's foam is the Crystal Palace from the First World Exposition in London 1851. In their physicality these atmospheres constitute humans above all in terms of 'breathability' (Latour and Gagliardi, 2006), and, in *Schäume*, considerable text is devoted to how human beings can breathe in space stations. The Crystal Palace was a particular site of incubation: a container in which transplanted plants from tropical regions might survive. There is an artificial breathability in this constructed greenhouse: it is a site of a 'multi-naturalism'. It is a shared atmosphere, such as that of project-networks in design and the culture industries; like file-sharing networks. Another such shared atmosphere, which is actually called an atmosphere (*kuqi)* by its participants, is the Japanese video-tagging metadata platform in Japan, Nico Nico Douga. Here participants write on video content as it streams (Bachmann, 2011). We become topological subjectivities in Sloterdijk's plural spherology. We are our technologies, our tastes, our lifestyles and brands, our literal spaces. These are constantly under deformation, always a different figure showing, yet having their topological equivalent the structures of meaning comprise us as singular 'rings of string'. Further, like foam, these are fragile and always threatening to burst.

These structures of meaning are what Niklas Luhmann addresses in, as Sloterdijk (2004: 328f.) notes, his assumption of the excess of semantics over function. Luhmann's topological modernity will supersede an earlier topographical modernity – described by Talcott Parsons – in which function as distinct from semantics was driving social systems. For Luhmann, social systems have both functional and semantic levels. In contemporary societies the semantic – which is also a question of communication – overflows the functional (Koschorke and Vismann, 1999). It is this semantic excess that provides the power that drives the morphing of topological spaces, topological objects. Thus Parsonian functionally driven systems are involved in a logic of reproduction and external causation from the environment. Luhmann's topological systems are involved in a logic of production, of a self-organization driven by semantic overflow (Schützeichel, 2003). The above-mentioned co-evolution of contemporary topological subjectivities works through what Varela and Luhmann saw as the 'structural coupling' of these systems.

With semantic excess, structure breaks loose from function. Function still reproduces, but structure produces. The old structural functionalism very well described topographical modernity – every structure had a function: the church, the family, etc. In late and topological modernity, the driving structures are now the semantic structures, for us also information structures, and finally structures of the imaginary. This is an imaginary in excess of function that drives media culture, consumer culture, and the knowledge and information society. It drives not real but intellectual property, in its chronic invention. Not only does structure break loose from function, but structure becomes deeper; the depth of surfaces that are spaces in themselves. And they no longer just reproduce, they invent, they produce. In functionalism and topographical modernity the system was organized from the outside, while now, in the presence of this semantic excess, the system is organized, driven and caused from the inside. The old topographical functionalism, the ideal-ego paradigm of the Lacanian imaginary, was one of the functions. Now this function itself becomes topological, becomes productive and drives the self-invention of the system.

The Imaginary

We encounter the imaginary in, for example, the work of Emile Durkheim and Walter Benjamin: in both cases, curiously, in the context of religion. In Emile Durkheim's *Elementary Forms of Religious Life* (2008), there is an imaginary and a symbolic. The symbolic is a *social* symbolic. But the imaginary, for Durkheim, is very distinctly an individual phenomenon, it happens at the level of individual psychology. Durkheim is very much the rationalist, his Comtean positivism standing in opposition to the empiricism of the contemporaneous British anthropology. So, for Durkheim, the symbolic is rationalist and the imaginary empiricist: the symbolic resolutely *a priori*, Durkheim's social *a priori* and the imaginary *a posteriori*. For Durkheim the symbolic fixes social relations, it makes society and social continuity possible (Alexander, 2005). In comparison, the imaginary and images are fleeting, protean.

Durkheim criticizes the empiricists' focus on dreams. Yet the imaginary is largely what is at work in dreams. The symbolic tends to represent rationally, through the categories of an emergent logic, while the imaginary represents proto-logically or illogically, through what Freud sees as sublimation, condensation and over-determination. The symbolic works through determination in its symbols, while the imaginary works through under-determined or over-determined representations, which, as in dreams, condense and merge. The symbolic works through the clear and distinct, the imaginary through what we might call the dazed and confused. The protean nature, the plasticity, of such images and such an imagining-capacity is incipiently topological.

Benjamin's (1996b) 'On Language' features, on the one hand, human language and, on the other, the language of things. Like Durkheim, Benjamin too insisted that non-humans have imaginaries while only humans partake of the symbolic. Benjamin's thing-language only utters images, operates mimetically, through the imaginary. Thing-language images do not classify, cannot analyse, unlike the language of man. The language of things, for Benjamin, also does not judge. It is such judgement – the shift to a language of judgement – that causes man's Fall from the Garden of Eden. Eve listened to the serpent and ate fruit from the tree of knowledge. In doing so she engineered a shift in human language from the proper nouns of naming, from this God-given language of singularity, to a judging language of the common noun: a language that brings particulars under universals. Such a language of judgement put humans in the place of God and led to the Fall. But the language of things and the imaginary does not judge. Benjamin's things communicate through the imaginary in a figural mode of representation. Humans encounter these communications and the task of Benjamin's translator is discursively to translate these thing images again into singularities, into the proper. Our point is that both Durkheim and Benjamin give us a rationalist, *a priori* and *symbolic* language of judgement as counterposed to an *imaginary*, shared also by non-humans, an indeterminate and over-determinate language of images that can never work analytically, can never subsume particular under universal. The language of things is *a posteriori*.

Productive Imaginary: From Kant to Heidegger

Kant (1929: 142–3) develops the faculty of the imagination (*Einbildungskraft*) – the schemata of the imagination – in the first edition of *The Critique of Pure Reason*. The 'schemata' of the imagination mediate between intuition and the understanding. Intuition is a passive faculty, taking in and representing the manifold through the categories of time and space. The imagination works in productive syntheses on the intuition's representations and then presents these to the understanding. The concepts or the categories of the understanding are not genres under which are determined specifics or particulars. They are instead more like logical operations such as cause, identity, relation and syllogism that enable us to subsume particulars under universals. The schema of the imagination work similarly. They are not contents nor forms, but an enabling frame. In judgements of the beautiful, the faculty of the imagination is in consonance with the understanding. In judgements of the sublime the faculties are in a relation of dissonance: now the perception is too much for the understanding, leaving the imagination to deal with it. Kant calls judgement *Urteilskraft*, just as the imagination is *Einbildungskraft*. He does not call the understanding *Verstandeskraft*, but just *Der Verstand*. So judgement is shot through with this power, of making images. Indeed Marxian labour-power, as *Arbeitskraft*, seems to be modelled on the actual productive capacities of the imagination. The early Marx's connection to the Romanticism-influenced young Hegelians would have fostered this. The imagination and labour-power are more productive than is the understanding: imagination working with the raw materials of intuition.

Kant's third critique is less *a priori* than the first and second critiques. Only in the third critique does Kant not start from the subject in general, from the transcendental unity of apperception, but instead from singular, feeling subjectivity. Only the third critique is critique of *judgement* in a strict sense. With Castoriadis (1987) we see that *a priori* notions of being, justice and politics are *determinate* in a way that a productive and topological imaginary is not. Once a given social imaginary is constituted, it operates less through *a priori* deduction or *a posteriori* induction than through what Gilbert Simondon calls *trans*duction (Stiegler, 2007).[7] Transductive systems consist of a constellation of 'social facts' inductively emergent from social relations. Then these same facts metamorphose into quasi-determinate norms that help steer the system. Kant understood 'Enlightenment' in terms of the 'what can I know?', the 'what should I do?' and the 'what can I hope?' (Palmquist, 2011). In this the what-can-I-know maps onto the first critique and the faculty of the understanding. And the what-should-I-do is homologous to the ethics of practical reason and the faculty of reason. The what-can-I-hope, for its part, connects to judgement and the imaginary. The what-can-I-hope is – for example, for Marx and Benjamin – the basis of critical theory. Kant further notes that the third critique and judgement is a 'bridge' between the first and second critiques. Now we see the double role of the imaginary: as, first, a schema that connects the intuition and the understanding; and, second, as the mediator between understanding and reason, between necessity and freedom.

For Fichte and Schelling this productive imaginary goes further. Their idealism and *a priori*sm[8] forgets that Kant was trying to square the circle between empiricism and rationalism in his synthetic *a priori*. Kant's *a priori* synthetic judgements try to bring what were previously the mutually exclusive and seemingly exhaustive *a priori* analytic judgements of rationalism and the posterior synthetic judgements of empiricism. With Fichte and Schelling, who were Romantics and idealists, the imagination is the primordial *a priori* (Kearney, 1988). Now the imaginary is not just a bridge but the condition of possibility of both understanding and reason. Fichte's and Schelling's *a priori* is not the condition of possibility but the principle of production of what we encounter. For them Kant's productive imaginary actually generates not just art but nature and social life too. Now Kant's transcendental and synthetic unity of apperception that allowed knowledge of the world becomes an equally transcendental and synthetic unity of world production. This is Fichte's '*Ich*', his literal subject that 'posits' the world. Kant and the Romantics saw this is a question of '*determination*'. In the one case determination by a cognitive *a priori*, in the other from a productive *a priori*. Kant's productive imagination synthesizes from the raw materials given to the intuition. Fichte and Schelling's imaginary does not synthesize from the empirical. For them, there is no empirical apart from what is produced from out of the '*Ich*' itself.

Heidegger gave an entire year of lectures on Kant just before he wrote *Being and Time*. A year after *Being and Time* he shows that he understands *Dasein* in the paradigm of the imagination in *Kant and the Problem of Metaphysics* (1997). Already schooled by Husserl, whom Heidegger and his contemporaries read as breaking with the Kantian unknowability of noumena, Heidegger had to settle accounts with Germany's predominant neo-Kantianism. The neo-Kantians had an empirical reading of Kant. For them synthetic *a priori* judgements were primarily synthetic judgements, that dealt with facts only loosely mediated by the intuition of a transcendental aesthetic, and not at all further determined or synthesized by the imagination. They turned to the second edition of *The Critique of Pure Reason*, in which the *Einbildungskraft* all but disappears. Heidegger goes back to the *a priori* Kantianism of the Romantics and idealists. Heidegger refashions subjectivity (*Dasein*) on the paradigm of the imagination. At stake is the existential *a priori* of ontological subjectivity: the condition of possibility of neither cognition (*a priori* synthetic judgements) nor moral action but of ontological existence. Heidegger is engaging not so much with experience (whether cognitive or aesthetic) but with being on the level of human subjectivity of existence. This existential *a priori* drives *Being and Time*. This ontological existence, in contrast to Kant's subjectivity (transcendental and synthetic unity of apperception), is not general but singular, is not a question of abstract observation but of an embedded life-world. This ontological subjectivity is driven by the productive imagination.[9]

Yet Heidegger's productive imagination is fundamentally temporal. It works very much like Husserl's phenomenological subjectivity. This is a critique of Newtonian time in which every moment is just a present and in which time is reversible, in which time is seen in terms of an object moving mechanically though container space. In contrast, for Husserl each perceived now also contains a past and present, a primary retention and a primary protention. In addition each present is modified, indeed bracketed through the operation of an imagined (i.e. not perceived) secondary protention and secondary retention (Stiegler, 2009). For Husserl this imaginary yields phenomenological knowledge, for Heidegger ontological existence. In *Being and Time* the secondary retention comes with thrown-ness (*Geworfenheit*), the secondary protention with anticipation. Both are the condition of possibility of ontological subjectivity, which is *Besorgen* ('care'). The Kantian subject was outside of time, while his object was in Newtonian, mechanistic time. For Heidegger, both subject and object (*Seiende*) are in an existential world and time. *Dasein* is now not universal but singular and relates to beings, now not as particulars but as other singularities. Subjectivity, as care, relates to beings thus, not in a scientific attitude but via a poetics. Here only human beings, only *Dasein*, have the secondary and properly imaginary protention. This imagination makes the care of beings possible, and it imagines subjectivity's own proper death. *Dasein* as existential imaginary is both singular and finite.

Towards the Social Imaginary

Cornelius Castoriadis's *The Imaginary Institution of Society* (1987) is an insistent, sociological and spatial critique of Heidegger. Most important, Castoriadis breaks with Heidegger's *a priori*sm. For him (1987: 257–60) every *a priori*sm, from Kant to Heidegger, must presume an unacceptable determinism. Heidegger and, for that matter, Kant never stop speaking of determination: of *bestimmen* or *Bestimmungen*. For Kant the ultimate condition of possibility of experience and judgement is Reason (*Vernunft*), on which understanding is contingent. Reason and its practical, active movement drive the show. So at stake are not just the 'epistemological' determinations of positivist causation and analysis, but also ontological determination. For Castoriadis the social imaginary cannot be an imaginary or an imagination if it is determined. The imaginary and social imaginary must not operate in the manner of an original or 'primordial' determinant. Thus *Dasein* and the wealth of categories in *Sein und Zeit* – from anticipation to thrown-ness to care, to world – are determinations of Being. But Being itself is not time here. *Dasein* instead is time. Being, Castoriadis (1987: 198–9) notes, determines the time that *Dasein* and beings and indeed the imaginary are.

Castoriadis insists on a move from the individual subject to a social dyad. Leibniz's *a priori*sm of plural substance, the monad, is another such determinism: the monad cannot have doors and windows and hence cannot enter into relations of inter-subjectivity, cannot be the basis of a *social* imaginary. Every modern body of *a priori*st thought, starting from the substantial *a priori*sm of Descartes, Spinoza and Leibniz, presupposes an individualism of the subject. It can never, as Simmel (1994) noted, be inter-subjective, dyadic or sociological. In Kant and Heidegger, subject and substance part ways. The Kantian subject as unity of apperception and Heideggerian *Dasein* are not substances. They are instead conditions of possibility of, on the one hand, experience, and, on the other, ontological existence. As such, again, both presume the single subject and not the dyad. Indeed Husserl's phenomenology can never give us a transcendental inter-subjectivity, without the entire phenomenological conceptual apparatus breaking down. Every modern *a priori* must thus start from a transcendental subject and not an inter-subjectivity. To begin from the dyad, we must, as Alfred Schutz (1967) understood, descend from the transcendental to the empirical. It is necessary to move from time's interiority to the exteriority of space.

The imagination in Heidegger's *Kantbuch* is fundamentally temporal. This is the problem for Castoriadis and for us. The imaginary in Heidegger loses all spatiality: it loses the dimension of the figure. The imaginary in Heidegger is heteronomously determined by Being itself. The social imaginary needs to break with this determining *a priori* of Heidegger's Being. The social imaginary is largely self-determining: as dyad and multiplicity, it is also *inter*-determining. The social imaginary comprises non-monadic subjectivities with windows and doors. The social imaginary for Castoriadis (1987: 146f.) is the site at which the chain of signifiers ends. It is comprised of pure signifieds, the core and impossible-to-enunciate meanings at the heart of a social multiplicity.

This set of pure signifieds drives the self-determination of the social. It is comprised of not images but imagings. It produces images in its self-transformation. As a process of largely self-determining figurations, the social imaginary is also temporal. It is not in space, but it is a space; as process it exists not in time but is a temporality.

In the 21st century, this social imaginary takes the form of a system. There was always technology. But there is a tipping point at which human subjects become integrally ensconced in human–technical systems – with the predominance of ubiquitous media, a range of technologies, the image-society, brands and consumer capitalism. Social systems, once rightly described as structural-functional by Parsons, become increasingly communications systems, Luhmann's (1987) semantic systems. The structure of these systems is the semantic surplus over function. It is this that drives and self-organizes the systems. Again, unlike Parsons' functional systems, which were largely valid before the predominance of technological culture, these semantically over-determined systems begin to produce their own environments. So we are dealing now with a multiplicity of environments that are themselves topological, psychic and social imaginaries. These topological imaginaries relate to one another through structural coupling. This presumes an openness to semantic interchange between subjectivities and between subjects and objects. It also presumes a coupling on a structural level, on the level of fundamental meanings. In the context of communications, media, design, art and technology such coupling is often largely on the level of the imaginary. In such a world objects communicate to us through images, while we as subjects translate and engage in symbolic exchange with the objects.

Concluding Illustrations: Culture Industry and the Chinese Economy

The culture industries are such imaginary-driven topological systems. In cultural objects, a range of products are topological equivalents in that they have a set of shared properties, e.g. the Virgin brand, or Apple or Google. Here the products that de-form into one another find their topological equivalence in the brand. This equivalence is marked in intellectual property: in copyright and, in particular, trademark (Lury, 2004). Not so much the real property of the commodity or the means of production, intellectual property is the shared property of the morphing contemporary cultural object. It may, for example, be the intellectual property in the algorithm that drives the de-forming images on your screen. Here the generative entity of the topological equivalents is this algorithm. At stake here, again, is not the post-object of the real (which is a post-object *temporality*). Indeed both Castoriadis and Lyotard were in disagreement with the pure Cantorian mathematics of the Bourbaki group. For Bourbaki the core of this is a pure mathematical axiomatic. It is this that is at the heart of Badiou's real. Castoriadis objected: the first axiom must somehow be imagined. For Lyotard too the axiomatic cannot fully exclude the figural. In this sense, through fundamentally breaking with form and container space, the mathematics of the social imaginary is incipiently topological.

This topological object that is the brand or algorithm is still an object. And as such it operates spatially: not in a space but as a space, as for example in the brand environment described by Moor (2007). All of this is irreducibly figural in that we are dealing with the metamorphosing faces and figures of products, which then fold inward to the intensive locus of their structural equivalence. These topological, hence deformational, object-spaces then couple, not only with one another, but with a range and a succession of psychic and social imaginaries. These subjectivities, as topological spaces, are atmospheres. They are incubators and cocoons and more or less breathable. To the extent that these foam-like encapsulated topological subjectivities couple, they form social imaginaries. This is again through information and image and exchange. In, for example, Luke Fowler's image and music and video file-sharing platform Shadazz we see such an inter-breathable atmosphere, a shared imaginary. We see social imaginaries in atmospheres of, for example, project-networks in architecture, art and the culture industries. We encounter them in larger-scale urban imaginaries, city topologies. It is this that is the stake in Lefebvre's (co-)production of urban space.

This is the world, the cultural world of our increasingly topological modernity. It is a world in which capital itself operates increasingly not through the linearity of the symbolic and the commodity, but through the logic of the self-organizing social imaginary and intellectual property. This is a world in which capital accumulates through the sort of individualization that is constituted when *Globen*, when the topographical universal mind and topographical subjectivity, shatters into a million fragments like the exploding heads in David Cronenberg's *Scanners*. After which each of these heads in its capsule, in its individualized atmosphere, is integrated into now self-organizing micro-circuits of capital. Yet Peter Murphy et al. (2010) have made a telling distinction between how the imaginary and symbolic work.

They distinguishes between (cognitive) judgement on the one hand and imagination on the other. For Murphy, judgement works through analysis while the imagination works through synthesis. If judgement comes across two entities, it separates them out, analyses them and identifies their distinctive characteristics. If the imaginary comes across these two elements, it finds a way to synthesize them, to cobble them together and to make something. This is how Schumpeter, Murphy continues, understood the creatively destructive entrepreneur. Schumpeter's entrepreneur, that fourth factor, indeed fourth figure of production, is not a Judaeo-Christian creator. The entrepreneur is in a situation: he is not putting pre-assembled means and ends together as in the classical model of economic and social action. He comes across whatever elements or resources are lying about and, in one way or another, he manages to assemble them together. He synthesizes something. He, with a number of others, makes something. This is the productive and social imaginary. In a neoliberal age, Schumpeter's social entrepreneur has been transmogrified, as Foucault (2008) notes, into Gary Becker's 'human capital'. Here, even difference has come under the spell of neoliberal capitalism's self-accumulation. Schumpeter's difference of invention becomes your obligation to accumulate your own human capital.

If the culture industries give us one illustration of the topological, then Bruno Latour in his above-mentioned co-edited *Atmosphères de la politique* gives us at least an implicit topology in the book's notion of atmosphere. Latour in the book brings Sloterdijk and François Jullien, among others, together. But Jullien, perhaps the West's leading cultural theorist of China, does not really there develop a notion of atmosphere that works in Chinese culture. Let me, by way of a concluding illustration, make an attempt to do this here. Giovanni Arrighi (2008) has at length argued that Adam Smith, and not Karl Marx, gives us a window on the Chinese economy. Arrighi rightly reads Smith and classical political economy as empiricist, in contrast to the rationalism of neoclassical (and neoliberal) economics. Arrighi contends that, in comparison to western neoliberalism, the Chinese economy works in such an empiricist mode. The implication is that the Chinese economy features not just such empiricism but an enhanced role for the imaginary: that it is largely an economy of not 'the sphere', but instead of atmospheres.

Michel Foucault in *The Birth of Biopolitics* (2008) also understands classical political economy of liberalism as effectively empiricist while there is only the governmentality of the body with neoclassicism and neoliberalism.[10] Adam Smith indeed worked very closely with David Hume and was the student of empiricist moral philosopher Francis Hutcheson. Smith's contemporary, Immanuel Kant, rejected Hutcheson's 'moral sense theory' in *The Critique of Practical Reason* for his own *a priori* morality. Smith, in *The Theory of the Moral Sentiments* insists instead on a rigorously *a posteriori* morality (see Haakonssen, 2002). Yet he too disagrees with his teacher. Smith says morality works not through a sixth, moral sense, indeed not directly through sense perception at all. It works, Smith specifies, instead through the *imagination*. We cannot sense what another person feels. We can only imagine it. Smith saw this as happening through a sort of 'mirror'. At stake here, as Arrighi recognizes, are much more embedded economic relations, characteristic of Chinese economic relations, in which the moral and the economic are not to be analytically separated. Arrighi explicitly and Foucault implicitly see this in contradistinction to the disembedded and individualist western neoliberal economy.

The Chinese economy is also famously empiricist in its rejection of the set of *a priori* principles embodied in the 'Washington Consensus'. Following such principles has led to the brutal and all-at-once privatization, cuts in welfare spending and abolition on capital controls that were enacted in Russia, Mexico, Argentina and elsewhere. In China, in contrast, there was the trial-and-error development of a Special Enterprise Zone in Shenzhen and Xiamen; and later local and experimental initiatives in local–state public investment in Shanghai-Pudong in the 1990s and now, from 2007, in the 'Chongqing Model'. Jullien himself focuses on the Taoist *wu wei* of classical Chinese thought, which he contrasts to the centrality of action of the *you wei* in Greek thought. But there is a very similar *you wei* at the centre of Max Weber's theory of social action. This is no coincidence because Weber's *zweckrational* and *wertrational* action categories are explicitly not empirical but instead rational.

In a very important sense, the disembedded and instrumental neoclassical economic actor that, as Callon (1995) comments, is prevalent in western economies is at the same time Sloterdijk's 'sphere'. Its background assumptions – from Laozi's (and Jullien's) *wu wei*, of not action but situated activity – is the 'atmosphere'. Wang Hui in his 现代中文思想的兴起 (*The Rise of Modern Chinese Thought*, 2007) argues explicitly against Weber in outlining a distinctly Chinese mode of modernity. Wang Hui sees the basis of this in Confucianist civilization. His focus is in particular on the Confucianist 'rites and music' or 'rites and ceremonies'(儀禮). Here the rites and music are again the background assumptions that serve as a basis for action. Some 300 years later in Zhuangzi the rites and ceremonies are much more secularized, yet still follow, as Schwartz (1985) noted, a logic of *wu wei*. They are a set of background assumptions, implicit knowledge. They are a sort of spatio-temporal atmosphere, rather than the focused 'sphere' of subject-verb-object, goal-directed. The latter, which is assumed in neoclassical economics and classical sociology, is at the heart of western neoliberal economic and social action. Thus in the particular modernity and economy of China we see an empiricism of the social imaginary: an *a posteriori* of atmospheres. This can bring us to speculate that perhaps the East was topological well before the western world. Maybe whatever new version of the topological imagination is emerging in the West is also implicitly a process of 'easternization'. Perhaps the question of topology is at the same time the question of what Gunder Frank (1998) so presciently called 're-Orient'.[11]

Indeed, there are strong parallels between the figure in deformation in Chinese and in western art. François Jullien's 2009 book, entitled *The Great Image Has No Form, or On the Nonobject through Painting*, is a study mainly of landscape painting in Song Dynasty China. It is, as is the rest of Jullien's work, in contrast to say Wang Hui's above-mentioned Confucianism, fundamentally Daoist.[12] In Jullien's *Great Image* we see the Song painters such as Dong Yuan and Guo Xi, as well as Yuan and Qing artists Zhao Mengfu and Shitao, portray an image in deformation. We see mountains dissolve into clouds, and the sparseness of disintegrating trees. These are, as in our above descriptions of topology, figures in movement whose form is in the process of disappearance yet never quite does disappear into the full indifferentiation of the Dao. This is an art of figuration and the figure but not form. Its very process of deformation lends to its space indeed a temporality, one that at the same time belies understanding the topological as simply spatial, but instead incorporating a complex space-time. It is not just the form of the materials of art that are a figure in deformation, but the object itself being rendered which is at the same time a nonobject. The landscapes, the mountains and trees and clouds are in a movement of disintegration. Here the differentiation and light of the *yang* is always tending to the dark side and indistinction of the mountain's *yin*. The object itself is also understood as topological: less in the western sense of the life drive of higher levels of energy and organization, but instead of the entropic death instinct. Yet this is a death instinct with its own proper *qi*, its own energy of regeneration.

Fast forward to contemporary Shanghai and we see Yang Fudong's video-art cycle *Seven Intellectuals in a Bamboo Forest*. The rural and mountainous setting of much of this work is not just about intellectuals in exile. It is also a question of the (in)significance of the human subject-object in the landscape, in a landscape that is as much featureless void as comprised of mountains. Indeed the Mandarin term for landscape is *shanshui* (山水) or literally 'mountain-water'. This has been echoed in Isaac Julien's work with Yang in Julien's nine-screen video installation, *Ten Thousand Waves*, shot in the even more rugged and hostile mountains of Guangxi province. Here, as in classical Song art, there is always an implicit movement from the unity and light of the form to the multiplicity, darkness and void of the formless. Yet formlessness or the pure multiplicity of the real and the void are never achieved.[13] There is instead still figuration: the object and figure in a process of deformation.

We see a similar figure in deformation in Francis Bacon's above-mentioned paintings as described by Deleuze. There are arguably two Deleuzes: an early and perhaps middle Deleuze of *Logic of Sense* and especially *Difference and Repetition* (2004) and a late 'topological Deleuze' of *Bacon* (2003) and *The Fold: Leibniz and the Baroque* (1988). The Deleuze of *Difference and Repetition* (2004) is the theorist of the virtual and the actual as described by the very best of the Deleuze scholars (see DeLanda, 2002; Massumi, 2002). In important ways the dichotomy of virtual and actual are quite similar to Badiou's (and Žižek's) dichotomy of real and symbolic. In both there is a beyond-experience of the real (virtual), which is conceived along the lines of pure multiplicity. A pure multiplicity does not have features, and thus cannot be experienced. But in Chinese landscape painting the Dao is never a pure multiplicity, never a pure darkness or void, but always incorporates at the same time the featured-ness of the *yang*, and thus, though not actual, can nonetheless be experienced. Deleuze's baroque culture is also not an unexperienceable virtual but instead an infolded object. In *The Fold*, Deleuze focuses on El Greco's painting. In the baroque the unity of objects becomes infolded multiplicities, and the pure multiplicity of El Greco's pure light becomes object, undergoes figuration. Deleuze describes El Greco in a register similar to McLuhan's contrast of 'light-on' media, such as the novel, and light-through media, such as television, computers (and indeed mediaeval stained-glass church windows). Thus El Greco's paintings are understood in terms of a light-through of pure light as distinct from the light-on straightforward actual of the Renaissance. This is not a question of actual versus virtual or real versus symbolic but instead of the topological. The topological is experienced, yet is always in a process of infolding into what is beyond experience. This also is what Deleuze (2003: 13–14) calls, in contrast to figurative art, Francis Bacon's figure in deformation. We recall here that for (early) Deleuze multiplicity is a plenitude while for Badiou it is emptiness or void. My point is that neither can be experienced. In *The Fold*, middle and late Deleuze, however, multiplicity is experienced. Indeed the notion of 'fold' is derived from 'manifold', and manifold, in German *Mannigfaltigkeit*, is multiplicity. If the object thus infolds then multiplicity is no longer a virtual but is instead experienced. And topological objects, unlike virtual objects, can be experienced.

This brings us back again to the imaginary, which stands somewhere in between the indistinction of the real and the clear and distinct representation of the symbolic. The imaginary works though imitation and thus stands in contrast to the rules and deductive operations of the symbolic. The imaginary and social imaginary is never clear and distinct: like Lyotard's figural it works through a dreamlike paradigm. The imaginary's spatial under- and over-determination is overlain by its temporal under- and over-determination, in which past and future are brought into the present. The imagination, we recall, for Kant puts a first frame on the indeterminate multiplicity of the outside world; before this a further more analytic determination is imposed by the concepts of understanding (the symbolic). Thus, if topography works in the clear and distinct, in the register of the actual, of the symbolic, and the real operates in the void, the pure multiplicity of what is beyond experience, then topology works in the not-so-clear and distinct, the only partially determined, or alternatively in the dreamlike over-determination, in the logic of deformation of the (social) imaginary.

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Notes

1. I am not making any claims in this article to an original reading of Kant. The reading of Kant is used to set up and make clear the more general argument that works from topology to space and the figure, and to an understanding of the social imaginary that is not rationalist but empiricist.
2. In *Francis Bacon: The Logic of Sensation*, Deleuze (2003) gives us a vision which is at least implicitly topological. Here Deleuze does not use the language of the virtual and actual. Instead he shows how Bacon's work is not figurative, but instead figural. This process of figuration works through what Deleuze calls a 'logic of sensation'. Sensation here does not 'render the visible' in any sense, even as, say, Impressionism and Cubism, through cutting into facet planes, do. Deleuze's other modal artists are the post-Impressionists, who, along with Bacon, in contrast 'render visible'. Render visible what? Indeed sensation. Render visible through sensation. Here sensation works physically through the nervous system and constitutes a sort of medium embracing artist, viewer and work of art. The figure is carved, as it were, out of sensation and so is the ground, the two standing in tension with one another, with neither really getting the upper hand. The figure, whether George Dyer, Lucian Freud or Bacon, is painted not as representation but as carved out of a block of sensation. So we have an equality of sphere and atmosphere and a figure in a process of what Deleuze literally calls 'deformation'.
3. Here the classic text is of course Jean-François Lyotard's *Discours, figure* (1985). At about the time Lyotard was completing this text, he was engaging in debates with the Bourbaki mathematics thinkers.
4. This article has benefited from encounters in Melbourne and Sydney in April 2011 with Peter Murphy, Nikos Papastergiadis and James Donald – all who have written books on the imaginary. It has also benefited from exchanges on this in March and April 2012 with my students and colleagues, in particular Wang Min An, at Nanjing and Wuhan universities. I would like to thank especially He Chengzhou and Zhou Xian at Nanjing. But also my assistants there, Hu Ke and Zhan Yuelan, who worked with me on preparing my lectures in both Mandarin and English.
5. I am indebted on these points to discussions with Sascha Rashof.
6. I am grateful to Nikos Papastergiadis on this point.
7. I am grateful to Bogdan Dragos for this point.
8. On Schelling and Ernst Bloch, see Sloterdijk (1998: 325–6).

9. As much as we must admire the power of Heidegger's 'Kant book', its idea of the imagination is very different from what is advocated here. Heidegger, self-consciously, gives a one-sided heavily rationalist reading of Kant. The whole empirical content and dimension in Kant's critique of metaphysics disappears in Heidegger's existential *a priori*. This article is very much from the opposite side. Our social imaginary, in contrast to Heidegger's philosophical imaginary, is very much empiricist. Heidegger and Kant will have no time for psychology or sociology. This article has more in common with the psychology we see in Sloterdijk, in Lacan, and what we will see in Adam Smith, than with Heidegger's (or for that matter Fichte's and Schelling's) rigorous (starting from first principles) *a priori*.
10. This is a persistent theme in social theory. Thus Simmel saw the original opening of markets in such a positive way, only for this to be killed off by its subsequent rationalization in '*das Soziale*'. For Horkheimer and Adorno this *was* the dialectic of the Enlightenment. Markets and liberalism were an empiricist breakthrough of the *ancien regime*. Then these markets, in a dialectical movement, came under the spell of capitalism's rationalism. Foucault makes a clear distinction between liberal political economy and neoliberalism. He does speak less of neoclassical economics. Further, though, there is a contrast of Adam Smith and Gary Becker (neoliberal) in *The Birth of Biopolitics*, and at least the inference that the latter and not so much the former involves biopolitical governance, Foucault does not make the specific empiricism versus rationalist (*a priori*) distinction that I make in this article.
11. On empiricism in the Chinese economy, see David Wank (1999). This is also consistent with the more than 400 interviews carried out between 2006 and 2009 in the ESRC Project, 'Risk Cultures in China: An Economic Sociology'. These will be drawn on in Keith et al. (2013). I hope the reader will forgive the paucity of empirical examples in this article. It is largely an essay in social and cultural theory. I hope that the illustrations will make the theoretical case clearer.
12. I am indebted to Michael Dutton's insight on this.
13. Here and in much of this paper I use 'void' and 'multiplicity' as if they were interchangeable, as in for example Badiou's work. I am aware that elsewhere in this volume and especially in the introduction, void and multiplicity are used rather as opposites, so that an intensive multiplicity is very much a plenitude whereas the void is very much an emptiness. I guess what I am suggesting here is that this plenitude/emptiness opposition is not operative in Daoism and perhaps also Buddhism. Instead the Dao would seem to be both emptiness and plenitude.I am indebted to discussions with Celia Lury on this point.

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On Some Uses and Abuses of Topology in the Social Analysis of Technology (Or the Problem with Smart Meters)

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Abstract
This paper examines the limits and possibilities of topological approaches in the social analysis of technology. It proposes that topology should be considered not just as a *theory* to be adopted, but equally as a *device* that is deployed in social life in a variety of ways. Digital technologies help to make clear why: these technologies have facilitated the spread of a topological imagination, but they have also enabled a *weak* form of topological imagination, one that leaves in place deterministic ideas about technology as the principal driver of social change. This paper examines this situation and alternatives to it through an empirical case, that of smart electricity meters. On the one hand, these technologies enable only a limited 'expansion of the frame' on technology, one in which the primacy of technology is maintained. But they are also used to render relations between technology and society more complexly. I explore topological devices deployed in this second way, such as the digital visualization tool of tag clouding and propose that this device enables an empirical mode of critique: here, topology does not just help to foreground the entanglement of the social and the technical, it also helps to dramatize the contingent, non-coherent unfolding of issues.

Keywords
actor-network theory, digital devices, issue mapping, smart energy technology, social studies of technology, socio-technical change, topology

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Introduction

It is hard to overestimate the importance of topology, loosely defined, to the development of social studies of technology in recent decades. Topological ideas have been a significant source of inspiration for several different approaches in this field, and can be recognized in the idea of the *inter-relatedness* of technology and society. These approaches have done much to help dismantle the idea that technology and society occupy different domains. Now classic contributions to the social studies of technology have proposed the concept of a hybrid network, or heterogeneous 'assemblage', which is variously composed of social, technical and natural entities, as our best chance at understanding the role of technology in social life (Callon et al., 1986; Latour, 1988; Haraway, 1994; Mol and Law, 1994). These studies reference uses of topology in the sciences, from mathematics to theoretical physics, in particular the analytic category of *'entities-in-relation'*, proposing that social studies of technology should follow these other fields: they too should adopt this topological notion as their primary category of analysis.

But something seems to have changed, which requires us to re-consider the use of this central concept in the social analysis of technology. Over the last ten years or so, the use of topological ideas to conceive of technology in relational terms has become increasingly widespread. These ideas can be recognized in the proliferation of network visualizations, in digital networked media, and the invocation of concepts of complexity in a broad array of settings (see on this point also Boltanksi and Chiapello, 2005). Today, then, it is not just social students of technology who deploy topological ideas in order to render technology analysable, but a whole range of social agents. This entails a change of status of topology in the social analysis of technology. In the social studies of technology, topology has been mostly understood as *a theoretical construct,* as a conceptual language that can help social theory to render explicit the structure of socio-technical phenomena. However, at the current juncture, topology must also be understood as *a device,* as a way of structuring phenomena in practice, which is enabled (and disabled) by particular technologies. We must, then, attend more closely to how a topological imagination is facilitated by specific material apparatuses deployed across social life.

Crucially, to approach topology as a device means to adopt a fairly minimal definition of it in a mathematical sense, as the important question becomes that of how a topological imagination of technology and society arises and *takes form* in material practices. The issue becomes that of the empirical specification of a topological imaginary of technology and society; to consider that it may be deployed in a range of different ways. One of the striking facts about the recent spread of topological approaches to technology and society, I argue, is how often it does *not* translate into the kinds of insights for which sociologists of technology have appreciated these approaches in the past. In the social studies of technology, topological ideas were principally taken up in order to challenge a particular dominant ideal concerning the role of technology in society, which we can call the 'primacy of technology'. However, while topology is today frequently used to analyse and organize technology in social terms, this often leaves undisturbed the understanding of technology as the principal 'driver' of social change.

In this context, it becomes especially important for social analysts to distinguish between seemingly similar ways of using topological approaches in the social analysis and organization of technology. Rather than dramatizing the opposition between pre-topological and topological understandings of society and technology – and making the case for the latter over against the former – we must attend to more subtle differences between a range of topological analyses of this relation, in particular between those that do and those that do not problematize the primacy of technology. We must distinguish between 'weak' and 'strong' versions of the topologization of technology and society, and become more demanding of how topology is deployed in practice.

To this end, I will here turn to an empirical field in which topology has been deployed with special intensity in recent years, that of smart meter technology. This technology has captured the imagination of engineers, designers, sociologists, policy-makers, and advertisers alike, and it has enabled a variety of different topological analyses of technology and society in a range of fields, with a number of different implications for our understanding of the relation between the social and the technical. As such, smart meters provide a useful object for demonstrating the differences between a limited and a more radical topologization of the social and the technical. To clarify this difference, I will turn to the phenomenon of the 'issuefication' of smart meters. But let us begin by considering the use of topology as a device.

Expanding the Frame? The Neat Complexities of Smart Electricity Meters

Energy technology is certainly not the only site, but it is an especially prominent one in which topological ideas are being invoked in order to envision relations between social and technological change. Devices from wind turbines to solar panels are today granted special significance as examples of how we could 'manage' a turbulent world; they have become powerful instances of the project to bring social, technological and environmental change into alignment with one another. Importantly, digital technology tends to figure in a privileged role, as what enables this convergence of different forms of change. Here is a rather enchanted version of this general idea as it figures in a recent IBM advertisement:

> Fortunately our energy can be made smart. It can be managed like the global complex system that it is. We can now instrument everything from the meter in the home to the turbines in the plants to the network itself. ... All of this instrumentation generates new data, which advanced analytics can turn into insight, so that better decisions can be made in real time. Decisions by individuals and business on how they can consume more efficiently. Decisions by utility companies on how they can better manage delivery and balance loads. Decisions by governments and societies on how to preserve the environment.[1]

Advertisements like these make various connections between technology, society, and nature by evoking a classic trope drawn from cybernetics, that of the complex system (Nye, 1999; DeLanda, 1991; Edwards, 2000). In referring to 'complex systems', such publicity material invokes a 'topological imaginary': it highlights (a) the *dynamic* nature of technical and social arrangements and (b) the *interrelatedness* of different levels or orders, in this case technology, society and the environment.

In invoking such ideas, promotional accounts of technology call to mind classic concepts from the sociology of technology. Sociologists have long insisted on the entanglement of technology and society, with some arguing that if we want to properly appreciate their mutual imbrication, we must adopt a 'dynamic ontology' or, indeed, a 'topological imagination'. This argument is often associated with social studies of technology of recent decades, but it is worth pointing out that classic social theorists, too, deployed proto-topological ideas in order to dissolve the separation between the technical and the social. Thus, the post-pragmatist social theorist Alfred Schutz proposed that social reality in technological societies is organized through changing 'topographies' of relevance (Schutz, 1964; see also Schutz, 1970). In his account, everyday subjects and experts do not inhabit different orders of social and technical knowledge, but each accesses different 'regions' of social and technical knowledge depending on their tasks at hand, and these regions themselves are constantly changing as an consequence of the emergence of new technologies and forms of expertise.

In the 1980s and 1990s, sociologists of technology further developed topological ideas in empirical studies. Authors associated with actor-network theory (ANT), such as Latour (1993), Callon (1986), and Mol and Law (1994), and feminist scholars of technology like Haraway (1994) and Suchman (2005) coined concepts like the 'heterogeneous network' and the 'socio-technical assemblage'. These concepts highlight that social and technical entities in practice are always already entangled, not just on the level of our knowledge about the world (as Schutz had demonstrated) but materially or 'ontologically' speaking. This idea was especially elaborated in actor-network theory, which sought to sabotage a debate then existing in social theory, about whether the social shapes the technical or the other way around. If social and technical entities are in practice always encountered as entangled in heterogeneous formations, as ANT and feminist scholars proposed, then a strict separation between the social and the technical, and hence this question about what shapes what, makes no sense (Haraway, 1994; see also Star, 1991).

In developing these perspectives, these social analysts of technology drew inspiration from early 20th-century physics, and relativity theory in particular, where topological ideas had found an influential application, as in the idea that 'objects-in-relation' generate their own space-times (Latour, 1988; Callon et al., 1986). In theoretical physics, these ideas had helped turn space and time from '*a priori*' into '*a posteriori*' categories, and, in an indirect way, this enabled the reformulation of the theoretical question of the relation between the social and the technical. It made it possible to suspend the tacit habit of sociological theory to model social space on classic 'Euclidean' space, with its familiar geometry of stable, singular entities positioned against the external backdrop of a static space and linear time. The rejection of this geometry dissolved an engrained conceptual pattern of the debate about society 'versus' technology: that debate demanded a decision *a priori*, on theoretical grounds, as to whether we should think of technology as invading social space or vice versa. In positing the heterogeneous or 'socio-technical' network as the primary category of analysis, each configuration of elements could now be said to generate its own distinct space-time, with its particular scales, extension and rhythm, emerging from the changing relations among a diverse set of entities (Latour, 1993; Michael, 2000; Mol and Law, 1994). This conceptual move did not only dissolve the issue of the analytic priority of the social or the technical, it also directed attention away from the relation *between* technology and society and towards dynamics that are *internal* to socio-technical formations.

The adoption of a topological imaginary is thus crucial to understanding both the conceptual interventions and normative commitments of the social studies of technology, and especially actor-network theory. But at the same time, these interventions and commitments *cannot* be understood as the results, *in and of themselves*, of a topological imagination. This is becoming clear today, as a whole range of actors invoke topological ideas in order to analyse technology in social terms, but do not share the commitments of ANT and feminist STS. Arguably, then, a topological understanding of technology and society is today no longer purely an issue of sociological theory: the propagation of such an imaginary now presents a much more widely shared societal project, and indeed an operation enabled by technology itself.

A recent lead article in a popular science and technology magazine called SEED, on 'how social science can help solve climate change', provides a case in point. This piece begins by acknowledging the complexity of the social, stating that 'human beings' decision-making processes are probably as complicated as the climate system itself', proposing that the contribution of social science is critical to 'solving the environmental crisis'.[2] In envisioning a future role for a social science of complexity, technology is singled out as crucial. According to the article (and many others) the new social science of complexity will prove its worth by informing the design of environmental awareness technologies and 'other devices to help funnel us into more pro-environmental behaviour'. For this reason, it may be useful or even necessary for us, who are involved in the social analysis of technology today, to approach the topological imagination of technology and society not as a theoretical construct but on the level of devices.

As is clear from the above, in the social studies of technology topology has been used to make a highly *abstract* intervention in social theory, as it provided inspiration for an alternative conception of the relation between society and technology. But a topological imaginary is today deployed *in a much more concrete way* to conceive of technology in social terms. In the current context, digital devices themselves invoke topological ideas in order to bring the social and the technological together. To elaborate this point through another example, the Energy Detective is a web-based application designed to showcase the opportunities opened up by smart electricity meters for generating, visualizing and analysing energy data in an interactive way. Drawing on a feed from a smart meter, this device plots energy use along a temporal axis. The result is a real-time graph, which is marked up by users, noting things like toasters being switched on and off, the fact that it is Friday night, and the presence of teenagers in the house,[3] or how smart they and their devices are in doing the laundry at night rather than during the day (see Figure 1). Such a device highlights continuities between the social and the technical in ways that are not dissimilar to those outlined by sociologists.

We can, then, make an analogy between an *argument* from the social studies of technology and a *technical operation* enabled by the smart meter. To drive this point home, we might say that an application like the smart energy detective performs a conceptual operation advocated by social analysts of technology in the past: that of 'expanding the frame' on technology. The anthropologist of technology Lucy Suchman has characterized the social studies of technology as committed to this operation: in her account, social studies advocate a move away from a restrictive focus on technology as the principal agent of innovation, and an expansion of frames of analysis to foreground socio-technical processes of 'the ongoing, collective practices of sociomaterial configuration, and reconfiguration in use' (Suchman, 2005: 12). Suchman's account entails a topological imagination of society and technology, as the concept of

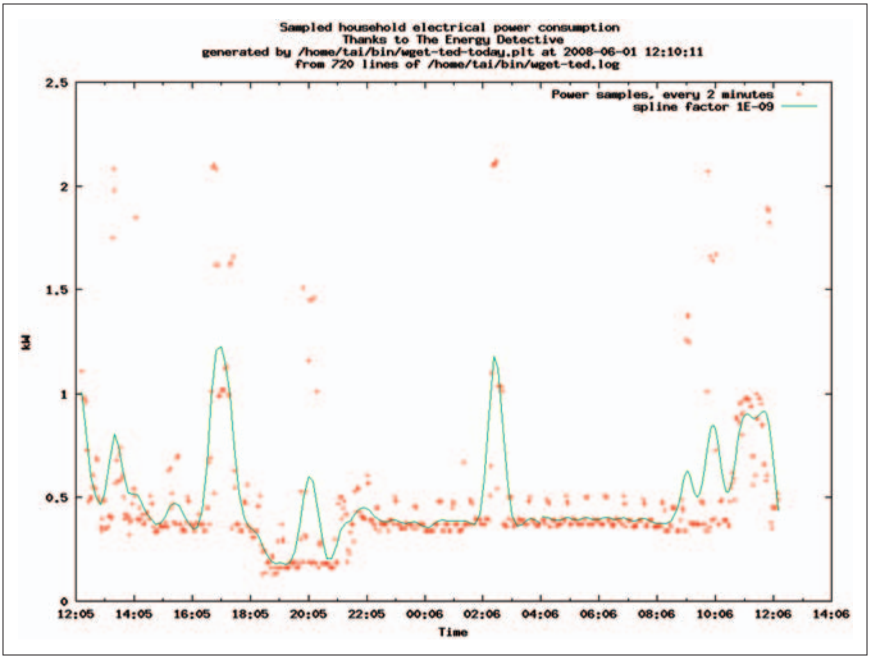

Figure 1. Overnight use of high-draw appliances ('We're quite pleased with the new Sears/LG laundry boxes. The dryer has a rare feature, a delay before operating'). Eastpole's photostream, Flickr, 1 June 2008.

sociomaterial reconfiguration gives pride of place to heterogeneous objects that stand in dynamic relations to one another. The aforementioned proto-topological thinker Alfred Schutz equally insisted on the importance of 'frame expansion' in relation to society and technology. In his famous essay on 'The Well-Informed Citizen' (1964), he defined the role of the citizen in a technological society in terms of the task of 'expanding the frame'. In these societies, Schutz argued, the invention of new technologies of transport, energy and communication renders social life more complex and expands the times and spaces in which social life unfolds. To deal with this situation everyday subjects must learn how to 'reduce, as much as possible, the zone of the irrelevant' (Schutz, 1964).

One could then say that digital energy technologies are currently being configured as devices of frame expansion: in some ways, though only in some, graphs like that produced by the Energy Detective 'expand the frame' on energy use. They broaden the range of entities considered relevant to energy use beyond the 'strictly technical', as they include elements such as teenagers in the equation of energy use, and situate them on the same plane as technical elements like toasters. And the broadening of the frame here too translates into a focus on dynamic processes in which both social and technical entities are caught up. As digital devices allow for the monitoring and analysis of energy-in-use, they make it possible to render energy demand as a dynamic practice, in which an array of heterogeneous – at least at first sight – entities are implicated. To some degree, then, smart energy meters can be said to enable the very topological imagination that has been singled out by social thinkers as what our current technological condition requires. Indeed, they can be said to enact what the sociologist Helga Nowotny (2002) refers to as the 'expansive present', a term she proposes for the space-time that in her view is characteristic of the 'post-environmental' phase we are in today. Here, taking the environment into account no longer takes the form of a colonization of the future, onto which scenarios of environmental disaster and/or utopia are projected. Rather, it now operates through a maximization of the entities to be taken into consideration in the expansive present of social action: species, communities, lifestyles, and so on.

Nevertheless, while current imaginations of everyday energy technology bear some similarities to sociological ideas about the mutual imbrication of the social and the technical, we should also note the ways in which they do *not*, in fact, 'expand the frame' on technology at all. Smart energy meters may be presented, in advertising and other publicity materials, as means to broaden the range of entities considered relevant to energy use, but they do so in ways that are very limited.

It has been observed that the spread of ideas from cybernetics throughout societal discourses, in the 1990s and 2000s, has resulted in their weakening (Boltanksi and Chiapello, 2005; Brown, 2004). We can also observe this in relation to devices that 'expand the frame' on energy use, on at least two specific points. Firstly, while these devices invoke topological ideas to approximate the social and the technical, they tend *not* to conceive of the social in topological terms. An especially clear instance of this asymmetry can be found in *Teatime Britain*, a BBC-commissioned video that places us in the control room of the manager of the British Grid, at the end of *Coronation Street*. The end of this popular TV soap is followed by a surge in kettle boiling across Britain, requiring the manager to make an intervention, and to bring online a French hydraulic dam at the last minute. On the one hand, such a vignette renders energy as a dynamic socio-technical process – as unfolding in a space-time of flexibility, liveness, and responsiveness. On the other hand, the social here figures as a scalable national phenomenon (households in front of their TVs) that is neatly reducible to the technical (surge).

As in the IBM ad above, society is here defined in solidly scalar terms, a tiered system with individual consumers at one end and the national system at the other. This imagination of society is distinctly un-topological: a key feature of the topological conception of society in the sociology of technology has precisely been the idea that social arrangements do *not* fit the classic scalar space, which is associated with Euclidean geometry. In a topological society, the nation is *not* necessarily bigger or stronger than, say, an electricity meter, and the domestic is not necessarily situated at a lower level than a map of the world. By contrast, devices like the Energy Detective continue to define the social in scalar terms. While this technology evokes a hybrid ontology involving both teenagers and toasters, the entities it posits all fit neatly into the envelope of 'domestic life'. The device, then, only 'expands the frame' to include relatively 'safe' micro-entities like teenagers, and not more complicated entities like 'carbon markets' or 'peak oil'. This suggests a more general point about current deployments of topology as a device for defining technology in social terms: even as the idea of dynamic space-time is used to bring into view the social dimension of technology, society itself continues to be defined in its 'Euclidean' capacity of a scalar arrangement composed of distinct levels of the micro, meso and macro, which together form a neatly organized whole or 'total space'.

There is also a second and perhaps even more important problem with 'topological devices' like the Energy Detective: a device like this does *not* enable a non-deterministic understanding of the relations between technological and social change. The Energy Detective, in rendering the social topologically, nevertheless still presents social entities in the role of what Harvey Molotch has persuasively called 'just another f*** dependent variable'. Energy technology continues to figure as the principal source of innovation, as something that enables the social but is in no way reducible to it. Even as the topological notion of complexity is used to bring society, technology and the environment together in a platform for energy use, *the idea of technological innovation as the principal driver of change remains in place*. This topological device does not challenge the 'primacy of technology'.

One could say that the devices of frame expansion discussed so far deviate from the concept of frame expansion in that they still contribute to a 'seeing double'. On the one hand, these devices render everyday practices in topological terms, as they highlight the ongoing reconfiguration of 'heterogeneous assemblages' involving toasters and teenagers. On the other hand, these devices do not extend the topological imagination to social entities themselves, which continue to be framed in scalar terms, and neither do they apply it to the relation between *technological and social change*, which continues to be defined as a causal one, however minimally speaking. These devices, one could say, welcome complexity within the frame of technological systems, but *not* a complication of the frame, as the 'roll-out' of a technological system remains the critical operator of social change.

One response to this situation is to insist on the radical nature of topological *theories* of society and technology, as opposed to these devices. But I would instead like to explore further the idea that digital devices offer ways to 'expand the frame' on technology. There may be different ways to configure digital technologies as topological devices of sorts, and different ways of rendering technology social by these means. To the 'weak' topology of a digital application like Energy Detective, we may be able to oppose 'stronger' topologies afforded by other kinds of devices. In other words, the proliferation of topological machines in digital culture does *necessarily* entail the watering down of the sociological idea of the mutual entanglement of the social and the technical, but may also enable us to elaborate it further.

Mapping Controversies: Smart Meters as Problematic Objects

In order to challenge the 'weak' use of topology described above, in which complexity is only welcomed *within* the technological frame, we could start by recognizing that digital energy technologies are also *objects* of frame expansion.[4] That is to say, digital energy technologies do not only serve as *devices* for expanding the frame on energy practices, they also figure as *objects* of such operations, and this insofar as they have become topics of *public controversy*. Devices like smart electricity meters, in recent years, have become the focus of a whole array of advocacy, research, and lobbying activities, in industrial, policy, scientific, non-governmental and creative circles (Darby, 2010; see also Michael and Gaver, 2009). These activities, too, can be said to involve attempts to 'expand the frame' on technology: scientific and political engagements with electricity metering, too, aim to broaden the range of entities to be taken into account in relation to energy: they seek to demonstrate the relevance of concerns ranging from fuel poverty to the presence of graphic displays on domestic meters (Preston and White, 2010).

Work in actor-network theory has long argued that, from a topological perspective on technology, *controversies about technology* are especially important. This work has proposed that controversies make possible frame expansions on technology too, not unlike those advocated by sociologists themselves.[5] Controversy, it is argued, offers an occasion to establish the relevance of many more entities in relation to a particular technology than is otherwise possible (Latour, 2001; Barry, 2002; Callon et al., 2001; Fraser, 2007; see also Marres, 2007).[6] That is, when technologies become issues, the number of concerns that must be taken into account in relation to said technologies are radically broadened. And such an understanding of public controversy entails a topological imagination of society and technology in at least two ways. Firstly, a focus on the transformation of objects into issues entails a *dynamic* understanding of objects, suggesting that things may enter into quite radically different states when they become subject to controversy, or processes of 'issuefication' (Marres and Rogers, 2005). Secondly, such an approach highlights the *interrelatedness* of different orders: where objects turn into issues, scientific, moral and social concerns turn out to be intimately related and entangled (Latour, 2001). Public controversies thus evince a dynamic of 'frame expansion' too. When we consider how public controversies unfold on digital platforms, we get into view a particular version of this topological dynamic, one that may offer a stronger alternative to the 'weak' topologies discussed above.

Before elaborating this point, however, I want to establish the difference between topological and 'Euclidean' understandings of public controversy, and the spaces and times in which they unfold, as this can help to clarify what is at stake in the adoption of a topological approach. A Euclidean perspective on controversy can be recognized in accounts that model controversy on 'public debate'. Such accounts tend to project an abstract debate space onto the issue under consideration, and then seek to position different actors in this space, to indicate their various perspectives or 'viewpoints' on the issue (Mol, 2002). Such an imagination of public controversy assumes that the space of controversy is analytically distinct from the controversy itself. One could say that a Euclidian imagination of controversy lifts social actors into an ideal space of public debate, in which actors are expected to settle into a single position that is true to their viewpoint, but this position-taking is not assumed to affect the shape of the space of debate itself. To give an empirical example, traces of such an approach can be recognized in an account of controversies about smart electricity meters in the 1990s by Marvin et al. (1999):

> A context needs to be created in which utilities, manufacturers and communications companies can be supplemented with the missing voices of regulators and user groups, such as environmental and community organisations.

In an account like this, the principal aim of controversy is the establishment of a space in which different actors' views ('missing voices') can be included in the domestication of new technology. Controversy here makes possible the explication of actors' perspectives, so that a more inclusive definition of the object may result.

A topological ontology of public controversy differs from the Euclidean one on a number of points. As the former defines controversy in terms of the transformation of objects into issues, it enables a much more dynamic understanding of the spaces and times of controversies. A topological imagination of controversy, that is, recognizes the capacity of controversy to produce *variations* in the spaces and times of issues. And rather than defining controversy in terms of actors taking positions, it entails the unfolding of heterogeneous – social, technological, environmental, political, economic – concerns. Digital devices, I want to argue, have the capacity to enable this kind of topological rendering of the space of controversy; here, topology offers a device, and not just a theory, for imagining the relation between technology and society differently, and for performing the stronger type of 'frame expansion'.

This can become clear if we consider the use of digital tools for the analysis and visualization of public controversy. Online applications for data analysis and visualization, that is, enable dynamic, and arguably 'topological', renderings of controversy (November and Latour, 2010; Scharnhorst and Wouters, 2006). However, what makes matters especially complicated here is that these applications have built into them particular *methods* of analysis and visualization, on which social studies of technology has also relied in the past to analyse controversies. To speak of the deployment of topology as a device, in this case, is then to do more than suggest an analogy between a sociological concept and digital technologies. It is to highlight that certain methods of 'topological' analysis have become built into digital technologies in recent times.

Sociologists of technology have long relied on methods of network and textual analysis in order to capture the unfolding of controversies in ways that we can call 'topological' (Callon et al., 1983; Leydersdorff, 1996). In order to map the 'frame expansions' on technology occurring in controversies, they produced visualizations of the unfolding relations between heterogeneous actors and terms caught up in public controversy. Today the proliferation of digital technologies means that similar methods are deployed much more widely to analyse and visualize issues in digital networked media (Rogers and Marres, 2000). Indeed, network and textual analysis tools are now routinely deployed in digital culture, in the form of search engines that rely on hyperlink analysis to capture evolving relevance relations (Google), and of blogs that use clouding software to disclose 'dynamic content' (Worldle) (Van Couvering, 2007; Rogers, 2009, see also Marres, 2012). And this proliferation of network and textual analysis across social life in the guise of 'digital methods' has consequences for the social analysis of public controversy. Here too, we can note a change in status of the topological analysis of technology and society.

In classic controversy analyses in the social studies of science and technology a topological conception of public controversy had *analytic* status: the concept of heterogeneous assemblages unfolding in a dynamic space-time was projected onto empirical material by virtue of the *methods and concepts* deployed in social studies of public controversies about technology. By contrast, in the context of digital culture, the topological configuration of controversy spaces must be understood as an *empirical* effect. It is partly the consequence of the deployment of 'topological devices' of network and textual analysis across digital culture.[7] An example of this

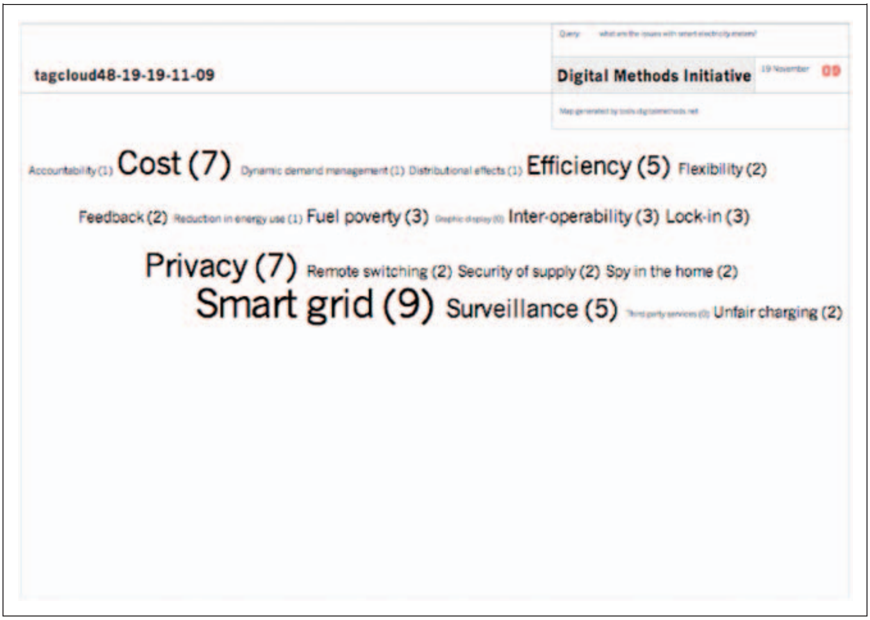

Figure 2. Tag cloud, frequencies of terms in a UK controversy about smart electricity meter according to the Googlescraper, November 2009.

type of topological rendering of public controversy, produced with the aid of a tool of web analysis, can help to make this clear.

Figure 2 presents the result of a web-based textual analysis of a recent public controversy about smart energy meters in the UK. The controversy in question flared up in the fall of 2009, after the publication by the Department of Energy and Climate Change (DECC) of its impact assessment of 'smart metering of gas and electricity in the domestic sector'. In the week following the publication of this report, a range of news stories raised concerns, as the consumer organization Consumer Focus suggested that smart meters could be used by utility companies to switch off non-paying customers.[8] Smart meters, these stories also suggested, could provide a channel for third-party services, consumer applications that would run on top of smart meters, and as such would serve as what *The Daily Telegraph* called a 'spy in the home'.[9] In order to find out whether these issues were the subject of a wider controversy, I used a web-based tool called the Googlescraper, which piggy-backs on Google to determine whether terms have resonance on selected web pages.[10] Querying a set of web pages of NGOs' blogs, company and news sites, which link to the DECC Impact assessment, I found the distribution of terms illustrated in Figure 2. Such an 'issue cloud' visualization can help to specify the type of 'frame expansion' on technology that is enabled by digital devices. The figure shows a range of concerns that became associated with smart meters on the occasion of DECC's impact assessment report, or perhaps one could say, it provides an indication of the 'controversiality' of smart energy meters in a particular time and space, namely that opened up by this report.

Such a rendering itself can be accounted for in several ways. Thus, we may approach web pages as representing actor positions, and understand the weighing of terms going on here in terms of actors putting their weight behind certain issues and not others. As Bruno Latour and Richard Rogers have also argued, web analysis offers a way to take up an idea of the 20th-century American journalist Walter Lippmann, that 'actor partisanship' provides an effective measure for clarifying complex processes of issue formation (Latour, 2008; Rogers and Marres, 2002). But there is also another way of reading the issue cloud, one that plays up the difference that a topological rendering of controversy can make to our conception of controversy. As the figure provides indications of the scope of terms that are currently active in the controversy on smart electricity meters, it can be taken as disclosing the 'state of issuefication' of the object called smart meter. Here controversy involves not so much actors taking positions but a process of the problematization of objects, by which they become charged with various social, economic, political problematics or issues.[11]

An analysis of public controversy as a process of 'issuefication' can be distinguished from the other perspectives on public controversies about technology outlined above, and has implications for how we define 'expansions of the frame' on technology. Firstly, online issue mapping can be distinguished from approaches that define controversy in terms of public debate. Deploying a digital research tool like the Googlescraper, controversy analysis is not so much a matter of determining once and for all the positions of actors and their inclusion in, or exclusion from, debate spaces. Rather, it becomes a way of finding out about the dynamic composition of objects in terms of issues or actors in information spaces that are always in flux. Which is to say, to analyse processes of issuefication with the aid of digital devices is to adopt an explicitly topological approach to public controversy.

Just as in the case of the framing of smart meters as 'social technologies' discussed in section 2, a focus on public debate typically involves a form of 'seeing double', but from the opposite direction: here, the social, cultural and political processes of framing technology are affirmed, but the role of technology in organizing such processes of frame expansion is not really considered. That is, while such approaches recognize that technology may serve as an *object* of frame expansion, they do not acknowledge the role of technology as a *device* of frame expansion. As the abstract form of public debate is projected onto a given issue area, it becomes difficult to appreciate how spaces of issues are themselves organized by technological means. The space of controversy is here delineated by purely analytic means. By contrast, to analyse processes issuefication with the aid of a topological device like a tag cloud visualization makes it possible to examine the empirical unfolding of the space-times of issues. The topological unfolding of a space-time of controversy is revealed to be partly an artefact of the *devices used to render controversy visible and analysable*. The topological organization of controversy, that is, is here accomplished experimentally, through the deployment of digital devices. And this, in turn, has implications for how we imagine the relation between social and technological change.

Expanding the Frame on Socio-technical Change

In the above analysis of a controversial object, using a topological device does not only help us to appreciate *the entanglement of the social and the technical* in said object, but also brings into view the empirical unfolding of *the object qua issue*. This has implications for the long-standing debate flagged in the introduction, that about the relation between technological and social change, and how topology may contribute to our understanding of it. It disrupts a frequently made criticism of topological approaches to technology and society. Such approaches have been criticized for making it difficult to generalize meaningfully about societal and technological change. A topological imagination of technology and society has been said to come at a price: it reframes change as something internal to socio-technical collectives. And if socio-technical change is located inside 'on-going, collective practices of reconfiguration', as Lucy Suchmann (2005) has put it, then processes of change are likely to be rendered complex to the point of becoming impossible to summarize. A topological rendering of controversy, as discussed above, may offer a way of dealing with this risk of dissolving change into the minutiae of on-going practice insofar as it is able to bring into view a range of proliferating, contending *articulations* of socio-technical change.

The distribution of controversy terms across web pages dealing with smart meters in the UK ascribes to these objects different possible normative effects, in terms of privacy, surveillance, fuel poverty, remote disconnection, and so on. To be sure, the co-occurrence of these issue terms does *not* necessarily add up to any coherent picture of a changing world: smart meters may provide opportunities for the monitoring of consumer behaviour; *and* they are also critical to the making of a low-carbon economy and thereby to addressing the global environmental threat of climate change; *and* they are also likely to have 'distributional effects' that contribute to socio-economic inequality.[12] A cloud of such issues, that is, does not quite offer a generalization, but it does provide a screenshot of the distribution of types of socio-technological change, and thus gives a sense of the work of projection involved in the enactment of socio-technical change.

For this reason, issue analysis cannot really be said to render socio-technical change internal to socio-material practices. Yes: in exploring the issuefication of smart electricity meters, the question of socio-technological change is complexified, as it forces us to recognize the proliferation of diverging articulations of change. But: processes of change are *not* rendered so complex that it is no longer meaningful to envision more broad-stroked changes of socio-technical arrangements.[13] This does not put us in a comfortable situation. In a public controversy like that around smart energy meters, a range of issue terms are rendered relevant to this technology, but there is no assurance that these issues will ever cohere, if by that is meant that they might become mutually relevant. It is not self-evident that the issue terms necessarily add up to a single something. We might say that while problematizations of smart meters are abundant, these problematizations are not necessarily expansive.[14] These issues do *not* as a matter of course translate into anything that might deserve the name of a 'topology of relevance', in a variation on the aforementioned 'cartographies of relevance' invoked by Alfred Schutz. Issue mapping may easily end up disclosing non-controversies.[15] Online issue analysis, then, sensitizes us to the ways in which problematizations are abundant without being expansive, and invites us to take this seriously as a condition of social, technological and environmental change.

Conclusion

Digital devices enable a topological analysis of technology and society in a variety of ways. They make it possible to broaden the range of entities to be taken into account in relation to technology, and they do this with varying implications. In some cases, frame expansions result in a celebration of the entanglement of society and technology, highlighting the ways in which technologies are 'alive' with sociality. In other cases, topological renderings of technology demonstrate the multiplicity of issues opened up by that technology. That these different topological approaches to technology and society are increasingly prevalent places special requirements on the social studies of technology. In this context, it becomes less important to advocate a topological *understanding* of technology and society, as opposed to a non-topological one. Rather, we must now examine how topological *devices* are variously deployed to render technology social, and try to discern subtle but decisive differences between these various deployments. It now becomes our task, as social analysts of technology, to be *demanding* of topological analyses of technology and society. It is not enough to point at the great opportunities for a social analysis of complex dynamics that are enabled by the proliferation of digital technologies across society. It is not enough to affirm the mutual imbrication of technological and social arrangements, if this leaves in place assumptions about the neat alignment of technological and social change. We must demonstrate that a stronger form of topological analysis is called for, and provide pointers as to how this might be developed.

To this end, I have distinguished two ways of analysing technology and society topologically, two ways of 'expanding the frame' on technology. A first type of frame expansion focuses on technology-in-use, and is enabled by technologies like smart energy meters. Here, frame expansion helps to highlight proliferating connections between social and technological entities within a technologically delineated space, say that of energy-in-use. A second type of frame expansion is concerned with societal processes of the problematization of technology, which digital devices of issue analysis and visualisation can help to bring into view. In this case, the deployment of a topological device helps to bring into view dynamics of the 'issuefication' of technology, the unfolding of concerns in an empirical space-time of publicity. Where in the first case frame expansion results in the inclusion of more entities in the technological frame, in the second case it results in the problematization of technology. This difference matters insofar as it translates into a different analysis of the relations between technological and social change.

In the first case, a topological analysis of society and technology provides a way of recognizing the mutual imbrication of technology and society, but it does not affect assumptions about the primacy of technological over social change, or challenge the view that the former can stand in for the latter. In the second case, a topological analysis does translate into a different imagination of the relations between technological and social change: topological analysis here brings into view the proliferation of contending articulations of techno-social change, and, thus, a situation in which different forms and types of change are made visible, although they cannot be assumed to be neatly aligned. As frames are expanded on technology, and more and more entities prove to be implicated, socio-technical dynamics turn out to be much less coherent than expected.

In a situation in which topological devices are widely deployed to analyse and organize technology, linear, causal understandings of technology and society should perhaps cease to be the main focus of critique. Controversy analysis may point a way forward in this respect, in that it offers a way of performing critique by empirical means. Mapping controversies brings into view social processes of the problematization of technology, and as such, it depicts technology in a 'critical state', so to speak. Crucial to the topological rendering of controversy is that 'problematization' here takes the form of an empirical unfolding: problem-spaces and problem-times, it here become clear, are organized through empirically traceable keywords, hyperlinks and so on.[16] For this reason, mapping controversies may be said to offer a way of being critical that does *not* require a transcendentalizing move. To develop such empirical forms of critique requires more serious work and reflection on the tools and methods of topological analysis and, in particular, on the kinds of ontologies that get built into the software applications on which we rely. Here I have only flagged the broad difference between an ontology that focuses on the inclusion of heterogeneous entities versus an ontology which foregrounds processes of issuefication.

Finally, there is an important question of the imagination that needs addressing, which is the question of whether and how normative social science can handle the relative *non-coherence* of dynamic objects (Law, 2004). A demanding or critical mode of analysis has long been associated with paranoia, that is, with the risk of assuming coherence where there is none (Dean, 2000). The question raised here is whether social science can handle a risk of almost the opposite kind: is it possible to recognize the relative non-coherence of societal and technological processes, and still be demanding of them? We may reject easy assumptions of the alignment of social and technological change, but are we really capable of acknowledging the misalignment of different forms of change, and still formulate intelligent demands for change? The question seems especially urgent in the context of proliferating digital technologies, in which the complexity of change, the modification of collectives along multiple axes, and the ways in which change actually does not add up or point in one direction (for example, democratizing energy = increasing surveillance), are rendered legible in publicity media. Can we analyse change as not necessarily coherent, and still be demanding of it?

Notes

1. 'Smarter energy for a smarter planet', IBM Ad, *Financial Times*, special issue on the future of energy, 4 November 2009. See also http://www.ibm.com/smarterplanet/us/en/smart_grid/visions/index.html.
2. David Zax, 'The Last Experiment', *SEED Magazine*, 22 April 2009, http://seedmagazine.com/content/article/the_last_experiment/. The article offers a particular translation of the environmental crisis into a proposition of social science, one that turns this crisis into a behavioural problem: 'We know the climate demands action. We know all these things and yet we do not act. Why: we don't exactly know. And that makes climate change a question for social scientists like Ben Ho.'
3. These examples featured in a live presentation of Energy Detective outputs on the website of a smart energy company, Energy Circle. See http://www.energycircle.com/blog/2009/05/27/ted-open-source-how-we-went-live-with-our-electricity-use.
4. It is tempting to make an analogy here with the 'doubling of man' that is thematized in transcendental philosophy from Kant to Foucault (Rouse, 1994). According to this concept, it is distinctive of humans to be both the subject and object of reflection all at once, and the idea can perhaps be applied to technology as well.

5. Of course, controversies about science and technology have long been recognized as a useful site for complicating prevalent understandings of the relations between the social and the technical (Bloor, 1982; Latour, 1987; Collins and Pinch, 1998). In these events, public definitions of technology become destabilized, and this makes it much less likely for them to be cast in the role of the 'independent variable', as discussed above.
6. This notion of controversy as frame expansion was first proposed by Michel Callon in the 1980s. He foregrounded problematization as a central dynamic of scientific discovery and innovation, which in his account is the consequence of the imposition of a new frame on the situation, and as a consequence of this, the opening up of the definition of the situation and the terms mobilized in relation to it (Callon, 1980). Notions of framing themselves have a much longer history, going back at least to Goffmann, Schutz and Dewey, and further to phenomenological and (neo-)Kantian traditions.
7. This is one of the focal points of the recently concluded collaborative EU-project Mapping Controversies (MACOSPOL) initiated by Bruno Latour, together with Kristin Asdal, Massimiano Bucchi, Cordula Cropp, Dominique Lindhardt, François Mélard, Valerie November, Richard Rogers, Albena Yaneva, André Mogoutov and others, including myself. http://www.mappingcontroversies.net, see also www.issuemapping.net.
8. Consumer Focus, 'Reduce risks and increase benefits of smart meters', press release, London, 30 September 2009.
9. Alastair Jamieson, 'Smart meters could be "spy in the home"', *Daily Telegraph*, 11 October 2009.
10. The Googlescraper was designed by the Digital Methods group in Amsterdam, as part of the Mapping Controversies project.
11. Problematization is a concept adopted by Foucault and later in actor-network theory, and can be traced back to the pragmatist concept of the problematic situation. But these different approaches fill in the concept slightly differently: in Foucault, problematization figures as an attribute of discursive regimes (Rabinow, 2005) while in pragmatism problematization figures as an event: one could say that here it refers not so much to an epistemic effect as to an ontological moment. However, while Callon adopted the pragmatist notion of problematization in the study of innovation processes, he opted for an epistemic rather than an ontological version of it.
12. Max Hogg, 'Do smart meters actually save energy?', *Financial Times*, 11 May 2009.
13. Relative non-coherence also implies relative under-determinacy. As Sarah Darby (2008) concluded on different grounds: 'smart metering cannot be specified satisfactorily from any single standpoint, there are too many questions from too many directions'.
14. A similar point has been made by Annemarie Mol (2002), in her critique of controversy studies, namely that these studies do not sufficiently recognize the spatio-temporal distribution of science and technology. However, Mol's critique relies heavily on an ethnographic apprehension of topological distribution, and as such it risks what might be called 'methodological exceptionalism': it suggests that only with the aid of special fieldwork methods can we access topologies of irrelevance, suggesting that *this* frame expansion is the exclusive privilege of social studies.
15. To give an empirical indication of this: the 2009 controversy about smart meters occasioned by the DECC impact assessment did not translate into a

coherent 'issue network', at least not on the Web. The organizations, individuals and media outlets that reported critically on the outcome of its impact assessment aren't in actuality organized in a problem-specific configuration: their websites disclose only a very loosely connected network consisting of UK government and regulatory agencies, the UN climate agency IPPC, and a book called *Hot Air*.
16. This contrasts with the status of ontological incoherence in 'post-ANT', where it tends to be presented as a sub-discursive phenomenon, as a latent pattern that tends to escape mainstream empirical analysis.

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Digital Infrastructures and the Machinery of Topological Abstraction

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Abstract

Drawing on contemporary pragmatic philosophy and grounded in a reading of techniques associated with digital media as sophist practices of influence and manipulation, this paper proposes an 'experimental' reading of key aspects of the topological qualities of the infrastructure of the knowledge economy, with its obsessive attempts at measuring, recording and monitoring, or 'qualculation'. Taking seriously, albeit with humour, early criticisms of actor-network for its ostensibly Machiavellian proclivities, it offers a series of playful stratagems for the exploration and analysis of power as an emergent property of socio-technical relations. Topology, in this account, becomes relevant to cultural analysis because of the way that it allows us to think together processes constructive of the intensive continua of 'desiring production' with the sociotechnical operations of digital media infrastructures. Different elements operative within digital media (the super-hub, the power of small numbers, recursion and relational databases) are read stratagematically – as figures of a praxis (the material practice of immaterial labour), that reveals different facets of the operations of power, while also allowing for counter-tactics to be deployed. Rather than proposing a theoretical account or an empirical analysis, the paper develops what Stengers (2011) calls 'operative constructs', which become ingredients for further active exploration of and thinking about the topological qualities of mediatic infrastructure. The paper addresses four different and overlapping areas of digital media from a point of view that considers the plural, compositional quality of media/power relations.

Keywords

abstraction, affect, databases, immateriality, Machiavelli, manipulation, micropolitics, pragmatics

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Introduction

In this paper, some aspects of contemporary power and the topological qualities of its operations are examined by means of a consideration of the agency of technique and technical practice. This is something of a shift from the predominant Foucauldian emphasis on the way that configurations of knowledge shape the historical conditions, the historical 'a priori' of practices. The focus on technique here takes its inspiration instead from the exploration in science and technology studies of the socio-technically constructed qualities of social order. More specifically, it takes seriously both the early invocations of Machiavelli in STS (Latour, 1987) as well as later references to sophistry (Latour, 1999; Stengers, 2010), proposing in turn a 'stratagematic' reading of some of the operations of power.

The place of technique in Western knowledge practices and the desirability of considering it independently of the tacit privileging of the epistemic to which it is normally subject has been made most forcefully in the recent work of Isabelle Stengers (2010, 2012). In this paper we draw some of the consequences of that attempt at dissociation and the fruitful conception of techniques of influence deriving from it, in relationship to formal and informal, intentional and unintentional practices of manipulation and control. Understandings of computation and the processes and practices associated with it are habitually framed in epistemic terms – as the recurrent emphasis on ideas about modelling within computing science suggests. However, this tendency to focus on issues of knowledge can detract from a more material consideration of the way that digital artefacts give shape to fields of experience and the opportunities for action they embody. It is the pragmatic efficacy of 'grey' media forms that we are most interested in exploring here.[1] Following Machiavelli, we seek to adopt the point of view of power and the uncertainties and ambiguities attendant on its exercise.[2] Unstable alliances of actors are considered here in terms of the opportunities for manipulation and the experimental seeking of (uncertain) outcomes they present.

Of particular interest in this paper, then, are techniques operative within the field of software engineering and the configurations of digital artefacts that are constructed by it. This is an area of research that has suffered from the restrictively dichotomous nature of the conceptual frameworks typically used to analyse it. However, exploring digital artefacts from a point of view in which the technical and the social are treated on equal terms is indispensible. It has been further argued (Berg, 1997) that understanding the role of formal systems equally requires attention to what happens in the 'gap' between the formal and empirical, or what we think of here as the technical and the social: information technology has a habit of generating strange dynamics and new shapes in and of experience – forms of interruption (Wajcman and Rose, 2011) or precipitous anticipations or frustrated waiting (Mackenzie, 2010), that are inexplicable otherwise. The spatio-temporal configurations, or code/spaces (Kitchin and Dodge, 2011), that are generated around this gap have an increasingly significant role to play in the organization of everyday life, and they generate peculiar topological dynamics of their own, which require imaginative tools to be made visible. What we are interested in here are the un- or under-explored, anomalous or aberrant aspects of the 'abstract' materiality of the infrastructures of contemporary experience and the ways in which such aberrations can be or are being exploited.

Our approach may be characterized as 'stratagematic'. The term 'stratagem' here is borrowed from Arthur Schopenhauer, whose overlooked text *The Art of Always Being Right* (2004) develops a quasi-Machiavellian approach to the way in which aberrations of language may be used to win arguments. Schopenhauer's text is a dark and rather cynical re-visiting of the project, first started by Aristotle, of learning how to spot and then refute sophisms, because it brackets out any consideration of the ultimate truth or validity of arguments. For Schopenhauer, a stratagem points to a specific, pragmatically efficacious way of exploiting the sophistic materiality of discourse. Contemporary theory would in all likelihood consider Schopenhauer an advocate of the performativity of language, and there are some interesting points of contrast with contemporary invocations of the performative or virtuoso powers of language to be made in this regard (Virno, 2004; Callon, 2006). In this context, a stratagem may be considered as a performative, socio-technical operation that constructs the forms of topological continuity on which it appears to act.[3]

Presenting stratagems rather than searching for causes might seem odd. Not least because there is a good argument that all the sophisms that Aristotle sought to sniff out could be traced back to one root cause – homonymy as the 'radical evil' in language (Cassin, 1995). But exploring the phenomenological complexity of the ways in which the imperfections of a media form (such as language) can be and are exploited has a pragmatic goal: that of generating a certain kind of sensibility to the organization of power within a field of experience. In conformity with the origins of sophistry in the art or artfulness of 'tekhne', the discussion proposed here considers techniques and technologies in slightly different terms than the evidently instrumental qualities of their use might suggest is relevant. There is a need to consider the broader 'artfulness' of technologies and techniques as itself having effects in its own right, as something that can – and should – be evaluated on its own terms.

The register of 'artfulness' and the broader history of sophistic manipulation links the semiotico-material qualities of digital media to the field of affect or desiring production, pointing to a link that is often occulted or only considered in terms of the formal abstraction of the 'signifier', although the issue of topology has a long history in relationship to psychoanalysis. The stratagems here are situated in relationship to concerns about topology partly because they deal with what others have referred to in terms of the 'automatic production of space' (Thrift and French, 2002) and the 'technological unconscious' (Thrift, 2004a), with its own under-explored and labile constellation of topoi. Much of the material that we are concerned with here is also situated at points in which mathematically conceived forms are taken up in or indeed derived from social and cultural contexts. The computational (or quasi-computational) techniques with which we are concerned are addressed in terms of the way in which topological aspects of spatial (and temporal) relations – continuities, deformations, breaks and proximities – form the stakes of an ongoing productive construction. Power in the social sense here develops in proximity to the mathematico-technical 'power of the continuum' – a presumed mathematical characteristic of non-denumerable sets, operating in the transfinite, something which might best be understood here as a power of *continuation*.[4] When it comes to the role of the socio-technical in matters infrastructural, continuity and the capacities and properties that can be ascribed to it are themselves the object of myriad processes of not entirely seamless, somewhat glitchy construction. Topology is thus to be considered not – as one might be tempted – as a given of structure but as part of the stakes of a strange kind of socio-technical praxis that operates through both humans and nonhumans. It gives us a way to characterize pertinent aspects of the stratagematic operations of power.

In the following four stratagems, then, we offer a series of advisory notes on the state and operation of contemporary forms of power and the means by which it may be handled. Each stratagem tackles a specific aspect of the abstract materiality of digital media: the frenetic sensations of love in the age of the telephone; an intense investment in the abstracted space of small numbers; the formal-material continuities of recursion; and the proliferating relata of databases. In the tense, accelerated, environment of the knowledge economy, establishing continuity of flow – work, data, libido – is paramount.[5] These stratagems disclose the delicate operations by which such continuity might be and sometimes is, obtained, and the risks incurred.

Be Everything but Available

In his text of 1923, *Zoo, or Letters not about Love* (2001), the formalist writer Viktor Shklovsky fills pages and pages with a diastolic correspondence, which, while rarely echoed by the other side of the epistolary heartbeat, is drenched in the immolating rapture of love. His letters to Alya provide traces of a hunger that consumes him, eating up all of the mental currency of attention that he has in his pockets. However, this is a love for a woman who, besides stipulating that he must not write to her about love, will not pick up the phone. Living in an era before the automated answer, Shklovsky feels the world reorganized. One of the many ways it is so is through the conjunctions of different spaces, but also of different emotional and linguistic intensities, squeezed down a copper wire. One of those spaces is absence. The story has numerous registers, devices and ruses by which love is figured, but one dimension that is rarely noticed is its mathematical content. Five times over the course of this short book, Shklovsky makes an allusion to non-Euclidian geometry as exemplifying the world turned upside down magnificence of love. Although he does not name it, the figure he uses is one that is core to Lobachevski's (1955) hyperbolic geometry, with its possibility of an infinity of parallel lines arrayed around and surging through a single point. Every experience of the world, every waking state, turns into an anticipation of and hunger for the beloved. The sensation of his adoration of her is compared to the moment in which a fine woollen scarf is drawn through a gold ring: every aspect of the fabric of the universe converges on this one wondrous point, and passes out through the other side, recomposed. Shklovsky's problem is that the loved one may not feel reducible to this point of convergence or may feel it slightly to her side, missing the point, and his text offers a precursory mapping of the topology of love, the plastic field of intensities out of which it is constituted and the operations that are required to refigure its particular constellation of relations. But, in its condensation of two figures – of the loved one, the one who will not answer the ringing mechanism, who will not become a node, and the one who connects to everything, who recomposes the universe by simply being in it – Shklovksy equally stages and prefigures network analysis through a geometry of affect: the loved one is the super-hub of reality.

One of the conditions of love is the warping of time, the speed at which an endless embrace seems to pass, and the slow monotony of time spent unwillingly apart. However, there is another – spatial – effect of passion that provides a rescension of the evolution of networks and which must also be used. That is the capacity for abundance, of being everything. Elsa Triolet, who plays the role of Alya in the novel, inadvertently took on and trumped the role of the Emperor, as described in Dean and Massumi's *First and Last Emperors* (1992), to rule by being everywhere – to be everything, to saturate the lover's universe – and to be nowhere, unreachable, detained in the bath, in dalliances with fancy cars or in dances with men decorated with ear rings or a repulsive Englishness, with a million other things. The pain of the lover lies in the fact that the loved one is everything, but yet is absent, following a different trajectory.

Writing on evolution, Henri Bergson compares the trajectory of a single life, the process of speciation, the development of a genera, with the trajectory of fragments from an exploding shell. The blast recapitulates its branching through a hierarchy of entities. Each species – one cluster. Each organism – only ever capable of being one fragment. Each mutation – one spin from true. Nature, however, has the capacity to encompass all: shell, explosion and shrapnel, and is in nowise bound to make the sacrifice of differentiation (Bergson, 1998 [1911]: 100). The special madness of love is an encounter with the condensation of all of nature in one being and a recognition of all of one's pre-personal power unfolding in that universe, recognizing it not as a totality but something that is also mutually unfolding. The figure of the fully graphed centralized network, the summa of all possible events, or of connections, is also that of the loved one, the universe. This is the tragedy of the single life, of mortality, when it is brought into contact with reality of rejection, or of the apparent impossibility of not living an infinite number of lives simultaneously.

For just as 'the probability of a global epidemic depends on the number and configuration of initial infectives' (Ball et al., 1997: 61), so the problem of the lover, as faced by Shklovsky, is to saturate the imaginary of the recipient of the letters, which are not about love, with burning, enticing or subtle reminders of the lover and the rapture the loved one might share in. Each ruse in the letters becomes a means of bending flat inattentiveness or bemused dismissal, of opening up a gateway to the universe of love, to the full force of its explosion. Each simple point swells in anticipation that it might be the one to draw the loved one in. What is to be hoped is that there is an absence of symmetry between the point of attraction, which is small – an observation, a joke, a copula of wordings – and the massively expanding universe in which the lover anticipates being joined. Rather than the writer's work being to manipulate language to induce the reader into shedding perceptual habits, setting the elements of the world free from their mundane associations, it is to suffuse the world with the inevitability of the reciprocation of love.

But more trivial passions can also be turned to account. We are told that in the interval between the saturation of connection of the super-hub and the happiness of the isolate (the one who stays in the bath and refuses to pick up the telephone) there is a growing capacity for new opportunities for the harnessing of value to emerge (Anderson, 2006; Brynjolfsson et al., 2007). In a market made smoother by the ease of connections between nodes, what was once detritus finds its buyer, a meager supply finds its true users, and amateurs of all sorts find their devoted fans. Every needle finds its necessary haystack. To put it another way, there is less excess that cannot be leveraged to a point of consumption. A difficulty presents itself, however. In making themselves available, the agents of these minor passions are compelled to compete with the proliferation of ruses, cons, games, lines, seductions, choices of trajectory, of all of those others who are also operating in this modality of space. The abundance of pretenders to super-hub status can tend to obliterate the possibility of choosing, rather than submitting to, the spatiality of absence. A great roiling abundance of minor gateways, slight triggers into patches of the universe get their hustle on under every stone and each mouse-click. After all, one does not want to be reduced to a dot.

In matters of networked connectivity, then, the issue is not just that the saturation of affective possibilities explored by the lover presages the simple techniques of attention management adopted in the information economy. It is that the affinities of familiar network topology with intimate emotional state are such that social production and desiring production (a distinction due to Deleuze and Guattari, 1987) are linked here so intimately that they may be considered two descriptors for the same scale-free movement. In literary form, Shklovksy's *Letters* offer us the means for exploring the topological map of movements that this production sketches out and the traps attendant on it.

Stir Faith in Small Numbers

In the complex topologies of networked infrastructure, small numbers are taken to be decisive. One is reminded of the power of the few sufficiently many times to make such an assertion suspicious. Look at how many members the Bolshevik Party had in 1917, how many Al Qaeda operatives it took to bring down the World Trade Center, and how few people it takes to run the basic technical operations of Wikipedia. Parables and commonplaces abound with the power of tiny increments yielding a radical difference. Guerrilla warfare relies upon the disproportionate effects that may be gained by the war of the flea and on the combination of precision, imperceptibility and unpredictability of small forces accurately deployed (Rogers, 1757; Taber, 2002). The function of sainthood, as an exemplary state of being, relies upon the rarity – yet presumable attainability – of the ascetic holy life in a world of temptation. The effects of small numbers are pressed upon us as exemplars of the instability of global systems and of the power of the individual to effect real social change. In a world of molar aggregates and the probabilistic function of the law of large numbers, the appeal to small numbers and their improbable consequences offers something of the order of amelioration or palliative.[6] Fantastic effects are yielded in such accounts through minimal, but well-chosen or accidental, acts that ripple through volatile systems. So, the exercise of virtù under conditions of digital infrastructure dictates that one should seek out the simple . . . and then distrust it.

An important critical response to such accounts is to look for the background mechanisms, the popular support, subsidiary operators and alliances, technical pre-conditions and the conceptual structuration of entities that make a certain result more likely: material infrastructural devices and associated practices that are generative of the abstracted spaces, the peculiar topological continua in which small numbers are invested in with such alacrity. The spring-time of blossoming events has its own nameless natural history, but one which has only a very loose relation to a proper phylogeny or to the principles of identity by which it might be named or called to order. But equally, if it seems a miracle from nowhere is required, these are the elements that must remain cloaked, established so as to appear tangential, or which simply recede from the foreground of perception in the greyness of attenuated contrasts. The stability of a system can then no longer confidently be said to be reliant upon its nesting within larger systems that guarantee it. Another response might be to turn to Poisson distributions (modelling the probability of events whose averages are known) and their own kind of articulations of the true nature of randomness, mathematical models of the ability of microscopically slight differences to effect significant results (Tasic, n.d.; Guy, 1988).

The experience of living in conditions determined by large numbers, of homogeneous populations of probability (which is, effectively, the condition of the contemporary), involves focusing one's attention on the opportunity provided by small numbers – whether that be the opportunity of winning the lottery or of being immediately and inexplicably recognized for one's innate and unique talent in a televisual extravaganza. It is not an experience that has been predominant over the course of human history, even if it suggests parallels with folk wisdom about chance or good fortune. In the modern world, it is an experience that media, cultural imaginaries and the economic ideologies of self-affirmation and opportunity seem particularly proficient at generating as a state of ever-extensible, statistically grounded, hope, as a correlate of unrestricted, exponential growth in the production of data.

But, given the emphasis on the power of small numbers in the contemporary imaginary, the question of whether the topology of media systems that arise during periods in which there is such effervescent affective investment in them are configured in such a manner as to accentuate the effectiveness of the small is one that is yet to be answered. The fantastic yields of computer viruses, worms and bugs are often proffered as a state to aspire to, in which the smallest of operators reaches a magnificent climax for millions within days of being launched – witness in parallel the corporate adoption of viral marketing, network production of the soundbite or seeking of promotional effects through video-clips on YouTube, as only the most obvious of instances (Alt, 2005; Parikka, 2007). The yearning to be the bearer of such a difference, of being able to sense participation in such a moment, in turn drives the sales of sugary, parascientific narratives that seek only to confirm it as a possibility (Gladwell, 2001). Redemption by an encounter with the non-linear sublime replaces the need for strategy in many minds, but as such it is also something from which stratagems can be derived in turn.

Small numbers work because the topological spaces out of which statistics are extracted are not friction-free environments. Whether such topological continua are, at least rhetorically, said to exist as markets, the noiseless environment of information theory, or a technology that implements it, homogeneity is in reality a difficult condition to identify. Hence the micropolitical event is able to make use of small differentiations in opportunity, event-texture, speed and the conjunction of forces and chances, differentiations the heterogeneity of which become occluded in the statistics. Machiavelli uses the metaphor of a wildly flooding river to describe the propensities of such fortune, and advises preparation and adaptation as a way both to modify and cope with the behaviour of an aleatory world and audacity as a means of bringing a mythically feminized luck to the point of subdual and consummation (Machiavelli, 1964: 130–3). Somehow though, in the present day, coupling preparation with audacity seems to translate into the expectation that minuscule variation – the righteous gesture, the personal disaggregation from the norm, the presence of a video or a document in a database – might just be all it takes for something to change for the better. Connectedness across abstracted, statistically homogenized spaces generates the hope of exceptionality, the data point that tips and inflects against the grain.

The yearning for the significance of small gestures comes in part from dismay at the effects of the large or monolithic. A citizen may hope to do something utterly innocuous, seemingly trivial, but, in so doing, incidentally render the world perfect. Such expansive hopes are shared by those who buy lottery tickets, stir viral froths online, or determine that it is best to think positively. In the case of micropolitics, the idea of the small gesture that proliferates may be its own Straussian 'noble lie' (Strauss, 1978). It is, however, a mode of belief that is – as is suggested shortly – deeply suited to the naturally quantitative topologies of networked and computational digital media and the forms of calculus – or even 'qualculus' – to which they give rise, but which also tends to flatten out what used to be seen as different scales. Indeed it may even be the slippage *between* scales of reality – the blurring of the differences between, say, the autonomous circulation of the soundbite, the small circuits of local issue politics, and global movements of capital – which accounts for the nostalgia for individual agency associated with the cultural investment into the power of small numbers. Statistics here generates a space of topological continuity where in most other respects there are tectonic cracks, disconnected circuits, poorly meshing practices and disaggregating assemblages of broken agents.

Micropolitical gestures predicated on the validity of the small numbers model implies the possibility – even the necessity – of continuity of scales, the transversality of shifts across orders of reality that disappear in the notionally homogeneous space of statistics. But it also implies an important inverse. An action at the macro-scale – that of states, intergovernmental bodies, standards setting organizations, corporations, armies, or other molar entities – may ultimately dwindle to nothing, the full force of its signal decaying in the endless circuits it traverses and in the minor modifications and impossibilities it may succumb to as it tangles with the complications of the micro-scale, with what engineers call 'implementation details'. Policy decisions predicated on the influencing of motives – as in the current appeal to behaviour and its economic ramifications (everything is confidence) – amount to nothing without the appropriate taking into account of the different operations of different scales of reality. The folds of particular topological fields don't necessarily mesh, with the result that a suave and debonair politician who cringes under studio lights may scale up as badly as the verbal pyrotechnics of the habitué of the studio interview scale down to the level of the 'little people' when engaging in walkabout small talk.

In a further inversion, the reverse of this aspect of the micro-political imaginary is to be found in the developing field of risk management in public and corporate governance. First order risks, such as malfunctions, direct failures of task, or loss of property or revenue, blur in relation to second order risks such as loss of reputation and brand-damage (Power, 2007). The maintenance of good practice at every stage and scale of a work-cycle is a means of minimizing the ability of things to migrate from being minor problems to those of massive scale without any intervening passage-points of escalation. The mythical yield that marks the transition from nowhere to everywhere; from mundane normalcy to utter collapse; from the pain of conformity to revolution; from unknown to stardom; from a sluggardly to an inspired economy, appears now to some to be as reliable as a train timetable, given the right throw of the dice.

The propensity to develop intensive forms of affective investment in extremely small numbers derives in part from the power to process many numbers which computation provides. The relatively recent ability to work with the massively scaled computation of phenomena in complex topological geometries, to simulate nonlinear dynamic systems and to engage in advanced forms of modelling renders such phenomena visible, apparently tractable and open to interpretation and use. The ability to find hitherto unnoticeable, or unproduceable, disproportionate effects through being able to sort through an exponentially larger number of possible combinations inspires the possibility that any slight modification of behaviour may yield spectacular results. In turn, the ability of programs to interpret, interact with and actively inhabit such topological spaces of proximity brings them closer to the surface of daily awareness. The computational re-instantiation and acceleration of the power of small numbers resonates with their often promulgated relation to networks and their elaboration of a form that is topological, that is at once continuous yet composed of discrete parts, with no limit of scale. The eagerness to find in networks – those of computers in particular – a form with ubiquitous explanatory powers, despite their limited topological qualities, in turn reasserts the power of small numbers and the ability to traverse scales. At the same time though, it seeks to find a means of explaining the function that such network relations play, a means of turning such a function into something recognizable within historically more traditional infrastructures of communication and action.

The growing resonance of the power of small things comes about most potently because of the recognition that within certain configurations of relations, they can indeed make the most crucial difference: the possession of a visa, word of a loophole, access to food, conditions which can be difficult, if not impossible, to arrange. These are trivial things, the matters of everyday life, and their absence may yield death, or its double, attrition. But the finality of the everyday event is such that it tends to stay in its own place in the hierarchy of abstraction layers. Unless accidentally taken up elsewhere, or benefiting from the propitious generosity of an error, it stays within its own proper domain, ending the process. In such cases, there is no real interplay between audacity and preparation, as they speak different languages and cannot refer to each other.

Conceptualized in terms of a logic of representation, statistical invocations of small numbers sometimes make it difficult to see what such invocations *do*. Conversely, abstractions, such as those produced by statistics, even those which are most often criticized for reifying or occluding a relationship to the real can, by such means, induce the emergence of a topological continuum and hence traverse scales of reality, introducing probabilistic, determining or contingent effects. Rather than a representational function, faith in small numbers is bolstered because number provides a relation of dimensionality capable of jumping and uniting scales (the enumeration of asylum seekers, atoms, jars of jam, states, available registers, the fewness of fish left in the sea, the repetitious form of short multifarious lists of things that aim to trigger a sense of wonder at the manyness and variability of things), acquiring proximities that in turn provide a relationship between abstraction and the mechanics of narrative traction, a technics of relation.[7]

Invoke Recursion

Recursion is one of the special pleasures of programmers, the use of a procedure that involves a series of discrete steps, one of which entails the relaunch of the procedure. An algorithmically specifiable technique for generating continua, it is a constant relaunching that aids both programmatic concision and economy, and which doesn't have to be simply stacked inside itself, as is often thought the case. Recursion may involve the launch of another procedure which in turn relaunches the first one – such as a piece of software working its way through websites by following one link then another, at each point splitting into a copy of itself carrying out the same behaviour, deleting itself once an end point in the chain of links has been reached. In this respect, recursion exemplifies a process of automatic production, of time, over time.

If topology involves a means of recognizing the invariance of forms in space, recursion offers a means of establishing temporal invariance. Here the characteristic problems of topology, of homotopy and continuous functions manifest in relational terms are articulated through the arrangement of staging sequences and processes. Calculus itself, originally invented to track 'the motions of the planets, the comets, the moon and the sea' (Newton, in Koyré and Cohen, 1972), is a tool for tracing recursions across time, but it is also thus a means for describing the cyclical movements of a world, one that it is wise to be able to step out from as well as being able to bend oneself and others towards. As a stratagem, recursion is immediately distinguishable from one that aims all too simply at domination, and it highlights the importance of establishing a continuum through processual iteration. But it is a stratagem the very formal, algorithmic qualities of which also compel its use in a moderate manner, with due attention to the conditions under which termination is achieved.

As a technique, recursion is typically handled by a loop, a sequence of instructions in which a program performs a set of operations, looping back to repeat them again until a specific condition is satisfied. But recursion may also be something far more systematic and pleasing – a characteristic feature of some entity or other definable in terms of the kind of recursive mathematical function that programmers are taught to exploit. First of all, recursion is not inevitably a re-instantiation of the same (Deleuze, 1994). It may consist of a derivable pattern of activity, of self-similarity, but in a condition in which each recursive event is different, in terms of its scale, location in time, in the complications it may entail, and in terms of its place in relation to its nesting within other recursions or to those in which it is in turn nested. As such, recursion may be used to organize heterogeneous material into a continuous, self-consistent pattern.

Control requires recursion, and this is its innovative answer to the ancient question put to Socrates in Plato's *The Republic*, and then repeated by Juvenal: *quis custodiet ipsos custodes*? Who watches the watchmen? To which the answer was: their own deluded sense of duty – checks and balances. The recursiveness of control mechanisms in the operations of digital media infrastructures creates a situation in which no upper layer, required to draw on its merely moral strength to fight the seductions of corruption, is required, since another cycle of recursion can always be called upon to top it out. That recursion has this potential requires that it be handled meticulously in order for it not to spill out in unrecuperable ways, generating patterns in excess of the tacit norms of its exercise. As formalizations increasingly spread out from programmable systems into those that exhibit greater degrees of unpredictability, the usefulness of implementing recursive forms increases. One notable recent example is the use of eye-tracking devices to monitor, control and derive information from the eye-movements of those watching CCTV feeds (Vural and Akgul, 2009).

The answer to the question of who controls control is, then, that when control controls controlling, control is formally dextrous enough to conjugate itself, endlessly. An automatism that has acquired such solid entrenchment in the perceptual, affective and conceptual habits of experience that it acquires an agency all of its own. This creates a situation in which there is a cyclical deferral of control, no identifiable centre to it, and at the same time, control is able to enact itself at multi-scalar levels with more or less appropriate specificity and variety, enacted through a 'business ontology' (Fisher, 2009: 17) that is codified in protocols and standards of corporate governance used to structure action through a flexible, abstracted formal-technical grammar. At this point, resistance to control is not something of interest simply to underlings or those who are used to being the appendages of their devices, but to any who need to take the initiative of utilizing disturbance or taking a little creative autonomy. Needless to say, the anonymous algorithmic perfection of such an admirably constructed world does not yet exist, except in tendency. But as a concrete abstraction unfolding with hands-free autonomy into the various locales of the real, it offers much to desire. Not to mourn, but to organize.

However, such organization does not arise from a revolutionary rationalism, an imperative to establish media systems as a 'clean slate',[8] to ground all future operations on a foundational scission with the past and start anew under perfect conditions, but rather from working with the messiness, intractability and chaos which pertains. What needs to be established is the minimally homogeneous continuum of relations to enable all this recursively constructed activity to take place – this is the strategy of cloud computing and social network facilitation, for instance. Such a stratagem is one that works well to supplement or triangulate the perils of audit in which quantitatively fixed terms of required achievement simply become fixtures to be worked around. With recursion, the workaround is already anticipated, tracked and installed as the next target: it operates in a cybernetic dance of target finding and avoidance.

The stratagematic efficacy of recursion as a technique derives from the way in which it draws on particular kinds of patterning that already exist in things, people, processes, organizations themselves. Yet the risks that it poses derive from the inevitably incomplete characterization that a recursive function provides: extending a process through recursion can generate forms of continuity that rapidly diverge and loop off in directions initially unforeseen. The formal and the empirical do not mesh: poorly implemented recursion may even have the propensity to rapidly generate extreme phenomena.[9]

Look after Your Relations

Within the panoply of technical devices that have established a crucial importance in the generation of digital media infrastructure and the topological continua they help produce, the database has a critical but under-theorized role. Like much in the field of infrastructure and the technical and sociological discourses relating to it, it has the grey, attenuated, aesthetic quality of being boring. A crucial but often unremarked grey media form, the database generally fails to stimulate – and stimulates the failure of – attention (Star, 1999: 377). Such a quality is not without its merits, since inciting failures of attention – through the grey recession and withdrawal of contrasts – is also a crucial means of veiling things of most interest. However, the database also offers another possibility – that of drawing participants into, and/or implicating them within a system that draws on their activity in the production of socio-technically conditioned topological continua. Whilst not exactly making databases immediately gratifying, this is a possibility that can be achieved via the popular – Web 2.0 – approach of facilitation at the front end, data-mining at the rear – although there are also other openings. Relational databases have become such a crucial part of the conceptual and material infrastructure of the present that it is difficult to imagine many contemporary media systems without their existence as a foundation.[10]

In a short series of key papers founding his development of the Relational Database Management System (1990), Edgar Codd (1970) established a sophisticated understanding of all entities in a tabular system as dynamic, in states of possible or actual combination. Such combination was made possible either through the analytical fragmentation of entities into predicates articulating qualities or attributes as data or, without undergoing any preliminary fragmentation, by creating the conditions for ‘born digital’ materials to be generated, *ab initio*, as such entities. Work of this sort establishes the conditions for data not simply to be stored but to be structured, and Codd’s work also went on to establish these states of combination as fundamental, but finite, entities to be handled as such and in their own right. The development of a field of reality the material stuff of which is to one degree or another interpretable and manipulable as elements in a table allows for the amassing of relations between the entities in that table. Importantly, guided by a keen insight into the importance of bringing data-handling out of the hands of specialists, Codd also shifted database design towards the realm of natural rather than formal, procedural languages. Data-banks were to become useful to people other than stock-controllers or technicians. Gradually, as data entry, deletion, modification, sorting and query, grew, perhaps by one or more remove, into the habits of daily life, such entities also began to populate the everyday.

Because of their high degree of abstraction as structure-building devices, relational databases are immensely useful and work as a critically generative part of what we can understand as the abstract infrastructure of flexibilization and of the increasingly interpretable nature of processes and resources. The data model that a database implements provides a rough and ready sketch of the ontology of the entity or entities modelled – task, role, process, department, organization – that is usually glossed as a 'universe of discourse'. However, the interpretability to which databases give rise should not be mistaken for transparency – in part because transparency should not be so mistaken either – and all kinds of users would be wise to recognize and to work with this.

The tractability of data and the relations it entails depends in no small part on the degree of normalization of that data and the structures it is entered into and becomes an element of. Normalization – technically understood as part of the optimization of the design of a database – involves the treatment of each piece of data and each relation as a separate entity. It involves the stripping away of unnecessary hierarchies or other structures within data and the literal abstraction of the attributes of an entity and the treatment of these as entities in their own right. For the entry 'God' in a nominal table 'Deities', the attribute 'Good' would thus be stored in a separate table (along with other possible attributes – 'Evil', 'Omnipotent', etc.) and a 'key' linking the two be created. This means that as data is updated, deleted or inserted, it does not carry with it any dependencies on other data or structures (such as a nesting within a set of parent-child nodes). If God is deleted, one need not delete the Good as well – the relational algebra of the normalized database allows some other entity – Man, Capital, etc. – to be inserted in his place. Normalization implies a certain neutrality as to the relative importance of one datum compared to another. And what it thus allows is for a query to be formulated through any point in the set of relations mapped by the table. 'SELECT * FROM dbo.Deities WHERE dbo.Deities.TranscendentValue NOT IN ('Good','Evil')'. Non-normalized data offers one kind of resistance, in that it requires nested sets of dependencies. A red round thing may be a cricket ball or an apple, and neither may exactly be round, but once they are normalized and interpretable as simply exemplars of bearers of one or more of the categorizations, red, round, thing, they lose their specificity. The quality of irreducibility is transferred from the entity described to the categories its qualities are organized into. Or, to put it more speculatively: in the normalized ontology of the database, every predicate is presumed alienated from the outset: the more tractable the data becomes for machine handling, the more the predicates it seeks to capture in a structured way, the more abstracted it becomes as a generative matrix, situated on a 'body without organs' or recording surface (Deleuze and Guattari, 1987) for the senseless proliferation of relata.[11]

Relational databases have, in principle, infinite capacities of scalability, complexity and – due to their capacity for abstraction – variety, although to affirm such a capacity is to test luck as much as logic or logistics. The unlimited addition of predicates to any entity whatever – approximating what philosophers might call the infinite comprehension of a concept[12] – is always possible, albeit at the cost of 'performance degradation' (the more attributes an entity has, the more tables have to be searched and so on). Built upon the ability of a Turing Machine to make possible the computation of any formalizable statement, databases enable the organization of populations of normalized statements – generating machinically formulated discourse, of the kind one finds as the result of a 'search' or which provides the matter of decision support systems. That the data itself is normalized has no bearing on whether what it handles – what the data is 'about' – is in turn formalized – although a world in which life imitates data has more than a little desirability. This is why databases are so crucial in establishing productive or generative links between rules, structures and the outside world. This capacity for logical ordering enables the induction of combinatoriality and sorting for things without the database as well as within it; the introduction of new kinds of entity that are natively 'artificial' (Simon, 1996); and the production of new rules for relations, the harvesting of relations generated by the population of databases by live data-generating processes.

But whilst databases, and the ontology of models that they develop, are typically understood in terms of a logic of representation, as a device to enable better logistical control of the entities that the database models (stock in a warehouse, music downloads, security profiles), a more interesting way to think about the database is as a kind of topological *machine*, a device that intentionally or unintentionally engineers connections between things, generating continuities. Any table of related data, a nomograph or even a bus timetable, establishing links between a finite number of stable, discrete, and interconnected entities, is a topological machine. They establish networks of relations, the points of intersection between data and what that data links to and triggers. Topology tends to describe a network from a position outside of that network (it would require a higher dimensional topology to incorporate the topological generation of topologies). But when considered as topological machines, relational databases work through systems of relations to create, confirm or discover relations, and, as such, work to generate new and potentially arbitrary kinds of continuity as well as the properties of the figures thereby generated. Where topology offers an analytic device for understanding proximities, continuities and so on, topological machines operate synthetically to generate the same.

As more and more data flows through and into the databases established to capture it, something other than the logistical imagination is able to grow. Data-mining allows for the identification of unforeseen relations and factors (hidden variables, new patterns between existing variables, an 'evidence base'). This in turn establishes the possibility for actions predicated on the basis of topologically abstracted patterns of data, which are thereby enacted into existence: market niches (the subprime mortgage stratum), actuarial risks (the subprime mortgage stratum), no-go areas for political discourse (the subprime mortgage stratum), and so on. Concentrations of data, and the information it grounds, establish new centres of gravity as they couple with sorting systems, giving shape to a politics based on probabilities, the seductive allure of small numbers, and the correlationist certainties of large ones. This may give rise to multiple kinds of masking of hidden factors beneath a shimmer of data abstracted from its relation to other scales of reality. On the other hand, relational databases make tractable, sortable and usable relations that are not apparent otherwise. On the face of it, most databases are best understood as describing sets, operating through the working methods of predicate logic (Kuhns, 1967). They allow the selection, differentiation, union, analysis and possible projection of the attributes of a relation, opening up a set of possibilities, configuring a field of action, facilitating a decision, in the absence of any direct consideration of the state or states of the referents to which the data 'belongs'.

The relational algebra of the database entails that it can – in theory – usually be entered at any point, via predicates (or attributes), by relation or by entity, allowing data to be retrieved and sorted on that basis. In this way, every element can be sorted by its actual relations, consisting of its categorical, relational derived relation or non-relation to all other elements. As databases increasingly face towards users configured as consumers, the restraint of access to such ways of working is often a key feature. For instance, try to find a way of searching for all books of a certain price on an online bookseller. Whilst they offer a parade of desire from one title to the next, to sort them by other means remains unavailable.[13] Ways into the network of relations are constrained. Certain ways of accessing data are preferred, as normalized connections between tables suggest particular kinds of orderings – the potentially flat quality of a network of elements is technically organized as a hierarchy, arranging the links in a manner in which they only flow one way. Gaining access to the knowledge of a topology implied in the formal algebra of relations is thus a tricky matter. Whilst topological machines typically only allow the privileged gaze of overview to those with the correct access setting, this is only to read them as conforming to traditional models of power and does not address the broader possibilities to which they give rise.

One way in which databases can encourage us to develop an understanding of other formations and modes of exercise of power is through a quality that is inherent to them: the production of relations and of disassociations. The aggregation of vast 'banks' of data – to work with a term that described them at their birth – sees the operation of all the forms of experimentation, consolidation and power to convince that are typical of those banks that specialize in money. Whilst a taxonomy of the modes of aggregation, circulation, speculation and dissipation of capital is constantly being drawn up, it is at present left solely to the stratagematic imagination to work this out in practice in the case of data. A means by which this imagination stimulates itself is in the ability to cross-reference data from different sources,[14] and to aggregate databases using common standards, effectively consolidating them into one body. Such strategies are relevant across all sectors, but there is little rigorous work done on their effective yields in control and prediction, and hence little advance restraint upon them or their consequences. With the possibilities for formally consistent working across databases – maintained as if they were one vast description of the ontology of the model of the world embedded in data – being currently rather limited (despite the optimistic promotion of open data models[15]), the induction of arbitrary relations between them, implying false continuities, abrupt changes of person and personality, status, credit rating, security risk and so on is an ever present possibility. Uncanny proximities are generated by separate sets of data that don't quite match, there is a calculated generation of conflicting qualities, and a systematic production of ambiguity as databases mesh slightly or fall grossly out of synch with each other and other scales of reality. In the extensively surveilled transparency of database nations, opacities that yield malice and misfortune – but perhaps also the scope for black humour – offer the starting point for the empirical investigation of the arbitrary topologies of the laboratory of the world.

Conclusion

It is not always easy to abstract out or distil the stratagematic qualities of the techniques by which specific relations, modalities of the exercise of and processes for the formation of power are generated. This is especially so when such techniques are operative within a broader domain of relations loosely characterized, and poorly understood, as socio-technical. At least when Schopenhauer wrote *The Art of Always Being Right* he had centuries of philosophical reflection on – and regulation of – language to draw on. In the grey media that give form to the present, by contrast, it is a matter for practical experimentation, the densely connected, highly ramified consequences of which are better explored with the tutelary help of topology. Such exploration is a task that is as important as it is difficult, particularly if one seeks to avoid the ever-present temptation to understand or explain (away) the myriad socio-technical forms that make up the abstract infrastructure of the contemporary by simple reference to pre-existing macro-agents or structures.

By questioning the presumed order of articulation of the technical and the scientific implicit in technoscience, a sensitivity towards the weightiness or flightiness (or both) of affective or intensive state that we experience in our relations with such toolings can be created, pointing towards the contingently – and hence contestably – constructed quality of the relations thus produced.

The stratagems explored here, then, do not provide a unified, continuous or even consistent vision. Linking formalism to the faulty, glitchy materiality of the empirical, they thus emphasize the unsettled, not quite stable aspects of the topology of socio-technical relations emerging through techniques of unspoken or unseen media. Whilst media studies itself remains largely screened off from such processes, all the while they go to work.

Notes

1. By 'grey' media we mean those technologies and techniques of mediation that are often discussed in terms of 'information infrastructure' or which tend to figure within the workplace as component elements of business information systems and so on. A more extensive exploration of such media, adopting the position taken here, is proposed in Fuller and Goffey (2012). Further consideration is given there to the axiological qualities of the operations of such media.
2. Recent work on Machiavelli draws attention to uncertainties in the reading of him as an advocate of deception and emphasizes the ironic practice of dissimulation evident in his writing. See Benner (2009).
3. In this respect stratagems are not unlike the practices constructive of bodies without organs in Deleuze and Guattari: a surface is constructed at the same time as the elements that circulate on it. See Deleuze and Guattari (2004).
4. The contrast between algebra and topology has been a crucial element in the work of Alain Badiou, who uses it – in part – in a speculative exploration of the continuum hypothesis. The *subject*, for Badiou, occupies a crucial role in the excesses of continuation (see for example Badiou, 2009). From a somewhat different point of view, Whitehead marks this problem with his claim that there is no continuity of becoming 'only a becoming of continuity' (Whitehead, 1978: 53).
5. As in the mise en scene of globalization staged by Friedmann in his commentary *The World is Flat*. In a telling turn of phrase he evokes 'shooting' digital content round the office (see Friedman, 2006: 279).
6. It is to the statistical effects of the law of large numbers that Deleuze and Guattari (1987) appeal in their critical analysis of the gregariousness of the social cut off from desiring production.
7. The notion of a 'technique' – if not exactly a 'technics' – of relation is explored in Pignarre and Stengers (2011). The discussion of statistics proposed here is best read in conjunction with the imaginative claims about the

connections between statistics and perception proposed by Gabriel Tarde. See in particular the helpful preface to Tarde by Antoine (2001).

8. As in Stephen Toulmin's (1990) account of various versions of the founding of modernity.
9. Cf. Baudrillard (1993).
10. In this regard, they should be considered absolutely central to the operation of what Cochoy, Callon and Law, and Thrift have referred to as 'qualculation' (see Thrift, 2004b; Callon and Law, 2003).
11. A more detailed argument to explore the value of the Deleuze-Guattari concept of the body without organs and the quasi-Leibnizian hypothesis of the disjunctions of signs that are generated on it is unfortunately beyond the scope of this paper.
12. See the discussion of the Leibnizian logic of the concept in Deleuze (1994).
13. Equally it is worth considering the structuring role that restricted – proprietorial – access to the databases that sit 'behind' software applications can play: when an organization is unable to gain access to or modify the tacit ontology such a database embodies, organizational practices are tendentially obliged to model themselves and the knowledges they require on what the database allows.
14. See for example the United Kingdom's Regulation of Investigatory Powers Act 2000 (RIPA).
15. Hence the production of data exchange standards, often by some form of messaging protocol, but also through the development of datasets in a variety of domains (e.g. healthcare, insurance).

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Hearing Things and Dancing Numbers: Embodying Transformation, Topology at Tate Modern

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Abstract

This paper reports on a weekend performance event at the Tate Modern that explored how the senses of sound and movement can be used to apprehend geometrical and topological shapes and mathematical concepts. The sound sculpture *Knots and Donuts* spatialized sound and sonified space. It attuned the 'mind's ear' and the auditory imagination to conceive of a Borromean Knot and a torus within an immersive three-dimensional sound field. Through dance movement, the choreography of *Ordinal 5* actualized the specific mathematical entity as understood in category theory. Both parts of the programme are considered as a performance as research experiment with an audience. Its aim was to understand how the sensory experience of the embodied mind might provide a basis of rationality in which meaning is not restricted to text and image, that is, an embodied topology.

Keywords

embodiment, gesture, listening, mathematics, performance, sound

Can we *hear* geometrical and topological shapes? Is it possible to *dance* numbers? How can we *grasp* topological shapes and mathematical ideas through our senses of sound and movement? These were some of the questions explored in a recent sound sculpture and dance performance event at Tate Modern that Brian Rotman and I conceived as part of the Tate Topology speakers' series. With the so-called turn to embodiment

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and the issue of affect, the role of embodied sensory expression and impression is important for understanding ‘thinking’ outside the rubrics of cognitive processing, discourse or representation. For philosophy, traditionally vision has been privileged as the most ‘noble’ of the senses – on the basis of the distance it gives from corporeal contamination, unlike touch for instance. But with topology the mind’s eye loses its grip, it could be said, yielding to the possibility of auditory, gestural, kinetic and other forms of conceptualization. While a Möbius strip can easily be made by twisting a length of paper, a Klein bottle cannot be perfectly produced in the three dimensions of Euclidean space. The mathematical imagination leaps further than the places anyone can visualize. This is evidenced by the fact that a significant number of geometers and topologists, including the great Euler, have been blind (see Jackson, 2002). ‘Embodying Transformation’ was concerned with how topological relationships and mathematical concepts exceed the bounds of the visual, but by embracing rather than eschewing the senses.

The distinctive feature of the sound sculpture was to explore ‘acoustic space’ and the spatial dimension of sound.[1] An auditory image or gestalt can be described in many ways – a melody or a rhythm, the timbre or tone of a musical instrument or voice, or what a particular sound, a creaking door for instance, denotes. But with *Knots and Donuts* discrete sound sources were programmed to travel all around and through the listeners who were immersed in a three-dimensional auditory field filling the entire East Room of the Tate Modern (see Figure 1). Before the start, the audience were briefed to expect what the travelling sounds would describe (as a sparkler does in the dark). These were the geometrical shapes of a cylinder, sphere and figure of eight; and the topological figures of a Borromean Knot and torus (or donut). The sounds themselves consisted of various rolling balls, a roulette wheel, a bee buzzing and what was often interpreted as a rumble, swoosh and crash of an ocean wave. The audience were invited to sit, lie down or wander around in the near-darkness as they pleased.

The specialist hardware and software allowed the location and movement through space of a discrete auditory source to be controlled quite precisely.[2] This had the effect of converting sound – most often a diffused ephemeral effect – into a form of graphic expression – an ‘audiographic’ medium, that is, writing *with* or *in* sound (as distinct from the phonographic writing *of* sound). But this audiographic line, unlike one on paper, was drawn in three-dimensional space. At the pre-performance programming stage, tracing out its path as visualized on a screen with a retro computer game joystick felt like constructing a wire frame sculpture. The movement of sound sources across space (as with a marching band, or a carnival float) is not very often considered within the repertoire of musical or sound art composition techniques. But with *Knots and*

Figure 1. Audience in Julian Henriques' sonic sculpture *Knots and Donuts*, Tate Modern, 19 November 2011. Photo courtesy of Douglas Moody.

Donuts sound became a sculptural material, in the way that wood, metal or marble is normally considered to be.

One inspiration for the sonic sculpture was the avant-garde music tradition of Varèse, Stockhausen, Xenakis, Nono and others who treated the sound spatialization as a compositional element. Another was Bernhard Leitner's sound sculptures (see Leitner, 1998). But most important was the sonic engineering of the hugely powerful outdoor Jamaican dancehall sound systems (see Henriques, 2011). Here, the engineers often make a point of exploiting the circular travel of sounds around the triangular configuration of the three stacks of speakers. These sound effects, often incorporating gunshots, sirens and the like, serve as the signature of a particular sound system. In addition, Jamaican and other music producers often talk of 'building' a riddim (rhythm) track. So this idea of spatialization of sound and the consequent sonification of space could be said to have travelled from Trenchtown to the Tate.[3]

For the *Ordinal 5* dance, the audience returned to their seats to view the performance on the stage area they vacated. The mathematical concept danced was a commuting diagram for *Ordinal 5*, that is, the number five as counted in a sequence (see Figure 2). Rotman's approach was distinctive in that it was the choreographic expression of a *concept*, rather than a geometric shape as such.[4] The danced expression of the mathematical concept of *Ordinal 5* requires: a minimum number of six movement directions (or dancers), a specific number of positions in the space (on the dance floor) and sequencing in time of coincidence between dancer and position. The dancers all start on the same spot, and as long as they each get to their next assigned position and finish at the same spots, the mathematical concept can be said to have been expressed – to

Figure 2. *Ordinal 5* commuting diagram by Brian Rotman. Photo courtesy of Douglas Moody.

exactly the same extent as would be done with an equation or drawing with a conventional pen on paper diagram (see Figure 3).

The material from which both the sonic sculpture and the dance are built is embodied movement. With *Ordinal 5* this was the choreographed movement of the six dancers, including their vocal and facial expression and gestures, readily recognized as transforming their bodies through space and time in the dance on the stage area. With *Knots and Donuts* the movement was that of the sound source across the 3-D auditory field as well as at the more micro scale of the periodic motion of compression waves themselves. The point made here is this: while actualization is dependent on *some* mark, gesture, sound or other noticeable difference, it is independent of *which* particular medium of expression embodies the transformation.[5]

One reason for interest in this kind of event is methodological, as an experimental investigation. Audiences for the five performances were most forthcoming in the Q and A and informally afterwards. While sound alone is not particularly good for pinpointing location (and is typically used in cooperation with vision), the sound sculpture's novel demand for attentive listening was experienced as enjoyable. The auditory impression of the sound shapes proved to be quite a robust phenomenon. Several remarked on their being at the centre of the sound field and feeling its depth around them – rather than having sound frame a stage or screen at some distance from their point of listening. Another comment was that the naturally appropriate sound samples of a roulette ball, for instance, made locating its circular path through space quite easy. In addition, for several listeners the 'ocean wave' sound evoked deep associations of *childhood* seaside memories specifically, as distinct

Figure 3. Dancers in Brian Rotman's *Ordinal 5*. Photo courtesy of Douglas Moody.

from the more general kind of association that a listener might have for a particular piece of music.

The most important point to be made from the sound installation and dance, however, concerns the issue of embodiment for topology and mathematics itself. 'Embodying Transformation' was inspired by the idea that mathematical thinking should be conceived as an accomplishment of an enminded body, doing what bodies do, such as making gestures or touching things, rather than any purely abstract processes (whatever that might be), generated by a mind isolated or even opposed to material extension of the actual world. Such a line of thought – entirely *contra* to the orthodoxy of how most mathematicians might understand what they are doing – is what Brian Rotman has been establishing through several monographs (see Rotman, 1987, 1993, 2000, 2008). Rotman develops an argument that hinges on the distinction between, on the one hand, *notational* media that depend on metaphor, similitude and language system, and, on the other, *capture* media with their metonymy, synecdoche and analogue variation (see Rotman, 2008: 42). Embodied minds and enminded bodies then underpin what Rotman describes as:

> A psyche that is at once porous, heterotopic, distributed and pluralised, permeated by emergent collectives, crisscrossed by avatars and simulacra of itself. In short, a *para-human* agency which experiences itself as an 'I' becoming 'beside itself.' (Rotman, 2008: 134)

The challenge of this idea of mathematics as an embodied activity is addressed not only to conventional ideas of the mathematical mind, but also to those about bodies themselves. Once the conventional divided subject of mind/body has been dethroned, or decentred (Adlam et al., 1977), then all manner of exciting possibilities are opened up. Topological bodies concern relationships rather than identities, qualities rather than quantities, subjectivities and objectivities at the same time, enfolded insides and outsides, together with pasts, futures and presents – all in transitions and transformations. As one slogan put it: 'Occupy the Future.'[6] The implications of this lead to the consideration of embodied, situated and social ways of knowing, the nature of knowledge itself as *techné* and *phronēsis* (as discussed in Henriques, 2011), as distinct from more formal text-based epistemologies by which academic research still tends to define itself.[7]

Topological generalization – sacrificing the measure and angle of Euclidean geometry for the invariance of relationships that survive transformation – has been taken as evidence for the fundamental, even innate, nature of topological relationships rather than their abstract character. Jean Piaget argued that the child has a topological concept of space *before* he or she develops the conventional idea of Euclidean space.[8] According to the mathematician Alexei Sossinsky: 'the blind person who regains his sight does not distinguish a square from a circle: he sees only their topological equivalence' (Sossinsky, 2004: 13). Steven M. Rosen goes further, calling for a *phenomenological* topology, drawing on Husserl, Heidegger, Serres and others. Quoting Sheets-Johnstone ('Topology . . . is rooted in the body'; Sheets-Johnstone, 1990: 42) and Connor ('No matter how abstract it may become topology remains fundamentally bodily'; Connor, 2004), Rosen uses this topological body as a critique of the 'categorical separation' of classical cognition, for which 'the axiomatic base serving as its unquestioned point of departure is the self-evident intuition of *object-in-space-before-subject*' (Rosen, 2004: 12)..

The idea of invariance in topological transformation is indeed particularly useful for undermining such traditional ideas of consistency as being based on objects and their properties. Rotman uses this to develop the idea of a 'quantum self' that

> exists as a co-occurrence of virtual states, an 'I' which becomes actual or 'realised' and fixed as an 'objective' whole precisely when it is observed, subjected to psychic measurement or social control, or otherwise called upon to act, respond, be affected, and project agency. Such an 'I' would be a mass of tendencies, an assemblage in a perpetual state of becoming, rather than a monolithic being. (Rotman, 2008: 135)

It is also interesting to note that this and the idea of topological embodiment appears to be consistent with a Deleuzian conception of the body – which would most often be entirely antithetical to phenomenology. Brian Massumi in his account of the 'body topologic' puts it like this:

> The problem is that if the body were all and only in the present, it would be all and only what it is. Nothing is all and only what it is. A body present is in a dissolve: out of what it is just ceasing to be, into what it will already have become by the time it registers that something has happened. The present smudges the past and the future. It is more like a Doppler effect than a point: a movement that registers its arrival as an echo of its having just passed. The past and future resonate in the present . . . The past and future are in continuity with each other, in a moving-through-the-present: in transition. (Massumi, 2002: 200)

Topology thus comes to be about bodies, but perhaps not quite as we usually think we know them. This is not the conventional idea of a body as something or somehow without mind, an inert object, the Cartesian *res extensa*, lump of flesh, or sack of organs. Rather, it is the enminded body. So, on the other side of the false dichotomy, the topological body has little to do with the mind as *res cogitans*, or the abstract disembodied faculty of mathematics. The conclusion I draw from 'Embodying Transformation' is that the greater our sensitivity to the senses, the greater the sense of embodiment for topology.

Notes

'Embodying Transformation' was part of the performance programme of the Tate Topology talks series. It was staged in the East Room, Seventh Floor, Tate Modern, on 19–20 November 2011 (see http://www.tate.org.uk/whats-on/tate-modern/music-and-live-performance/embodying-transformation).

1. Marshal McLuhan (1989) is credited with the first use of the term 'acoustic space'.
2. The sonic engineering for this consisted of pre-programmed multi-track audio spatialization (see http://www.3daudioscape.org/homepage1.htm) diffused over a 12-channel sound system.
3. The underpinning ideas have also been tested in a number of previous sound and topology projects, often in collaboration with Martyn Ware and Illustrious, at Goldsmiths, University of London, the Future of Sound (March 2008), the Future of Light and Sound, Synaesthesia Symposium (March 2009), Large Scale Immersive Audio Experiment (October 2009), Performing Topology (March 2010) with Nicolas Salazar-Sutil and Brian Rotman and the Media and the Senses conference with the Circle of Sound sculpture (May 2011).

4. One notable example of this geometrical approach is Oskar Schlemmer's *Triadic Ballet* (1927) (see http://www.youtube.com/watch?v=xMDtwC76HjA).
5. This is consistent with Stern's concept of 'amodal' perception (see Stern, 1985) and also Chion's concept of 'transsensorial' perception (see Chion, 1994: 136–7).
6. Appearing on the information tent at St Paul's, London, 18 December 2011.
7. This erosion of boundaries and dichotomies has methodological implications for the ongoing 'practice as research', where in the academy the status of performance and exhibition has yet to be recognized as a valid research output on a par with publication (see Sullivan, 2009; Barrett and Bolt, 2007).
8. See Piaget and Inhelder (1956); this work has also been criticized (see Kapadia, 1974).

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