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Mappings

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Introduction

Mapping how things move through space is a significant challenge. Creating workable cartographic representations that can meaningful display particularities of movement and also aid the investigation of the patterns and different process of mobilities has stretched mapping practice and is, in many respects, still an unresolved challenge for cartographers, information designers and visualisation programmers. Producing aesthetically pleasing and analytically useful maps of spaces of mobility has become one of the key research frontiers in cartography and geovisualisation (Andrienko et al 2008; Dodge et al 2009; Dykes and Mountain 2003).

Mapping as a process of knowledge creation is more than just drawing lines on the page or displaying dots on screens and, as such, a major aspect of the challenge of visualising mobilities in a meaningful form comes before epistemological actions (data symbolisation and graphic inscription), and instead lies in ontological decision-making around what is deemed mappable in a given domain and then which data is actively selected for mapmaking. As has been well documented, mapping as a process of abstracting reality, operating with both technological constraints and socially-determined values, works by selection and classification to construct a partial but believable representation that provides a convincing solution to a particular problem. What is chosen to be mapped is as important as the cartographic design or the utility of the finished representation. This ontological basis of mapping is easily overlooked but very much evident in the cartographies of movement. Only certain aspects of mobility are deemed mappable and fewer still are selected for survey, classification and inscription.

Mapping the structures of what outwardly appear to be material objects to human eyes and hands at microscopic, atomic or now subatomic scales reveal that physical things are not solid but composed of the incessant motion of waves/particles of energy. At another scale, the ground under our feet appears fixed but we know from geological evidence that the earth's surface is made up of moving tectonic plates (continental drift of the Eurasian plate is about 20mm per year, imperceptibly slow in human terms but sufficient to completely reshape the Earth over a few million years). What's more, the periodicities of the day, months and the seasons of the year, demonstrate that we are all riding on a planet in very rapid rotation and orbital motion[1]. And if we accept conventional astronomic theory, premised upon Edwin Hubble's (1929) ground-breaking observations, all matter in the visible universe is moving outwards at the speed of 77 kilometres per second per 3.26 million light-years from the time-space 'big bang' origin. Indeed, some of the first mapping representations produced in recorded history were quasi-religious diagrams plotting observed celestial motion and granting power to priests to predict future occurrences in the sky (Figure 1).

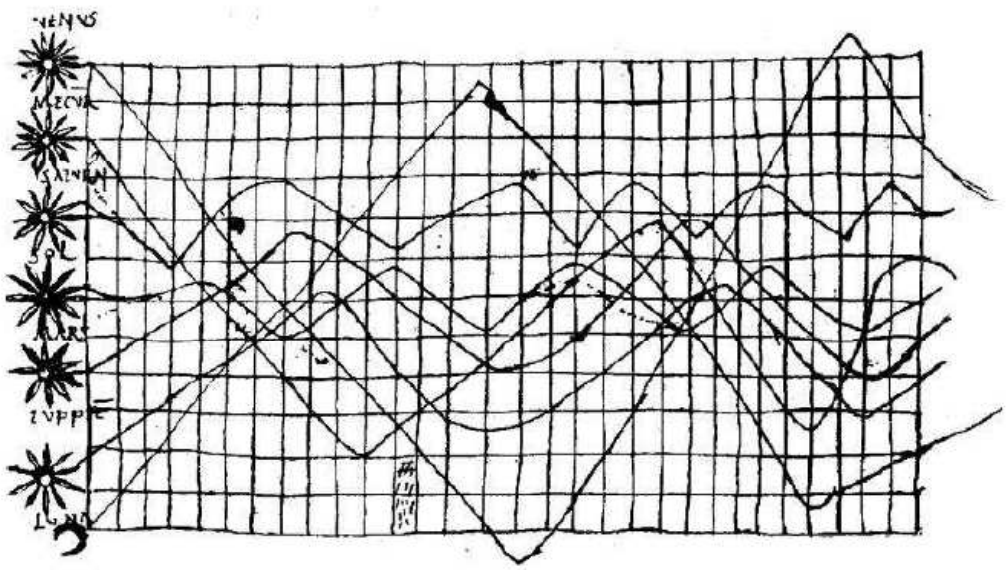

Figure 1. An early spatial graphing of moving object. Dating from the tenth century it was designed to plot the cyclical motion of seven planetary bodies across a grid of time intervals. Graph found in the appendix to commentaries by Macrobius on *In Somnium Scripionus*. (Source: Author scan from Funkhouser 1936: 261).

Closely coupled to spatial movement at multiple scales in terms of the ontological challenges in mapping is that everything is in process in terms of temporal change. As with space, much of the passage through time occurs at scales too short or too long for unaided human perception. The apparent fixity of terrestrial geomorphology is an artefact because the processes of change work beyond human lifespans but when mapping at longer time scales the surface of the planet is ceaselessly changing, driven by the inexorable, transforming forces of volcanism and weathering. So much of movement in space, change through time and the general dynamism of objects in time-space are never deemed mappable, captured or inscribed in cartographic products.

Static cartography - fixing space, freezing time, stopping motion

The ontological difficulties in mapping mobility are multiplied because of the common media of representations for topographic cartography, and scientific diagrammings more generally, have been static inscriptions fixed on paper. Conventional mapping practice has typically dealt with the fact that everything moves and everything is changing by actively denying this reality in the process of abstraction. The working solution of most mapmakers down through history has often been to represent phenomena and process by artificially freezing time at some arbitrary point and halting movement or simply ignoring things that were mobile. As a consequence, nearly all cartography is fixed in time and provides a static representation of space. This is so obvious that it is easy to overlook when using conventional map products.

The lack of temporal sensitivity in most cartographic design means that so much of the spontaneity and serendipity of everyday events that make places feel alive is not conventionally deemed representable in topographic maps. Maps are a lifeless media. Beyond narrow technical concerns for legible inscriptions, this freezing has important ideological implications because the resulting maps inherently privilege the status-quo and entrench power-relations that are most easily ‘frozen’[2]. Such fixity of things and locking-down of events into regular time slots is really a cartographic fiction, and it gives an artificial sense of permanence to the world that is really working as a series of dynamic, overlapping and often contested processes.

Static maps are inherently and particularly selective in what they can show and crucially in what is not chosen to be shown. The surveyor’s gaze has always favoured things that

appear fixed in the landscape (or with relatively long durations to human sensibilities). According to Bunge (1971: iv) the result is that "[m]aps attempt to integrate over time, that is, maps assume an average span of time. This means that nothing that moves is mapped, and therefore property is inherently preferred over humans." As things that move or change quickly and unpredictably tend not to get mapped[3], this is clearly problematic for constructing worthwhile and workable representations of many aspects of human culture - like the daily flux of cities - as the actual work and social activities are never mapped. Look at the largest scale urban mapping available and there is evidently a high level of detail of physical structures but nothing on the changing social and economic relations transacted everyday or the myriad of mobile bodies, objects and flows that inhabit the spaces and beckon places into being.

How things can move is neither simple nor singular in nature. There many kinds of movements and an unknown number of patterns. In developing suitable mapping approaches and cartographic design metaphors it can help to start to make sense of the plethora of kinds of movement by imposing taxonomic categories. This is beginning to happen with useful work in cognitive cartography, transport studies and GIScience (e.g. Hirtle et al 2010; Schwanen and Kwan 2012), but as yet appears to be no widely agreed taxonomy for mobility that can be readily exploited by mapmakers. Figure 2 presents one of the more useful efforts: a summation which displays a quite detailed (but probably not exhaustive) hierarchical classification of patterns of movement in terms of differing underlying motives for the activities. While the GIScience researchers acknowledge it is incomplete, they claim "classification and formalization of patterns is necessary to give guidelines for the development of visual and interactive methods that are expected to enable users to detect and explore patterns" (Dodge et al 2008: 2). These different patterns, resulting from distinct drivers, may well require different kinds of visual representations to communicate meaning, especially to a non-expert audience. Effective visual mapping of distinct kinds of mobility could also help to better determine the causation and perhaps even the real meanings that people attach their journeys. What is causing an observed convergence motion of group of people, for example, or is the rapidity of divergence of set of objects due to something significant (a flight from a new risk?). It seems likely that growing taxonomic sophistication will be useful to inform more appropriate mapping will be important to meeting the challenges of understanding mobilities.

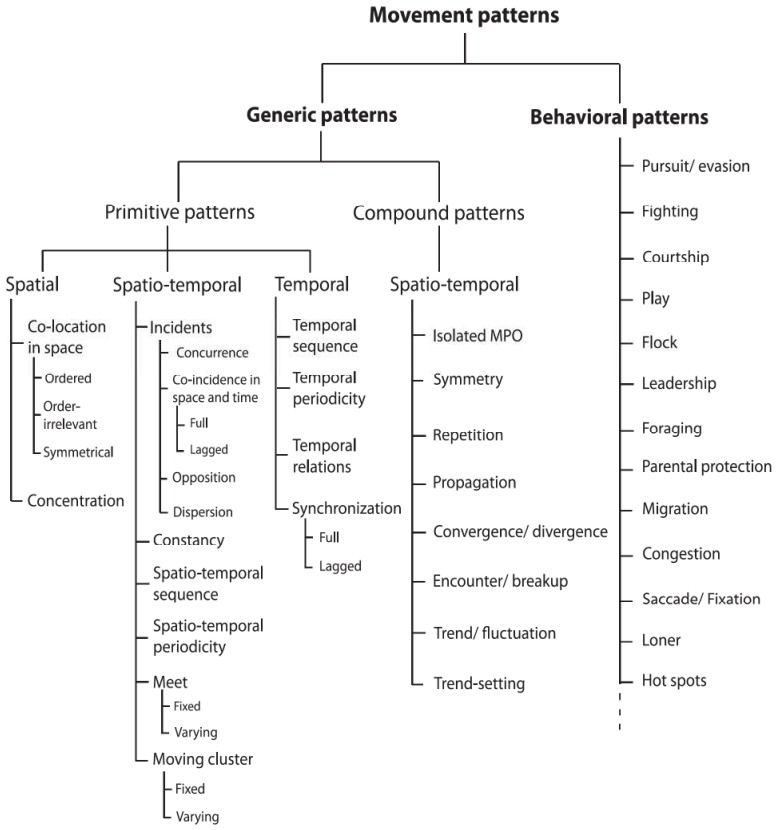

Figure 2. A useful attempt to taxonomise the different types of movement patterns as a preliminary to more effective visualisation of mobility. (Source: Dodge et al 2008: 3.)

In real world applications such mapping can swiftly become a technical challenge in terms of the sheer data volumes involved in tracking potentially millions of individual objects or aggregated points of movement at fine granularity in space and through time. Dealing with realistic scales of data has indeed been one pragmatic reason why much mobile and temporally dynamic phenomenon has never mapped[4]. In addition to the 'big data' challenge, there has also been a serious aesthetics concerns, as designers and mapmakers have struggled to develop a meaningful and effective visual language to display motion on static media of distribution. In many respects existing representational solutions for envisioning space, such as the conventions within topographic cartography (e.g. familiar graphic palette of points, line and area styles on 'default' British maps produced by the Ordnance Survey), and thematic mapping (with its shaded polygons and proportionally sized symbols) have lacked the semiotic capability to really convey the dynamic nature of physical mobility or temporal change.

Solutions to mapping mobilities

The ontological and technical challenges of representing physical movements and temporally dynamic processes have spurred cartographers, and latterly researchers in geovisualization and information visualization, to develop novel solutions. These solutions can be broadly grouped into three kinds of mapping: firstly, extending static, single, cartographic images through clever graphic designs; secondly, making maps that change through the medium of animation; and thirdly, using digital technology to deliver ego-centred maps that are interactive and dynamically updated in harness with the person's movement. We will review each of these approaches in turn, considering a range of exemplars.

(i) Developing clever graphical designs

Whilst acknowledging the general weaknesses of much conventional cartographic design in adequately capturing a world of moving objects and representing dynamic change, there have been some notable attempts to develop creative solutions to display mobility through static spatial imagery. Here we will consider, in particular, flow maps and 'fish-tank' time geography diagrams as some of the more sophisticated design innovations, and while these are not widely deployed in real-world contexts, they do nonetheless show what can be done with ingenuity and skill. As such they may seem unusual and unconventional ways of representing geography and spatial patterns, and are typically not well covered, if at all, in mainstream cartography textbooks. What's more, they formed part of the default palette of semi-automated designs afforded in mapping software and GIS suites.

Flow mapping can be defined as the production of a graphic "on which the amount of movement along a linear path is stressed, usually by lines of varying thickness" (Dent 1995: 234). As a mapping technique it emerged in the nineteenth century creative 'explosion' of thematic cartography developed purposefully for the needs of state to understand the increasingly complex economic and social make-up of industrialising nations, with their rapidly growing populations and expanding cities (cf. Robinson 1982). Conventionally the first flow map is credited to Henry Drury Harness, who had the task of representing the pattern of passengers travelling on Ireland's new railway network for a report to Parliament (Robinson 1955). Although now acknowledged as an innovative design, it is unclear how widely seen or influential were Harness's railway

flow maps of 1837. Another more widely known mapping of the spatiality of flows also arises from the ‘golden age’ of inventive thematic cartography in the nineteenth century. It was created by a retired civil engineer, Charles Joseph Minard, in 1869. It seems simple at first glance, but it provides a surprisingly sophisticated mapping of the movement of the French army in the Russian campaign of 1812/13, in which over 400,000 soldiers under Napoleon’s command either deserted or died. His *Carte Figurative* provides a distinctly diagrammatic form of mapping, and a highly effective and efficient representation of a complex, multi-dimensional set of data, recording the movements of a massive army over many months and several thousand miles from the River Niemer in present day Poland to occupy Moscow, before being forced to retreat again (cf. Friendly 2006; Robinson 1967).

Flow maps as a cartographic design solution that can tie together the scale of movement with spatial location and direction remain a distinctive and somewhat specialised approach, although they have been developed since the work of nineteenth century pioneers such as Drury and Minard. A contemporary deployment of flow mapping has conducted by quantitative human geographer Danny Dorling as part of his extensive and ongoing analysis of inequalities in British society. Dorling has a deep interest in developing creative and clever maps and diagrams to visualise the latent socio-spatial pattern locked in large demographic datasets such as the UK national censuses. In particular, Dorling has exploited cartograms to radically distort spaces of representation to show more clearly social reality (see some of his recent books for copious examples, such as Dorling 2012; Dorling and Thomas 2011). As the pre-eminent data source for the State, documenting the social makeup of the nation, censuses tend to privilege fixed populations in space and time (people are tied to a single ‘night-time’ residential address as recorded on midnight on one designated census day). More recent decennial censuses in the UK have, however, asked employed people about their daily ‘journey to work’ and also recorded previous addresses one year before the census date to try capture some measure of residential migration. These questions have provided the raw variables to create unique population-level movement datasets that can be analysed as flow matrices between zones and mapped as flow maps.

Dorling has experimented with how such large and complex patterns of aggregate movement might be visualised, and two exemplars of his work in this direction exploiting data from the 1981 census for England and Wales are displayed in Figure 3. In trying to synthesise and visualise such a large volume of data on a single flow map there are clearly challenges of legibility of detail for individual zones, in spite of the exaggeration of geographic scale by the use of the cartogram projection. However, such mapping does capture some of the essence of mobility at a societal level by detailing the sheer complexity of daily commuting and significant amount of multi-scalar annual residential moves. Mapping the dynamic nature of social space through movement at the national scale is often never seen and can therefore be perceived as somewhat unconventional. Instead the vast majority of official reports and academic analyses of the structure of society relies on a small trope of descriptive statistics, a narrow range of charts and the tyranny of the choropleth as default thematic cartography[5].

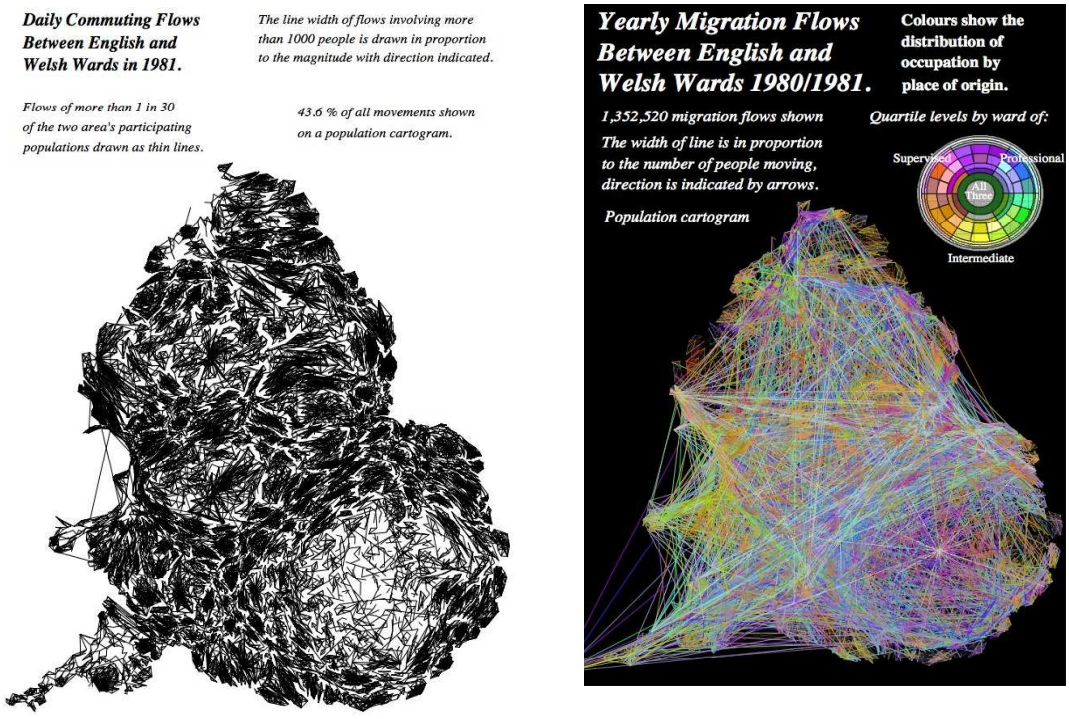

Figure 3. Innovative mapping of movement at the societal scale produced by geographer Danny Dorling to visually demonstrate the complicity of flows between thousands of places in England and Wales. (Source: Dorling 2011, pp. 181, 197. Reproduced by permission of Danny Dorling.)

The amount of information encoded in the flow map with variable sized bands and movement arrows can be increased by exploiting other graphic variables for these symbols, most obviously shading styles and colour hue. A colour ramp may be used to indicate varying speed along the line of movement or intensity of traffic.

Flow line maps are not the only way to visualise movement through space. Another quite different means to represent movement is equally distinctive because it is little seen in comparison to the default designs of thematic cartography. This method of mapping exploits perspective drawings to create a sense of a third dimension on a flat image that can be used to represent time, and thus movement. These pseudo-3D maps are termed space-time cubes (STC) - or more colloquially, 'fish-tank' diagrams - and the design metaphor arose principally out of Torsten Hägerstrand's influential work in the 1970s developing the approach to human activity known as 'Time Geography'. Figure 4 is one of his original path diagrams, the precursor for more complicated STCs displaying people's daily mobility.

Mapping time-space by 'fish-tank' diagrams focuses attention on the paths that individuals or groups take as they go about their daily activities, as well as highlighting the places they dwell in between periods of movement. The projection of movement up into the z-dimension above the x, y ground plane is a quite simple concept in visual design terms but can prove effective in revealing personal mobility (cf. Lenntorp 1978; Kwan 1999). People's accessibility is mappable via this method in relation to the social structures of modern living and physical constraints of moving the corporeal body which shape everyday spatiality, in often subtle ways (e.g., the provision of free workplace car parking or stopping points along public transport routes and the frequencies of service, the timings of the school day and the shift patterns set forth by employers).

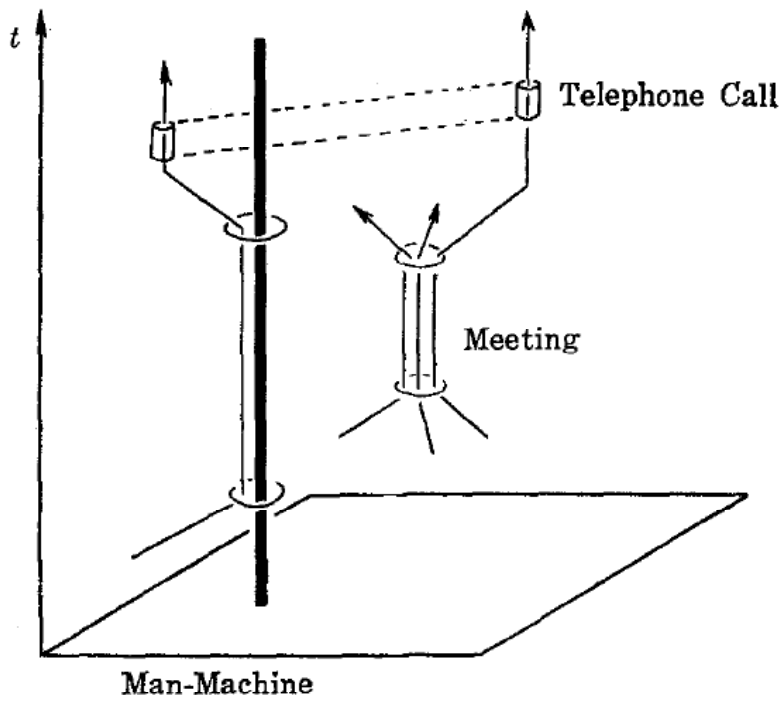

Figure 4. An idealised way to model movement encompassing the notion of paths through Time Geography developed by Torsten Hägerstrand and presented in his influential 1970 paper 'What about people in regional science'. (Source: Author scan from Hägerstrand 1970: 14.)

Space-time cubes can become surprisingly complex to draw in practice, as questions of geographical scale present a representational challenge when trying to map out real lives, as well as a result of the legibility required of the base map to facilitate interpretation. Also, thought needs to given to how best to scale the time axis and the granularity of units to appropriately capture the changes, but also to cope with long periods of little or no mobility. Yet effectively designed STCs can show the ratio of being motionless to mobile in daily life, along with the innate creativity in sequencing and chaining-together of activities in time and space to facilitate solutions to daily tasks. Most people's daily mobility is habitual, citational and strictly local in scale; and much is about going to specific places for face-to-face interaction. STCs are particularly useful for showing so-called 'coupling constraints' which tie people together at agreed points in space and time. Such practical constraints limit others scope of potential travel.

The significance of different transport infrastructures and communication technologies to everyday mobilities – and people's differential access to them – can be effectively displayed using STCs. For example in his doctoral research David Mountain (2005)

visualised his movement paths, recorded via GPS tracklogs, and using colour coding in his fish-tank diagrams to delineate different modes of travel (walking, cycling, public transport) (cf. Dykes and Mountain 2003). Equally the more expansive spatial flexibility (seen by some as 'freedom') of the private car, can radically extend personal mobility in comparison to someone tied to public transport timetables. In the 'fish-tank' diagrams, the vectors of travel are intuitively mapped by the length of the path in the horizontal plane equating to geographical distance and the slope of the line indicating the speed of movement. Steeply sloping paths provide records of slow physical movement, while shallow gradient represents rapid travel. What is harder to visually encode is the cost of movement, the degree of sustainability or otherwise of travel patterns dependent on fossil fuels. There is also scope to visualise the distance traversing nature of telecommunication (e.g. the action of a point-to-point phone call represented in Hägerstrand's initial visual model, Figure 5 above; cf. Adams 2000), although how to fit more complex online activity, which is potentially multi-scalar in nature, is more difficult because the 'wormhole' effects created by virtual interaction cannot be represented within the coordinate space of the single 'fish-tank' (although see efforts by Kwan 2000).

Analysis conducted within Time Geography has often been based on small samples of individuals, using primary data gathered by intensive qualitative methods, and the results presented by hand-drawn diagramming practice. This approach has been quantitatively extended in the last decade or so by exploiting the automatic capture of time-stamped movement data (via GPS and the tracking of mobile devices) making it possible to efficiently map out many people's activity space. Displaying the time-space paths of hundreds or thousands of people at a city-wide scale required a shift from hand crafted cartography to computerised mapping. The work of Mei-Po Kwan (cf. 1999, 2000; Kwan and Lee 2003) is especially noteworthy in this regard where she has exploited geovisualisation concepts to chart masses of individual space-time paths in a three dimensional GIS. An example, shown in Figure 5, in which the local 'fish-tank' metaphor is remade into a city-wide 'aquarium', with potential to show something of the mobile throng of daily activity that brings urban space alive. As Kwan and Lee (2003: 51) note, "unlike quantitative methods that tend to reduce the dimensionality of data in the process of analysis, 3D geovisualization may retain the complexity of the original data to the extent that human visual processing is still capable of handling."

There is additional flexibility of visualising the STC within 3D GIS because it enables the user to interactively select and classify what is shown, along with the ability to query individual paths (and stations along a path) and crucially to control the viewing perspective by panning and zooming. The potentialities of geovisualisation provide a much greater scope for the display of large data volumes, but this cannot necessarily overcome the fundamental limits of this metaphor for mapping individual movement (cf. Kraak 2003), most particularly legibility issues within congested urban centres at peak times, with over-plotting of multiple paths into a bewildering mess. This mode of mapping also struggles when the temporal dimension expands beyond the daily or weekly, and with the difficulty of showing the wide spatial scale of occasional long distance trip, overseas holidays or events like a spell of hospitalisation.

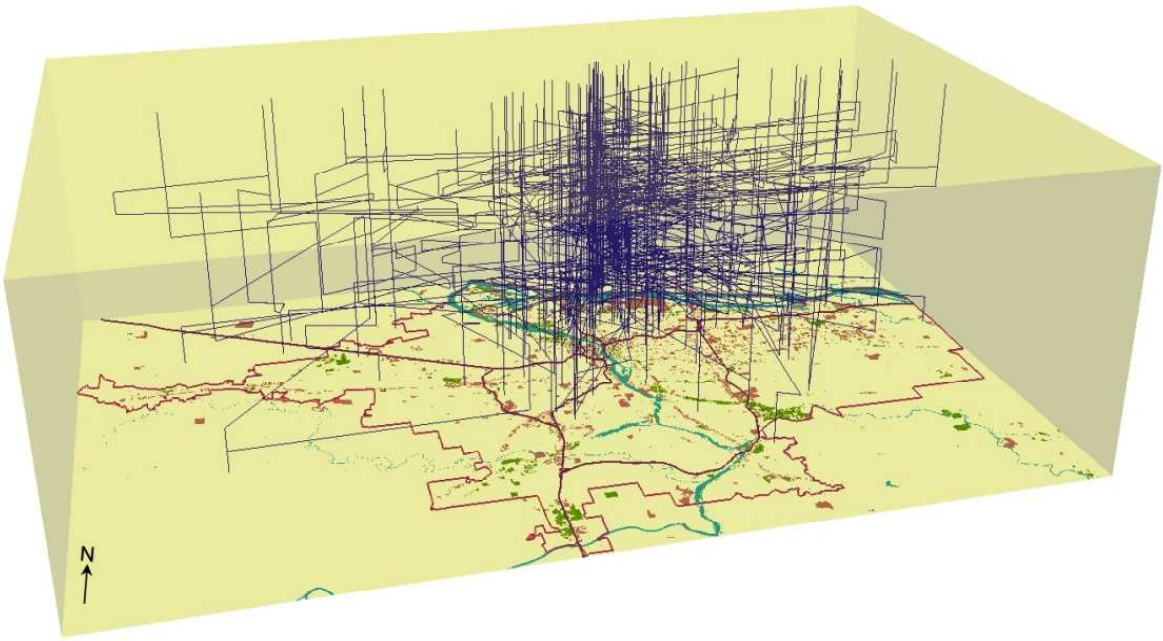

Figure 5. An example of Mei-Po Kwan's work exploiting the power of 3D GIS to extend the single STC to visualise many people. In this case the time-space 'aquarium' is showing paths of a sample of African and Asian American people in the city of Portland, USA. (Source: Kwan and Lee 2003: 60.)

(ii) Developments in map animation to show movement

Beyond clever graphic symbology of flow mapping and technical sophistication involved in plotting 3D pathways in time-space 'fish-tanks', perhaps the most obvious way to show physical movement of object and material change in the landscape is to make an animated map. The development of animation in film is testament to the potential for showing life-like change by displaying a sequence of still images in rapid progression. There are many different components to an animation that can be modified (and manipulated) to produce very different visual effects. While map animation would appear to be ideally suited to showing mobile phenomena, and has obvious advantages over a conventional static cartographic image – fundamentally because the mapmaker is able to display *additional* spatial data over and above one single map – research has questioned whether people can easily read map animations compared to a single map solution, and how far they can reliably cognise spatial information when images are only visible to them for a fraction of second (Harrower 2004).

In general terms there are three major kinds of map animation: temporal animation, showing change (such as 'canned' 24 hour weather forecast animations widely seen on television and the web); motion focused animation, showing moving objects (tracking site such for buses and train and planes); and the dynamic viewpoint animation, where the camera [the viewer's perspective] seems to move (the virtual flight over a map landscape or zoom from space to ground level satellite imagery beloved by news media). The basic types can be combined to create more complex movies and when used with interactive display controls, then cartography crosses over into the realm of geovisualization.

As an exemplar of the genre, Figure 6 shows one frame of an animation of the motion of a hurricane, one of the most dynamic aspects of weather and, because of its unpredictable mobility, a real hazard to life and property in susceptible parts of the world. Here the viewpoint (camera) is fixed and a static regional base map gives spatial context over which a moving phenomenon is animated and also temporal change (although the time duration is not indicated to the viewer). The dynamic element in the animation is the swarm of arrowheads representing wind speed; these track across the map in an intensifying vortex towards landfall on the Louisiana coastline. The size of

the arrow symbols increases to denote increasing speed, which is combined with colour to try to connote something of the raw power of the hurricane.

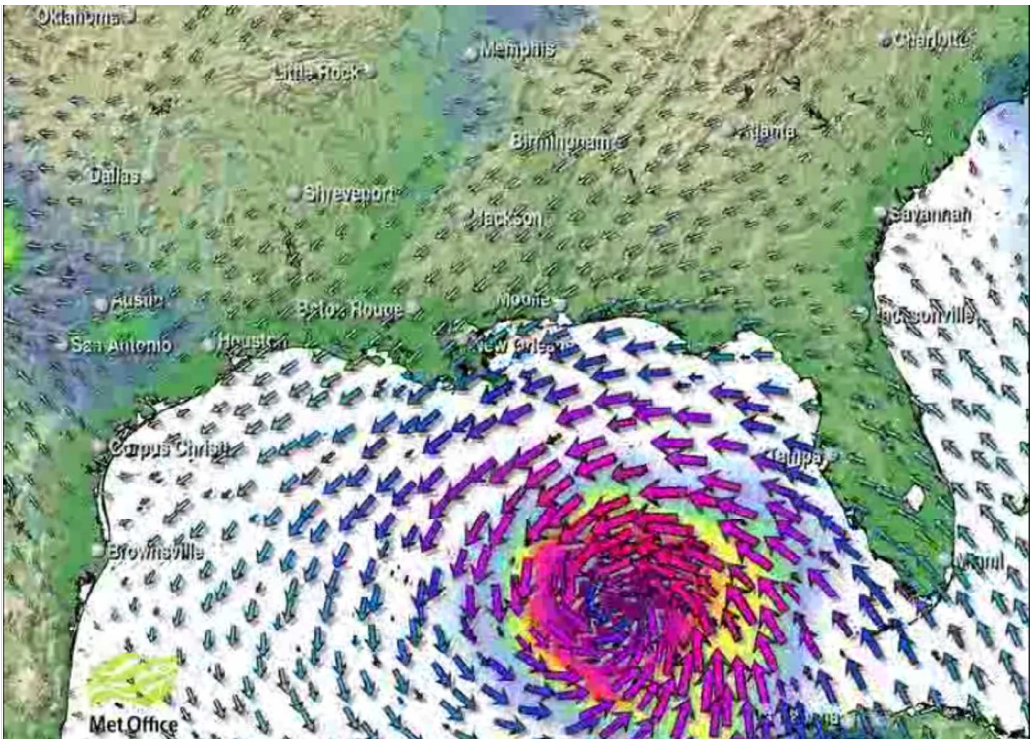

Figure 6. Sample frame from a two minute map animation plotting the final track hurricane Katrina which did so much damage in August 2005. (Source: Royal Meteorological Society, originally online at http://www.rmets.org/video/climate/katrina.php. Author screen capture.)

As noted above, the tracking of people's movement has become much more feasible with digital devices, GPS and cellular communication networks. The movement databases can be usefully represented via map animations and the possibilities were well exploredin an innovative experimental art project conducted by Esther Polak and the Waag Society in 2002. Called *Amsterdam RealTime* the initial project was tracking a small sample of volunteers as they moved about the city, with an updating map displayed in the Waag Society gallery as part of a larger public exhibition. The project developed its own tracking hardware system to do this by adapting a PDA to link to a GPS and share the location coordinates continuously by mobile phone protocols. Tracking the volunteers throughout Amsterdam showed how surprisingly detailed spatial patterns of urban circulation could be built over several weeks which were shown in short map animations (Figure 7).

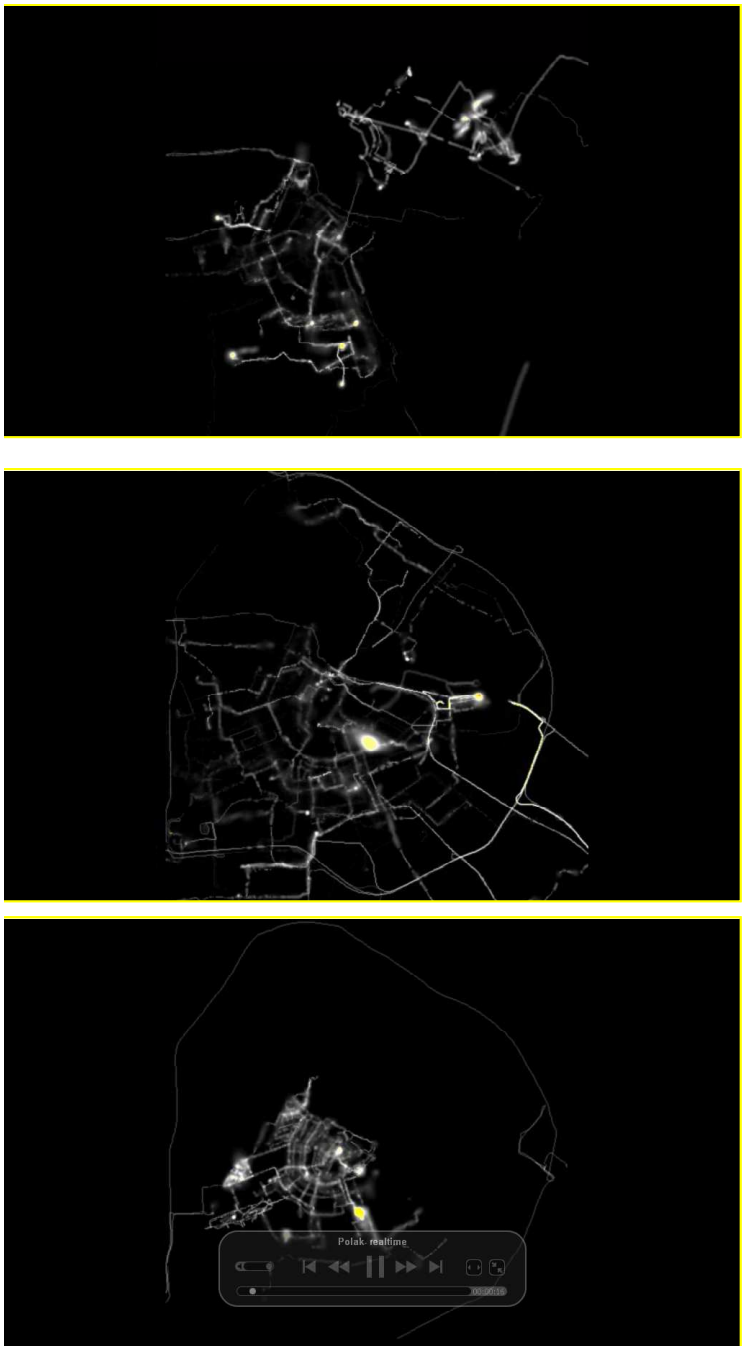

Figure 7. Sample frames from a five minute map animation of the some of results of the *Amsterdam RealTime* project, 2002. (Source: Original map animation available at http://realtime.waag.org/en_index.html. Author screenshots. Reproduced by permission of Esther Polak and Waag Society.)

The act of animating multiple map frames can be a powerful visualisation technique for mobile objects and dynamic phenomena. It can reveal things that would be unseen in single, static cartographic displays, but one needs to be careful that what is revealed is actually 'real' and not merely an artefact emerging from the map animation process itself. A particular challenge in this regard is how cartographers handle scaling of the time dimension when making map animations. Most often real-time needs to re-scaled

to make a feasible display for viewers by either speeding up movement or slowing down change.

Animating maps to show mobile spatial phenomena has potential but may raise as many challenges as it solves for the cartographer, including in the practicality of design. For example, how do you convey details of the passage of time on the map key that informs but does not distract the viewer? Can map animations show multiple parameters for rapidly moving objects given that viewers cannot dwell on details or easily make comparisons with a complex legend? In this regard map animations are often grossly simplified in comparison to the amount of data that can be effectively conveyed on well-designed single thematic maps which can be considered at length. Therefore they might not be an efficient way to map spatial phenomena. In the future the development of more effective map animations could perhaps learn much from cinematography. As map animations become more sophisticated in terms of their design look and modes of user interaction then perhaps their intrinsic cartographic basis is morphing into something distinct from 'a map'. Here one might argue that cartographic approaches remain valuable even as more interactive visualisation become possible, in much the same way that photography - based on single, static images - remains a powerful visual media in spite of the availability sophistication of cinematography and interactive video.

(iii) Emergence of ego-centred, dynamic mapping

The availability of and easy access to very detailed urban mapping, largely for free[6], has become taken-for-granted in many countries over the past few years, reflecting a radical shake-up of the political economy of cartographic production, and efficiency gains from online delivery. Many people today are carrying around mobile devices with sophisticated mapping capabilities that were the preserve of the best-equipped elite military forces only a decade or so ago[7]. This is remarkable because most people regard it as unremarkable! The availability of such detailed cartography on-demand taken everywhere with the user is quite clearly contributing to new mappings of mobility, and is perhaps itself even changing how and why we move.

Mobile maps are challenging mapmakers and interaction designers to develop effective cartographic design solutions that can convey meaning on small screens and often in adverse viewing conditions. Beyond issues of design, there are also deeper conceptual

changes to the fundamental nature of the map in this age of wireless access, as the map becomes ego-centred and generated from dynamic 'real-time' data. The result is that mapping seems to be much more personal and much more present – this makes it potentially much more useful for mapping mobile societies. There is a perceptible and significant shift with people no longer being consumers of a fixed range of cartographic products, instead they are becoming mapmakers able to enrol increasingly sophisticated spatial data (like satellite imagery and Streetviews) to envision their own geographical context in a relevant way.

As noted in the introduction to this chapter, conventional maps were static and tended not to show things that moved or changed, but now they are becoming dynamic, carried on mobile devices and using cartographic data that updates in time according to the person's spatial context. Map use is no longer fixed to particular places (e.g. sitting at a library desk or in front of an expensive graphics workstation). Cartography appears to be more flexible and mutable when rendered on-demand from a GIS database, with the addition of feature query and spatial searching, quite unlike carrying a trusty printed A-Z street atlas with it fixed geographical extents tied to one preset scale and the size of the printed page, along with its alphabetical index of road names at the back in a tiny hard-to-read font. The satnav capability of mobile mapping, with its keyed destination, calculated route and especially the reassurance of turn-by-turn directions, is potent and potentially changing how people engage with urban space (cf. Axon et al 2012).

These different informational arrangements have been characterised in terms of the emergence of 'ubiquitous cartography' (Gartner et al 2007), being premised upon new, quicker, and cheaper modes for capturing geospatial data, including the rise of volunteered and crowdsourced mapping (Dodge and Kitchin 2013). As important is the increased coverage, reliability and transmission bandwidth of wireless networks that are now easily taken-for-granted, but have to be engineered and maintained[8]. Equally significant for mobile mapping are the transparent mechanisms for continuously generating spatial positioning that are good enough to put the user's dot at about the right spot on their map. The capability of handheld devices is growing and evolving novel interface controls, coupled with continuous access to software services that seem to exist magically 'in the cloud'. The result is that smartphones, combining communication and computation, are highly functional and peculiarly compelling,

acting as personal ‘helpers’ that many people now find indispensable – they are carried lovingly everywhere, positioned in prime spots on tabletops and are the first thing people look at when waking in the morning. They are arguably the most significant technology of the age, able to extend bodies and augment cognitive abilities. This techno-human hybrid is most evident in the ways that mobile devices help in navigating space more efficiently, find the right places and locate the people they want to meet. These abilities, labelled as ‘location-based services’ (LBS), are one of the ‘killer apps’ that have made smartphones so seductive to their owners and promise many commercial opportunities for those able to monetize mapping and spatial search services.

These mobile devices and LBS are forming a new kind of map, what one might call the ‘me-map’ which always positions the viewer at the centre of the mapped world and crucially can update the orientation and location in harness to their movement through space (Dodge et al 2009). “Unlike the geocentric maps that serve many purposes and many users in a balanced manner”, according to Meng (2005: 12), “an egocentric map is intended for an individual person for his task at hand.” Importantly, the attribute data displayed on the base map can be context relevant showing only selected aspects that are important to a person at that time and at that particular location. In this sense the ego-centred nature of the map is more than just getting the x, y location; it is about delivering mapping that fits the moment. The touch screen interface of the latest smartphones is also significant because it shifts the role of map from ‘surface’ representation to a tactile interface to spatial information, with people caressing the screen, almost massaging the map. This ability to control the me-map in such an intimate way hints at its perceptual power and deepens the connection between screen display and embodied activity.

The rise of ‘me-maps’ as one of the most deeply mobile forms of media currently seen, is significant for how people interact with the world and as such should also be subject to critical scrutiny for the risks and threats that might result from the undoubted opportunities and benefits in LBS. Firstly, as such mobile mapping is so intuitive and becomes in many respects ubiquitous then people’s reliance on them becomes over-dependence. And with such dependence comes risks that a few dominant LBS providers, as key ‘ring-holders’ for ego-centric cartography, will hold undue power to determine what people see on their maps (and crucially what they don’t see). This

monopolistic control of the map databases is compounded, especially when the few alternative cartographic products cease to be available, as is apparent in the rapid decline in the quality print maps. As we come to rely on the smartphone screen as our sole source of information, do we and should we trust the mapping presented to us – remembering the suppliers are unaccountable and profit-motivated companies like Google, Apple, and Microsoft? They are often more secretive about their practices than state agencies, claiming the right of commercial confidence. It could be argued that on-demand egocentric mapping has greater scope for deceptive manipulation because they are more matched to the individual user than mass-printed map products. The spatial search at the heart of LBS can also be easily and covertly distorted to highlight features like favoured businesses and to deny the existence of others (see analysis by Zook and Graham 2007). While there is no tangible evidence of such overly-discriminatory practices, one can imagine mobile mapping algorithms that work to deny access to the 'wrong' kind of people but deliberately direct the 'right' people to more expensive, profitable places. This is plausible because the intrinsic, personalised, locative nature of 'me-maps' is such that they can completely invade an individual's spatial privacy. Many people do not consider their smartphone screen to be a two-way medium, so that while it maps for you it is also mapping you for those who control the service. Mobile mapping arguably breaches people's commonsense notions of freedom of movement and anonymity of activity.

The depth of this intensive and intimate surveillance within dynamic me-mapping, and the risks to personal identity and the autonomy of self, is clearly indicated by the number of powerful interests seeking to exploit mobile phone tracking data. Mobile network operators have also proved reluctant to reveal what data they store, what they can do with it and with whom they share it or sell it onto. This was illustrated by German politician Malte Spitz who challenged the regulation around the retention of personal transactional data by large companies by suing his mobile phone provider Deutsche Telekom to release some 35,000 data records on his activity from August 2009 – February 2010. To highlight this issue he presented his own data online (Figure 10): "Seen individually, the pieces of data are mostly inconsequential and harmless. But taken together, they provide …a profile – a clear picture of a person's habits and preferences, and indeed, of his or her life." (Biermann 2011: no pagination).

Major demographic and marketing corporations are keenly interested in such continuous profiles created by mobile devices. So too are a number of academics working in harness with network operators and LBS companies (e.g. Ratti et al 2006). The micro-geography of movement and its relatively easy availability from mobile devices has also been a boon to law enforcement agencies. The suspect's mobile phone is now seen by police as one of most vital piece of evidence to be seized during an arrest, and a whole new branch of digital forensics is developing to strip the data and analyse it (e.g. Nutter 2008).

The voluntary carrying of smartphones everywhere and their seductive egocentric mapping services takes individual surveillance to a new level of granularity by observing people continuously through space-time, along with the capacity to link movement patterns and positions of dwelling to information searches, pictures taken, payments made and social communications sent and received. This kind of matrix of data on material activity and daily behaviours has the potential, when analysed appropriately, to reveal key aspects of people's identity and the meanings they attach to places and events. Such intensification of spatial surveillance, often seen as an essential and unavoidable part of participation in the mobile society, is creating a digital shadow of people's lives, of unparalleled detail, in the databases of massive corporations that run the networks, control the handset software, and offer alluring free mobile services.

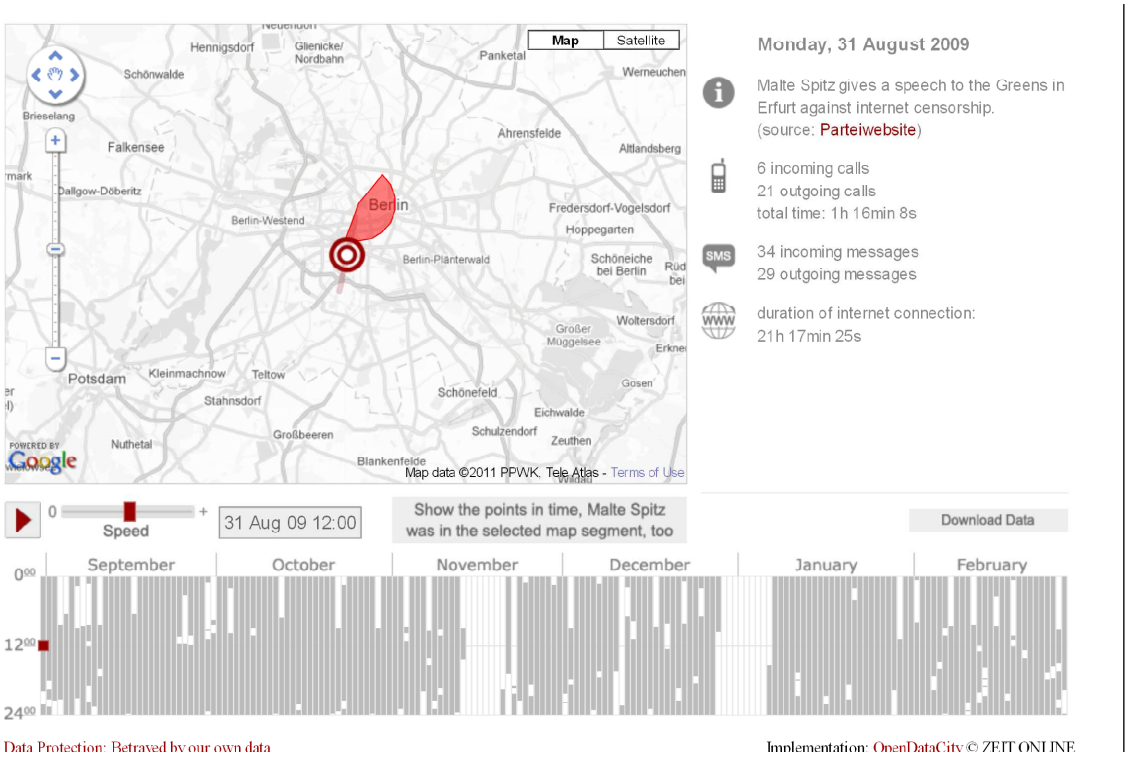

Figure 8. 'Tell-all Telephone", an interactive mapping tool allowing users to probe six months worth of communications data for German Green Party politician Malte Spitz. (Source: Author screen capture of http://www.zeit.de/datenschutz/malte-spitz-data-retention.)

In many respects the continuous tracking of people's movements and physical activities through their mobile devices is just the tip of the iceberg for automated real-time tracking of moving objects. It is widely predicted that in the near future that everything that moves and has significant value will be uniquely tagged with RFIDs and tracked by a dense mesh of sensors (Kitchin and Dodge 2011). Tracking all shipping containers around the world is routine today but soon there will be complete tracking of everything manufactured within these millions of shipments, how the goods move through the distribution channels, retail sites and places of consumption and then where they are disposed.

Conclusions

In conventional form the map is a poor means to represent the world in motion, it has been a static medium unsuited to showing change and movement. Maps typically seek to present a timeless view of space, arguably as part of their denial of their subjective and partial nature, and to project an aura of objectivity that they represent reality in an accurate and trustworthy fashion. There has been considerable creative design work by

cartographers and others to overcome these limitations, with some of the most promising developments in terms of flow mapping and the more experimental work with animation techniques to make short map movies. In appearance, the most novel design solutions are the so-called ‘fish-tank’ diagrams that can provide a revealing mapping of time geography and when carefully drawn using real data they have potential to display the daily choreography that is hard to represent on conventional ‘flat’ maps.

Despite significant developments in the past decade or so with greater volumes of detailed tracking data and the rapid development of ego-centred ‘me-maps’, there are many challenges in mapping movement. It is an exciting area of research in academia and an active frontier for applied science by industry. Finding the right way to map mobility that can expose something of the underlying causes and the real social meaning or economic value attached to it will be very useful in understanding and coping with a changing world. It raises profound ethical issues regarding privacy of movement and autonomy of activity, with the ‘spy’ behind the smartphone screen potentially watching – and recording – everywhere people go. Yet one must acknowledge a duality, here, because such intensive and intimate mappings of the movements of people can undoubtedly have positive applications; for example in applied research to better guide transport planners, property developers and architects to effect structural change in cities that is in harmony with major social drivers of mobility and can also shape future travel pattern in ways needed to meet other beneficial goals (like sustainability, safety or social inclusion). As such, being better able to map mobility could contribute to meeting significant environmental, social and economics challenges facing contemporary societies.

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[1] The rotational spin of the Earth is around 1000 miles an hour at the equator and the annual procession around the Sun is at the velocity of 107,300 km/h.

[2] Of course, the elements of the landscape that are deemed permanent and mappable are themselves culturally contingent and vary over time. Topographic maps in the nineteenth century often indicated watering places for horses, for example, reflecting the dominant mode of transport of the time. Many 'general' purpose maps today would highlight petrol stations above bus stops, reflecting the dominant interests of car drivers above other forms of travel.

[3] Governmental concern over the last couple of centuries with evermore detailed mapping of the weather is an interesting exception to the rule. Efforts to map (and in some senses, thereby, control) future weather patterns is clearly useful to many hegemonic interests, not least the military (cf. Monmonier 1999).

[4] This is changing due to the well documented improvements in computation, the automation of data capture and the declining costs of storage (cf. Kitchin and Dodge 2011). Following in the coat tails on natural sciences and biomedical science, there is

much interest in the humanities and social sciences in tackling analysis with ‘big data’ that was previously considered impractical or completely unfeasible.

[5] This is comparable to the dominance of Excel with its design defaults and helpful wizards which tend to diminish the diversity of ways in which data is charted. Similar arguments made about the pernicious influence of PowerPoint on how presentations are made (cf. Tufte 2003).

[6] It is far from free, of course. The huge capital costs of granting no-cost public access to high-resolution satellite imagery are being met, in part, by revenues from geographically-targeted advertising, but it is also being heavily subsidised at the moment by large corporations, like Google and Microsoft as they seek to entice users to their sites and to dominate the marketplace for online mapping. There is no guarantee that no-cost user access will continue to be provided by such corporations in the future.

[7] At least for the affluent minority in industrial economies, with the right devices and technical savvy to work them. The long standing issues of ‘digital divides’ remain unresolved.

[8] It is somewhat ironic that flexible, mobile mapping is also dependent on a fixed and immobile infrastructure. The network hardware needed to support mobile services is substantial but hidden, with wireless telecommunications dependent on a dense forest of antennas connected to broadband and fibre-optic cables.