Multi-Scale and Multi-Form Visualisation of Human Movement Patterns in the context of Space, Time and Activity: From Timeline to Ringmap

Jinfeng Zhao[1], Pip Forer[1] and Andrew S. Harvey[2]
jzha024@sgges.auckland.ac.nz, p.forer@auckland.ac.nz and harvey@smu.ca

[1] The School of Geography, Geology and Environmental Science, The University of Auckland, New Zealand
[2] Time Use Research Centre, Saint Mary's University, Halifax, Nova Scotia, Canada

This paper explores the issues associated with visualising and analysing data sets of human movement which are relatively rich in knowledge of human activity.

Technological advances have increasingly made high volume and high-resolution movement data available and affordable, as witnessed by the growing assemblage of data from animal tracking research (Kays and Wikelski 2007, Laube et al 2007). This burgeoning corpus underlines the significance attached to enhancing our knowledge of mobility and behaviour over space. Typically such animal research is interested in activity but with only few exceptions implies that data from space-time tracks (where this is possible) and not directly. Considerable research is needed on representing the tracks themselves, the process of implying activity or behaviour, and the impacts of the moving animals on the environment. Significant aspects of these general challenges are outlined by Andrienko and Andrienko (2007) and Dykes and Mountain (2003), many aspects of which apply to human movement analysis.

While work with human movement data partly shares a common agenda with animal or inert insentient object tracking it also has its own particular problems and opportunities.. The problems are dominated by privacy and ethics issues, and particular opportunities arise from the ability to directly interrogate the actor's activities over time. Fundamental to human movement is motivation, whether by need or desire, and the outcome of successful motivation is an activity or linked series of activities, which may comprise, include or bye-pass the need for non-trivial movement. We argue that activity choice is fundamentally entwined with the generation of space-time paths of individuals, and a record of chosen activities constitutes a prime dimension in the description of such paths. Consequently it should be seen as a significant component in the search for structure in large movement fields and this conclusion leads us to find ways to conceptualise and visualise data sets that enjoy measurement on the axes of space, time and activity (s,t,a).

The links between (s), (t), and (a) are clearly very strong. Movement is closely linked to the definition and specification of activities, and the choice of activities is typically conditioned by an individual's specific location in time or space. Some activities are embedded within a movement phase (skiing downhill, for instance) and others spark the need for movement (for example, the need for water results in a trip to the well). Not only is movement itself a particular kind of activity but it also creates spatial and temporal connections among other kinds of activities (Hanson 1979). In turn changing activity patterns generate profound implications for movement behaviour (Harvey, Taylor et al. 1997). All these intertwining relations between movement and activity indicate that it is valuable to view movements as activity patterns rather than isolated trips in space and time (Jones 1979; Burnett and Hanson 1982; Zhao 2003). Although the idea is simple, the implications are fundamental and far reaching (Jones 1979: 62).

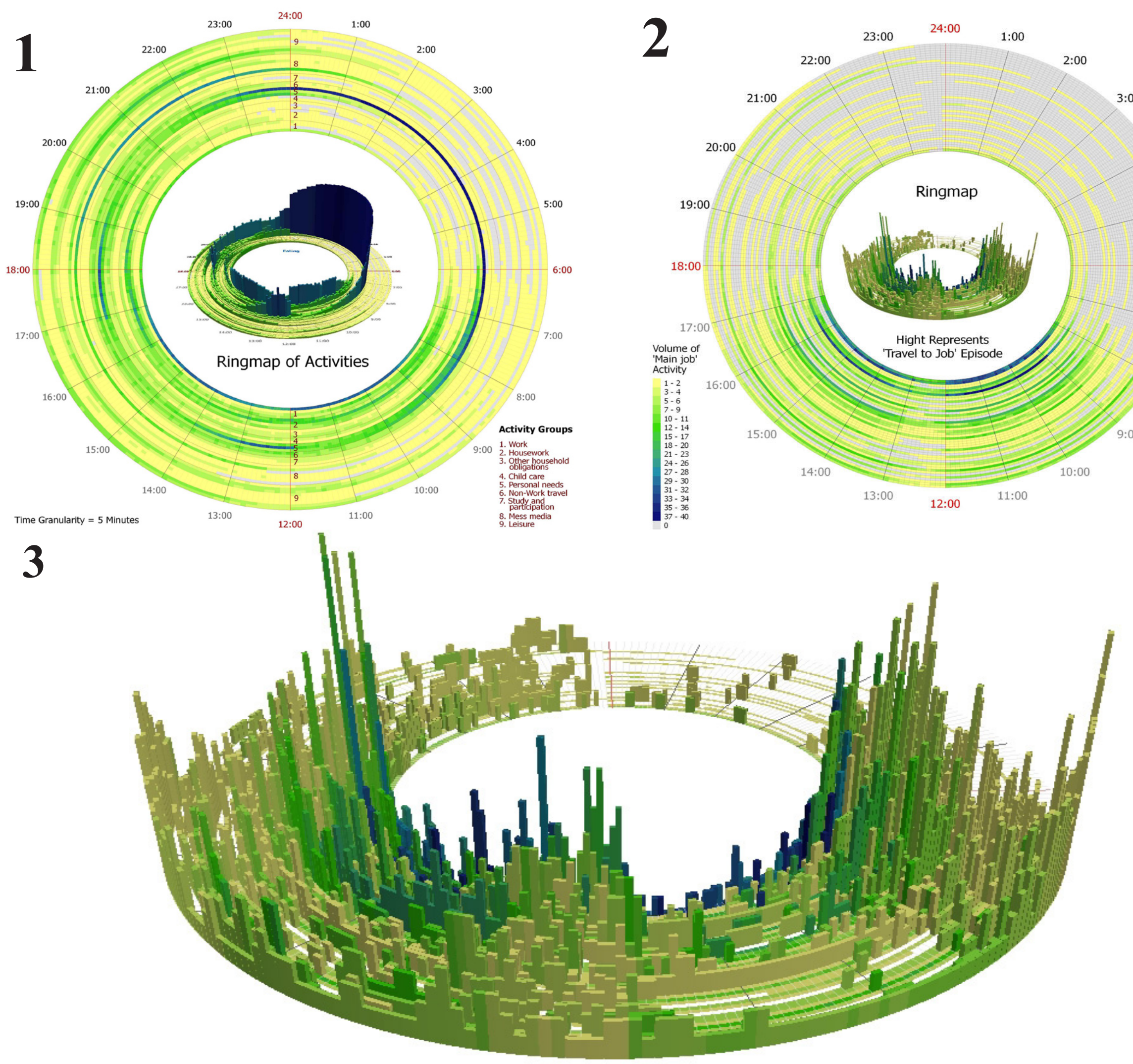
In this framework movement constitutes three key components, space, time and activity (s,t,a), each of these components being open to various way of expression and implementation at different scales of aggregation (for instance cyclic or linear time expressed by the hour or minute, or locations being points or city blocks).. Such generalisations may also involve combinations of the dimensions, an instance of this being the concepts of episode or event which involves the association of a period of time with a certain spatial extent and a consistent class of activity. A second concept might be the idea of an ensemble of activities representong a wider project such as the various positioning of child care, eating and travel underlying parents enjoying a child-free theatre visit. Such constructs can be represented using (s), (t) and (a) components, with each component itself enjoying several possible representations. Here (s,t,a) model space can be absolute or relative and can be 1, 2, or 3-dimensional; time can be linear, cyclic or episodic; and activity can have varied classifications at different scales or nature of purpose. This paper uses the (s,t,a) data model to explore different forms of representation of movement data sets based around a spectrum of visualisations involving a variety of generalisations and representations of (s,t,a) space (Zhao, Forer et al. 2006). Research is reported on the operators used for transforming one form of representation of movement into another, and for expressing the dimensions of representation at different levels of generalisation.

The data used for exploring these issues are drawn from the 1971 Halifax Time Use Study, a data set which contains the (s,t,a) ingredients necessary for exploring the the properties of visualisation and exploratory data analysis with such data sets (Goodchild and Janelle 1984). The survey includes 2,141 respondent records of time, duration, location and the kind of activity being undertaken, of which some 50% are currently fully coded for location and so can be used to generate complete daily timelines in a time geographic sense.

The multidimensionality and richness of movement data challenges our understanding, and as Andrienko and Andrienko (2007: 125) comment. “Irrespective of the size of a data set, movement data are difficult to visualise and analyse because of the quite complex data structure, which involves time, space, multiple entities, and multiple movement characteristics”. They also note that visualisation alone may not be sufficient when exploring massive movement data sets due to technical and human perceptual and cognitive limitations (Andrienko and Andrienko op.cit.). Timelines have a wide currency for representing (s,t,a) data for small numbers of individuals, but are knwon to have significant problems when visualising multiple time lines and generalising these to show the structural patterns emerging from such data (Zhao 2003; Andrienko and Andrienko 2007) Although a variety of elaborations have been proposed (Forer 1998; Kwan 2000; Zhao 2003; Forer, Huisman et al. 2007) these remain largely unresolved. Nonetheless, timelines in various forms can be used as a focal graphic for multiple, linked graphic representations.

The visualusation strategy that this paper explores adopts the common use of various assemblages of linked graphics to allow experimentation in different environments (CommonGIS , GeoVista and ArcGIS modules), but is distinguished by concentrating on two strategies. The broader one is to provide a set of generalisations related to the nature of (s,t,a), mappings which are explored through recognized operations such as selection and multiple views combined with an emphasis on an ability to display vertical links (multiple generalisations) with horizontal ones (multiple representations) of various dimensions of the movement data . The second feature is an emphasis on visualisations that allow effective browsing of activity relationships in a spatiotemporal context.

The work reported here utilises a number of well known representations of movement patterns, including the space-time aquarium previously noted. However it augments a space-time based view as a focal reference with an activity-based one which is a useful complement . This approach emphasizes activity and cyclic time as dominant issues in its representation (see below) and builds on recent work by Bale and Chapman on Kaleidomaps (Bale et al 2007). This is the ‘Ringmap’ , which is composed of multiple concentric circular sectors. Each 360 degree ring represents values in cyclic time for an entity (activity or zone) , with each sector of the ring representing a time period of a specified



temporal granularity, with an exact position on the ordered time wheel.

The three graphics below illustrate the evolution of the ringmap. Figure 1 show a basic ring representation of activity and time, where the rings represent multiple activities over time each ring showing varying participation in that activity. In Figure 2 each spatial zone displays the extent of that activity in each time segment, and each ring is zone of Halifax. Inset is a three dimensional representation of the same data but with work and travel activities being shown. This can be seen in more detail as figure 3. This representation is designed for interactive screen use that integrates with various operations for selecting activities, times or places for the generation of differern pespectives. In this situation, where rings refer to spatial zones, the ringmap can allow links to spatial view as well as embodying its own spatiality (for instance ordering the rings by rank distance (on any metric) from a central place such as the CBD).

We report on developments in variants of this representation, and on a range of generalisations across the (s,t,a) variables which can be utilized in the ringmap and other representations. These include viewing various hierarchical levels or combinations of activity classes, various functional spatial zonings for aggregation, and different definitions of episodes or multi-activity bundles (Figure 4). This follows Fabrikant and Skupin's assessment that "Generalisation is not just about information loss" (Fabrikant and Skupin 2005: 670) but allows us to see different information (Chaudhry and Mackaness 2006). Hence we seek tools to visualise and analyse data at the scale and/or perspectives "where geographical [or other variable] variance is maximized or where spatial processes are best understood" (Muller, Weibel et al. 1995: 3). Our particular concern is the question of how best to identify preferable representations from consideration of the nature of the spatial process being considered, in this case everyday life.

As there are no truly universal generalisation methods (Weibel 1995), different approaches of generalisation have been considered for these data. Generalisation of (s,t,a) movement data involves spatial, temporal and activity abstraction, which are different in nature but closely related and interactive. This raises challenges and requires different treatments in generalisation. Codification of such data refers to the process that reduces a complex entity into a coded prototype where the critical issues are sequence, rhythm and pattern. This is fundamental in much of the work on movement classification (Harvey 1997; Marble, Gou et al. 1997; Laube, Imfeld et al. 2005; Laube, Dennis et al. 2007) . The work of Andre Skupin (2007) offers extension on this which are identified.

Codification across various dimensions is one of the key approaches to discovering and recognising knowledge in movement data sets, and interactive, comparative and explorative visualisation clearly offers opportunities in this respect, notwithstanding the limited software for this specific purpose.This paper focuses on the potential revealed by using a pivotal display graphic with a heavy time/activity weighting to explore related issues of movement, using different generalisations and codifications. Having reported progress in the areas of generalisation and particular areas of visualisation, the paper ends with a short discussion of whether integrating closely process related dimensions into dynamic data sets assists or complicates the elucidation and visualisation of the spatiotemporal pattern.

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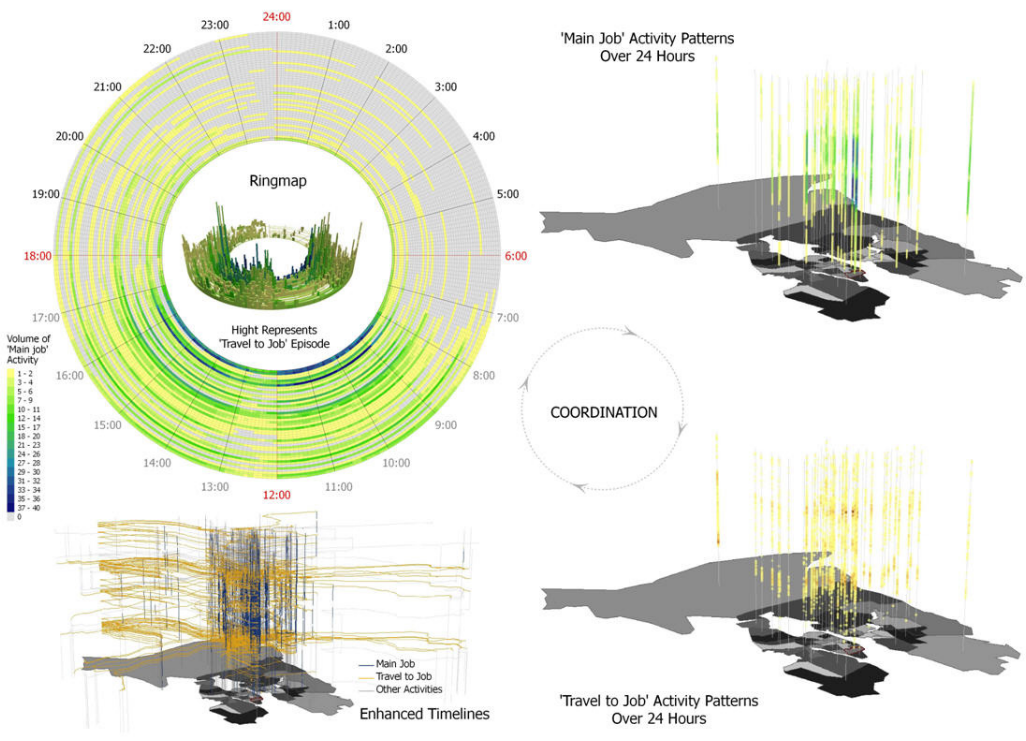

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