Testing the Usability of Time-Geographic Maps

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1. Introduction

Time geography (Hägerstrand 1970) was first proposed in the 1970s as a mapping framework focused on representing individual accessibility under certain constraints. In general time-geographic maps are maps which explicitly incorporate time as a visual variable into a map. Time-geographic maps can be compared to other methods of mapping which attempt to represent dynamic phenomena, such as Tobler's (1987) depiction of population movement by scaled arrows. Central to construction of time-geographic maps is the concept of constraints. Hägerstrand (1970) categorizes the concept of constraints as fitting within one of three types: capability, authority, and coupling. Capability constraints address the physical limitation of individuals, such as those imposed by the need to eat or sleep. Authority constraints refer specifically to levels of access at an individual level. Coupling constraints are recognized as the necessity of certain activities to form production, consumption, social and miscellaneous activity bundles (Pred 1977).

Time-geographic maps are situated within a *space-time cube* which utilizes spatial two-dimensional (2D) axis, x and y, along with a third temporal axis, z. An individual's *space-time path* is constructed by drawing straight lines connecting known space-time points such as those provided by travel-diary survey data (see Kwan, 2000). A *space-time prism* (Figure 1) then represents all of the potential space-time paths an individual might have taken during a specific time range thereby delimiting the feasible set of opportunities within a person's reach (Forer, 1998). In theory, the prism is the intersection of two cones. The slope of the cone shows a given possible maximum velocity for the represented individual from a known point in space, while the space-time path indicates an individual's activities in both space and time. Using the maximum velocity assumption we can then conceptualize how an individual's potential path space (Wu & Miller, 2001), represented by the interior of the cone, intersects with a known site x_j, by showing all of the locations in space and time that an individual could have occupied during the time range interval (t_i, t_j). The range of individual travel capability then is constrained only by a defined maximum velocity, signified as v. This velocity is, mathematically, the subtraction of a known time segment, $t_j - t_i$, divided by the distance between known control points, $x_j - x_i$. The concept of velocity, expressed as potential path area (PPA), is integral to a time-geographic approach. Therefore a potential path representation is used to show the points in space and time that the person could occupy during this travel episode (Miller, 2005).

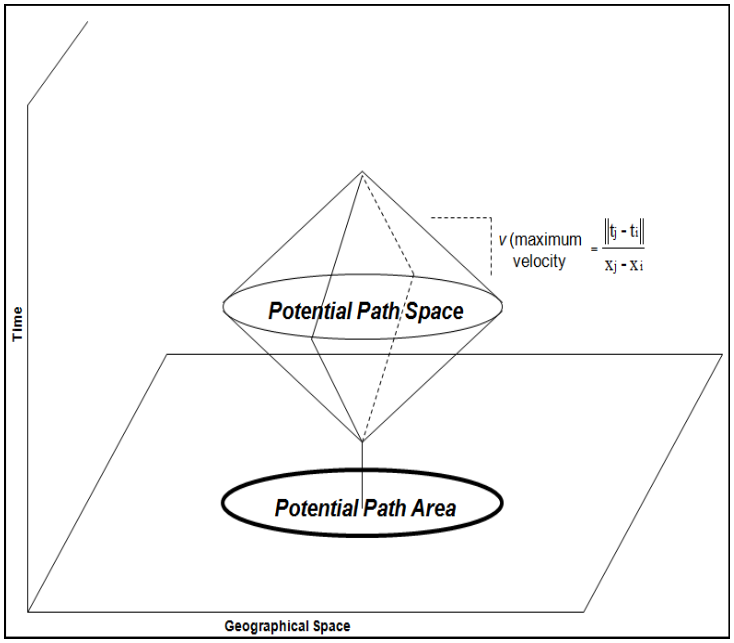

Figure 1 - Space-time Prism

Time geography offers potentially useful tools for both the analysis and visualization of mobility and accessibility. However, some thirty years after its introduction time geography remains on the research frontiers. And while the use of time geography to visualize movements has been proposed in many potential applications (Lentorp 2003; Moore et al. 2003), it continues to pose a number of operational barriers (Kwan 2000) - most notably in the areas of measurement and usability. The measurement issues of the time-geographic approach have largely been taken up by Miller (1991), who has focused on the more analytically rigorous capacity of time geography. With advances in computing and graphics technologies, the time geographic framework has become a more feasible tool for analysis and hypothesis generation. Therefore, a second barrier to overcome for creating effective time geographic maps, and the focus of this research, is assessment of the usability issues of time-geographic maps.

2. Methodology

To assess the usability of time geographic maps cartographic visualizations were developed for the purpose of revealing space-time location factors through crime event exploration. The maps were developed using Google SketchUp which provides users with tools for interacting with the map (e.g. zoom, pan and orbit). This approach puts the time-geographic framework within a specific context which could then be assessed for usability. Unique to the methodology of this dissertation is a test of the utility of the time geographic framework for use representing crime events that occur at unknown points in space and time and, more broadly, events in general that appear at unknown points in space and time. The practice of mapping a crime is traditionally realized by highlighting a single point, or an aggregated single point, which can be aligned with the convergence of the elements of the crime triangle being the offender, opportunity, and victim. However, the reduction of certain crime events to a single point may not always effectively serve the investigative process.

Therefore, the crime triangle really breaks down when one considers non-static or mobile types of crime such as the case of a robbery on a moving train as depicted by Newton (2004). In this case the victim and offender do meet in time and space, but the exact time and location is unknown for use in a crime map. The time-geographic approach seems particularly suited for these types of crime because it contextualizes the conditions influencing human activity. Time geography accounts for consumption of time by movement in space and the fact that situations are always rooted in past situations, and limited human ability (Unwin, 1992). Coincidently these conditions are relevant to the challenge of mobility in crime mapping. A crime cannot occur without the ability for an offender to be at the location of the crime when it is determined to have occurred. Therefore, if the actual location, or time, of a crime incident is unknown, then a mapping of known victim, or offender activity may reveal certain knowledge about where, and when, the crime was likely to occur.

Experts -- both researchers and practitioners -- were recruited based on their involvement in the crime mapping community. These interviews were consistent with methods that have been previously applied in usability studies evaluating the effectiveness of *geovisualizaiton* methods (Olson & Brewer 1997). Separate interviews were conducted with individual experts, thereby avoiding the influence of group opinion (Stewart & Shamdasani 1990). Participants were selected from two groups: practitioners and scholars. Crime analysts and crime mapping scholars frequently use maps to uncover hotspots, criminal networks, flows and investigative leads. Individual law enforcement agencies were contacted to set up interviews with practicing crime analyst and additional interviews were conducted at professional and academic conferences.

At each interview session participants were presented with a crime scenario (pickpocketing in a crowded shopping district) which assumes a single offender acting on two victims within a given range of time. And while victim space and time paths were known and provided, no offender data was given other than the constraint of velocity. The concepts of time geography were explained at the start and again as they were introduced during the exercise. The semi-structured interview process consisted of four map iterations utilizing same crime scenario conducted as a cognitive walkthrough. Cognitive walkthrough is a usability inspection method that evaluates the design of a user interface for its ease of exploratory learning where the user has set goals, performs actions, and evaluates feedback (Polson et al. 1992). With each maps iteration the tools of time geography were further incorporated. Participants were asked questions throughout to test their understanding of the tools of time geography based on the visual representation of the map. The final map incorporated many of the tools fundamental to time geography (Figure 2).

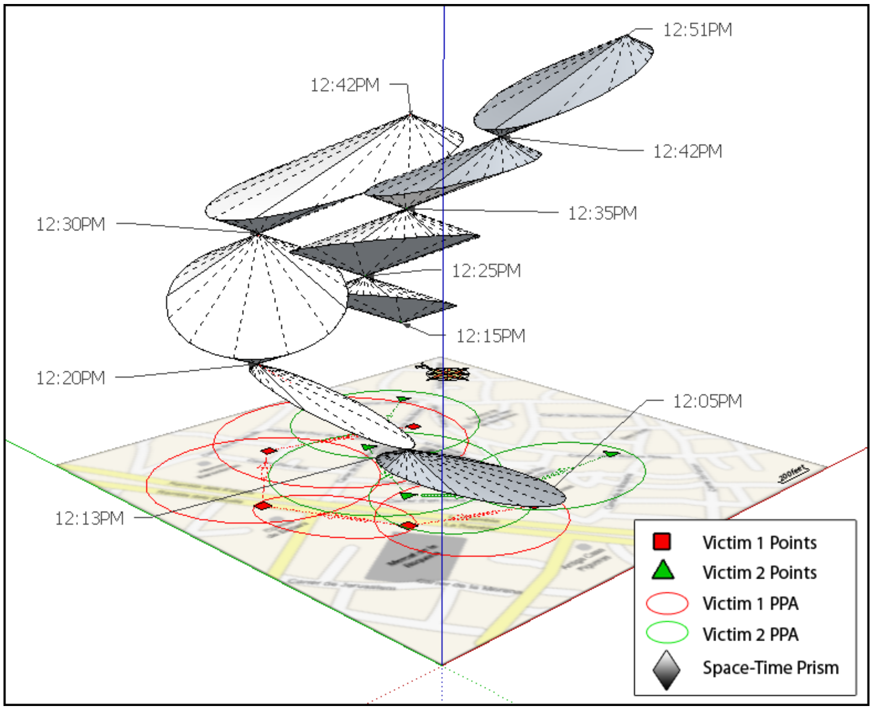

Figure 2 –Time-Geographic Map

During the usability interviews participants were shown first a space-time path map and then space-time prism map. Participants were then tasked with locating the time at which two victims, represented in the maps, were at their closest. With the addition of the space-time prism participants should have been able to conclude an answer in the range of 12:25 and 12:30. During this iteration participants were encouraged to interact with the map through the available tools (e.g. pan, orbit and zoom) which was required to answer this question with certainty. And while some participants answered with by selecting a certain narrow time range, most selected a wider range signifying the uncertainty of their answers (Figure 3). This is but one example from the usability interview process of how time-geographic maps were explicitly tested. Questions meant to evoke more implied analysis were utilized to test scenario context and the spatial implications the time-geographic maps (not included in this abstract).

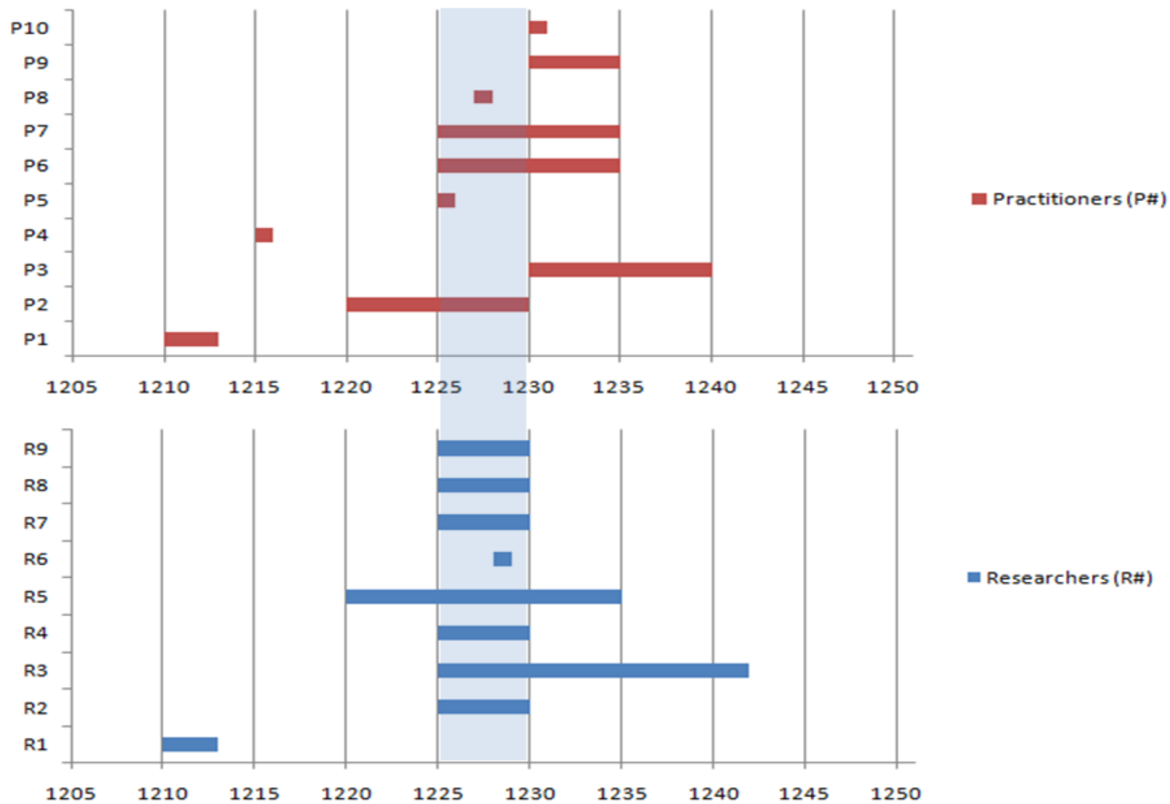

Figure 3 –Time-Geographic Map

Nine crime mapping researchers and ten practicing crime mapping analyst were interviewed from 2009-2010. Each interview lasted approximately 45 minutes. Preliminary results from the interviews suggest that the potential usability of time-geographic maps is more readily perceived by crime mapping researchers than practitioners. Further, practicing crime analyst, positioned at the intersection of street-level police work and back-office spatial analysis note the challenges that would be faced in explaining time-geographic maps to their law enforcement counterparts.

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References

Forer, P. (1998). Geometric approaches to the nexus of time, space, and microprocess: Implementing a practical model for mundane socio-spatial systems. In: Spatial and Temporal Reasoning in Geographic Information Systems, M. J. Egenhofer & R. G. Golledge (eds.) (New York: Oxford University Press, pp. 171-190.

Hägerstrand, T. (1970). What about people in regional science? *Papers of the Regional Science Association* 24, 7-21.

Kwan, M.-P. (2000). Interactive geovisualisation of activity-travel patterns using three-dimensional geographical information systems: A methodological exploration with a large data set. *Transportation Research C* 8, 185-203.

Lenntorp, B (2003) The drama of real-life in a time-geographic disguise. Paper presented at the Sixth Theo Quant Meeting, Besancon, France. Retrieved on February 14, 2009 from the website of the Université de Franche-Comté, thema.univ-fcomte.fr/theoq/pdf/2003/03Lenntorp.pdf

Miller, H. J. (1991). Modeling accessibility using space-time prism concepts within geographical information systems, *International Journal of Geographical Information Systems*, 5, 287-301.

Miller, H. J. (2005). A measurement theory for time geography, *Geographical Analysis*, 37, 17-45.

Moore , A, Whigham, P, Holt, A, Aldridge, C & Hodge, K. (2003). A Time Geography Approach to the Visualisation of Sport. CD-ROM of Proceedings of GeoComputation 2003, University of Southampton, UK.

Newton, A. D. (2004). Crime on public transport: 'Static' and 'non-static' (moving) crime events, *Western Criminology Review*, 5, 25-42.

Olson, J. M. & Brewer, C. A. (1997). An evaluation of color selections to accommodate map users with color-vision impairments, *Annals of the Association of American Geographers, 87*, 103-134.

Pred, A. (1977). The choreography of existence: Comments on Hägerstrand's time-geography and its usefulness, *Economic Geography*, 53, 207-221.

Polson, P.G., Lewis, C., Rieman, J., & Wharton, C. (1992). Cognitive walkthroughs: A method for theory-based evaluation of user interfaces. *International Journal of Man-Machine Studies* 36, p.p. 741-773.

Watts, E.F. & Rule, J.T. *Descriptive geometry*, Prentice-Hall, Inc., Englewood Cliffs, N.J., 1946

Stewart, D. W., & Shamdasani, P. N. (1990). Focus Groups: Theory and Practice. London: Sage.

Tobler, W. (1987). An experiment in migration mapping by computer, The American Cartographer, 14(2), 155-163.

Unwin T. (1992) *The place of geography* Longman, Harlow

Wu, Y-H. & Miller, H. J. (2001). Computational tools for measuring space-timeaccessibility within dynamic flow transportation networks, Journal of Transportation and Statistics, 4(2/3), 1-14.