Visual Analysis of Human Activities

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A major difficulty in the analysis of disaggregate human activity behavior arises from the fact that individual movement in space-time is a complex trajectory with many interacting dimensions. These include the location, timing, duration, sequencing and type of activities and/or trips. This characteristic of human activity behavior has made the simultaneous analysis of its many dimensions difficult. Two approaches to overcoming this difficulty are often pursued by researchers. One is to decompose activity patterns into their component dimensions and focus only on a few dimensions at a time. The other is to treat activity behavior as a multidimensional whole and use multivariate methods to derive generalized activity patterns from a large number of variables. For instance, through the use of multivariate group identification methods (such as clustering or pattern recognition algorithms), complex behavioral patterns can be represented by some general characteristics and organized into relatively small number of homogenous classes.

While these conventional methods are useful for modeling purposes and for discovering the complex interrelations among variables, they also have serious limitations. First, few of these methods were designed to handle real geographical locations and context of human activities and trips. Often, the spatial dimension is represented by some measures derived from real geographical locations (e.g. distance or direction from a reference point such as home or workplace of an individual). Further, locational information of activities and trips was often aggregated with respect to a zonal division of the study area (e.g. traffic analysis zones). Using such zone-based data, measurement of location and/or distance involves using zone centroids where information about activity locations in geographic space and their spatial relations with other urban opportunities is lost.

Second, since many analytical methods (e.g. log-linear models) are designed to deal with categorical data, organizing the original data in terms of discrete units of space and time has been a necessary step in most quantitative analyses of activity-travel patterns in the past. Discretization of temporal variables, such as the start time or duration of activities, involves dividing the relevant span of time into several units and assigning each activity or trip into the appropriate class (e.g. dividing a day into 8 or 12 temporal divisions into which activities or trips are grouped). Discretization of spatial variables, such as distance from home, involves dividing the relevant distance range into several “rings”. Since both the spatial and temporal dimensions are continuous, results of any analysis that are based upon these discretized variables may be affected by the particular schema of spatial and/or temporal divisions used. The problem may be serious when dealing with the interaction between spatial and temporal variables since two discretized variables are involved.

Third, the amount and complexity of activity-travel data have increased considerably in recent years. Without effective methods for exploring these data, the researcher may need to model activity patterns without a preliminary understanding of the behavioral characteristics or uniqueness of the individuals in the sample at hand. This can be costly in later stages of a study if the model's specifications fail to take into account of the behavioral anomalies involved. Since exploratory data analysis (EDA) can often lead to more focused and fruitful methods or models in later stages of a study, the recent development and use of geovisualization suggest a possible direction for overcoming the problem.

In this paper I draw from my recent studies to suggest that GIS-based 3D geovisualization offers considerable promise in overcoming these three limitations of past studies on human activity behavior. Specifically I seek to illustrate that 3D geovisualization is effective for enhancing our understanding of the interaction between space and time in human activity behavior, for exploring human hybrid activity-travel patterns (i.e. the interaction between of people's activities and/or travel in both the physical and virtual worlds), and for taking qualitative information and human emotions and feelings into account. These examples are drawn from my recent studies that used three different activity-travel diary data sets I collected.

The first set of examples illustrates how interactive 3D geovisualization based on the time-geographic framework can be fruitfully deployed for enhancing our understanding of human activity behavior (Kwan 2000; Kwan and Lee 2004). Several geovisualization methods for dealing with the spatial and temporal dimensions of human activity-travel patterns at the same time while avoiding the interpretative complexity of multivariate pattern generalization or recognition methods will be described. Advantages of the methods will be highlighted. For instance, significance of the temporal dimension and its interaction with the spatial dimension in structuring the daily space-time trajectories of individuals can be clearly revealed (Kwan 2004). Further, using 3D geovisualization as an exploratory tool may lead to more focused analysis in later stages of a study. They can also help the formulation of more realistic computational or behavioral travel models.

Since the Internet now plays an important role in shaping people's daily activities and travel, we can no longer ignore the effect of the Internet in any analysis of human activity behavior. The second set of examples illustrates how our understanding of human hybrid activity patterns can be enhanced using 3D geovisualization (Ren and Kwan 2006). Two geovisualization approaches using 3D and 2D GIS techniques will be discussed: information cube and hybrid 3D space-time paths, and a new representation of 2D space-time paths that incorporates parallel coordinate plots. How these two methods allow us to uncover important patterns in hybrid human activity-travel behavior will be described.

As shown in recent studies of human activity behavior, approaches that rely solely on quantitative activity data tend to offer limited understanding of individual behavior and the situational factors that help explain such behavior. The third example addresses the need for understanding people's emotions and feelings and for GIS to analyze qualitative material, especially textual material. It explores the possibility of incorporating qualitative data analysis capabilities in GIS, and involves the conceptualization, design and implementation of a 3D visualization and qualitative analysis component (called 3D-

VQGIS) in GIS (Kwan and Ding 2006). This illustration shows that capabilities for the recursive and interactive analysis of qualitative data can be incorporated into 3D geovisualization environment of a GIS.

Together these three sets of illustrations show that GIS-based visual analysis of human activity behavior is a fruitful endeavor. It can be applied in a wide range of areas and has several advantages. First, since GIS are capable of integrating large amounts of geographic data in various formats and from different sources into a comprehensive geographic database, they are able to generate far more complex and realistic representations of the urban environment than conventional methods. The concrete spatial context they provide can greatly facilitate exploratory spatial data analysis and the identification of spatial relations in the data. Results can also be exported to spatial analysis packages for performing formal spatial analysis. Second, 3D visual analysis provides a dynamic and interactive environment that is much more flexible than the conventional mode of data analysis. The researcher can directly manipulate the attributes of a scene and its features, and change the views, alter parameters, query data and see the results of any of these actions easily. Third, 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. Lastly, with many useful navigational capabilities such as fly-through, zooming, panning and dynamic rotation, as well as the multimedia capabilities to generate map animation series such as 3D “walk-throughs” and “fly-bys”, the researcher can create a “virtual world” that represents the urban environment with very high level of realism.

References

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

Kwan, Mei-Po. 2004. GIS methods in time-geographic research: Geocomputation and geovisualization of human activity patterns. *Geografiska Annaler B*, 86(4): 205-218.

Kwan, Mei-Po and Jiyeong Lee. 2004. Geovisualization of human activity patterns using 3D GIS: A time-geographic approach. In *Spatially Integrated Social Science*, 48-66, Michael F. Goodchild and Donald G. Janelle (eds). New York: Oxford University Press.

Kwan, Mei-Po and Guoxiang Ding. 2006. 3D-VQGIS: Extending GIS for Qualitative and Mixed-Method Research. Manuscript.

Ren, Fang and Mei-Po Kwan. 2006. Geovisualization of Human Hybrid Activity-Travel Patterns. Manuscript.