Synoptic Analysis of Space-time Activity Patterns

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Introduction

Global positioning systems (GPS) and related spatial technologies will soon be embedded as ubiquitous features of the nation's automobile pool and mobile phone networks, creating a dense systems of mobile sensors with the potential to document in real-time the continually changing patterns of vehicle occupancy on roads and human occupancy of space within urban regions. These developments provide a foundation for the dynamic synoptic mapping of urban activity systems and new ways to explore issues and solutions in transportation planning.

Synoptic analysis has been an important research area in climatology, meteorology, and oceanography for decades, providing valuable insight about processes of both long and short duration over geographical space. The key to success in these disciplines is associated with large sets of distributed information sensors that provide continuous coverage over space and time, widely accepted procedures for standardized measurements, and visualization tools for rendering analytical and descriptive results in a short time frame. Although analogy with human activity is not straightforward, researchers over the past half-century have invoked synoptic concepts to better understand changes in urban and regional activity systems. Examples include Chapin and Stewart's 1953 experiments in mapping population densities in selected U.S. cities for different times of the day; Stewart and Warntz's 1958 conceptualization of population potential fields—continuous non-uniform surfaces that change over time as a consequence of population movements and spatial variations in growth rates; Angel and Hyman's 1976 modeling of urban velocity fields as a basis for estimating travel times; Taylor and Parkes' 1975 analysis of plausible but fictitious census-like variables for eight different times of the day for a stylized city; and Janelle, Klinkenberg, and Goodchild's 1998 use of Halifax space-time diary data to link conceptually and empirically individual space-time paths with diurnal changes in ecological patterns of human activity.

The more explicit focus on individual space-time paths and space-time prisms (pioneered by Hägerstrand 1970 and demonstrated in the work of Lenntorp 1978, Burns 1979, Kwan and Lee 2004, and Miller and Wu 2000) are best seen in the context of the opportunities and constraints that exist in the unfolding time ecologies of urban spaces and behavioral settings. The ability to link tracking data with activity diaries and social surveys would provide a more complete contextual base for interpreting individual activity behavior and for defining the time ecology of urban regions. This would add important new understanding of human activity patterns across diurnal and weekly cycles and permit more encompassing measures of accessibility based on Hägerstrand's (1970) time geography model of society.

The Vision

GPS or cell-phone based dense tracking data provide the foundation for the dynamic modeling of behavior in contemporary cities and for applications that draw on the rich theoretical insight of time-geography. Access to dense tracking data permits dramatically new ways of measuring and representing human activity patterns. Researchers will be able to zoom in and out spatially and at any level of temporal aggregation to produce measures and maps of dynamic shifts in population densities. Other measures potentially include traffic densities, ratios of cars to trucks, proportions of within-region to pass-through traffic, surface representations of average travel speeds, congestion indexes, and weekend to weekday ratios, along with other indicators for exploratory research and diagnostic use. In combination with social and diary surveys, these dense tracking data can yield temporal variations in social group integration, dynamic measures of spatial concentration, at-risk populations to threatening events, and a wide range of other indicators of human occupancy in space and time. Such data could be used to display a dynamic representation of population potential surfaces (Warntz 1966) and velocity fields (Angel and Hyman (1976), illustrating their utility for determining minimum paths and for allocating public services that account for diurnal variations in the serviced populations. They might also be used to assess the significance of such concepts as accessibility and opportunity for answering questions about health risk, social exclusion and equity, and optimality in facility or service allocation.

What is Needed?

To bring about applications of responsive synoptic analysis of space-time activity patterns, there is a need to set in place methods for collecting, analyzing, and modeling changing patterns of behavior over diurnal weekly, and other periodicities. In contrast to decennial census data and travel survey methodologies, the synoptic approach relies on data that are continuous over time and space, and it requires procedures for the automated real-time visualization of traffic and human movement behavior in space. Thus, through use of global positioning systems (GPS) or cellular technologies for dense tracking of subjects, and through data visualization tools, a dynamic conversion of these data into mapped patterns and index measures is possible. Although this approach opens up a wide variety of new opportunities for plan evaluation in urban and transportation planning, it also poses significant challenges about how to manage large complex datasets that simultaneously reference space and time, how to use effectively such data for inference assessment, and how to protect the location privacy rights of individuals while minimizing the resultant loss of scientific and social value to the information. In this position statement, I am suggesting the need to develop proof-of-concept research based on the use of existing data sets on vehicle movements to:

(1) demonstrate a synoptic approach for analyzing movement behavior in selected American cities;

(2) document the value of this approach for modeling space-time patterns of activity behavior;

(3) address issues of how to manage extensive space-time data sets;

(4) define and test procedures for protecting individual location privacy rights;

(5) assess the feasibility of linking GPS tracking data with respondent activity diaries in urban regions; and

(6) establish strategies to implement dense tracking for continuous synoptic mapping for urban regions. A plan for the deployment of a large-scale, real-time implementation of these methods in a major American city is needed.

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