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Place-Based versus People-Based Geographic Information Science

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Abstract

Geographic information science and technologies are revolutionizing basic and applied science by allowing integrated holistic approaches to the analysis of geographic locations and their attributes. However, the increasing mobility and connectivity of many people in the world means that the relationships between people and place are becoming more subtle and complex, rendering a place-based perspective incomplete. This article discusses the need to move beyond a place-based perspective in geographic information science to include a people-based perspective (i.e., the individual in space and time). It reviews the theories and technologies that can support the people-based perspective and provides some example applications of the people-based perspective.

Introduction

The concept of place rightly occupies the core of geographic thought. Geographic location provides a fundamental strategy for organizing and synthesizing observations about the real world (Berry 1964). Location provides a holistic, integrative way of understanding phenomena often considered in isolation by other disciplines and perspectives (National Research Council 1997). Geographic information science and geographic information systems (GIS) enhance this central focus of geographic inquiry by facilitating the collection, storage, analysis and communication of locational data and information, encouraging holistic and integrative thinking about places.

Places are not simply a semantic convenience. It is a meaningful lens for viewing the world because it is orderly with respect to geographic space. Physical and human phenomena tend to organize by geographic location for a simple reason: overcoming space requires expenditure of resources, energy, and time, a charge that nature (including humans) attempt to minimize subject to constraints and other objectives. The often-quoted Tobler's First Law of Geography summarizes this empirical regularity: things are more related with proximity in geographic space (Miller 2004; Tobler 1970). Human activities also tend to organize with respect to geographic location due to the friction of distance and the consequent competition for advantageous location, co-location with others performing similar or complementary activities, and the selective interchange of people, material and information among locations. As Couclelis (1996) points out, all of the classic human geographic theories and models characterize the spatial organization of human activities as a function of distance; this includes movement and communication (spatial interaction theory), the number, location, and size of cities (central place theory), agriculture (von Thünen), industrial production (Weber), household location (Alonso), economic development (core-periphery models), and urban land use (Lowry models).

Influencing the relationships between people, place, and activity are the technologies to mitigate the friction of distance. Transportation technologies reduce the friction of distance for physical movement and communication technologies reduce this friction for information exchange. Abler (1975) refers to these as *space-adjusting technologies* because they literally change the nature of experienced space with respect to the time, cost, and effort required to move people, material, or information among locations, resulting in a consequent impact on the distribution of human activities.

Transportation and communication technologies have been available for centuries; conveyances and media such as the chariot, clipper ship, mail, railroads, telegraph and telephone had well-documented transformative effects on societies and economies (see, for example, Standage 1998; Winston 1998; Wright 2000). The differential impact of space-adjusting technologies can be accommodated from a purely place-based perspective. For example, consider the three classical theories of urban form: these reflect different eras of transportation technologies, including walking (concentric zone theory), railway (sector theory), and automobile (multiple nuclei theory) (see Hartshorn 1992). Similarly, transportation can also be encompassed in quantitative place-based models; examples include Mayhew and Hyman (2000) and O'Kelly (1989). However, in the late 20th and the early 21st centuries, the widespread deployment and democratization of technologies such as the automobile, commercial aviation, the Internet, and the mobile phone has resulted in an unprecedented explosion in the mobility and connectivity for many people in the world. It is possible that we have passed a threshold beyond which a place-based perspective alone is no longer viable.

This article argues that the place-based orientation of geographic information science, and geographic science more generally, should be extended to encompass a people-based perspective. Instead of using places as a surrogate for people and their activities, a people-based focuses directly on individuals' activities in space and time, and their use of places in both the real and virtual world. This argument is not new: it has been made by others, mostly notably Hägerstrand (1970), but also Falk and Abler (1980) and Pred (1984). However, a reinvigorated argument and literature review is appropriate at this time given the recent developments in transportation and communications technologies discussed above, as well as contemporary developments in the theories and geo-spatial technologies that can support a mature people-based science. The dream of pioneers such as Hägerstrand, Abler, and Pred can now become reality, and is even more imperative given the highly mobile and connected world in which we now live.

The next section of this article discusses the changing nature of place: it reviews the effects of space-adjusting technologies in creating space-time convergence, high mobility, and telepresence, the increasing likelihood that these trends will lead to scientists to a fallacy when inferring the characteristics and experiences of people from places. The following section reviews recent developments in people-based theories and technologies; these include time geography in its classical form, as well as the new and more robust theory that has emerged over the past decade or so. It also discusses the rise of location-aware technologies, geo-simulation, mobile objects databases, and spatio-temporal knowledge discovery techniques that can support a people-based perspective. The next section discusses the sensitive issue of locational privacy and the need to balance these rights and concerns with the benefits that can accrue from a people-based perspective. This article concludes with some examples of people-based science in a variety of application domains.

The Changing Nature of Place

SPACE–TIME CONVERGENCE

Space-time convergence describes the dramatic impact of space-adjusting technologies on the organization of human activities in geographic space (Janelle 1969). Transportation technologies literally bring places closer together with respect to the travel time required. For example, the time distance between Portland, Maine and San Diego, California, has shrunk from 2 years on foot in the 16th century CE (Common Era), 8 months on horseback in the 17th century, 4 months by stagecoach in the 19th century, 4 days by rail in the early 20th century, to 5 hours by airplane in the late 20th/early 21st centuries (Figure 1). If we use a walking speed of 4.8 km per hour as a metric, San Diego has 'moved' to a location only 24 km from Portland relative to the 16th century, meaning that the time-distance between the cities has shrunk by over 4023 km in 400 years (Lowe and Moryadas 1975). Similarly, the time-distance between London and Edinburgh shrunk at an average rate of 29.3 min per year over the period from 1650 to 1950 CE (Janelle 1969) while the time-distance from Boston to New York City converged at an average rate of 20.7 min per year between 1800 and 2000 CE (Janelle 2004). Space-time convergence operates at local scales: cities have shrunk with respect to time-distance as urban transportation technologies have progressed from walking, to horse-cars, electric streetcars and the automobile (Hartshorn 1992, Chapter 9).

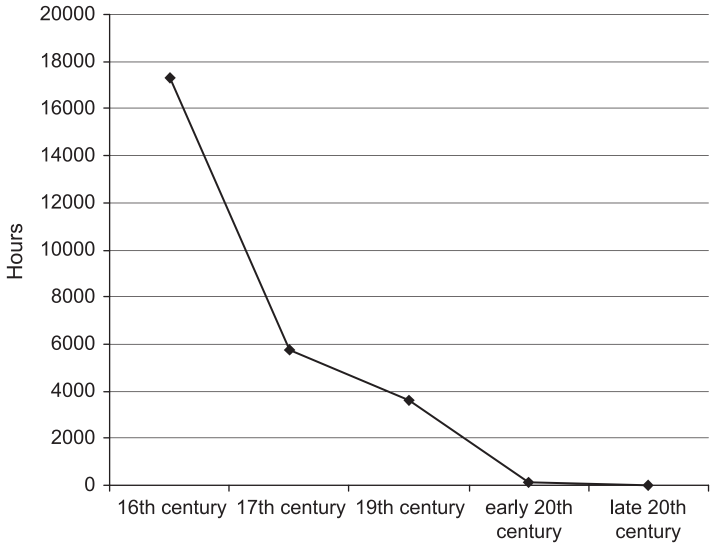

Fig. 1. Hours required to traverse North America (after Lowe and Moryadas 1975).

Transportation-induced space-time convergence has dramatically increased the mobility and spatial range of individuals, particularly in the latter half of the 20th and early 21st centuries as these technologies have become more accessible, flexible, and convivial. For example, at the end of the 17th century people in the Netherlands traveled on average only 40 km per year; today this is the average *daily* travel distance for citizens of that country (Bertolini and Dijst 2003). The trend toward greater mobility is increasing: data suggests that personal income and mobility increased in tandem in the late 20th century, with some regions such as the United States experiencing a doubling of vehicle-miles traveled between 1960 and 1990 while other regions such as China experiencing a ten-fold increase in mobility over the same period (Banister and Stead 2004; Schafer and Victor 1997). Other trends indicative of growing mobility are increasing commuting distances, the dramatic growth of non-work travel, and the increase in the diversity of activity and travel patterns (Bertolini and Dijst 2003; Hanson 2004; Nelson and Niles 2000). Mobility can also create countervailing effects to space-time convergence: as cities have become sprawled and congested it is possible for locations to become more distant with respect to travel time and experience space-time *divergence* (Janelle 2004).

Information and communication technologies (ICT) have also generated space-time convergence in a similar manner to transportation technologies. For example, Abler (1971) notes that a trans-continental phone call in the United States required 14 min to establish in the 1920s, 1 min in the 1950s and only 30 sec in the 1970s, implying a convergence rate of 16.2 sec per year (Lowe and Moryadas 1975). The increasing efficiency and

Table 1. Communication modes based on spatial and temporal constraints (Janelle 1995, 2004; Miller 2005b, 2007b).

		Spatial presence	Telepresence
Temporal	Synchronous	SP Face to face (F2F)	ST Telephone Instant messaging Television Radio Teleconferencing
	Asynchronous	AP Refrigerator notes Hospital charts	AT Mail Email Fax machines Printed media Webpages

spectrum of contemporary ICTs are creating more drastic convergence effects. Throughout much of human history, participating in an event meant that you were physically in a specific location at the specific time where and when the event occurred. ICTs are removing these spatial and temporal constraints on interaction by allowing participation through *telepresence* rather than physical presence.

Table 1 classifies communication modes based on their spatial and temporal constraints (Janelle 1995, 2004). *Synchronous presence* (SP) corresponds to face-to-face (F2F) interaction: this requires co-location in space and coincidence in time. *Asynchronous presence* (AP) requires co-location in space but not coincidence in time: examples include notes left on an office door. *Synchronous telepresence* (ST) requires only coincidence in time: telephones, radio, and instant messaging services allow individuals to communicate among different places but only at the same time. *Asynchronous telepresence* (AT) does not require co-location in space or coincidence in time: this includes printed media, email, text messages, and webpages (Miller 2005b). Many of our place-based artifacts and social organization can be traced to an historical reliance on SP interaction. Cities were created in part to facilitate F2F interaction; so were our transportation systems, stadiums, theaters, classrooms, and offices. More of our interactions are moving toward asynchronous and telepresent interaction. AT interaction is largely free of spatial and temporal constraints (Miller 2007b).

Transportation and ICTs are not independent: they have complex interrelationships that affect the demand and timing in both realms. ICTs can be a *substitute* for transportation; for example, online shopping or telecommuting can reduce the need to physically travel and conduct these activities at bookstores or offices. ICTs can also *complement* transportation: for example, the ability to email colleagues can lead to more physical meetings. Transportation and ICTs can also *modify* activities in either realm by changing the location and timing of activities without a net increase or decrease in their frequency. An example is better coordination with family and friends for social activities through email and mobile phones (Krizek and Johnson 2003; Mokhtarian 1990; Mokhtarian and Meenakshisundaram 1999). In addition, beyond these direct effects are indirect effects mitigated by societal context and the growth of new economic sectors (e.g., e-medicine) and applications (e.g., private transportation planning though online traffic reports and intelligent transportation systems) hardly imaginable in previous eras (Bannister and Stead 2004).

PLACE-BASED FALLACY

A *place-based fallacy* occurs when one incorrectly infers the attributes, activities, or experiences of people from places. In the past, when people, place, and activities were more tightly coupled due to the higher friction of distance, it was possible to infer the activities and characteristics of people from key locations such as their home or work locations. However, space-time convergence is creating more complex relationships between people, place, and activities, meaning that inferring the characteristic and activities of people from places is increasingly problematic. People can conduct more activities in more places, as well as more activities in a single place. Although people may share key places such as work and home locations, mobility and connectivity means that their lifestyles and daily experiences may be dramatically different. Mobility and connectivity are also making activities and places more fluid and dynamic.

Mobility and connectivity allow fragmentation of activities with respect to their location, timing and the manner in which they are conducted. Spatial fragmentation occurs because there is no longer a close connection between particular places and activities. For example, with resources such as a portable computer and an Internet access point, as well as sufficient mobility, a person can work at home, a coffee shop, a hotel room, an airport, or a public park. Consequently, there is no longer a privileged location for work; this activity is split among an indefinite number of locations. Temporal fragmentation allows greater flexibility with respect to the timing of activities. For example, work need not occur during traditional business hours, or shopping during designated trading hours. Finally, there is no longer a single way to conduct a given activity: a meeting can occur in person or via teleconferencing. The result is a historically unprecedented independence of activities from places, times, and modes (Couclelis 2000; Lenz and Nobis 2007).

The nature of personal time is also changing. The rise of industrialized societies created a subtle internalization of external time regulation and discipline through mechanisms such as clocks, work schedules, and trading hours. The availability of activities at more places and times is loosening the time regulation imposed by the industrial society. At an individual level, this manifests as shorter planning times for activities and decreasing time discipline with respect to meeting appointments. An example is 'flocking' behavior where individuals develop only vague social plans in advance and instead allow events, meeting times, and places to evolve in real-time through cells phones and texting (see Rheingold 2002). Another manifestation is the extension of formerly time-restricted activities into other time frames (e.g., working during evenings, weekends, or when traveling). At a societal level, we are seeing the withdrawal of rigid time schedules, the emergence of flexible work schedules (sometimes referred to as *flextime*), expanded operating hours for shops and other facilities, and increasing demand for 24/7 availability for both offline and online activities (Lenz and Nobis 2007).

Mobility, connectivity, and the fragmentation of activities also means that life experiences can vary widely, even among people who share key locations such as home or work. Although more research is required, there is compelling evidence that activity and interaction patterns vary widely with respect to gender role, age, and socio-economic status. For example, a sharp distinction exists between gender roles with respect to activity and travel patterns: women spend more time on household maintenance activities, resulting in more frequent and shorter trips and more complex trip chaining when traveling outside the house (see, for example, Gordon et al. 1989; Hanson and Hanson 1981; Kwan 1999; Lu and Pas 1999). Age differences with respect to the use of ICTs persist, with younger people more likely to use services as such texting and instant messaging for social interaction and the organization of social activities (CNN 2006; Rheingold 2002). Time-use data also suggests differences in the number of social contacts among gender roles and life-cycle stages (Harvey and Taylor 2000).

Places have a dynamic nature: there are diurnal and weekly patterns to the use of geographic space (e.g., Goodchild and Janelle 1984; Janelle and Goodchiild 1983). The increasing interactions among individuals in real-time afforded by ICTs may be accelerating these temporal patterns and making them more complex and less predictable. ICTs allow the rapid reallocation of people and the more intensive use of resources, speeding up the metabolism of cities. These changes are creating new challenges for research, policy, and planning. A hypercoordinated city creates the potential for positive feedback loops and nonlinear dynamics, meaning that the city becomes more complex and less predictable. Decentralization of control and coordination weakens the foundation of policy and planning because this is based on centralized control and coordination. The lack of one-to-one correspondences between activities, places, and times confounds the analyst's and planner's attempts to understand and organize human activities by place and time (Couclelis 2000; Gleick 1999; Miller 2007b; Townsend 2000; Zook et al. 2004).

THE DEATH OF DISTANCE?

While the effects of recent space-adjusting technologies are profound, it is important not to overstate the case. Although mobility and connectivity are making activities loosely coupled with respect to space, rumors of the death of distance are greatly exaggerated. Space-time convergence is not equal everywhere; indeed, it is very uneven, as are reactions to this convergence. In addition, although mobility and connectivity can fragment some activities, others remain firmly grounded in physical space.

In an address to the 1999 Environmental Systems Research Institute User Conference in San Diego, CA, USA, Waldo Tobler noted that the world is *shrinking but shriveling*. While most geographic locations are becoming closer on an absolute scale and in a synoptic sense, the relative differences in transportation costs are increasing due to factors such as congestion, varying abilities to pay for transportation services, a relative decline in public investment in transportation, the privatization and rationalization of some transportation networks, and the collapse of networks in some regions of the world. Extending this idea, we can also note that communications technologies are not universally distributed or accessible. The privatization of public telecommunications monopolies and the dismantling of regulatory regimes have led to a shift from universal and uniform to uneven and unequal communication services as private telecommunication firms concentrate resources on lucrative customers (Graham and Marvin 1996). Although communications technologies can liberate some activities from specific times and places, these technologies have a physical basis in fiber, routers, hubs, access points, and towers, and the geography of telecommunications infrastructure influences the geography of virtual activities (Gorman and Malecki 2002; Graham and Marvin 1996; Zook 2001). For example, although there is no longer a privileged location associated with work, one might be reluctant to upload a sensitive and large database in a public place with an insecure wireless network and multiple users competing for its limited bandwidth A persistent digital divide persists across social, income and ethnic and geographical dimensions: the majority of the world's 6 billion people will never have an email address (Castells 2001; Couclelis 1996). Finally, the relationships between activities in the real and virtual worlds are often mitigated by the cultural and social background of the individual. For example, in a study of cell phone usage in Brazil, de Souza e Silva (2007) found that low-income users appropriate the technology in unusual and surprising ways compared with the affluent users in developed countries traditionally considered by communication theorists and analysts. This includes using cell phones to receive calls but public landline phone to make calls due to the relative costs, leading to an asymmetry in the freeing of interpersonal interaction from spatial constraints. The shrinking but shriveling world is creating a complex geography of mobility, connectivity, and accessibility.

Increasingly, we exist in a hybrid world created by the intertwining of the physical world and the virtual world. However, it is the physical world ultimately trumps the virtual world (Couclelis 2007). While we can browse a vendor and order a new shirt in the virtual world, it must be manufactured, stored, shipped, and consumed in the real world. Although we can work in a coffee shop, the ingredients of the latté we enjoy were cultivated, processed, and shipped in the real world, and the employee who prepared it so nicely had to travel from home to the coffee shop to do so. Furthermore, the fact that we choose to work in a coffee shop rather than an office or home implies that the physical setting of work is still important even if it is nontraditional. Distance is not dead, but its significance and effects on geography are becoming more complex, subtle, and interesting (Couclelis 1996).

Rather than using places as a surrogate for people, people-based science focuses directly on the individual in space and time. A people-based perspective examines the individual, the activities that comprise her life, their distribution in space and time, the availability of resources to overcome spatial separation among activities, and the constraints imposed by required activities such as work. Using time as a common denominator, people-based science can accommodate activity fragmentation better than traditional place-based science. People-based models and analysis are also sensitive to differences in activity schedules and the availability of transportation and ICTs resources among different social groups, age cohorts, cultures, gender roles, and household organization (Couclelis 2000, Kwan and Weber 2003; Miller 2005c, 2007b). This does not replace the place-based perspective but rather extends it to encompass a more complete picture of peoples' use of places in both the physical and virtual worlds.

People-Based Science: Theories and Technologies

The theories and technologies for a people-based science have matured sufficiently such that it is poised for major advances. *Time geography* provides the conceptual and theoretical basis for analysis of individual activities in space and time (Hägerstrand 1970). Time geography has been available since the 1960s, and others have suggested its usefulness in extending the place-based perspective to incorporate the dynamic human processes through which places evolve (Pred 1984), as well as the connectivity afforded by telecommunications technologies (Falk and Abler 1980). However, recent developments in time-geographic theory and methods are greatly increasing its realism, relevance, and power.

Enabling technologies include location-aware technologies, mobile object databases, agent-based technologies, and spatio-temporal knowledge discovery. *Location-aware technologies* (LAT) provide the means for collecting data on activities in space and time, and *agent-based technologies* provide methods for simulating these data. *Mobile object databases* provide the means for storing and querying the spatio-temporal data in people-based science, while *spatio-temporal knowledge discovery* provides tools for understanding these voluminous and complex data.

CLASSICAL TIME GEOGRAPHY

Time geography is a constraints-oriented approach to understanding human activities in space and time: it highlights the necessary (but not sufficient) conditions for all human activities and interactions (Pred 1977). Time geography recognizes that human activities have spatial and temporal dimensions: activities occur at particular places for limited durations. Participating in activities requires allocating scarce available time, including time required for travel to or communication with the locations where the activities occur. Constraints on activity participation include the location and timing of some events such as home and work, the residual time budget outside these some events and the resources available for trading time for space in physical movement or virtual interaction (Hägerstrand 1970).

Hägerstrand (1970) identifies three major classes of constraints on human activities in space and time. *Capability constraints* limit the activities of individuals through their own physical capabilities and/or available resources. For example, individuals with private automobiles can generally travel faster through space than individuals who walk or rely on public transportation. *Coupling constraints* define where, when and for how long an individual has to join with other individuals for shared activities. *Authority constraints* are fiat restrictions over particular space-time domains. For example, a gated suburban community can impose more constraints than a traditional city neighborhood because private space can be more effectively restricted from occupancy during specific times and by individuals who are not residents or not performing services for residents.

Hägerstrand (1970) also classifies activities based on their fluidity. *Fixed* activities are those that cannot be easily rescheduled or relocated (e.g., work, meetings), while *flexible* activities can be more easily rescheduled and/or can occur at more than one location (e.g., shopping, recreation). Although these categories can be arbitrary, they provide an effective means for understanding how the location and timing of some activities condition accessibility to other activities. Fixed activities act as *space-time anchors* because other activities must occur at the temporal gaps between fixed activities.

Two central concepts in time geography are the space-time *path* and *prism*. Figure 2 illustrates a space-time path among activity locations or *stations* in two-dimensional space, with time represented by the z-axis orthogonal to the plane. The path is vertical when the individual is stationary at an activity location and becomes more horizontal when he or she is moving through space. The slope of the path is determined by the apparent movement velocity (i.e., the trade of time for space allowed

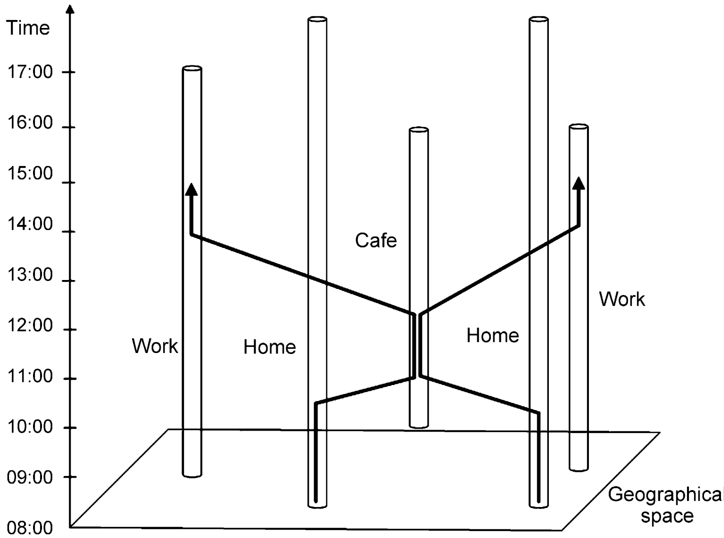

Fig. 2. Space-time paths and stations.

by the individual's transportation resources within that environment). Coupling constraints lead to *bundling* of the space-time paths of individuals, typically at stations. Cylinders represent the activity stations in Figure 2, with the length of each cylinder with respect to the z-axis indicating its availability in time. Note that the two paths are bundling at a café (Miller 2007b).

Figure 3 illustrates a space-time prism: this is a direct measure of a person's accessibility to the environment and activities. Fixed activities and coupling constraints anchor a space-time prism because by definition these allow only one spatial possibility during their duration. For example, the first anchor in Figure 3 could be the person home, while the second anchor could be their workplace. At some time during the time interval between when the home activity ends and the work activity begins, the person wishes to stop at some location to conduct an activity, say, meet a friend at a cafe. Given these anchoring activities and a maximum velocity of movement, we can construct the prism as the subset of locations in space and time that is available to the person. The region inside the prism comprises locations in space-time where an individual could be during that episode. An activity is not accessible to this person during this episode unless its location and duration intersects with the prism to a sufficient degree, with this determined by the minimum time required to conduct the activity. Similarly, two people cannot meet unless their prisms intersect to a sufficient degree. The projection of the prism to the two-dimensional plane is the *potential path area*: this comprises the region in geographic space where the person can be during that episode (Miller 2007b).

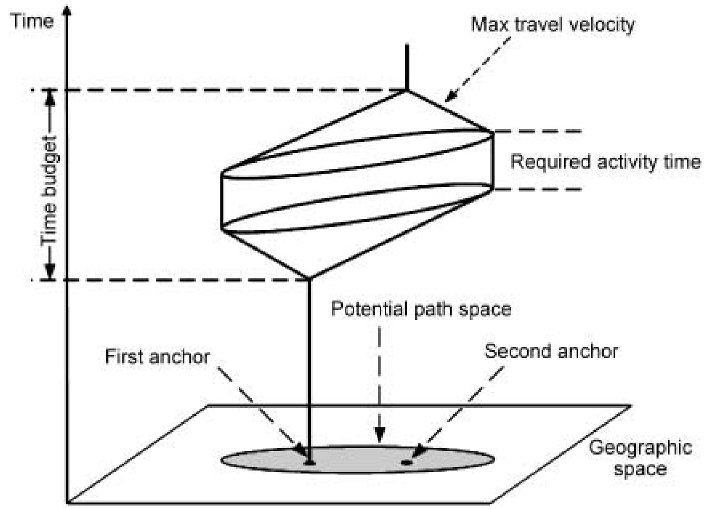

Fig. 3. A space-time prism.

THE NEW TIME GEOGRAPHY

Three major weaknesses of classical time geography limit its relevance to a mobile and connected world: (i) the *uniform travel velocity assumption*; (ii) a *lack of analytical rigor* that can support high-resolution measurement and analysis; and (iii) its *physical orientation* that neglects virtual activities and interactions. However, a new time geography is emerging that resolves these weaknesses and improves it as a foundation for a mature people-based science.

The assumption of a uniform travel velocity across time and space is at odds with a world where high mobility is creating a world that is shriveling as much as shrinking. The world is becoming increasingly crowded, particularly in urban areas, saturating transportation systems and creating substantial variations in travel velocities across space and time due to congestion. It is possible to relax the uniform velocity assumption by defining paths and prisms within transportation networks, capturing variations in travel velocities across network arcs (Miller 1991).

Figure 4 illustrates two *network time prism* products. The left half of the figure illustrates a *potential path tree* (PPT): this provides the reachable nodes in a transportation network given link-specific travel times, a time budget and anchor points (in this case, a single anchor point indicated by the disc). The right half of the figure provides a *potential network area* (PNA): this provides the reachable locations in a network regardless of whether they occur at nodes or within links. The PNA is more realistic than the PPT but requires additional computational effort. The PPT

Fig. 4. A potential path tree (left side) and potential network area (right side).

requires solving the shortest path tree based on the anchoring location. The PNA requires the network transformation method developed by Okabe and Kitamura (1996): this involves solving the shortest path tree from all nodes in the network and inserting new nodes corresponding to breakpoints or boundaries between shortest paths (see Miller 1999; Okabe and Kitamura 1996).

Extensions of the basic network time prism include informational constraints, multimodal networks, and dynamic networks. Kwan and Hong (1998) incorporate cognitive constraints into a network time prism through spatial overlay with georeferenced survey data indicating individuals' locational preferences and knowledge about the environment. Using time as a common denominator to integrate modes, O'Sullivan et al. (2000) estimate network time prisms based on a multimodal public transit network and walking to/from transit stops. A *dynamic network prism* is a space-time prism within a network with time-varying velocities. Wu and Miller (2000) calculate dynamic PPTs using dynamics such as those generated from a discrete time-dynamic flow model or traffic data captured at discrete intervals of time. Calculating NTP products within networks with continuous time dynamics is an open research issue.

A second weakness of classical time geography is a lack of a rigorous analytical foundation. Concepts such as the path and prism, and relationships such as bundling, path–prism intersections and prism–prism intersections, are described only informally. While this was sufficient in the past, the development and deployment of high-resolution measurement technologies such as LATs and simulation methods such as agent-based technologies (see below) expose this lack of rigor: classical time geography is not sufficiently developed to support measurement and analysis using these high-resolution technologies.

Attempts to improve the rigor of time-geographic analysis date back to the pioneering work of Lenntorp (1976) and Burns (1979). Lenntorp (1976) uses a simulation approach to measure space-time accessibility using the number of feasible activity schedules as a surrogate. This study includes analytical calculations of the prism volume and the PPA size for different cases. Burns (1979) uses analytical calculations of space-time prism properties under different scenarios and metrics to assess the impacts of transportation and temporal policies on accessibility. However, in both cases the analytical calculations are limited to specific properties (prism volume and PPA size): the prism itself cannot be derived nor it relationships with other prisms and paths.

General, analytical definitions of fundamental time-geographic concepts and relationships that can support high-resolution measurement are possible through disaggregation with respect to time. For example, at any instant t, the space-time prism defined by anchors $\mathbf{x}_i$, $\mathbf{x}_j$ with required presence at times t_i, t_j (respectively), maximum travel velocity v and stationary activity time a is:

$$Z_{ij}(t) = \{\mathbf{x} \mid f_i(t) \cap p_j(t) \cap g_{ij}\} \tag{1}$$

where:

$$f_i(t) = \{\mathbf{x} \mid \|\mathbf{x} - \mathbf{x}_i\| \leq (t - t_i)v\} \tag{2}$$

$$p_j(t) = \{\mathbf{x} \mid \|\mathbf{x}_j - \mathbf{x}\| \leq (t_j - t)v\} \tag{3}$$

$$g_{ij} = \{\mathbf{x} \mid \|\mathbf{x} - \mathbf{x}_i\| + \|\mathbf{x}_j - \mathbf{x}\| \leq (t_j - t_i - a)v\} \tag{4}$$

$f_i(t)$ is the *future disc*: the locations that can be reached by time t when leaving from $\mathbf{x}_i$ at time t_i. $p_j(t)$ is the *past disc*: these are the locations that can reach $\mathbf{x}_j$ by the remaining time $t_j - t$. These sets are 'discs' because they are compact spatial sets consisting of all locations within a fixed distance of a point. g_{ij} is the *geo-ellipse*: it constrains the prism locations to account for any stationary activity time a during the time interval. It is equivalent to the *potential path area* of classical time geography (Miller 2005a). Figure 5 illustrates the logical construction required to solve the prism at time t. Note that these definitions are not limited to the two-dimensional space of classical time geography: they are general for any dimensional space, although in time geography we are mainly interested in one dimension (networks), two dimensions (the plane), and three dimensions (natural space).

The future disc, past disc, and geo-ellipse are simple geometric entities in low-dimensional space: the future and past discs are lines in one spatial dimension, circles in two dimensions and spheres in three dimensions. The geo-ellipse is a line, ellipse and ellipsoid in one, two, and three spatial dimensions, respectively. Analytical solutions and tractable numeric

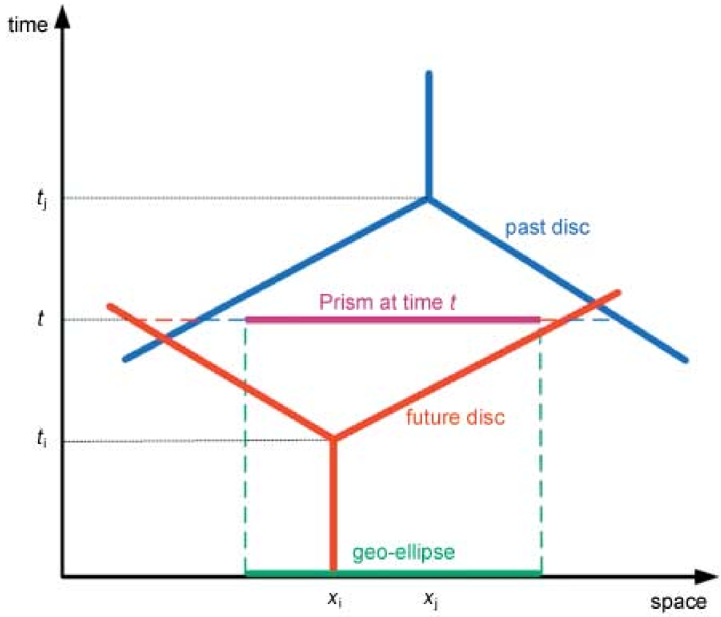

Fig. 5. Analytical definition of the prism at time t.

procedures are available for solving intersections among these objects. In addition, it is possible to solve for temporal subintervals of the prism's existence when some sets spatially encompass other sets, and therefore the latter sets can be ignored. Similarly, relationships such as bundling and intersections between paths and prisms at a given moment in time are also simple geometric problems easily measured and solved at high levels of resolution (Miller 2005a).

A third major weakness of classical time geography is a focus on physical movement and presence. Although classical time geography recognizes the possibility of virtual interaction (e.g., telephony), this is muted relative to travel and physical interaction. The Janelle communication modes in Table 1 provide a means for extending time geography to encompass virtual interaction. Yu (2006) conceptualizes the Janelle modes in Table 1, as spatial and temporal relationships between space-time paths and prisms. Using this as a foundation, he designs and implements GIS software for maintaining, querying, and analyzing data on space-time activities and accessibility in both physical and virtual realms. Figure 6 illustrates this approach for demarcating potential spatio-temporal interactions via the space-time prism. The gray areas in the prisms indicate places and times when each actor can access ICTs, while the hatched areas indicates places and times when physical or virtual interaction can occur.

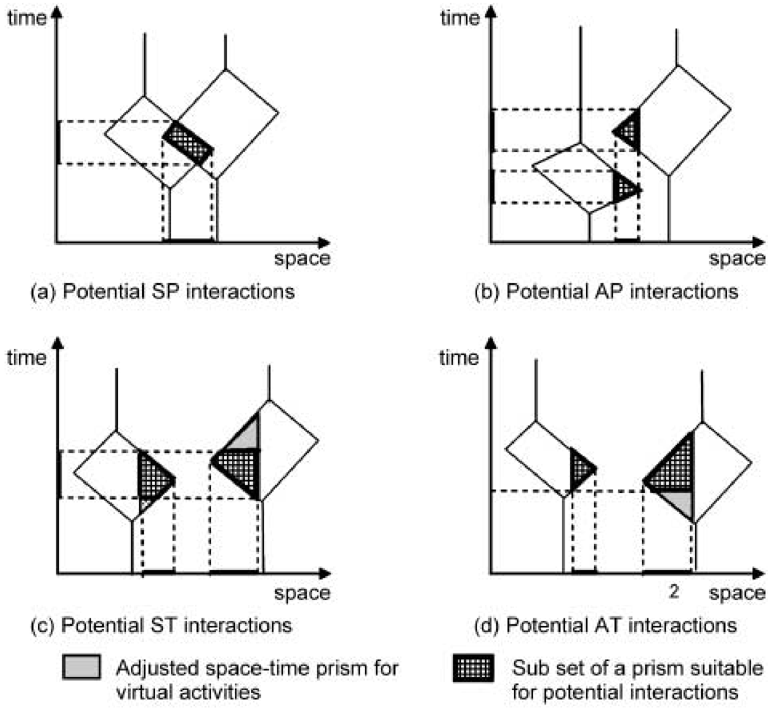

Fig. 6. Space-time prisms and potential spatial-temporal interactions (after Yu and Shaw 2007).

Another strategy for extending time geography to encompass virtual interaction is to introduce new communication objects and relationships and derive constraints using the analytical measurement theory discussed above. A *portal* is a type of space-time station where a person can access communication services. It includes an ICT point source, an access range and time intervals when the service is available. Portals correspond to real-world entities such as wired telephony and Internet connections, wireless access points, and cellular telephone base stations. Figure 7 illustrates two portals and a space-time path. An individual can access a communication service only if his or her paths or prism intersect with the service footprint of an appropriate portal.

Message windows are time intervals corresponding to potential or actual communication events. A *general message window* is a temporal interval when an individual could potentially send a message, while a *strict message window* is a temporal interval corresponding to an actual message. Because communication can be asymmetric, we also distinguish between *send* and *receive* message windows. Figure 8 illustrates general and strict message windows. Table 2 illustrates the type of questions we can ask with respect to pairings of general and strict message windows.

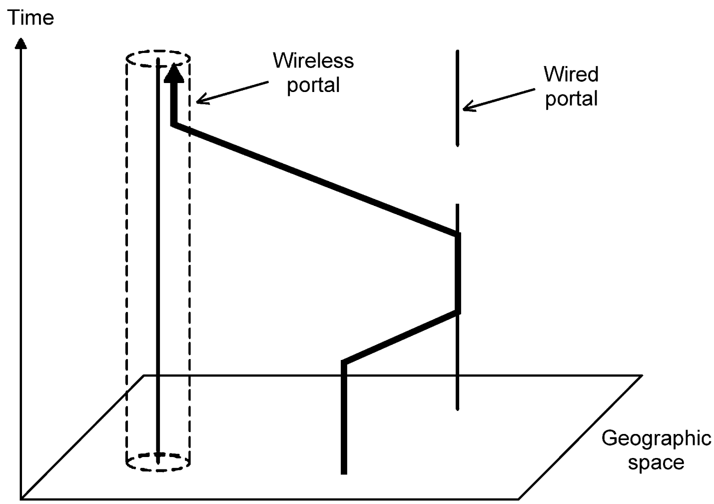

Fig. 7. A space-time path and portals.

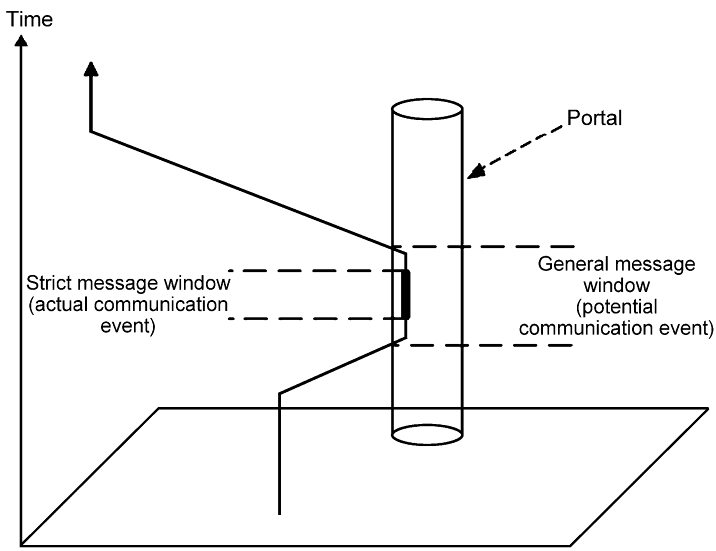

Fig. 8. General and strict message windows.

Using the new time-geographic objects of portal and message windows, it is possible to derive the spatial and temporal constraints on the telepresence interaction modes described in Table 1. Spatial constraints correspond to intersection of a path or prism with a portal, generating a message window. We can derive temporal constraints on message windows using the well-known Allen time predicates that encompass all possible

Table 2. Types of interactions between message windows (Miller 2005b).

	Receive	
Send	**General**	**Strict**
General	General spatio-temporal bounds on virtual interaction	Who could have sent a specific message?
Strict	Who could receive a specific message?	Process theory: actual message transmission

relationships between two intervals of time (Allen 1984). There are eight logical cases corresponding to pairings of general and strict message windows (Table 2), as well as synchronous versus asynchronous interactions (Table 1). For example, consider the case of a general send window and a strict receive window. The temporal constraints on these interactions are:

$$\text{(Synchronous interaction)} \quad t_i^s \leq t_k^r \wedge t_j^s \geq t_l^r \tag{5}$$

$$\text{(Asynchronous interaction)} \quad t_i^s < t_k^r \tag{6}$$

With the side conditions:

$$\begin{array}{ll} t_j^s - t_i^s \geq t_l^r - t_k^r, & t_j^s \leq t_k^r \\ t_k^r - t_i^s \geq t_l^r - t_k^r, & t_j^s > t_k^r \end{array} \tag{7}$$

where $t^s = [t_i^s, t_j^s]$ and $t^r = [t_k^r, t_l^r]$ are the time intervals corresponding to the send and receive windows, respectively. For synchronous interaction, the send window must begin at the same time or earlier and end at the same time or later than the sent message. This implies that the person sending the message must interact with a portal for at least as long as the received message. For asynchronous interaction, the send window must begin at any time before the message was received. The side conditions require the send window to be at least as large as the received message if they meet or are disjoint. If the windows overlap, the residual time in the send window prior to the message event must be at least as large as the message itself for the interaction to be feasible (i.e., to send the message, an agent must have interacted with a portal prior to its transmission for at least as long as the message itself). It is also possible to encompass message delays using a temporal offset, as well as constraints based on minimum times required to construct or transmit messages (Miller 2005b).

A remaining research issue in time geography is the nature of fixed activities in the new era of mobility and connectivity. As noted previously, activities and time attitudes are becoming more fragmented and fluid. Simple and binary concepts in classical time geography such as anchor points, activity schedules and the static boundary between accessibility and nonaccessibility implied by the prism cannot accommodate the fluidity of activities and constraints. Extending time geography to include fluid constraints is a valuable research topic (Forer et al. 2007).

LOCATION-AWARE TECHNOLOGIES

People-based science is data hungry. In addition to detailed representation of a geographic environment, required are data on activities in space and time at the individual level. The best traditional method for generating these data is the activity diary: this requires subjects to record activities either in a free-format manner or at predetermined time periods (Ettema et al. 1996; Pas and Harvey 1996). Nevertheless, this method has significant problems, in particular, the underreporting of short trips and the number of stops during multipurpose trips (Brog et al. 1982; Golledge and Zhou 2001; Purvis 1990).

Location-aware technologies (LAT) are devices that can report their geographic location in near-real time. These have potential to greatly reduce the cost and improve the accuracy of collecting space-time activity data (Greaves and Stopher 1998; Murakami and Wagner 1999; Stopher and Wilmot 2000). LATs typically exploit one or more georeferencing strategies. *Radiolocation methods* use wireless communication systems and determine location using methods such as those based on the time, time difference, or angle of the signals' arrivals at base stations from mobile clients. The *global positioning system* (GPS) exploits time differences of signals arriving from satellites in Earth orbit. *Interpolation methods* use distances and directions from a known location along a route to determine the current location. Other methods include acoustic, optical, and magnetic tracking (Grejner-Brzezinska 2004).

An emerging LAT is *radiofrequency identification* (RFID) tags. RFID tags are cheap and light devices attached to objects and transmit data to fixed readers using passive or active methods. Passive tags contain no power source and rely on the current generated by passing through the electromagnetic field from the reader, while active tags contain a power source to transmit the outgoing signal. Passive tags are cheaper, smaller, and lighter, but have a very limited range and expensive readers that cannot track multiple tags simultaneously. Active tags are heavier and more expensive, but have a longer range and cheaper readers than can track multiple tags simultaneously. RFID tags must self-identify to the reader because the reader conducts the location calculations; this implies that RFID systems have greater potential for surveillance and privacy violations (see Morville 2005). It is likely that RFID tags will become a central feature in the retailing industry due to potentials for real-time supply chain management. WalMart is requiring that all pallets and cases shipped to their distribution center be equipped with these tags (Roberti 2003). RFID tags also have applications beyond supply chain management; examples include automated toll collection, passports, airline baggage tracking, and VIP services in casinos and resorts. While these applications can allow for greater efficiency, security, and convenience, they raise the possibility of individual tracking through the products and services that individuals use and potential privacy violations (Eckfeldt 2005; McGinty 2004; Shih et al. 2005).

LATs enable *location-based services* (LBS). LBS provide targeted information to individuals based on their geographic location though wireless communication networks and devices such as portable computers, personal digital assistants, mobile phones, and in-vehicle navigation systems (Benson 2001). Information services include emergency response, navigation, friend-finding, traffic information, fleet management, local news, tourist information, and concierge services (Spiekermann 2004). LBS are widely expected to be the 'killer application' for wireless Internet devices: some predict worldwide deployment levels reaching 1 billion devices by 2010 (Bennahum 2001; Smyth 2001). LBS could be a very rich source of space-time activity data if issues regarding privacy and propriety can be resolved (Miller 2007b).

Another technology that can capture data on activities in space and time are *geosensor networks*. These are interconnected, communicating, and georeferenced computing devices that monitor a geographic environment. The geographic scales monitored can range from a single room to an entire city or ecosystem. The devices are typically heterogeneous, ranging from temperature and humidity sensors to video cameras and other imagery capture devices. Geosensor networks can also capture the evolution of the phenomenon or environment over time. Geosensor networks can provide fixed stations for tracking individual vehicles, identify traffic patterns and determine possible stops for a vehicle, as it traveles across a given domain in the absence of mobile technologies such as GPS or RFID (Stefanidis 2006; Stefanidis and Nittel 2004).

MICROSIMULATION AND AGENT-BASED TECHNOLOGIES

Microsimulation refers to the modeling and analysis of social phenomena at disaggregate levels to order to better understand outcomes at aggregate levels. This contrasts with modeling directly at the aggregate-level using governing equations or other structures that postulate artificial entities and relationships as surrogates for phenomena that emerge from individual actions and interactions. Microsimulation has a substantial tradition in social science, dating back to attempts to modeling the US economy in the 1950s (Clarke and Holm 1987).

Agent-based modeling (ABM) is technique closely related to microsimulation that has emerged from computer science. ABM uses software representations of agents to simulate the dynamics of complex systems through the behaviors and interactions of its individual agents. The agent perspective views systems as collections of autonomous, adaptive, and interacting agents. An *agent* is an independent unit that ties to fulfill a set of goals in a complex, dynamic environment. An agent is *autonomous* if its actions are independent (i.e., it makes decisions based on its sensory inputs and goals without an external controlling mechanism). An agent is *adaptive* if its behavior can improve over time through a learning process. Agents interact by exchanging physical or virtual (informational) resources (Maes 1995). Agents can represent people, households, animals, firms, organizations, regions, countries, and so on, depending on the scale of the analysis and the elemental units hypothesized for that scale. The increasing availability of high-resolution data and GIS tools for handling these data facilitate ABM in geographic research (Benenson and Torrens 2004). Applications of ABM include economics (Epstein 1999), environmental management (Gimblett et al. 2002; Hare and Deadman 2004) land-use/land-cover change (Parker et al. 2003), societies and culture (Epstein and Axell 1996), transportation (Balmer et al. 2004), and human movement at micoscales (Batty et al. 2003).

The convergence of microsimulation, ABM, and time geography can offer complementary strengths for analyzing and understanding human phenomena. Microsimulation offers a tradition of computational approaches to understanding how microlevel behavior creates dynamic human phenomena, as well as standards for model estimation and validation. However, microsimulation models typically represent human behavior in a quasi-aggregate and isolated manner because behaviors manifest from cohorts rather than individual actions, interactions among humans, and interactions between humans and the environment. In time geography, interactions among humans and with the environment are fundamental, but linkages between individual behaviors and aggregate social and environmental dynamics are only conceptual in nature. ABM offers a rigorous but rich approach to simulating human phenomena from the bottom-up, as well as the concepts of adaptation, self-organization, and emergence to capture linkages between individual behavior and aggregate dynamics. ABM can benefit from time geography's precise statement of the necessary conditions for human actions and interactions, as well as microsimulation's adherence to estimation and validation standards (Boman and Holm 2004).

MOBILE OBJECTS DATABASES

Mobile objects databases (MOD) store data about entities that can change their geometry continuously, include changes in location, sizes and shapes. Existing database management systems (DBMS), even spatio-temporal DBMS, are not well equipped to handle data on mobile objects. Specifically, they are not well equipped to handle the following capabilities (Wolfson et al. 1998):

- *Location modeling*. Existing DBMS cannot handle continuously changing data such as the location of moving objects. In DBMS, data are assumed to be constant unless it is *explicitly* modified. Using standard database update techniques to explicitly update the geometry of a moving object would be computationally expensive. But unless this is done on a very frequent basis, the answers to queries about continuously changing objects would be out of date very quickly. One method is to update the database only when the object has moved to a sufficient degree, with this threshold determined by a user-specified error tolerance (Moreira et al. 1999).
- *Query languages*. Traditional query languages such as structured query language are not well-equipped to handle the spatio-temporal queries required by an MOD. These include: 'Retrieve all objects that will intersect a polygon within the next 3 minutes.' 'Retrieve all objects that will come within 1 mile of each other and the time when this will occur.' An example of an MOD and query language is the *moving objects spatio-temporal* data model (Sistla et al. 1998).
- *Uncertainty/imprecision*. Although the geometry of a moving object is changing continuously, digital technology for recording these geometries (such as a GPS tracking a vehicle), as well as digital technologies for storing these data (such as computer-based DBMS) has finite resolution: it can only record and store position at finite intervals. In addition, each one of these positions will have a degree of imprecision. Therefore, the position of an object at any given moment in time will have a degree of uncertainty due to the finite nature of digital technology and the imprecision of position fixing. Methods for dealing with uncertainty including determining upper and lower bounds on object position (Sistla et al. 1998), calculating an error ellipse (Pfoser and Jensen 1999) and statistical line fitting (Moreira et al. 1999).

In addition to storing data and supporting queries on movement in space with respect to time, people-based science must also store and query data on people's activities. Wang and Cheng (2001) describe a relational database design that accommodates transportation events and activities. Their data model enforces space-time constraints among activity and travel locations and timings and can also maintain data on activity interactions and organization within a household unit. However, their data model does not support a full range of temporal operators, and the relational design does not capture the semantic richness of their conceptual model, particularly with respect to decision-making, planning, and scheduling. Frihida et al. (2002) design an object-oriented database with a fuller range of temporal operators and less mismatch between the semantic richness at the conceptual level and the logical implementation. Frihida et al. (2004) extend this model for constructing and querying the space-time paths.

SPATIO-TEMPORAL KNOWLEDGE DISCOVERY

A difficulty with analysis of human activities in space and time is the combinatorial explosion of the information space. Decisions such as the number, sequencing, timing of activities, mode, and route choice are interlinked, implying an information space that is exponential with respect to choice dimensions (Ben-Akiva and Bowman 1998). Traditional methods such as statistical techniques or utility maximizing models can only explore a very small subset of the complex and vast information space of space-time activities in geographic and virtual space.

Knowledge discovery from databases (KDD) is an interdisciplinary field that attempts to leverage the enormous amount of data being collected and stored in databases and data repositories. Although better known as 'data mining', this activity is only one component of a human centered process of extracting information through exploratory analysis of massive digital databases and distilling this information into useful knowledge. *Geographic knowledge discovery* (GKD) is a specialized subfield of KDD that exploits the particular nature of georeferenced data such as the properties of spatial dependency and spatial hetereogeneity, spatial relationships such as distance, least cost paths, direction and connectivity, the morphology of spatial entities, and the diverse nature of digital geographic databases (Miller and Han 2001). *Spatio-temporal knowledge discovery* (STKD) is a specialized subfield of GKD that attempts to leverage spatio-temporal databases. In all three domains, there is a postulate that hidden in massive databases are 'interesting' (surprising, nontrivial, useful, understandable) patterns that cannot be discovered by traditional techniques that require a priori hypotheses, have difficulty with noisy, monitored (as opposed to sampled) data, and are not computationally scalable.

New techniques for knowledge discovery with spatio-temporal data are emerging, including techniques for exploring mobile objects data. For example, Laube et al. (2005) develop primitives for describing and representing individual and group motion patterns in point objects and implement pattern matching software based on these primitives for exploring mobile objects data. While this is useful, a critical need is STKD methodology that can encompass data on movements, as well as the activities associated with the mobile objects. Also required are techniques that can encompass interactions and activities in virtual space, as well as geographic space.

Also emerging are visualization techniques for space-time paths and prisms. Although promising, applications are limited to a relatively small number of paths over a limited time span (such as 1 day) relative to a simple map view of geographic space (e.g., Kwan 2000). Although results have been illuminating and promising, required are capabilities for visually summarizing and exploring thousands of paths over multiple time scales within multiple linked views of geographic and attribute space. Kraak

(2003) develops a space-time cube approach that allows flexible visualization of space-time paths in different types of spaces, as well as the ability to 'drill down' into the data through querying.

Scalable techniques for massive space-time activity databases can exploit the inherent parallelism in these data. Space-time activity can be decomposed into parallel computations based on the algorithmic tasks performed and/ or data parallelism (the latter with respect to space, time, or space-time). Emerging computational techniques such as those based on grid-computing architectures has promise to extract information from these databases (see Armstrong et al. 2005).

Locational Privacy

Movements and activities in geographic and cyberspace space are a signature that reveals much about an individual. At the extreme, *geoslavery* can emerge where dominant individuals or entities monitor and exert implicit or explicit control over the location and activities of other individuals (Dobson and Fisher 2003). Concerns about the negative use of locational data are legitimate, and there is a need to balance these potential abuses against the individual and societal benefits that can accrue from more sensitive understanding of human phenomena and its variety at the individual level. *Locational privacy* is an emerging concept that suggests individuals have rights to their signature in space and time and can determine when, how, and to what extent location information is communicated to others (Armstrong 2002; Armstrong et al. 1999; Duckham et al. 2006). Techniques are emerging for preserving locational privacy, while ensuring these data are available for beneficial purposes such as basic and applied research, as well as LBS.

Strategies for protecting locational privacy include *regulation*, *privacy policies*, *anonymity*, and *obfuscation* (Duckham et al. 2006). Regulation and privacy policies are trust-based mechanisms for defining unacceptable uses of location information. However, trust can be broken, making these strategies vulnerable to unintentional and intentional disclosure. Anonymity detaches locational information from an individual's identity. However, GIS can integrate locational information with other data such as remotely sensed imagery, georeferenced social, economic and cadastral data, point-of-sale data, credit card transactions, traffic monitoring and video surveillance imagery, and other geosensor network data, allowing identity to be inferred (see Monmonier 2002). Obfuscation techniques deliberately degrade locational information, using error and uncertainty to protect privacy. Obfuscation techniques include *geographic masking* for static data (Armstrong et al. 1999). Duckham et al. (2006) extend the obfuscation approach to mobile objects. They also consider ways to counter potential threats from third parties who can refine their knowledge of a mobile object and compromise the obfuscation.

Conclusion

Geographic information science and GIS are greatly enhancing the ability to perform analysis based on geographic location. While a place-based perspective is viable and valuable, transportation and communication technologies are dramatically changing the relationships between people and place by creating space-time convergence and the fragmentation of activities across space and time. This article argues that the place-based perspective in geographic information science should be extended to include a people-based perspective that focuses on individuals in space and time and their allocation of activities in the physical and virtual worlds. A people-based perspective builds on classical time geography through contemporary enhancements in calculating its entities and relationships within transportation networks, at high levels of resolution and in virtual space. Similarly, recent advances in geospatial technologies and science such as location-aware technologies, agent-based simulation, mobile objects databases, and spatio-temporal knowledge discovery can also advance a people-based perspective in a wide spectrum of application domains. Basic and scientific advancements must be balanced against locational privacy concerns: methods must be developed to protect individual privacy while allowing the use of these data for the good of society and the individual.

A people-based science has great potential for generating new insights to human phenomena and solutions to vexing societal problems. Although still in a formative stage, a nascent people-based approach can be discerned in a wide spectrum of the human sciences. This article concludes with a brief discussion of the progress and possibilities of a people-based perspective across several domains.

- *Transportation planning*. Transportation planning in the United States and elsewhere is traditionally based on aggregate, place-based forecasting methods that view travel demands as functions of place and space, not people. Consequently, these methods cannot easily handle the increasing use of communication technologies and their complex interactions with travel behavior. In addition, these methods can only suggest transportation solutions for problems, when other solutions (such as flextime or extending facility operating hours) may be more effective. Fortunately, new methods are emerging for analyzing human activities in space and time (Timmermans et al. 2002), and many transportation departments and metropolitan-planning organizations are collecting space-time data using GPS and other LATs. However, it is still challenging to incorporate these data and methods into a planning process that often demands realistically obtainable goals and unequivocal estimates that can fit within cost-benefit analyses.
- *Emergency evacuation*. Emergencies evacuations of neighborhoods and cities are a special type of travel demand that occurs in a compressed

time frame and under duress. Similar to transportation planning, most evacuation plans are based on aggregate methods that focus on the transportation dimensions of the problem. However, evacuation events can be radically different depending on the time of day and day of the week when the emergency occurs: for example, a neighborhood is more populated at 2 a.m. than it is at 2 p.m. Similarly, individual level behaviors such as delays in departing can make substantial differences in the efficiency and speed of the evacuation event. Cova and Johnson (2002) have pioneered a microlevel, people-based approach to simulating evacuation events that can address these issues.

- *Epidemiology and environmental risk assessment*. Most models of infectious disease spread assume a simplistic, 'equal mixing' process where all members of a population are equally likely to interact and therefore spread an agent. However, although people are more mobile than in the past their movements are not random, and highly but selectively mobile individuals substantially affect the spread of disease over space and time. Similarly, assessing exposure to risk agents and vectors in an environment based only on home or work locations is incomplete if people spend much of their time in other, often widely disparate, locations (Jacquez 2000; Jacquez et al. 2005; Löytönen 1998).
- *Urban theory and models*. As noted previously in this article, the place-based orientation of traditional urban theories and models are problematic if people and activities are becoming less tightly coupled with space. Time is also an issue. As Wegener (1994) points out, one of the challenges in urban modeling is the complex superposition of dynamical processes that operate over different time frames, including slowly changing, spatially fixed entities (such as land use and networks), medium time dynamics such as employment and residential locations, and mobile entities that change their state in real time (such as people and goods). The emergence of a highly dynamic, fluid, and hypercoordinated city makes the handling of this dynamical superposition even more challenging for place-based theories and models with 'lock-step' temporal dynamics. A more appropriate modeling strategy is one that encompasses both spatially fixed and mobile entities with flexible handling of time, allowing collective dynamics to emerge from heterogeneous dynamics at the individual level (Benenson and Torrens 2004).
- *Facility location and scheduling*. Most facility location methods only consider the accessibility of the proposed service to places such as home and work. This can lead to misleading and inappropriate solutions. For example, a medical facility located nearby a person's home is useless if its operating hours do not correspond to the times when that person is home. Sensitive facility planning requires the combined location and timing of facilities with respect to individuals' activity patterns and plans.
- *Social networks and community*. Social benefits or capital accrue from a person's embeddedness within a network of interpersonal relationships

and connections. These relations provide immediate social and psychological benefits, the potential for learning about job and other opportunities, as well as a pool of resources (see Grieco 1995). While the structure of these networks is well studied, less well understood is when and where these networks form. Traditionally, these networks form at key locations such as home and work, as well as public forums such as the town square or High Street. However, mobility and connectivity mean that social networks can be more geographically disparate, heterogeneous, and fluid. This raises questions about the nature and quality of these emerging networks, as well as their effects on social capital and community. It also raises questions about how to design and plan communities and settings (in both the physical and virtual worlds) to replace the traditional foci for social network formation.

- *Social exclusion*. Social exclusion refers to the relative disadvantage that some members of society experience with respect to the resources, opportunities, and life experiences expected in a given society. This is typically measured at the neighborhood-level using attributes such as income levels, unemployment, health deprivation, educational attainment, and access to services and opportunities. However, place-based manifestations of social exclusion are epiphenomena that emerge from individual-level dynamic life trajectories operating within a given socio-spatial context. Social exclusion is about places and people over time: it happens to specific individuals at particular moments in time, and the interactions of these trajectories manifest as complex social and spatial dynamics such as increasing segregation, declining neighborhoods, unemployment, and rising crime (Byrne 1999; Miller 2007a). For example, the process of gentrification may look positive from a place-based perspective but less so from a people-based perspective that considers the displacement of vulnerable populations and the disruption of community ties (National Research Council 2001).

Short Biography

Harvey J. Miller is Professor and Chair of the Department of Geography at the University of Utah. His research and teaching interests include geographic information systems, spatial analysis, and geocomputational techniques applied to understanding how transportation and communication technologies shape individual lives and urban morphology. He is specifically interested in *time geography*; this examines individuals' allocation of time among activities in space and its implications for individual and collective spatial dynamics. Since 1989, he has published approximately 40 papers in journals, books, and conference proceedings on these topics. He is author (with Shih-Lung Shaw) of the *Geographic Information Systems for Transportation: Principles and Applications* (Oxford University

Press) and editor (with Jiawei Han) of *Geographic Data Mining and Knowledge Discovery* (Taylor and Francis) and *Societies and Cities in the Age of Instant Access* (Springer). Harvey serves on the editorial boards of *Geographical Analysis*, *International Journal of Geographical Information Science, Journal of Regional Science, Transportation* and the *URISA Journal.* He was the North American Editor of *International Journal of Geographical Information Science* from 2000 to 2004. Harvey was also a Councilor-at-Large of the North American Regional Science Council (2000–2003), a member of the Board of Directors of the University Consortium for Geographic Information Science (2000–2003), and Chair of the Spatial Analysis and Modeling specialty group of the Association of American Geographers (1998–2000). Harvey is also active in several US National Academies committees, including membership in the National Research Council policy committees addressing 'Spatial information infrastructure for multimodal transportation systems' (2001–2003) and 'Identifying data needs for place-based decision making' (2000–2002) and the Transportation Research Board committees on Geographic Information Science and Applications (2002–present) and Visualization in Transportation (2003–present). In 2005–2008, he is serving as co-Chair of the Transportation Research Board Committee on Geographic Information Science and Applications.

Note

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