SPECIALIST MEETING ON LOCATION-BASED SERVICES

Jointly sponsored by the Center for Spatially Integrated Social Science, and the University Consortium for Geographic Information Science

Upham Hotel, Santa Barbara
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FINAL REPORT

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Introduction

Background

The Global Positioning System and cellular technologies are enabling a new generation of mobile electronic devices that are capable of measuring their position on the Earth's surface, and of modifying the information they collect and present based on that knowledge. The Wireless Communication and Public Safety Act of 1999 permits operators of cellular networks to release the geographic locations of users in certain emergency situations, and a range of electronic services are now being developed and offered to assist users in finding nearby businesses and other facilities. A location-based service (LBS) can be defined as an information service that exploits the ability of technology to know where it is, and to modify the information it presents accordingly. LBS technology is inherently distributed, mobile, and potentially ubiquitous. Its services can augment the information provided directly to observers through the normal human senses, by allowing them to access information in databases that represents what cannot be sensed, either because it is beyond the reach of the senses, or was true in the past; or might be true in the future. Its services can also allow data to be analyzed as they are collected, in a progressive construction of knowledge. The Open GIS Consortium (http://www.opengis.org/) has begun a number of initiatives related to technical specifications for LBS, and there are comparable efforts in Europe and in international standards organizations.

In December, 2001 the Center for Spatially Integrated Social Science (CSISS; http://csiss.org) and the University Consortium for Geographic Information Science (UCGIS; http://www.ucgis.org) held a specialist meeting to explore these new services, and their implications and significance for the social sciences and for geographic information science. There are a number of reasons for believing that LBS will have significant impact on the social sciences, stemming from three basic arguments. First, LBS today represents only the beginning of a series of technological innovations that can potentially impact society in numerous ways, ranging from surveillance and the invasion of personal privacy, to technologically induced changes in human spatial behavior, the role of location in social networks, and the spatial structuring of retail and other services. Second, LBS has the potential to provide novel sources of data to social science, including detailed information about daily activities and their locations. Third, LBS technology has the potential to allow researchers to access databases, and conduct sophisticated analysis of data, while located in the field, and immediately following acquisition of data. As such, it may eventually revolutionize social science fieldwork.

CSISS is funded by the National Science Foundation as an investment in the infrastructure of social science research. Its specific objectives are:

- To encourage and expand applications of new geographic information technologies and newly available geographically referenced data in the social sciences.

- To introduce the next generation of scholars to this integrated approach to social science research.
- To foster collaborative interdisciplinary networks that address core issues in the social sciences using this approach.
- To develop a successful clearinghouse for the tools, case studies, educational opportunities, and other resources needed by this approach.

CSISS sponsors specialist meetings to identify the infrastructure investments needed to facilitate research on major and emerging themes in social science research. Thus its interest in a specialist meeting on LBS is two-fold: to explore a new geographic information technology, and its potential for the social sciences; and to identify the types of research infrastructure that would assist social science researchers to become engaged in LBS-based research.

UCGIS is a consortium of academic institutions, government agencies, and affiliated corporations interested in research and education in geographic information science; that is, in the fundamental issues surrounding the development and use of geographic information technologies. Its published research agenda includes a focus on distributed and mobile systems, and covers many of the issues addressed in this specialist meeting.

The meeting followed the format developed by the National Center for Geographic Information and Analysis (NCGIA; http://www.ncgia.org/) beginning in 1988, and successfully implemented now in over 30 meetings. Specialist meetings are designed to build a community of scholars interested in research in an emerging topic; to determine the state of scientific knowledge about the topic; and to develop and publish a research agenda, including short-term and long-term projects, that will address outstanding and researchable problems.

Specific issues addressed at the LBS specialist meeting included:

- the use of LBS to support primary data capture in the social sciences, with emphasis on spatial and temporal components;
- requirements for new representations, and for analytic tools to visualize and investigate such data;
- privacy and related issues associated with LBS data;
- new forms of social behavior enabled by LBS;
- new technologies that extend current concepts of LBS;
- needs for learning materials, examples, and other resources that can help to facilitate social-science research related to LBS;
- the use of LBS-derived data for modeling in the social sciences.

The specialist meeting was held December 14–15, 2001 at the Upham Hotel in Santa Barbara, CA. The process used to plan for the meeting and to select participants followed established NCGIA practice, and included:

1. Formation of a steering committee, consisting of researchers already working in

the field with established reputations, and including a cross-section of specialists in the subtopics of the meeting.

2. Issuance of an open call for participation, distributed electronically and through printed media such as society newsletters. Respondents were asked to submit a short resumé, and a short paper providing a personal perspective on one or more of the issues that formed the agenda of the meeting.
3. Selection of successful respondents to the open call, and issuance of invitations to additional individuals. Both groups were selected on the basis of their research interests, and their ability to provide appropriate regional, disciplinary, ethnic, or gender diversity.

The selected participants, their affiliations, and their position papers are available on the CSISS web site at http://www.csiss.org/events/meetings/location-based/participants.htm.

Agenda

Following NCGIA practice, the meeting agenda consisted of a mix of plenary presentations, plenary discussion, and small group discussion. The two-day meeting was divided into five sections: an introduction, including short statements by each participant; three cycles of presentation and discussion; and a closing session. To structure the discussion, three themes were identified for the three cycles:

1. The scope of LBS and its significance for the social sciences.
2. The social implications of LBS.
3. The technology of LBS.

The speakers invited to address each of these topics in an initial plenary presentation were Jonathan Raper, Professor of Geographic Information Science in the School of Informatics at City University in London; Michael Curry, Professor of Geography at the University of California, Los Angeles; and Jon Spinney of Environmental Systems Research Institute (ESRI), Redlands, CA.

During the lunch break on the second day of the workshop a number of demonstrations were given of LBS technology. Keith Clarke demonstrated the wearable technology being featured in Project Battuta at UCSB (http://dg.statlab.iastate.edu/dg/). Such tools have the potential to revolutionize field work, by making it possible to analyze data as they are being collected, and to download and upload data using wireless links—in essence, to perform all of the functions of desktop information technology in the field. ESRI demonstrated ArcPad 5.1, the latest version of its field GIS. Hanan Samet demonstrated his spatial browser, and MeiPo Kwan showed some of the results of her analysis of the Portland, OR tracking data.

This report follows the meeting's structure in summarizing the presentations and discussion in three sections, and ends with a summary of the closing discussion and meeting conclusions.

The scope of LBS

Theoretical frameworks

Several established theoretical frameworks might frame research in LBS, though to date no specifically relevant theory has been proposed. Hägerstrand (1970) is widely acknowledged to be the originator of modern interest in the tracks of people through space and time, and the processes and constraints that govern such tracks. LBS can provide abundant *tracking* data on the daily movements of people, and is already widely used in ecology to track the behavior of animals. Tracking data normally consists of a sequence of tuples $\langle x,y,t \rangle$ ordered by t, indicating the location (x,y) of the moving object at intervals of time denoted by t.

Another established theoretical framework is represented by classical location theory, and the work of Christaller, Lösch, and Weber, among others. Such theories address the locational choices made by individuals or groups, and the economic and social bases for these choices. Location theory can provide a framework for understanding the locations chosen for servers, LBS devices, clients, and other components of computing networks; and the locations chosen for the human intelligence that makes use of such components. (Goodchild, 2001).

Spatial choice models might provide a third theoretical framework. Such models deal with the impacts of distance on interactions of various kinds, from telephone traffic to migration and commuting. LBS has the potential to alter the impact of distance, and to generate behaviors consistent with new kinds of distances more reflective of impediments to social interaction.

A final theoretical framework is provided by geographic information science, and the topics contained within the research agenda of UCGIS (UCGIS, 1996; http://www.ucgis.org/). They include theories of the representation of space and time (Peuquet, 2002), theories of human–computer interaction and its cognitive dimensions, and many other relevant topics.

Plenary presentation

Jonathan Raper opened the discussion of the scope of LBS for the social sciences in a comprehensive presentation. He began by noting that LBS requires two types of location: the current (or recent) location of the device, and the locations of relevant features that form the basis of the service: locations of points (*e.g.*, restaurants), lines (*e.g.*, roads, or the tracks of other users), or areas (*e.g.*, parks, beaches). The second class is already well understood and exploited in many conventional GIS services; it is the ability to know the first that provides the impetus to LBS, because conventional devices such as desktops and laptops have no way of knowing where they are.

The most abundant LBS device is the cellular or mobile phone, and Jonathan presented recent statistics on its adoption. The rate of increase has been softening somewhat in Europe, North America, and Japan, but continues to accelerate in China. In mid-2000 there were roughly 250 million users in Europe, 100 million in the U.S., and 60 million in Japan. The rates of adoption reflect different regional policies: in Europe, rapid adoption has been facilitated by government sponsorship of uniform standards and seamless service.

There is currently substantial convergence between different portable technologies, including cellphones, personal digital assistants (PDAs), laptops, palm computers, and tablets. Through time it is expected that an integrated technology will evolve that offers a range of services through a single personal device.

Jonathan Raper saw four social implications of these technological developments, and divided the remainder of his presentation into four parts. First, LBS will lead to the ***commodification of location***, as locational information acquires value and is available to be traded and exchanged. Location is already an important component in the algorithms used to charge users for cellular service. Carriers might pass locational information to organizations as part of a location-based subscription service purchased by the customer, who would in return receive information related to current location, such as the state of congestion on nearby roads. Customers might purchase services that alert them when certain locational conditions exist, such as the locations of pets or children. A number of providers are developing or already offering such services, and related standards are being developed and promoted through such organizations as the Location Interoperability Forum and the Open GIS Consortium.

The Wireless Communication and Public Safety Act of 1999 in the US defines conditions under which network operators can release locations to emergency services, and other legislative frameworks are likely to appear to govern other uses of locational information. In the UK the Regulation of Investigatory Powers Act of 2001 can require recovery of locational information for intelligence purposes. Despite these initiative, however, there remains much uncertainty surrounding the use of locational information, and many outstanding questions:

- Is there adequate regulatory protection for the use of location in traffic data? Who has access to the location? How long should it be kept for? What geographic resolution is available?
- What contractual provisions exist for location? Is there a model contract? Where can location information be transferred for processing?
- Do users have control over their locational information?

The second of the four issues is ***privacy***, a concept that relates to individuals, and their desire to guard against intrusion, appropriation, or breach of confidence. Article 8 of the European Charter of Human Rights asserts that:

- "Everyone has the right to respect for his private and family life, his home and his correspondence.
- There shall be no interference by a public authority with the exercise of this right except ... in accordance with the law and (as) is necessary in a democratic society."

Privacy in the context of information implies a right to fair processing (as protected by the UK Data Protection Act of 1998, for example), the right to private communication (as protected by the UK Human Rights Act of 1998, for example), the right of authentication, and the right of anonymity. These rights also carry responsibilities: to participate in society (*e.g.*, to register for elections), to follow rules of etiquette in communication, and to avoid impersonation.

Few people seem to be aware of the full implications of today's information society, and the vast information resources that are commonly available about individuals. In an article in 1999 the *Economist* proposed the following guidelines for those wishing to remain unrecorded:

> "They are always watching you. Use cash. Do not give your phone number, social security number or address. Do not fill in questionnaires. Demand that credit firms remove you from marketing lists. Check your medical records often. Keep your telephone number unlisted. Never leave your mobile phone on. Do not use credit or discount cards. If you must use the Internet, use someone else's computer. Assume that all calls, voice mail, email and computer use are monitored." (*Economist*, May 1, 1999)

At present no legislation exists dealing explicitly with locational privacy. An article in *GeoEurope* in January 2001 argued that two types of identity should be recognized: a *private persona* that is absolutely protected, and a *public persona* that can be traded by consent, but that is disconnected from the private persona.

Jonathan Raper's third issue is ***locational profiling***, including tracking of the user, and characteristics associated with the track, such as speed of movement, positional accuracy, and the relevance of information to the user. For example, the information needs of a user traveling in a car are very different from those of a pedestrian. A number of examples of tracks were shown, collected from individuals over various periods of time, during normal working days, and during vacations. It is possible to analyze tracks, to obtain estimates of speed, or to make inferences about activities based on the speed and geometric nature of the track, or to transform them into density surfaces, although at this point we have little understanding of what is possible, or what can be learned that is of interest to social scientists.

The fourth issue concerns the ***social use of location***. The pricing structure of cellphones has encouraged very heavy use by those under 30, and for largely social purposes. For example, the Short Message Service (SMS) is being heavily used to exchange information about location, and to facilitate meeting or finding friends. Mobile devices are capable of supporting virtual communities that interact regularly but never meet; and of encouraging *flocking* or *swarming* behavior among social groups. "At the University of St Andrews, royal hottie Prince William can't even go out for drinks with friends without being tracked electronically by a pack of networked women" (Garreau, 2002). New concepts of place are emerging that should be of substantial interest to social scientists. If sufficiently widely adopted, certain types of LBS have the potential to modify behavior and restructure some aspects of society, for example by facilitating behaviors that disperse traffic and reduce congestion. Social scientists should also be interested in the effects of such trends when not all citizens can participate, because of the cost of access to the associated services, or because some citizens are not willing to share their public personas.

These possibilities are being actively explored in a number of European research projects, and a summary list and WWW links can be found at David Mountain's web site http://www.soi.city.ac.uk/~dmm. The position paper by Anthony Townsend at http://www.csiss.org/events/meetings/location-based/other-papers.htm refers to several comparable US initiatives. For a current commercial service see AT&T's Find Friends, http://www.attwireless.com/mmode.

Plenary discussion

Doug Richardson raised the issue of criminal use of LBS to plan activities. Were there ways of protecting systems from such abuses?

Helen Couclelis saw a substantial difference between *pull* and *push* services, the former initiated by users and the latter by providers. She suggested that many push services had met substantial resistance in the marketplace and wondered if this was a determining factor in the success of certain technologies. Jonathan Raper responded that it is notoriously difficult to assess demand for new technologies, and that one should expect diffusion around early adopters.

Amy Glasmeier raised the question of public versus private initiative and investment, which is potential explanation of the substantial differences in European and North American experience. Which aspects of new technologies are best suited to public involvement, and which are best left to the private sector?

Social implications

Plenary presentation

The introductory presentation in this section of the workshop was made by Michael Curry, who drew from a prepared text, *Beyond Ant Farm: Some Thoughts on Location Based Services*. He began by drawing a parallel between a world of LBS and the ant farm, a toy in which the activities of ants are utterly visible from outside or above, and noted that the analogy had a certain resonance—either unnerving or reassuring, depending on one's point of view. But the ant farm misses an important point about human spatial behavior and its relationship to LBS: that human activity is not simply a matter of motion in space, but is actually far more complex.

Traditional teaching in geography has emphasized three approaches to geographic description: the topographic, the chorographic, and the geographic. The topographic focuses on relative position: "What is next to this?", "What will I see when I move from here to there?", "What does one see when one is there?". The chorographic focuses on the characterization of areas as having homogeneous properties. Finally, the geographic represents the surface of the Earth as if seen from above, and allows for the description of gradation in mathematical terms. Michael Curry suggested that we approach the social implications of LBS in this framework.

Consider the typical LBS scenario, one that has attracted much attention recently because of its implications for privacy, and one that seems particularly appropriate to the ***topographic*** perspective. Walking down the street, one's cellphone rings, and announces a discount at a Starbuck's immediately ahead. Many people are repelled by this scenario, but why? One view is that the cellphone is part of a bubble surrounding each individual, and privacy is invaded when the bubble is pierced. Unwanted FAXes or email spam seem to fall into the same category. But there is a difference, because the cellphone scenario implies that someone, somewhere knows where you are.

The cellphone example also fails to recognize the degree to which people constantly and willingly surrender information about themselves, when they make credit card purchases, ATM transactions, or use automatic toll systems on highways. Instead, Michael Curry suggested that we examine the question from a different perspective, and look at the degree to which the call from Starbucks offends because it interrupts an otherwise normal and predictable activity. In that sense the cellphone scenario is very different from being observed on a surveillance camera—the former constitutes a disruption, but the latter does not.

The ***chorographic*** perspective suggests a different concern, with the growing practice of profiling, or the identification of individuals with the characteristics of the regions in which they live—"you are where you live". Redlining, or the practice of denying mortgages or insurance based on area of residence, is an old example of the social implications of a chorographic perspective, and a more recent example is geodemographics, the subfield of market research that uses neighborhood profiles to target customers. Recently, there have been announcements of a more dynamic form of geodemographics that assigns characteristics to people based on where they work, and there is an obvious potential to use LBS to similarly profile groups.

Finally, Michael Curry suggested that we look at LBS from a ***geographic*** perspective, and at the unintended consequences of the ability to know location. One is E-911, the program that extends street addressing to rural areas in order to improve the ability of individuals to report their locations to emergency response agencies. Such systems tend to replace the personal knowledge of local dispatchers with more systematic and orderly approaches, but in doing so reduce the importance of local organizations, and recast institutional power relations.

Discussion

In the plenary discussion that followed the presentation, Andrew Frank wondered whether the issue of intrusion couldn't be handled by market economics, by offering customer rebates in return for being pushed information, and how such a market might operate. Michael Curry saw limits to this possibility: we have ethical concerns about markets in body parts and blood, and perhaps there are analogous concerns about trading in intrusion. Mike Dobson suggested that concerns about intrusion might be related to age; are young people less concerned? Stuart Sweeney noted that a market already exists in a limited form, in the common practice of store loyalty cards which exchange a limited privacy invasion for modest discounts.

This short plenary discussion was followed by small-group discussion on the issues discussed in the two previous plenary presentations, on the scope of LBS and its social impacts. Several major points emerged, and are reflected the topics listed in the research agenda section of the conclusion to this report.

Technology

Plenary presentation

Jonathan Spinney made the opening presentation in the technology section. He dealt first with the various technical solutions to the question of cellphone location. Cell Global

Identity (CGI) identifies the cell containing the phone, and thus locates to an accuracy determined by cell size, which can vary from less than 1km to tens of km. Timing Advance technology locates a user within a cell by timing the transmission of signals, but provides only a marginal advance in positional accuracy. A Global Positioning System (GPS) device integrated with the cellphone can resolve location to the accuracy of GPS, which may be better than 10m in some areas, but much poorer in areas where the sky is partially obscured, and inoperable inside buildings or in deep urban canyons. CGI and GPS are both compatible with second-generation (2G) cellphone technology. The next generation, or third-generation (3G) technology, makes use of Observed Time Difference (OTD), which resolves location to much better than a cell by observing time of transmission to multiple cell towers. Experiments have shown that OTD can provide positioning to 100m 100% of the time, and to 50m 75% of the time. In summary, current devices have difficulty resolving to much better than 1km, but future devices are likely to resolve location to tens of meters or better.

If locational information is available using one of these technologies, then it can be handled by specialized network architectures. A Mobile Positioning Center (MPC) collects and manages locational information, and interfaces with trusted applications that make use of locations. A Gateway Mobile Location Center (GMLC) manages the authorization, authentication, and billing of LBS users, and deals with such issues as privacy. Both types of centers use GIS data to manage the locational aspects of the network, and to provide any LBS that are hosted internally, rather than provided by third parties.

Whether LBS are provided directly from MPCs or GMLCs or by third parties, it is clear that GIS is a fundamental technology required by most LBS applications. The following generic GIS functions seem to be the most relevant:

- Geocoding and reverse geocoding
- Proximity search
- Nearest neighbor search
- Geodetic conversion
- Point-in-polygon operation
- Distance calculation
- Multi-modal routing
- Spatio-temporal dynamic calculations
- Mobile device map rendering

Currently, many organizations are working on standards to define the interaction between GMLCs and third-party LBS providers.

Discussion

Harlan Onsrud pointed out that many applications of new cellphone technologies use peer-to-peer (P2P) rather than client-server architectures. For example, AT&T's Find Friends service allows a user to locate friends who have agreed to make their locations known to the user, in the P2P style of Napster.

Amy Glasmeier was interested in historical analogs to the introduction of LBS, and whether much could be learned from them. Contrary to much prior experience, standards in LBS have in many cases preceded the roll-out of services, and it is possible that many will prove to be sub-optimal. Discussion returned to the intriguing comparison of N America and Europe, and the problem of accounting for dramatic differences in innovation and adoption. Jonathan Spinney pointed out that the abundance of space in N America made it easier to lay landlines—in other words, the more rapid adoption of wireless in Europe has a simple geographic explanation. The N American practice of charging wireless users for incoming calls is also a substantial deterrent to use.

Many new research and infrastructure ideas emerged from the small-group discussions. One group suggested that one could approach LBS data and its potential for social science by making an analogy to remote sensing, as a new source of data that has revolutionized much research in geography, geology, oceanography, and other Earth sciences. Like Earth images, tracks can be parsed into segments; classified by relating the characteristics of tracks to models of human behavior and to ancillary sources of data; interpreted by humans or artificial intelligence; and modeled to learn about relevant processes. Issues of data volume, archiving, data access, and metadata also show interesting and potentially useful similarities to remote sensing.

The ability to infer information of relevance to social science from tracks is clearly critical. One group suggested an LBS version of the Turing test: given a track, how easy is it to tell what the person making the track was doing? What types of activity are easily detectable from characteristic track forms, and what types of activity are indistinguishable from other types? The remote sensing analogy seems appropriate here also.

Conclusions

The need for investment in research infrastructure

Participants identified many ways in which investment in research infrastructure might jump-start a social science research program in LBS. The following topics were proposed:

- There is a need for tools to visualize and analyze LBS data. To date little effort has gone into the development of tests, models, and software packages, in part because data have been scarce, and in part because little progress has been made in developing appropriate theoretical frameworks. CSISS could take a lead in developing suitable tools and making them available. Tools should be easily integrated with GIS packages.
- Research might be stimulated by publicizing the availability of appropriate data sets that could be mined for patterns, anomalies, and systematic behaviors. Several suitable data sets exist, but their availability is not widely known. Metadata standards should be developed by the research community to foster sharing of data.
- It would be useful if prototypes of LBS technologies could be made available to

the research community, perhaps through a suitable technology *bank* run by an organization such as CSISS. CSISS could also facilitate linkages between researchers and the vendor community.

- Educational modules would be very helpful in allowing instructors to address LBS in courses. A WWW-based primer on LBS would be helpful, especially if it included a glossary of terms and acronyms.
- CSISS could foster the development of an LBS research community if it sponsored a register of LBS interests, to help researchers find others with similar interests.
- CSISS could extend its program of workshops by giving short courses on LBS at social science meetings.
- Social science researchers might benefit from participation in the LBS standards discussions currently under way, notably through the Open GIS Consortium.

An LBS research agenda

Numerous potentially researchable topics emerged from the workshop. The most substantial are listed below, ordered from the more technical in nature to the more social.

- What types of representations are possible with tracking data, and what characteristics define their comparative usefulness? How important is accuracy of representation, and how critical is data volume?
- Tracking data is not likely to be collected under rigorous sampling designs, and is likely therefore to contain biases of various kinds. We need a better understanding of the nature of such biases.
- In principle, tracking data can be collected either by a device that travels with the moving object, or by one or more fixed devices, or a combination of both. What are the limiting factors in choosing between these two approaches?
- Progressive and adaptive sampling are both facilitated by LBS, and are likely to be of growing importance. We need a more comprehensive theory of such forms of sampling, and a better understanding of their effects.
- Tracking data is potentially voluminous, reflecting the power of LBS technology, but we have very little knowledge of the relationship between sampling density and value to social science. High-frequency data may simply not be interesting.
- What methods of visualization are appropriate to LBS and tracking data, and how can they facilitate the identification of patterns and anomalies in large data sets?
- There is a need for methods of analysis that infer activity types from the form of tracking data, and other potentially available ancillary data such as the characteristics or socioeconomic status of the person being tracked. We need a library of track types, an understanding of the distinguishability of each common form of mobile human activity, and an understanding of the importance of sampling rate and spatial accuracy in each case. Alternatively, we need to define a new set of activity types that are both detectable in tracks and of interest in social

science, given the potential abundance of such data from LBS.

- Is it possible to detect such conditions as driving under the influence of alcohol from an LBS track?
- Data mining techniques are already being used to discover misuse of credit cards, based in part on abnormal behavior in space and time. Other data mining tools could be developed for purposes more closely related to social science, including the detection of types of behavior from tracking data.
- Can LBS be protected against misuse in support of criminal activities? Are there patterns of behavior associated with criminal behavior that can be detected by analysis or data mining of tracking data?
- The nature of individual objects' mobility affects the questions we can ask as social scientists. What kinds of questions can be asked about pedestrians, people moving in vehicles, or people on public transit?
- How do LBS tracks reflect settlement patterns, and to what extent can one be obtained by analysis of the other?
- There is a pressing need for new theory, to frame the new analytic tools and models. New theory should deal with the types of behavior revealed by tracking, and with the impacts of LBS on behavior of consumers and entrepreneurs.
- Many location theories assume perfect information on the part of actors. Will the widespread adoption of LBS make this assumption more tenable?
- What properties of human behavior are conserved under the types of technological changes exemplified by LBS? What properties are conserved in narrowly defined contexts such as shopping, migration, or journeys to work.
- How can tracking data be used to calibrate or verify the agent-based simulation models being built in spatial social science?
- LBS has the potential to affect profoundly the spatial organization of society, and the behavior of individuals and groups within it. How rapidly will this occur? Which social groups will lead the process and which will lag?
- Will LBS adoption lead to fundamental change in retailiing structure? Will retail outlets become more dispersed or more concentrated in space, and what impact will LBS have on microscale location strategies (*e.g.*, within malls, or along streets)?
- There is a need for a better understanding of why some technologies succeed and others fail. Can social science provide the intellectual framework and motivation to study the adoption of LBS, in a search for better predictive models?
- Will LBS reduce or increase the digital divide? What differences in the adoption and use of LBS exist based on age, gender, ethnicity, or other factors? How important is price as a factor in adoption, and is there a need for policies that attempt to attenuate its effects?
- What is the geography of cellphone access, and what geographic factors limit the

use of LBS?

- Is LBS *green*—in other words, does it lead to improvement or deterioration in the environment?
- What factors determine how people react to the intrusiveness of LBS, and their willingness to trade privacy? Are there differences due to gender, age, or ethnicity?
- Is it possible to insert privacy as an issue into the early stages of LBS technology design?
- What legal liabilities might be associated with the use of LBS? Is an LBS provider liable in case of misdirection?

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