Learning and Navigating Built Environments: Individuals' Travel Patterns and Spatial Knowledge Measured in the Field with a Mobile Geographic Information System

Drew Dara-Abrams

Department of Geography
University of California, Santa Barbara
Santa Barbara, CA 93106-4060 U.S.A.
http://drew.dara-abrams.com/
drew@geog.ucsb.edu

1 Introduction

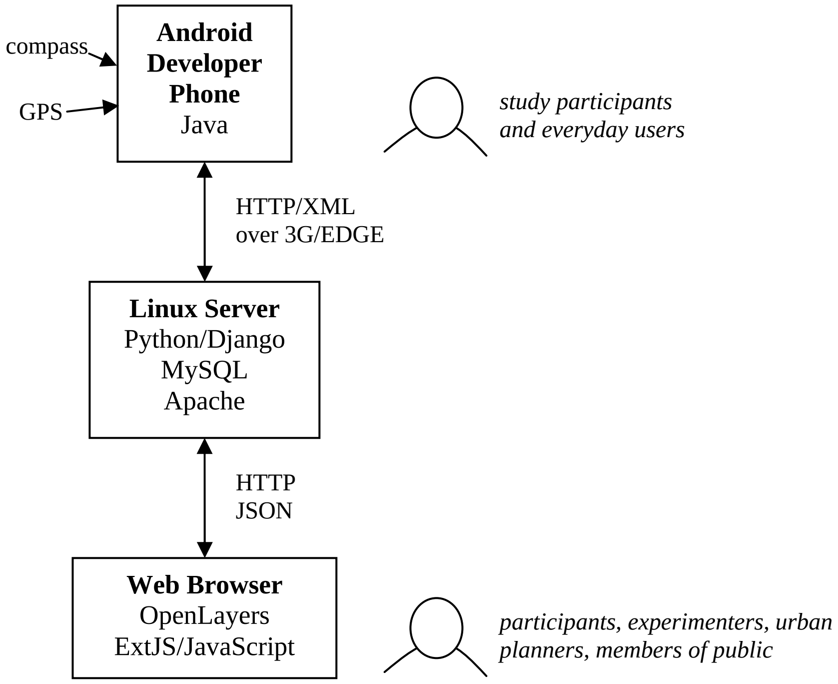
How do people explore and learn unfamiliar cities over time? What are the places they remember, the places they forget? How is their knowledge for the places they do remember shaped and distorted? And how can mobile technology help us to address these particular questions and the overall psychology of urban travel? These are questions concerning spatial cognition and location-based services (LBS) that I am considering in my dissertation. Spatial cognition research has traditionally been performed with participants in controlled lab settings, where the surroundings are not necessarily natural but the results are precise. Research on the use of LBS, on the other hand, is often performed in the field in a less formal, more ethnographic manner. Because of technical and practical limitations, neither sort of study usually lasts long enough to measure learning over time. My goal is to use the latest technology to run automated and exacting studies of people's behavior and cognition out in their everyday surroundings over extended periods of time in order to address those questions in spatial cognition and LBS.

In addition to a set of psychological findings, my dissertation will produce a distributed *cognitive surveying* system—a novel LBS in itself—for measuring, analyzing, visualizing, and sharing people's navigation practices and spatial knowledge. By releasing the system as open source, I hope to enable other researchers in spatial cognition and LBS to elaborate on this work, LBS developers to integrate pieces into their own applications, architects and urban planners to deploy the system when they want to measure how their environments are used—user-centered design on the scale of the city, if you will—and even curious amateurs to readout their "cognitive maps" around town and when traveling to new places.

2 Cognitive Surveying

Cognitive surveying is a framework of computational techniques I have developed to enable the automated and precise measurement of spatial knowledge and navigation practices in everyday environments (detailed in Dara-Abrams, 2008). Much like the equipment and techniques used by land surveyors, the cognitive surveying system uses a small mobile computer, a GPS unit, and a digital compass. Every user carries such a device, which tracks their movement. Using the device, participants also label locations that they consider meaningful as landmarks. The device then prompts them to point and estimate the distance toward other, out-of-sight landmarks. Based on these piecemeal measurements, the system can then produce analyses, both quantitative and qualitative, as well as geovisualizations, such as a “cognitive map” for each person.

The cognitive surveying system I am currently developing includes three components: Android smartphones carried by participants, a server that processes and stores the data, and desktop computers for using interactive geovisualizations of the data. Here is the overall system architecture:



In effect, the cognitive surveying system will be a distributed geographic information system (GIS). The mobile will use sampling algorithms to determine when to ask its user a question—to point to an out-of-sight landmark, for example. The server will store these direction estimates in a measurement-based GIS, so that analyses are run on the fly from the original readings, correctly propagating GPS and compass error through all calculations (Goodchild, 2002). Map displays and other geovisualizations of the measurements will be produced in an interactive format as is now done everyday with Google Maps and Google Earth “mash-ups,” yet there is a key difference: These geovisualizations are not of the physical world as it exists but instead of the world as it is perceived, remembered, and traveled by individuals. As in OpenStreetMap and Google MapMaker, users are contributing geographic information, but in the case of cognitive surveying, the user-contributed geographic information is personal travel patterns and spatial knowledge collected as people go about their daily lives in the field.

Along with visualization, the client interface will provide a toolkit of analysis and mining functions to make sense of all this data. For example: multidimensional scaling to combine participants’ estimates of the directions and distances between landmarks (Waller & Haun, 2003); bidimensional regression to analyze the fit between where people imagine landmarks to be located and their true location (Friedman & Kohler, 2003); and sequence analysis to identify recurring trips by individuals and groups (Shoval & Isaacson, 2007). The cognitive surveying system will make these analysis methods available and easy to use for researchers, urban planners, and interested amateurs alike.

Collecting and analyzing personal geographic information is also key to humanizing LBS. The techniques of cognitive surveying will produce a set of landmarks for each user, weighted by their knowledge for each location, which can be used to personalize route directions (Raubal & Winter, 2002). Also available are subjective distances that represent how long each user thinks a travel segment will take to traverse, which can be used for travel constraint planning (Raubal, Miller, & Bridwell, 2004). Furthermore, using the techniques of cognitive surveying, an LBS will know how experienced a user is traveling through certain areas, which can be used to formulate route directions of varying detail (Srinivas & Hirtle, 2006).

3 Empirical Studies

To test the cognitive surveying system and to address empirical questions in spatial cognition, I am running three studies of increasing complexity.

The first study will be a real-world version of the “traveling salesman” problem. Participants will need to travel around the University of California, Santa Barbara campus, visiting a list of buildings in the most efficient route, all the while carrying a cognitive surveying system. After returning to the lab, participants will have a chance to view their travel patterns and spatial knowledge using interactive geovisualizations as part of one-on-one user-centered design sessions.

The second study will take the cognitive surveying system off campus. Residents of Santa Barbara will carry a system with them for an entire week, occasionally pausing to mark a landmark, point toward another out-of-sight landmark, and so on. Each participant will have the chance to view their own data in user-centered design sessions, and after aggregating all the results, we will also have a relatively comprehensive data set of “cognitive maps” for the Santa Barbara metropolitan area, which we will share with local urban planners and with the general public.

The third study will return to the UCSB campus in time for a new academic quarter of students to arrive. We will ask 30 of these first-years to carry a cognitive surveying system with them, giving us a glimpse into their changing travel patterns and developing spatial knowledge over the course of their first 10 weeks in Santa Barbara. As before, we will share the resulting interactive geovisualizations with the participants, the planners, and the public.

These three studies have been designed to complement empirical research that has already been performed in lab settings and under more controlled conditions on systematic distortions in spatial knowledge (e.g., Moar & Bower, 1983), navigation and route choice (e.g., Golledge, 1995), and learning the layouts of environments over time, also known as spatial microgenesis (e.g., Ishikawa & Montello, 2006). The results of my dissertation studies will, I hope, reproduce in more natural settings these establish findings and provide a more complete explanation of how spatial knowledge acquisition and navigation practices interact over time in the real world.

4 Expected Outcomes and Results

An Open Source System for In-field Studies: This research will produce a fully working cognitive surveying system, built as a distributed GIS with smartphones on one end and interactive geovisualizations on the other end, which will be open source and ready for others to use. Out of the box, the system will let anyone with an Android phone begin to measure, analyze, visualize, and share their travel patterns and their spatial knowledge in a precise and consistent manner.

Applications for Researchers, Professionals, and Amateurs: In a series of three studies, I am testing the cognitive surveying system and using it to assess the spatial cognition of amateurs under a variety of conditions: trying to complete the navigation challenge of the “traveling salesman” problem, going about an ordinary week around town, and becoming familiar with a university campus. The resulting data will help address questions concerning systematic distortions in spatial knowledge, route choice and navigation practices, and spatial microgenesis. At the same time, just as important will be the ways in which the participants, members of the general public, and professional planners explore, analyze, use this personal geographic information. Conducting user-centered design sessions with each of these groups will indicate how the techniques and the data of cognitive surveying can be used for personal curiosity, scientific research, and professional practice now and in the future.

References

Dara-Abrams, D. (2008). Cognitive surveying: A framework for mobile data collection, analysis, and visualization of spatial knowledge and navigation practices. In *Spatial cognition VI. Learning, reasoning, and talking about space* (pp. 138-153).

Friedman, A., & Kohler, B. (2003). Bidimensional regression: Assessing the configural similarity and accuracy of cognitive maps and other two-dimensional data sets. *Psychological Methods, 8*(4), 468-491.

Golledge, R. G. (1995). Path selection and route preference in human navigation: A progress report. In *Spatial Information Theory* (Vol. 988, pp. 207-222). Berlin: Springer.

Goodchild, M. F. (2002). Measurement-based GIS. In W. Shi, P. F. Fisher, & M. F. Goodchild (Eds.), *Spatial Data Quality* (pp. 5-17). New York: Taylor and Francis.

Ishikawa, T., & Montello, D. R. (2006). Spatial knowledge acquisition from direct experience in the environment: Individual differences in the development of metric knowledge and the integration of separately learned places. *Cognitive Psychology, 52,* 93-129.

Moar, I., & Bower, G. H. (1983). Inconsistency in spatial knowledge. *Memory & Cognition*, 11(2), 107-13.

Raubal, M., & Winter, S. (2002). Enriching wayfinding instructions with local landmarks. In M. Egenhofer & D. M. Mark (Eds.), *Geographic information science* (pp. 243-259). Heidelberg: Springer.

Raubal, M., Miller, H. J., & Bridwell, S. (2004). User-centred time geography for location-based services. *Geografiska Annaler: Series B, Human Geography*, *86*(4), 245-265.

Shoval, N., & Isaacson, M. (2007). Sequence alignment as a method for human activity analysis in space and time. *Annals of the Association of American Geographers, 97*(2), 282-297.

Srinivas, S., & Hirtle, S. C. (2006). Knowledge-based schematization of route directions. In T. Barkowsky, M. Knauff, G. Ligozat, & D. R. Montello (Eds.), *Spatial cognition V: Reasoning, action, interaction* (pp. 346–364). Berlin: Springer.

Waller, D., & Haun, D. B. M. (2003). Scaling techniques for modeling directional knowledge. *Behavior Research Methods, Instruments, & Computers*, *35,* 285-293.

Acknowledgements

Many thanks to the members of my doctoral committee, who have helped me to develop and refine these ideas: Martin Raubal, Dan Montello, Mary Hegarty, and the late and much missed Reg Golledge. Thanks also to the University of California, Santa Barbara Graduate Division for travel funding and to the U.S. National Science Foundation for generous support through the Interactive Digital Multimedia IGERT (grant number DGE-0221713) and a Graduate Research Fellowship.