Cognitive subdivisions in outdoor navigation

Mahsa Sadat Naseri, Farid karimipour

School of Surveying and Geospatial Engineering, College of Engineering, University of Tehran

Abstract. Navigation aids provide users with a route as a sequence of turn by turn instructions, each of which guides the user from one decision point to the next. Along the extensive research on enriching navigation aids with the elements of spatial cognition, this research provokes the idea of including cognitive subdivisions of space in outdoor navigation. As the first step, we present the results of a field study to investigate the influence of cognitive subdivisions on human navigation process.

Keywords. *Spatial cognition, Outdoor navigation, Spatial knowledge, Cognitive map, Navigation instruction*

1. Introduction

Navigation aids provide users with a route as a sequence of turn by turn instructions, each of which guides the user from one decision point to the next. Such geometric-based instructions result in a passive exploration of the environment, which has the least influence on improving spatial knowledge of the user. Instead, humans actively employ different forms and representations of spatial information in the navigation procedure. They depend on their cognitive representation of space (in the form of landmark, route, and survey knowledge) to perform navigational tasks in large scale environments (Dillon et al., 1993; Golledge, 1999).

There has been extensive research on enriching navigational aids with the elements of spatial cognition in order to improve their efficiency. However, as described in Section 2.2., they mostly consider landmark and route knowledge. Although survey knowledge is a key element of humans' spatial

LBS 2016
13th Conference on Location-Based Services
Vienna, 14–16 November 2016

Published in "Proceedings of the 13th International Conference on Location-Based Services", edited by Georg Gartner and Haosheng Huang, LBS 2016, 14-16 November 2016, Vienna, Austria.

mental representation (Tversky, 1993), to the best of our knowledge, there has not been considerable research on including such knowledge in outdoor navigation.

This research provokes the idea of including cognitive subdivisions of space in outdoor navigation. As Kuipers (1978) stated, information in mind is hierarchical; and the sequences of containing districts about the desired places are checked from the "top down" to find the smallest district containing the origin and destination. As we have all experienced, such cognitive subdivisions can contribute in our navigational tasks.

As the first step of this idea, this paper presents the results of a field study to investigate the influence of cognitive subdivisions on human navigation process. For this, Section 2 reviews the existing related research on enriching navigational aids with the elements of human spatial cognition. Section 3 provides details about designing the field study and presents the statistical results. Finally, Section 4 concludes the paper and introduces the future steps of the research.

2. Enriching Navigational Aids with the Elements of Human Spatial Cognition: State-of-the-Art

Wayfinding is one of the substantial human activities in daily life, that concerns about how to reach from a current location to a desired place (Timpf et al., 1992). According to Lynch's definition of wayfinding as "a consistent use and organization of definite sensory cues from the external environment" (Lynch, 1960), wayfinding is a complex task in which people apply several skills such as various spatial, cognitive, and behavioral abilities (Raubal & Winter, 2002). Wayfinding involves organizing multiple behavioral and cognitive abilities that are spatially distributed. Therefore, it is influenced by humans' sensory abilities and environmental factors.

On the other hand, the mode of environment exploration influences wayfinding behaviors (Feldman & Acredolo, 1979). While exploring the environment, humans update their spatial knowledge and cognitive map, which support their future wayfinding behavior. Although active exploration of the environment improves spatial information, increasing use of navigation applications has led to a modern passive exploration of the environment.

There has been a significant body of research on considering cognitive representations of space —in the form of landmark, route, and survey knowledge (Siegel & White, 1975) in the navigation procedure. At the level of landmark knowledge, (Raubal & Winter, 2002) proposed an approach to enrich wayfinding instructions with local landmarks, which automatically extracts local landmarks from datasets and integrates them in wayfinding instructions. (Duckham et al., 2010) developed a weighting model for generating routing instructions that annotate simple routes with references to landmarks. (Klippel & Winter, 2005) proposed an approach to formalize the structural salience of objects along routes, upon which landmarks are automatically integrated into route directions. On the other hand, at the level of rout knowledge, (Tomko et al., 2008) introduced a criterion to rank streets in a network, which reflects the interaction of people with the streets.

There has not been considerable research on including survey knowledge in outdoor navigation. An exception is a line of research by Zelatanova and her colleagues (Zlatanova et al., 2013; Kruminaite, 2014; Krūminaitė & Zlatanova, 2014) to develop a conceptual model for determination of space subdivisions (as a form of survey knowledge) in indoor navigation.

3. Field Study: Design and Results

A field study was designed to investigate the influence of cognitive subdivisions on human navigation process. We paid particular attention to the role of landmarks and subdivisions mentioned in route directions and how often they were effective in acquiring spatial knowledge by comparing the searching time and area.

The participants were divided into two groups of familiar and unfamiliar with the area. For the unfamiliar group, the influence of cognitive subdivisions on navigation were investigated: They were provided information to navigate to certain destinations using (1) plain turn by turn instructions, (2) instructions enriched with local landmarks and (3) instructions enriched with subdivisions. For the familiar group, on the other hand, they were asked to provide instructions for navigating to certain destinations in order to see how often and what type of cognitive elements they use. In this case, should they include cognitive subdivisions in their instructions, they were asked to sketch the boundary of the subdivisions on the map. Note that although individual differences are critically significant to perception of environmental (Li & Klippel, 2014), this research is largely mute with respect to this.

In general, based on the results of the questionnaires, all participants ─no matter if they are familiar or unfamiliar with the environment─ reported that use of subdivisions in navigation instructions improves their wayfinding efficiency and helps them to remember mental representation and make it more accurate. In other words, this type of information develops a connection between the spatial experience and navigation instruction, which means that cognitive subdivision-based instructions lead to learning the environment and improving the navigation process.

Specifically, evaluating the results show that:

- Enriching the navigational instructions with cognitive subdivisions eases the navigation for the users with prior-knowledge of the subdivisions. In the case of unfamiliarity with the subdivisions, this information helps the users to acquire this knowledge and deploy it in future navigation systems. It means that cognitive subdivisions assist people to create a local cognitive representation which can support wayfinding and enrich their spatial mental representations.
- People often includes cognitive subdivisions in their instructions if they have prior-knowledge of the area. Interestingly, if they just got familiar with a subdivision in the former series of questions, they immediately used them in providing navigation instructions in the latter.
- Users provides different boundary for subdivisions, but this imprecision does not affect their navigation. This is along with what (Tversky, 1993) states that everyday spatial descriptions used by people are not very precise, but they are frequently produced and readily understood.

4. Conclusion

This study investigates the influence of subdivision on navigation instructions. The results of the field study indicate that enriching navigational instruction by cognitive subdivisions lead to active exploration of the environment and assist memory in spatial information acquisition. We are now working on an approach to generalize the navigational instructions based on the knowledge of the user from the cognitive subdivisions.

References

Dillon, A., J. Richardson, et al. (1993). Space-the final chapter or why physical representations are not semantic intentions. Hypertext: A psychological perspective.

Duckham, M., S. Winter, et al. (2010). Including landmarks in routing instructions. Journal of Location Based Services, 4(1): 28-52.

Feldman, A. and L. Acredolo (1979). The effect of active versus passive exploration on memory for spatial location in children. Child development: 698-704.

Golledge, R. G. (1999). Wayfinding behavior: Cognitive mapping and other spatial processes, JHU press.

Klippel, A. and S. Winter (2005). Structural salience of landmarks for route directions. Spatial information theory, Springer: 347-362.
Kruminaite, M. (2014). Space Subdivision for Indoor Navigation, TU Delft, Delft University of Technology.
Krūminaitė, M. and S. Zlatanova (2014). Indoor space subdivision for indoor navigation. Proceedings of the Sixth ACM SIGSPATIAL International Workshop on Indoor Spatial Awareness, ACM.
Kuipers, B. (1978). Modeling spatial knowledge*. Cognitive science, 2(2): 129-153.
Li, R. and A. Klippel (2014). Wayfinding Behaviors in Complex Buildings The Impact of Environmental Legibility and Familiarity. Environment and Behavior: 0013916514550243.
Lynch, K. (1960). The image of the city, MIT press.
Raubal, M. and S. Winter (2002). Enriching wayfinding instructions with local landmarks, Springer.
Siegel, A. W. and S. H. White (1975). The development of spatial representations of large-scale environments. Advances in child development and behavior, 10: 9.
Timpf, S., G. S. Volta, et al. (1992). A conceptual model of wayfinding using multiple levels of abstraction. Theories and methods of spatio-temporal reasoning in geographic space, Springer: 348-367.
Tomko, M., S. Winter, et al. (2008). Experiential hierarchies of streets. Computers, Environment and Urban Systems, 32(1): 41-52.
Tversky, B. (1993). Cognitive maps, cognitive collages, and spatial mental models. Spatial Information Theory A Theoretical Basis for GIS, Springer: 14-24.
Zlatanova, S., L. Liu, et al. (2013). A conceptual framework of space subdivision for indoor navigation. Proceedings of the Fifth ACM SIGSPATIAL International Workshop on Indoor Spatial Awareness, ACM.