Enhancing indoor spatial knowledge through navigation map design with landmark hierarchy

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Abstract. Landmarks are an important cognitive element in conveying route information in indoor navigation, and their extraction methods have matured. However, in the existing indoor navigation maps, the representation of landmarks is not optimal, making it difficult to obtain spatial knowledge related to navigation (e.g., landmark knowledge and route knowledge). To close this gap, we propose a conceptual model of indoor navigation map design with a landmark hierarchy containing three levels by adjusting the size and highlight of landmark expression, which should contribute to enhancing indoor spatial knowledge. As a proof of concept, a case study is being conducted to evaluate the differences in indoor spatial knowledge of users.

Keywords. Indoor navigation, Landmarks, Spatial knowledge, Map design

1. Introduction

In an era marked by rapid urbanization, especially in complex environments (e.g., airports, hospitals, shopping malls, etc.), navigating indoor spaces efficiently and confidently is a challenge, particularly for newcomers, individuals with impairments, and older people.

Published in "Proceedings of the 18th International Conference on Location Based Services (LBS 2023)", edited by Haosheng Huang, Nico Van de Weghe and Georg Gartner, LBS 2023, 20-22 November 2023 Ghent, Belgium.

This contribution underwent single-blind peer review based on the paper.
https://doi.org/10.34726/5725

Indoor space lacks semantic annotation, such as road signs as in the outdoor case (Zhou et al., 2023). However, many spatial entities contain rich semantic information around them. Spatial entities with key characteristics recognizable and memorable can become landmarks (Sorrows and Hirtle, 1999), which serve as an important cognitive element to convey route information in indoor navigation (Denis, 1997). Landmarks are fundamental to spatial knowledge acquisition, because landmark knowledge is developed before route and survey knowledge (Golledge, 1999).

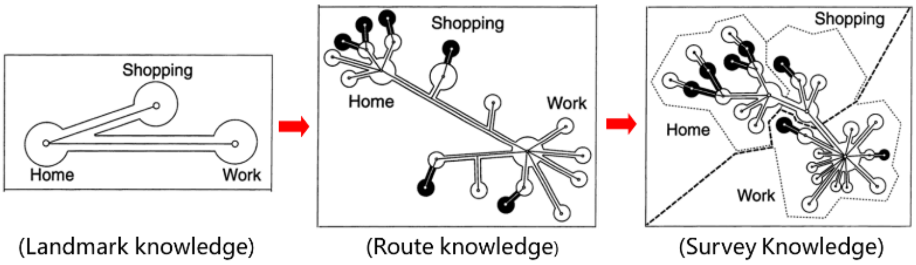

Figure 1. Anchor point theory of spatial knowledge acquisition (Golledge, 1999).

Many studies have adopted and revised the outdoor landmark salience model in indoor landmark selection (Lyu et al., 2015; Zhou et al., 2022). Despite the relative maturity of the calculation methods used for modeling indoor landmarks, there often exists confusion as to how they are represented in navigation maps, especially lacking a clear hierarchy. In the existing indoor navigation maps (Lorenz et al., 2013; Ludwig et al., 2023), the landmarks along the route have no hierarchical expression, making it difficult for users to focus on, and mentally construct spatial knowledge related to navigation.

In summary, there is a need for a navigation map with a hierarchical expression for landmarks that supports both the efficiency of navigation and the acquisition of spatial knowledge for users. Accordingly, we propose an indoor navigation map with a landmark hierarchy that is expected to enhance the spatial knowledge of users in navigation tasks. A case study is also proposed to evaluate the differences regarding the indoor spatial knowledge of users using different map designs.

2. Conceptual model of Indoor navigation map design

As illustrated in Figure 2, Ipsmap (ZIIT, 2023), which is a typical conventional indoor navigation map design, usually displays landmarks on the screen in the same size of symbol or text without hierarchy (Figure 3). In our proposed map design (Prototype map), landmarks along the route are considered to express their hierarchy containing three levels (Figure 4):

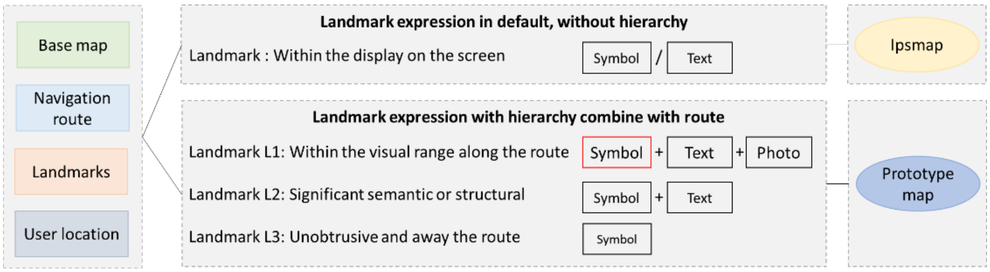

Figure 2. Conceptualized indoor navigation map design with different landmark expression.

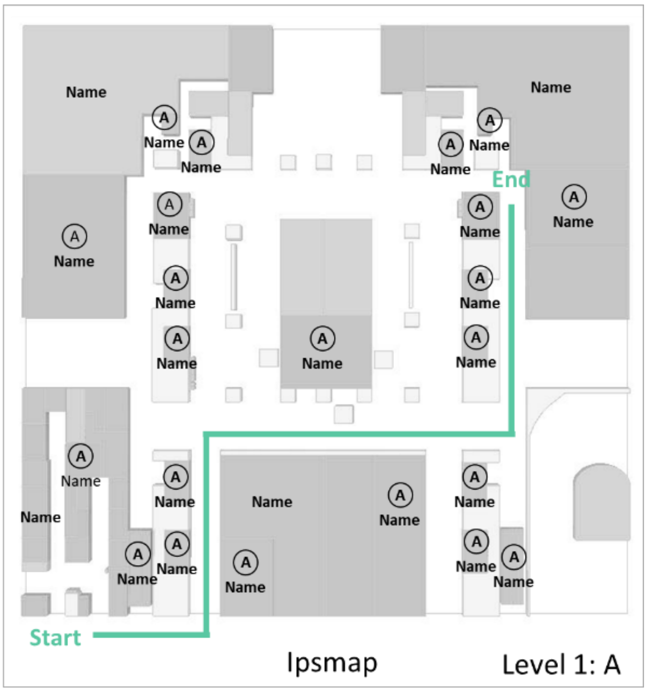

Figure 3. Conceptualization of the Ipsmap design.

Level 1 (L1, highest): The expression of landmarks within the visual range of the route should typically prioritize enlarging the size of symbols with highlights, enlarging annotations size, and adding photos to provide more detailed information. Level 2 (L2): Some significant landmarks of high semantic or structural salience in indoor space can be expressed in a second size of symbols and text to emphasize their importance. Level 3 (L3): The remaining landmarks may only be expressed using a third, smallest size of symbols.

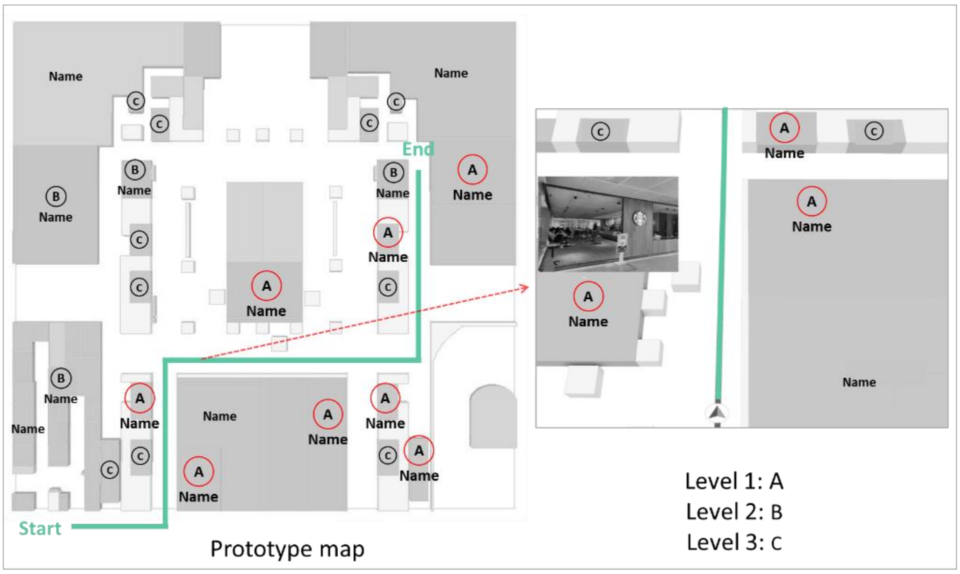

Figure 4. Conceptualization of the proposed indoor navigation map design.

3. Methodology

3.1. Map Design

Firstly, we should select the indoor landmarks in the study area. This part is derived from the previous work on indoor landmark selection based on the Analytic Hierarchy Process (AHP) (Zhu et al., 2019).

The research will employ a 2 × 2 mixed factorial design. The between-subject variable, the sense of direction of participants, has two levels: good and poor. Each participant will be asked to select different maps for navigation: Ipsmap and the Prototype map.

3.2. Evaluation Procedure and Measures

In the user study, sketch maps and landmark locating tasks can be used to assess the results of spatial knowledge acquisition (Liu et al., 2021). The whole procedure will include the following six steps: Steps 1 to 3 have already been completed, and Steps 4 to 6 have not yet been completed.

(1) Demographic information questionnaire. Each participant was first asked to fill in her/his basic information, including gender and age.

(2) Santa Barbara Sense of Direction Scale questionnaire (Hegarty et al., 2002). According to the normal distribution direction scale scores (Dong et al., 2021), a score above 3.89 can be seen as a person having a good sense of direction, otherwise as having a poor sense of direction.

(3) Recalling landmark locating tasks and sketch map drawing. The participants were asked to recall the landmark locations along the route in the base map and draw the sketch map after the navigation tasks.

(4) Pairwise comparison of navigation task completion time between the Ipsmap and the Prototype map user groups.

(5) Pairwise comparison of the correct rate of recalling landmark locations between the Ipsmap and the Prototype map user groups.

(6) Comparison of the correct rate of recalling landmark locations between users with a good sense of direction and a poor sense of direction in the Ipsmap group and the Prototype map group.

4. Case study

We selected the outpatient facility of a hospital in Nanjing, China, as the case study area. Currently, we have finished the user experiments. The pairwise comparison results will be analyzed, which will help to verify whether the proposed navigation map design can enhance spatial knowledge.

5. Acknowledgments

This research was supported by the National Key R&D Program of China (No.2021YFE0112300), National Natural Science Foundation of China (NSFC) (No.41930104), Postgraduate Research and Practice Innovation Program of Jiangsu Province (No.KYCX22_1571), and the scholarship program of the China Scholarship Council (No.202206860028).

References

Denis, M. (1997). The description of routes: A cognitive approach to the production of spatial discourse. Current psychology of cognition, 16, 409-458.

Dong, W., Wu, Y., Qin, T., Bian, X., Zhao, Y., He, Y., ... & Yu, C. (2021). What is the difference between augmented reality and 2D navigation electronic maps in pedestrian wayfinding?. Cartography and Geographic Information Science, 48(3), 225-240.

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

Hegarty, M., Richardson, A. E., Montello, D. R., Lovelace, K., & Subbiah, I. (2002). Development of a self-report measure of environmental spatial ability. Intelligence, 30(5), 425-447.

Liu, B., Ding, L., & Meng, L. (2021). Spatial knowledge acquisition with virtual semantic landmarks in mixed reality-based indoor navigation. Cartography and Geographic Information Science, 48(4), 305-319.

Lorenz, A., Thierbach, C., Baur, N., & Kolbe, T. H. (2013). Map design aspects, route complexity, or social background? Factors influencing user satisfaction with indoor navigation maps. Cartography and Geographic Information Science, 40(3), 201-209.

Ludwig, B., Donabauer, G., Ramsauer, D., & Subari, K. A. (2023). Urwalking: Indoor navigation for research and daily use. KI-Künstliche Intelligenz, 1-8.

Lyu, H., Yu, Z., & Meng, L. (2015). A computational method for indoor landmark extraction. Progress in Location-Based Services 2014, 45-59.

Sorrows, M. E., & Hirtle, S. C. (1999). The nature of landmarks for real and electronic spaces. In Spatial Information Theory. Cognitive and Computational Foundations of Geographic Information Science: International Conference COSIT'99 Stade, Germany, August 25–29, 1999 Proceedings 4 (pp. 37-50). Springer Berlin Heidelberg.

Zhejiang Ipsmap Information Technology (ZIIT) Co.,Ltd. (2023). "Ipsmap". Available online: https://www.ipsmap.com/ (accessed on 30 August 2023)

Zhou, J., Weibel, R., Fu, C., Zhou, Z., Zhu, L., & Shen, J. (2023). Indoor navigation map design based on the analysis of space characteristics. Abstracts of the ICA, 6, 291.

Zhou, Z., Weibel, R., & Huang, H. (2022). Familiarity-dependent computational modelling of indoor landmark selection for route communication: a ranking approach. International Journal of Geographical Information Science, 36(3), 514-546.

Zhu, L., Švedová, H., Shen, J., Stachoň, Z., Shi, J., Snopková, D., & Li, X. (2019). An instance-based scoring system for indoor landmark salience evaluation. Geografie, 124(2), 103–131.