# Supporting inferences in space – A wayfinding task in a multilevel building

Carsten P. J. Gondorf [1], Cui Jian[2]

[1] Transregional Collaborative Research Center SFB/TR 8 Spatial Cognition, University of Bremen, Enrique-Schmidt-Str. 5, D-28359 Bremen, Germany
[1]gondorf@uni-bremen.de, [2]ken@informatik.uni-bremen.de

**Abstract.** The explorative study presented in this paper investigates indoor way-finding strategies and inferences of users in an unknown building. Participants were asked to find two consecutive targets in a multilevel building with the help of written route instructions. Routes were generated by a dialogue system and tested against adjusted instructions containing additional architectural information. The empirical findings suggest that selectively adding structural information can help (1) to build up a participant's cognitive map and support inferences about returning paths, (2) a guidance system optimize its wayfinding process to avoid redundancy with respect to the human-friendly principle, and (3) to improve to a great extent the effectiveness and efficiency of the system itself, and generate more adaptive and intuitive route instructions.

**Keywords:** indoor wayfinding strategies, spatial inferences, cognitive map

## 1 Introduction

The purpose of the study was to test whether selectively adding information about the architectural structure of a building to a set of instructions provides additional inferences about the returning path, leading the user to choose another, perhaps shorter way back.

As for the instructions we used a dialogue system that automatically generates indoor route instructions when asked about locations, using text-based natural language input and output (cf. [2]). We are interested in how the behavioral findings could help (1) to improve route instruction generation according to cognitive principles underlying human route descriptions [6], and (2) to improve, to some extent, the effectiveness and efficiency of the system itself and generate more adaptive and intuitive route instructions.

Recent approaches to indoor wayfinding have encountered difficulties in their investigation in conference centers [3], libraries [1], and others. Hölscher et al. [4, 5] for instance, suggest the following taxonomy in cases of incomplete spatial information for complex multilevel buildings (a) central point strategy – more likely to be used by first-time-visitors/unexperienced users – hanging on to well-known parts of the building (e.g. main entry hall, main stairs etc.); (b) direction strategy; (c) floor strategy.

According to Kuipers [7] places can be connected by associated movement responses; concatenating such place recognition-triggered responses then constructs a linear route. If two or more crossing routes are merged together, a network occurs, i.e. an internal mental representation of the environment. This representation is dynamic enough to describe intuitive spatial relationships and relative positions of places.

## 2 Infokiosk

The written instructions given in-advance were derived from a dialogue system – called *Infokiosk* – which was developed and implemented in our research group I5-DiaSpace.

The route instructions generator of the current system runs on a combined computational model that consists of three sequential processing steps:

- GUARD (Generation of Unambiguous, Adapted Route Directions, cf. [2]) generates the “context-specific” low level route directions out of raw route paths that lead to a given destination.
- GOHLI (Generation of High Level Instructions, cf. [2]) segments the low-level route directions coming from GUARD and generates the high-level route instructions on the basis of major direction changes.
- GOSLRI (Generation of Structuring Landmarks Related Instructions), which is the primary focus in this paper, takes high-level route instructions from GOHLI as input, and generates High-level structuring landmarks-based route instructions.

## 3 Experiment

32 participants (20 women/12 men) with little or no prior familiarity were asked to undertake wayfinding tasks in a multi-level building (GW2 – University of Bremen). They were all German native speakers and university students with an average age of 22.91 (age range 20-35, SD=4.518). For participation they received either course credit or were paid €6 Euro each. With the given detailed written paper-based route instructions, they had to find two consecutive targets - as well as their way back to the starting point.

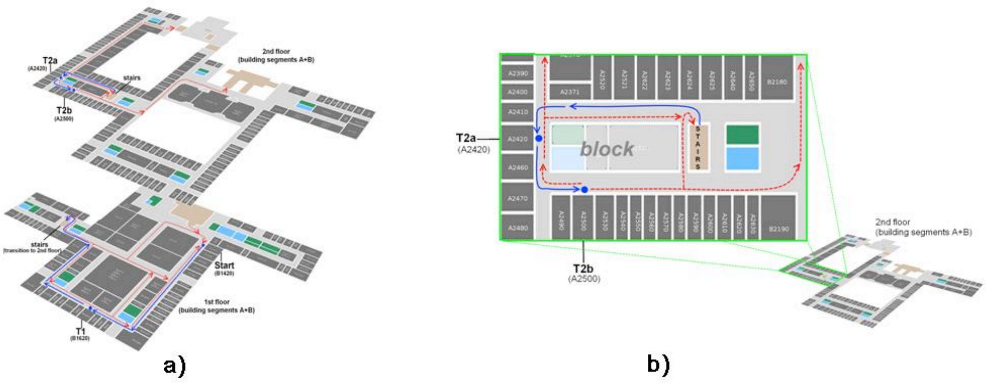


**Fig. 1**. Map views of the test environment, GW2, University of Bremen. (a) Shows building segments A/B, 1st and 2nd floor. Continuous lines indicate the path from the start point to first target (T1) and to target (2a) and (2b) on 2nd floor; dashed lines present a continuum of chosen returning paths. (b) Block scenario on 2nd floor.

Instructions were always given with respect to the point of departure. The movement commands in the instructions were all aligned to an egocentric frame of reference, e.g. "Turn around and go straight until the next hallway on the left-hand side." Adjusted versions were preceded by a short description, containing the floor and section of the building, in or on which the target is determined. Furthermore and most importantly for the scenario, on the 2nd floor we provided the explicit naming of an additional structuring path+landmark: *go around the block*. The *block* is a salient, structuring element of this particular environment (22x7meter), already perceivable while going up the stairs (see Fig. 1b).

The first target to reach was situated on the 1st floor and stayed the same for each subject – room B1620. The only difference was that each participant was given only either a system-generated (IS) or an adjusted instruction (IA). The second goal was on the 2nd floor and was divided into target (2a), room A2420, and target (2b), room A2500 (see Fig. 1b) – selection was done by taking into account the block structure and visibility of the stairs. That is, participants with target 2b had to walk further around the block (see Fig. 1b). The transition took place at a staircase in building segment A. The task started and ended on the 1st floor at room B1420. For this, as well as for the whole wayfinding task the users were instructed to think aloud and verbalize their thoughts and considerations. After reaching target (2a/b) the participants were instructed to hand back the instructions and walk to the starting point (they were not given any restrictions or assignments). After the task was completed, each participant was asked to fill two questionnaires – one for individual differences in spatial orientation, and the other asked about the performed task.

# 4 Results

All participants reached the two described targets (1, 2a/b) and got back to the starting point. By coding the chosen paths back by total numbers it was feasible to apply a set of nonparametric tests to the collected data. Analysis was carried out particularly for the type of instruction, i.e. target to reach on 2nd floor (T2a/b), and floor.

A total number of 23 participants chose the same returning path on the 2nd floor. Just 6 out of 32 participants continued walking around the block and used it as shortcut on the 2nd floor – 5 of them got the adjusted instruction (Target 2b) vs. one with a system generated instruction (T2b). A chi-square test was used for analysis based on floors and by comparable conditions, i.e. IS1 → T2a vs. IA1 → T2a on the one hand, and IS2 → T2b vs. IA2 → T2b on the other hand. For 1st floor for conditions IS(1) and IA(1) from target (2a) to the starting point ($\chi^2$ =1.3, *df*=4, *p*>0.85; Cramér's *V*=0.28), and for IS(2) and IA(2) from target (2b) (($\chi^2$ =0.34, *df*=2, *p*>0.84; Cramér's *V*=0.14). For 2nd floor from target (2a) ($\chi^2$ =1.1, *df*=2, *p*>0.58; Cramér's *V*=0.25), from target (2b) (($\chi^2$ =4.26, *df*=1, *p*<0.05; Cramér's *V*=0.51). This result supports the above described distribution of returning paths by total numbers for respective floors. Participants who handed out instruction IA2 were more likely to take the shortcut on their way back on 2nd floor in order to reach the stairs, i.e. to go back to the starting point, compared with their counterparts with IS(2).

This holds also for the evaluation of the walking distance of IS(2) compared with IA(2). A one-way ANOVA revealed a significant effect for walking distance on 2nd floor: $F$ (1, 14)=5.091, p<0.05; $\eta^2$=0.27. This is mainly due to the fact that 7 out of 8 participants in condition IS(2) chose the same and thus longer returning path (~29.4m) – compared to 3 in condition IA(2). The shortcut (~21m) further around the block and thus in the direction of the stairs was selected by four participants in both conditions.

Participants' walking paths used for their return on the 1st floor back to the starting point showed a wide continuum of total returning paths across all conditions (see Fig.1a). This suggests a combination of central-point strategy and recognition-triggered response. The first review of the elicited data confirmed the behavioral findings for 1st floor: the central-point strategy was applied by 17 and recognition-triggered response by 13 people.

Furthermore, the analysis of question (9a) of the general questionnaire revealed, that participants who started with the system generated instruction (IS2) would change their walking preferences if confronted with a bird's-eye view of the scenario on the 2nd floor. Six out of eight would choose the shortcut ($\chi^2$ =8.0, *df*=2, *p*<0.05; Cramér's *V*=1.0).

# 5 Discussion

The task was to reach two consecutive targets in a multilevel building with the help of a given route instruction. Both types of instruction served their purpose – all participants successfully reached their respective target on the 2$^{nd}$ floor and starting point. The qualitative analyses support the assumption that, due to the additional structural cue *block* + path, the participants built up (or faster updated) a more detailed internal mental representation of the environmental setting and thus were more likely to choose another, shorter returning path.

Therefore, the presented block structure is believed to be a good landmark, regarding the choice of a cognitively efficient return path. This in turn could be utilized for the generation of route descriptions by the presented guidance system. By accordingly annotating maps and implementing these kind of block structures as salient structuring landmarks it is not only possible to save user/body turns and make the generated adaptive instructions briefer and thus easier to recall, but also help novice building users with this cue to build up (i.e. faster update) their internal mental representation.

One key feature of an adaptive wayfinding guidance system is that, route instructions should be generated according to the cognitive principles underlying human route descriptions [6]. However, good general cognitive principles that can provide useful wayfinding information specifically suitable to human users within certain situations are in fact very difficult to discover. The empirical finding involving structuring landmarks such as blocks in this paper can help a guidance system optimize its wayfinding process to avoid redundancy with respect to the human-friendly principle, and therefore, improve to a great extent the effectiveness and efficiency of the system itself and generate more adaptive and intuitive route instructions. Specific landmarks such as blocks will be instantiated as salient structuring landmarks and used by the GOSLRI component to generate high-level structuring landmark-based route instructions.

Further research will address the degree of complexity and accuracy regarding additional architectural information implemented in indoor wayfinding instructions, e.g. regarding block size etc.

## Acknowledgments

Thanks go to the German Science Fund (DFG) for funding and the research team of I5-DiaSpace of SFB/TR8 Spatial Cognition at the University of Bremen.

## References

1. Carlson, L.A., Hölscher, C., Shipley, T.F., Conroy Dalton,R.: Getting Lost in Buildings Current Directions in Psychological Science 2010, pp. 19–284 (2010)
2. Cuayáhuitl, H., Dethlefs, N., Frommberger, L., Richter, K-F., Bateman, J. : Generating Adaptive Route Instructions Using Hierarchical Reinforcement Learning. In: Hölscher, C., et al. (eds.) Spatial Cognition V - Reasoning, Action, Interaction, pp. 319–334. Springer, Berlin (2010)
3. Hölscher, C., Brösamle, M., Vrachliotis, G.: Challenges in Multi-level Wayfinding: A Case-study with Space Syntax technique. Environment and Planning B: Planning & Design (in press)
4. Hölscher, C., Büchner, S., Meilinger, T., Strube, G.: Wayfinding Strategies and Map Use in a Multi-Building Ensemble. In T. Barkowsky et al. (eds.): Spatial Cognition V - Reasoning, Action, Interaction., pp. 365–380. Springer, Berlin (2007)
5. Hölscher, C., Meilinger, T., Vrachliotis, G., Brösamle, M., Knauff, M.: Finding the Way Inside: Linking Architectural Design Analysis and Cognitive Processes. In: Freksa, C., et al. (eds.) Spatial Cognition IV - Reasoning, Action, Interaction, pp. 1–23. Springer, Berlin (2005)
6. Klippel, A., Hansen, S., Richter, K.-F., & Winter, S. Urban Granularities - A Data Structure for Cognitively Ergonomic Route Directions. GeoInformatica, 13 (2), pp. 223-247 (2009)
7. Kuipers, B.: Modeling spatial knowledge. Cognitive Science, 2: pp. 129–153 (1978)