Supporting Orientation During Indoor and Outdoor Navigation

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Abstract Supporting orientation is one of the major challenges when designing pedestrian navigation systems. Especially for indoor areas, it is still an open question, which landmarks can be used to support the cognitive process of orientation. Furthermore, it has to be analyzed whether the referenced landmark type has to be adapted to different instruction types like verbal and visual displays. In order to address these questions we conducted a study with 132 participants who had to navigate different routes and give verbal instructions supplemented by drawing sketch maps. Our results show that orientation information is important in indoor areas, too. Moreover, the instruction type significantly influences the chosen orientation information. We therefore argue that it is important to incorporate orientation information in future indoor navigation systems and adapt the information based on the instruction type.

Keywords Pedestrian navigation · Orientation · Sketch maps

1 Motivation

Several indoor navigation prototypes were developed in the past years. Nevertheless, navigation interfaces for indoor environments are still less explored compared to outdoor environments (Huang and Gartner 2010). Common navigation prototypes rely on different depiction ranging from augmented or virtual reality interfaces to plain

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map depictions with different levels of complexity (for an overview and discussion of possible depictions see e.g. Butz et al. (2001)). All in all, map depiction in combination with text instructions are the most popular form of communicating route instruction (Huang and Gartner 2010). Moreover, the majority of these systems uses turn-by-turn instructions to guide the wayfinder.

Nevertheless, landmarks, and especially landmarks that can be used to maintain orientation during a complex navigation task are missing in most prototypes (Anacta et al. 2016). Orientation during navigation implies that human beings are able to identify their own position in relation to the objects in the environment and their potential destination in order to reach a specific point (Golledge 1999). Landmarks can help to support this cognitive process. At decision points, landmarks are required to maintain orientation (Michon and Denis 2001). On the other hand, these salient objects can also be used to support (global) orientation at non decision points (Anacta et al. 2016).

The study presented in this paper addresses the research question which landmarks are chosen by wayfinders to support orientation at non decision points while navigating a complex indoor/outdoor area. Therefore, we conducted a study in order to gain a deeper understanding how human beings would describe a route through this environment and which landmarks are used to explain these routes. The participants had very good spatial knowledge of the test area and had to give verbal route instructions while navigating. Moreover, they had to draw a sketch map after the task in order to collect visual route instructions. We analyzed the gained data with two research questions in mind. First, do participants use different landmark types in verbal route instructions compared to their sketch maps? Second, are different landmark types used for indoor areas compared to outdoor areas? Consequently, we are expanding the work and ideas of Anacta et al. (2016) for indoor environments.

The remainder of this paper is structured as follows. First of all, we report on the related work concerning landmark classification, which was used to annotate our data. In the following section our study and the annotation process is described in detail and the results are presented. Finally, the implications of our findings and ongoing work is discussed.

2 Landmark Classification

Basically, the rough subdivision into global and local landmarks is a frequently used classification (Winter et al. 2008). Local landmarks can be located at decision points or along the route, whereas global landmarks are located off the route and are therefore not necessarily immediately visible. Moreover, decision points can be subdivided in potential choice points and route choice points where a turn of direction has to be made (Lovelace et al. 1999). A more detailed framework for landmark classification is proposed in Schwering et al. (2013) and extended in Anacta et al. (2016). The authors additionally distinguish point-like and regional landmarks. They introduce orientation landmarks and subdivide the categorization depending on whether

the instruction includes a turning movement or not. The authors found out that more than half of the instructions people give support orientation. Only about a quarter of the instructions are related to a turn information.

We based our annotation on the landmark categories described in Schwering et al. (2013) and Anacta et al. (2016) but simplified them to the following.

- OGL: orientation using global landmark (off the route)
- OLL: orientation using local landmark (at the route)
- NTLL: non turning movment using local landmark (at potential decision point)
- TLL: turning movement using local landmark (at decision point)

Consequently, our annotation focuses on orientation landmarks, which consist of OGL, OLL, and NTLL, as they do not imply a turning action (Anacta et al. 2016). Moreover, we also counted the amount of TLL, as this type is the most prominent landmark category in turn-by-turn instructions.

3   Study

In the next subsections the experimental set-up, the annotation process and the results are described.

3.1   Test Environment

The study took place at the University of Regensburg, which is a large-scale campus covering an area of approximately $0.5\,km^2$. It consists of several partly connected buildings which can be reached using either indoor paths or traversing the outdoor campus area (see Fig. 1, left). The buildings consist of several levels with office rooms, lecture halls and public places like cafeterias and shops. The whole campus is already modeled in order to compute routes through the different buildings. An example of the complexity of a building model is shown in Fig. 1 (right).

3.2   Participants

Students of an undergraduate course were instructed to recruit test users for the study described in this paper. The recruitment of the participants was a course requirement. This resulted in a test sample of 132 participants. 81 male and 51 female persons participated in the study. All of the participants were students at the University with different courses of study and have been studying for at least one semester (mean = 5.9) . Their mean age was 23.1 years with a standard deviation of 3.0 (range:19–32). All in all, participants had expert knowledge of the area and visit the place on a regular basis.
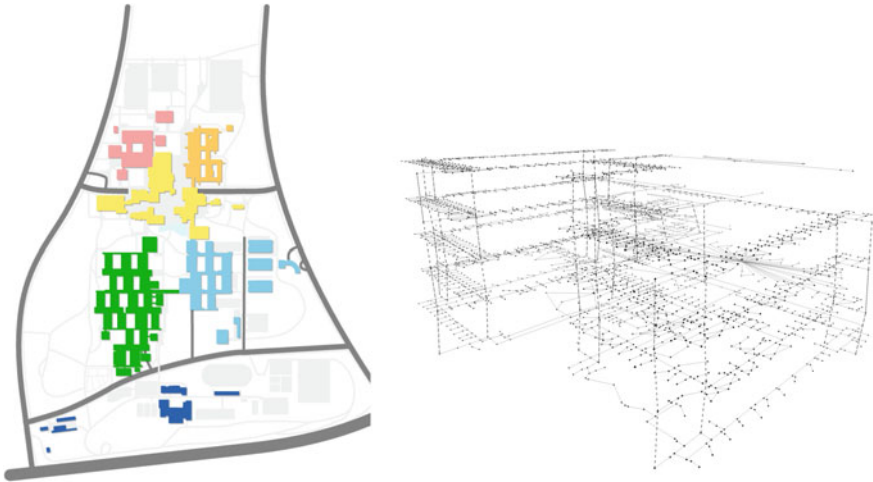
Fig. 1 Overview of the test area (*left*) and graph model of an exemplary building (*right*)

3.3 Procedure

The study consisted of three parts. Before the experiment, participants could freely chose a route on the campus. One restriction was that it had to go through at least two areas of the university (including the buildings and the outdoor area) to ensure sufficient complexity of the collected data. Moreover, participants had to confirm that they are very familiar with the route. The participants were informed beforehand that the route choice would be restricted.

After filling in a form concerning their demographic data, test persons navigated the chosen route accompanied by two test supervisors. The latter meanwhile noted the exact course of the route in architectural floor plans that were not visible to the participants. The data collected during the first part of the experiment was used to analyze whether participants deviate from the shortest route, if they are free to choose their own preferred route. Moreover, we analyzed which factors like the amount of indoor and outdoor path or the number of stairs that have to be taken influence this decision (see Müller et al. 2017).

Afterwards, participant were asked to walk back the same route, this time giving verbal route instructions as if they would explain the route to a stranger. This "thinking aloud" method was already proposed by Sefelin et al. (2005) in order to gain a set of landmarks that can be used to guide a person. The verbal instructions were noted and the position of the participant and the referenced objects were marked in the architectural plans.

Choosing a route and generating route instructions can be cognitively demanding tasks. We divided the experiment into two parts to separate these spatial reasoning tasks in order to unburden the participants during the experiment.

As a last step, the participants were asked to draw a sketch map of the route they have chosen on a A4 sized paper. They were free to add any information they liked. The instruction was to draw a map that could be used by strangers to find the way. No time limit was given.

3.4 Annotation

For the results and considerations presented in this paper, the data of phase two and three of the experiment was used (see Sect. 3.3). First of all, the sketch maps and the verbal route instructions had to be annotated. Figure 2 shows an example of a sketch map. Gray-shaded areas indicate indoor environments. Circles represent global landmarks (OGL). In the exemplary sketch map these are the lecture hall "Audimax" (OGL_1), a pizzeria (OGL_2), a lake (OGL_3), and the computer
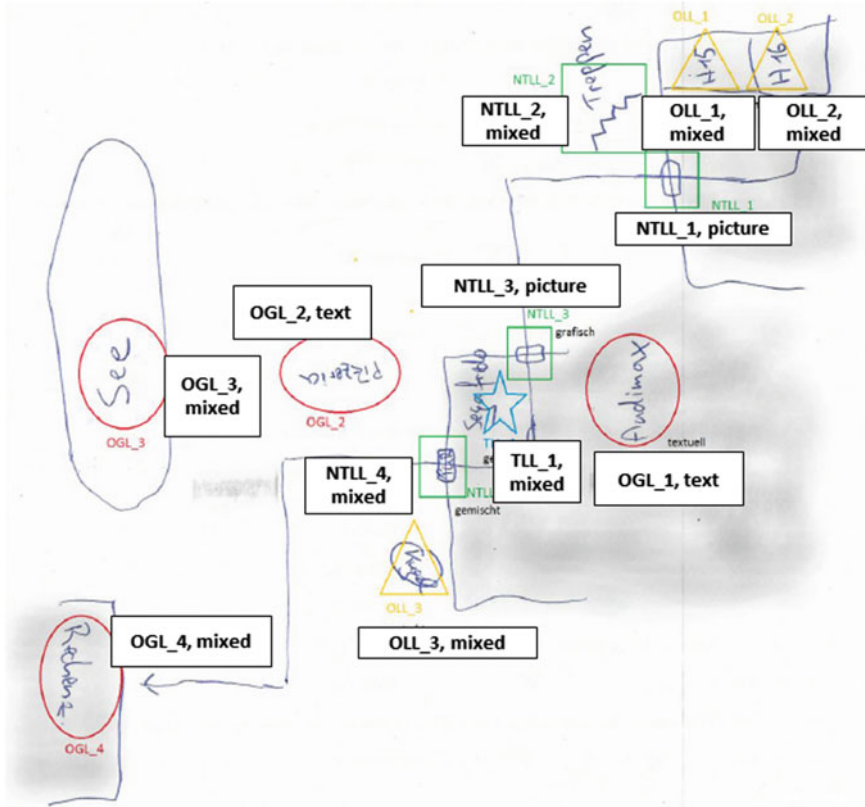

Fig. 2 Example of an annotated sketch map

center (OGL_4). Squares indicate local landmarks without turning movements like doors (NTLL_1, NTLL_3, NTLL_4) or stairs (NTLL_2). Triangles are local landmarks used for orientation (like lecture halls OLL_1 + OLL_2 and artwork OLL_3). Finally, stars represent landmarks where a change of direction is needed (a cafeteria TLL_1). Moreover, we annotated whether the landmark is depicted graphically, using a text label, or whether these techniques are mixed. These different drawing methods are not discussed in this paper, but could be topic of future work. Our classification is only based on the position of the landmark relative to the route. Therefore, the annotation did not differ for indoor and outdoor landmarks. The same annotation process was applied to the transcribed verbal route instruction. The following example is translated from German to English.

- (Outdoor) Go straight ahead up the stairs (NTLL).
- (Outdoor) Enter the building.
- (Indoor) Pass the lecture hall "Audimax" (OGL) and go to the toilets (OLL).
- (Indoor) Go left at the cafeteria (TLL).
- (Outdoor) Pass the pizzeria (OGL), the "Kugel"[1] (OLL) and the library (OGL) are on your left.
- (Outdoor) Go left in front of the lake (TLL).
- (Indoor) Enter the building through the door (NTLL).

3.5 Results

The mean route length of the chosen routes was 350.7 m (SD = 120.6), with a mean indoor part of 206.8 m (SD = 112.8) and a mean outdoor part of 143.9 m (SD = 139.4) in length. We formulated different hypotheses according to our research question if the navigation area (H_1 and H_2) and the instruction type (H_3 and H_4) influence the chosen landmarks.

- H_1: In the sketch maps, the amount of orientation landmarks differs for indoor and outdoor environments.
- H_2: In the verbal instruction, the amount of orientation landmarks differs for indoor and outdoor environments.
- H_3: In indoor areas, the amount of orientation landmarks differs for the verbal route instructions and sketch maps.
- H_4: In outdoor areas, the amount of orientation landmarks differs for the verbal route instructions and sketch maps.

Orientation landmarks are defined as OLL (orientation local landmark), OGL (orientation global landmark), NTLL (non turning local landmark), therefore landmarks at decision points were not taken into account. Each landmark type was analyzed separately. To calculate the differences between the amount of indoor and

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[1]The "Kugel" is a large and well-known work of art at the university.

Table 1 Mean distribution of landmark type in % (SM = sketch map; VI = verbal instruction)

	Indoor (SM)	Outdoor (SM)	Indoor (VI)	Outdoor (VI)
OLL	35.1	25.2	28.5	30.5
OGL	7.9	19.1	1.2	7.8
NTLL	44.0	36.0	53.5	38.4
TLL	13.0	19.7	16.8	23.3

outdoor landmarks, we calculated the relative amount of landmarks, since the routes contained more indoor parts for the majority of the participants. This means, we calculated the percentage of chosen OLL, OGL, NTLL, and TLL separately for indoor and outdoor areas and different instruction type (see Table 1 for the descriptive statistics).

None of the data was normally distributed, we therefore conducted a Wilcoxon signed-rank test. The results show that concerning H_1, for all three landmark types the nullhypothesis can be rejected ($p < 0.01$). For indoor areas, significantly more OLL and NTLL are drawn, whereas less global landmarks are referenced.

In the verbal route descriptions the same significant results were found for global landmarks and NTLL, therefore H_2 can be assumed for these landmark types.

In outdoor areas, global landmarks are drawn more often in sketch maps than used in route instructions ($p < 0.001$). On the other hand, OLL and OGL differ significantly in indoor environments in both conditions (SM and VI). Local landmarks (OLL) and global Landmarks (OGL) are drawn more often in sketch maps ($p < 0.001$).

The most frequent landmark type for both instruction types is a local landmark at a decision point where no turn of direction is implied. Local landmarks at turning points only make up about 20% of the landmarks. This clearly indicates the need for orientation landmarks for indoor and outdoor navigation.

4 Conclusion and Future Work

To summarize the results, we found out that global landmarks are significantly less relevant in indoor environments for both, sketch maps and verbal instructions. Moreover, sketch maps contain more global landmarks compared to verbal instructions. The second finding is in line with the results for outdoor areas reported in Anacta et al. (2016).

Global landmarks can be used to give an overview of the wayfinding area but have to be well-known and ideally highly visible. These objects are rather rare in indoor environments. When navigating in an indoor area, it seem pointless to refer to a global landmark that is located outdoors. Furthermore, local landmarks at potential decision points are mentioned more often in indoor environments. Our results give
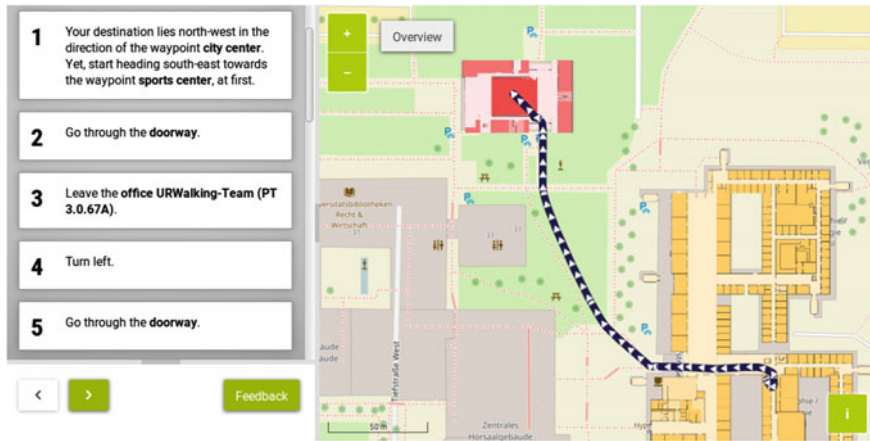
Fig. 3 Screenshot of our navigation system incorporating different landmark types

hints that map material should reference global landmarks to maintain orientation, whereas textual instructions should rely on local landmarks for orientation.

In the present study only participants who were very familiar with the test environment were part of the test sample. The related work shows that this factor influences the decision which landmarks and how many objects are chosen (Lovelace et al. 1999). It is part of future work to examine whether the chosen landmarks of our experiment are helpful for unfamiliar wayfinders.

All in all, the results show that orientation landmarks are an important landmark type for both, indoor and outdoor areas. Nevertheless, the type of landmark preferred by the users differs depending on the area and type of instruction. Therefore, our future work will focus on how to integrate the different landmarks for different environments and different instruction types like text and map-based descriptions. An example of our preliminary realization of these concepts is given in Fig. 3. Our next step will be to graphically highlight global landmarks and to analyze at which route points orientation landmarks should be included.

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