Where is the Landmark? Eye Tracking Studies in Large-Scale Indoor Environments

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Abstract. Several studies show that the use of landmarks is crucial for pedestrian navigations systems. Furthermore, there are well-defined landmark features like its visual salience. However, the assessment and the selection of landmarks especially in large scale indoor environments is rarely examined. We conducted a user study in the university of Regensburg and assessed the visual attraction of objects with an eye tracker. Our findings show that functional landmarks like doors and stairs are most likely to be looked at and named as a landmark. Moreover, we could prove that measuring visual salience only is not sufficient to identify landmarks with regard to the use in a pedestrian navigation system.

Keywords: Landmarks, Eye Tracking, Wayfinding, Landmark Salience, Pedestrian Navigation Systems

1 Motivation - Using Landmarks for Pedestrian Navigation Systems

Where do people look at when navigating in a large scale indoor environment like a shopping center, a train station or a university? And - even more important - what objects can assist them to find their way? It is a fact that pedestrians prefer route instructions based on landmarks since they are considered to be the most effective way to communicate navigation instructions [6]. The importance of this type of navigational aid is well reported [2, 6, 10, 11, 17, 18]. In general, a landmark's salience is considered to result from visual, semantic and structural properties, accompanied by its advance visibility [14, 17, 18]. However, it is still an open question, which features of an object are the most essential to assess its suitability for serving as a landmark. This is especially problematic in indoor environments: Instructions require a higher density of landmarks since the route usually contains more turns but then there is a smaller choice of landmark categories despite the high diversity of distinct objects available [1, 9]. Nowadays high-tech devices and fast data transfer make pedestrian navigation systems feasible [9]. Even though there is strong evidence that people tend to get lost indoors more easily than outdoors [1] there is still a lack of scalable and practicable solutions for navigation systems in large-scale indoor environments. Especially the

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selection and use of landmarks is either not the research focus or done subjectively by the associated researchers, see e.g. [5, 8, 15]. [7] examines the selection of landmarks in indoor environments but does neither conduct a real world experiment, nor is the research focused on general landmark categories to choose for pedestrian navigation systems. All in all, most surveys explore the evaluation of the salience of outdoor landmarks [2, 6, 10, 11, 18]. Regarding indoor eye tracking studies in the field of wayfinding, most of the work does not analyze the selection or assessment of landmarks. Furthermore, it is often conducted in virtual environments [4, 16] so that the findings cannot be easily applied to real world scenarios. [12] focus on sign placement in a nursing home and thus on only one landmark type. Once again, there is little research on real world eye tracking for the selection and examination of landmarks in indoor environments.

The contribution of our work reported in this paper is that we get a close look how indoor space is perceived while navigating in a real world scenario. Our findings are made by conducting a user study described in the next paragraph. We point out that the visual attraction of a landmark does not seem to be the most important feature when it comes to the use for indoor pedestrian navigation systems and show that functional landmarks are most suitable for indoor guidance.

2 User Study

We carried out a real-world experiment in the rather complex indoor environment of the university of Regensburg with 34 participants (16 male, 18 female). Their age ranged from 19 to 30 years (average: 22.5 years). Our main research questions were to identify where people look at and which landmarks are selected in indoor environments during a navigational task. The test route consisted of seven turns of direction, two transitions of building parts and three floor changes (Fig. 1 left). Test persons had to complete two runs. At first, they followed the experiment instructor wearing a mobile eye tracker meanwhile their gazes were recorded so that the visual attraction of objects along the test route was assessed.

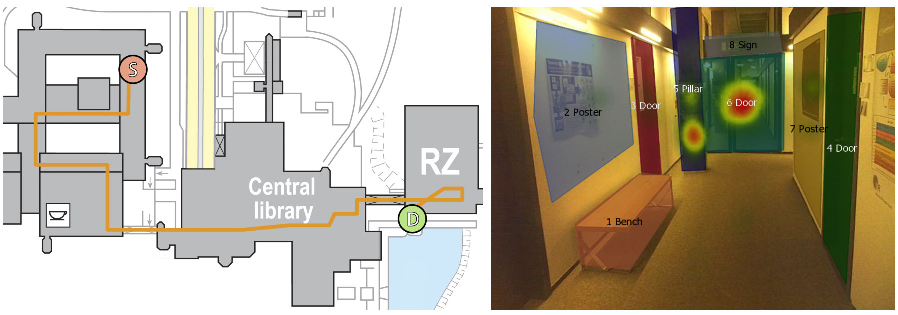

Fig. 1. Test route with start point (S) and destination (D) (left); Exemplary reference view with areas of interest and heat map (right)

The instructor did not give route instructions. Participants were told to look at their surroundings and try to remember objects that can be used to describe the route to a stranger afterwards. Thus, the test person's attention was directed to salient objects that can serve as landmarks in route instructions. This avoids the phenomenon described in [3]: In their study participants selected salient objects that may not be included in routing instructions (for example objects that are likely to be moved such as cars in outdoor areas). The first run was conducted according to the findings of [6], who point out that previous spatial knowledge is crucial for wayfinding decisions and thus for selecting landmarks. Consequently, in the second run participants named landmarks as though they would explain the route to a stranger and the test supervisor recorded this data manually in addition to the eye tracking data of the first run. The second run was done accordingly to the experiment design to collect landmarks of [13]. In this run no eye tracking data was recorded. Subsequently, the gaze data was manually mapped to Reference Views using the SMI BeGaze-Software which also automatically identifies fixations in the dynamic context. Gazes at objects that had to be passed such as stairs or doors were not mapped while the test person was walking on or going through them, since these fixations are only needed for locomotion. 258 potential landmark candidates like elevators, escalators, stairs, doors, plants, information boards and signs [1, 9] were defined as areas of interest (Fig. 1 right). Afterwards they were assigned to one of four landmark categories:

- Architecture (Arch): Pillars and fronts
- Function (Func): Doors, stairs and elevators
- Information (Info): Signs and posters
- Furniture (Furn): Tables, chairs, benches and vending machines

Overall, participants selected 953 landmarks (median 22,5 per person) and fixated 2593 objects (median 83,5 per person). As shown in the first two rows of Table 1, test persons primarily looked at functional objects. This does not only result from the fact that more functional objects are located along the test route. Row three shows that the probability that a user fixates a functional object is 40%, which is relatively high compared to the remaining categories. Similar and even more distinct results were achieved concerning the selection of landmarks (4-6 in Table 1). Besides this findings, we calculated the median of the fixation times of selected landmarks. Very surprisingly, the median for every category except for functional objects is 0 ms (functional objects: 564 ms). This means that more than half of the selected landmarks were never fixated at all. Consequently, this relation was closer examined. Contrary to our assumption that selected landmarks were fixated previously, row seven in Table 1 underlines that there are less overlapping values between the groups than expected. A remarkable example is the furniture category: For only 26% of the selected landmarks gazes could be detected.

Observations \ Category (cat)	Arch	Func	Info	Furn	$\sum_{cat}$
(1) #(fixated objects in cat)	613	990	648	342	2593
(2) P(cat|fix=true)	0.24	0.38	0.25	0.13	1.00
(3) P(fix=true|cat)	0.31	0.40	0.33	0.20	-
(4) #(selected objects in cat)	142	549	131	131	953
(5) P(cat|sel=true)	0.15	0.58	0.14	0.14	1.00
(6) P(fix=true|cat)	0.07	0.22	0.07	0.08	-
(7) #(selected and fixated objects in cat)	56	384	48	34	522

Table 1. Observations separated by different landmark categories: Total number of fixated (1) and selected (4) objects for every category. Probability that a fixated (2) or selected (5) object belongs to a certain category. Probability that an object of a certain category is fixated (3) or selected (6). Intersecting set of selected and fixated objects (7).

3 Discussion and Future Work

All in all, the implications of our findings are that a pedestrian navigation system should propose functional landmarks in the surroundings of the user since they are most likely to serve as landmark and can be recognized and named easily.

It is a matter of further investigation why a lot of selected landmarks are not fixated in the first run. Possible reasons for this could be that test persons already had spatial knowledge of the environment previous to the experiment. Moreover, participants could have recognized objects with peripheral vision which cannot be detected by contemporary eye trackers.

Currently we are conducting similar studies in shopping centers, trains stations and exhibition halls. The next step is to consolidate this data and identify how the salience of an indoor object can be calculated e.g. relatively to its position on the route and its category. In this context, functional landmarks seem to be the most promising candidates. Furthermore, our study shows that it is necessary to collect more features and not exclusively visual attraction. If the navigation system can select the most salient landmarks on the route, several interface design decisions arise. How many landmarks should be displayed and how? Do we really need a map to guide the user if we have landmarks? Evaluating the usability of a pedestrian navigation interface is a manifold research topic on its own and a lot of researchers already deal with this problem. We believe that our current work can help to realize a user-friendly and particularly scalable indoor pedestrian navigation system.

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