Providing directions in indoor spaces: two approaches for public displays compared

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Abstract

Navigating public buildings can be challenging for people unfamiliar with their interior. In addition to smartphones, public displays can support indoor navigation. In this paper, we describe and evaluate two approaches to provide memorable multimodal directions via a kiosk system upon entry into a building. Results from an initial user study indicate that people can successfully navigate to their destination using such directions and that map-based directions may lead to a better performance than photo-based directions. A subsequent deployment study with an improved system confirmed the overall preference towards the map-based approach.
Keywords: Indoor navigation, public displays, evaluation

1 Introduction

Navigating large public buildings like hospitals or airports can be challenging, particularly for first-time visitors. In order to support people in finding their destination, different means have been proposed. Good *signage* is not always available and generally lacks personalized information. *Mobile devices* can support indoor navigation but usually require accurate indoor positioning (i.e. via a supporting infrastructure), and expecting everyone to carry a suitable device (cf. [16]) may exclude some users. *Interactive kiosk systems* are an alternative means that address some of these shortcomings.

The approach we propose here relies on a stationary, touch-enabled kiosk system without requiring additional devices or an extensive infrastructure. Users search for their destination and then memorize the instructions. Our research focuses on how to convey indoor directions to people who are unfamiliar with the building. We compare the efficiency and memorability of a photo-based approach showing a single photo and a map-based approach displaying a floor plan. We evaluate aspects such as understandability, error rates, and performance in an in-situ study in an office building. Based on those results, we improved the system for a deployment study in the same building. In this study, we focused on preferences for either the map-based or the photo-based approach and interaction times.

In the following, we first discuss related work and introduce our approach. We then report on a user study and the subsequent deployment study that we ran to evaluate the approach. Finally, we briefly discuss the results and conclude by summarizing the key insights.

2 Related Work

There is an extensive amount of related work on navigation support. Here, we mainly reviewed work that uses large displays to support indoor navigation.

According to Carlson et al. [3], wayfinding is affected by the structure of the building, the strategy a user applies, and the completeness of the cognitive map. Montello [13] and other researchers [7, 1] distinguish between planning and moving. In our system, users choose a destination to receive route directions (planning) and then walk towards the target location using the memorized instructions (moving).

GAUDI [10] also consists of a kiosk system showing a list of destinations but includes a network of distributed situated displays. Users select a destination and then follow arrows shown on displays placed throughout the building. While this approach supports indoor navigation, it also requires an extensive infrastructure.

Hermes 2 [16] incorporates a mobile device to provide directions via downloadable videos and maps. The mobile device can be combined with arrows shown on office door displays along the route. This facilitates personalization but still requires a display infrastructure and a mobile device. IRREAL [2] used a similar approach.

The Rotating Compass system [15] projects arrows onto the floor at decision points. Vibration signals on personal devices inform people when the arrow is pointing in the direction they should follow. This system provides privacy but also depends on a display infrastructure and mobile devices.

In summary, most of the previously proposed approaches can provide directions but do also require an extensive infrastructure and/or a mobile device. They mainly convey directions using arrows, maps, and other media. Our approach only requires a single display, incorporates photographs or maps, and provides memorable navigation instructions.

3 Approach

In order to provide personalized indoor directions with minimal technology, we designed an approach to generate directions, which cover the entire route. They thus need to be memorable given that human short-term memory is limited [12]. While the shortest path may be the fastest route, it is often complicated and hard to describe concisely [14]. We thus had to select a route that can be described concisely. Therefore, we partitioned each floor into subareas comprising several targets (similar to [4]) and then chose the least complex path to the subarea containing the destination (i.e. containing fewest turns). The origin of the partitioning is the central elevator (next to the main staircase), which is clearly visible from all floors. In addition, directions only include instructions for decision points, which further reduces the complexity of the directions.

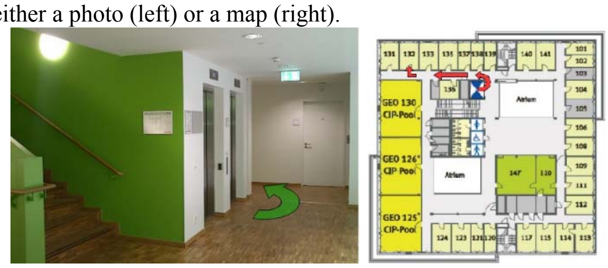
The resulting directions include textual instructions such as *``After leaving the elevator on the first floor, turn left twice and go ahead along the corridor until you reach the second last door on the right side (Room 132)."* supplemented by either a map or a photo (cf. Fig. 1). Photographical descriptions start at the elevator (key landmark) and aim at covering as much of the route as possible. The design of the arrows and the textual description are based on the concept of spatial chunking and wayfinding choremes [8, 9]. A photo shows many details and can thus facilitate fast recognition and hence potentially successful navigation.

A map (floor plan) depicting the layout of the corresponding floor and the destination can also complement wayfinding instructions. Figure 1 (right) shows an example route highlighted using the same arrows as before. Maps show the entire route and correspond to locally mounted floor plans, thus potentially facilitating successful navigation as well.

4 User study

In order to assess and compare the photo-based and map-based directions, we conducted a user study in a university building with a square layout (Fig. 1) with six floors. Access to different floors is provided by two staircases hidden behind doors and a central one. Adjacent to the main staircase are two elevators. Due to their unique orientation and visibility, the elevators are useful landmarks. Visitors see them first when entering the building. It is thus likely that they will choose one of these two options to reach another floor. Even if a visitor uses the main staircase, the elevator can still serve as a reference.

Figure 1: Complementing textual wayfinding instructions with either a photo (left) or a map (right).



24 students (13 female, 11 male) were recruited for the user study, all of them unfamiliar with the building.

Directions comprising textual instructions and an augmented photo or map were displayed on a 23" touchscreen.

4.1 Procedure

Participants had to reach two destinations, one using a photo and one using a map. The two targets were at different locations to minimize learning effects. Participants were divided into four counter-balanced groups to counteract order effects. They were asked to fill out a questionnaire for basic background information and to think aloud during the wayfinding portion. Afterwards, the first task was explained and performed, e.g. *``Try to find James Hanson using the display in the entrance hall using a photo."* An observer followed participants measuring their times and noting errors (i.e. deviating from the given route). The measured time included the interaction with the system and the time needed to complete one task. After each task, a questionnaire assessing effort and acceptance was handed out.

Next, the user had to find the second destination using the method not used in the first task. Afterwards all participants were asked to complete the same questionnaire as before but for the second method, supplemented by a question about the preference between both methods. The questionnaire contained the ``Usefulness, Satisfaction and Ease of use" questionnaire (USE) [11], the Santa Barbara Sense of Direction (SBSOD) questionnaire [6], and NASA Task Load Index (NASA TLX) [5].

4.2 Results

The study produced a number of interesting findings summarized in Tab. 1. The USE and the SBSOD questionnaires use a seven point Likert scale, ranging from 1 (not familiar/strong disagreement) to 7 (very familiar/strong agreement). NASA TLX uses a scale from 1 (very low) to 20 (very high). The SBSOD questionnaire produced an average score of 3.65.

Table 1: Key study results: average times needed for interaction and for wayfinding, results of questionnaires, usage preferences (Yes/Maybe/No) and total errors produced.

Objects	Interaction	Wayfinding	USE	NASA TLX	Use (Y/M/N)	Errors
Photo	52 s	151 s	5.4	5.7	11/8/5	14
Map	49 s	117 s	6.2	4.5	17/7/0	6

Familiarity with navigation systems ranged from 1 to 7 (mean value: 4.0). Table 1 summarizes the results for comparing both methods. While interaction times were very similar, 52 s (standard deviation σ=29 s) using the photo and 49 s (σ=25 s) using the map, the wayfinding times differed greatly: 151 s (σ=67 s) using the photo and 117 s (σ=28 s) using the map. A two-sample t-test analysis indicates that the generated averages of the wayfinding times are significantly different with α=0.05.

The interaction times indicate a learning effect. For the first task, participants needed an average time of 65 s (σ=30 s) to obtain the particular information. For the second task, they needed an average time of 37 s (σ=15 s). A two-sample t-test analysis indicates that the generated averages are significantly different with α=0.001.

Contrasting the USE and NASA TLX results, we observed that maps received better usability scores and resulted in lower reported workload. A two-sample t-test analysis indicates that the generated averages of the USE values are significantly different with α=0.05.

A similar pattern emerged as we analyzed the preference values: more people would use maps than photos when being under time pressure (17 vs. 11). Five participants would not use photos, whereas no one rejected map-supported directions entirely. Participants committed more than twice as many errors when using the photo-supported approach (14 vs. 6).

While 19 participants preferred maps, five favored photos. Destinations were reached directly via the proposed route in 34 out 48 cases. Nobody failed entirely. Six participants were confused about the instruction *``Turn left twice"* in combination with the photo shown left in Fig. 1: they turned three times in total instead of two times.

Three people deviated from the suggested route. Everyone used the main staircase or the elevator and not one of the hidden staircases.

5 Deployment study

In order to collect real world usage data and to receive further insights into the usability of the system, we conducted a deployment study in the same building. We installed a slightly updated version of the system, and then recorded interactions for ten weeks.

5.1 System improvements

Results of the user study indicated several potential improvements for the system.

To increase the visibility of the destination, the colored map was greyed out and the destination room was highlighted in orange. Photos considered confusing were replaced by photographs showing larger parts of the floor while keeping the elevator as main reference point. Figure 2 shows the same destinations as above with improved illustrations. Sentences were split into smaller pieces and placed below each other yielding an enhanced overview. Ambiguous expressions such as *``Turn left twice"* were replaced by *``Turn left"* and *``Take the left corridor"*.

Figure 2: Improved route instructions. Left: Floor plan. Right: Photograph with elevator.

5.2 Procedure and apparatus

All interactions were logged by the system, e.g. when users switched from one visualization to another, as were the times needed for the interaction. Both visualizations appeared with equal chances to ensure comparability. Navigation instructions were displayed on a 32" wall-mounted touchscreen display inside the entrance hall (Fig. 3). The display was subdivided vertically into three parts: The upper part showed navigation instructions. A small middle section allowed users to select a language and to return to the starting page. The lower part was dedicated to selecting destinations. In contrast to the previous study, usage was not restricted to first-time visitors.

Figure 3: System with navigation instructions in the foyer.

Table 2: Outcome of deployment study: Interaction times and changes of illustration with respect to all appliances, when starting with a map, and when starting with a photo.

Objects	In total	When started with a map	When started with a photo
Interaction time	36 s	39 s	33 s
Switch illustration	175	134	39

5.3 Results

The results of the deployment study are summarized in Tab. 2. In total, we recorded a thousand uses of the system, 513 of which started with a map, the remaining 487 started with a photo. The average duration of use from the first interaction to the last interaction was 36 seconds (σ=43 s): 39 seconds (σ=48 s) when starting with a map and 33 seconds (σ=36 s) when starting with a photo. A two-sample t-test analysis indicated that the generated averages are significantly different with α=0.05.

Users changed the visualization to the alternative solution on 175 occasions: users switched 134 times to the map when starting with a photo and 39 times from the map to the photo. On 825 occasions, people used the preset visualization.

6 Discussion

Overall, the map-based approach seemed to best the photo-based approach. It received higher USE values, required less time and effort to complete the task, and resulted in fewer errors. More participants found the destination directly and the majority preferred this method. It appeared that the instruction *``Leave the staircase on the first floor and turn left twice"* confused nine participants. Six of them used the photo, which did not show the entire route. These participants might have overlooked that they turned left one time already when leaving the staircase/elevator resulting in a third, erroneous turn. The map may have compensated this issue as it depicts the entire route. The potentially ambiguous combination of text and photo could (partially) explain the lower rating of the photo-based approach.

The deployment study confirmed our initial impression of people preferring the map. More than three times as many people switched from the photo to the map than vice versa. Users may need the map as a confirmation since the photo does not show the entire route. In contrast, the map seems to provide an overview and does not depend on a confirmation using the photo. Maps indicating a whole floor convey survey knowledge better than a photo representing only a subset of the route. People's preference for the map might also result from being more familiar with using maps as navigation aids. The homogeneity of the building might be another reason as it lacks distinctive landmarks making it difficult to localize the memorized photo while navigating. Nevertheless, the majority did not change the visualization and used the preset illustration. The average interaction times when using a photo is shorter than when using a map, though both values are still similar. Compared to the previous study, this aspect in favor of the photo is reversed.

The initial user study was subject to a number of limitations in addition to the ambiguous photo. The study took place in a single building and did not use a large, representative selection of participants. Therefore, studies in more complex buildings with a different interior structure and a larger cohort of participants would considerably improve the generalizability of the results. Furthermore, thinking aloud may has influenced users' behavior.

The deployment study is limited as well. Due to relying on logging alone it was not possible to distinguish people actually searching for information from those who just played with the system out of curiosity. Logging started with the first touch on the screen and finished with the last touch. Thus it is unclear how much time users spent in front of the display right before the first and after the last interaction. Since users could switch between both visualizations, comparability between the average times of both studies is limited. The partitioning of the floors may be inapplicable to buildings missing a key landmark like an elevator.

Despite these limitations, the study provides initial evidence that one-time multimedia directions can help people to successfully navigate buildings. The majority of the participants was able to memorize and follow the given directions. Maps complementing textual directions resulted in better performances than photos, though further studies are needed to fully assess this aspect. The deployment study shows that such a system is perceived as useful and it continues to receive regular use.

7 Conclusion

In this paper, we proposed an approach to produce directions for indoor environments without an extensive infrastructure or mobile devices. It relies on using the least-complex instead of the shortest route, describing the entire route instead of only segments, and partitioning environments to simplify directions. Directions are complemented by augmented photos or maps to increase memorability. We reported on an in-situ user study that employed a prototypical system to guide people to locations inside an unfamiliar building. The results indicate that such a system can facilitate successful indoor navigation.

In a subsequent deployment study we improved the visualization and the textual descriptions based on the results from the user study. Results confirmed that people favor the map-based over the photo-based approach and continue using the system. Consequently, the proposed approach may constitute an efficient means to provide indoor directions.

While the work presented here resulted in initial insights into this type of indoor navigation support, there are a number of promising directions for further research. Observation studies with interviews and evaluations in different buildings (larger, more complex) would yield further insights into the properties and limitations of providing one-time, memorable directions.

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