Icon-based Navigation

Kai-Florian Richter
Department of Computing Science
Umeå University
Umeå, Sweden
kai-florian.richter@umu.se

Arvid Horned
Umeå University
Umeå, Sweden
arho0004@student.umu.se

Kristoffer Karlsson
Umeå University
Umeå, Sweden
krka0050@student.umu.se

Abstract

Icon-based navigation uses a minimalist approach to mobile navigation assistance by offering navigators only icon displays representing landmark objects at waypoints along a route in an indoor environment. In this paper, we motivate this new concept and its usefulness, present a first prototype implementation exploring the concept, and results of an initial empirical evaluation. While results are not fully conclusive, they point to the potential of this kind of navigation assistance.

Keywords: wayfinding, landmarks, indoor, location-based services

1 Introduction

Navigation in large indoor environments can be challenging for those new to a building complex or for the occasional visitor (e.g., Carlson *et al.*, 2010), partly due to the more segregated nature of such spaces compared to outdoor spaces (Richter, Winter & Santosa, 2011). In many public spaces, this issue is addressed by installing systems of signage and you-are-here maps. But in today's age of smart phones and mobile Internet, there is an increasing number of approaches providing navigation assistance for indoor spaces on mobile devices.

Such indoor navigation assistance faces several challenges, among them the lack of a globally available positioning mechanism as provided by the Global Positioning System (GPS) for outdoor spaces. Instead, almost all approaches rely on either some specialized positioning infrastructure installed in the buildings, or the mapping of some signal patterns to locations in the building, or both (Winter *et al.*, 2017). Further challenges lie in representing indoor spaces in a way suitable for routing and navigation (Lorenz, Ohlbach & Stoffel, 2006; Richter, Winter & Santosa, 2011; Viaene, De Wulf & De Maeyer, 2016), and in providing navigation information to users in an adequate way. For a select—but increasing—number of buildings, it is now possible to use Google Maps™ as you would for outdoor environments.

But whether simply transferring principles of outdoor navigation assistance to indoor spaces is the ideal solution remains questionable. Navigation often involves level changes, and the space is often experienced as more immediate—with walls just next to the navigator—compared to outdoor spaces that have a more open-space feel (Fontaine, 2001; Hölscher *et al.*, 2006). This immediateness may require both the need for displaying more details on a map and the need for providing more overview in order to allow for relating a navigator's current position to the overall space. Creating such a map display on mobile devices with their limited screen estate poses a significant challenge (Dillemuth, 2009; Gustafson *et al.*, 2008; Wenig *et al.*, 2016).

Such considerations led us to conceive mobile indoor navigation assistance that ideally a) does not require highly accurate positioning mechanisms and b) lets us get away with presenting as little—or as simplified—information as possible. We opted for only using icons representing salient reference points ("landmarks") and, accordingly, term this kind of navigation assistance "icon-based navigation." In previous work we demonstrated that an abstract map representation just showing ordering of and rough direction information between decision points suffices for successful indoor navigation (Bigler *et al.*, 2014); restricting presentation to only icons represents at least one more level of abstraction. In thi paper, we present the principal considerations behind this approach and a first prototype implementation that is used to explore the concept further, as well as results of an initial user study demonstrating the feasibility of icon-based navigation.

2 Icon-based Navigation

The aim of icon-based navigation is to present a user with navigation instructions that are 1) easy to read off a mobile device, 2) easy to relate to the indoor environment at hand, and 3) easy to implement using positioning mechanisms of varying accuracy and precision. We chose to use an icon-based presentation based on the following considerations:

1) Icons only require little screen space; considerably less than a map. They are simple, abstract graphical representations of real-world objects or concepts. Carefully choosing icons will make it easy for users to relate them to the object they represent even with just a short glance, i.e., they may take less time to process than textual instructions. In addition, it is possible to add further (iconic) information representing the wayfinding action (e.g., to go up some stairs or to pass through a door).

2) Using icons to represent real-world objects corresponds to pointing out reference objects in an environment, i.e., they link wayfinding actions with locations in the space. Ideally, these objects will be salient and relevant to the navigation task, i.e., have a landmark character (Richter & Winter, 2014).

This will make it easier for navigators to identify which action to perform where. And since people will (need to) look for the objects referred to by the icons in their surrounding environment, this will likely increase their engagement with the environment and the navigation task. Thus, they may learn more of the environment countering some of the effects of disengagement and lack of attention observed with current mobile navigation assistance (e.g., Gardony *et al.*, 2013; Leshed *et al.*, 2008).

3) As navigators will have to identify the location of the referenced objects in the environment, and then perform the according wayfinding action in relation to that object, there is no need to precisely position users in an indoor environment when triggering instructions. It will suffice to ensure that they are in an area close enough, such that the object is perceivable. This allows for some flexibility in the exact positioning mechanisms connected to an icon-based navigation system, thus, at least alleviating one of the major challenges of indoor navigation assistance addressed above.

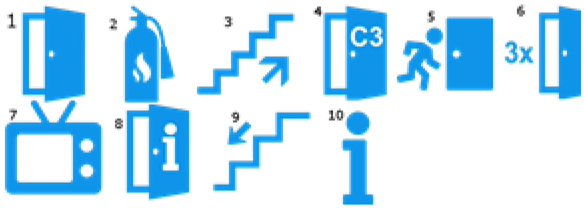
3 Prototype Implementation

In order to test the feasibility of our envisioned concept of icon-based navigation, and to being able to further explore how to best design such assistance, we implemented a first prototype of an icon-based navigation assistance system as an Android application—termed Inavicon. For now, the prototype is restricted to operate in one of our university's buildings, which still enables an initial exploration of the concept, and to empirically assess whether such a navigation process works.

3.1 Landmarks and Icons

We explored the building looking for objects that are at the same time easily recognizable, suited to be represented in icon form, and useful in a navigation context, i.e., may serve as landmarks. In that, we followed the classification of indoor landmarks by Ohm *et al.* (2014). Additionally, we ensured that other landmarks are visible from the current object's location in order to allow for seamless navigation between waypoints (see Section 3.3). Figure 1 shows the icons depicting the sequence of landmarks that need to be passed along the route used in the evaluation (Section 4). The initial choice of icons was somewhat ad-hoc; currently we are working on a systematic taxonomy of suitable icons and their design, which will eventually be confirmed by an empirical evaluation.

Figure 1: Icons representing the sequence of landmarks for the evaluation route.



Source: Icons made by Freepik from www.flaticon.com; modified.

3.2 Positioning

As discussed above, icon-based navigation requires a positioning mechanism in order to know that navigators are close to a waypoint (but it may do without; see Section 5).

For each identified landmark, we define a geofence around it. Once a navigator enters this fence, they are deemed to be close enough to the landmark to detect it. Geofences were implemented using Proximi.io[1]. Positioning relies on a mapping of geomagnetic field readings to locations in the building. For the prototype, we mapped two floors of the building using IndoorAtlas tools[2].

3.3 Interface and Navigation Process

As discussed in Section 2, one aim of icon-based navigation is to keep information presentation to a minimum. Accordingly, the user interface is rather simple. Figure 2 shows the interface at different stages during the navigation process.

At the start of a route, a user is faced with a simple button. Pressing that button, the first icon is displayed, representing the first landmark to reach. This landmark needs to be visible

Figure 2: Snapshots of the prototype user interface. Left the start screen, the middle showing an example of an icon representing the next waypoint; to the right highlighting an icon to indicate that the waypoint has been reached.

[2] https://www.indooratlas.com

from the origin of the route. Once a navigator enters the geofence of the displayed landmark, the icon on the screen is highlighted to indicate that the landmark has been reached. Then the next icon appears indicating the next landmark. This repeats until the navigator has reached their destination.

4 Evaluation

We performed a first empirical user study in order to explore whether the concept of icon-based navigation is feasible at all and to get some first insights into how navigators perceive and perform with such assistance.

4.1 Participants, Material, and Methods

In total, 25 people (about one third women, two thirds men, between 20 to 30 years old) participated in the study. They were randomly divided into two groups of 13 and 12 participants, respectively. One group used Inavicon; the other group received a textual description of the same route, which was displayed as a text message in the phone's messaging app.

We used a Motorola Nexus 6 running Android 7.0. We selected one route through the university building as our evaluation route. The route included two level changes and several right and left turns, as well as the passing through doors. The selected route did not reflect typical routes through the building, so even if participants were partially familiar with the building, the specific route was new to them.

Participants were informed that we were testing indoor navigation assistance tools. They were instructed to walk from origin to destination following the respective instructions, using a slow, controlled pace. The group using Inavicon were familiarized with the app first. Participants were followed by one of the authors who recorded any interesting navigation behavior, such as stops, navigation errors (wrong turns), and hesitations, as well as the time it took to complete the route. After route following, we performed a semi-structured interview with the participants asking about which strategies they had used while navigating; the Inavicon group was also asked about their perception of usefulness and performance of the app and how it may be improved. We do not detail these qualitative results here (but see Section 5 for some of the feedback we received).

Finally, we asked participants in both groups to pick photos of all spatial scenes they had encountered along the route from a stack of 14 photos, of which 7 were correct. Participants were then asked to sort these photos in order of appearance along the route. Scoring of this memory test was done following Oliver & Burnett (2008). The maximum possible score is +17, the minimum score -14.

4.2 Results

In the analysis, we excluded data from one participant because they failed to follow the instructions.

Table 1 lists the means and standard deviations for the two groups regarding the different factors measured in the experiment. The Inavicon group was slower than the text group. The difference is statistically significant according to a t-test for independent measurements ($t(22)=2.97$, $p=0.007$). We also observe a high variance in this factor, indicating that the performance of participants varied widely.

Table 1: Descriptive results of the evaluation study.

Group	Time (s)	Errors	Hesitations	Memory test
Inavicon	328.15 (72.25)	1.15 (0.9)	2.31 (0.856)	4.31 (3.79)
text	261.17 (44.21)	0.92 (0.67)	2.58 (1.08)	3.83 (2.55)

We do not find statistically significant differences for errors and hesitations between the two groups. The Inavicon group had a higher score on the memory test than the 'text' group, but this is not statistically different. Note that these scores are lower than expected and show a high variance in both groups. Six participants received a score of 0 by picking as many correct images as incorrect ones.

5 Discussion and Outlook

Overall—and most importantly—results demonstrate that icon-based navigation works in principle. Participants did find the destination, making one wayfinding error on average—as did those receiving the textual description of the route.

However, participants took significantly longer using Inavicon compared to the text group. This may partly be explained by navigators needing to actively search for the next object to go to once they have reached the current waypoint, i.e., they engage in a visual search task that may take some time in some instances. Further, in order to keep the evaluation simple from a technological perspective, the text message showed the complete instructions at once. This may have helped participants to prepare for upcoming decision situations, reducing the time they needed. As part of future work, we plan to compare Inavicon to 'traditional' turn-by-turn instructions to account for the current differences in instruction mode. Additionally, we found that the chosen positioning mechanism was not always stable. Sometimes participants had to wait for the app to catch up to their actual location, and sometimes it would not change to the next icon in time (or too soon), leading to some confusion and waiting time. These issues highlight the need for developing positioning mechanisms that are infrastructure-independent (Löchtefeld *et al.*, 2010; Winter *et al.*, 2017), which is another aspect of future work.

We found no differences in the acquired spatial knowledge between the two groups. Given that the scores for the route knowledge test are lower than expected for both groups, we can assume that the test was likely too difficult for the participants. This may be partly attributed to the photo stimuli used in the test, some of which may not always have captured spatial scenes in an appropriate way for participants to know whether they had encountered that scene. And partly participants reported difficulties to always reliably identify what object and/or action an icon refers to, an issue which may also be reflected in scene recognition, and one we are addressing in our current work. For example, participants in the Inavicon group reported difficulties in interpreting the door icons. Despite findings that functional landmarks, such as doors, receive a lot of perceptual attention (Ohm *et al.*, 2014), there are often multiple doors visible at any given location, meaning they are not necessarily always the ideal landmark to use in instructions. Navigators must identify the correct door first—supported here by adding a label to the door icons. And second, the correct action must be identified, for example interpreting an open door as corresponding to passing through that door. Still, most errors and hesitations occurred at the same locations across participants, and independent of experimental condition. This indicates that these locations were difficult to navigate regardless of instruction mode (cf. Bigler *et al.*, 2014).

Given these issues, another aspect of future work will comprise of more systematically creating an 'icon vocabulary', i.e., a taxonomy of objects that are easy to identify in the real world, have a corresponding easy to interpret icon representation, and that are generally well suited to denote navigation actions. Finally, some fallback strategies need to be developed in case some areas of an indoor space may not contain any suitable landmark objects at all.

In summary, we see these first results of icon-based navigation as very encouraging, and as opening up avenues for promising future research.

References

Bigler, S., Brügger, A., Utzinger, F. & Richter, K.-F. (2014) Up, down, turn around: Assisted wayfinding involving level changes. In: Christian Freksa, Bernhard Nebel, Mary Hegarty, & Thomas Barkowsky (eds.). *Spatial Cognition IX*.. 2014 pp. 176–189. doi:10.1007/978-3-319-11215-2_13.

Carlson, L.A., Hölscher, C., Shipley, T.F. & Dalton, R.C. (2010) Getting Lost in Buildings. *Current Directions in Psychological Science*. 19 (5), 284–289. doi:10.1177/0963721410383243.

Dillemuth, J.A. (2009) Navigation Tasks with Small-Display Maps: The Sum of the Parts Does Not Equal the Whole. *Cartographica: The International Journal for Geographic Information and Geovisualization*. 44 (3), 187–200. doi:10.3138/carto.44.3.187.

Fontaine, S. (2001) Spatial Cognition and the Processing of Verticality in Underground Environments. In: Daniel R Montello (ed.). *Spatial Information Theory*. Lecture Notes in Computer Science. [Online]. 2001 Berlin, Springer. pp. 387–399. doi:10.1007/3-540-45424-1_26.

Gardony, A.L., Brunyé, T.T., Mahoney, C.R. & Taylor, H.A. (2013) How Navigational Aids Impair Spatial Memory: Evidence for Divided Attention. *Spatial Cognition & Computation*. 13 (4), 319–350. doi:10.1080/13875868.2013.792821.

Gustafson, S., Baudisch, P., Gutwin, C. & Irani, P. (2008) Wedge: Clutter-free visualization of off-screen locations. In: *CHI '08: Proceeding of the Twenty-Sixth Annual SIGCHI Conference on Human Factors in Computing Systems*.. 2008 New York, ACM. pp. 787–796. doi:http://doi.acm.org/10.1145/1357054.1357179.

Hölscher, C., Meilinger, T., Vrachliotis, G., Brösamle, M., et al. (2006) Up the Down Staircase: Wayfinding Strategies in Multi-Level Buildings. *Journal of Environmental Psychology*. 26 (4), 284–299.

Leshed, G., Velden, T., Rieger, O., Kot, B., et al. (2008) In-Car {GPS} Navigation: Engagement with and Disengagement from the Environment. In: *CHI '08: Proceeding of the twenty-sixth annual SIGCHI conference on Human factors in computing systems*.. 2008 New York, NY, USA, ACM. pp. 1675–1684. doi:http://doi.acm.org/10.1145/1357054.1357316.

Löchtefeld, M., Gehring, S., Schöning, J. & Krüger, A. (2010) PINwI: Pedestrian Indoor Navigation Without Infrastructure. In: *Proceedings of the 6th Nordic Conference on Human-Computer Interaction: Extending Boundaries*. 2010 New York, NY, ACM. pp. 731–734. doi:10.1145/1868914.1869016.

Lorenz, B., Ohlbach, H.-J. & Stoffel, E.-P. (2006) A Hybrid Spatial Model for Representing Indoor Environments. In: Carswell James D. & Taro Tezuka (eds.). *Web and Wireless Geographical Information Systems*. Lecture Notes in Computer Science. 2006 Berlin, Springer. pp. 102–112.

Ohm, C., Müller, M., Ludwig, B. & Bienk, S. (2014) Where is the Landmark? Eye Tracking Studies in Large-Scale Indoor Environments. In: Peter Kiefer, Ioannis Giannopoulos, Martin Raubal, & Antonio Krüger (eds.). *2nd International Workshop on Eye Tracking for Spatial Research*. 2014 Vienna, Austria. pp. 47–51.

Oliver, K.J. & Burnett, G.E. (2008) Learning-oriented Vehicle Navigation Systems: A Preliminary Investigation in a Driving Simulator. In: *Proceedings of the 10th International Conference on Human Computer Interaction with Mobile Devices and Services*. MobileHCI '08. 2008 New York, NY, ACM. pp. 119–126. doi:10.1145/1409240.1409254.

Richter, K.-F. & Winter, S. (2014) *Landmarks: Giscience for intelligent services*. Springer International Publishing. doi:10.1007/978-3-319-05732-3.

Richter, K.-F., Winter, S. & Santosa, S. (2011) Hierarchical Representations of Indoor Spaces. *Environment and Planning B: Planning and Design*. 38 (6), 1052–1070. doi:10.1068/b37057.

Viaene, P., De Wulf, A. & De Maeyer, P. (2016) Indoor landmark-based path-finding utilising the expanded connectivity of an endpoint partition. *Environment and Planning B: Planning and Design*. doi:10.1177/0265813516670901.

Wenig, D., Steenbergen, A., Schöning, J., Hecht, B., et al. (2016) ScrollingHome: Bringing Image-based Indoor Navigation to Smartwatches. In: *Proceedings of the 18th International Conference on Human-Computer Interaction with Mobile Devices and Services*. MobileHCI '16. 2016 New York, NY, ACM. pp. 400–406. doi:10.1145/2935334.2935373.

Winter, S., Tomko, M., Vasardani, M., Richter, K.-F., et al. (2017) Indoor Localization and Navigation Independent of Sensor Based Technologies. *SIGSPATIAL Special*. 9 (1), 19–26. doi:10.1145/3124104.3124109.