Where To Go And How To Get There: Guidelines For Indoor Landmark-Based Navigation In A Museum Context

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Abstract
Technology-supported indoor navigation is not easy; there are many technological challenges as well as UI challenges that need to be addressed. A set of user interface guidelines for designing a navigation system in a CH setting has been developed based on our experience and current best practices. In this paper, we describe an implementation of our guidelines in an indoor navigation system that supports visitors in a cultural Heritage (CH) setting. The system was developed to provide a user-friendly tool for route navigation, based on photo landmarks. Maps, landmarks and contextual information are used in order to navigate. In addition the system supports visitors who meander off the path while navigating

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Mobile museum guides; indoor navigation; cultural heritage

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H.5.m. Information interfaces and presentation (e.g., HCI): Miscellaneous

Related Work (I)
Humans similarly to honeybees, tend to use a simple strategy of landmark navigation as opposed to metric survey knowledge of the environment as used by maps [1, 5]. One of the advantages of landmark navigation is that it can use a positioning system that is based on partial positional knowledge (i.e., know when a user is near certain locations) rather than complete positional knowledge.

Landmarks can be used verbally as part of directions [15] or via photos [2,19]. Photos can be used for two tasks in the navigation process: confirmation and decision [2]. [14] discuss what features make for "good" or salient (in their terminology) landmarks. The features they list include those of visual attraction (facade: area, shape, color, visibility), and semantic attraction. They also give an objective measure for salience [20].

Introduction
Navigation support is an important service for mobile users. In particular, indoor users in a Cultural Heritage (CH) environment may not know what to see, where to go, or how to get to various locations. In fact, one of the most frequent questions asked at a major museum is "How to get to the bathroom?" [12]. While the above is true for all museums, additional questions arise in an instrumented museum such as how can I get to a specific exhibit, where and how can I find my group members and more.

To answer these questions many systems make use of positioning techniques to provide navigation support [8]. Outdoor positioning can be considered as a primarily solved problem, mainly due to the use of GPS. However, this is not the case for indoor positioning, and subsequently indoor navigation. In spite of numerous attempts and a variety of technologies experimented with, there is still no prevalent solution for the requirements of determining museum visitor's location [9]. In addition to inherent technological limitations of indoor positioning technologies, museums have their own constraints when it comes to installation of sensors in their space – the sensors need to be invisible and to require no infrastructure (e.g. power, communication, due to some buildings being historical structures and not allowing changes) and low maintenance (due to budget constraints). Furthermore, a museum is a densely populated space, with many artifacts and points of interests on the way. This poses a major challenge to any positioning system – the required accuracy has to be in the areas of a few tens of centimeters As a result, presently, there is no integrated solution (even though parts exist) that address these requirements. Given the incomplete positioning information and the density and complexity of museums, providing navigation support to individuals and groups in the museum becomes a complex challenge.

We introduce an indoor navigational system that combines "light weight" proximity-based positioning system, together with maps and landmark navigation. When users look to find their way from one place to another, they are supported along their route by a series of photo images of landmarks they can spot (some from far away and others as they get closer), and instructions on how to move from one landmark to the next one. Instructions include a directional arrow that is updated according to the users' orientation. In addition, since visitors often do not come to the museum alone, and since it is recommended to support small groups at museums [10], information about the whereabouts of group members is provided and directions can be given in order to meet together at a certain place or just to get to a place where another group member is. In addition, places which are congested (that is occupied above a recommended maximum) are marked. A routing engine is used to determine the path between the source and destination targets and also to determine which paths have alternatives. Our navigation system supports internationalization (I18N) (instructions available in supported languages) and accessibility (A11Y) (through a special database which supports navigation routes for users with accessibility

Navigation System Design
Because our positioning data does not provide us with continuous positioning (as given outdoors with GPS), and because the museum is dense with artifacts and

RELATED WORK (II)

A recent work by Mulloni, Seichter and Schmalstieg combined instructions with a variety of sensor information for the use of pedestrian indoor landmark navigation [13]. They presented four main objectives of their system: (1) robustness to user's failures and path deviations, (2) low instrumentation of the environment; at sparse info points, the users can reset and re-orient themselves, (3) adaptation of the interface depending on the localization accuracy and on the user activity, (4) the interface should interactively flow from one activity to the next with minimal user input. Our system builds on this work also supporting these main objectives. However, while Mulloni et al. had the users actively localize their position by pointing the handheld device onto situated QR codes, our landmark navigation system is based on an automatic positioning system

exhibits, we decided to base the navigation system on landmarks. When the visitor asks to navigate to a certain location, the system divides the path into several segments according to salient landmarks on the way. The system then guides the user from one landmark to another till the user reaches the destination. For each segment, the system shows the next target landmark and the direction (using a superimposed arrow) the user needs to go to reach that landmark. The system detects when the user is in proximity of the landmark and automatically presents the next segment (with the next landmark).

Design Process

To design and implement the navigation system we used techniques from User Centered Design (UCD), including Iterative design, Think Aloud (TA), and Heuristic Evaluation (HE) [17]. In the course of developing the navigation system, 12 visitors were shadowed and asked to comment out loud about using the navigation system and guide (TA). This was done as an iterative process at various stages of the design. In addition at 4 points in the design/implement iterative cycle the system or mockups were shown to various UI experts (HE).

Design choices influenced by the use of the UCD were:

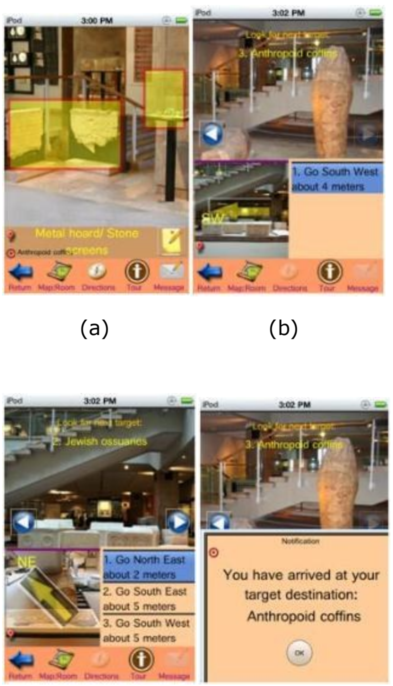
- Show both source and target images of the current location and next target landmark (users were confused when shown only one image: was it showing where am I now or where do I want to go?).
- Allow the user to manually scroll through the list of landmarks (previous landmarks the user already passed, as well as future ones he hasn't reached yet). This design was due to positioning system problems. Because the system did not always detect the user at a position. If this is the case, the user should still be able to manually go to the next landmark.
- Place the direction arrow on the source window. During think aloud it was mentioned a number of times that having the arrow on the big target window was confusing.
- The arrows should point N, S, E, W. Directions such as NE, SW are confusing.
- Use only landmarks that were detected by the system. An early version included landmarks that could not be detected by the system (were not instrumented). This was very confusing.
- Decisions on use of colors and icons.
- Using labels on icons when possible.

Design Assumptions and Guidelines

Our existing environment, plus the user centered design process, plus guidelines from other works, drove the design and implementation considerations [7]. Our major goal in design and implementation of the navigation system was to create an overall positive user experience We present here the resulting design assumption and guidelines of our navigation system.

DESIGN ASSUMPTIONS

1. **Leisure Activity**- Museum visit is a leisure activity [4]. Therefore, user experience is more important than performance.
2. **Low Instrumentation**- Beacons are expensive and hence exist primarily at points which have content.
3. **Positioning Unstable**- The positioning information is not always stable, and sometimes users are not detected.
4. **Unfamiliarity**- Users are not familiar with the museum and the mobile guide. Many visitors are first-time visitors that would use the system only once.



(a) (b)

(c) (d)

Figure 2. Landmark navigation step by step

5. **Navigation Inertia**- People tend to walk in a straight line (inertia) unless some force pulls away [3]

From these assumptions, as well as other considerations we devised the following guidelines:

Design guidelines - navigation

DG1. **Navigation Variety**- A variety of navigation technologies are preferred. [3] **Navigation Robustness**- Robustness to user's failures and path deviations [13].

DG2. **Navigation Redundancy**- "Provide redundant wayfinding clues. Some visitors prefer to ask directions, some prefer to get it on their own. Having redundant cues will increase the chance that visitors notice cues and give him/her a choice. Recurring clues also give a feeling of security to visitor" [3]

DG3. **Navigation Minimal Input**- The interface should interactively flow from one place to the next with minimal user input [13].

DG4. **Navigation Minimize Choice**- "Environments should be designed with a minimum number of choice points" [3]

DG5. **Navigation Simple Geometry**- Simple geometric forms such as circles, squares are best for paths. "Intersections with angles other than 90 degrees make it more difficult to form a genitive path. Therefore, pathways that form right angles should be preferred."[3]

DG6. **Navigation Deviation**- Users should have an easy way to stop navigation and view items along the way.

Design guidelines - maps

DG7. **Map YAH**- You are here symbol should be provided on a map [3]. Preferably with the pin icon [16]

DG8. **Map Simplicity**- "Features on maps should be simplified as possible. Too much detail causes confusion" [3, 6, 11]

DG9. **Map Landmarks**- The map should include easily identifiable landmarks [3]

System description

Usage scenario

Figure 2 shows a typical usage scenario in which a visitor wishes to go from the current position to a chosen destination. In the example, the user sees the current location (Metal hoard, Figure 2a) and has already chosen the destination (Anthropoids coffins). The user prompts the navigation by pressing the "Directions" icon on the bottom of the screen. If going to the destination involves alternative routes he is given a dialog asking to choose which route he prefers (DG5). Routes that are physically accessible are marked with a wheelchair icon (See Fig. 3). After pressing the direction icon, the user is then shown the path by a series of images of landmarks. He or she can look (scroll) through the list to see how many segments exist (DG3). On the current position segment (Fig. 2b, and 2c) the user sees the next landmark on the top, and the previous position (previous identified landmark) image on the bottom left corner. There is an arrow overlaid on the previous position image showing the user which way to go. The arrow is adjusted according to the visitors' compass orientation. Between landmarks, the user gets directional information to progress to the next landmark (bottom right corner of Figure 2b and 2c). As the user advances towards and

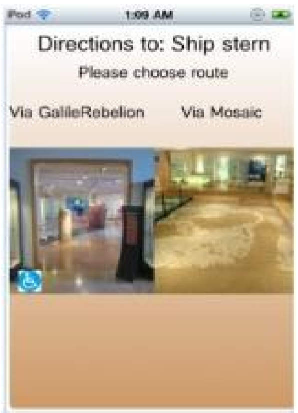


Figure 3. Choose route from alternatives

arrives to a new landmark, the screen automatically changes to show the next landmark (DG4). When the user arrives, a popup dialog (DG2), informs the user that he or she has arrived at the destination target (Figure 2d).

Graphical User Interface

The directional navigation GUI consists of a horizontal scroll panel which fills the device. Inside the horizontal scroll panel there is a series of "Segment Panels" (Figure 5 b, and c). An individual Segment Panel consists of 5 areas: 1) the small source image (bottom left), 2) the large destination image (top), 3) the destination title(A1) , 4) the direction textual description consisting of a list of steps (bottom right)(DG3) and 5) A direction finder (arrow) overlaid on the small source image which shows the user in which direction to walk to the next destination, plus a mnemonic for direction which is placed at the tip of the arrow, corresponding to the direction given in the step 3 (reinforcing which direction the user has to go, since navigation by compass points is known to be difficult). Normally an arrow is shown for going North, East, West, South, Up, down, etc. The arrow is adjusted according to the users' current orientation as it is obtained from the blind, to show what direction to walk to.

Navigation (Landmarks, Directions and choosing alternatives)

Navigation is based on landmarks. The landmarks used are the exhibit areas as well as the entrances and exists that are used within the PIL guide. Using the exhibit areas as landmarks has a number of advantages. Firstly, these areas already have beacons that recognize them in the positioning system. There is a limit to how much one can alter the museum environment, and each beacon needs to be carefully placed so it would not aesthetically interfere. Secondly, we want the users to become familiar with the exhibit areas, perhaps even viewing presentations about certain exhibits when they are navigating from one point to the other. This also informs the user where are exhibits which contain information which may possibly capture their interest. Thirdly, exhibit areas have unique characteristics and many of them have salient features that make them good candidates for landmarks. The use of landmarks also has the advantage of creating a "scenic route" between the current location and the destination [8].

Directions are given in compass type directions (of north, north-east etc). This approach was selected, even though directions given in terms of left and right, back and forward are more natural than compass type [18]. This was due to the fact that in order to give directions of left, right, back, forward, the system needs to know the user's exact position; while our system knows the user's orientation (using the compass within the user's blind), and knows that the user is near an exhibit, it does not know the exact location of the user in respect to that exhibit. For example, if the exhibit is located at the center of the room, the user can be on the west side of the exhibit facing the exhibit, or can be on the east side, with the back to the exhibit. We have discovered in early think aloud sessions that directions in terms of left, right, back and forward were very confusing in some cases. We therefore use compass orientations which are invariant to which way the user is standing. We use the adjusted (for orientation) arrows to point the visitor in the correct direction at the current location. We use the arrow at the current location to point the user in the right direction (and label it with the compass direction (N, NE, E, SE, S, SW, W, NW or UP, DOWN) so that the user is familiar with the direction (See Figure 2b and 2c bottom left corner). In the case of up and down in the elevator or stairs, up and down arrows are used (without adjustment for orientation). To assist the user, we reiterate in the verbal directions to go in the direction of the arrow (DG3). When a position is nearby (and we can't determine accurately orientation and direction) we use a series of concentric circles as an icon instead of the arrow to represent this navigation state.

The Routing engine provides the path between two exhibits (or alternatively we call them points of interest (POI)). It is based on a modified shortest path graph algorithm, where the POIs are the vertices and the existing connections between the POIs are the edges. The POIs have associated with them a name, position, size, type (whether they are an exhibit, entrance, bathroom, gift shop, etc.), orientation (how one faces the POI) and media (images) associated with the POI. Attributes associated and used by the connection between POIs are type (elevator, stairs, bridge, escalator, ramp, etc...), visibility from source (can you see the endpoint from the source point), traversal (do you pass by or go-thru the POI), and media (images of the path). Distances (path length) are derived automatically from the location coordinates.

One of the salient features of the system is that users are given a choice in how they want to navigate to a certain destination (DG3, DG4). The purpose of this choice is not to change the destination, but rather it allows the user to choose the route he or she wishes to travel by. In general, more choice increases user satisfaction as long as it is not overwhelming [17]. For groups it encourages discussion about which way to proceed. Figure 3 shows the screen presented to the user when there is a choice of two routes when setting a destination. The user can then choose a route by pressing on one of the images.

Discussion and Future Work

Navigation in the CH environment differs from the general navigation problem. One main difference is that a museum visit is a leisure activity and users can meander off the standard path. Visitors are not only interested in getting from the source to the destination, but may in certain circumstances be interested in looking at exhibits that appear on the way or take the longer path in order to see other exhibits on the way. In response to this, we developed our "routing engine" to use points of interest as landmarks as a solution to handle users going off the proposed "path". We also give users the option to choose between alternative navigation paths, even if it is clear that one path is longer than the other. The choice includes an image of the most salient exhibit on the way, so the visitor can choose a longer path that includes an important exhibit. A second difference is in using landmarks for the navigation. Museums are usually full and crowded with salient objects. Therefore, it is natural to use the exhibits themselves augmented with room entrances, exits, stairs and elevators for landmarks.

From the observation of the experiment groups and the Think Aloud studies it emerged that people’s preferences regarding the navigational system varied widely. Some visitors preferred directions while others preferred maps. These preferences may also change during one's visit as often visitors start with directions and then revert on using the map after one is more familiar with the environment. Another distinction that arose from these studies is that visitors preferred directions for navigating between rooms, and used maps for navigating within a room. In addition, while maps are inherently a visual or analogical format, directions are thought of as primarily a descriptive format. The use of landmarks moves the categorization of directions towards the visual or analogical category, thus making better use of our visual senses.

The next step, of course, is to evaluate the system. The system is currently deployed at the Hecht museum and is regularly used by visitors of the museum. We are now in the process of gathering quantitative and qualitative data from the use of real visitors. This, alongside with user studies that are specifically designed to examine the usability and utility of the system will help us evaluate the navigation system.

In possible future studies, it would also be interesting to examine group navigation. Another possible direction is "micro-navigation", that is, navigating around the exhibit itself, pointing out interesting features, and giving views of the exhibit which could not be seen from the glass exhibit case.

Conclusions

This research has focused on developing a navigational system in the indoor CH setting, focusing on directions via landmarks and maps. In developing our navigational system, a framework of the information needed to support navigation in the CH environment was created. Maps, landmarks and contextual information are used in order to aid navigation and are integrated to work together. In addition, we defined a set of assumptions and design guidelines for mobile museum navigation that were validated by developing our system. In summary, photo landmark directions, combined with maps, have the potential to be a viable option for navigation in the cultural heritage environment. An evaluation of the system will validate its usefulness as a practical solution.

References

1. Aslan, I., Schwalm, M., Baus, J., Krüger, A. and Schwartz, T. Acquisition of spatial knowledge in location aware mobile pedestrian navigation systems. In Anonymous *Proceedings of the 8th conference on Human-computer interaction with mobile devices and services.* (). ACM, , 2006, 108.

2. Beeharee, A. K. and Steed, A. A natural wayfinding exploiting photos in pedestrian navigation systems. In Anonymous *Proceedings of the 8th conference on Human-computer interaction with mobile devices and services.* (). ACM, , 2006, 81-88.

3. Bitgood, S. and Cota, A. Principles of orientation and circulation within exhibitions. Visitor Behavior, 10, 2 (1995), 7-8.

4. Falk, J. H. *Identity and the museum visitor experience.* Left Coast Press Walnut Creek, CA, 2009.

5. Foo, P., Warren, W. H., Duchon, A. and Tarr, M. J. Do Humans Integrate Routes Into a Cognitive Map? Map-Versus Landmark-Based Navigation of Novel Shortcuts. Journal of Experimental Psychology: Learning, Memory, and Cognition, 31, 2 (2005), 195-215.

6. Gubi, K., Wasinger, R., Fry, M., Kay, J., Kuflik, T. and Kummerfeld, B. Towards a Generic Platform for Indoor Localisation Using Existing Infrastructure and Symbolic Maps. In Anonymous *CEUR-WS.org/Vol-609, Proceedings of UMAP Workshop, Architectures and building blocks of web-based user-adaptive systems*, 2010, 11-16.

7. Hevner, A. R., March, S. T., Park, J. and Ram, S. Design science in information systems research. Mis Quarterly, (2004), 75-105.

8. Karimi, H. A. *Universal navigation.* Springer, 2011.

9. Kuflik, T., Lanir, J., Dim, E., Wecker, A., Corra, M., Zancanaro, M. and Stock, O. Indoor positioning: challenges and solutions for indoor cultural heritage sites. In Anonymous *Proceedings of the 15th international conference on Intelligent user interfaces.* ACM, , 2011, 375-378.

10. Lanir, J., Kuflik, T., Dim, E., Wecker, A. J., & Stock, O. The influence of a location-aware mobile guide on museum visitors' behavior. Interacting with Computers, 2013

11. Lavie, T., Oron-Gilad, T. and Meyer, J. Aesthetics and usability of in-vehicle navigation displays. International Journal of Human-Computer Studies, 69, 1 (2011), 80-99.

12. Lube-Perry, L. Workshop: Museums and Mobiles. (2011).

12. Mulloni, A., Seichter, H. and Schmalstieg, D. Handheld Augmented Reality Indoor Navigation with Activity-Based Instructions. In Anonymous *Proceedings of the 13th International Conference on Human Computer Interaction with Mobile Devices and Services.* (). ACM, 2011, 211-220.

14. Nothegger, C., Winter, S. and Raubal, M. Selection of salient features for route directions. Spatial Cognition and Computation, 4, 2 (2004), 113-136.

15. Nurmi, P., Salovaara, A., Bhattacharya, S., Pulkkinen, T. and Kahl, G. Influence of landmark-based navigation instructions on user attention in indoor smart spaces. In Anonymous *Proceedings of the 15th international conference on Intelligent user interfaces.* ACM, 2011, 33-42.

16. Puikkonen, A., Sarjanoja, A. H., Haveri, M., Huhtala, J. and Häkkilä, J. Towards designing better maps for indoor navigation: experiences from a case study. In Anonymous *Proceedings of the 8th International Conference on Mobile and Ubiquitous Multimedia.* ACM, 2009, 16.

17. Shneiderman, B. and Plaisant, C. *Designing the user interface.* Addison-Wesley Reading, MA, 2009.

18. Ward, S. L., Newcombe, N. and Overton, W. F. Turn left at the church, or three miles north. Environ. Behav., 18, 2 (1986), 192-213.

19. Wecker, A. J., Lanir, J., Kuflik, T., & Stock, O. (2011). Pathlight: supporting navigation of small groups in the museum context. In Proceedings of the 13th International Conference on Human Computer Interaction with Mobile Devices and Services (pp. 569-574). ACM.

20. Winter, S., Raubal, M. and Nothegger, C. Focalizing measures of salience for wayfinding. Map-based Mobile Services-Theories, Methods and Implementations, (2005), 127-142.