Details-on-demand Mobile Visual Interface for Facilitating Indoor Wayfinding

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1. Introduction

Wayfinding in indoor spaces, as well as transition between outdoor and indoor spaces (O/I spaces), is a common but sometimes difficult and tedious process in everyday life. This is particularly evident for indoor travel through complex buildings where traditional external aids, such as signs or You-Are-Here maps, are often absent or inadequate (Moeser et al., 1988). In these instances, navigators can become frustrated, stressed, and get lost or disoriented. Therefore, an indoor wayfinding tool with an efficient, intuitive, and user-friendly visual interface could be very useful in people's daily lives.

Traditional interfaces for indoor navigation employ 2D maps with a fixed top-down, north-up viewpoint and only visualize details about a single-level (e.g. floor) of the space. North-up displays maintain an external reference frame, thus emphasizing global awareness, whereas track-up displays employ an egocentric frame, thereby improving local guidance (Taylor et al., 2008). Solely emphasizing global awareness or local cues is not optimal for a spatial display, as both types of information are important for navigation (Taylor et al., 2008). Similarly, using visualization of only single-level building details may not be optimal, as users may need to access different details based on different wayfinding demands.

A better approach is to flexibly combine the advantages of multiple viewpoints and indoor visualization techniques based on these demands, which are categorized according to the user requirements encapsulated in the five navigation phases illustrated in Table 1.

Table 1. Five levels of wayfinding demands for transition between O/I spaces.

Levels	Navigation phases	Spaces	Wayfinding demands
Level 1	Plan to enter a building	O	Overview of building, such as functional areas, entrances, etc.
Level 2	Enter a building	O/I	Learn main floor layout, important features (elevators, staircases, etc.)
Level 3	Navigation on one floor	I	Learn current floor layout
Level 4	Navigation between floors	I	Integrating vertical information
Level 5	Plan to exit a building	I/O	Overview of the spatial reference of O/I

This research proposes a details-on-demand mobile visual interface for facilitating indoor wayfinding and transition between O/I spaces. Details-on-demand in our research means that the optimal visual interface is dynamically adaptive to users' specific wayfinding demands (e.g., as listed in Table 1). Our hypothesis is that the details-on-demand visual interface is a more intuitive, user-friendly, and efficient visual interface for facilitating spatial learning and real-time indoor wayfinding and seamless transition between O/I spaces than the standard use of fixed-viewpoint, single-level visual interfaces.

Three empirical studies are designed (discussed in section 2) to evaluate the optimal visual interface variables, as listed in Table 2, on each level of wayfinding demands.

Although several studies have previously investigated these visualization variables for indoor wayfinding in isolation (Chittaro et al., 2006; Münzer et al., 2011), our research is the first known effort to combine these variables in a unified informatics framework.

Table 2. Visual interface variables affecting indoor wayfinding performance.

Variables	Option	Other Options
Map type	2D map	3D map
Viewpoint	First-person (egocentric)	Third-person (bird's-eye view)
Map orientation	North-up	Track-up
Assistance Information	Static	Animation,without assistance
Visualization object filtering	Wall	Window, door, etc. (based on O/I spaces ontology)

2. Experimental Design

Empirical experiments will be conducted with humans using immersive Virtual Environments (VEs) coupled with a simulated PDA-sized screen as the visual interface to display information about navigation assistance. The advantage of using VEs is that we can leverage accurate real-time indoor positioning and tracking and easily manipulate the simulated building layouts and information content.

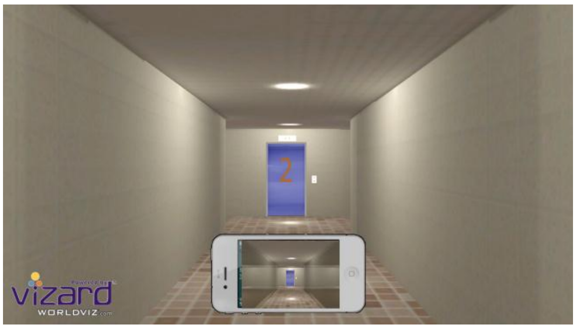
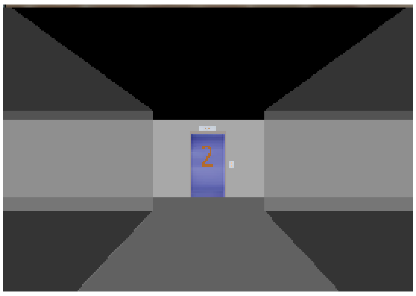


Figure 1. Experimental environment in VEs.

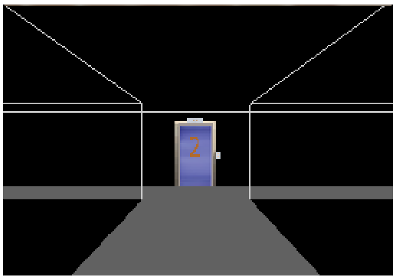
2.1 Experiment 1: Assessing the visual granularity of 3D indoor maps

One practical question for these 3D map based navigation systems is how the realism of the 3D maps affects human navigation performance? We experimentally evaluate four simulation fidelity conditions which manipulate the level of visual granularity provided to the user by a simulated mobile device during learning of two-story virtual buildings.

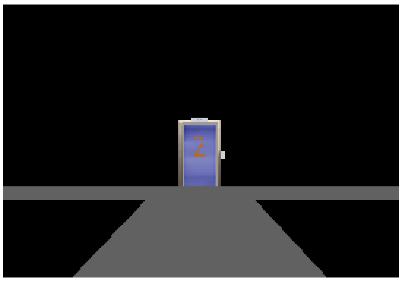
High fidelity model



Low fidelity model



Wireframe model



Sparse model

Figure 2. Four simulation fidelity conditions.

Twenty participants were recruited from the University of Maine student body. All participants self-reported as having normal (or corrected to normal) vision. All gave informed consent and received monetary compensation for their time. Results indicated that the sparse model led to significantly higher navigation accuracy (whether subjects successfully indicated the correct location and orientation of the target) than the low fidelity model and that navigation efficiency (shortest route length over travelled route length) with the sparse model was significantly higher than both the high fidelity and low fidelity models (Giudice & Li, 2012). Our results also showed that it is more difficult for people to maintain the spatial relation of objects between floors than within floors.

2.2 Experiment 2: Integrating vertical information

Indoor wayfinding performance involving floor level changes is greatly hindered by disorientation during vertical travel (Soeda et al., 1997; Montello et al., 1993; Holscher et al., 2006). In Experiment 2, we will empirically evaluate the optimal mobile interface for supporting users' development of a multi-level 3D cognitive map to facilitate vertical travel in indoor spaces. This experiment corresponds to level 4 of the wayfinding demands, listed in Table 1.

Li and Giudice proposed that access to simulated global indoor landmarks during navigation will facilitate user's ability to visualize the vertical structure of the space, which in turn is hypothesized as leading to more accurate multi-level cognitive map development (Li & Giudice, 2012). Simulated global indoor landmarks, as shown in Figure 3, include transition landmarks and contiguous landmarks, which can be displayed on a mobile device (Li & Giudice, 2012). Contiguous landmarks are conceptualized as vertically aligned landmarks, while transition landmarks can be conceptualized as the elements that connect layers (e.g., elevators or staircases). In Experiment 2, there are three conditions: 1. control group: traditional 2D-based indoor maps (widely used in available indoor navigation systems); 2. birds'-eye view 3D-based indoor maps without highlighting global landmarks; 3. birds'-eye view 3D-based indoor maps highlighting global landmarks. Our hypothesis is that users in our experiment will navigate most efficiently and develop the most accurate multi-level cognitive maps with condition 3, as the global landmarks are believed to provide a fixed frame of reference in multi-level indoor spaces (Li & Giudice, 2012).

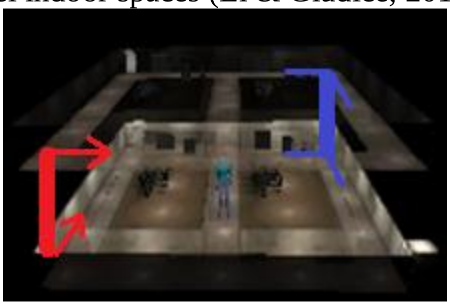


Figure 3. 3D map north-up bird's-eye view (the red and blue lines represent the transitions landmarks and contiguous landmarks respectively).

2.3 Experiment 3: Supporting seamless transition between O/I spaces

As shown in Figure 4, many people have similar experiences in using the wrong exit to get to their car in the parking lot. Experiment 3 is designed to address such problems by evaluating the optimal visual interface for supporting seamless transition between O/I spaces. This experiment corresponds to level 1 and level 5 of the wayfinding demands listed in Table 1.

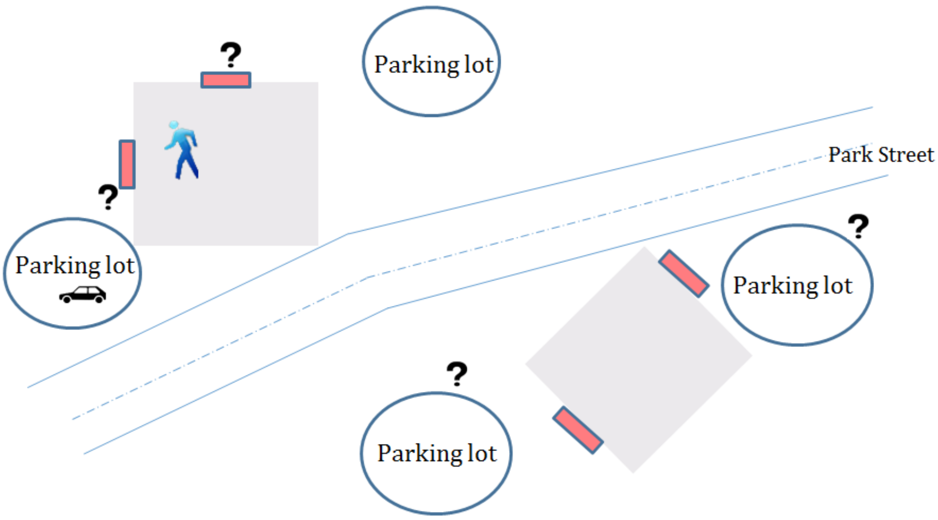


Figure 4. Scenarios for transition between Outdoor/Indoor spaces.

Experiment 3 comprises two conditions: 1. control group: traditional 2D-based maps (e.g. Google Maps, Bing Maps, etc.); 2. O/I spaces transition maps, which are birds'-eye view 3D-based indoor maps highlighting domain-specific information, e.g. exit, adjacent roads and outdoor landmarks, etc. Our hypothesis is that the O/I transition map is the optimal display for supporting seamless transitions between O/I spaces, as it emphasizes the spatial relations between spatial domains based on visualizing the most important information supporting the user's current wayfinding demands.

3. Conclusion

This research proposes a details-on-demand mobile interface for facilitating spatial learning and navigation of complex indoor spaces and transition to outdoor spaces using a visual interface which dynamically adapts the information content displayed as a function of real-time wayfinding demands. Further empirical studies will be conducted to show the efficacy of this interface as being more intuitive, user-friendly, and efficient than traditional fixed-detail navigation displays.

Acknowledgements: This research was supported by NSF grant: IIS-0916219.

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