Wearable Tactile Display of Landmarks and Direction for Pedestrian Navigation: A User Survey and Evaluation

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ABSTRACT

This research investigates representation techniques for spatial and related information in the design of tactile displays for pedestrian navigation systems. The paper reports on a user survey that identified and categorized landmarks used in pedestrian navigation in the urban context. The results show commonalities of landmark use in urban spaces worldwide. The survey results were then used in an experimental study that compared two tactile techniques for landmark representation using one or two actuators. Techniques were compared on 4 measures: distinguishability, learnability, memorability, and user preferences. Results from the lab-based evaluation showed that users performed equally well using either technique to represent just landmarks alone. However, when landmark representations were presented together with directional signals, performance with the one-actuator technique was significantly reduced while performance with the two-actuator approach remained unchanged. The results of this ongoing research programme can be used to help guide design for presenting key landmark information on wearable tactile displays.

Keywords: Landmarks, Mobile Display, Pedestrian Navigation, Tactile Display, Tactile Feedback, Visual Clutter, Wearable Technologies

1. INTRODUCTION

Tactile navigation displays have the potential to be deployed as an alternative or complement to visual navigation displays. They have been reported to work effectively in environments where there are different forms of noise and environmental constraints and when users’ attention, visibility and audibility may be limited (Tan et al., 2003; Van Erp et al., 2005; Duistermaat, 2005; Ross & Blasch, 2000).

Our eventual design goal is to create a spatial display that imposes fewer requirements for extensive transformations between frames of reference by a human operator (Millar & Al-Attar, 2004) and allows the user to achieve high task performance in challenging situations. Outstanding challenges with tactile displays for navigation systems include selection of spatial information types and their representation. In

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In this paper, we describe two linked empirical studies. The first identifies contextually prioritised landmark categories important for different types of navigation. The second describes an experimental comparison of tactile representation techniques for such landmark categories on a wearable device for pedestrian navigation.

2. USER SURVEY OF LANDMARK USE

Several researchers, May et al. (2003), Burnett et al. (2001), Raubal and Winter (2002), and Klippel and Winter (2005), have suggested that a navigation system’s value could be improved by providing landmark information in addition to the common use of directional information, however, there has been no reported use of landmark information in tactile navigation displays.

Landmarks for human navigation can be any objects or places that are stationary, distinct and salient (May et al., 2003; Grabler et al., 2008). Landmarks are identified by their salience (Raubal & Winter, 2002; Klippel & Winter 2005), subjectively and depending on the mode of navigation (Allen, 1999). That is, landmarks are not objective and universal but are chosen subjectively by individuals, particularly in learning and recalling turning points along routes (Sorrows & Hirtle, 1999).

Landmarks play two major roles in navigation: as an organizing concept for space and as a navigation tool (Golledge, 1999). In organizing space, landmarks can represent a cluster of objects at a higher level of abstraction or scale and present an anchor for understanding local spatial relations (Golledge, 1999). For example, symbolic landmarks, such as the Eiffel Tower in Paris or the Statue of Liberty in New York, can come to represent an entire city. They serve as reference points; other landmarks or objects are recalled as being near them and not vice versa. These symbolic landmarks are defined by their visibility from a distance and, especially, their great cultural importance (Sorrows & Hirtle, 1999).

As a navigation tool, landmarks are used to identify decision, origin and destination points. They also provide confirmation of route progress and orientation cues for homing vectors (Golledge, 1999). Landmarks enable the human to construct spatial relationships between objects and routes for the development of her cognitive map of the space (Raubal & Winter, 2002; Millonig & Schechtner, 2005; Michon & Denis, 2001).

According to Allen (1999), human wayfinding can be categorized into three types: traveling to a familiar destination (commuting); traveling to an unknown destination (questing); and exploring the area, which may or may not involve visiting important landmarks (exploring).

Based on human perception and memory limitations, previous research has recommended that the number of tactile patterns to be presented should not exceed seven (Millonig & Schechtner, 2005; Chan et al., 2005; Gallace et al., 2006). These findings suggest an upper bound on the number of landmarks it may be useful to represent within a given navigation task and context. Given such a constraint, it is important to identify a small set of landmarks that are most likely to be useful. However, existing navigation systems typically present quite large sets of landmark information (Millonig & Schechtner, 2005; Nokia Maps™ 2.0; Garmin Nuvi™) (see the Appendix). Our first study empirically identified and classified a set of landmarks or landmark types appropriate for use in tactile navigation systems that support the three navigation purposes, commuting, questing and exploring.

Online and Face to Face Survey

Given our desire to include participants from different urban settings around the world, an online survey was an appropriate approach for this study. However, online surveys can be limited by their lack of direct interaction between interviewer and interviewee, therefore, we also conducted face-to-face interviews in situ with...
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