Comparison of Spatial Knowledge Acquisition with Different Presentation Forms in the Context of GPS-based Pedestrian Navigation

Haosheng Huang, Manuela Schmidt, Georg Gartner

Abstract—This paper deals with current ongoing efforts to investigate the influence of different presentation forms on spatial knowledge acquisition. The acquisition of spatial knowledge based on map, augmented reality (AR), and language is analyzed and compared in an empirical test for GPS-based pedestrian navigation. This paper describes the hypothesis and the methodology. Also work in progress on interpreting the results is presented. It is proposed that the results will be very useful for future mobile navigation system developments, as navigation systems typically use different presentation forms for conveying information, which may affect users' spatial knowledge acquistion, and thus influence wayfinding success.

Index Terms—Pedestrian navigation, LBS, Spatial knowledge acquisition, Map, Augmented reality (AR), Language.

1 Introduction

The increasing ubiquity of GPS-enabled mobile devices has led to the introduction of mobile pedestrian navigation systems, which aim at effectively assisting pedestrian's wayfinding tasks in an unfamiliar environment. Research on mobile wayfinding services mainly focuses on three parts: positioning, route selection, and route communication [1]. Positioning determines the position of the user. Route calculation focuses on computing the "best" route from origin to destination. How to communicate route information efficiently and enable wayfinders to easily find their way with little cognitive load is the key question of route communication.

Maps are important presentation forms when communicating route information. They can help the user to get an overview of the area. Provided that directions are indicated with arrows on the map, tests with mobile devices, which are comparably small in size, showed that even then maps are the most efficient tool for describing directions [2]. Verbal guiding instructions have also been shown to be a helpful tool for wayfinding. An experiment by [3] indicated that test persons who have to find part of a route with the help of a map and the other part with verbal guidance did not show major performance changes after switching the presentation form. Recently, verbal guiding instructions enriched with landmarks and semantic information were also proposed for route communication [4]. Augmented reality (AR), which enhances the real environment with registered virtual information overlays, is another approach for conveying route information. AR, especially hand-held display AR, was found to be very suited for wayfinding as it puts route instructions directly into the real visual context of a user [5]. Other presentation forms which can be employed for route communication include signs, images, video, and 3D presentation.

Spatial knowledge acquisition is needed to build mental representations which can be referred to for wayfinding and other spatial tasks. In order to gain an in-depth understanding of the effectiveness of different presentation forms in guiding pedestrians, it should be carefully investigated how these presentation forms influence the acquisition of spatial knowledge.

This paper aims at investigating the influence of digital map, AR, and language on spatial knowledge acquisition in the context of GPS-based pedestrian navigation.

• *All authors are with the Institute of Geoinformation and Cartography, Vienna University of Technology, E-Mail: {haosheng.huang, manuela.schmidt, georg.gartner}@tuwien.ac.at.*

2 Related Work

Mental representations of space are referred to when humans have to act in space, e.g., find a way [6]. During wayfinding, humans make route decisions to find a connection between a start point and an end point. Therefore sequences beneath decision points are planned. When moving, this plan is monitored permanently by referring to objects of the real world and comparing them with the mental representations for route confirmation [7]. Spatial knowledge acquisition is needed to build mental representations which can be referred to for wayfinding. Various methods can be used to acquire spatial knowledge, including sensual perception of the real world as well as acquisition from models of the real world, such as map, AR, and verbal description. Personal skills and abilities have a big influence on spatial knowledge acquisition [8–9].

Three levels of spatial knowledge can be distinguished [10]: 1) landmark knowledge comprises salient points of reference in the environment, 2) route knowledge puts landmarks into sequence (e.g., navigation paths), and 3) survey or configurational knowledge allows people to locate landmarks and routes within a general frame of reference. When analyzing mental maps (the results of spatial knowledge acquisition), the method of sketch maps is often used. [11] demonstrated distorted distances and angles in sketch maps, and showed that relative overestimation of length were found with routes in the town centre, with routes having several major bends, and with short routes. [12] and [13] pointed out that the skills of drawing correct angles and finding a way are not significantly correlated. As a result, [7] proposed to stick to topological interpretation of sketch maps only, as [14] mentioned, and enhance possible results by additional methods of estimating distance or direction, such as pointing methods ("where is the starting point").

There is related research on comparing the influence of various presentation forms on spatial knowledge acquisitions in the context of pedestrian wayfinding. [2] showed that different presentation forms used when navigating along an unknown route, could highly influence the generalization of the user's mental map which could again influence wayfinding success. [3] compared map and language in guiding wayfinders, and investigated the differences of spatial knowledge acquisition with map and language. The "Wizard of Oz" prototyping [15] was often employed in these empirical tests. However, it is important to note that little work has been done on comparing the influence of digital map, AR, and language on spatial knowledge acquisition in the context of GPS-based pedestrian navigation.

3 HYPOTHESES

The overall research goal is to investigate differences in spatial knowledge acquisition with different presentation forms, comparing digital map, AR, and language (enriched with landmarks and semantic information) in the context of GPS-based pedestrian navigation.

Hypothesis 1: In the context of GPS-based pedestrian navigation, the presentation form digital map results in better spatial knowledge acquisition compared to language and AR, reflected by:

1) More accuracy in pointing the starting point,
2) More topological accurate sketch maps: more accurate in the sketched turns, more accurate in sketched landmarks and route configurations,
3) More accurate in marking the half of the route.

Hypothesis 2: Higher spatial ability scores as measured by the Santa Barbara Sense of Direction Scale [16] correlate with better spatial knowledge acquisitions.

4 METHODOLOGY

Based on the above hypotheses, an empirical test has been set up. Thereby possible differences in spatial knowledge acquisition – caused by different presentation forms – during navigation with GPS-based system were detected. The basic concept was to test the hypotheses in a real world scenario.

A route in the city centre of Salzburg was selected. The route was divided into three sub-routes, with each including a number of waypoints. The test was performed with 24 persons, which were also divided into three groups. For each sub-route, these three groups each used one of the presentation forms (digital map, AR, and language). When they reached the next sub-route, they used another presentation form. The whole test can be completed within 2 hours.

The test setting included an instruction phase by the instructor, where the test conditions were explained. Before they started, test persons were asked to answer the Santa Barbara Sense of Direction Scale, which can be used to measure their spatial abilities. During their navigation, test persons were observed by the instructor, and their movement and interaction with the navigation system were recorded by a logger. When the test persons reached the end of each sub-route, they were asked to solve some tasks and answer some questions:

1) To give an approximate direction to the starting point: measured in angle.
2) To draw a sketch map of the area they just passed as precisely as possible: focusing on the route (e.g., street names) and landmarks (on route and off route).
3) To mark the half of the route on the sketched map.
4) Familiarity with the sub-route.

5 WORK IN PROGRESS

The field test was completed in October 2010. Currently, we are analyzing the data. The analysis focuses on the sense of direction (the pointing task), sketch maps, and sense of distance (marking half of the route), as well as the relationship of spatial abilities and spatial knowledge acquisition, the relationship of familiarities and spatial knowledge acquisition, and the relationship of spatial knowledge acquisition and performance of wayfinding.

Results of the analysis will be available before the GeoViz conference.

6 CONCLUSIONS

GPS-based pedestrian navigation systems have become increasingly popular. Different presentation forms are often employed for conveying route information. This paper reported a work in progress, which investigates the influence of digital map, AR, and language on spatial knowledge acquisition in the context of GPS-based pedestrian navigation. The hypotheses, methodology and current efforts were presented.

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