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Location Awareness, Orientation and Navigation: Lessons Learned from the SmartInside Project

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ABSTRACT

This paper presents four studies on indoor/outdoor localization, orientation and navigation in the context of the European SmartInside project. The findings of the studies are outlined and remaining research questions are described.

Author Keywords

Navigation; orientation; mobile maps; location awareness; location sharing; indoor positioning; haptic guidance.

ACM Classification Keywords

H.5.m. Information interfaces and presentation (e.g., HCI): Miscellaneous; H.5.3 Group and Organization Interfaces: Collaborative Computing; D.m. Miscellaneous: Software psychology.

INTRODUCTION

This paper presents four studies carried out in the context of the SmartInside project. The goal of the SmartInside project was to develop techniques for and gain insights on navigation aids in complex (indoor) environments, such as large fairs, airports, or hospitals. In the course of the project (2010-2012), we have carried out four studies investigating aspects related to (1) usage of large standing maps, (2) indoor positioning, (3) evaluation of a mobile map app for a large fair, the Paris Air Show, and (4) evaluation of a haptic belt for navigation. Rather than presenting the details of every study, we focus here on the questions that were triggered by specific findings, related to the workshop themes of location awareness, location sharing, and human sociability in complex, unknown environments.

STUDY 1: MAP USAGE AT PARIS CAR FAIR

To investigate how maps are used in a complex environment, we visited the Mondial de l'Automobile (Oct 7-9, 2010), one of the largest public car fairs in Europe. The show was distributed over eight different pavilions (only 3 are directly connected), extending in total around 228,000 square meters. We observed (two researchers taking notes) the behaviour of visitors consulting large free-standing maps and their use of orientation aids in the halls. We also performed interviews with leaving visitors to investigate their views on the navigation means available. Findings included the following (for more details, see [1]):

- Many visitors of the fair come in groups, and their use of maps reflects this. Among other things, we recorded 39 episodes of map usage, documenting the behaviour of 8 individuals and 31 groups consisting of 2 to 5 people (mean group size for the group episodes was 2.42). In 12 of the 31 group episodes, one person took the role of navigating captain for the group, but in other cases, group use of the maps included many cases of communication and collaboration, often in the form of pointing actions (clear gestures with the hand or something in the hand in a particular direction).
- Different ways of pointing could be distinguished, e.g., single touch, tapping, stroking, or circling. By pointing, people directed other people's attention to a particular place on the map or index, which seemed to serve various communicative goals: answering queries (often implicit) about the location of a point of interest, proposing locations to visit, suggesting a route, correcting navigational misunderstandings, and confirming decisions.
- People often pointed at multiple things (on average, 2.68 distinct items per group episode), of different kinds. They pointed, in order of frequency from high to low, at the maps, at the index, and at other things, including arrow signs, building letter signs, stands, buildings, stairways and electric walkways. The order was often as follows (although often only part of the sequence occurred): search whether an object of interest is present in the index, search for its location on the map, and then translate the information found to the real world context in the visible range to establish orientation and determine direction.
- Many people mentioned that they did not separate (despite having different interests) because they were

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afraid of not finding each other back again, and would appreciate a mobile map app that shows group members' locations.

The following issues and questions were raised by these findings:

- How can we support collaborative use of maps (including suggestions, clarifications and negotiations about destinations and routes) in a mobile context?
- How do we support synchronization and joint attention in map-related group decision making processes, where members of a group may or may not be co-located in physical space, and may or may not be looking or interacting with the same device (e.g., see [2])?

STUDY 2: INDOOR POSITIONING

Localization based services are now introduced for outdoor scenarios, but such services also have a large potential for certain indoor scenarios, such as shopping malls, convention centres, medical centres, large museums and university complexes. Outdoor localization can rely on Global Navigation Satellite Systems (GNSS) such as the GPS (U.S.), GLONASS (Russia), Compass (China), and Galileo (EU) systems. Yet, indoor those satellite signals cannot be received, which means that one has to rely on different means. Solutions could be the installation of pseudolites [3] or by relying on other ground based signals, such as WiFi and GPRS beacons.

In the SmartInside project, experiments were performed to compare localization based on WiFi and GPRS beacons. For fingerprinting, we used an HTC Desire smartphone on a robot equipped with odometry and laser scanner to provide accurate position information. Two datasets were recorded over a distance of approximately 500 meters, on the 3rd floor of our university, as depicted in Fig. 1, one with 1739 WiFi and 4055 GPRS measurements, the other with 1623 WiFi and 4090 GPRS measurements.

Localization was done by doing a search for each WiFi or GPRS measurement in the ground truth set and using the position information of the 10 nearest neighbors to update a particle filter [4] with 500 particles. For the prediction step in the particle filter we assumed constant speed.

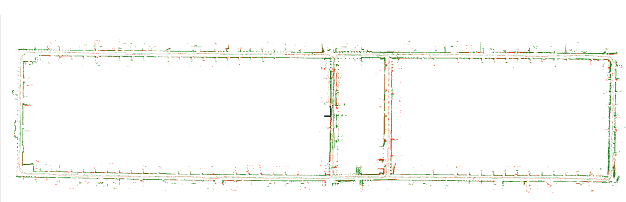

Fig 1. Map of the 3rd floor of the University of Amsterdam generated by a robot equipped with odometry and a laser scanner, showing the position of the walls as measured by the laser scanner while recording the two datasets. One set is depicted in green, the other in red.

Results and findings:

- Using one dataset as ground truth and the other as the test set (measurements perceived by a potential user) we could localize with an average error of around 2.5 meters.
- The precision of localization depends on accuracy of the fingerprinting process, characteristics of the building architecture, the presence of objects in the building, and crowdedness of the network. Also, some WiFi network managers vary the strength of WiFi beacon signals depending on the number of devices that access them. This reduces precision when using methods that assume stable signal strengths.
- The particle filter estimate sometimes gives multiple clusters of possible user locations. For the user interface, the decision was made to display only the most probable location, the center of the largest cluster of particles, to make it easier to interpret for the user.
- Our SmartInside project partners from industry, Insiteo and Silicom, have addressed gateway communication methods and modifications of phone chipsets to realize an ISM pseudolite solution at Toulouse Blagnac Airport. This allows more precise triangulation methods for localization than is possible with WiFi-based methods, albeit at a higher cost for hardware and complexity, related to the synchronization of pseudolite beacons.

The following issues and questions were raised by these findings:

- To what extent could a user make sense of more complex predictions (of one's own but also other people's locations) as provided by the particle filter is something that should be assessed empirically.
- Can we counteract, circumvent or compensate for these sources of imprecision, or should they be communicated to users as such, so that they become more knowledgeable about their reliability?
- With respect to sharing of location information, it is not only a matter of precision, but also privacy - a user might want to grant friends access to specific information about his/her location while only sharing less specific information with others.

STUDY 3: MAP APP FOR PARIS AIR SHOW

We tested a mobile map application (developed by Insiteo, a company specialized in indoor navigation solutions) that was especially designed for the Paris Air Show at Le Bourget Airport, France. The Paris Air Show contains a complex fair layout, a large number of exhibits (~2000 exhibitors), a large area (130,000 m2 of rented space), and requires visitors (~47,000 per day) to move between multiple buildings.

The functionality included an overview map of all halls and outdoor spaces, hall-specific maps of the fair, a graphical visualization of the user's current position, graphical visualizations of the current locations of people who share their position with the application (the MeetMe feature), services such as route planning to a selected destination, and information about fair exhibitors.

Findings from this evaluation included (for more, see [5]):

- People were enthusiastic about the system, showing their location on a map, as well as the location of stands, and locations of other people (MeetMe)
- People could succesfully find locations of stands, and another person using the map app on a mobile phone

But, on the other hand:

- People had problems determining where they were (in the unknown environment of a large fair) - showing one's position on a map does not guarantee good orientation.
- People varied widely in how much they paid attention to their environment (e.g., in most cases, not making use of navigational aids in environment, in some cases, getting lost in navigation, even bumping into people).
- For some, searching and trying to meet another person (whose location they could see on the mobile map) resembled playing a game in which they controlled the dot representing their own position by walking around.
- Relating information from one map (on the mobile phone) to another map (a paper map) was not straightforward, due to different graphical conventions used, in terms of colour coding and orientation (north up vs. aligned with main axis of building).

These findings raise the following issues:

- Orientation (in the sense of knowing one's location, and what is where in the immediate environment) and navigation (in the sense of knowing where to go) are perhaps not as tightly coupled as described in the traditional wayfinding literature [6, 7], and may therefore require different forms of support.
- Different wayfinding tasks may be served by other modalities such as audio [8] or haptic feedback [9, 10, 11], instead of, or in combination with visual maps.

STUDY 4: HAPTIC SUPPORT FOR NAVIGATION

In a recent experiment, described in more detail in [12], Steltenpohl and Bouwer have studied the use of haptic guidance for navigation on bicycles, using a system called Vibrobelt. The system consists of a belt around the waist with eight vibrotactiles (front, back, left, right, and the four directions in between), controlled by a location-aware smartphone app, and gives tactile navigation instructions to the next waypoint and the destination, incorporating information about direction and distance. Twenty participants evaluated Vibrobelt, while cycling a route with each system through a residential area. For comparison, they cycled another route with a graphical map app running on a smartphone mounted in between the bike's handlebars.

Findings include the following:

- All participants were able to reach their destinations based on the haptic guidance, albeit slightly slower (14%, on average) than in the visual condition (in contrast with findings for haptic guidance for pedestrians by Pielot and Boll [11]). On average, people's preferences for both applications (Vibrobelt vs. visual map app) were equal, with three participants indicating an absolute preference for the tactile system.
- In the visual condition, participants spent on average 28% of their time looking at the screen, while cycling. Complaints included having to look at the screen, finding it difficult to operate the device while cycling, and low visibility of information on the screen due to reflection. Two near-accidents (requiring braking to avoid collision or making others do the same) occurred in the visual condition, compared to none in the tactile condition. Still, people liked the route overview and familiarity of the visual system, and this seemed to be associated with better route recall when asked to draw the route on a map afterwards.
- In the tactile condition, most (12/20) participants reported feeling less distracted than in the visual condition. Vibrobelt was appreciated for several reasons, including its intuitive usage, being fun and exciting to use, presenting the right information at the right time, and allowing them to focus on the surrounding traffic. This was associated with lower error rates, on average, for recognizing pictures taken along the route. Points of critique included the intensity of the vibrations (often found too low) and the difficulty of differentiating between waypoint and endpoint information, which was encoded differently in the vibration signals.

This raises the following concerns:

- Feeling distracted by having to look at, search for, or interact with information on a mobile phone is a serious concern for people in a mobile context, e.g., navigating in traffic. This is true for people cycling [12, 13], but also in cars [14, 15], and for pedestrians [5, 11].
- Haptic interfaces can provide guidance for navigation [11, 12] that may lead to a reduced feeling of distraction, but more experimentation is necessary to test this thoroughly empirically.
- More experience is needed by developers and users to arrive at systems that are intuitive to use while being able to handle complex, dynamic information,

including information about waypoint and endpoint, and direction and distance, as described here, but also information about Points Of Interests (e.g., see [13]), the presence of other people [5, 16], and traffic information.

- How to combine haptic signals with visual and other modalities effectively is another matter to be explored.

CONCLUSION

We have presented findings from and reflections on four studies carried out in the context of the SmartInside project, to provide insights into the ways in which people interact with maps and other forms of support for localization, orientation and navigation.

Clearly, technical improvements are still required to increase localization precision and reliability. In addition, more research is necessary on how people can (and perhaps should learn to) divide (or combine) their attention between mobile devices (i.e., a virtual environment) and their current physical environment. A mobile map with automated position information seems able to draw so much attention away from the environment that users can get 'lost in navigation'. Multimodal solutions, such as the haptic belt discussed in the section about study 4, can perhaps provide part of the solution.

For other purposes where location awareness or sharing plays a role, application designers should realize that orientation and sense making of maps can not be taken for granted, and that people's use of information from maps often takes place with a great deal of communication, both verbal and non-verbal (i.e., pointing), both on a map, and off the map. More research is desired into these collaborative aspects of navigation to design location-aware services that exploit and support our perceptual, cognitive and social abilities to deal with maps and location-based information.

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