Supporting Orientation for Blind People Using Museum Guides

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Abstract
Novel environments exploiting recent technology can enhance several tasks in applications such as mobile guides. However, in the many museum mobile guides that have been proposed, accessibility is often not explicitly addressed and the benefits of such technology are rarely made available to blind users. In this paper, we propose a solution for flexible orientation support in a multimodal and location-aware museum guide, which has been developed specifically for blind users.

Keywords
Mobile guides, sensing technology, accessibility, blind users.

ACM Classification Keywords
H5.m. Information interfaces and presentation (e.g., HCI).

Introduction
In recent years, several mobile guides for museums and exhibitions have been developed and deployed. Various proposals have been put forward in order to provide such guides with multimodal interfaces (e.g. graphical and vocal). Research on location-aware computing has also been active, leading to new hardware/software solutions for indoor localization

purposes. Positioning capabilities are exploited in many ways: highlighting nearby artwork(s) helps users to identify which item must be selected on the device to get additional information. Another example of context-dependent service is the automatic generation of a path indicating how to reach a given artwork. Some of the first approaches in this area [5] have considered the possibility of automatically generating audio comments associated to the nearest artwork. However, this solution can be rather rigid, since a user may be close to one artwork but interested in another one farther away. Moreover, most approaches have also neglected the special needs of disabled users accessing a mobile guide. In this case graphical support for orientation (such as [3]) is not accessible and different solutions need to be investigated.

In this paper we propose a multimodal and location-aware museum guide, which has been specifically designed for visually impaired people to provide them with flexible orientation support. Our aim is now to bring the benefits of location-aware sensing to blind users by enhancing a mobile guide with reliable orientation support. In this way even blind users can access information regarding artworks or scientific specimens in their original locations, even if they cannot directly appreciate them. Such support can assist blind users both when they can touch an item on display and when it is not possible. In fact, if blind users can receive notional and (alternative) descriptive information on the artworks available, they can have a more enjoyable and informative visit. In addition, such support can enhance a blind person's museum visit together with their family and/or friends. Thanks such support blind visitors can be more autonomous and socially integrated.

In the following after discussing related work, we first describe the architecture of the proposed system and illustrate the orientation tasks supported. Then, we report on some first user tests and provide indications for future work.

Related Work

Navbelt [7] is an obstacle avoidance aid for the blind walking through unfamiliar environments. It exploits custom hardware (a combination of ultrasonic sensors and headphones). The wearable orientation system described in [6] is intended to support the visually disabled in hazardous situations such as street-crossings. The equipment of such guides consists of many dedicated devices, some in a rucksack, that the user is requested to wear. Our guide aims to provide a more compact and cost-effective solution. The recent progress of handheld computers and mobile phones has enabled the development of compact wearable aid systems for the blind. An example is the RadioVirgilio/Sesamonet [2] guidance system, based on a cane with embedded RFID (Radio Frequency IDentification) -reader and a Bluetooth module. Sensed data are sent via Bluetooth to the handheld device (which is also connected to a remote server) that guides the user by means of speech-synthesized instructions. However, this solution requires that blind users follow predefined paths, thus limiting the user's freedom of movement. The features and an evaluation of a handheld guide for supporting blind visitors through an indoor exhibition are presented in [1]: the most interesting points of the exhibition are tagged with RFID transponders. Since the mobile device is equipped with an RFID-reader, the application can detect the RFID tag nearest the user and provide vocal information about the current area. According to the

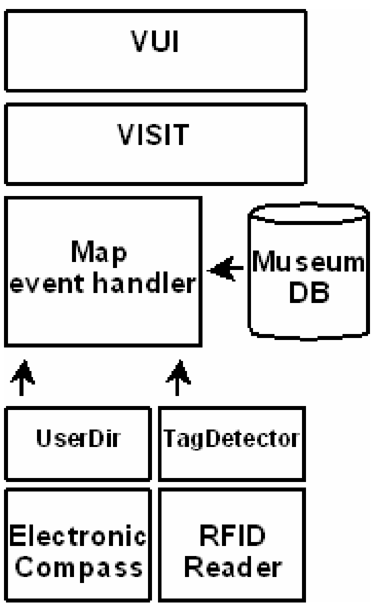

figure 1: Architecture schema of our mobile guide system.

user test results, the guide was judged as useful, though it did not provide any help to reach specific points of interest. Our guide is better able to support blind users by means of both localization and direction aids. The former is enabled by active RFID technology, which provides user position, while the latter exploits a wearable electronic compass that furnishes the absolute orientation. We also consider audio feedback in supporting the orientation tasks. While this type of technique has already been considered in mobile devices (see for example [4]) we propose a novel solution for supporting blind users' orientation.

System Architecture

The orientation capability discussed here is a support we have integrated into a location-aware guide already in use at a museum. To this end, we use a localization infrastructure based on a number of RFID tags deployed along the exhibition area of the museum: each tag is placed by an artwork. The correspondence between artworks and tags is specified in the museum database. The position of each artwork within the room is stored in the database as well: in our accessible museum guide artwork position is essential for suggesting the right direction to the user. Figure 1 summarizes the architecture of our system. Bottom-up in the schema:

- *RFID-Reader* is an hardware module that detects the RFID tags in the environment. It is a CF (Compact Flash) card plugged into the slot of the handheld device and has been provided by Identec Solutions[1]. Each tag transmits its ID with a constant power level to enable detection within about 5 meters. For each tag the RFID reader also detects its signal power (that is, the RSSI – Received Signal Strength Indication, which depends on how far the tag is), reporting it to the software layer. A location event is triggered when a new RFID tag is detected or when the signal strength of a tag has changed.
- *TagDetector* is the software embedding the RFID monitoring thread that generates location events. It interfaces with the RFID reader through pre-compiled software modules provided by the hardware manufacturer.
- *Electronic Compass* is the device for sensing user direction in absolute orientation degrees. The compass is needed because calculating the user motion vector based on the signals detected from the RFID tag network is rather problematic. Since none of the existing commercial solutions seemed to be suitable for a mobile application, we expressly designed and developed the device to meet our requirements. It consists of an analogue compass sensor and a microcontroller that manages ADC (Analogue to Digital Conversion) and data serialization. The compass device is battery operated, has an embedded Bluetooth interface with SPP (Serial Port Profile) and is detected by the PDA as a wireless peripheral. The small size and low weight of the compass device make it easily wearable. Figure 2 illustrates a blind user carrying the PDA and wearing the compass as a necklace.
- *UserDir* is the interface software to the compass device. It reads and filters the stream of values and computes the direction 3 times per second as a value in the interval [0,359] degrees with respect to the North of the Earth's Magnetic Field.

[1] http://www.identecsolutions.com

- *Museum DB* is an XML specification of the whole museum: authors, artworks, sections and associations between artworks and RFID tags. These resources make up a simple GIS (Geographical Information System) that holds enough information (sections geometry and artworks positions) for supporting a blind user.
- *Map Event Handler* is the module that catches the events triggered by the *TagDetector*, asks the *UserDir* for the direction and queries the *Museum DB*.
- *Visit* supports automatic access to museum info such as artworks and section descriptions.
- *VUI (Vocal User Interface)* exploits an embedded TTS engine, provided by Loquendo[2], which synthesizes the speech for describing artworks/sections and for giving direction tips on the fly ("*… rotate left…*", "*… carry on in this direction*", "*Please, stop!*").

Supported Orientation Tasks Evaluation

In the early integration of the compass support we opted to use vocal instructions to guide the user. Depending on the direction change needed to guide the user to a specific location, the application synthesizes speech such as "*turn X degrees left/right*" (with X ≤ 180). When the right direction is reached the user is asked to move towards the artwork by the instruction: "*slowly approach the artwork continuing in this direction*". When the user enters the destination area (about 5 meters around the artwork tag) s/he receives a notification and a "beep" starts to sound repeatedly.

[2] http://www.loquendo.com

The frequency of the beeping depends on the current distance from the destination tag: the faster the beeping, the closer the destination. We consider distance monitoring as the only way to ensure the user reaches a point of interest. The compass support is useful to direct the user towards the artwork, but the system has no information about the path taken.

figure 2: A blind user carrying the mobile guide (PDA in the left hand and electronic compass round the neck).

We conducted a preliminary test of the first prototype with two blind users. Initially, they were instructed to reach an artwork by exploiting only the distance support, that is the repetitive sound indicating how far the destination tag is. Both users accomplished the task, but they took quite a long time. Users reported that looking for an artwork placed many meters away from the current one is too complex a task if no direction aid is provided. This is due to the need for scanning almost the entire room before reaching the suggested destination. A second session trial was performed on the guide version enhanced with the compass module. Users were able to discover the proposed artwork location and arrived very near the associated tag. The compass support was judged essential and some improvements were suggested. The first user would have preferred a continuous sound with variable frequency rather than vocal tips: he stated that degrees-based tips are not intuitive. The second user, on the contrary, appreciated the vocal aid but pointed out that not everyone is familiar with measurements in degrees. She suggested indicating the direction by simple sentences such as "*rotate left/right*" or "*turn back*". All in all, users found the orientation support to be a reasonable way to help the blind in visiting a museum independently.

Keeping in mind the observations, we performed a second user test involving a larger number of blind users. The main goal of the new test was to compare the usability of two prototype versions with different types of feedback. More specifically, the evaluation was targeted at answering the following questions: (1) Can an electronic compass support a museum visit? (2) What is the most appropriate feedback for a user?

We recruited five participants: four of them totally blind from the birth and one with a little residual vision. The age ranged from 33 to 69 years. Four of them use a computer with a screen reader in Windows environment daily. None of them had any experience with PDAs. The evaluation regarded two new versions of the guide that differ from the one previously tested only in the type of audio feedback. The first version adopted simplified vocal tips such as "*rotate left a bit*" and repetitive "beep" sounds with variable delay to indicate distance. The second version used a continuous sound with variable frequency to suggest direction and repetitive "beeping" sounds with variable frequency to signal the distance. In the latter version, the frequency of the direction sound decreased as the right orientation was achieved. Once aligned, on the contrary, the distance sound frequency increased as the user approached the target.

Users were asked to reach a specific artwork by exploiting the compass-based guide. Because the experiment was also aimed at analyzing the kind of feedback, each user tried to reach different artworks by using the two versions of our prototype. In order to avoid a possible bias due to the learning process, three users used the vocal version first and then afterwards the one based only on the sounds; whereas for the others the process was inverted. The task assigned was to start from a specific artwork to reach another one. The artworks to reach were different for the two guide versions. We observed the users as they performed their tasks. The start and finish time was recorded for each user and for each task. At the end of the tests, users were asked to fill in a questionnaire to collect subjective comments and suggestions.

All the users were able to accomplish the assigned tasks. The recorded time for each user for each task revealed a significant time saving in localizing the artwork by using the version with both vocal and sound support. Just one user spent more time using the version with vocal feedback. For the other users, the time saved ranged from 50% to 82% (M=35.57%). Users indicated they encountered some difficulties in carrying out the tasks due to the response times of the system. This referred to the time lag of the direction tips and it has been improved by better filtering the compass event stream.

Concerning subjective opinions, the users could express a value from 1 (the most negative value) to 5 (the most positive value) with respect to various aspects. The users declared that the RFID technology can be a useful support (M=3.6; S.D.=1.6) not only for localization, but also for daily activities. However, some of them reported that this methodology should be integrated with other technologies in order to be more precise and reliable. On the other hand, regarding the use of an electronic compass in a museum context, the users reported that such a support would be a useful assistance to allow a blind person to freely move among the artworks (M=4; S.D.=1.2). The users were asked to report their preferences regarding the two feedback versions. Most users (4 out of 5) preferred vocal and sound feedback, while one user reported that using only sounds would have been better because sound feedback might be more intuitive and less annoying. This can be easily explained by the fact that he is an expert user in electronic devices. The other users preferred the version with vocal and sound support, declaring that such support is more intuitive especially for a non-expert who is using the system for the first time. In fact, our prototype is designed to be used in a museum context where visitors have no time to learn and become familiar with the guide. However, regarding sounds, one user suggested using different kinds of sounds (e.g. just three types) and well recognizable (i.e., they should have very different frequencies) because very similar sounds could not be easily differentiated.

Conclusions and Future Work

We have developed and tested a prototype museum guide for supporting blind people in orientating themselves. The user feedback was generally positive and encouraging. Future work will be dedicated to considering other modalities for the guide feedback (in particular tactile feedback) and for sensing distance from obstacles to avoid collisions. We also plan to include the possibility of supporting customizable feedback in order to allow the guide to take into account user preferences.

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