Exploiting RFIDs and Tilt-Based Interaction for Mobile Museum Guides Accessible to Vision-Impaired Users

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Abstract. In this paper, we present a study aiming to investigate how tilt-based interaction, along with RFIDs for localization, can be exploited to support blind users in interacting with mobile guides. We describe the design proposed and report on a first user study, which also compared two different ways to provide audio feedback (short sounds or vocal messages) for the tilt-based interaction.

Keywords: Mobile guides, Accessibility, Tilt-based interaction, Blind users, RFIDS.

1 Introduction

In recent years there has been an increasing interest in developing mobile guides for towns and museums. Novel devices equipped with appropriate software can facilitate visually-impaired people in autonomous orientation and in exploring the surrounding environment. We have carried out a study on accessible mobile guides, which has focused on the investigation whether multiple modalities, such as gestures, RFID-based location awareness, audio and voice, can provide useful support in this context.

We decided to investigate a new modality to interact with a PDA by users with visual impairments because using a PDA is quite challenging for such users. Indeed, various available PDA models have different hardware features and screen reader commands, thus blind users need to spend a long time to become familiar with a PDA. Moreover, learning to use screen readers requires a good deal of effort because, apart from learning the commands for controlling the operating system and the applications, the user needs to learn the screen reader commands as well. In addition, the disabled already accustomed to the use of screen readers for desktop systems are not facilitated because PDA screen readers require different interactions. The limited number of keys available on PDAs does not contribute to make easier the task, which becomes unfeasible for occasional users such as museum visitors. Therefore, we have investigated the use of new techniques able to overcome such issues. In particular, we have considered the integration in an accessible guide of two emerging technologies: RFIDs and tilt interaction based on accelerometers. Currently, several types of RFID readers that can be plugged in mobile device are available and tags can be associated to artworks, thus enabling location-aware guides. Even tilt interaction based on accelerometers has started to be applied in several contexts (for example, the Wii console,

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IPhone, some smartphones). We conducted a first experiment with passive RFID tags and tilt-based interaction [7], which was useful to have a better understanding of such technologies and raised the idea of investigating whether they can be better exploited to make a digital museum guide accessible to blind and/or sight-impaired users. In particular, in this paper we discuss a solution aimed at exploiting active RFID tags and tilt-based interaction in order to make a museum guide accessible for vision-impaired users and report on a first user study, which also compared two ways to provide audio feedback for the tilt-based interaction.

2 Related Work

As already noted, the use of PDA is quite challenging for the blind. For example, Mobile Speak Pocket (http://www.codefactory.es/en/products.asp?id=98), a screen reader for Windows Mobile operating system, divides the PDA screen into four areas delimited by the four screen corners. The available commands depend on touching these areas. Three kinds of touch can be used: single, double or long touch. In this way, twelve commands are available, but a good deal of effort is required by the user to learn and remember these commands, which are not based on keys. In addition, to become familiar with all commands may take a lot of time, and consequently such PDA readers cannot be used in a museum. Then, we investigated the use of other techniques enabling the disabled to use a digital museum guide.

The use of RFID technologies in museums is likely to increase, especially for creating new experiences and extending learning. In [6] the authors explore a custom-designed RFID application called eXspot being prototyped and evaluated in various museums. The Talking Points project [4] and an RFID-based robotic guide [5] are two examples of how to create a system for attaching information to places and objects, in a format that can be used to improve outdoor and indoor navigation for blind people. SesamoNet [2] consists of a system aiming to improve blind and low vision users' mobility by coupling tactile perceptions with hearing aids. While such a system is useful for moving along only predefined paths, we want to provide a guide that allows the disabled user to explore the surrounding environment freely.

Some of the classical problems of location systems have been addressed in [3], in particular the issue of being able to process different kinds of sensory data. The underlying idea is that different types of communication senders have different characteristics. In particular, authors consider a combination of active RFID tags and infrared beacons Active RFID tags use radial emission whereas infrared beacons are conical. Due to reflections and other physical factors that affect the radio signal, on the one hand receiving RFID tags may provide less evidence that a user is in the vicinity of the tags than an infrared beacon. Therefore, the authors propose a new probabilistic approach for sensor fusion, based on "geo referenced" Dynamic Bayesian Networks (geoDBN): with this approach a new estimation of user's current position is calculated after each new measurement and is based on the current sensory data, as well as on the previous data. A weighted combination of the old and new data is achieved through inference in the respective geoDBN. However, in that work accessibility issues have not been addressed.

In our approach, we have used active RFID tags associated to artworks and one infrared beacon at the entrance of each room to identify the tags of the artworks that are in the same room. In [8] the authors examine the use of device orientation to navigate through one-dimensional lists or menus. A vibrotactile output was used as feedback. The experiments conducted found that motion input and vibrotactile output positively affected user performance and experience. We also use the same type of accelerometer, but together with RFID support in order to improve accessibility for blind users. We decided to use the audio channel rather than vibrotactile feedback to investigate whether the vision-impaired can better perceive events through various types of short sounds. 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 were tagged with RFID transponders. Since the mobile device was equipped with an RFID reader, the application could detect the RFID tag nearest the user and provide vocal information about the current area. Our guide aims to provide the blind with better support through tilt-based interaction, which allows them to control the guide with small, single-hand movements.

3 Guide Overview

In order to make the museum guide accessible to vision-impaired users, we designed a prototype based on vocal output and gestural input. We decided to develop a voice-based application rather than using an existing screen reader, since screen readers require a good deal of effort to learn to use them efficiently. Furthermore, interacting through the PDA keys might be difficult for the blind, because the keys can be difficult to be recognised by touch and they can vary a lot depending on the device. Then, in order to simplify user interactions, we use gestures to enter commands and navigate in the interface. Thus, the PDA is equipped with an RFID reader able to read active tags and a 2D accelerometer able to recognise small movements of the handheld device. The vocal support suitable for blind people is provided through a voice synthesizer. Artwork selection is obtained by scanning the RFID tags associated with the artworks, and single handed tilt gestures are used to control and navigate the UI and multimedia information. The active RFID tags used are powered by an embedded battery and they send the signal within an area of several tens of meters. The RFID reader we used is equipped with a compact antenna that can detect tags within an area of up to 5 meters. The beacon technology enables tags to automatically transmit their ID about every 1-2 seconds; in this way, their detection is not affected by the number of users, since the readers do not send any request to the tags. Localization at the application layer is performed by estimating the nearest tag and obtaining the associated artwork(s). Every time the RFID reader is interrogated, it provides the list of visible tags. Each list element contains the ID and the RSSI of a visible tag. The application localization support keeps a list of all the tags that have been detected at least once. In the application each tag is associated with its last reported RSSI and the time elapsed since its last detection. Only tags that have been detected recently are considered in the computation. The best tag is always the one with the highest RSSI. However, a “new tag event” is generated only if the new tag is the best candidate for N consecutive queries. The value of N is specified in the application settings to achieve a trade-off between reliability and speed of the localization: the higher it is, the more reliable the localization will be, but also the more time it will take to update the identification of the closest artworks. The value of N must be carefully chosen, especially when tag density is high (i.e. artworks are very close), in order to avoid erroneous detections. To facilitate localization an RSSI threshold is used to adjust the reader sensitivity. Lower sensitivity makes the reader report only the nearest tags and simplifies the application layer computation. Nevertheless, when many artworks are too close each other they may be detected as a single tag. When this happens, the guide automatically highlights nearby artworks with squared frames around the corresponding icons.

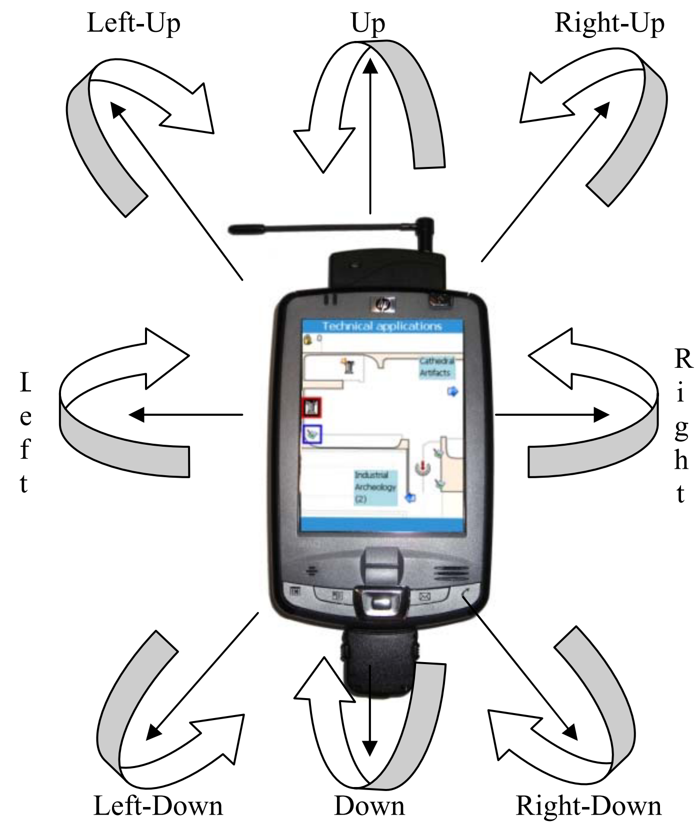

Fig. 1. The tilting movements supported by the prototype

The choice of combining RFID support with the accelerometer-based sensor was supported by the fact that all the equipment (RFID and tilt-based sensor) could be contained in a single device (the augmented PDA) which in turn can be controlled with a single hand, then the blind can use one hand to handle the PDA, and the other one to "touch" the artwork when this is possible. In addition, the control of such augmented device is not dependent from any specific characteristic (e.g.: position of keys, etc.) of the considered PDA, but is connected only to 2D gesture movements.

4 Tilt-Based Interaction with the Mobile Guide

The gesture modality in our approach utilises a 2D acceleration sensor hardware by Ecertech attached to Pocket PC PDAs and SmartPhones through standard interfaces. The sensor produces signals that are interpreted as events by the tilt manager-data processing module of the mobile device. The movements are detected by an accelerometer and, depending on the direction and speed of such movements, they are translated into suitable actions/events (selection, navigation or activation) on the user interface. The possible tilt movements supported by the prototype are highlighted in Figure 1. Left-down, Down and Right-down movements have in common the fact that they are all carried out by tilting the top part of the PDA towards the user, and consequently the bottom part away from the user (as represented by the three bottom arrows in Figure 1). In particular, if the direction involves only the vertical axis, the movement is Down. If a component on the horizontal axis is also involved, the movement will be Left-Down or Right-Down, depending on the direction. It works in a similar way for the Left-Up, Up, and Right-Up movements: the difference is that they are all carried out by tilting the top part of the PDA away from the user. The two remaining movements, Left and Right are carried out by tilting the left and right border of the PDA away from the user. In the following, we indicate by "vertical" and "horizontal" tilt movements those involving *only* the related axis (e.g. Up and Down movements are both 'vertical', tilting movements, whereas Left and Right are 'horizontal'). We consider the remaining movements as diagonal tilt movements. Our prototype uses a tilt monitoring algorithm based on angle thresholds calculated in relation to the position of the device when the user presses the button key. As for the size of the angle threshold, in order for a tilt movement to be detected, an angle of 18° must be exceeded by the user either on the vertical or on the horizontal axis (or both, if the tilt movement is diagonal). However, not only the width of the angle has been considered: indeed the algorithm performs three control cycles to discriminate whether a tilt event has been captured, and the time that has to pass before performing the next control cycle is 50 ms. In practice, the above settings mean that the application interprets a movement as a tilt movement (and it triggers consequently the related event on the UI) only when the user tilts the device on an angle of at least 18° and maintain this position for about 150 ms. We also introduced a latency time of 180 ms that has to elapse before the next tilt event is detected (it was introduced in order to give the user enough time to return the PDA back to its initial position). The angle of 18° was identified in such a way to avoid involuntary user movements, after empirical trials with the users. Such settings are 'default' settings, but they can be changed to better fit user's preferences.

4.1 Tilting Features

The mapping between the actions on the user interface and the tilt-based movements were selected in such a way to make them as intuitive and easy to remember as possible, also exploiting (when possible) associations with the users' experience in everyday life. For instance, the choice of associating the left tilt movement for diminishing the volume and the right tilt movement for increasing it is based on the consideration that in our culture we typically start from the left and go to the right (e.g.: in writing). Thus, moving rightwards is generally interpreted as going forward (increasing) while moving leftwards is interpreted as going back (decreasing). Then, depending on the current active state of the UI, in our support the horizontal tilt is used for activating different events: when an audio message is rendered an horizontal tilt controlled the volume (left tilt for decreasing it, and right tilt for increasing it), otherwise the horizontal tilt was used to scan all the user interface elements included in the current presentation. By using the 'Down' movement it is possible to confirm an already selected element (it acts as an enter button) and depending on the element currently selected, further actions are available. For instance, when the description of an artwork is opened, it is automatically rendered using the vocal modality; then, using a tilt 'Up', the voice can be put in pause/play; through horizontal tilt the volume can be controlled (left for diminishing it, right for augmenting it). Moreover, the central PDA button can be used to deactivate/re-activate the tilting modality at any time, allowing the user to change the coordinates of the initial reference position.

5 Audio and RFID Support

A vocal support is provided to read all functions, messages and descriptions of artworks. An audio support (voice messages or sounds) has been used to provide feedback of the tilt interactions. We developed two versions of our prototype, to investigate what kind of audio feedback - short sounds or vocal messages - of the performed interactions is more effective for a vision-impaired user. The first version uses very short sounds to inform the user that a specific tilt event has been detected. Different sounds were used to differentiate the detected events. A sound with an ascending tone sound has been used for confirming event (tilt 'down') and a descendent one for closing a presentation (right up tilt). In another version, those sounds were replaced with short vocal messages. For example, when moving among the interacting elements, feedback messages such as "previous element" or "next element" can be perceived. Each museum artwork is associated with a tag and each tag has a unique ID number. A single tag can be associated with more than one neighboring artwork, when they are very close. When the user enters a new room, the application automatically detects it by the infrared beacon at the room entrance and the new room is vocally described. To facilitate the localization accuracy, only the RFID tags associated with the artworks in the current room are considered. In general, when a new RFID tag is detected, a short sound is played to inform users. Then, a brief vocal introduction to the detected artwork(s) is provided by a TTS (Text To Speech) engine. This allows blind users to build a mental map of the museum. By tilting the device the user may select one of the detected artworks and request its vocal description. The main benefit of a dynamically generated audio description is that the audio file is not physically stored on the PDA but it is created "on the fly" by the Loquendo Embedded TTS, which has been used as vocal engine (http://actor.loquendo.com/actor-demo/default.asp). Whenever the central PDA hard button is pressed to reactivate the tilt, a brief message suggests the user to put the PDA in the new initial position; a "ding" sound confirms its recording.

6 User Test

We performed an evaluation of our prototype in order to collect users' feedback. The test involved 10 vision-impaired people (7 males and 3 female) with the average age of 56 (ranging between 33 and 68), and recruited through a local association for the blind. Eight out of ten were totally blind and the remaining two had a little vision residual. However, these two latter users were not able to see the screen as well as the artworks. Before starting the exercise, the users were given an explanation of the motivations of the study and the features of the mobile museum guide. Then, they were provided with a brief training session for learning the tilting movements.

The users tested two versions of the software prototype (one using only sounds for feedback, the other one using vocal messages). It was a within-subjects test, half users started with a version and half with the other one. After the exercise, users were asked to fill in a questionnaire asking for general information (age, education level, level of expertise on using PDA/electronic mobile guides, etc.), and for data more related to the evaluation test (e.g.: aspects regarding accessibility issues, vocal support, etc.).

People involved in the tests reported to be, on average, not familiar with using PDA systems (M=1.2 in a 1-5 scale in which 1 is the worst score and the 5 is the best one; SD= 0.63). On the contrary, most of them (8 out of 10) indicated they have a mobile phone made accessible thanks to a screen reader for symbian-based smart phones (e.g. Nokia smart phones). Six users out of ten have never used an electronic museum guide before the test. Users judged the choice of using tilt movements for navigating within the user interface of the PDA as having a sufficient level (M= 3.3; SD= 0.95) of usability. In addition, they judged a little better (M= 3.6; SD= 0.97) the associations between the tilt movements and the actions triggered correspondingly on the user interface. Some of them found the diagonal tilt a bit more difficult to carry out with respect to movements involving only one axis (e.g.: horizontal/vertical tilt).

Furthermore, users judged the vocal support of the user interface in a pretty good way (M= 3.7; SD= 1.25), and also the choice of using different sounds for providing feedback to the different tilt movements was judged pretty well (M= 3.6; SD= 1.58), although some of them would have appreciated a louder audio volume. Regarding audio support, the users were asked to report their preferences about feedback: using i)only sounds, ii)only vocal messages, iii) both of them. Most users (6 out of 10) reported to prefer a mixed solution, only one person preferred only sounds, three persons preferred only vocal messages. For example, when moving among the artwork elements (i.e. left or right tilting), a message "next artwork" is preferred; whereas for "confirm" or "close" operation, a short sound as feedback is enough. Moreover, they judged well the associations between tilt movements and the corresponding feedback sounds (M= 4.13; SD= 1.13). The accessibility of the user interface was judged more than sufficient (M= 3.6; SD= 0.97), whereas the question whether it was easy to get awareness of the different artworks existing in a section and get the related description received very satisfactory judgments (M= 4.5; SD= 0.7). Moreover, users were asked to judge the part of the mobile guide devoted to presenting location-aware information: it was rated sufficiently good (M= 3.6; SD= 1.74), as well as the information regarding the artworks that the mobile guide automatically identified as being currently the nearest to the user (M= 3.5; SD= 0.98). All in all, the users evaluated the UI in a sufficiently positive way (M= 3.7; SD= 0.67). Almost all agreed that the prototype has good potentialities, which can be exploited after getting familiarity with the tilt modality.

7 Conclusions and Future Work

We have presented the results of our study on integrated support based on tilt-based interaction and RFIDs for accessible mobile guides. Our work aims to understand the potentialities of the application of this technology, which appears promising and encouraging, even if there is still room for improvement. We plan to add an orientation support to our guide by using a wearable compass with Bluetooth interface in order to allow the guide to determine the artworks that are actually in front of the user. We also plan to provide additional feedback to the user through a vibrotactile user interface, to complement the auditory feedback already provided.

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