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Vibrotactile feedback to aid blind users of mobile guides

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A B S T R A C T

In this work, we report on a solution for providing support to the blind using mobile museum guides by exploiting the haptic channel as a complement to the audio/vocal one. The overall goal is to improve the autonomy and social integration of blind visitors. We followed an iterative approach in which the proposed system went through various user evaluations and further refinements. The final solution includes vibrotactile feedback enhancement for orientation and obstacle avoidance obtained through the use of unobtrusive actuators applied to two of the user's fingers combined with an electronic compass and obstacle detector sensors connected wirelessly to the mobile guide. Our study indicates that vibrotactile feedback is particularly useful to provide frequent unobtrusive indications of useful dynamic information, such as the level of proximity of an obstacle or the distance from the right orientation.

1. Introduction

Technological support is increasingly used to provide services and products that are more suitable for a wide variety of users in several different contexts. Technologies also provide new opportunities to allow users with special needs—such as people with disabilities—to access or perform activities previously impossible or particularly difficult to do (e.g. accessing digital information for blind people). There is increasingly enormous potential to harness mobile devices (cells and PDAs) capabilities for use in assistive technologies or in developing supporting tool (see for example [1]). However, to achieve such a result accessibility principles should be applied when developing a product or service.

Accessibility is a general term used to indicate that a product (e.g., device, service, environment) is accessible to as many people as possible, including those with disabilities. This is an important feature of systems to allow users with different abilities to access or use them. In this perspective, a multi-modal approach can represent a valuable way to support various interaction modes, such as speech, gesture and handwriting for input and spoken prompts. Thus, by combining various interaction modalities, it is possible to obtain an interactive interface suitable for users with varying abilities. A well-designed multi-modal application can be used by people with a wide variety of impairments. Visually impaired users rely on the voice modality with some keypad input. Hearing-impaired users rely on the visual modality with some speech input, and so forth.

In this regard, we decided to consider museum environments to investigate how to design and implement a multi-modal mobile application that can be easily used by blind people in this domain [2]. The aim of our study is to provide blind visitors with greater autonomy. Even if the blind cannot view museum items, visiting an exhibition autonomously can represent a good way to integrate the vision-impaired into a group (e.g. family or friends) and is more effective than obtaining cultural information from a Web site or multimedia CD.

In particular, in this work we investigate how the haptic channel, in conjunction with the audio/vocal one, can provide better support for the use of mobile museum guides for blind users. People who are blind or visually

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impaired must rely upon senses other than sight to perceive diverse information (e.g., shape, dimensions, etc.). Haptic interface technology allows building tangible data surfaces to provide an additional modality for data exploration and analysis. Unfortunately, the amount of information that can be perceived through touch is less than that which can be perceived through vision. Consequently, multi-modal approaches should be investigated to enhance the perception of blind and visually impaired people.

In the paper, after discussing some related work, we briefly introduce the key features of our proposal. We then report on the various versions that have been developed and the associated user tests. We indicate how the results of such tests have been considered in the evolution of the work up to the final version. Lastly, some conclusions along with indications for future work are provided.

2. Related work

In general, the use of haptic output for mobile users has already been considered in several studies. For example, an array of nine tactile actuators making up a wearable vibrotactile display was studied in [3]. Brewster and others [4] deal with *Tactons*, structured vibrotactile messages carrying complex information: they studied the use of haptic feedback alone to encode three different parameters (*Rhythm*, *Roughness* and *Spatial Location*) exploiting several vibrotactile actuators. The above-mentioned authors highlight the potential suitability of their proposals with mobile devices such as PDAs, but the reported user tests are limited to stationary environments.

An evaluation of tactile output supporting mobile interaction is provided in [5], which presents the benefits that may be gained from haptic feedback. The tests showed that user performance significantly improves when haptic stimuli are provided to alert users about unwanted operations (e.g. double clicks or slips during text insertion).

The previously cited works mainly focus on the advantages of exploiting the haptic channel as a complement to the visual one and do not regard solutions for blind users.

The literature also contains some proposals for supporting blind users' mobility. For example, in [6] a haptic direction indicator prototype is proposed to support visually impaired users in various emergency situations. User requirement studies indicate that in specific situations (e.g. emergencies) the supporting device should be small so that it can be easily held in the hand. A more general purpose navigation system has been proposed in [7], which adopts tactile perception to inform the blind user about the distance to an obstacle. The authors claim that using multiple sources of vibration to convey information about the environment is more effective than audible feedback. Variable and synchronized vibration pulses have been used to enhance sense of orientation and distance for the user. The navigation system is based on sonar sensors, an embedded micro-controller system and an array of vibrotactile actuators. To convey information to the user exploiting the sensitivity of the hand, the authors tried to combine all three tactile perception parameters: the location of the active vibrotactile actuator, the intensity of the feedback, and pulse duration. However, the proposed hardware seems to be a stand-alone device without any possibility of adapting it to other applications (e.g. customizing the output of a mobile guide).

The recent progress of handheld computers and mobile phones has enabled the development of compact wearable aid systems for the blind, often in combination with RFID or similar technologies. Possible applications are related to indoor solutions to support visually impaired people in mobility and orientation. RadioVirgilio/Sesamonet [8] is a guidance system, based on a cane with embedded RFID 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. This solution is based on a general purpose handheld device, which requires blind users to follow predefined paths, thus limiting the user's freedom of movement. The RFID-based indoor navigation system for blind people proposed in [9] aims to help them find the shortest path to a destination, as well as to help them if they get lost. The proposed system embeds RFID tags into a footpath that can be detected by an RFID reader with a cane antenna. The dedicated device is portable and equipped with a headphone for navigation where only voice (i.e. mp3 recordings) is used to guide the users. The system however does not include any obstacle detector. Our proposed system combines RFID-based localization, to determine the current user position, with a compass, to provide information on heading; a distance sensor is also used to provide information on the distance from stationary and/or moving obstacles. Another RFID-enabled navigation for the blind has been proposed in [10]. Detected tags provide the coordinates of their location, as well as other information. Orientation is supported by vibrotactile output. An interesting novelty is that the system does not depend on a centralized database. However, like RadioVirgilio/Sesamonet, it focuses on navigation through predefined paths marked by RFID tags. GLIDEO [11] is a different solution for providing blind users with audio information about RFID-tagged objects in their surroundings (such as temperature and weight). The RFID reader is embedded in a glove to let the user freely explore the area.

Coroama [12] also describes an assistive system exploiting electronic markers to provide useful information to the visually impaired. Tagged objects are detectable by a mobile device that provides descriptive information. Tomitsch et al. [13] propose exploiting audio-tactile location markers (ALMs), which use an approach of combined audible signals and tactile identification, for making real-world tags accessible for users. Passive near field communication (NFC) tags are used to mark an object. Since NFC tags are activated at low ranges (below 10 cm), Bluetooth technology is used to locate them from greater distances. An audible signal is used to identify the position of the tag, when a mobile device (i.e. cell phone) is detected in the neighbourhood through