A Prototype Audio-Tactile Map System with an Advanced Auditory Display

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ABSTRACT

Tactile surfaces can display information in a variety of applications for all users, but can be of particular benefit to blind and visually impaired individuals. One example is the use of paper-based tactile maps as navigational aids for interior and exterior spaces; visually impaired individuals may use these to practice and learn a route prior to journeying. The addition of an interactive auditory display can enhance such interfaces by providing additional information. This article presents a prototype system which tracks the actions of a user’s hands over a tactile surface and responds with sonic feedback. The initial application is an Audio-Tactile Map (ATM); the auditory display provides verbalised information as well as environmental sounds useful for navigation. Two versions of the interface are presented; a desktop version intended as a large-format information point and a mobile version which uses a tablet computer overlain with tactile paper. Details of these implementations are provided, including observations drawn from the participation of a partially-sighted individual in the design process. A usability test with five visually impaired subjects also gives a favourable assessment of the mobile version.

Keywords: Audio-Tactile Map, Auditory Display, Binaural, Psychoacoustics, Tactile Interface

INTRODUCTION

Tactile displays are those which transmit information through features that can be determined by touch and are often used to improve accessibility for blind and visually impaired users. These may take a variety of approaches including electronic devices with actuated pins, but it is possible to produce comparatively inexpensive paper-based versions.

The addition of a sensing capacity to such a static, low-cost display would be beneficial; tracking the touch of the user would enable the delivery of additional information specific to

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a tactile feature. This may be accomplished in a number of ways with off-the-shelf consumer technology and can have benefits for visually impaired users who rely on such displays by facilitating multi-modal information delivery through an additional feedback channel.

This article describes the initial development of a system which adds an interactive auditory display to a paper-based tactile surface. The first implementation is a navigational aid for blind and visually impaired users; an Audio-Tactile Map (ATM). The prototype system presents geographical information on tactile paper and provides interactive audio feedback. Two interface versions are described which use different sensing mechanisms; the first uses an affordable camera-based controller and the other a mobile tablet computer.

The next section reviews existing approaches to the provision of navigational aids for blind and visually impaired individuals in order to position the ATM system in context. Previous work is summarised suggesting that tactile displays combined with sophisticated auditory displays may have benefits for navigational applications.

**NAVIGATIONAL AIDS FOR THE VISUALLY IMPAIRED**

It is common for blind people to explore a new location (such as a work environment) when there is little other traffic present, in an effort to develop a mental map of the location; the spatial model developed from gathering this experiential knowledge is a cognitive map (Kuipers, 1978). From the outset, it was the intention of the ATM project to address this type of scenario by providing a virtual reality tool which can help a visually impaired individual to form a cognitive map of a location remotely, before visiting the physical site (Picinali et al., 2014a). Assistive navigational technology for blind and visually impaired individuals takes a number of approaches, but may be broadly classified into in-navigation or pre-navigation tools, the latter of these being of primary concern here. The reader is directed to literature reviews included in documentation of the background experimental work for the present project (Picinali et al., 2014a) and early-stage documentation of the ATM project (O’Sullivan et al., 2014a, O’Sullivan et al., 2014b).

Mobile devices equipped with Global Positioning System (GPS) technology allow visually impaired travellers to receive direction while in transit via an auditory and/or a tactile display. In the case of the former, Rowell & Ungar (2003) found that synthesised verbal delivery can be distracting at times, but a comprehensive review of the effectiveness of in-navigation systems in outdoor environments was positive (Loomis, 2001). The Blind Maps system is a concept providing an assisting-device with real-time tactile feedback only, i.e. no audio (Spitz et al., 2012). It was designed as a portable clip-on peripheral for the Apple iPhone for use with on-line map applications. The device renders symbols on an actuated pin display to direct the user during a journey, allowing aural focus to be kept on surroundings. An example of a navigational tool that is currently active is Open Street Map for the Blind (OSMB), as described in Rifat et al. (2011) and with information available online. This is an open-source, user-maintained map system which is audio-based and delivered via mobile phones equipped with screen readers. OSMB is a well-considered list of established world features and associated audio tags that aid mapping and system development by the contributors. More generally, design guidelines for assistive devices for blind pedestrians that aim to help spatial cognition have been suggested by Gallay et al. (2013).

In situations where GPS does not function properly, such as inside buildings, alternative methods must locate the user within the space (Loomis et al., 2005). Solutions to the problem of indoor navigation include the use of infrared technology (Gill, 1996) and the Drishti system, which uses GPS when available for outdoor navigation and ultrasonic range-finding sensors when indoors (Ran et al., 2004). Other notable research by Swobodzinkinski and Raubal (2009) identified way-finding principles for interior...
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