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Audio Tactile Maps (ATM) System for Environmental Exploration by Visually-impaired Individuals

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Abstract

Navigation within open and closed spaces requires analysis of a variety of acoustic, proprioceptive and tactile cues; a task that is well-developed in many visually-impaired individuals but for which sighted individuals rely almost entirely on vision. For the visually-impaired, the creation of a cognitive map of a space can be a long process for which the individual may repeat various paths numerous times. While this action is typically performed by the individual on-site, it is of some interest to investigate to what degree this task can be performed off-site using a virtual simulator. We propose a tactile map navigation system with interactive auditory display. The system is based on a paper tactile map upon which the user's hands are tracked. Audio feedback provides; (i) information on user-selected map features, (ii) dynamic navigation information as the hand is moved, (iii) guidance on how to reach the location of one hand (arrival point) from the location of the other hand (departure point) and (iv) additional interactive 3D-audio cues useful for navigation. This demo paper presents an overview of the initial technical development stage.

Categories and Subject Descriptors (according to ACM CCS): H.3.3 [User Interfaces]: Auditory (non-speech) feedback—Input devices and strategies (e.g., mouse, touchscreen) K.4.2 [Social Issues]: Assistive technologies for persons with disabilities—

1. Introduction

While observing a blind individual moving in his home, avoiding obstacles and finding the right trajectories as if he was normally sighted, we started wondering how a similar performance could be obtained in other unknown environments. Giving the possibility to blind individuals to explore a closed or open space safely through an audio-tactile map can help them in creating a mental representation of the environment itself and/or of the path they will need to travel. This can result in improved safety when introduced to unknown environments, increased independence and, as a direct consequence, decreased marginalization in society.

Acoustic and tactile information supplement the dominating visual sense in sighted individuals, but are these that provide the main sensory experience for blind or visually-impaired individuals. Relying on the tactile/haptic and aural senses for navigation can be problematic, however, if suitably accessible guidance tools are not available. The project presented here attempts to provide a solution in the form of a low-cost, interactive map system focused on tactile and aural sense modalities, for use prior to navigating the environment. At this early stage, this demo-paper is limited to; (i) detailing the initial technological development and evaluation work and (ii) outlining the future direction of the project. A literature review on navigation by visually-impaired individuals and other audio-tactile map and guidance systems can be found in [OPFC14].

2. The ATM system

A prototype interface system is presented which provides an auditory display for users interacting with a tactile map. The use of comparatively inexpensive camera technology in place of multi-touch devices and tablets used in other systems will keep the system low-cost. The maps are printed on micro-capsule *swell paper* which uses a type of oven called a *fuser* to produce raised textures at various heat settings (*www.zychem-ltd.co.uk*).

The current software was developed to provide two categories of feedback. The first presents the user with information about specific landmarks and can be used to find out about buildings, roads or other key features of the map- this is the EXPLORATION MODE of operation. The second is de-

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signed as a NAVIGATION MODE, presenting the user with an interactive, sequential route between two chosen landmarks. Intermediate way-points are provided which describe nearby landmarks and features, helping to create a cognitive map of the route.

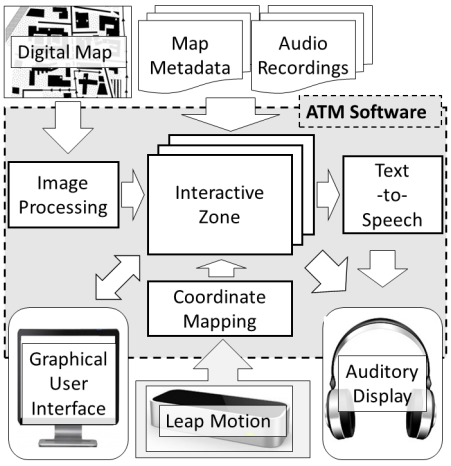
2.1. Hardware Set-up

A Leap Motion device (*www.leapmotion.com/*) is used to track the hands on the tactile map. This device has a pair of cameras and illumination technology contained within a small form factor enclosure, making it unobtrusive and well-suited to the current application. The coordinates and orientations of hands, fingers and tools in view of the device are transmitted to a computer.

2.2. Software Architecture

To facilitate rapid-prototyping while maintaining flexibility, the current software was developed in the Java language and consists of a number of modules. A digitised map and data files are loaded and the map is analysed using an image processing module to automatically extract regions of interest of arbitrary shape. In the present example, each of the campus buildings is segmented and labelled. Building labels are combined with associated meta-data such as the building name and audio files for that map location. At run-time, a software ZONE is specified for each building; tracking data is projected onto the map coordinates and a ZONE returns its information when selected. The system graphical user interface (GUI) displays information for sighted individuals and also provides access to some settings. The current system tracks hands over the map and selection is implemented via a push-button switch in EXPLORATION MODE. However, the NAVIGATION MODE requires both hands to be used to select departure and arrival points, so the system is switched into this mode of operation when two hands are detected. The functional overview of the ATM prototype can be seen in Figure 1.

Figure 1: *Functional overview of ATM prototype.*



2.3. Auditory Feedback

The ATM system delivers spatial audio over headphones (but with mono-compatibility for loudspeaker playback) and uses audio in two ways; text-to-speech synthesis of map meta-data and through sounds of characteristic acoustical features of spaces. Interaction with the map produces audio feedback in both EXPLORATION and NAVIGATION modes and the nature of sounds produced is context sensitive. When a user selects a map feature, the information contained in the associated map zone is rendered using a basic text-to-speech engine.

2.3.1. Environmental Sounds

Certain map features have environmental sounds associated with them; for example a river will trigger sounds of flowing water when selected. These sounds are either recorded using binaural microphones at the associated locations, or synthesised and binaurally spatialized, allowing for the reproduction of realistic 3D soundfields using a pair of headphones.

2.3.2. Self-produced Sounds

Observations in previous experiments [PADK] highlighted that blind individuals often make use of self-produced noises, such as finger-snapping and footsteps, to determine the position of an obstacle, wall, and/or object in a space. During exploration or navigation, the user can activate the playback of binaural recordings of self-produced noises, reproduced in specific locations within the environment.

3. Future Work

A video demo of the current prototype has been produced (*http://www.tech.dmu.ac.uk/ lpicinali/ATM.mov*). Further interactive tests are being carried out with multiple subjects and with extended system features, as the natural interactions of users with the ATM must be assessed so that it may be iteratively improved. More sophisticated treatment of audio content is being implemented, including:

- Addition of realistic reverberation to an improved text-to-speech generator.
- Dynamic, real-time acoustical rendering of sounds reproduced by the user during map exploration.
- Integration of head-tracking facilities for a more realistic binaural rendering

Features to be added to the software include the ability to zoom/pan and highlight different layers of information, as well as an *operator mode* for data-entry and zone-editing.

References

[OPFC14] O'SULLIVAN L., PICINALI L., FEAKES C., CAWTHORNE D.: Audio tactile maps (atm) system for the exploration of digital heritage buildings by visually-impaired individuals - first prototype and preliminary evaluation. In *Proc. Forum Acusticum 2014* (2014). 1

[PADK] PICINALI L., AFONSO A., DENIS M., KATZ B. F.: Exploration of architectural spaces by blind people using auditory virtual reality for the construction of spatial knowledge. 2

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