Smart cane outdoor navigation system for visually impaired and blind persons

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ABSTRACT

This paper presents prototype of an outdoor navigation system designed to assist visually impaired (VI) and blind persons in outdoor navigation. It assists VI persons in moving independently on sidewalks in urban areas using an augmented guidance cane and informs them about points of interests (POI) through serialized braille encoded vibrational guidance messages. Augmented guidance cane, magnet points' trail, metallic trail, and pulsing magnet apparatus for transmission of serialized braille encoded guidance messages in the form of vibration are the features of the proposed navigation system. Magnet points' trail, metallic trail, and pulsing magnet apparatuses will be installed on the special sidewalks for the visually impaired persons in city centers. VI persons will be able to sense magnet points' trail or metallic trail through augmented guidance cane. It will assist them to walk independently being oriented on the sidewalks. Pulsing magnet apparatuses will be installed at the verge of the POIs on the sidewalks. VI persons will be able to sense the serialized braille vibrational messages through augmented guidance cane and become aware of the POI. Numbers of usability experiments are designed to evaluate the usability of the proposed system in qualitative interviews sessions. It is expected that the results of the qualitative interviews and the test sessions will provide valuable information to make this prototype a full-fledged system ready to be deployed.

1. INTRODUCTION

Navigating complex routes and finding objects of interest are challenging tasks for the VI persons and in today's world there is a lack of infrastructures to make it easier. One of the most problematic tasks for them is outdoor navigation. They cannot do it without assistance even if the place is small. This element is typically termed as Macro-Navigation or Orientation in the literature (Katz et al, 2012a). It includes multiple processes such as being oriented, selecting an appropriate path, maintaining the path, and detecting when the destination has been reached (Downs and Stea, 1977). These tasks are dedicated to processing the remote environment, beyond the immediate perceptible ones. In the case of visual impairment, main cues (e.g. landmarks and paths) for sensing the environment are degraded. This results in difficulties relating to correct orientation or heading, piloting (i.e. guidance from place to place using land marks) and retaining the path etc. (Katz et al, 2012b).

Despite over a decade of intensive research and development, the problem of delivering an effective navigation system to the blind and vision impaired remains largely unsolved (Kamiński and Bruniecki, 2012, Wise et al, 2012). Navigation support for VI people involves the use of textured paving blocks, guide dogs, GPS based navigation systems, and different sensors and wireless based systems among others (Hersh and Johnson, 2010). Macro-navigation systems are almost exclusively based on the use of Global Positioning System (GPS) with adaptations for VI users. Other technologies widely used for macro navigation are the Radio Frequency Identification (RFID) and using radio waves emitted from a wireless LAN access point (Domingo, 2012, Yelamarthi et al, 2010). Though these technologies and navigation assistances suffer from certain limitations for being an optimum solution for a navigation system for the VI persons. Compared to public spaces and transport facilities, no progress is being made in providing commercial facilities with textured paving blocks. Although guide dogs are effective on obstacle-free safe walkways, they cannot locate a person's destination (Katz et al, 2012b). As for GPS, the highest quality signal is reserved for military use, and the signal available for civilian use is intentionally degraded. The precision of civilian GPS is 10 meters (33 ft.) (Letham, 2011). This is insufficient accuracy for such systems. GPS also often suffers from serious errors caused by multipath

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propagation (Bauer, Marcus, and Gerd, 2012). RFID technology has reportedly many shortcomings including fluctuating signals accuracy, signals disruption, reader and/or tag collision, slow read rates. Wireless LAN access point method has encountered issues with fluctuating positional accuracy due to reflected signals from the wireless LAN, obstacles, or the surrounding environment (Kolodziej and Hjelm, 2010). Studies into guidance systems using tactile maps, which are effective in creating mental maps, are also underway. However, it takes time to understand tactile maps by touch, and therefore, they are difficult to use when on the move (Nakajima and Haruyama, 2012).

To address these kind of issues, our study aims to develop a usable system that enables VI persons, especially the blind/deaf blind walking independently in urban areas and finding points of interest (POI) like post office, shopping mall, bar or coffee shop etc. The proposed prototype is designed using magnet trails, metallic trails, pulsing magnet apparatus, and a serialized version of braille writing system. It helps VI persons in orienting and piloting their journey on the sidewalks and informs them about POIs in the surroundings through serialized braille encoded vibrational guidance messages.

This study is organized as follows. Sections II describes serialized braille code. Section III illustrates proposed prototype for the overall system design, hardware components of the system, and the serialized braille vibrational messages transformation method is described. Section IV describes qualitative interview session and usability tests. Section V concludes the paper with describing results and summary of the study.

2. SERIALIZED BRAILE CODE

Braille is a tactile writing system enabling blind and partially sighted people to read and write through touching braille characters (Braille, 1829). Braille is chosen as communication medium for the prototype to communicate with blind users. Though reading braille is difficult than writing braille. That's why it's difficult to use braille as a communication method in navigation systems for VI persons. For that reason, a serialized braille code compliant of the traditional braille is developed for this study

2.1 *Serialized braille transformation*

The numbering system that is assigned to braille cell dots is basic for the conversion of conventional braille into serialized braille. The braille code consists of three rows and two columns i.e. three by two matrix of cells. Position of each dot is assigned a specific number and combinations of those dots formulate different braille characters. A serialized braille code could be devised by positioning two columns serially rather than parallel and get numeral value for each braille character.

3. SYSTEM DESIGN

The system comprises of four components:

- *Augmented guidance cane*
- *Stationary magnet points Trail*
- *Metallic trail*
- *Pulsing magnet apparatus*

Stationary magnets points trail and metallic trail are two contending components. Either of these will be used as part of system after experimentation during user tests.

3.1 *Augmented Guidance Cane*

It is a regular white cane used by visually impaired persons fitted with a small magnetic reader at its bottom, Fig 1 C. The magnetic reader is a ring shaped N40 type powerful Neodymium magnet installed on tip of the cane.

3.2 *Stationary Magnet Points Trail*

Stationary magnet points trail will be made on the sidewalks for the blind and VI persons in city centre. It will comprise of powerful Neodymium N42 type disc magnets buried beneath trail on sidewalk, Fig1 A. A VI person walking on sidewalks can sense and follow these magnetic points to walk through her augmented guidance cane.

3.3 *Metallic Trail*

Metallic trail comprises of pure iron tabular pipe buried underneath the sidewalks, Fig1 B. The VI persons can sense and follow the metallic channel through their augmented guidance cane.

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3.4 *Pulsing Magnet Apparatus*

Pulsing magnet apparatus generates and relays magnetized serialized braille vibrational guidance messages about POI, Fig 1 D. These are installed at the verge of POIs on sidewalk. When a VI person reaches at pulsing magnet apparatus, she can feel the serialized vibration emitted from it through her cane and becomes aware of POI. These serialized vibrations emit serialized encoded guidance message that VI can get by decoding it.

3.4.1 Architecture of Pulsing Magnet Apparatus: Architecture of pulsing magnet apparatus comprises of four components:

- *Micro Controller Unit (MCU).* MCU encodes a guidance message into serialized braille form and sends it to an electromagnetic coil in the form of serialized electric pulses.
- *Electromagnetic coil.* An electromagnetic coil developed in the lab is used to emit serialized braille vibrational message through pulsing electromagnetism, Fig 1 E. It replicates the serialized electric pulses sent from MCU in the form of pulsing electromagnetism. The polarity of electromagnetism is reversed with each pulse. The reversing polarity causes white cane magnetic reader to be pushed and pulled by electromagnetic coil with each pulse. This phenomena cause vibration effect
- *H-Bridge.* An H-Bridge is used in pulsing magnet apparatus to change polarity of the electrometric coil. An H-bridge is an electronic circuit that enables a voltage to be applied across a load in either direction (Williams, 2002).
- *Reed-Switch.* The reed switch is an electrical switch operated by an applied magnetic field. It is used to save power consumption. Reed turns on the pulsing magnet apparatus when it detects the magnetism of augmented cane carried by VI persons and turns it off when magnetism is absent.

4. QUALITATIVE INTERVIEWS SESSION

A semi structured interviews session is designed to collect complementary qualitative data from stack holders of the system. First session is a comprehensive study that investigates blind end users' white cane usage pattern, outdoor visits routine, role of alternative senses in navigation, acceptability of new assistance approaches, and post-test feedback about current prototype, appendix A. The interviews are guided by dramaturgical model (Myers and Newman, 2007).

4.1 *Quality function deployment (QFD)*

Quality Function Deployment is a method for satisfying customers by translating their demands into design targets and quality assurance points (Akao, 2004). It will be used to transform user demands into design quality.

5. USABILITY TESTING

Usability test sessions to test the usability of the system and remove problematic features from it are designed. These test sessions will be done involving real blind persons will be conducted in autumn 2014.

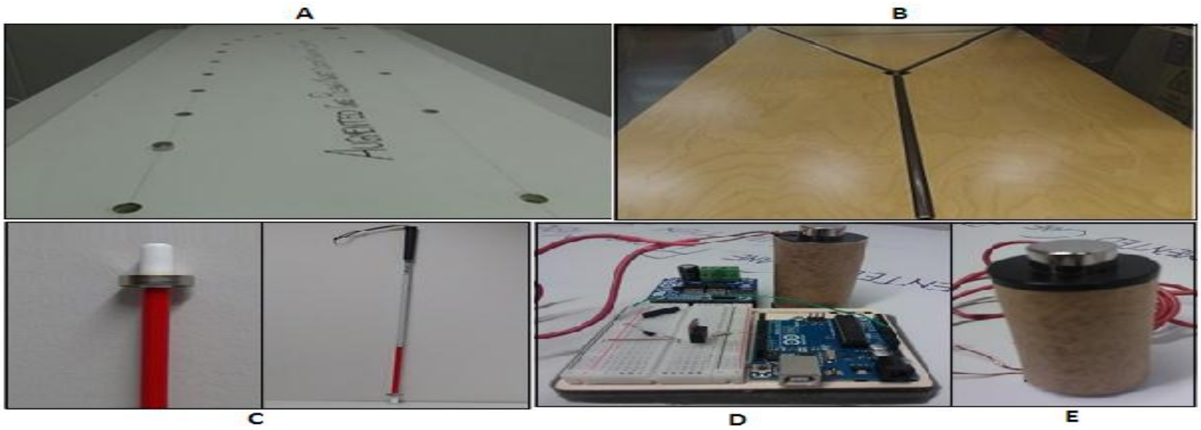

Figure 1. *(A) Magnet points trail test bed, (B) Metallic trail test bed, (C) Augmented guidance cane, (D) Pulsing magnet apparatus, (E) Electromagnet coil.*

6. CONCLUSIONS

In this paper, prototype of an outdoor navigation system to assist visually impaired blind persons in outdoor navigation is presented. Three learning phases of overall system for end users and usability tests to evaluate usability factors of the system in each of its three learning phases is been described. Result of usability testing could improve design of prototype based on feedback of end users. Quality function deployment (QFD) framework will be used to convert user demands into design quality. We expect that participants could complete their tasks with the help of navigation system. Task accomplishment could fulfill expected efficacy and effectiveness of system. Usability test will provide with actionable suggestion to increase usability of navigation system.

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