Advanced Navigation Assistance Aids for the Visually Impaired and Blind Persons

Babar Chaudary[1], Petri Pulli[1] and Helal Chowdhry[2]

[1]University of Oulu, Department of Information Processing Science,
Oulu, Finland
{babar.chaudary, petri.pulli @oulu.fi

[2]University of Oulu, Department of Electrical Engineering,
Oulu, Finland
fougi@ee.oulu.fi

ABSTRACT

Finding ones way to a known or unknown destination, navigating complex routes and buildings, finding inanimate points of interest and pathways; these are all tasks that can be challenging for the persons with visual impairment or blindness. The research project presented in this article is directed towards increasing the autonomy of visually impaired (VI) persons in exterior and interior, large scale and small scale, known and unknown environments. It is done through a combination of navigation assistance systems. These navigation aids are designed using magnetism and electromagnetism based walking trails; Visible Light Communication (VLC) based indoor position data acquisition; tactile, voice and Braille interfaces based walking cane for the navigation guidance. This article presents the overall navigation portfolio for all the prototypes that are designed for the outdoor and indoor navigation assistance. These new types of navigation and assistance aids are developed through participative design with potential VI users and educators for the VI persons. In addition, this article reports a comprehensive complementary qualitative study designed to investigate acceptance of advanced technological navigation assistance aids by the VI persons.

1. INTRODUCTION

Navigating complex routes and finding objects of interest are challenging tasks for the VI and blind persons and in today's world there is a lack of infrastructures to make it easier. Navigation includes two action components: mobility and orientation [1]. Mobility or micro-navigation relates to sensing the immediate (near-field or indoor) environment including potential paths in the vicinity for the purpose of moving through it. The second component, orientation or macro-navigation involves processing the remote environment, beyond the immediate perceptible ones. It includes multiple processes such as being oriented, selecting an appropriate path, maintaining the path, and detecting when the destination has been reached [1]. These tasks are dedicated to processing the remote environment, beyond the immediate perceptible ones. In the case of visual impairment, the main cues (e.g. landmarks and paths) for sensing the environment are degraded. This results in difficulties relating to moving & heading in both navigation components [2]. A system that assists VI persons' navigation in real time will be of great benefit.

Despite over a decade of intensive research and development, the problem of delivering an effective navigation system to the vision impaired remains largely unsolved [3]. Navigation support for the VI persons involves the use of textured paving blocks, guide dogs, GPS based navigation systems, different sensors and wireless based systems among others [4]. Other technologies widely used are the Radio Frequency Identification (RFID), using radio waves emitted from a wireless LAN access points, infrared (IR), Bluetooth, and ultrasound based identification (USID) [5]. Though these technologies and navigation aids suffer from certain limitations for being an optimum solution for the navigation assistance system for the VI persons. Compared to the public spaces and transport facilities, no progress is being made in providing commercial facilities along textured paving blocks. Although guide dogs are effective for obstacle-free safe walkways, they cannot locate destination of a person [6]. As for the GPS, the perceived accuracy is not always sufficient for the blind navigation in urban areas. This is largely due to satellites visibility problem because of tall and congested buildings. The urbanization phenomenon also slows down GPS start up time. Most GPS systems use speech to convey directions to the user, but this approach is not valid for real-time tasks, thus more fundamental audio and haptic interfaces are required. GPS indoor unavailability limits its use in indoor navigation systems [7]. The RFID technology has many shortcomings including fluctuating signals accuracy, signals disruption, reader and/or tag collision, slow read rates [8]. The 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 [8]. The drawback of IR based systems is that natural and artificial light can interfere with IR [9]. IR based systems are costly to install due to the large number of tags that need to be installed and maintenance [10]. For Bluetooth beacons based systems, the user has to walk slower than with other techniques because of the device delay [11]. It slows down the mobility. Bluetooth beacons also suffer from heavy installation cost, maintenance, and line of site as for RFID and IR technologies [12]. Ultrasound based systems have the problem that walls may reflect or block ultrasound signals [13], which result in less accurate localization. The other drawback of using ultrasound for localization is required line of sight between the receivers and beacons [14]. The studies into guidance systems using tactile maps, that 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 be used when on the move [15].

To address these kinds of issues, this study aims to create a usable system that enables the VI persons' independent outdoor orientation as well assist them in indoor mobility. Many concepts of the proposed navigation system are being designed and their prototypes are at different levels of the development. This article is organized as: section 2 gives details of serialized braille code that is a variant of traditional braille code and is developed to be used as one of the communication mechanism in these prototypes. Section 3 provides detail of Smart Cane Outdoor Navigation System for overall system design. Section 4 provides details of of Smart Grip Outdoor Navigation System for overall system design. Section 5 describes Visible Light Communication (VLC) based Smart Grip Indoor Navigation System for overall system design. Section 6 reports a comprehensive qualitative study designed to investigate acceptance of technological navigation assistance aids by VI and blind persons. Section 7 provides timeline with development status of all artifacts of this project. Section 8 concludes this article.

2. BRAILLE CODE

Braille is a tactile writing/reading system enabling blind & partially sighted people to read & write through touching braille characters [16]. Braille system employs group of dots embossed on a paper or some other flat surface to represent printed letters and numbers. The system's basic "braille cell" is illustrated in Figure.1. It consists of six dots-like the points of a domino-arranged in vertical columns of three dots each. For convenience, a standard numbering system has been established for the dots whereby the dots in the left column are numbered downward from one to three, and the dots in the right column are numbered downward from four to six [17]. From the basic Braille cell, 63 dot patterns and a blank can be formed for a total of 64 possible symbol variations. In conventional braille, these patterns, easily identifiable to the touch, represent letters of the alphabets, numbers, punctuation signs, and also certain common letter combinations (such as "ch" and "gh") along with a few common words ("and", "for", "of", "the", "with").

2.1 Serialized Braille Code

Braille is chosen as one of communication mechanism for the prototypes to send guidance information to the Blind/deaf-blind and VI users. Though reading Braille is difficult than writing Braille. That's why it's difficult to use Braille as a communication method in such navigation systems for the VI persons.

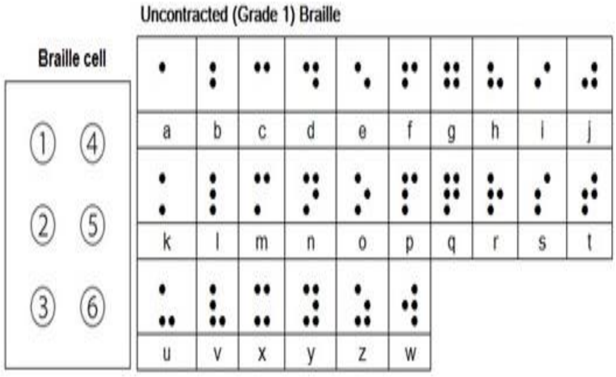

Figure 1. Braille cell and Braille alphabet [14].

Alphabet	a	b	c	d	e	f	g	h	i	j
Brail Code	⠁	⠃	⠉	⠙	⠑	⠋	⠛	⠓	⠊	⠚
Serializ-ed Brail	1	12	14	145	15	124	1245	125	24	245
Alphabet	k	l	m	n	o	p	q	r	s	t
Brail Code	⠅	⠇	⠍	⠝	⠕	⠏	⠟	⠗	⠎	⠞
Serializ-ed Brail	13	123	134	1345	135	1234	12345	1235	234	2345
Alphabet	u	v	w	x	y	z				
Brail Code	⠥	⠧	⠺	⠭	⠽	⠵				
Serializ-ed Brail	136	1236	2456	1356	13456	1356				

Figure 2. Serialized Braille code.

For that reason, a serialized Braille version compliant of the traditional Braille is developed for this study. Benefit of the serialized Braille version is that a message encoded into it can be sent & read in the form of vibration. That makes it handy to use braille on the go.

2.2 Serialized Braille Code Transformation Logic

The numbering system that is assigned to the Braille cell dots is basic for the conversion of conventional Braille into serialized Braille form. The Braille code consists of three rows and two columns i.e. three by two metrics of cells. Position of each dot in a Braille cell is assigned a specific number and combinations of those dots formulate different Braille characters, Figure 1. A serialized Braille could be devised by positioning two columns serially rather than parallel and get numeral value for each Braille character, as shown in Figure 2. This modified Braille code (i.e. a serialized Braille) can be sent and received in tactile form and auditory form. In tactile mode, in the form of different combinations of vibration, and same way in auditory mode the cells of a column could be presented by different tonal frequencies and combinations (i.e. distinctive time gape with tones). A serialized code could be easily leaned by blind persons who have already learned original Braille code. Tactile mode would be especially advantageous for the deaf blind users.

3. SMART CANE OUTDOOR NAVIGATION SYSTEM

Smart cane outdoor navigation system is a navigation system designed to enable VI persons' walking independently in urban areas and help them finding points of interest (POI) around e.g. post office, shopping mall, coffee shop etc. Augmented cane, stationary magnet points' trail, metallic trail, and transmission of guidance information to VI persons in the form of serialized Brail vibrations through pulsing magnet apparatus are the features of the navigation system. Magnet points trail and metallic trail are two of the contending components of the proposed system. Either of these will be chosen as component of the system after end user tests. Magnetic points' trail or metallic trail and pulsing magnet apparatus will be installed on special sidewalk for the VI persons in the city centers. VI persons can follow the trail of magnetism or metallic trail on sidewalks using augmented cane and walk independently being oriented towards their destination. They are informed about POI along the sidewalk through serialized braille encoded guidance messages relayed through pulsing magnet apparatus in the form of serialized Braille vibration. VI persons can sense the serialized Braille vibrations through the augmented cane and become aware of POI ahead. By decoding the serialized Braille code, they can get guidance information about underlying POI.

Figure 3. Augmented cane.

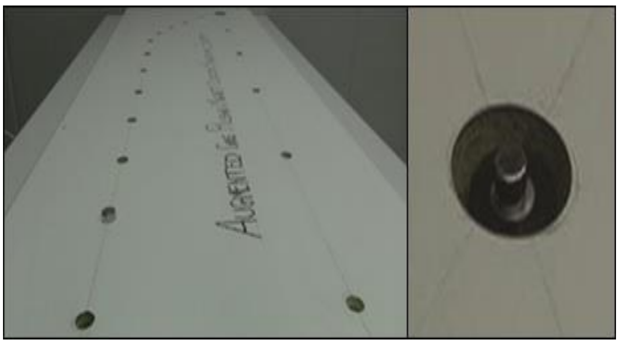

Figure 4. Magnet points' trail test bed.

Figure 5. Metallic' trail test bed.

3.1 System Design

The proposed navigation system prototype comprises of following four components:

3.1.1 Augmented cane: It is the walking stick that VI persons will use to take assistance from the underlying navigation assistance infrastructure while walking on the sidewalks in the city centers. It is basically a regular white cane used by VI persons augmented with a small powerful ring shaped Neodymium magnet [18] reader at its bottom, Figure 3.

3.1.2 Stationary Magnet Points' Trail: Stationary magnet points trail will be made on the sidewalks for the VI persons in the city centres. This trail will contain powerful disc type Neodymium magnets [18] buried beneath the sidewalk forming a trail of magnetism on the sidewalk, Figure 4. A VI person walking on the sidewalk can sense and follow the trail of magnetism through her augmented cane magnetic reader. It will assist her walking independently being oriented on the sidewalk towards her destination.

3.1.3 Metallic Trail: The Metallic trail is the second of the contending components to be made on the sidewalks in the city centres. It comprises of a tubular pure iron metallic pipe buried underneath the sidewalk, Figure 5. The VI persons can sense and follow the metallic channel through their augmented cane magnet reader. It will assist them walking independently on the sidewalk being oriented towards their destination. Some part of the metallic pipe will be kept exposed to the surface. It will expedite sensing the metallic trail and aid in channelling the cane over it.

3.1.4 Pulsing Magnet Apparatus: The Pulsing magnet apparatus generates magnetized serialized vibrations to relay serialized Braille encoded guidance message about a POI for the VI persons' guidance, Figure 6A. The apparatus will be installed at the verge of the POIs on the sidewalks or at a point where a path is splitting into more trails, see Figure 5. When a VI person approaches at a POI following walking trail through her augmented cane, she can sense the serialized vibration emitted from the pulsing magnet apparatus through her augmented cane and becomes aware of the POI there. The serialized vibrations transmit serialized encoded guidance message that VI person can get by decoding the serialized vibrations.

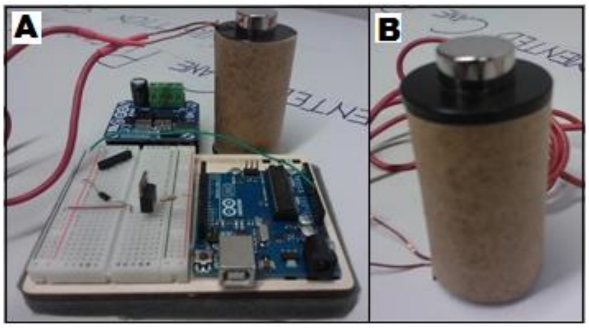

Figure 6. Pulsing magnet apparatus.

3.1.4.1 Architecture of Pulsing Magnet Apparatus

- *Micro Controller Unit (MCU):* The MCU (Arduino UNO [19]) executes the serialized braille transformation logic. It encodes a guidance message into the serialized braille form. The encoded message is then sent to an electromagnetic coil in the form of serialized electric pulses.
- *Electromagnetic coil:* An iron core electromagnetic coil is used to emit the serialized braille encoded message in the form of vibration through pulsing electromagnetism, Figure 6 B. The Electromagnetic coil 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 successive reversing pulse. This phenomena cause vibration effect to augmented cane. The electromagnet coil used is designed and developed indigenously for this project at university of Oulu because commercially available coils were not found appropriate after experimentation.
- *H-Bridge:* An H-Bridge is used to change polarity of the electrometric coil with each successive electric pulse. The H-bridge is an electronic circuit that enables a voltage to be applied across a load in either direction. These circuits are often used in robotics and other applications to allow DC motors to run forwards and backwards [20].
- *Reed-Switch:* The reed switch is an electrical switch operated by an applied magnetic field. It consists of a pair of contacts on ferrous metal reeds in a hermetically sealed glass envelope. The contacts may be normally open, closing when a magnetic field is present. Once the magnet is pulled away from the switch, the reed switch will go back to its original position [21]. It is used in pulsing magnet apparatus to save power consumption. Pulsing magnet apparatus is not relaying serialized braille vibration all the time. It is activated when a VI person approaches to it with her augmented cane. The magnetism of magnetic reader of the cane connects the reed-switch that turns on the pulsing magnet apparatus and it starts relaying serialized braille vibrational guidance message. When VI person once leaves the place and magnetism of the cane's magnet reader is absent again, the reed-switch is open again and pulsing magnet apparatus turns off.

3.2 Qualitative Interviews

A semi structured interviews sessions with open-ended question is designed to collect qualitative data for this study. It is a comprehensive study that in first session investigates blind and VI end users' white cane usage pattern in different environments (i.e. indoor, outdoor), premises (i.e. sidewalk with flat surface, trails like in some park, corridor, big halls etc.), seasons (i.e. winter, summer, rainy day, snows etc.), outdoor visits routine, role of alternative senses like hearing in navigation, and post-test feed-back about current prototype for the acceptability, see appendix A. The Post-test feedback session will be conducted to get feedback of the users about prototype during usability tests of the system. The interviews are guided by dramaturgical model [22]. The selection of the users for the sample group will ensure that they represent a subset of the study paradigm, to guarantee the scope of the study. Permission of the interviewee will be asked to perform the audio recording of the interview for later analysis of more reliable data collection ensuring his/her privacy rights. The interviews will be conducted in native language of the end users in different countries of the world including Finland, Sweden, Pakistan, Japan, and Kenya, starting from Finland and Sweden. Face to face interview is preferred way but if preferred by the user interview questionnaire can be sent and answered by email.

3.2.1 Results of the Qualitative Interviews Session 1: First phase of the qualitative interviews' session is underway in Finland and Sweden. Six to ten interviews of VI and blind end users relating to different sex and age are planned to be conducted in each country.

In Finland, four interviews have been conducted so far, three of blind persons and one blind navigation expert. The blind persons being interviewed are a retired research lead at a research institute who is late blind, a 20 years old school girl blind by birth, and a 27 years old late blind school girl. All interviewees are total blind with a zero level visual acuity, though 3rd interviewee can distinguish between light and darkness. All end users requested to be interviewed by an email questionnaire and they were available for further clarification of theirs answers. Their answers are very revealing and contain a good deal of research rich data.

First and third interviewee uses only white cane for outdoor navigation while the second interviewee uses white cane and a navigator too. White cane helps them in navigation in all environments, premises, and seasons. In extreme weather conditions like in a slippery snow, it's their conscious that help them more (like in balancing the body) together with a white cane. In rainy season, watery pitfalls are especially difficult for them and white cane is of little use to discover those. Big halls are especially challenging with white cane. Those are impossible to navigate without directions given.

First two participants typically use a sighted guide when navigating in outdoor environments, who would help them with working out a route. Typically both of them plan their visits in advance but because of sighted guide, they may also decide to visit some place instantaneously. The third interviewee navigates outdoor independently using her white cane. She also typically plan her visit in advance but sometimes decide to visit some place instantaneously. Neither of the first two interviewees drive a car nor ride a taxi or bus independently. The third interviewee used echolocation to find position of the bus or car. The white helped her in riding up and down from the bus by sensing the stairs, foothold of the bus and sidewalk using it.

All interviewees' ranked usage of alternative sense i.e. hearing questioned mainly here to be a very necessary aid in navigation. The third interviewee uses echolocation a lot while indoor and outdoor for assistance in navigation. Though she told echolocation is difficult in outdoor because of the noise. An ideal navigation system for first interviewee is a tele assistance guidance system while for the second interviewee a real time navigator. The third interviewee feels a real time navigator with navigation instructions in a form other than voice will be ideal. All interviewees show positive opinion about the proposed navigation system and show willingness to be part of the test session.

One semi structured interview of an Oulu University Hospital, Finland white cane instructor for deaf-blind and VI persons is conducted to put voice of experts into the research. His opinion about the proposed system for assisting VI persons in independent navigating on sidewalk was positive. He finds this prototype especially useful for the deaf-blind persons and for it being always available.

In Sweden, three interviews have been conducted so far. First interviewee is 60 years old late blind female, second is a 54 years old late deaf-blind female who was born VI, and third interviewee is a 54 years old deaf-blind female.

First interviewee rarely uses white cane for outdoor navigation assistance, most of the time navigate with an assistance. The second and third interviewees use white cane regularly for navigation assistance. The first interviewee uses white cane to find the edge of the path in all kind of outdoor pavements and follow it for orientation in navigation. The second and third interviewees rolls their cane easily on a flat pavement during navigation while bricks pavements are difficult to roll or swipe the cane. The cane tend to stick in holes/joints. So they don't walk hurriedly on those. They don't trust much on a white cane while walking on a trail or on a grassy surface. So they remain very careful and try to move back to hard if they ends up on a trail or grass. The third interviewee use to seek help from the assistant in such situation.

The first interviewee rarely independently rides a bus or car. The second and third interviewees use their white cane to feel when they are near to a bus and also to sense the road. The cane helps them in riding on and off from the bus in sensing the foothold, stairs, edges of the road and its height. Same way to reach a car or taxi, and they fold their cane when riding in the car or taxi. In a rainy season, the first interview finds it difficult to detect water puddle on the way. The second interviewee faces same difficulties and avoid to go outside while raining or be in a hurry. While third interviewee don't find any trouble. First interview feels difficult to differentiate between ice and snow on the sidewalks. The second and third interviewees find no difficulty in rolling and swiping their cane to navigate outdoor in snow. Though second interviewee calls for an escort in the case of heavy snow as it becomes impossible for her to get sense of the surface with a white cane in such situation. Third participant also faces same difficulties in case of heavy snow. Hard and slippery ice is more challenging for second interviewee to navigate. She sometimes ends up broken ankle despite walking slowly and carefully. Third interviewee finds it easy to navigate on a hard and slippery ice.

Navigating in a corridor is rather easy for all participants. They can find the wall through their cane and follow it. They can find doors and stairs etc. with the help of cane during navigation and avoid possible hurdles like left overs of people. Big halls are especially challenging for navigation. They are difficult to navigate for first interviewee if especial mates are not available. While second interviewee tries to follow other people sensing the surface through her cane. Third interviewee also finds big halls challenging to navigate without assistance. On stairs and escalators, the first interviewee uses the railing to hold while walking or using those. She uses cane to find start and end of the stairs and feet to feel start and end of escalator. While second interviewee use cane to feel threshold and height of stairs to walk and same way for escalator but being more cautious to squeeze. The third interviewee does same for stairs but need help of assistant on escalator because of being deaf, as she said. First interviewee don't use cane in the case of lift while second and third interviewee uses cane to find height of lift floor and when door opens.

The first interviewee uses hearing aid a lot while navigating while second and third interviewees are deaf. First participant plan her visit in advance but also alter instantaneously because often she walks with a sighted guide. While second interviewee prefer to always plan in advance as she has a bad sense of directions. Both interviewee do not use any kind of technological navigation aid. The third interviewee always decide in advance and navigate with assistant. An assistant and a GPS based system that tells about current place are the ideal navigation aid for first interviewee. While second interviewee feels separate walkways for VI with guidance embedded in the infrastructure would be ideal for navigation from her prospect. The third interviewee thinks a white stick and an assistant to be best navigation tool for her.

3.3 Quality Function Deployment (QFD)

Quality function deployment (QFD) framework will be used to transform user demands into the system's design quality. QFD is a method for satisfying customers by translating their demands into design targets and quality assurance points. QFD is the converting of customer demands (WHATs) into quality characteristics (QCs) (HOWs) and developing a quality plan for the finished product by systematically deploying the relationships between customer demands and the QCs, starting with the quality elements in the product plan. Later, QFD deploys this WHATs and HOWs relationship with each identified quality element of the process plan and production plan. The overall quality of the product is formed through this network of relationships [23].

3.4 Usability Testing

The main objective of conducting usability experiment is to remove problematic issues from assisting users to walk independently on a predefined route and inform them about POI through serialized braille vibrational message. Problematic issues mostly cause failure in achieving maximum desired system's usability. Analyzing tasks of usability test facilitates designing system's concept more accurately.

3.4.1 Test setting: Test users in all experiments will be VI persons fully blind or partial blind. The minimum number of participants in each test will be four. A video camera will be used to record test participants' activity in all tests. A usability matrix will be used to record the results of all tests manually on a paper sheet. A separate matrix sheet will be printed and used for each user with his name. Later usability matrix data will be saved on computer for further analysis by suitable tools. The results collected through usability matrix will help to investigate effectiveness, efficacy, satisfaction, and learnability of the system.

3.4.2 *Test scenarios:* There are three phases of learnability for the system.

- 1st phase: User follows walking trail successfully.
- 2nd phase: User senses the vibration at successfully a given POI through her augmented cane.
- 3rd phase: User reads the braille message successfully through vibration.

First phase tests will help deciding which walking trail will be used as component of the system. For 2nd phase testing, experiment will find if users are able to sense serialized vibrations successfully at a given POI through their white can or not. For 3rd phase testing, experiment will find if users are able to read serialized braille encoded guidance message about a given POI successfully or not.

4. SMART GRIP OUTDOOR NAVIGATION SYSTEM

It is an advanced variant of the smart cane outdoor navigation system with implementation of advanced user interface concepts through a smart grip. It utilizes same stationary magnet point's trail or metallic trail infrastructure for the VI person's independent navigation. The guidance information about POIs is relayed wirelessly from wireless Braille beacons installed at the verge of the POIs on sidewalks. The smart grip receives this wirelessly relayed information. It relays the guidance information for VI person's guidance in three forms:

- Grip vibration - serialized Braille output
- Full scale tactile Brail cell – Braille output
- Bluetooth earpiece - Voice output

VI users will be able to choose/configure the suitable output channel per their convenience.

4.1 System Design

The proposed navigation system comprises of following four components:

4.1.1 Smart Grip:

The smart grip provides implementation of advanced user interface concepts offered by this variant of outdoor navigation support system. It will replace normal grip of a routine white cane. The cane will contain a magnetic reader at its bottom for user to take assistance for independent navigation from stationary magnet points' trail or metallic trail on sidewalks as described in section 3.1.

The smart grip will receive guidance information from the wireless Braille beacons. It will relay guidance information about POI in three forms:

- Vibration form by grip vibration
- Tactile form by Full scale braille cell
- Voice form through Bluetooth earpiece

Users can choose any output form to get guidance depending on their ease and convenience.

4.1.2 Wireless Braille beacon

The wireless Braille beacons relay guidance information to VI persons wirelessly. These will be installed at the verge of POIs on sidewalks.

4.1.3 Magnet Points' Trail

Magnet points' trail works same way as in the case of smart cane outdoor navigation system, section 3.1.2.

4.1.4 Metallic Trail

Metallic trail works same way as in the case of smart cane outdoor navigation system, section 3.1.3.

5. VISIBLE LIGHT COMMUNICATION BASED SMART GRIP INDOOR NAVIGATION SYSTEM

Solid-state-based light emitting diode (LED) lighting is rapidly becoming the mainstream for illumination solutions [24]. These luminaries are also capable for data transmission, which has no negative influence to their illumination functionality [25]. The proposed VLC based indoor navigation system is an indoor version of the smart grip outdoor navigation system. It assists VI & blind persons in walking independently inside a building through informing them about doors, lifts, stairs, and other indoor installation in the form of voice, vibration, or full scale Braille cell. The guidance information is stored in the LED lights on the ceiling of the building. Each LED serves as guidance information transmitter. A photodiode installed on the top of the grip receives this guidance data from nearest LED. This data is processed by the MCU that is installed on the smart grip. Guidance information retrieved from the LED based on the current location of the blind user is provided to her through any preferred output channel (i.e. vibration, full scale Braille, or voice), Figure 7. This is how proposed system helps VI persons in independent navigation inside a building.

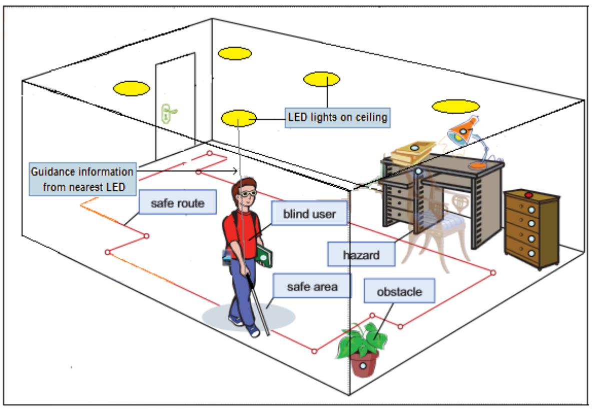

Figure 7. Visible light communication based smart grip indoor navigation system scenario.

6. QUALITATIVE STUDY FOR ACEPTANCE OF TECHNOLOGICAL NAVIGATION ASSISTANCE AIDS BY VISUALLY IMPAIRED AND BLIND PERSONS

It is a comprehensive study that is designed to investigate acceptance of technological navigation assistance by VI and blind persons. It is part of the qualitative interviews' and test session that is already underway to put voice of users into proposed navigation system's requirements, design, and validation phase. The data gathering procedure for this study is two-phased. First phase is gathering general data about assistive technology usage and acceptance by VI persons. The second phase is a set of interviews conducted in a laboratory setting after VI persons try out smart cane outdoor navigation system. There is also a possibility for using other prototypes too in addition to that.

7. TIMELINE

Work on all prototypes is underway. Table 1 provides detail of current status of all prototypes.

8. CONCLUSIONS

In this paper, the prototypes of a navigation portfolio to assist visually impaired deaf-blind and blind persons in outdoor/indoor navigation and a complementary qualitative study is presented. The improvement of the autonomy and functional capabilities of people with special needs is often achieved through the use of assistive technologies. These technologies ensure an improvement of the general welfare of the people by assisting them to integrate into the society, enhancing their capabilities. However, their design will be limited if real end users requirements are not gathered through interaction with them. In this article, advanced navigation assistance aids to assist the visually impaired persons in outdoor and indoor environment are presented for all designed prototypes. A qualitative study to put the voice of users into design and validation process of the proposed prototypes and to investigate acceptance of technological navigation assistance aids by VI persons is presented. It is expected that the results of the qualitative interviews and test sessions will provide valuable information to make these prototypes full-fledged systems ready to be deployed. The qualitative study will help remove the problematic issues from proposed navigation systems that restrain users from technology adoption.

Table 1. Timeline.

Construct	Status
Smart Cane Outdoor Navigation System	The prototype is under development, pilot test of the system with real user in laboratory will be done in Autumn 2014. Qualitative interviews' 1st session in Finland and Sweden is underway. Second phase of interviews i.e. post-test feedback interviews will be done in Autumn 2014 after pilot test. First phase of qualitative interviews in Pakistan is scheduled in October-November 2014.
Smart Grip Outdoor Navigation System	The prototype is being developed as master thesis started in Spring 2014; it will be ready for testing by end of 2014 - start of 2015.
VLC based Smart Grip Indoor Navigation System	Work on prototype is underway; it will be ready for testing by end of 2014 or start of 2015. 1st demonstration will be on a smart phone. Later when smart grip will be ready, it will be tested using it.
Qualitative Survey for Acceptance of New Navigation Assistance Aids By VI Blind Persons	The first phase of gathering general data about assistive technology usage and acceptance by VI persons is underway since summer 2014. The second phase of gathering data through smart cane testing by VI persons will be conducted later in the autumn 2014.

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APPENDIX A

List of Questions for interview Session 1		
Theoretical Construct	**Questions**	**Indicators**
Introduction	1. Who we are and why we are doing this interview (general introduction)?	***Acquaintance***
Categorizing Characteristics of interviewee-I	2. Do you use white cane for navigation assistance?	***White cane acquaintance***
Outdoor Cane Usage	3. How do you use cane on sidewalk that surface is flat? 4. How do you use cane on walking street that is built by bricks? 5. How do you use cane on a trail like in some of parks? 6. How do you manage to ride a bus, taxi, or private car? 7. How do you use cane when it's raining outside? 8. How do you use cane in soft snow outside? 9. How do you use cane in hard snow outside? 10. How do you use cane in hard slippery snow outside?	***Urban environment cane usage pattern*** ***Transportation usage*** ***Seasonal cane usage pattern***
Indoor Cane Usage	11. How do you use cane in corridor? 12. How do you use cane in a big hall 13. How do you use cane on stairs? 14. How do you use cane on an escalator? 15. How do you use cane in a lift?	***Indoor cane usage pattern***
Alternative navigation aid and decision making	16. How hearing help you in navigation outdoor and navigation indoor? 17. Do you plan your visit in advance or do you make decision where to visit while walking? 18. What are the places you visit in Summer and in winter and how often?	***How much info to be relayed about POIs***
Suggestion	19. Do you use any kind of assistance technology? 20. What is ideal guidance system for you? 21. How would you compare this system with other navigation systems?	***View of ideal navigation aid***
Categorizing Characteristics of interviewee - II	22. What is your date of birth? 23. Do you lose sight late or blind by birth? 24. What is the cause of your visual impairment? 25. On a scale of 1-5 where 1 means nonexistent and 5 means perfect, how would you rate your vision in the following areas: a. Visual acuity b. Field of vision c. Night blindness d. Sensitivity to light e. Color blindness	***Background info*** ***Degree & reason of blindness***
Post demo feedback	26. What do you think of this system? 27. How do you compare this system with any navigation assistance your currently use for outdoor navigation like ordinary white cane or any navigator application? 28. What potential difficulties of yours when you navigate outdoor do you think this system could solve? 29. Would you like to use this system?	***End users view and acceptance of proposed system***