Journal of Engineering and Science Research 4 (4): 12-19, 2020
e-ISSN: 2289-7127

DOI: 10.26666/rmp.jesr.2020.4.3

Enhancing the Usability of Tactile Map for the Visually Impaired

Muzaireen Minhat, Nasuha Lee Abdullah, Rosnah Idrus, Pantea Keikhosrokiani
School of Computer Sciences, Universiti Sains Malaysia, Malaysia

Abstract: Assistive technology is initiated to aid those visually impaired to fulfil their tasks independently, rapidly, and easily. As such, tactile map is an assistive technology that has been widely used for navigation to enable those visually impaired to visualize the geographical information about a particular place. Nevertheless, its usability and availability in Malaysia are scant. This paper aims to investigate the usability issues of tactile map, identify the requirements and proposed a conceptual prototype named TacTalk. Qualitative research method in the form of face to face interviews were carried out with the visually impaired residing at Saint Nicholas' Home for the Blind in Penang. Results from the findings identified four emerging usability issues: poor design of tactile map due to limited space, misinterpretation of information, complexity of symbols used and difficulty in memorizing directions. The proposed solution, 'TacTalk', refers to a 'talking tactile map' incorporated with audio support. TacTalk is comprised of two components, which are: a tactile map with built-in buttons, and a mobile application that plays the audio files. There is a connection between the buttons on the map and the TacTalk mobile application via Bluetooth. An audio instruction is played when the button is pressed by the user. The results of this work hope to overcome the fear of the visually impaired to travel alone. Hopefully, it can inspire and empower them to explore the use of assistive technology in future.

Key words: *Tactile map, visually impaired, assistive technology, indoor navigation for visually impaired.*

INTRODUCTION

Normal vision, moderate visual impairment, severe visual impairment, and blindness are the four levels of visual function enlisted by the International Classification of Diseases [1]. In fact, the term 'low vision' reflects moderate and severe visual impairments, and when associated with blindness, it is known as visual impairment [1]. Those visually impaired are confronted with numerous restrictions, especially in indoor navigation, which can be reduced by interventions allocated for the disable community. Assistive technology assists those disabled, particularly the visually impaired, to perform their daily tasks rapidly, easily, and independently. Such technology reduces social barriers experienced by those disabled and the society [2]. The major aspect that restricts the visually impaired to navigate independently is the personal frustration to memorize large amount of information [3]. Even though many navigation systems was developed to assist the visually impaired, it has remained a big concern. The visually impaired usually prefer employing a caretaker to take them around, but a caretaker cannot be available at all times. In addition, the fear of getting lost has hindered unaided navigation. The fear eventually grows at places deemed as unfamiliar. Moreover, there are also times when the directions given by those surrounding appear complicated, in which they may end up getting lost. Using a map is a routine, especially while navigating to unaware areas. Unlike ones with sight, the visually impaired cannot access the normal map as it requires visual support for reading and comprehension [4]. One of the assistive technologies that are widely used for navigation devised specifically for the visually impaired is the tactile map. Tactile map is a distinctive map that is equipped with Braille labeling. Unfortunately, this application has not been widely used by the visually impaired community in Malaysia based on the results retrieved from interview sessions held in this study. Therefore, it is important to identify usability issues related to tactile map, which is the primary purpose of this study. This study also proposes a conceptual prototype of a talking tactile map called 'TacTalk', so as to enhance the usability of tactile map. TacTalk refers to a tactile map that comes with audio support. The paper began with review and comparison of the prior works, followed by methodology, and interview results at St. Nicholas Home for the Blind. Next, further details of

Corresponding Author: Nasuha Lee Abdullah, School of Computer Sciences, 11800 USM Penang, Malaysia, 0194784131

TacTalk are explained and this is followed by discussion and conclusion.

RELATED WORKS

Assistive Technology in Indoor Navigation

The rapid development in construction, renovation, and upgrading infrastructure of buildings has restricted those visually impaired from navigating independently. The visually impaired find it more challenging when public buildings, such as hospitals, banks, government offices, and schools, undergo renovations or relocations. Not only there is lack of information on these changes, but typically, such information is not accessible properly [5]. Hence, in order to enhance the quality of life among those visually impaired, many studies related to the effectiveness of assistive technologies have been carried out. Recent studies by [6], as well as [7], revealed that audio-tactile map is more effective in aiding the visually impaired to generate a cognitive map of the route.

Assistive Technology in Mobile Devices

Numerous assistive technology-based devices were developed to assist the visually impaired to navigate independently, including mobile computing platforms, as well as electronic and wearable devices. Therefore, developers must consider the basic needs for the visually impaired when developing such new mobile technology. Some fundamental requirements that should be incorporated in the assistive technology are audio and tactile elements [8] .The present technology provides an opportunity for various applications to be integrated and run on mobile devices efficiently. This has led to the increasing tendency of growth in various applications that have been proven to aid the disable community, especially among those visually impaired, to manage their mobile devices. An electronic travel aid, navigational assistance module, text-to-speech applications, and virtual audio displays are some instances of the existing applications [8]. Furthermore, the increasing user-friendly interfaces and modes of interaction have opened avenues for rehabilitation and training, especially for those visually impaired [8] . Android and iOS have been constantly improving their accessibility features to ease those visually impaired in handling their mobile devices. Some of these android-based applications include TalkBack, KickBack, and SoundBack (TKS), whereas iOS is comprised of AVSpeech Synthesizer, VoiceOver, and Siri, to name a few, as built-in applications. In addition, mobile devices are equipped with advanced sensory capabilities, where they can help in establishing interaction with the environment [8]. Nevertheless, the sensory technology capabilities highly rely on the advancement of these devices. Thus, the interaction between users and environment through the devices might suggest some restrictions.

Accessibility of Visual Map for the Blind

Much significant effort has been taken in producing visual maps which are accessible to the visually impaired [9]. Designs and features of the map appear to be the most critical aspects that should be considered so as to ease comprehension and to embed user-friendly element, especially for usage among those visually impaired. Some of the basic map abilities which are required for users required are to explore a map, to identify the map borders, and to determine the position within or outside of the map, to identify the path between source and destination, as well as the ability to explore any additional related issues [10]. Therefore, in order to make a visual map accessible for the visually impaired, some of the following aspects have to be included. First, the user should be able to read the textual content through the help of assistive technology, such as screen reader or voice synthesizer. Second, the map should include audio icons and aural symbols in order to provide additional information when the user explores the map [10]. The design of the audio icons must be in the form of a raised dot in a particular size that is suitable within the map [9]. The next essential aspect refers to touch and vibration feedback. The map must be able to have special tactile material for each item and the ability to give different intensity of vibration to inform the user on a specific area [10]. The visually impaired would face some restrictions in accessing certain information, especially when the map is web-based. In order to address this issue, touch screens can replace the function of the mouse, where it can be mapped with a touch-screen click. Meanwhile, a single mouse click can be mapped on double touch screen clicks and a longer touch might load a page with full details of the specific place. For those visually impaired, tactile map appears to be one of the many solutions as access to a normal visual map is impossible. On top of that, for independent orientation and mobility, the tactile map is an effective tool that can be used by those visually impaired [4]. Touch screens, vibration feedback, and other channels, such as auditory, vibrotactil or braille, are also some possible strategies to make visual map accessible for those visually impaired [10]. For example, a university website accessibility evaluation had been performed so as to determine the requirements for visually impaired users [11].

Tactile Map

Tactile map consists of a set of labeling, street density, line style, and scaling criteria [4]. The labeling on a tactile map includes symbols and Braille. The symbols are used to explain the direction towards the intended places and they are built with slightly raised surfaces, along with the Braille, in order to describe the map of the building. In fact, there are two types of tactile maps, which are: static and portable. The static map is also known as in-situ map. The variance between these two types refers to the basic ways that offer information regarding the layout. In-situ is a large static map that provides a simple and straightforward overview of a certain place with simple orientation information. The map should be simple as the users have to remember the information upon walking away from the map, while the portable tactile map can be more detailed. Basically, the portable tactile map offers more information, in comparison to the in-situ map although the in-situ map may provide a good overview of a particular place, hence benefitting the visually impaired. Most importantly, designing a tactile map is a crucial aspect to consider for the visually impaired so as to offer better visualization of their environment. In fact, numerous tactile maps have been developed to help the visually impaired in navigating in an independent manner [12] The proposed design with audio aid could help the visually impaired to comprehend the map better. One instance is the Talking TMAP, which refers to the combination between Talking Tactile Tablet (TTT) and TMAP. The audio buttons briefly explain the geographical information of a particular area to the user; hence providing better visualization of their surrounding [4]. However, the audio labels button must be in a suitable size so as to fit in the map and for the user to identify the button. On top of that, an interactive audio label at every turn of a journey should be embedded into the map. The number of audio buttons inserted should be suitable with the needs of a particular area. For example, on a long route inside a building, the distance between each button should be relevant to remind the user of his or her location [9].

Assistive Technology Tools

A white stick or a cane is the common tool used by the visually impaired to navigate [13]. A research that focused on enhancing the cane or white stick is the RadioVirgilio/SesamoNet [13]. It uses mobile and wireless technology, together with text-to-speech system and mobile-based database to design a system. The system works when the antenna detects the tag in the ground and assists the users to follow the right direction. It offers support for the visually impaired as it can keep a user on the safe path, apart from providing geographical information when navigating. The system also informs the user about the turns and obstacles along the path [13]. Another device that can help the visually impaired is the Eye-Helper. It helps them with independent grocery shopping due to its wearable device that consists of computer vision features and audio interfaces. In addition, audio aid embedded in the devices helps the visually impaired to choose the target grocery items by generating a series of beeps, which depends on angle, distance, and height between the user and the target grocery items [14].

Comparison between the Current Assistive Technology Designs for Navigation

Table 1 : Comparison of Assistive Technology Designs

	Eye-Helper [14]	Sesamo Net [13]	TacMap [15]	Talking TMAP [4]	Proposed Design, TacTalk
Hardware/ Software	Computer Vision, Wearable Device	RFID tag, RFID Cane Reader	Tactile Map	Tactile map, Talking Tactile Tablet	Talking Tactile Map, TacTalk mobile apps
Audio Support	Yes	Yes	No	Yes	Yes
Map	No	No	Yes	Yes	Yes
Portability	No	Yes	No	No	Yes
Usability	Low	High	High	Medium	High

The objective of the comparison is to ensure that the proposed design, TacTalk, could overcome the shortcomings of the existing assistive technology designs.

METHODS

In order to fulfill the objectives of this study, a research framework is proposed which consists of few steps throughout the study as illustrated in Figure 1. Firstly, the problem domain is identified for indoor navigation for building floor plan for public office, school, hospital, mall, etc. among the visually impaired. Secondly, preliminary data is collected using literature review focusing on the information and tools related to visually impaired navigation and tactile map. Afterwards, the research problem is defined which focuses on the usability and accessibility issues of tactile map that leads to difficulty for the visually impaired to use. Furthermore, the availability of the tactile map is not very high in Malaysia; hence, the tool is disregarded by the visually impaired in this country.

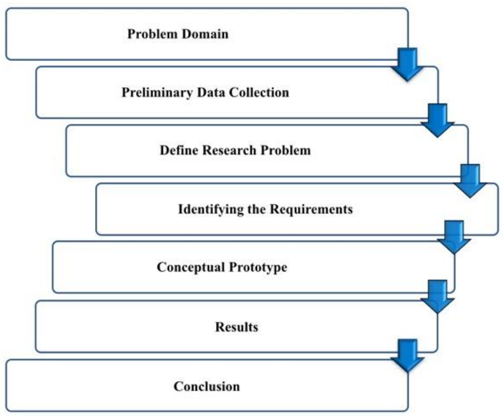

Figure 1 Research Method

In order to propose a solution, the requirements, including the issues on tactile map and the visually impairers' knowledge on mobile devices, are identified. These requirements were utilized as the fundamental for the next steps. Afterwards, interview sessions with the visually impaired was conducted at Saint Nicholas' Home for the Blind located in Penang. Face-to-face interview sessions was carried out using open-ended questions to collect qualitative data. The interview sessions lasted for approximately 30 to 45 minutes for each session and 6 visually-impaired respondents participated in this study. A questionnaire that is comprised of 16 open-ended questions had been used as a tool for this interview. The questionnaire includes the items related to the usage of mobile or smartphone among the respondents, navigation, and usage of tactile map. The objective is to gain enhanced understanding of the problems, the issues, and the requirements for indoor navigation, as well as the technology competency among the respondents. Instances of the interview questions are: How do you navigate in indoor places, such as a mall, hospital or public office? What are the challenges that you face? Are you familiar with tactile map? If yes, how often do you use it? What are the difficulties that you face when using the tactile map? If no, are you interested in using it in the future? These questions only served as a guide to start the conversation. During the actual session, the researcher probed further when necessary. The interview results led to the identification of problems faced by the visually impaired while indoor navigation, along with emerging issues related to tactile map. A total number of 6 interviews were recorded, transcribed, and analyzed. The thematic analysis was performed by reading the transcripts to find and conclude the main points or inputs. The thematic analysis refers to the process of encoding qualitative information by using a defined theme [16]. A conceptual prototype called TacTalk was proposed, once the interview results had been justified and requirements had been identified. Consequently, the result of the conceptual map is illustrated and the study is ended with a conclusion. In summary, the research methodology consists of seven steps, which are: (1) Identification of problem domain, (2) Review of related works, (3) Defining research problem, (4) Identification of requirements, (5) Discussion of results, (6) Proposal of the conceptual design, and lastly, (7) Conclusion of the research.

RESULTS

The results and implication of interview sessions at the St. Nicholas Home for the Blind with six visually impaired respondents are reported in the results section. The interview results are divided into three sections including: (1) the level of competencies on mobile devices among the visually impaired, (2) the usability issues of tactile map, and (3) the requirements for the proposed conceptual design. The results indicated that the respondents were far from being tech-savvy as most of them were still fumbling with the applications embedded in smartphones. Thus, they may need quite some times to learn the more intricate applications such as navigation. The most fearful feeling that a visually impaired may experience is getting lost and they usually trust human guides, instead of navigation applications. Therefore, instead of devising new navigation applications, it is more useful to propose an enhanced Based on the results, respondents emphasized on five usability issues related to tactile map in which the first one refers to the existing tactile map with space issues and poor design. The existing tactile map utilized several special symbols and Braille labeling for the visually impaired to be in ease [9]. Nevertheless, combination of these two features within the same map needs more space, and therefore, less information can be placed on the map. Misinterpretation while exploring the tactile map is considered as the second usability issue pointe by the respondents. Although, there are large tactile maps with sufficient information, too many symbols are included on the maps. Based on the respondents, when the size of tactile map is too big they may get confused and get lost while exploring the map. Furthermore, they have pointed on the complexity of tactile map as the third issue. In precise, this issue can

be relevant to the information available on the tactile map. In addition, the respondents preferred to have a map in a very large scale to include all features [17]. However, the findings from the research signified that the respondents would like to have an overview and impressions of the building, instead of all the detailed features in the tactile map. Visually impaired cannot memorize the directions is considered as the fourth issue of the tactile map. Those respondents who have experience use of the tactile map claimed that it is indeed a suitable tool to aid them in directing path. However, it is hard to keep remembering the direction until they arrive at the intended location. The respondents further stated that although they could understand and remember the path, confusion creeps in upon navigation. One of the respondents added that she was distracted while she bumped into someone during navigation. Availability of the tactile map especially in Malaysia, which is the most commonly reported, is considered as the last issue of this study. Based on the report, tactile map is hardly available in Malaysia although it can be considered as a valuable tool for the visually impaired. The unraveled usability issues in this study may be the reason for the visually impaired to be ignorant about the usage of tactile map. Consequently, highlighted issues from this study can be used as guidelines to propose the new concept of tactile map.
The requirements to solve issues related to usability of tactile map was identified and summarized in Table 2. The respondents stated that it is insufficient to only rely on their touch sense while exploring the tactile map. They further proposed that audio support should be embedded to enhance the usability of tactile map.

Tactile map that focuses on the specific needs of the visually impaired.

Table 2: Summary of usability issues

	Usability issues	Proposed Solutions
1	Space issues result in poor design of tactile map	Audio description on the summary or brief information of the building
2	Misinterpretation of information on tactile map	Audio description about location and surrounding of the user
3	Complexity of symbols used in tactile map	Audio contains direction only from the map to the targeted place
4	Difficulty in memorizing directions	
5	Availability of tactile map in public places	Future work

PROPOSED CONCEPTUAL DESIGN

The proposed solution is named TacTalk, which comprised of two main components: (1) a tactile map with built-in buttons, and (2) a mobile apps to play the audio file once the button is pressed on the tactile map. The proposed system architecture of TacTalk is illustrated in Figure 2.

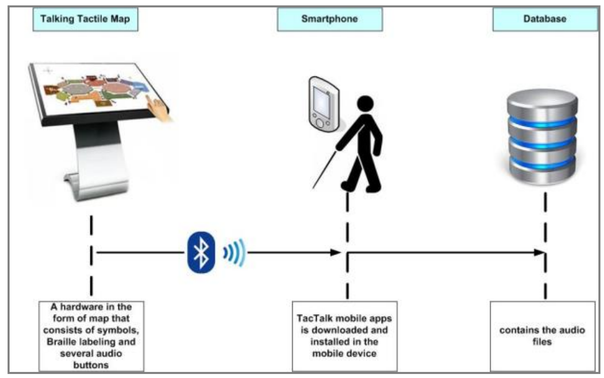

Figure 2 Architecture of proposed system

The TacTalk mobile app has a built-in database which includes audio files linked to the TacTalk map. The audio can only be played once the Smartphone is connected to the TacTalk map. The TacTalk map is enhanced from the existing tactile map. A special feature, which is built-in audio buttons is added into TacTalk map to distinguish it from the existing one. The normal tactile map includes only the symbols and the Braille labeling, while the TacTalk map has a built-in Bluetooth transmitter. This built-in Bluetooth transmitter is connected to the buttons that functions as a switch to play the audio files available in the TacTalk mobile app database.

The TacTalk map is a type of hardware in the form of a map that consists of symbols, Braille labeling, and several audio buttons. The design of the tactile map is based on Guidelines and Standards for Tactile Graphics [18]. Based on the guidelines, some universal symbols had been used to design the tactile map, including stairs, elevator, entrance, and main hallway. The proposed design is illustrated in Figure 3 (translated from Braille to ease comprehension among readers) The blue circles indicate the audio buttons.

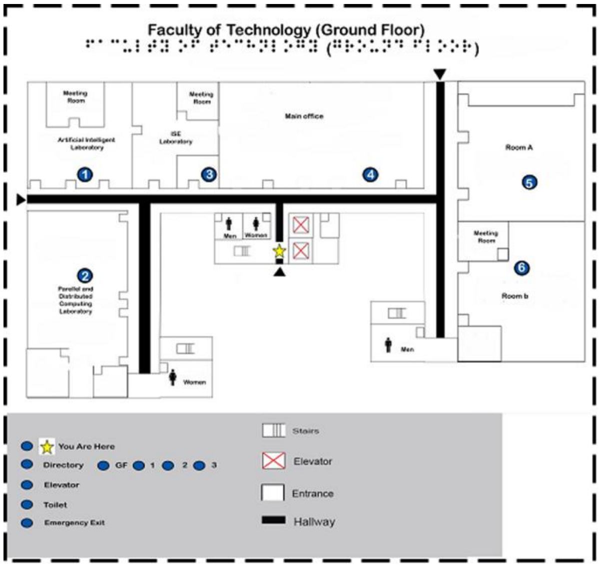

Figure 3 The Proposed Design of Talking Tactile Map Translated from Braille

The button serves to mark the places of interest within a building. As portrayed in Figure 3, six buttons indicate six places of interest at the ground floor in the building. Next, additional nine buttons are embedded in the map legend. On top of that, the places in the tactile map are labeled in Braille so as to enable those visually impaired to access and to explore the area with ease. Furthermore, as depicted earlier, the TacTalk map is embedded with a Bluetooth transmitter in order to connect with the user's smartphone. Therefore, a user has to download the TacTalk mobile application onto their smartphone before they can be connected to the TacTalk map. The audio available in the TacTalk mobile application provides both the description and the direction of a specific location in the tactile map. With reference to TacTalk map design (Figure 3), it is comprised of two parts, which are: legend and tactile map.

The TacTalk map is placed next to the 'You Are Here' location. Besides, the tactile map is comprised of Braille labels, six audio buttons indicated by blue circle, as well as symbols, such as entrance, stairs, elevator, and hallway. Meanwhile, the TacTalk map legend consists of nine audio buttons, which are: 'You Are Here' button, Directory, GF, 1F, 2F, and 3F buttons, as well as buttons to indicate elevators and washrooms. The representation of the symbols used is also included in the legend. Sample of the audio content whenever the use press a button is as follow:-

Button You are here: The symbol that represents 'You Are Here' is the yellow star found on the TacTalk map that can be touched by the visually impaired. As for the legend, an audio button is placed next to the yellow star symbol. It plays the audio that describes the surrounding of the user upon pressing. An example of the audio file content is "You are at the Ground floor of the Faculty of Technology building. Your location is at the entrance, where you are in the middle between stairs and elevators. There are two elevators located side by side on your right. There are stairs available at your left side. You can move three steps forward to enter the main hallway, where the main office, the classes, and the laboratories are located."

Directory G 1 2 3: The directory button notifies a user the buttons available on the tactile map that can help the user to gain direction to the target place. The audio describes the general view of the current floor. There are also GF, 1F, 2F, and 3F buttons that contain audio files describing the general view from the ground floor to the third floor. The user can choose the floor that he/she wants to listen to. An example of the audio content is "There are six buttons available on the tactile map that give direction. You can press the button to get the direction of the location that you desire to go to. This is the ground floor of the building. There are main office, two rooms, and three laboratories available at this level. You can move three steps forward to be at the main hallway. There is a main office door in front when you arrive at the main hallway. There are three laboratories on the left side of the hallway and two classes on the right side of the hallway. The left side has the ISE laboratory, the artificial intelligent laboratory, and the IT laboratory. The right side of the hallway has room A and room B. This level consists of two washrooms for men and two washrooms for women. There are three stairs available in this building. Three entrances are available to enter into the building and the main entrance is at your six o'clock."

DISCUSSION AND CONCLUSION

One of the main concerns and distress among the visually impaired is navigation. The fear of getting lost hinders them from navigating independently. Although many assistive technologies are available with specific focus on navigation for the visually impaired, not many are specially designed for indoor navigation. As such, this study has proposed the TacTalk map and mobile application, which could serve as the directory of a building. This work, however, can be further enhanced by determining the scalability of the TacTalk mobile application. The present database is a built-in database which can be downloaded along with the application. This can be performed as the audio files in the database are focused only on one TacTalk map. In fact, more audio files could be developed in the future and the scalability of the built-in database must be considered as well.

In addition, the design of TacTalk adopts concept of modular product design to reduce complexity and increase efficiency in manufacturing [19]. Cost for producing TacTalk is optimized by leveraging on the functionality of smartphones. As the audio files is built in within the TacTalk mobile application, it can ease the manufacturing of TacTalk map. The manufacturer only needs to define where to add the audio switches (buttons) on the map and attach a Bluetooth transmitter. The details on the directions is handled separately via TacTalk mobile application. Hence, more TacTalk maps can be produced in the future as it is easily duplicated.

All three objectives of the research have been fulfilled. First, investigation of the usability issues of the tactile map. Four usability issues have been identified: poor design of tactile map due to limited space, misinterpretation of information, complexity of symbols used and difficulty in memorizing directions. Second, identify requirements in enhancing usability issues. The visually impaired prefer audio format instead of Braille to describe directions on the map. Audio description on background information of the building, information about users' surrounding and description of direction from the map to the targeted place are the proposed solutions for a tactile map. Finally, conceptual prototype of TacTalk is proposed and hence fulfilled the third objective.
The results of this work hope to break the fear of the visually impaired to travel alone. Hopefully, it can inspire them to explore the use of assistive technology in future.

ACKNOWLEDGMENTS

This work was supported by Universiti Sains Malaysia. The authors gratefully acknowledge the respondents from Penang Saint Nicholas' Home for the Blind.

.

REFERENCES

[1] Blindness and vision impairment. (2020). Retrieved from https://www.who.int/en/news-room/fact-sheets/detail/blindness-and-visual-impairment

[2] Medcalf, L. (2015). *Technology helping visually impaired 'See'*. Retrieved from Easterseals Crossroads website: http://www.eastersealstech.com/2015/02/04/eyewear-helps-visually-impaired-see/

[3] Ganz, A., Schafer, J., Gandhi, S., Puleo, E., Wilson, C., & Robertson, M. (2012). PERCEPT indoor navigation system for the blind and visually impaired: architecture and experimentation. *International journal of telemedicine and applications, 2012*, 19.

[4] Miele, J. A., Landau, S., & Gilden, D. (2006). Talking TMAP: Automated generation of audio-tactile maps using Smith-Kettlewell's TMAP software. *British Journal of Visual Impairment, 24*(2), 93-100. [5] Mukhia, P. 1981. Performance and aerodynamic analysis of the Thai four bladed wooden rotor coupled to a ladder pump. M.Eng. thesis, AIT.

[5] Duarte, K., Cecilio, J., Silva, J. S., & Furtado, P. (2014). Information and assisted navigation system for blind people. Paper presented at the Proceedings of the 8th International Conference on Sensing Technology, Liverpool, UK.

[6]Papadopoulos, K., Koustriava, E., & Koukourikos, P. (2017). Orientation and mobility aids for individuals with blindness: Verbal description vs. audio-tactile map. *Assistive Technology*, 1-10.

[7] Papadopoulos, K., Koustriava, E., & Barouti, M. (2017). Cognitive maps of individuals with blindness for familiar and unfamiliar spaces: Construction through audio-tactile maps and walked experience. *Computers in Human Behavior, 75*, 376-384.

[8] Csapó, Á., Wersényi, G., Nagy, H., & Stockman, T. (2015). A survey of assistive technologies and applications for blind users on mobile platforms: a review and foundation for research. *Journal on Multimodal User Interfaces, 9*(4), 275-286

[9] Paladugu, D. A., Wang, Z., & Li, B. (2010). On presenting audio-tactile maps to visually impaired users for getting directions. Paper presented at the Conference on Human Factors in Computing Systems Atlanta, Georgia, USA.

[10]Buzzi, M. C., Buzzi, M., Leporini, B., & Martusciello, L. (2011). Making visual maps accessible to the blind. Paper presented at the International Conference on Universal Access in Human-Computer Interaction, Berlin, Heidelberg.

[11] Hassouna, M. S., Sahari, N., & Ismail, A. (2017). University website accessibility for totally blind users. *Journal of ICT, 16*(1), 63-80.

[12] Hillis, C. (2005). Talking Images: Museums, galleries and heritage sites. *International Congress Series, 1282*, 855-859.

[13] D'Atri, E., Medaglia, C. M., Serbanati, A., Ceipidor, U. B., Panizzi, E., & D'Atri, A. (2007). A system to aid blind people in the mobility: A usability test and its results. Paper presented at the Systems, 2007. ICONS'07. Second International Conference on.

[14] Wang, E. (2015). Project Eye-Helper An Assistive Technology for Blind Grocery Shoppers. Paper presented at the The 17th International ACM SIGACCESS Conference on Computers and Accessibility, Lisbon, Portugal.

[15]Chamberlain, P., & Dieng, P. (2011). Looking good, feeling good–Tac Map: A navigation system for the

blind. Paper presented at the The role of inclusive design in making social innovation happen, London, UK

[16] Boyatzis, R. E. (1998). *Transforming qualitative information: Thematic analysis and code development*. Thousand Oaks, CA, US: Sage Publications, Inc.

[17] Rowell, J., & Ungar, S. (2005). Feeling our way: tactile map user requirements-a survey. Paper presented at the International Cartographic Conference, La Coruna.

[18] Braille Authority of North America (2010). *Guidelines and standards for Tactile graphics.*

[19] Okudan Kremer, G. E., Ma, J., Chiu, M.-C., & Lin, T.-K. (2013). Product Modularity and Implications for the Reverse Supply Chain. *Supply Chain Forum: An International Journal, 14*(2), 54-69.