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GPS-enabled smart stick guide for campus accessibility at King Abdulaziz University

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Abstract

This study focuses on improving the mobility and self-reliance of blind students to navigate university campuses. The main objective of this study was to design and develop a Smart Guide application, integrating a smart stick and application to help blind students navigate the university and its buildings safely and adequately. This system applies a combination of different components such as an obstacle sensor positioned on the stick to detect any obstacle, a global positioning system (GPS) module for instantaneous location tracking, and light sensors to make students aware of the changes in environmental lighting and to assist connection between the blind students, their guardians, and building security guards, enabling timely assistance in case of walking difficulties or emergencies. The Arduino board technology was employed for hardware integration, implementing ultrasonic and light sensors, and GPS modules, although the application is developed using Arduino IDE and XCode IDE. An iterative waterfall development methodology was utilized to implement this smart stick. The primary results demonstrate that the obstacles have been detected by the system successfully and are aware of users at the time, while the GPS module's effectiveness assures connectivity with guardians and security. The safety and mobility of blind students have been significantly enhanced by the system's real-time location tracking and environmental observation. This study exhibits the development of merging sustaining hardware and software solutions to enhance availability for visually impaired students in university and provide an innovative and balanced system for extensive application. Future studies will focus on advancing navigation competence in outdoor environments and managing challenges related to emergency buttons and sensors.

Keywords

GPS, Smart Stick, obstacle sensor, blind students

I. Introduction

Blindness is a common disability among individuals worldwide. Around 90% of the world's visually impaired population lives in developing nations [1]. The statistics of the World Health Organization (WHO) state that 39 million people are blind and about 285 million are visually impaired [2]. Middle East residents have 12.5% of blind [3]. Sightless individuals suffer from various obstacles; one of these obstacles is finding their way out [4]. Utilization of walking stick is one of the solutions, which is also known as a white cane. It is a mobility equipment that assists a blind individual in scanning their surroundings environment [5]. Tactile paving, which is a yellow textured ground surface, serves as another method employed alongside a walking stick to aid individuals who are blind [6]. However, it is not broadly utilized, as it should be in public areas; it is perhaps utilized in a few commercial zones [4]. The International Arrangement of Diseases [7] defines visual impairment as a condition where distance sight is impaired, resulting in visual acuity worse than 3/60. A study was designed as an observational, cross-sectional investigation of data regarding the ocular health of 2214 eyes from 1107 European Caucasian individuals. The majority of these individuals reside in Lodz, a city in central Poland. Visual impairment was described as having 20/200 distance visual acuity, while blindness was characterized as a best-corrected visual acuity (BCVA) of less than 20/200 in both eyes. It was determined that 27.5% of the subjects experienced visual impairment [8].

Recent developments in facilitating technology have been involved in enhancing navigation for visually impaired individuals. The development of smart walking aids with sensors, alarms, and a global positioning system (GPS) for enhanced navigation has been investigated by several studies. Shovlet developed a device called Nava let, a multifunctional portable personalized computer that could identify barriers positioned indoors. It depended on two factors; the first one was that noise perception can vary depending on the nature of the interruption. One activity was intended for forward movement while another activity was used when an obstacle was encountered. Furthermore, if the blind individual stands in an incorrect location, the smart cane will provide a warning regarding their position [9]. In other studies, smart walking sticks, that aware of the obstacles but they have also some limitations, such as the absence of voice navigation in these previous systems [10]. A structural model incorporating Bluetooth Low Energy (BLE) and a modified long range wide area network (LoRaWAN) has been developed in recent studies for simultaneous vehicle detection in insubstantial waters and boat traffic monitoring. These networks were tested in real time to assist boat traffic observing challenges [11].

Furthermore, a recent study discussed a secured blockchain technology, which is incorporated in distributed cloud storage structures. It has smart disparities to assist data privacy, probity, and availability. The system empowers secure data exchange over publicly usable cloud storage with the combination of Ethereum Blockchain with Rivest Shamir Adleman (RSA) encoding and validation schemes [12].

Another noteworthy development in favorable technology is the use of convolutional neural networks (CNN) for locating and positioning objects determined by the design of a 360° dead-angle-free smart desk lamp. In this system, CNNs are utilized for visual tracking to provide lightning and guide individuals to a particular position [13].

An experimental energy utilization model and a developmental algorithm-based route planning algorithm were discussed in a recent study, which acquired greater energy adaptability in the produced routes compared with other advanced evolutionary algorithms with comparable purpose and restrictions [14]. Another study developed a white smart stick to detect obstacles only at outdoor, which is also appropriate for indoor use. For the detection of obstacles, infrared (IR) sensors have also been used in smart walking sticks to send vibration alerts to blind users [15]. However, there might be a restriction for IR sensors in smart walking sticks because of which they could not effectively detect distant obstacles [16].

Tactile paving is utilized at King AbdulAziz University (KAU) by sight-impaired students. Thus, they required assistance from people with sight for walking. This study mainly aims to assist blind individuals, especially blind students of KAU, to find their way throughout the university. In this study, the GPS-enabled smart stick guide is designed particularly for campus accessibility at KAU, contributing specialized navigation solutions that incorporate GPS technology with simultaneous detection of obstacles. Unlike previous studies, which constantly aim at multi-purpose smart sticks or indoor navigation systems, this study described the exceptional needs of visually impaired students in navigating complicated campuses of universities, specifically at KAU.

This study bridges the gap in campus navigation systems for blind students by developing a smart stick guide that incorporates GPS-guided navigation, along with ultrasonic and light sensors. Thereby, we provide a customized solution that improves movability and self-reliance for students at KAU.

The supposed GPS-enabled smart stick guide is a remarkable advancement in facilitative technology, providing a flexible solution that can be adjusted for use in other universities or public environments. This revolution contributes to the wider achievement of improving accessibility and encouraging diversity for students with visual impairments.

II. Materials and Methods

Figure 1 shows the flowchart in designing and implementing smart stick system.

a. Sampling

The operational feasibility was conducted on a visually impaired female student at KAU using questionnaires created with Google Forms. To know about the target group's acceptance of the project idea, questionnaires were used to know how they deal with the problem of navigation.

a.i System architecture

Figure 2 displays the architecture of Smart Guide System, which consists of three layers. The user interface layer receives the information from the three different users, manages it at the application layer, and stores the data in the database layer.

User interface, the first layer, includes three interfaces for the different users: blind student, blind's guardian, and security guard. The second layer is the application layer, which manages and processes the operations; it contains two components, the Smart Guide application and the Smart Stick. Smart Guide application manages the users' accounts and the map navigation. Simultaneously, the Smart Stick, which the blind student uses, scans the surroundings while navigating, gives alarms in case of obstacles and darkness, and sends the emergency alarms. The third layer is the database layer. It consists of Users Database, which includes the users' database and stores the different users' data, and the Maps Database, which stores the building's data and the maps of each destination.

b. Data structure design

The data of Smart Guide application are stored and managed using two databases: Firebase database

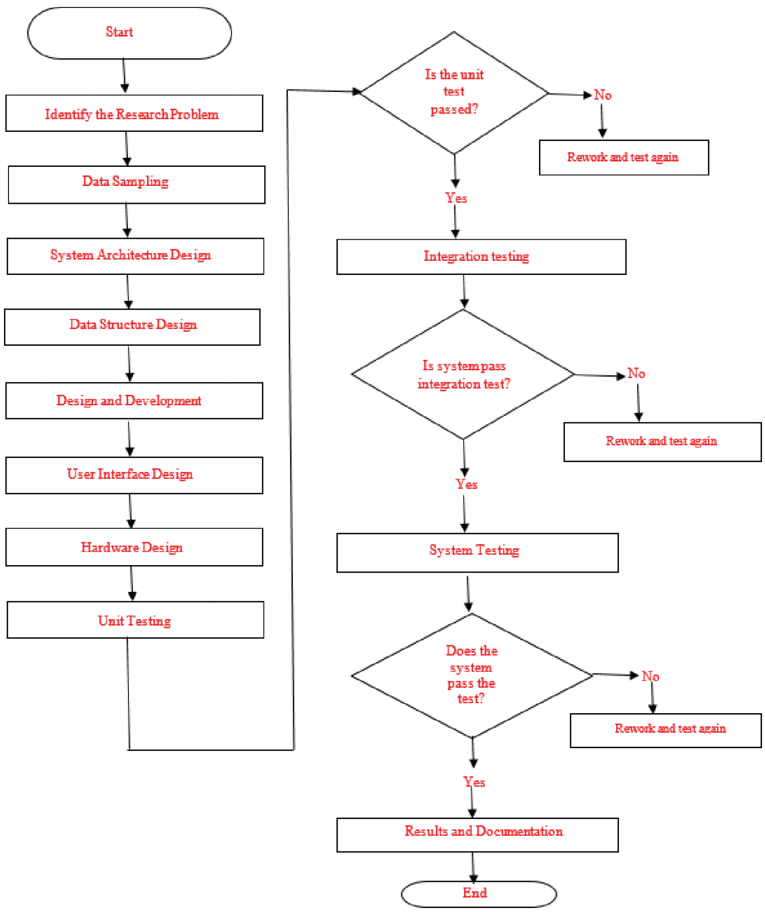


Figure 1: Flowchart of smart stick system.

and Placenote cloud. The user's data are stored in the Firebase database, a NoSQL database that uses collections and documents. This collection holds the users' data like emails, names, passwords, and user types, such as student, guardian, or security guard. The building's maps are stored on the Placenote cloud.

c. Design

The application is presented in the Arabic language. Since blind users use screen readers to understand and get what is shown on the screen, the application interfaces should be compatible with screen readers. Screen readers read the elements on the screen and indicate their type. The user can move their fingers to the right or left to slide between and choose different screen features. Then they can double-tap the interface to opt for the chosen feature. For iOS, the built-in screen reader is called VoiceOver. The interfaces are designed considering them to be suitable for blind users, not forgetting that they should be compatible with screen readers while programing them.

d. User interface design

The application was developed for the iOS platform and programed in XCode IDE using the Swift language. Since the application is intended for blind people, the accessibility guidelines for a blind individual were followed and user-friendly interfaces were designed.

e. Hardware design

A block diagram has been created to show how the hardware component will be connected. Figure 3 shows the Arduino board and connected components, which are installed on the stick. Arduino microcontrollers with several modules and sensors improve navigation and provide real-time assistance interaction for blind individuals. Ultrasonic and light sensors send data to the microcontroller; based on that, the microcontroller will either turn on the light or give an alert or vibration to the users. These sensors play an important role in the detection of obstacles, allowing the system to recognize close objects and obstacles in real time. By radiating ultrasonic waves and calculating the time it takes for them to return, these sensors can accurately measure the distance to obstacles. The system is powered by a 9 V rechargeable battery that supplies power to the microcontroller and other components. The accuracy of battery life span may contrast depending upon the usage of modules and frequency of LED light and vibration motor. The location of the blind student is determined by GPS module and sent to the microcontroller, while sensors for detecting

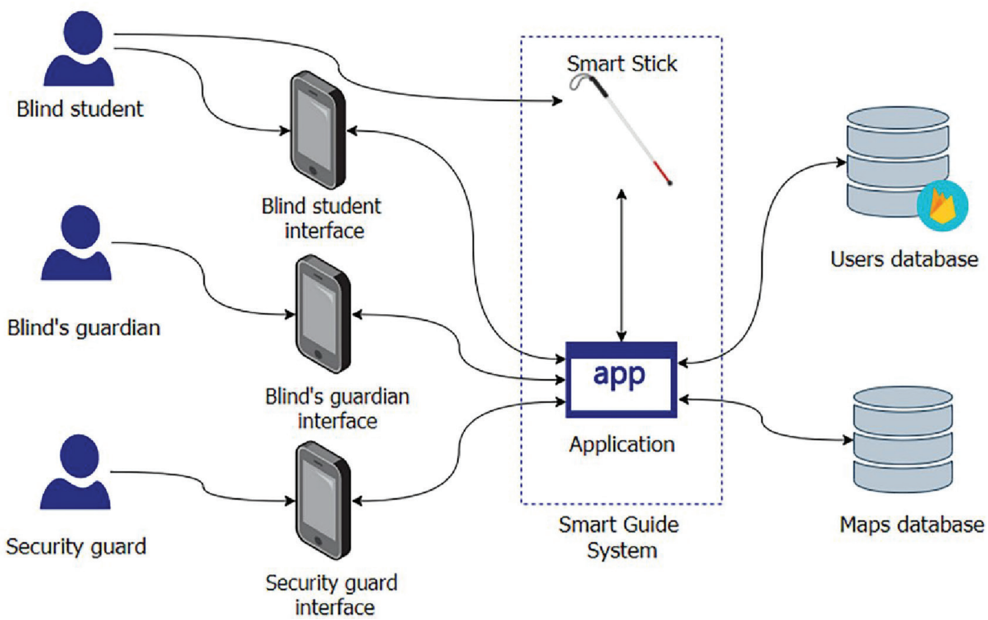


Figure 2: Smart Guide system architecture.

additional risks can improve the utility and strength of the Smart Stick.

The push button in Figure 3 is the emergency button, which gives a signal to the microcontroller if the blind student presses it. The microcontroller sends the blind student's location from the GPS module to the guardian and security guard.

The components used to build the smart stick are described below in Table 1.

III. Result

a. Unit testing

The unit test was conducted for each function built using Arduino, XCode, and Unity. The test case ID indicates, which software was tested, "A" for Arduino, "X" for XCode, and "U" for Unity. Table 2 displays some cases with results.

b. Integration testing

The next stage was integration testing. The test was conducted to evaluate the integration of the units, functions, and screens. Table 3 lists the cases of inteagration tests.

c. System testing

A system testing was conducted to test all the Smart Guide system features; including the Smart Guide application features and the Smart Stick features, to make sure it works. All the features passed the test. The Smart Guide system works well as a whole system. Figure 4 shows the final design and output of the smart stick.

IV. Discussion

In this study, the proposed stick was linked to the application and supported by a range of characteristics to help blind university students in navigation. These characteristics comprise light sensor, obstacle sensor, and GPS technology to send real-time location and navigate while activating the emergency switch of the stick. Furthermore, the application enables users to select a map of the building from the available plans. Similarly, a study introduced a walking

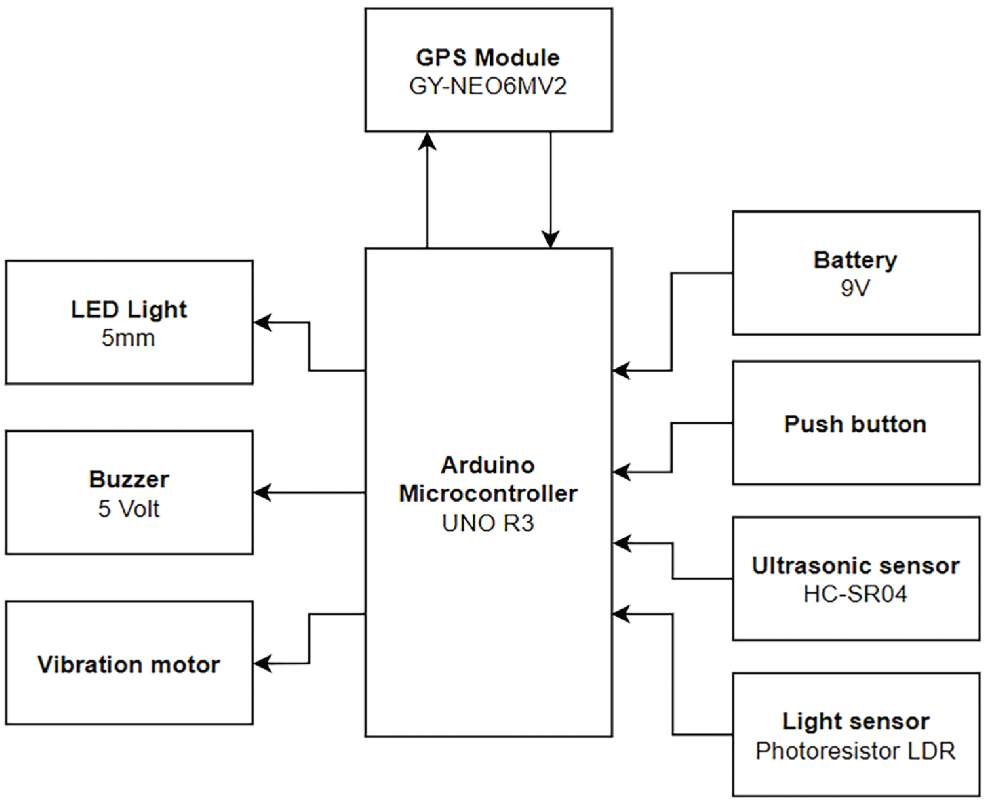
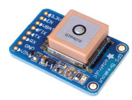


Figure 3: Hardware block diagram.

Table 1: Hardware components

	Component description	Component image
1	The Arduino board is a microcontroller connected to the application and the other components.	
2	An ultrasonic sensor is utilized to sense the barrier in a specified range.	
3	The light sensor is used to measure the intensity of light in a place.	
4	A buzzer is used to give a sound during emergencies and when detecting an obstacle.	
5	The push button is used as an emergency button.	
6	LED light is used to turn it on in dark places.	
7	The vibration motor gives vibrations to alert the blind student.	
8	GPS module is utilized to detect the location of the visually impaired student.	

GPS, global positioning system.

stick to assist visually impaired individuals linked to Android-based applications [17]. It utilizes a GPS module and a Raspberry Pi microprocessor accompanied by sensors. This stick had various characteristics such as identifying barriers and water puddles in the person's way. The GPS module was employed to trace the individual by parents. Utilizing an emergency application, the person was in contact with parents and family. Another research [18] presented a resolution for blind people to walk safely around utilizing a smart stick with three ultrasonic sensors positioned in the left, right, and front of the stick to identify coming barriers accompanied by a buzzer alarm and a vibrating motor to warn the person.

Furthermore, this study outlines the design and implementation of a walking cane for individuals with visual impairments, which relies on an ultrasonic sensor. The HCSR04 ultrasonic sensor module was employed to detect obstacles in the path of the visually impaired person, and a bell was utilized to provide a personal alert. This project was executed using the PIC micro-controller 16F877A. The walking stick was intended to offer a secure means of navigation for blind individuals, as it can identify obstacles within a distance range of 5–35 cm [19]. Correspondingly, a smart electronic aid for the visually impaired was introduced. The smart cane offered a remedy for individuals with visual impairments who encounter challenges in recognizing obstacles and environmental alterations. It consists of three sensors: an infrared sensor, an ultrasonic sensor, and a flame sensor. The cane was capable of identifying obstacles within a range of approximately 2 m from the user. The objective of this system was to deliver an economical and dependable smart cane that can facilitate unrestricted navigation for those who are visually impaired [20]. Another small-sized bright stick was proposed with an efficient wearable gadget for tracing the track. Further, the stick could notify the person before the road. If a barrier was identified in

Table 2: Unit test

Test case ID	Test case description	Input data	Expected result	Actual result	Pass/fail
A01	Scanning a barrier at a 20 cm distance	Since a barrier at a 20 cm distance	Turning on buzzer and vibrator	The buzzer and vibrator turned on	Pass
A02	Sensing a dark place	Analog value <50	Turning on the buzzer and LED light	The buzzer and LED light turned on	Pass
X02	The user enters an invalid email for registration	First name = "Shahed" Last name = "Safar" E-mail = s12@gmail.com Password = s1234567 User type = Talab	Sign up fails	Failed to sign up	Pass
X05	The user enters the incorrect email for logging in	E-mail = r123@stu.kau.edu Password = 1234567r	Sign in fails	Failed sign in	Pass
X09	The user updates the password with incorrect inputs	Password = r1234567 Confirmed password = r123456	Update the password fails	Failed updating	Pass
U01	Getting directions for a destination	Destination name	Arrows pointing to the destination	Correct arrows pointing to the destination	Pass
U02	Getting accurate voice instructions to reach the destination	Destination name	Accurate and immediate voice instruction	Latency in voice instruction	Pass
U03	Recognizing Arabic words accurately	Saying the class number: "Hall" 128	Recognize the words correctly	Recognized the words correctly	Pass

the path, then it could recommend a secure route. Doubtless, it was an efficient characteristic. Moreover, the researcher intended to establish a camera connection to observe the path. The research initiates the idea of monitoring blind individuals in actual time [21].

Sherpa is a device developed by a French company called Handisco [22]. The device can be linked to any white cane; it is provided with a Bluetooth earpiece. Sherpa provides four main features. Localization gives the current location. Navigation provides the direction to reach the selected place. Signalization is connected to the pedestrian lights and warns the user if the light is red or green. Transportation, Sherpa is connected to the transportation system, gives information about the bus stops and the coming bus times. On the contrary, WeWALK is a smart cane that provides many features to assist visually impaired people [23]. The main features of WeWALK are detecting obstacles above the chest level using an ultrasonic sensor. It navigates using the free application for both iOS and Android platforms. It allows the user to save places and provides navigation through the cane when having the phone nearby. The user can also access bus timetables and bus stops, as well as receive directions to them.

A study presents a solution that utilizes the Internet of Things (IoT) paradigm to bridge the gap between the individual and the surrounding atmosphere. Various sensors can be employed to identify irregularities such as barriers, wet terrains, and staircases. The model explained here is an uncomplicated, sophisticated, and budget-friendly smart blind stick furnished with several IoT modules and sensors. In addition, this tool notifies the location of

Table 3: Integration test

Test ID	Test case objective	Test case description	Expected result	Remark
01	Test the transition from the sign-up screen to the desired user screen based on the user type field.	The user enters the required inputs for registration, including determining the user type.	Transition to the proper home screen for the chosen user type.	Positive result
02	Test the transition from the sign-in screen to the proper user home screen based on the data retrieved from the database.	The user enters the required inputs for signing in.	The application retrieves the user type from the database and transitions the user to their home screen.	Positive result
03	Test the connection of the student–guardian accounts.	The student enters the email of their guardian in the My Account tab.	The application shows a notification in the guardian account.	Positive result
04	Test the emergency alarm sent to the guardian to check the student's location.	The student tabs the emergency button on their main screen.	The application sends an alarm to the guardian to check the student's location.	Positive result
05	Test the integration of Unity-Xcode applications.	The student tabs the building button on their main screen.	The application shows the first interface from the Unity build, which asks for the floor.	Positive result

the person to the people who are concerned [24]. This contrastive analysis emphasizes that, while other studies convey general requirements, the system developed in this study specifically focuses on the problems faced by blind students in navigating university campuses. Likewise, this study incorporates a combination of ultrasonic sensors, a light sensor, an Arduino microcontroller, and a GPS module. This configuration is not only cost-effective but also accessible to university students, making it feasible and affordable, as the components used in this system are inexpensive and widely available, which materially lowers the cost of manufacturing. This makes it an adaptable option for implementation on a large scale. The integration of these technologies into a smart stick for blind individuals holds the promise of enhancing their mobility and independence, aligning with the broader aim of aiding individuals with visual impairment in navigating their surroundings more effectively. The fundamental tools and software, such as obstacle detection sensors, light sensors, and GPs module, were adjusted to implement Smart Stick according to KAU infrastructure. The Smart Guide Application can be easily adapted for use in other universities or public places with a minimal modification in hardware components and systems interface such as the light and ultrasonic sensors. The hardware components and systems interface are adaptable and will custom build to fit in different environments. This study contributes to the research community by addressing an expository gap in facilitative technologies for individuals with visually impaired, specifically focusing on indoor navigation for university environments. By integrating GPS technology with preloaded building maps and light and ultrasonic sensors, this system offers a unique, cost-effective, and scalable solution. The portable design and affordability make the system adaptable to several settings and prepare for future progress in assistive technologies. Additionally, this study highlights the importance of collaborative design, setting an example for integrating individuals' feedback into resultant repetitions, therefore establishing real-world suitability and effectiveness.

The limitation of this study is that the emergency button is not implemented due to some technical errors; however, an alternative option is used to track the location. The emergency button feature will be added in the future. The Smart Guide system can be enhanced by adding additional features in the future, i.e., a communication system between students and security guards. Moreover, 3D printing technique is utilized to design the shape of the stick according to the components attached to it. The

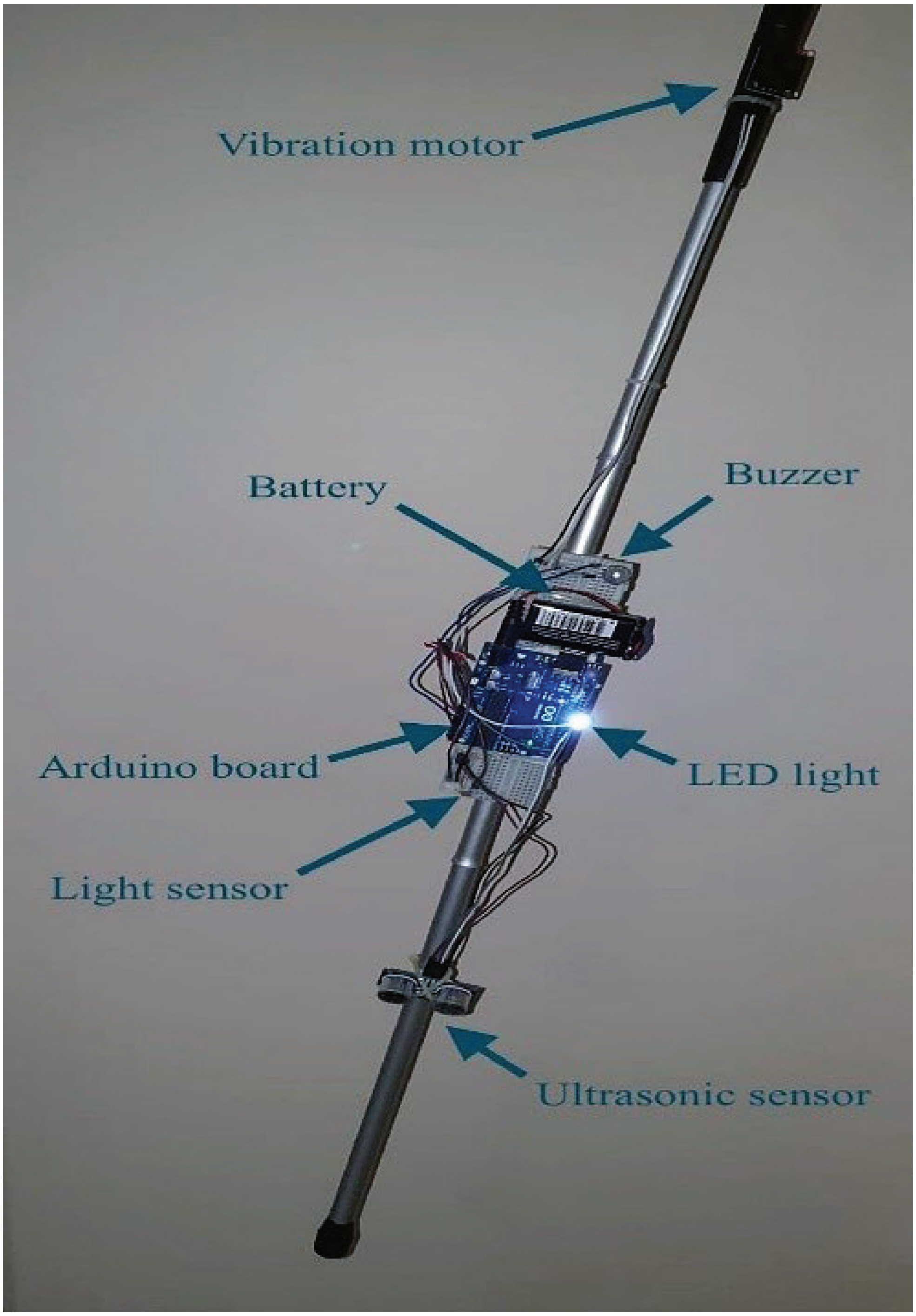


Figure 4: The smart stick.

primary focus of this study was to design a system for blind university students so they can easily navigate the campus buildings by using the Smart stick, which consists of ultrasonic sensor, GPS, and light sensor. These sensors help blind students to access the location inside the university and assist them in sending real-time locations. These sensors scan the environmental surroundings and give alarms in case of any obstacles and darkness within the campus. Another limitation of this study is that the application of the Smart stick is not tested outside the university and in different environmental conditions. The unit testing and system testing were conducted to validate the system's performance, which also include the GPS-based location sharing features. The accuracy of the GPS module has not been tested; however, the preloaded building maps were used to assist the weak or unavailable signals. Future studies will focus on the evaluation of GPs module accuracy and the implementation of this system beyond the university campus.

The blind students from the university were involved in systems testing but their feedback was not gathered. Future studies will focus on the incorporation of blind students' feedback into the system's design to make it more usable and effective and optimize it according to the students' feedback.

V. Conclusion

This study proposed the Smart Guide system to improve mobility and self-reliance for blind students at KAU. The system incorporates two sub-systems: A Smart Stick enabled with obstacle detection sensors and a GPS module, and a Smart Guide application that provides oral map navigation and voice commands. These features collectively provide real-time assistance and security, and are specialized to the needs of visually impaired students, establishing the system's perspective as a broad indoor navigation solution within university environments.

References

[1] S. Grover, A. Hassan, K. Yashaswi, N. K. Shind, "Smart blind stick. SSRG-IJECE", Vol. 7, 2020, pp. 19-23. doi: 10.14445/23488549/ijece-v7i5p104

[2] World Health Organization, "Universal eye health: a global action plan 2014-2019", [cited 26 Oct 2013]. Available from: https://www.who.int/publications-detail-redirect/universal-eye-health-a-global-action-plan-2014-2019.

[3] Health Days, "World Sight Day", [cited Sep. 15, 2020]. Available from: https://www.moh.gov.sa/en/HealthAwareness/HealthDay/2019/Pages/HealthDay-2019-10-10-001.aspx.

[4] WeCapable, "Daily Life Problems Faced by Blind People" [cited Aug. 14, 2018]. Available from: https://wecapable.com/problems-faced-by-blind-people.

[5] Vision Australia, "White canes: What you need to know | Vision Australia. Blindness and low vision services", [cited Nov 20, 2018]. Available from: https://www.visionaustralia.org/news/2019-10-15/white-canes-what-you-need-know.

[6] L. Kumar, "Meanings of Tactile Paving: A Blessing for Persons with Visual Impairment", [cited Mar 18, 2018]. Available from: https://wecapable.com/tactile-paving-tiles-meaning-blind-persons.

[7] P. Krawczyk, Ł. Święcicki, "ICD-11 vs. ICD-10-a review of updates and novelties introduced in the latest version of the WHO International Classification of Diseases", Psychiatria Polska, Vol. 54, pp. 7-20. doi: 10.12740/pp/103876

[8] M. S. Nowak, J. Smigielski, "The prevalence and causes of visual impairment and blindness among older adults in the city of Lodz Poland", Medicine, Vol. 94, 2015. doi: 10.1097/md.0000000000000505

[9] G. Prutha, B. M. Smitha, S. Kruthi, "Smart Cane for Blind People using Raspberry PI and Arduino".

[10] M. Gend, S. Pathan, C. Shedge, P. D. P. Potdar, "Smart ultrasonic walking stick for visually impaired people", International Journal of Advanced Research in Science, Communication and Technology, 2021, pp. 60–687. doi: 10.48175/ijarsct-1460

[11] Saputra, D, Gaol, F.L, Abdurachman, E, Sensuse, D.I, Matsuo, T. Architectural model and modified long range wide area network (LoRaWAN) for boat traffic monitoring and transport detection systems in shallow waters. *Emerging Science Journal*, Vol. 7, 2023, pp. 1188-1205.

[12] Gousteris, S, Stamatiou, Y.C, Halkiopoulos, C, Antonopoulou, H, Kostopoulos, N. Secure distributed cloud storage based on the blockchain technology and smart contracts. *Emerging Science Journal*, Vol. 7, 2023, pp. 469-479.

[13] Sun, J, Liu, Y. Design of 360° Dead-Angle-Free Smart Desk Lamp based on Visual Tracking. *HighTech and Innovation Journal*, Vol. 4, 2023, pp. 761-767.

[14] De Guzman, C.J.P, Chua, A.Y, Chu, T.S, Secco, E.L. Evolutionary Algorithm-Based Energy-Aware Path Planning with a Quadrotor for Warehouse Inventory Management. *HighTech and Innovation Journal*, Vol. 4, 2023, pp. 829-837.

[15] M. D. Messaoudi, B. A. Menelas, H. Mcheick, "Autonomous smart white cane navigation system for indoor usage. Technologies", Vol. 8, 2020. doi: 10.3390/technologies8030037

[16] A. Dey, K. Palit, "Smart ultra-sonic blind stick", Indian Science Cruiser, Vol. 32, 2018, pp. 32:16. doi: 10.24906/isc/2018/v32/i2/173568

[17] N. Sahoo, H.W. Lin, Y.H. Chang, "Design and implementation of a walking stick aid for visually challenged people", Sensors, Vol. 19, 2019, p. 130. doi: 10.3390/s19010130

[18] I. A. Satam, M. N. Al-Hamadani, A. H. Ahmed, “Design and implement smart blind stick”, Journal of Advanced Research in Dynamical and Control Systems Vol. 11, 2019, pp. 42-47.

[19] A. Agarwal, D. Kumar, A. Bhardwaj, “Ultrasonic stick for blind”, International journal of engineering and computer science, Vol. 4, 2015, pp. 11375-11378.

[20] D. E. Gbenga, A. I. Shani, A. L. Adekunle, “Smart walking stick for visually impaired people using ultrasonic sensors and Arduino”. International Journal of Engineering & Technology, Vol. 9, 2017, pp. 3435-3447. doi: 10.21817/ijet/2017/v9i5/170905302

[21] A. Nada, S. Mashelly, M. A. Fakhr, “Effective fast response smart stick for blind people”, In Proceedings of the second international Conference on Advances in bio-informatics and environmental engineering–ICABEE. 2015.

[22] Handisco, Sherpa par Handisco, “La 1ère canne blanche connectée – Handisco” (Cited Sept. 25, 2020). Available from: https://handisco.com/shop.

[23] WeWALK, WeWALK. “Enhancing Visually Impaired Mobility”, WeWALK Smart Cane. (cited Sep. 25, 2020). Available from: https://wewalk.io/en.

[24] A. I. Apu, A. A. Nayan, J. Ferdaous, “IoT-Based Smart Blind Stick”, InProceedings of the International Conference on Big Data, IoT, and Machine Learning: BIM 2021 2022 (pp. 447-460). Springer Singapore.