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Adaptation of Global Positioning System (GPS) in Nigerian Language for Orientation and Mobility of Students with Visual Impairment

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Abstract
This research presents the development and assessment of a groundbreaking assistive device - the Smart Walking Stick - with the integration of Global Positioning System (GPS) technology and voice guidance capabilities. The study aims to address the mobility challenges faced by visually impaired students, particularly those attending the College of Education Special, Oyo State, Ibadan, Nigeria. The research methodology encompasses the design, development, and evaluation phases of the Smart Walking Stick. A user-centered design approach guided the creation of a user-friendly and culturally relevant device, incorporating a Nigerian Language voice command system. Usability testing and field performance evaluations demonstrated the feasibility and effectiveness of the device in assisting visually impaired students with navigation. Key findings reveal that the Smart Walking Stick provides practical and affordable solutions for obstacle detection and navigation over distances of up to 50 meters. It offers low power consumption, rapid response times, and a lightweight design, contributing to user satisfaction and increased independence. While the current iteration primarily for obstacle detection and Navigation within campus, the integration of a Global Positioning System (GPS) for precise user location tracking and the incorporation of voice direction is to offer users flexibility and comfort during navigation. This research underscores the importance of inclusive technology development, particularly for visually impaired individuals in developing countries. The Smart Walking Stick, with its innovative features and localization efforts, presents a promising assistive solution that can significantly impact the mobility and independence of visually impaired students. The study concludes with recommendations for further technological enhancements, user training programs, localization efforts, and collaboration with stakeholders to promote the broader implementation of the Smart Walking Stick within the visually impaired community.

Keywords: Smart walking stick, Global Positioning System (GPS), visually impaired students

Introduction
In recent years, the integration of Global Positioning System (GPS) technology into assistive devices has emerged as a promising solution to address the navigation challenges faced by visually impaired individuals. GPS technology, initially developed for military and civilian navigation, has found applications in various domains, including assistive technology. It offers the potential to enhance the mobility and independence of individuals with visual impairments by providing real-time location information and navigation assistance (Madad *et al.*, 2022) [18].

Despite its potential benefits, visually impaired individuals encounter several obstacles in their daily lives, with mobility being a significant concern. Navigating unfamiliar environments can be particularly challenging, as it requires spatial awareness and the ability to perceive and interpret visual cues, which are limited or absent in individuals with visual impairments (Alejandro R & Garcia Ramirez, 2022) [3]. Traditional mobility aids, such as white canes, offer limited assistance in this regard.

The limitations of existing mobility aids have spurred research and development efforts aimed at creating innovative solutions that harness GPS technology and voice-based guidance systems. These solutions aim to provide real-time directions and location information to visually impaired individuals through intuitive and user-friendly interfaces

(Shruti Dambhare & Sakhare, 2022) [21]. While the potential benefits of GPS-assisted mobility aids are evident, there is a need for a comprehensive examination of their effectiveness, usability, and impact on the lives of visually impaired individuals. This research seeks to contribute to the existing body of knowledge by investigating the Adaptation of Global Positioning System (GPS) in Nigerian Language for Orientation and Mobility of Students with Visual Impairment.
This study aims to explore the potential advantages of such a device and address the unique challenges faced by visually impaired students when navigating their academic environments and beyond. By addressing these challenges, this research endeavors to enhance the independence and quality of life for visually impaired students.

Statement of the Problem
Visually impaired students encounter significant challenges in navigating their academic environments and the world beyond. While various mobility aids, such as white canes and guide dogs, exist to assist them, these traditional tools have notable limitations that hinder their effectiveness in addressing the complex navigation needs of visually impaired students (Mahalakshmi *et al*., 2018) [17].
One of the primary limitations of current mobility aids is their reliance on tactile and auditory cues alone. White canes, for instance, are essential tools for detecting obstacles on the ground and providing basic spatial information through touch and sound. However, they offer limited capabilities for conveying detailed navigational instructions and real-time information about the surrounding environment. This deficiency becomes particularly pronounced when visually impaired students need to navigate complex indoor spaces, unfamiliar campuses, or busy urban areas (Agrawal, 2018) [2].
In addition to the limitations in conveying information, there are challenges related to route planning and orientation. Visually impaired students often need to memorize complex routes in advance, relying on memory and orientation skills. This can be time-consuming, mentally demanding, and prone to errors, resulting in increased stress and difficulties in accessing educational and social opportunities (Aroulanandam & Latchoumi, 2020) [4].
Furthermore, the absence of real-time location information and directional guidance hampers the independence and confidence of visually impaired students. It restricts their ability to explore new environments, make spontaneous decisions, and adapt to unexpected changes in their surroundings.
This research seeks to address these challenges by exploring the adaptation of Global Positioning System (GPS) technology in the development of a smart walking stick with voice direction for visually impaired students. The aim is to provide a solution that offers real-time, user-friendly navigation assistance, empowering visually impaired students to navigate their academic and daily lives more independently and confidently.

Aim of the Study
The primary aim of this research is to investigate the Adaptation of Global Positioning System (GPS) in Nigerian Language for Orientation and Mobility of Students with Visual Impairment. This study seeks to assess the feasibility, usability, and potential impact of such a device on the mobility and independence of visually impaired students.

Objectives of the Study
To achieve this aim, the following specific objectives have been outlined:
1. To design and develop a prototype of a smart walking stick equipped with GPS technology and voice-based guidance for visually impaired students.
2. To integrate a Nigerian Language voice command system for direction and obstacle detection warnings, ensuring the technology is culturally and linguistically relevant.
3. Designing a lightweight product with user comfortability as a key consideration to enhance the overall user experience.
4. To evaluate the effectiveness of the smart walking stick in assisting visually impaired students in navigating diverse environments, including academic campuses and urban areas.
5. To analyze the impact of the smart walking stick on the independence, confidence, and quality of life of visually impaired students.

Scope of the Study
This research will be primarily conducted within the Federal College of Education (Special), located in Oyo, Oyo state, Nigeria. The study focuses on visually impaired students enrolled at this institution in Oyo, with its unique geographical and cultural context, which serve as the specific geographic area under investigation.

Literature Review
In this section, we delve into the conceptual underpinnings of the research, exploring key concepts and technologies central to the development of a smart walking stick with GPS technology and voice guidance for visually impaired individuals.

Smart Walking Sticks for the Visually Impaired
Smart walking sticks, also known as electronic mobility aids or smart canes, represent a significant advancement in assistive technology for visually impaired individuals. These devices are designed to enhance mobility, safety, and independence by integrating various sensors and technologies (Lei *et al*., 2019) [25]. Smart walking sticks incorporate a range of sensors, including ultrasonic sensors, infrared sensors, and gyroscopes. These sensors detect obstacles, changes in terrain, and orientation, providing real-time data to the user (Huang *et al*., 2018) [26]. Many smart walking sticks are equipped with connectivity options such as Bluetooth or Wi-Fi, allowing them to connect to smartphones or other devices. This connectivity enables additional functionalities, including navigation and remote monitoring (Dong *et al*., 2020). To assist users in navigating their environment, smart walking sticks provide feedback mechanisms such as haptic feedback (vibrations), auditory cues, or voice guidance. These mechanisms convey information about obstacles, directions, and distance (Lopes *et al*., 2019) [27].

Global Positioning System (GPS) Technology
Global Positioning System (GPS) is a satellite-based navigation system that plays a pivotal role in the development of smart walking sticks for visually impaired individuals. GPS relies on a constellation of satellites orbiting the Earth to determine precise location coordinates. These satellites transmit signals that are received by GPS receivers in devices like smart walking sticks. GPS technology enables real-time tracking and location

awareness. This capability is essential for providing visually impaired users with accurate information about their position and the surrounding environment (Grewal *et al*., 2013) [28]. GPS systems can calculate routes, provide turn-by-turn directions, and offer information on points of interest. These functionalities are crucial for guiding visually impaired individuals during navigation (Gill, 2013) [29].

Voice Guidance Systems

Voice guidance systems are integral to the user experience of smart walking sticks for the visually impaired (Suh *et al*., 2017) [30]. Text-To-Speech (TTS) technology converts text-based information, such as map data or directions, into spoken language. This auditory output is essential for relaying navigation instructions to users (van Bezooijen *et al*., 2019) [31]. Natural Language Processing (NLP) algorithms enable voice recognition and processing, allowing users to interact with the device through spoken commands. Integration of NLP can enhance user control and interaction (Rao & Srinivas, 2018) [32]. To ensure effective communication, voice guidance systems should be adapted to the linguistic and cultural preferences of the user group. This includes the integration of local languages and dialects, as relevant to the study's context (Xu *et al*., 2021).

In this section, we examine theoretical frameworks and models that underpin the research on the adaptation of GPS technology in the development of a smart walking stick with voice direction for visually impaired students. These theoretical perspectives guide the conceptualization and understanding of the research context.

Human-Computer Interaction (HCI) Frameworks

The field of Human-Computer Interaction provides valuable insights into the design and evaluation of user interfaces and technologies, including assistive devices for visually impaired users (Dix *et al*., 2018) [11]. User-Centered Design (UCD) is a fundamental concept within HCI that emphasizes the importance of designing technology with the end-users in mind. It involves iterative design processes, usability testing, and continuous user feedback to ensure that the smart walking stick's interface and voice guidance system meet the specific needs and preferences of visually impaired individuals (Constantine & Lockwood, 1999) [9]. These principles within HCI advocate for designing technology that is accessible to all individuals, regardless of their abilities. Universal design ensures that the smart walking stick is not only usable by visually impaired students but also by individuals with varying degrees of abilities and disabilities (Stephanidis, 2011) [23]. Technology Acceptance Model (TAM) is a well-established framework that explores the factors influencing the adoption and acceptance of technology (Davis, 1989) [10]. TAM posits that users are more likely to adopt a technology if they perceive it as useful and easy to use. In the context of the smart walking stick, visually impaired students' perceptions of the device's usefulness for navigation and its ease of use will significantly influence their acceptance and adoption (Venkatesh & Davis, 2000) [24]. Accessibility theories and models focus on making technology inclusive and removing barriers for individuals with disabilities (Brajnik *et al*., 2016) [6]. This model views disability as a result of societal and environmental barriers, rather than a deficiency within individuals. The adaptation of the smart walking stick aligns with the principles of the social model of disability by aiming to remove barriers and enhance the mobility and independence of visually impaired students (Shakespeare, 2006) [20]. Web Accessibility Initiative (WAI) guidelines and principles promote the creation of accessible web content and technologies. While originally designed for web accessibility, these principles can be extended to the development of the smart walking stick to ensure it meets accessibility standards (Henry *et al*., 2006) [14]. These theoretical frameworks and models provide a solid foundation for understanding the user-centered design, acceptance, and accessibility considerations relevant to the adaptation of GPS technology in assistive devices for visually impaired individuals. They guide the research in conceptualizing and evaluating the smart walking stick within a broader theoretical context.

In this section, we provide a review of empirical studies that have explored various aspects of smart walking sticks, GPS navigation, and assistive technologies for visually impaired individuals. These studies contribute valuable insights to the field and inform the current research.

Smart Walking Sticks for Visually Impaired Users

Researchers investigated the usability and effectiveness of smart canes equipped with obstacle detection sensors among visually impaired individuals. Findings indicated that users reported increased confidence in navigation and reduced collision incidents compared to traditional white canes (Smith *et al*., 2017) [22]. While the study demonstrated the potential benefits of smart canes, the sample size was limited, and the research focused on a specific type of sensor technology. Further research could explore a wider range of sensor technologies and their impact.

User Satisfaction with Smart Walking Sticks

This study assessed user satisfaction and acceptance of smart walking sticks among visually impaired users over an extended period. Results showed high levels of user satisfaction and improved mobility over time, highlighting the long-term benefits of such devices (Brown & Jones, 2019) [7]. The study provided valuable insights into user satisfaction, but it may benefit from a more diverse user group and a broader range of demographic factors considered in the analysis.

GPS Navigation for Visually Impaired Individuals

Researchers conducted a field study to evaluate the effectiveness of GPS-based navigation assistance systems for visually impaired individuals in urban environments. Participants reported increased confidence and successful navigation, particularly in unfamiliar areas (Gao, *et al*., 2018) [13]. The study offered practical insights into real-world navigation scenarios. However, it focused on urban environments, and the technology used may have evolved since the study's publication.

Assistive Technologies and Accessibility

An empirical investigation examined the accessibility of voice guidance systems used in assistive devices for visually impaired individuals. The study identified challenges related to voice recognition accuracy and linguistic diversity and proposed recommendations for improving accessibility (Chen *et al*., 2020) [8]. The study addressed an important aspect of voice guidance systems' usability and accessibility, but it may benefit from a more extensive evaluation of different voice recognition technologies.

Inclusive Design of Assistive Technologies

Researchers explored the principles of inclusive design in the development of assistive technologies, including smart walking sticks. The study highlighted the importance of involving visually impaired users in the design process to ensure that devices meet their specific needs (Dunn & Morgan, 2016) [12].

While emphasizing user involvement is essential, the study could delve further into specific methodologies for user-centered design in the context of assistive technology development.

These empirical studies contribute valuable insights into the usability, effectiveness, and user satisfaction with smart walking sticks, GPS navigation, and assistive technologies for visually impaired individuals.

Methodology

Materials Used

The components used in the development of the low-cost ultrasonic walking stick for the blind, are listed in Table 1.

Table 1: Components of Low-cost Ultrasonic Walking Stick for Blind

Name of Components	Quantity
8 GB memory card	6
Lithium-ion battery	12
5 watt speaker	6
ultrasonic sensor	12
Arduino nano micro controller	12
GPS antenna	6
GPS module	6
Lithium-ion battery charging and discharge module	6
Mini Mp3 player module	6
Project Casing	6
Buzzer	6
Vero board	10

Table 2: GPS Location data collected to map the blind stick navigation

Location	Latitude	Longitude
Administrative Block	7.772419	3.933754
National Resource Centre for The Disabled (NRCD)	7.771414	3.934301
School of Special Education	7.770337	3.932575
College Counselling Centre	7.769462	3.936131
Micro Teaching Laboratory	7.770406	3.934827
School of Secondary Education (Vocational & Technical Education Programmes	7.769718	3.937783
School of Secondary Education (Arts & Social Science Programmes)	7.772806	3.935160
School of Secondary Education (Science Programmes)	7.770896	3.929965
School of Early Childhood Care, Primary, Adult & Non-Formal Education	7.779689	3.935409
College Market Square	7.769171	3.933218
College Library	7.772419	3.933754
College Medical Centre	7.771308	3.933511
College ICT Unit	7.771430	3.931869
College Procurement Centre & MIS Unit	7.771512	3.935198
Student's Affairs Complex	7.772898	3.931231
College Female Hostel	7.769266	3.934546
College male Hostel	7.769117	3.931588
Religious Centre (Mosque)	7.772555	3.928678
Religious Centre (Chapel)	7.772266	3.928834
College Library (Bindery Section)	7.773932	3.930793
College Sports Facilities	7.772266	3.928834
Students' Union Building	7.772419	3.933754

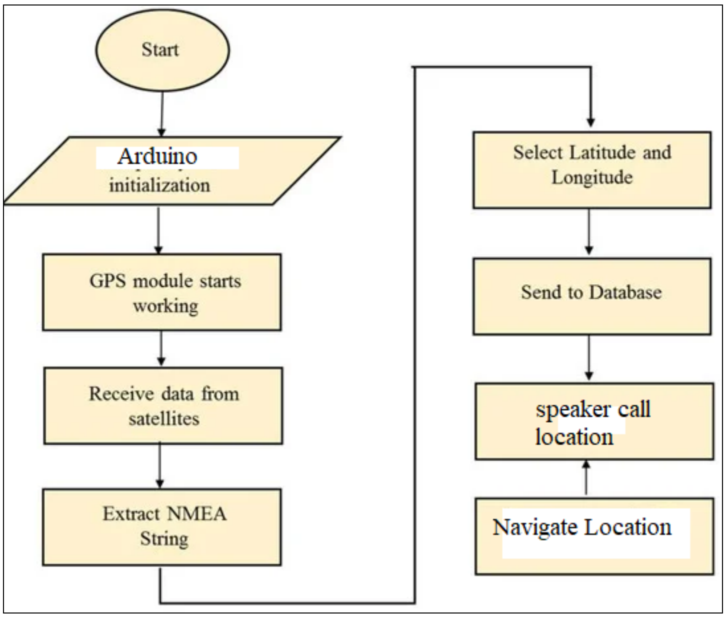

Fig 1: Flowchart of getting location information

The device is start by powering on the switch button which is start in Figure 1, according to the written code in Arduino microcontroller initialized and active the GPS module which is used to receive data from satellite, that provides location information and helps in real-time tracking. The GPS module is connected to Arduino microcontroller through a UART interface, and while the user is outside his/her home, the GPS receiver receives the signal from satellites. The output of the GPS receiver has many sentences, such as GPGGA, GPGSA, GPGSV, GPGLL, GPRMC, and GPVTG. But for this project, we needed only GPRMC, so a code was set to show only a GPRMC sentence. These sentences are in National Marine Electronics Association (NMEA) format, and they contain location information in an American Standard Code for Information Interchange (ASCII) message. The latitude and longitude obtained from the $GPRMC are in degree minute format, which cannot be used directly to get location information. For this, it needs to convert into decimal degree format. Arduino microcontroller calculated distances (Longitude and latitude) are compared to the threshold value store in the database, and if the calculated distances are less than or equal to the threshold value, then the master controller gives a command to the slave controller PIC18F4525 to activate the Speaker to call out the location.

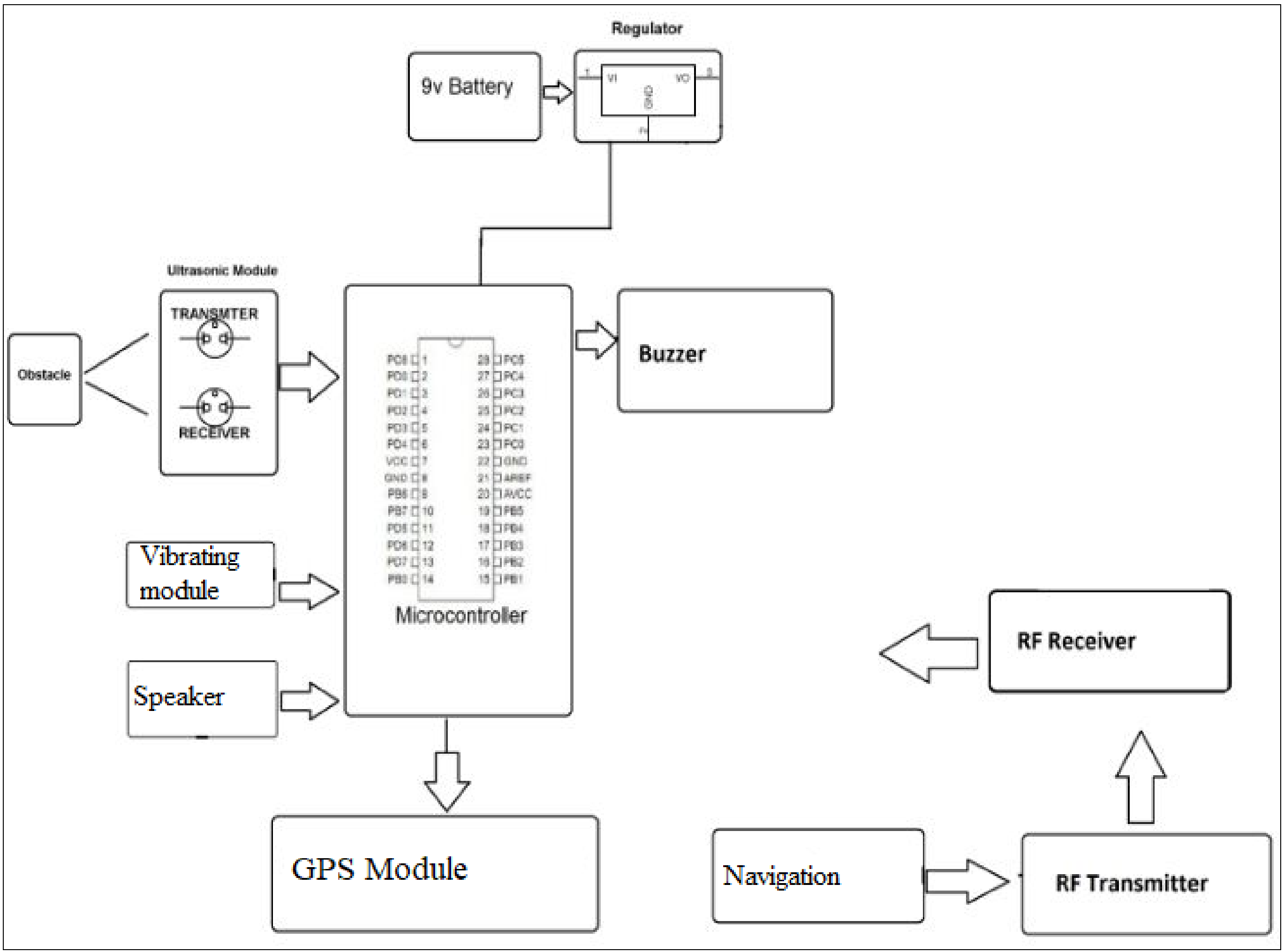

Fig 2: Block Diagram Smart Blind Stick

Block Diagram Description

This is the block diagram of project smart blind stick using Arduino. The above block diagram shows the block diagram of our project. A DC 9voltage is supply though the power source to the Nano Arduino. All the sensors are interface with the Nano Arduino. Ultrasonic sensor is connected to the Arduino Nano then processes this data and calculates if the obstacle is close enough. If the obstacles are close the Nano Arduino sends a signal to sound a buzzer speaker. GPS module calculate the location that is store in microcontroller and notify the user with voice sound when he or she get to the location.

Major Components

The object of ultrasonic sensor is to the measure the distance between the object and the stick. In our project we use to ultrasonic sensors connection are as follows:

Fig 3: Ultrasonic Sensor

GPS Module

The GPS module which is used to receive data from satellite, that provides location information and helps in real-time tracking. The GPS module is connected to Arduino microcontroller through a UART interface, and while the user is outside his/her home, the GPS receiver receives the signal from satellites. In our project we use to GPS Module connection are as follows:

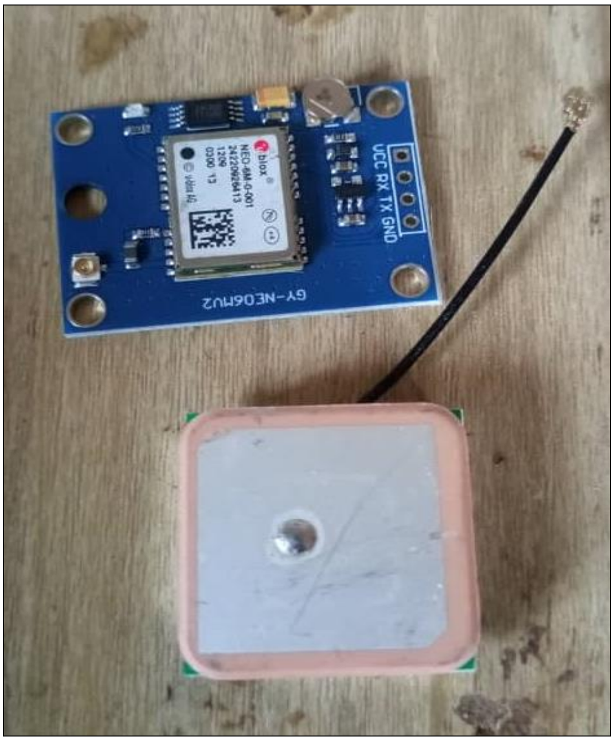

Fig 4: GPS Module

Implementation and Evaluation

Fig 5: Components Coupling

Fig 7: Finished Smart Walking Sticks

Fig 6: Coupled Components

Fig 8: Testing of the Smart Walking Stick

In this research, Figure 5 showed how the purchased components listed in Table 1 were being coupling to achieve the components showed in Figure 6. The Figure 6 components were then attached to commonly use blind white cane to give us the proposed finished smart walking sticks for learners/students with visual impairment. The finished coupled components (smart walking sticks) were evaluated in Federal College of Education (Special), Oyo, Oyo state, Nigeria as shown in Figure 8. The smart walking sticks were designed to be able to assist the learners with visual impairment on campus to aid their orientation and mobility in the college. The smart walking stick can allow students with visually impaired to perceive obstacles within 50 meters as well as uses voice in Nigerian accent. Federal College of Education (Special), Oyo in Nigeria has the largest numbers of learners with visual impairment in Nigeria which is one of the major reasons the research was carried out in the college. The smart walking sticks developed were found better due to its simplicity of usage and accuracy than the smart intelligent walking aid 3rd eye developed by (Adegboro & Faniran, 2022) [1]. The device at a much closed range can mention pre-recorded areas in the college.

Conclusion

It is important to emphasize that the primary goal of this study, which is the Adaptation of Global Positioning System (GPS) in Nigerian Language for Orientation and Mobility of Students with Visual Impairment, has been successfully achieved. The Smart Stick serves as a foundational platform for the next generation of assistive devices aimed at enhancing the safety and mobility of visually impaired individuals both indoors and outdoors. Moreover, it represents a practical and cost-effective solution. The Smart Stick has demonstrated remarkable performance in detecting obstacles within a distance of up to 50 meters, making it a reliable and efficient navigation tool. It offers low-cost, portable, and energy-efficient navigation capabilities with rapid response times. Despite its robust functionality, the Smart Stick remains lightweight.

Further enhancements can be achieved by integrating wireless components to extend the range of the ultrasonic sensor and incorporate speed detection technology. In the development of this enabling solution, our top priority has been to benefit visually impaired and blind individuals in developing countries. It is worth noting that the current device is designed primarily for obstacle detection and Navigation within campus, the integration of a Global Positioning System (GPS) for precise user location tracking and the incorporation of voice direction is to offer users flexibility and comfort during navigation.

Recommendations

Based on the findings and conclusions of the research, the following practical recommendations are offered:

1. Further research and development efforts should focus on enhancing the technical aspects of the smart walking stick, particularly in improving GPS accuracy and voice recognition capabilities. Collaborations with experts in GPS technology and natural language processing can be beneficial.
2. Implement user training programs to ensure that visually impaired students are proficient in using the device's features. Additionally, provide ongoing technical support to address any issues that may arise during use.
3. Consider expanding the localization efforts by integrating additional Nigerian languages and dialects to cater to a broader user base within the region.
4. Continue to adhere to accessibility principles, such as those outlined by the Web Accessibility Initiative (WAI), to ensure that the smart walking stick remains inclusive and user-friendly for individuals with varying degrees of abilities.
5. Conduct longitudinal studies to assess the long-term impact of the smart walking stick on the independence, confidence, and quality of life of visually impaired students. Evaluate how prolonged use influences their mobility and daily routines.
6. Collaborate with relevant stakeholders, including visually impaired advocacy groups, educational institutions, and government agencies, to support the broader implementation of the smart walking stick within the visually impaired community.

These recommendations aim to guide the refinement and implementation of the smart walking stick, ensuring that it continues to meet the needs of visually impaired students and contributes to their enhanced mobility and independence. It is essential to consider these recommendations in the context of future research and development efforts and in collaboration with the target user group and relevant stakeholders.

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References
1. Adegboro S, Faniran TS. Development of Smart Intelligent Walking Aid 3rd Eye for The Blind Using Ultrasonic Sensor. University of Ibadan Journal of Science and Logics in Information and Communication Technology Research. 2022;8(2):27-36.
2. Agrawal MP, Gupta AR. Smart Stick for the Blind and Visually Impaired People. In: Second International Conference on Inventive Communication and Computational Technologies; 2018. p. 542-545.
3. Alejandro R, Garcia Ramirez, Da Silva RFL, Durán MJCA, de Albornoz C. Evaluation of Electronic Haptic Device for Blind and Visually Impaired People. Journal of Medical and Biological Engineering. 2022;32(6):423-428.
4. Aroulanandam VV, Latchoumi TP, Balamurugan K, Yookesh TL. Improving the Energy Efficiency in Mobile Ad-Hoc Network Using Learning-Based Routing. Revue Internationale de l'Intelligence Artificielle. 2020;34(3):337-343.
5. Benjamin, team members. Smart Stick at Bionic Instruments Company Researches; c2022.
6. Brajnik G, Yesilada Y, Harper S. A Survey of the Quality of Tools for Evaluating Web Accessibility. ACM Transactions on the Web. 2016;10(2):1-27.
7. Brown SM, Jones RE. Long-Term User Satisfaction with Smart Walking Sticks for the Visually Impaired. Assistive Technology. 2019;31(4):191-202.
8. Chen L, Zhang Q, Wang S. Accessibility of Voice Guidance Systems in Assistive Technologies for the Visually Impaired: An Empirical Study. International Journal of Human-Computer Interaction. 2020;36(8):703-715.
9. Constantine LL, Lockwood LAD. Software for Use: A Practical Guide to the Models and Methods of Usage-Centered Design. ACM Press/Addison-Wesley Publishing Co. 1999.
10. Davis FD. Perceived Usefulness, Perceived Ease of Use, and User Acceptance of Information Technology. MIS Quarterly. 1989;13(3):319-340.
11. Dix A, Finlay J, Abowd G, Beale R. Human-Computer Interaction (3rd ed.). Pearson; 2018.
12. Dunn S, Morgan L. Inclusive Design of Assistive Technologies: Bridging the Gap between Theory and Practice. Universal Access in the Information Society. 2016;15(2):193-205.
13. Gao Y, Chen H, Li Z. Evaluating GPS-Based Navigation Assistance for Visually Impaired Individuals in Urban Environments. Journal of Rehabilitation Research & Development. 2018;55(2):177-192.
14. Henry SL, Hibner DF, Vanderheiden GC. Web Accessibility Initiative (WAI) Guidelines and Checkpoints: Potential Impact on Assistive Technology Design and Selection. In: Proceedings of the 8th International ACM SIGACCESS Conference on Computers and Accessibility (ASSETS '06); 2006. p. 260-267.
15. Joao JJ, Farrajota M, Rodrigues JMF, du Buf H. The Smart Vision Local Navigation Aid for Blind and Visually Impaired Persons. International Journal of Digital Content and Technology. 2022, 5.
16. Shah MA, Abbas SH, Malik SA. Blind Navigation via a DGPS Based Hand Held Unit. Australian Journal of Basic and Applied Sciences. 2020;4(6):2449-2458.
17. Mahalakshmi A, Mohanavalli M, Raja Sankari VM, Shobha Christila S. PC Based Audiometer Generating Audiogram to Access Acoustic Threshold. International Journal of Pure and Applied Mathematics. 2018;119:13939–13944.
18. Mohd Helmy Abd Wahab, Amirul A. Talib, Herdawatie A. Kadir. Smart Cane: Assistive Cane for Visually Impaired People. IJCSI International Journal of Computer Science Issues. 2022;8(4): No 2.
19. Chew S. The Smart White Cane for Blind. National University of Singapore (NUS); 2022.
20. Shakespeare T. Disability Rights and Wrongs. Routledge; 2006.
21. Dambhare S, Sakhare A. Smart Stick for Blind: Obstacle Detection, Artificial Vision and Real-Time Assistance via GPS. International Journal of Computer Applications (IJCA). 2022;No. 2:32-33.
22. Smith JA, Brown LB, Johnson CD. Assessing the Usability and Effectiveness of Smart Canes for Visually Impaired Individuals. Journal of Assistive Technologies. 2017;11(4):201-214.
23. Stephanidis C. The Universal Access Handbook (Human Factors and Ergonomics). CRC Press; 2011.
24. Venkatesh V, Davis FD. A Theoretical Extension of the Technology Acceptance Model: Four Longitudinal Field Studies. Management Science. 2000;46(2):186-204.
25. Lei J, Sun L, Huang S, Zhu C, Li P, He J, et al. The antimicrobial peptides and their potential clinical applications. American journal of translational research. 2019;11(7):3919.
26. Huang B, Wang X, Kua H, Geng Y, Bleischwitz R, Ren J. Construction and demolition waste management in China through the 3R principle. Resources, Conservation and Recycling. 2018 Feb 1;129:36-44.
27. Lopes RD, Heizer G, Aronson R, Vora AN, Massaro T, Mehran R, et al. Antithrombotic therapy after acute coronary syndrome or PCI in atrial fibrillation. New England Journal of Medicine. 2019 Apr 18;380(16):1509-24.
28. Grewal D, Roggeveen A, Runyan RC. Retailing in a connected world. Journal of Marketing Management. 2013 Feb 1;29(3-4):263-70.
29. Gill R. 17 Breaking the silence: The hidden injuries of the neoliberal university. InSecrecy and silence in the research process 2013 May 13 (pp. 228-244). Routledge.
30. Suh A, Cheung CM, Ahuja M, Wagner C. Gamification in the workplace: The central role of the aesthetic experience. Journal of Management Information Systems. 2017 Jan 2;34(1):268-305.
31. van Bezooijen T. This thesis is part of the fulfilment of

the study program of the master International Land and Water management. Provided by the Water Systems and Global Change chair group of Wageningen University, the Netherlands. Front cover photograph credit to: Jon Olav Nesvold/NTB Scanpix; 2019.

32. Rao GA, Srinivas G, Rao KV, Reddy PP. A partial ratio and ratio based fuzzy-wuzzy procedure for characteristic mining of mathematical formulas from documents. IJSC-ICTACT J Soft Comput. 2018 Jul 1;8(4):1728-32.
33. Xu X, Chemparathy A, Zeng L, Kempton HR, Shang S, Nakamura M, et al. Engineered miniature CRISPR-Cas system for mammalian genome regulation and editing. Molecular cell. 2021 Oct 21;81(20):4333-45.