Low-cost electronic bamboo walking stick: an innovative assistive mobility aid for the blind

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ABSTRACT

Present-day advancements in embedded systems have uncovered a wide area of innovation in inexpensive supportive systems for the visually impaired. Right from the uncomplicated white cane up to the most exceptional electronic walking stick, many designs have been proposed aiming at assisting and protecting visually challenged persons. This paper aims at contributing to these assistive aids by designing a bamboo stick sensor-based unit with ultrasonic and water detection sensors which is robust, cheap, and easily operated for the deprived blind person. Thus, improving the usefulness of the current white stick to consolidate both above-knee and below-knee deterrent identifications. The developed bamboo stick simply operates using ultrasound sensors for sensing the impediments before contact and a water detection sensor for water detection on the pathway. It offers vibration and different sound feedbacks to the operator per the spot of the obstacle. The results obtained by trial from a volunteer who walked an obstructed path blindfolded were excellent. The results ensure quick detection, safety and enhance the speed of mobility of the user. The simulations performed were accurate and relevant to the ultimate goal of the paper. The electronic bamboo walking stick developed can be used to guide the visually impaired in an indoor or outdoor environment.

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1. INTRODUCTION

Blindness or visual deficiency is a condition of coming up short on visual discernment or a state of not being able to see on account of damage, ailment or innate condition. Vision is the most significant part of human physiology as 83% of data that an individual acquires is through sight [1]. Globally, the latest data published by the World Health Organization (WHO) in 2019 estimated that over 2.2 billion people are living with visual impairment, out of whom 1 billion suffer moderate or severe eye problems [2]. In Africa alone, 26.3 million people suffer from some visual deficiency. Of these, 20.4 million have poor vision and 5.9 million are assessed to be visually impaired and finally, it is estimated that 15.3% of the global sightless populace live in Africa [3]. More so, over 190,000 persons in Ghana are blind, according to the 2015 Ghana blindness and visual impairment study (GBVIS) conducted under the auspices of the Ghana health service.

The prevalence rate of blindness among those aged 50 years and above was 4.0% and increases with age to 19.12% in those aged 80 years and above [4].

The white cane is regarded as the world's most widely used navigation aid for the blind. White cane can detect obstacles present on the ground, pits, puddles, uneven surfaces and also on steps [5]. White canes are made up of very light materials and provide ease of carrying them as it is foldable and easily fit into one's pocket [6]. As a result, the initial cost for white cane is much less. But speaking of overall cost, the case is not the same. A user requires a practice session of about 100 hours to get comfortable with the device so that he can walk safely and properly. Now the "100 hours" investment is considered an extra cost which is very high [7]. There are bunches of visually challenged individuals particularly in the African continent today who are poor, jobless and suffering while at the same time practising the essential things of day-by-day routine. This could put their experiences in danger while moving around. Therefore, there is an exigency to make provision of security and safety to blind people. Throughout the years, extensive research has been conducted in designing and developing devices that may protect the visually impaired from harm. The most common device used by the blind to guide their movement is the 'white cane' which is used especially when they are moving around outdoors [8], [9].

Lately, several frameworks for aiding the blind have been developed and are still being developed for better support to blind people. The improvement of the electronic walking stick is one of the rising developments in restoration design that could help the individual to explore around more effectively and serenely [10]. This developed system can be branded into two groups. The electronic travel aids (ETAs) as the first and the electronic orientation aids (EOAs), also known as hybrid ETAs as the second. ETAs are designed to spot impediments using sensors. EOAs spot locations using global positioning systems (GPS) and location-based services [11], [12]. Endeavours for the restoration of visually impaired individuals have been made for decades. A few gadgets that have been created throughout the years are as yet being produced for superior help to visually impaired individuals. Even though there are much-improved mobility systems, a lot of these poor and unemployed blind people require aids/devices to detect deterrents which are mostly assisted by humans or even guide dogs because the solutions provided for them through designed systems are very much expensive especially in Africa [13], [14].

Other assistive mobility systems in Mocanu *et al.* [15], which suggested a wearable device for effective snag locating using sensors, PC vision, and artificial intelligence (AI) technologies. An Arduino microcontroller, four ultrasonic sensors, a Bluetooth device, and a cell phone make up the framework. Both the sensors and the camera on the phone collect information about the obstacles and send it to the snag recognition module, which uses it to determine the presence of deterrents in the surrounding scene. For differentiating dynamic articles, a K-mean grouping computation was used, and for preparing and forecasting, a support vector machine (SVM) classifier was used. It generates an input signal for the externally tested individual as required. The suggested framework provides a better solution for obstacle detection since it combines sensors and AI algorithms, although it can only detect barriers up to the abdominal level.

Therib [16] presented a structure with a visually impaired stick to help the blind avoid collisions with obstacles. It is made up of a microprocessor and two SRF06 ultrasonic sensors: one is mounted at 400 cm on the stick to detect staircases or openings, and the other is used to detect obstructions such as a divider or obstacle in front of the visually impaired user. A dampness sensor detects wet surfaces or lakes, and a warning is provided by a vibration engine and a bell. Snags, cracks, stairways, and sodden surfaces may all be detected by the framework.

Radhika *et al.* [17], a structured smart cane for obstacle recognition and navigation was developed. Their proposed system employed infrared, ultrasonic and water sensors. It additionally employed GPS and a global system for mobile (GSM) modules. The framework is controlled by a battery-powered system. The components actualized in their proposed framework include two ultrasonic sensors, an infrared sensor, water sensor, GPS module, GSM / general packet radio service (GPRS) module, and an Arduino Uno microcontroller board (ATmega328P). This brilliant stick empowers the individual to make calls on the occasion of crisis through the GSM/GPRS module. It cautions the visually impaired individual through signal sound which increases as the client approaches the obstruction for a decision to be taken.

A framework was proposed by Ramadhan [18] which consists of a white stick embedded with ultrasound sensors and a vibrator and also GSM/GPS to give question recognition and continuously guide the user. At whatever point it detects an obstacle, it activates the vibrator. Besides, the proposed system allows monitoring of the user area by employing the GSM and GPS. Swain *et al.* [19], proposed a mobile stick where the parts utilized in the designed framework are an Arduino Uno microcontroller for preparing the signal from various sensors, pair of ultrasound sensors to recognize impediments, and an Infrared sensor for stairs identification. GPS-GSM components are likewise used to discover the area of the blind that will help with giving their area data with an enrolled contact on a cell phone. Furthermore, Aymaz and Çavdar [20] planned a framework that utilized a headset for the outwardly disabled. They utilized an ultrasonic sensor, a Bluetooth component (ISD2590), a sunlight-based board and a speaker. The outcome is the headset could distinguish the area of a hindrance in light of the criticism given.

Boppana *et al.* [21] devised a mind-boggling model stick that would serve as an effective guide for the elderly and Alzheimer's patients. This rod features many accents, making it a smart strolling stick. This walking stick can monitor a variety of health measures and alert the nearby critical health concentrate and supervisor of any abnormalities. This sharp stick can also aid older citizens in safely returning home if they become disoriented while out alone. The suggested stick may also be used to regulate household devices and remind clients to take their medications on time. This model was built with a simple wireless fidelity (Wi-Fi) chip and a transmission control protocol/internet protocol (TCP/IP) stack, as well as a microcontroller produced by “espressif” frameworks for controller functionality and appropriate sensors.

Grover *et al.* [22], the authors proposed a smart blind stick. The technology’s major goal is to assist blind persons in walking with total relief and independence. Three ultrasonic sensors, a panic switch, a navigation switch, Bluetooth, a soil moisture meter, and an Arduino Uno are all included in the blind stick. The smart blind stick uses sensors to detect the barrier in front of the user, as well as moisture sensing at the bottom to sense the wetness of the soil or ground, allowing the user to judge whether or not it is safe to walk on that surface.

Finally, Sen *et al.* [23] developed an artificial navigation system with configurable sensitivity using an ultrasonic proximity sensor and a GPS module to allow blind people to travel freely and independently in both indoor and outdoor environments. Using the reflecting qualities of ultrasound, this device can identify any form of oncoming obstruction including potholes. The system’s ability to attach to clothing, shoes, body parts and even the walking stick makes it more adaptable and dependable to use.

In this paper, a cheap, simple and easy to understand ETA, shrewd visually impaired electronic stick was created to improve the mobility of the visually impaired in a particular zone in Africa. The design includes a smaller-than-expected hand stick made from a free material (bamboo stick) with navigation technology to help the poor and visually handicapped move safely. The device would also keep the user away from any snags that might be experienced, regardless of whether fixed or moveable, to avert any conceivable mishap with this simple but high performing design.

2. RESEARCH METHOD

As it has been noted earlier that the implanted smart walking stick has several subsystems. These subsystems fundamentally are sensor-based. The integral scheme is designed with fundamental circuitry on an AVR microcontroller (Arduino Nano AT Mega 328).

2.1. Circuit simulation

The simulation of the system in Proteus works by uploading a hex file or a debug file to the microcontroller part on the schematic. It is then co-simulated laterally with analogue and digital electronic components connected to it. A hex file was created using the Arduino integrated development environment (IDE) and the file was uploaded to the microcontroller in Proteus for the simulation to begin. This is shown in Figure 1.

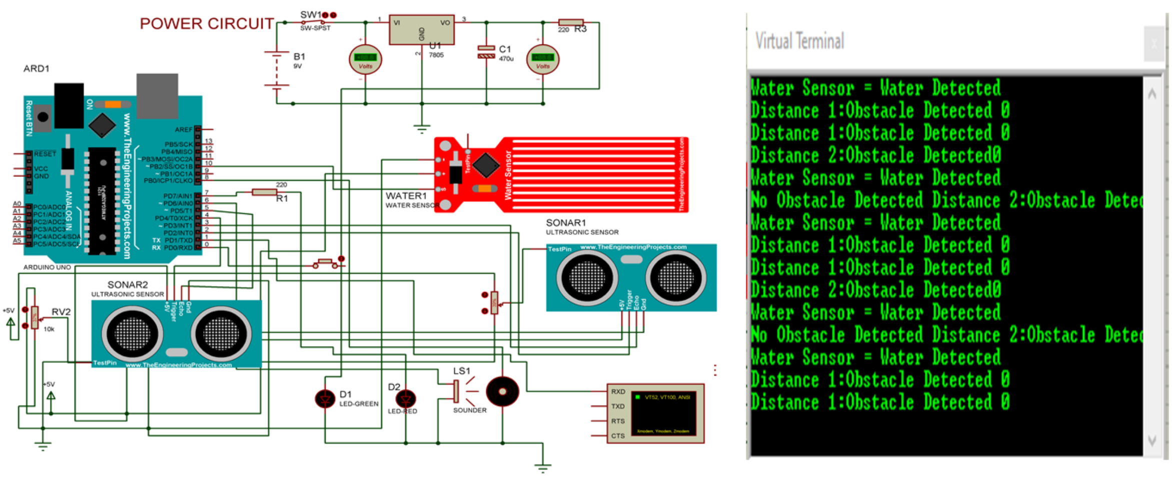

Figure 1. Circuit simulation with Proteus suite

2.2. Software working algorithm of the system

The system program was written using the Arduino in C. The flow chart of the system is shown in Figure 2, describing basically how the system integrates and executes. At the introductory stage, it will begin the framework by fueling the framework with battery power and resetting the ports of information. The information is ultrasonic sensor 1 (for direct impediment discovery, US1), ultrasonic sensor 2 (for pits, US2), and water identification sensor (for water location) and the outputs are the light-emitting diodes (LED), buzzer, and vibrator. On the off chance that US1 recognizes an obstruction with separation under 1.5 m, just LED and the buzzer will turn on. Once more, if US1 distinguishes an obstruction with separation under 1.0 m, just the LED, vibrator and buzzer will turn on. Other than that, if US2 distinguishes pits or potholes with a separation more prominent than 0.2 m, the buzzer, LED and vibration will go on to step over. At long last, when the water sensor recognizes water on the way the buzzer, LED and vibration will turn on. All location accompanies diverse yield signal sort and vibration design.

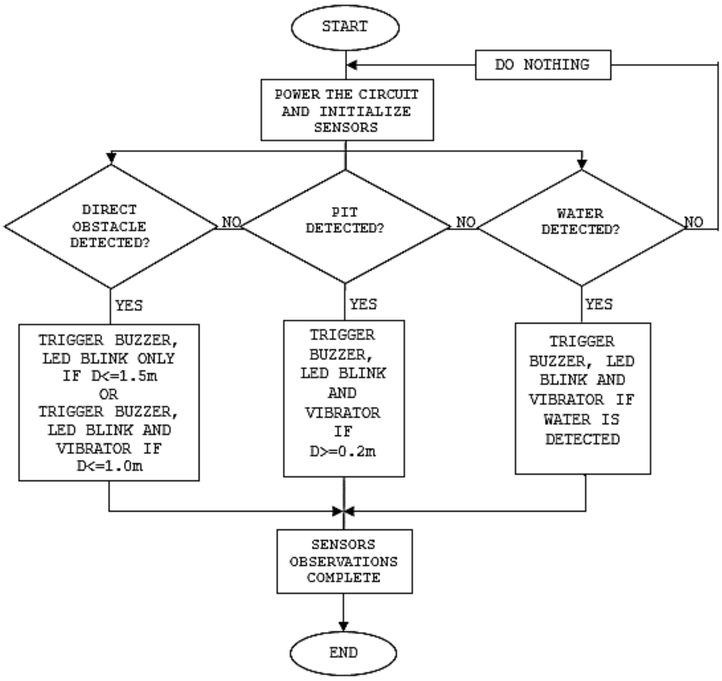

Figure 2. System design flow chart

2.3. Selection of Material

Figure 3 demonstrates the material picked to structure the electronic strolling stick which is the bamboo stick. The benefits of picking bamboo are because of a few elements which incorporate softness, straightness and since it develops rapidly it is likewise cheap or in some cases free. These characteristics permit the bamboo stick to be utilized from numerous points of view as a trade for wood, plastic or light metal. The electronic strolling stick estimates 100 cm long which is reasonable with the normal human stature.

Figure 3. Bamboo stick

3. RESULTS AND DISCUSSION

The general structure of the framework is shown in Figure 4. One of the fundamental criteria for the various kinds of obstructions being tried was the separation by sort of material as the first methodology for direct hindrance identification. Four materials: human being, metal, wood, and plastic were tried. The transmitted signal by the ultrasonic sensor was examined at given separations for every material tried.

The microcontroller assembles the reflected data from the hindrances by estimating the width of the reverberation beat signal. The beat width was seen as straightforwardly corresponding to the separation of the closest deterrent. Snags were situated progressively at a distance of 100 cm to 150 cm. The mean estimations of the separations as indicated by the four chosen materials are abridged in Table 1.

Table 1. Mean output distance of the selected material

S/No.	Selected material	Range (cm)	Mean distance measured (cm)	Calculated error
1.	Human Being	100	96	0.04
2.	Metal	120	118	0.02
3.	Wood	140	137	0.02
4.	Plastic	150	149	0.01

Figure 4. Overall system design

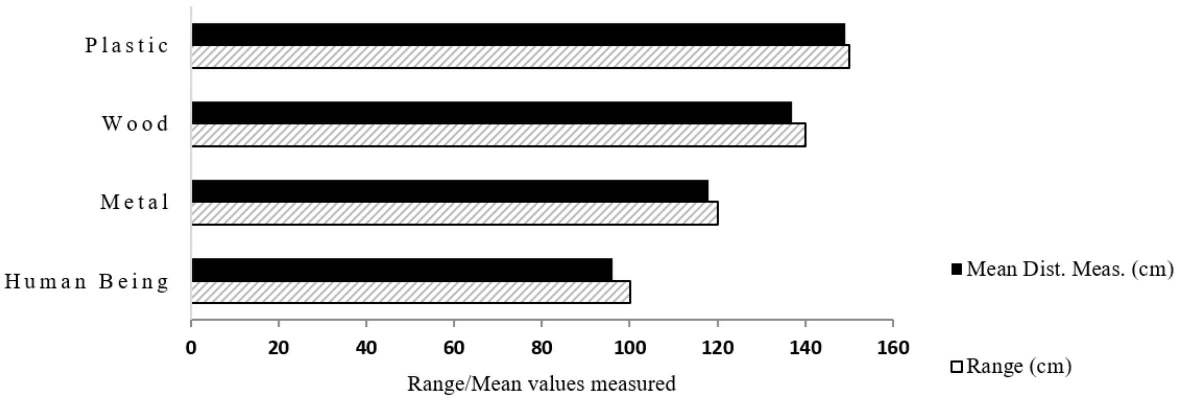

Figure 5. Range value and the measured value in the analysis of ultrasonic range finder

There is a slight contrast among the qualities estimated and seen according to the table. It shows that the gadget was not fit for indicating definite qualities and finished in mistakes. In any case, the mistake edge demonstrated shows that the sensor execution is as yet exact independent of the slight minor distinction. Figure 5 shows the diagram of the readings plotted.

Figure 6 displays the output results of the whole circuit system mounted on a solderless board to analyse the circuit performance before soldering and packaging were done. The programme code for the system was uploaded onto the microcontroller and the serial monitor was used to observe the performances of the sensors which worked perfectly as displayed. The output signals: the vibrator, buzzer and LED were found to be working according to the specified programme code. There was effective coordination between the software programme and the system hardware.

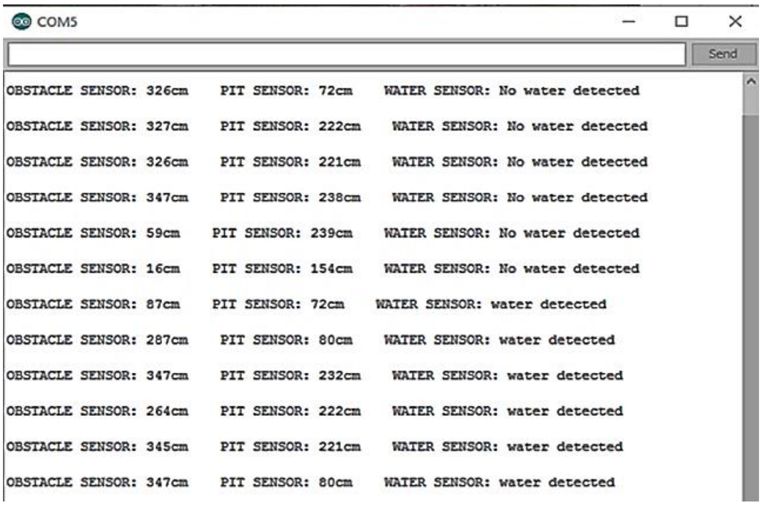

Figure 6. System circuit test result

At long last, the framework was tried on blindfolded persons utilizing deterrents of various materials and shapes at various separations. The direct obstacle detection test performed has been illustrated in Figure 7(a) and the pit and water detection test has been illustrated in Figure 7(b). The blindfolded individuals strolled in a deterred region yet because of the superiority of the framework they had the opportunity to explore through these ways. The aftereffects of the analysis were extremely reassuring. It uncovered an exactness of about 90% which shows that the framework is proficient and one of a kind in its ability in indicating the source and separation of the snags, pits and water that the blindfolded individual experienced. The volume control worked impeccably by decreasing the sound of the signal to the inclination of the client. This will assist the outwardly impeded individual with controlling the sound of the ringer at their predetermined area: church, workshops, gatherings and so forth, where the commotion is for the most part disallowed. The yield signals during snag, pit and water identifications are likewise outlined in Table 2.

Table 2. Output signal algorithm for the stick

S/No.	Sensor type	Distance (from the stick in cm)	Type of signal
1.	Ultrasonic sensor 1	≤ 150	Very fast and longer beep + LED
	(direct obstacle detection)	≤ 100	Very fast and longer beep + vibration + buzzer + LED
2.	Ultrasonic sensor 2 (pit detection)	> 20	Very low and long beep + vibration + buzzer + LED
3.	Water detection sensor	–	Very low and short beep + vibration + buzzer + LED

At the start of it all, every segment was investigated exclusively by running the code for each capacity to break down the outcomes and execute the system. We at that point joined the codes of each capacity as seen in Figure 6, and executed and coordinated all the segments into the bamboo strolling stick for execution. To assess the presence of the proposed direction framework, a few parameters were considered. The principal significant parameter is the power utilization of the framework and to what extent it will remain working without the need of changing the battery frequently. The accompanying appraisals are considered: utilization of electrical power of 0 W to 0.5 W is viewed as low power utilization, 0.5 W to 1 W as medium utilization, and higher than 1 W as high utilization [24]. This framework as of now devours an aggregate of 0.25 W of power which falls at the low power utilization scale and this is because of the absolute number of segments associated with the framework for a viable route to be accomplished, so the blind can use the electronic stick for a significant number of days before changing the battery.

A gadget that can discover deterrents all from 0 cm to 200 cm can be considered a low range gadget, with 200 cm to 400 cm as medium-range, while higher than 400 cm is considered as the high range [24]. Regarding the above concern, a convenient stick was planned dependent on the separation estimation guideline of ultrasonic sensors. The scope of the gadget was set to 100 cm to 150 cm for the upper sensor which is liable for discovery at head level and midriff level separately. Nonetheless, for the discovery of openings and abrupt knocks a similar rationale was material. The lower sensor was found to have a capacity to effortlessly recognize knocks of profundity more prominent than 20 cm. The ultrasonic sensor (HC-SR04) utilized has a medium scope of 400 cm, hence, more separations can be determined for a different location.

(a)

(b)

Figure 7. Overall system accuracy test: (a) direct obstacle detection and (b) pit and water detections

The planned framework is contrasted with Gbenga *et al*. [25] who proposed a minimal effort and lightweight framework structured with a microcontroller that provides signs and alarms to the outwardly hindered individual over any hindrance, water or dim zones through signalling sounds. The framework comprises deterrent and dampness identification sensors for getting, preparing and sending a signal to the caution framework which at long last alarms the client for brief activity. The framework was structured, customized utilizing C language and tried for precision and checked by the outwardly weakened individual. The gadget can differentiate impediments inside the separation of about 2 m from the client. The gadget built in this work is just equipped for distinguishing impediments and dampness. Openings cannot be distinguished utilizing this gadget nor the idea of a hindrance when contrasted with the proposed framework planned of 4 m for the ultrasonic sensor which recognizes pits and the free material (bamboo) utilized making it more affordable.

In the future, we will still make use of the free material, that is, the bamboo stick with components embedded into the stick for a better appearance. Data analyses will be explored with a higher algorithm to determine obstacles and events encountered by the visually impaired and people with gait disorders [26] to provide a safe path for navigation. Further work will involve the use of machine learning techniques to improve the design.

4. CONCLUSION

A cheap, steady and robust Arduino-based bamboo walking stick was designed and developed for visually impaired people who cannot afford the sophisticated brands by using ultrasonic sensors for sensing the impediments before direct contact and a water detection sensor for water detection on the pathway. This device offers vibration and sound feedback to the handler following the spot of the obstacle, pits or water in the walkway of the visually impaired individual. The results obtained by trial from a volunteer who walked on an obstructed path blindfolded were excellent. The results ensure quick detection, safety and enhance the speed of mobility of the user. The simulations performed were accurate and relevant to the ultimate goal of the design. The electronic bamboo walking stick developed can be used to guide the visually impaired in an indoor or outdoor environment.

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