Embedded Assistive Stick for Visually Impaired Persons

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***Abstract*—In this paper, a smart stick is intended and executed to aid blind persons so that they can walk independently without much difficulty. Firstly, pothole detection and avoidance system are implemented by setting the ultrasonic sensor at 30-degree angle on a suitable blind stick to sense if there is a hole or staircase in front of the blind at about 30 cm distance to avoid a person from falling and as a result may be producing many damages. Secondly, a moisture sensor is placed at the down of stick to measure the degree of water land soil moisture in forward-facing of the user and aware him as soon as that degree exceeds a measured level that may submerge the foot of him. Thirdly, knee above obstacle detection and avoidance system is implemented by using an additional ultrasonic sensor on the top of the stick to turn an alarm and vibration ON when there is a person, obstacle or wall at a distance of 50 cm in front to avoid an accident and thus helping the person to move independently. Fourthly, an ultrasonic sensor is placed down the stick at about 20 cm from the ground level to detect and avoid knee below obstacles and stairs at a distance of 70 cm in front of the user. Fifthly, a wireless remote consisting of RF modules (transmitter and receiver) is implemented, so if a person drops stick or forget it somewhere, he can press a switch of the remote consisting of transmitter part, and as a result alarm with vibrations will turn on, so the user can know the location of the stick. The stick is implemented practically using single wheel leg blinding cane, Arduino microcontroller three ultrasonic sensors RF modules. Also, two buzzers and two vibration motor are used on the stick to fit on when any difficulties occur.**

***Index Terms*—Smart stick, ultrasonic sensor, moisture sensor, Arduino microcontroller, buzzers, vibration motor, RF remote.**

I. INTRODUCTION

Worldwide, about 285 million individuals are visually impaired, out of which 39 million people are blind and around 246 people are moderate to severe visual impairment [1]. These persons have great trouble while interacting with other people. Most of these people rely on white canes which helps them to scan the obstacles in their surroundings and for local navigation. Visually Impaired persons need a capable device so that they can move around independently. Today we can see, there are so many techniques, and devices have been developed, which help these persons to move freely even in dynamic environment [2].

The continuous increase in some blind people brings the development of more reliable assistive devices across the world. Use of Assistive devices is the most reliable way of supporting visually impaired persons. In vision assistance past, white canes and attendant dogs were widely used for providing mobility assistance to visually impaired people. However, there is a large number of problems associated with white canes or guide dogs. White cane offers limited preview range in which user has to be very careful and saunter. Use of attendant dogs is also not appropriate for all the visually impaired people because they require training and coordination with dogs and also it is not reliable.

II. RELATED WORKS

Nitish Sukhija proposed Smart Stick for Blind Man. The stick consists of Ultrasonic Sensors, IR Sensors, and Atmega 8 microcontroller unit. It is a machine which follows a specified path [3]. It is easy to use and cost-effective. Ashraf Anwar proposed A Smart Stick for Assisting Blind People. The system consists of ultrasonic, IR, and light (LDR) sensor, a microcontroller (Arduino Uno R3), buzzers, vibrators [4]. It has Voice based navigation system with fire and light sensor which assist visually impaired people more effectively.

Mithiles Kumar proposed Low-Cost Smart Stick for Blind and Partially Sighted People. They used ultrasonic sensors, infrared sensors, water sensor, fire sensor and light (LDR) for sensing different parameters. It gives output in the form of speech instructor, vibrator, and buzzer, so both auditory and tactile feedback is provided [5]. It has a dual feedback system. It is also easy to use and cost-effective. DBG Crutch Based MSensors was designed based on the ultrasonic sensor distance measurement method, a guidance scheme for blind persons was proposed in [6]. The drive of this scheme is to help blind persons in spotting and ducking the obstacles in front, left and right of the person. It uses a grid of three ultrasonic sensors. The purpose of these sensors is to gather the distance data from different choices; the top sensor gives information about the overhead obstacle, and the remaining two are used for detecting front barriers. Also, the ultrasonic transmitting and receiving modules, voice and vibration modules and the key to switch between the feedback modules are used in this system. The whole system is controlled by the STC15F2K60S2 microcontroller.

Radio Frequency Identification Walking Stick (RFIWS) was designed in [7] to help blind persons circumnavigating on their path. This system aids in sensing and calculating the estimated distance between the path border and the blind being. RFID is used to handover and accept signal through radio wave medium. RFID tag with the reader is the main components of RFID equipment. Sharing Kumar proposed Multiple Distance Sensors Based Smart Stick for Visually Impaired People. They used Ultrasonic Sensors for obstacle detection, Bluetooth module, Arduino UNO, Vibration Motor to provide feedback to the user [8]. Stick can detect static and dynamic obstacles of any height which are in front of the person. BAWA Cane is an assistive device for the blind people which provides both above and below knee level obstacle detection and gives audio feedback [9]. It uses Bluetooth, ultrasonic sensors. It includes voice navigation, emergency alert to loved ones.

The above-discussed sticks don't give a solution to pot-hole and stairs detection, and also if a person loses a stick, he won't be able to find out the stick without other person's help. So in this paper, we are proposing the solutions for these problems along with water detection and obstacle detection part.

III. Proposed Stick

The block diagram of the proposed stick which is implemented in this paper is shown in Fig. 1. It consists of Arduino microcontroller, three ultrasonic sensors, two for obstacles and one for pot-hole detection. The moisture sensor is used for water and mud detection and vibration motor and buzzer for tactile and audio feedback to alert the user. It also consists of RF remote with transmitter and receiver part; here receiver part is attached to the stick which involves buzzer and vibration motor and transmitter part is with the user. It will help the user in finding a stick if the user forgets stick or drop stick somewhere. Fig. 2 shows smart stick.

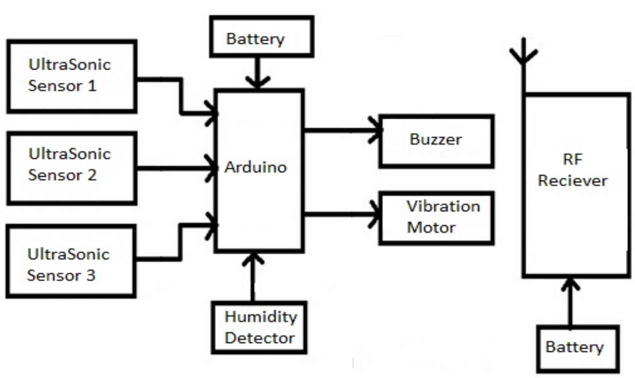

Fig. 1: Block Diagram of Proposed Stick

A. Hole Detection Process

The process that planned that is planned to detect the holes is designed by using ultrasonic sensor is placed on the stick tilted at an angle of about 30. Therefore keeping the sensor at the height of 60 cm, it can detect hole from the distance of 35 cm to show if there is any hole or downstairs in front of the user. If a hole or downstairs is discovered the stick will give audio and tactile feedback to the user by a buzzer and vibration motor.

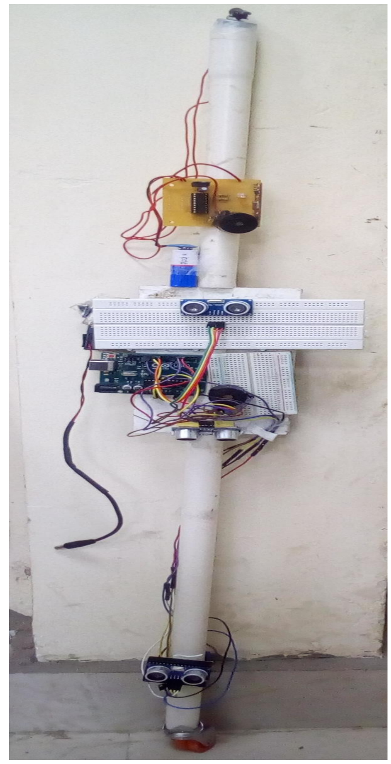

Fig. 2: Proposed Embedded Stick

B. Obstacle detection Process

The input consists of an ultrasonic sensor that is capable of detecting obstacles in front of it at a range of up to 70 cm. It is interfaced to the Arduino, which determines if an obstacle is too close to the cane and triggers the output if it is. The output consists of a vibration motor to provide a haptic response and a piezo buzzer for audio feedback. Block Diagram of the obstacle detection with feedback is shown in Fig. 3.

In this process there are two systems; one is knee above obstacle detection system in which ultrasonic sensor is placed on the stick at about 90 cm from the ground. And the other is knee below obstacle detection system in which ultrasonic sensor is placed on the stick at about 15 cm above the ground level. It can detect the obstacles of at least 15 cm in height.

C. Water and Mud detection process

In instruction to sense the water or mud, the moisture sensor is placed at the bottom of the stick. When the sensor detects water level, it alerts the user by providing tactile and audio feedback. Soil moisture sensors computed the volumetric water content ultimately by using some

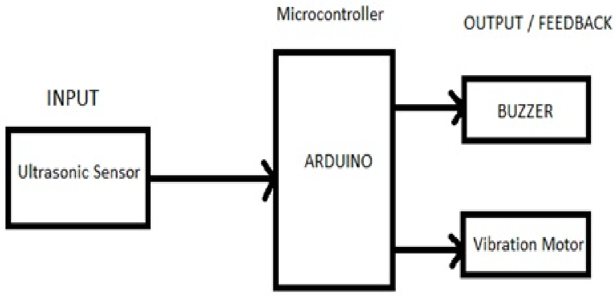

Fig. 3: Obstacle Detection with Feedback [10]

other property of the soil, such as electrical resistance, dielectric constant, or interaction with neutrons, as a proxy for the moisture content. The relation between the measured property and soil moisture must be calibrated and may vary depending on environmental factors such as soil type, temperature, or electric conductivity. Fig. 4 shows water detection.

Fig. 4: Water Detection

D. RF Remote

If the user misplaces the stick, RF remote will be helpful in finding the Stick; the transmitter part consists of a switch and receiver part consists of Buzzer and Vibration motor. Communication over Radio Frequency has many advantages as it doesnt require a line of sight connection between the transmitter and receiver as in case of Infrared communication. The range of RF communication is very high when compared to IR communication [11]. Here, wireless transmitter and receiver system using RF modules (RF Transmitter and RF Receiver) is implemented. Fig. 5 shows the picture of RF transmitter.

TABLE I: Functional parameters for the HC SR-04

Working Voltage	3.5 to 5 Volt DC
Working Current	15mA
Max Range	400 cm
Min Range	2 cm
Working Frequency	40 Hz
Dimension	45*20*15 mm
Measuring Angle	15 degree
Input Signal(Trigger)	10 microsecond TTL pulse

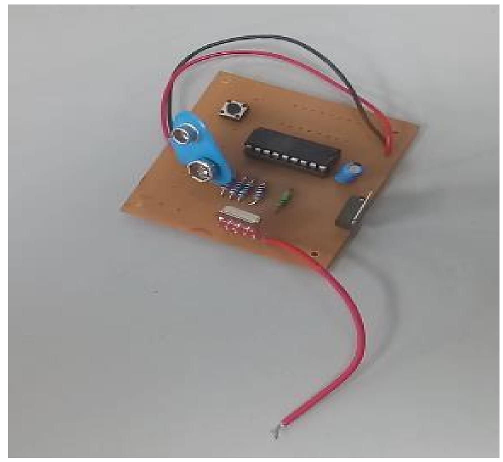

Fig. 5: RF Transmitter

This requires two small circuits. Receiver circuit which will be mounted on the blind mans stick. The other is a little remote RF transmitter circuit which will be used to locate the stick. The wireless data transmission is done using 433 MHz Radio Frequency signals that are modulated using Amplitude Shift Keying (ASK) Modulation technique [12]. To implement the wireless transmitter and receiver, we use an encoder IC HT12E and a decoder IC HT12D.

IV. Sensors with Orientation

Ultrasonic Sensor HC SR-04 is used in the presented stick to for obstacle detection and pot-hole detection. An Ultrasonic sensor is a sensor which can measure the distance from an object present in front of the sensor through sound waves. It determines distance by transmitting sound wave at a frequency of 40 Hz and listening for the corresponding stream to bounce back. By observing the elapsed time between the sound wave being produced and the wave came back, its possible to compute the distance between the ultrasonic sensor and the obstacle. Since it is believed that sound wave travels by air and speed of wind is 344 meters/sec, we can gross the time for the wave to arrive back and multiply it by 344 to calculate the total distance of the sound wave. Point to be taken here is that wave travelled two times the distance to the obstacle before it detected the ultrasonic sensor; to find the distance from the barrier, we have to divide the final length by 2. Fig. 6 describes the basic working of Ultrasonic sensor.

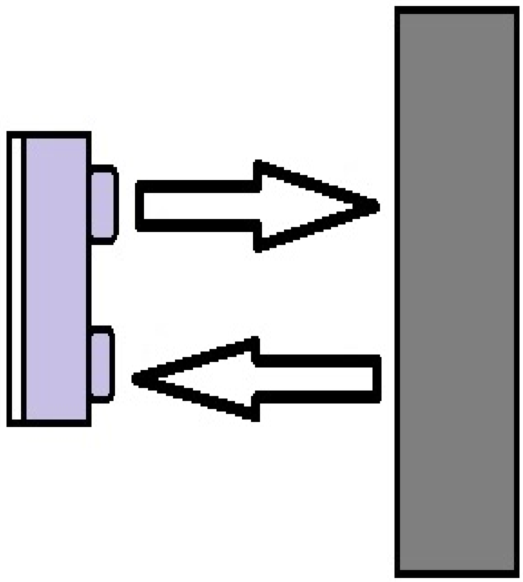

Fig. 6: Obstacle Detection using Ultrasonic Sensor

Ultrasonic Sensor module HC - SR04 gives non-contact range of 2cm - 400cm. The module consists of the control circuit, ultrasonic receiver, and transmitters. The basic working principal [13] is (1) It uses IO trigger for at least ten microseconds high signal, (2) The Ultrasonic sensor module repeatedly sends eight 40 kHz wave and sense if there is a signal comes back. (3) If the signal comes back in high level, time of high output IO duration is the time from sending a wave to receiving it back.

Distance = (high level time * speed of sound (344m/s))/2

A. *Ultrasonic Sensors vs IR Sensor*

Selecting a sensor is reliant on the application for which we want to use it. There are some limits when it comes to infrared sensors, such as the incapability of them to sense and detect obstacles in daylight due to intrusion. IR sensor can make external applications or shady inside applications quiet problematic [14]. Ultrasonic sensors work using sound waves, recognizing impediments is not affected by as many factors. And in case of our form, the stick should able to work correctly in both indoor and outdoor environment and also in daylight and the dark, so the ultrasonic sensor becomes best to use in our application. Obstacle detection mechanism using ultrasonic sensor is shown in fig. 6.

Advantages of Ultrasonic Sensor over Camera, IR, and PIR sensor: a) It has sensing capability which is sovereign of light; it will work same in the night also as in daylight while Camera wont give clear images in the night and IR sensors sensing capability is influenced by Sunlight.b) It is insensitive of environmental factors such as light, dust, smoke, vapor, etc. c) It can perform better for the obstacle types such as sponge, wood, plastic, tile, etc.

Now, in Ultrasonic sensors we tested with both HC SR-04 and HY SRF-05, there is no much difference between two when it comes to range and accuracy. Table II shows the comparison between two regarding functional parameters. It can be observed from the table 2, that HC SR-04 requires less voltage to operate, so less power consumption is there. Also, HC SR-04 is more precise then HY SRF-05. And HY SRF-05 has five pins, so it uses an extra pin of the microcontroller.

TABLE II: Comparison between HC SR-04 and HY SRF-05

Parameter	HC SR - 04	HY SRF - 05
Working Voltage	3.3 to 5 Volt	5 Volt
Static Current	< 2mA	< 2mA
Sensor Angle	<15 degrees	<15degrees
Detection Distance	2cm to 4m	2cm to 4m
Pin Number	4	5
Pins	VCC, trig, echo, GND	VCC, trig, echo, GND, OUT
Precision	3mm	2mm

V. Experimental Results

A mathematical model of sensor arrangement to detect Pot-hole and downstairs is discussed in this section. The ultrasonic sensor is placed on the stick 60 cm above the ground level tilted at an angle of 30 degrees.

A. *Mathematical model to calculate horizontal distance*

In this experiment, the aim is to check the constancy of the ultrasonic sensor evaluation and confirm the accuracy of the distance of the person from the obstacle. Fig. 7 shows the model designed to calculate horizontal distance. The sensor is tilted at an angle of 30 degrees. Thus the distance that we are calculating from the sensor reading is giving us the hypotenuse of the triangle. Pythagoras theorem is applied to compute the horizontal distance to the obstacle from the user. The real horizontal distance is then calculated to compare with the distance. Using Pythagoras theorem:

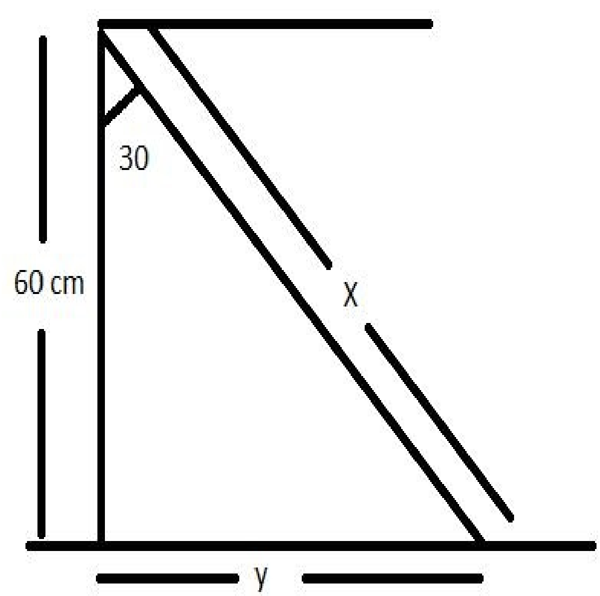

Fig. 7: Model to calculate horizontal distance

TABLE III: Comparison of sensor readings (cm)

Hypotenuse [Sensor Reading]	Actual Distance	Measured Distance	Error
105	80	78	2
120	90	85	5
135	100	102	2
150	110	109	1
165	120	120	0
180	110	112	2

$$B^2 = H^2 - P^2$$

$$B = \sqrt{H^2 - P^2}$$

Distance computed using Ultrasonic Sensor gives the value of Hypotenuse. From Table III, it is observed that the error is decidedly less when we calculate the distance from stick to obstacle, which we can consider satisfactory for the walking support system measurements. Assume x= distance[distance from sensor to obstacle]; y=horizontal distance[Distance from stick to obstacle]

$$y = \sqrt{x^2 - 60^2}$$

B. Mathematical model to calculate Obstacle height

The obstacle is located at different flat distances from the user. The model designed to calculate obstacle height is given in Fig. 8. Length of the hypo is read from the ultrasonic sensor records. Compute the angle by horizontal distance and hypotenuse:

$$a = cos^{-1}(horizontaldistance/hypotenuse)$$

Compute vertical projection of the hypo:

$$z = hypotenuse(sina)$$

Compute the altitude of the obstacle:

$$h = 60 - H$$

where, h= Height of the obstacle

According to Pythogoras theorem,

$$Cosa = Distance/Hypotenuse$$

$$a = Cos^{-1}(y/x)$$

Since,

$$Sina = Perpendicular/Hypotenuse$$

Therefore,

$$Sina = z/x$$

$$z = x(Sina)$$

Height of the Obstacle= Distance of Sensor from ground-vertical distance

$$h = 60 - z$$

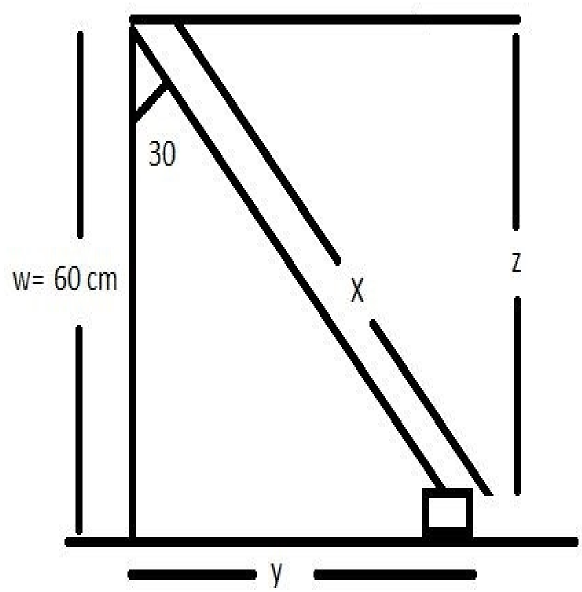

Fig. 8: Model to calculate Obstacle Height

TABLE IV: Calculation of object height(cm)

Height	Object Height from sensor	Actual Object Height	Error
90	30	40	10
88	28	34	6
85	25	36	11
88	28	34	6
86	26	32	6
80	20	29	9

From Table IV, it is observed that the error in calculating height of the obstacle is more, which is not reliable, but it can give us an idea about an obstacle, and we can classify the objects as small, medium and large according to their height.

VI. Conclusion

In this paper, a smart assistive device is designed and implemented to help blind or visually impaired people to safely-move among obstacles, holes, water, stairs and other hurdles faced by them in their daily life. The solution established is a user-friendly directional aid for them. The benefit of the system lies in the fact that it can prove to be a shallow price solution to millions of visually impaired people worldwide. It provides both knees below and knees above obstacle detection in both tactile and audio feedback. It can detect obstacles having a height of at least 15 cm. It can identify stairs and other obstacles from 70 cm. It can detect pot-hole from about 30 cm. It has one more advantage that if a person drops or forget stick somewhere, the person can find the stick by pressing the switch on transmitter from about 300 meters. Its limitations include less detection range of pothole which is 30 cm and it requires training for the user to use it.

References

[1] B. Sveny, G. Kovcs, and Z. T. Kardkovcs, "Blind guide - a virtual eye for guiding indoor and outdoor movement," in *5th IEEE Conference on Cognitive Infocommunications (CogInfoCom)*, pp. 343–347, Nov 2014.

[2] L. Tian, Y. Tian, and C. Yi, "Detecting good quality frames in videos captured by a wearable camera for blind navigation," in *IEEE International Conference on Bioinformatics and Biomedicine*, pp. 334–337, Dec 2013.

[3] N. Sukhija, S. Taksali, M. Jain, and R. Kumawat, "Smart stick for blind man," *International Journal of Electronic and Electrical Engineering*, vol. 7, no. 6, pp. 631–638, 2014.

[4] S. A. Ashraf Anwar, "A smart stick for assisting blind people," *Journal of Computer Engineering*, vol. 19, no. 3, pp. 86–90, 2017.

[5] M. Kumar, F. Kabir, and S. Roy, "Low cost smart stick for blind and partially sighted people," *International Journal of Advanced Engineering and Management*, vol. 2, no. 3, pp. 65–68, 2017.

[6] Y. Yi and L. Dong, "A design of blind-guide crutch based on multi-sensors," in *12th IEEE International Conference on Fuzzy Systems and Knowledge Discovery (FSKD)*, pp. 2288–2292, 2015.

[7] M. F. Saaid, I. Ismail, and M. Z. H. Noor, "Radio frequency identification walking stick (rfiws): A device for the blind," in *5th IEEE International Colloquium onSignal Processing & Its Applications,*, pp. 250–253, 2009.

[8] S. Sharma, M. Gupta, A. Kumar, M. Tripathi, and M. Singh Gaur, "Multiple distance sensors based smart stick for visually impaired people," in *7th IEEE Conference on Annual Computing and Communication*, pp. 1–5, 2017.

[9] *Bawa Cane*. https://www.bawa.tech/product/(accessed April 8, 2018).

[10] *Arduino-smart-cane-for-the-blind*. https://maker.pro/arduino/projects/arduino-smart-cane-for-the-blind(accessed April 8, 2018).

[11] *Wireless-rf-modules*. https://www.electronicshub.org/(accessed April 8, 2018).

[12] A. Nada, S. Mashaly, M. A. Fakhr, and A. F. Seddik, "Human and car detection system for blind people," in *4th International Conference on Bio-medical Engineering & Bio-technology*, 2015.

[13] K. S. K. Lokesh.A, Manjunath.T, "Electronic stick along with android smartphone's to the aid of blindly disabled individuals," *International Journal of Recent Trends in Engineering & Research*, vol. 2, no. 5, 2016.

[14] N. Alshbatat and A. Ilah, "Automated mobility and orientation system for blind or partially sighted people.," *International Journal on Smart Sensing & Intelligent Systems*, vol. 6, no. 2, 2013.