2020 IEEE Region 10 Symposium (TENSYMP), 5-7 June 2020, Dhaka, Bangladesh

Real Time Distance and Mobility Detection of Obstacles Using a Smart Multisensor Framework for Visually Impaired People

Dola Das, Prottoy Saha and Nawshin Tabassum
Department of Computer Science and Engineering
Khulna University of Engineering & Technology, Khulna-9203, Bangladesh
Email: dola.das@cse.kuet.ac.bd, prottoy@cse.kuet.ac.bd,
tabassum1407024@stud.kuet.ac.bd

***Abstract*—In the present era, every people wants to be self-reliant even if he is a visually impaired person. Even these people want to be self-reliant in the busy road or a crowded place. This paper offers a system that helps these people. The system includes three Ultrasonic Sonar sensors, three Passive Infrared sensors (PIR sensor), raspberry pi, SD card, vibrator and headphones. All equipment is built into a mobile cane. The PIR sensors allow the proposed system to detect movable obstacles like walking people, vehicles etc around the user in the left, the right and the front. The Ultrasonic Sonar sensors measure the distance and velocity of the movable object from the cane. Then the system notifies the user using vibration and audio message depending on the direction of the coming objects, distance and velocity. The system was experimented with real data for 7 times. The framework has given average accuracy for detecting movable object by PIR sensors is 85.9%, for distance and velocity measurement by ultrasonic sonar sensors are 91.84% and 85.04% respectively. Its accuracy is better and can be usable in real life.**

***Index Terms*—ultrasonic sonar sensor; PIR sensor; Visually impaired people.**

I. Introduction

According to recent WHO statistics, approximately 285 million people worldwide are visually impaired, 39 million of them are blind and 246 million have little vision [1].

Visually impaired persons face various challenges in conducting most of the normal activities done by normal people, such as recognizing obstacles that are stagnant or reactive and successfully approached across their pathways. Such practices are dangerous for people with visual impairments, particularly if the scenario is unknown. These situations motivated us to do such work.

A white cane is typically used by visually impaired people as a movement aid. White canes are inexpensive, lightweight and can detect obstacles on the field. The capacity of white cane to provide its consumers with navigable independence is extraordinarily limited.

Some scholars suggest such technologies such as Electronic Travel Assistance (ETA) [2]. But for visually handicapped people, these tools are not entirely accessible or practical.

The goal of this paper is to design a new device with a cane to help to detect static or active barriers and their movement, motion, direction etc for visually impaired people. The design method has been applied and tested in real-time settings for seven times in order to measure the gap from barriers to prevent these and its efficiency is higher. The system enables a visually impaired person to identify objects and prevent them by supplying navigational information to recover their path. The contribution of this work to this domain includes:

1) Making the device with combinations of two types of sensors like ultrasonic sonar sensors and PIR sensors.
2) Adding new features like velocity measurement with distance and movement direction of the coming object towards the visually impaired person in a busy area.
3) Collecting real-time data and finding out the accuracy compared with real data.
4) Notifying the user by audio message and vibrators.

The rest of the paper is arranged accordingly. Section II explains the related work on-going developments on this side. Section III defines the system description that is used to build a framework. Section IV outlines the evaluation outcomes of the system. Section V summarises conclusions to date.

II. Literature Review

Many systems are designed to benefit visually impaired persons. The work in this area is briefly described.

Sonic-Guide [3], Sonic-Pathfinder [4] and Guide-Cane [5] are some devices which can identify a truly inadequate barrier in front of the user but can't identify barriers on the floor. The white cane [6] and the smart cane [7] are some alternative devices which have certain limitations such as large size, difficulties in public use, and minimal detection of just a few items.

In order to lead the visually impaired people, in paper [8], only distance of the object was measured but no velocity was measured. In paper [9], distance was measured by ultrasonic sonar sensor and the part of our distance measurement was compared to this paper. Recent research efforts [10] centered on video analysis and compression methods for faster multi-core transmission as well as to object detection in very high-resolution optical remote sensing photos. But it is troublesome

978-1-7281-7366-5/20/$31.00 ©2020 IEEE

for visually impaired people to identify impediments using camera since heavy computational demands consume a lot of resources in video processing. In our system, the whole process can be done by some simple instruments, easy to use and calculation of every portion of the work is simple.

III. The System Description

In this experiment, there are two modules. The first one is the detection of the movable object with the PIR motion sensor and detection of the distance and velocity of that movable object. The second module is to notify the user by a vibrator and wired earphone. The proposed system was experimented on seven people because we were able to manage only seven people, who are visually impaired. The system overview is shown in Fig. 1.

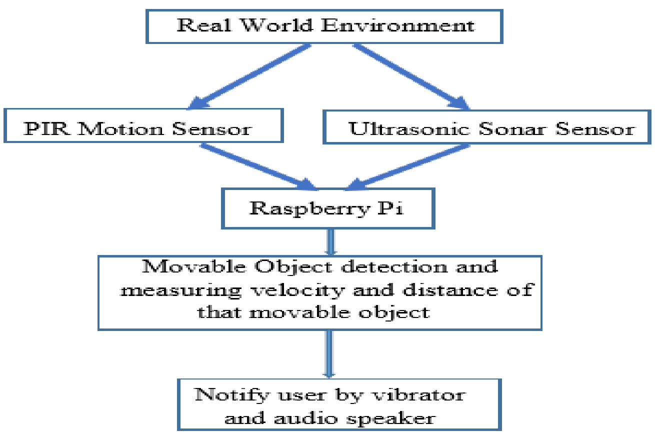

Fig. 1. Overview of the system.

A. Basic Principles

In our proposed system, PIR motion sensors and ultrasonic sonar sensors were used with a cane. Raspberry pi was used to control the whole system.

PIR sensor detects moving objects within the range of approximately 10m. It uses infrared radiation by a pyro electric sensor to detect the moving object. The heat produced by the object helps the sensor to detect [11]. According to Stefan-Boltzmann law, the density of heat flow between the source and the heated surface expressed as Eq (1) [12]-

$$q(\tau) = \sigma.C(T_2^4 - T_1^4) \tag{1}$$

Here, q represents the overall heat transfer from the emitter, C defines the multiplication of area and emissivity of the emitting surface, T reflects the absolute temperature of the emitting and cooler surface.

Ultrasonic sensor uses short and high-frequency sound pulses to detect objects in front of it. If the sound strikes an object, it is reflected back as echo signals to the sensor. Then the distance is calculated based on the time-span between the emitted_signal and received_echo. Normally the range of this sensor is 2cm to 400cm. The distance can be measured by Eq (2)

$$D = S \times T \tag{2}$$

Here, D is the distance, which need to be measured, S is the velocity of sound in air and T is the time-span.

B. Experimental Setup

In this experiment, a mobile cane is used. The whole system is embedded in the cane. There are three ultrasonic sonar sensors and three PIR motion sensors, which are attached in three sides of the cane. There is a vibrator within the touch of the user. A wired earphone is designed to use when the cane is used. The structure of the proposed system is shown in Fig. 2.

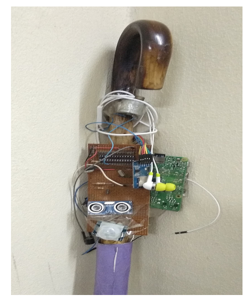

Fig. 2. structure of the proposed system.

C. System Operability

The entire system works as four phases. They are-

1) Interfacing sensors with raspberry pi.
2) Sending and receiving signals using sensors.
3) Calculating distance and velocity.
4) Notify the user.

When a blind people start to use this cane, all the time three PIR motion sensors continue to detect movable object. When there is a running object or car in front or side of the user, the audio signal notify the users according to the distance and velocity.

Three ultrasonic sonar sensors measure the velocity and distance of the movable object in front of and the two sides of the user. The distance is calculated then using time differences between sending the signal and receiving the echo to an object. The threshold value is selected 150 cm for both PIR sensor and ultrasonic sonar sensor. When any object or running vehicle comes in this range the audio alarm through earphone and vibration will notify the user. Vibration will be generated with vibrator according to the distance of the object from user up to 150cm distance and 5km/h velocity. When the object is out of 150cm and 5km/h, only an audio alarm will be generated. The direction of motion will also be notified to the user so that the user can be confirmed if the object is movable or not. Thus the user can be notified of running vehicles on the busy road. The flowchart of the working process is shown using Fig. 3.

The notification will be generated as Table I where, d1, d2 are 2 reference distance points by which the movement of an object is identified and measured by ultrasonic sonar sensor.

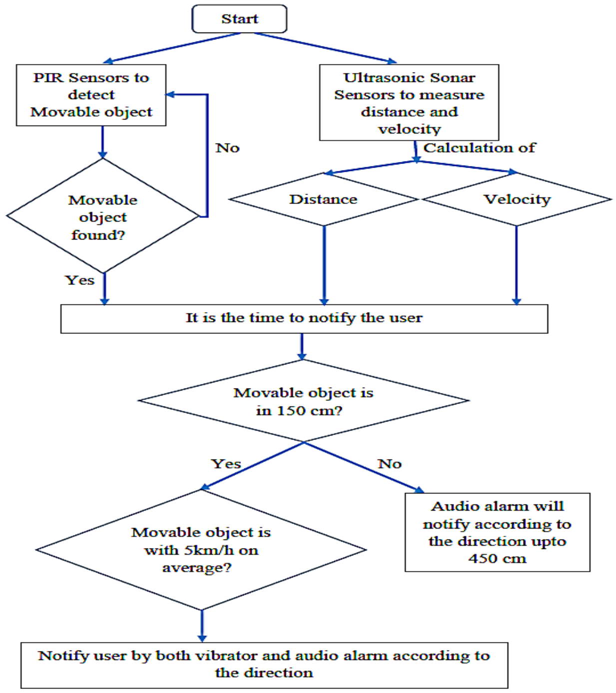

Fig. 3. Flowchart of the working process of the system.

TABLE I
AUDIO NOTIFICATIONS TO USER

Location of movable objects	**Audio messages**
In front of the user and d1, d2 are changing continuously	There is a object coming towards you.
In front of the user and d1, d2 are not changing	There is a object passing infront of you.
In the left side of the user and d3, d4 are changing continuously	There is a object coming towards from the left of you.
In the left side of the user and d3, d4 are not changing	There is a object passing from the left of you.
In the right side of the user and d5, d6 are changing continuously	There is a object coming towards from the right of you.
In the right side of the user and d5, d6 are not changing	There is a object passing from the right of you.

IV. Experimental Results

A. Movable Object Detection

The proposed system was used in a real time environment to measure its accurateness and error rates. At first, the PIR motion sensor detects the movable vehicle or object. The experiment was done for seven times as mentioned before and the experimental environment was same for each of the 7 visually impaired people. There were car, rickshaw, bicycle and some people for every experiment to sense their movement in front of and 2 sides by PIR sensor. The accuracy of sensing the number of movable objects was measured by True Positive (TP), True Negative (TN), False Positive (FP), False Negative (FN), Recall, Precision, and Accuracy-

$$Accuracy = \frac{TP + TN}{TP + TN + FP + FN} \tag{3}$$

TABLE II
MOTION DETECTION ANALYSIS BY PIR MOTION SENSOR (7 TIMES EXPERIMENTED)

No. of movable objects	**TP**	**TN**	**FP**	**FN**	**Recall %**	**Precision %**	**Accuracy %**
10	7	1	1	1	87.5	87.5	80
5	5	0	0	0	100	100	100
9	6	2	0	1	85.71	100	88.89
12	11	0	1	0	100	91.67	91.67
8	6	0	0	2	75	100	75
15	11	1	2	1	91.67	84.62	80
7	6	0	1	0	100	85.71	85.71

TABLE III
AVERAGE OF RECALL, PRECISION AND ACCURACY OF PIR SENSOR FOR MOVABLE OBJECT DETECTION

Average Recall %	Average Precision %	Average Accuracy %
91.41	92.79	85.9

$$Recall = \frac{TP}{TP + FN} \tag{4}$$

$$Precision = \frac{TP}{TP + FP} \tag{5}$$

The result Of sensing using PIR sensor is shown in Table II. The average accuracy of detecting movable objects from 7 periods is 85.9%. Table III shows the average value of the performance of PIR sensors for detecting movable objects.

B. Distance and Velocity Measurement of the Object

The ultrasonic sonar sensor continues to measure the distance of the obstacle or vehicle and calculates its velocity also. The data is stored in the SD card and finally notifies the user. Distance was measured up to 400cm by these sensors and generated alarm according to the reduction of the distance to the user respectively. When an object is in the 150cm range, the vibrator vibrates more forcefully. As there were three ultrasonic sonar sensors in three sides of the cane, the result of 7 experiments to measure distance is shown in Table IV. Each distance was measured three times by ultrasonic sonar sensors and the average result was taken for each experiment in the Table IV. These results were compared to [9]. The graphical representation of the actual distance and measured distance by the proposed system is shown in Fig. 4.

It shows that the difference between actual and measured distance is not so high. Now it is time to measure the velocity of the running object in front and side of the cane. In paper [8], distance is measured by the data fusion algorithm. In our paper, after measuring distance, velocity was measured by using 2 points as the distance is the gap between these points and the time is the passing time from one point to another. As we are measuring the velocity of a running object so these 2 points will be changing continuously. As there were seven times experiments, the average velocity for 5 seconds and actual velocity were shown for every 7 experiments in Table V and the graphical representation by Fig. 5. The velocity of the object was kept low speedy as our instruments were not so

TABLE IV
RESULT OF DISTANCE MEASUREMENT BY ULTRASONIC SONAR SENSORS

Actual Distance (cm)	Measured Distance of proposed system (cm)	Measured Distance of referenced system (cm)	Error of Proposed system %	Error of referenced system %
20	22.01	21.44	10.05	7.19
25	27.55	28.30	10.19	13.19
30	35.42	33.10	18.07	10.33
35	35.60	37.39	1.71	6.82
40	41.79	41.16	4.48	2.90
45	47.86	46.31	6.36	2.90
50	53.12	51.45	6.24	2.90

perfect. The system will notify the user about the object and from which side the object or vehicle is coming using Table. I.

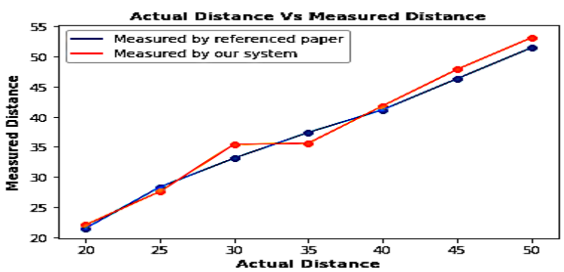

Fig. 4. Actual Distance Vs Measured Distance.

TABLE V
RESULT OF VELOCITY MEASUREMENT BY ULTRASONIC SONAR SENSORS

Actual (average) Velocity (km/h)	Measured (average) Velocity (km/h)	Error of the system %
5	5.83	16.7
7	8	14.29
10	11.2	12
13	16.8	29.23
20	22	10
25	27.9	11.7
30	33.21	10.8

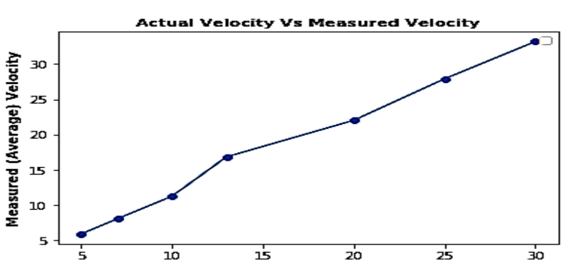

Fig. 5. Actual Velocity Vs Measured Velocity.

C. Discussion

In this paper, two types of sensors embedded in a cane are used to help visually impaired people in a busy road. Our estimation of movable object detection and its distance and velocity measurement is closer to the actual value and referenced work [9]. If we consider paper [8], our work is further improved. But our error rate is medium because our instruments were not fully reliable.

V. CONCLUSIONS

In the present world, the number of visually unable people is increasing. This proposed work can help a blind or visually impaired people to move or walk in the crowded place or on the road as it is an easily usable device. It also conveys low cost as only some sensors are used here. As we have experimented practically, this framework also trustworthy. In the comparison to other papers, the error rate is medium because of the instruments and the result is almost realistic.

In the future, we want to measure the distance and velocity of high speedy running vehicles more accurately. Also, we want to add more features to this work like water detection procedure so that the blind people can be notified if there is a water level in front of him or not and hole detection procedure etc with this system. Image processing can be used to take the work in a more advanced level.

REFERENCES

[1] R. R. Bourne, S. R. Flaxman, T. Braithwaite, M. V. Cicinelli, A. Das, J. B. Jonas, J. Keeffe, J. H. Kempen, J. Leasher, H. Limburg *et al.*, "Magnitude, temporal trends, and projections of the global prevalence of blindness and distance and near vision impairment: a systematic review and meta-analysis," *The Lancet Global Health*, vol. 5, no. 9, pp. e888–e897, 2017.

[2] J. Liu, J. Liu, L. Xu, and W. Jin, "Electronic travel aids for the blind based on sensory substitution," in *2010 5th International Conference on Computer Science & Education*. IEEE, 2010, pp. 1328–1331.

[3] J. L. Barth and E. Foulke, "Preview: A neglected variable in orientation and mobility." *Journal of Visual Impairment & Blindness*, 1979.

[4] A. G. Dodds *et al.*, "The sonic pathfinder: An evaluation." *Journal of Visual Impairment and Blindness*, vol. 78, no. 5, pp. 203–6, 1984.

[5] I. Ulrich and J. Borenstein, "The guidecane-applying mobile robot technologies to assist the visually impaired," *IEEE Transactions on Systems, Man, and Cybernetics-Part A: Systems and Humans*, vol. 31, no. 2, pp. 131–136, 2001.

[6] D. Yuan and R. Manduchi, "Dynamic environment exploration using a virtual white cane," in *2005 IEEE computer society conference on computer vision and pattern recognition (CVPR'05)*, vol. 1. IEEE, 2005, pp. 243–249.

[7] A. Tahat, "A wireless ranging system for the blind long-cane utilizing a smart-phone," in *2009 10th International Conference on Telecommunications*. IEEE, 2009, pp. 111–117.

[8] B. Ando, "A smart multisensor approach to assist blind people in specific urban navigation tasks," *IEEE Transactions on Neural Systems and Rehabilitation Engineering*, vol. 16, no. 6, pp. 592–594, 2008.

[9] A. A. Ebrahim, R. A. Rahim, A. Ahmad, and K. H. Abas, "Ultrasonic sensor for distance measurement."

[10] C. Yan, Y. Zhang, J. Xu, F. Dai, L. Li, Q. Dai, and F. Wu, "A highly parallel framework for hevc coding unit partitioning tree decision on many-core processors," *IEEE Signal Processing Letters*, vol. 21, no. 5, pp. 573–576, 2014.

[11] Y. Pawar, A. Chopde, and M. Nandre, "Motion detection using pir sensor," *change*, vol. 5, no. 04, 2018.

[12] B. E. Saleh and M. C. Teich, *Fundamentals of photonics*. john Wiley & sons, 2019.