Autonomous Path Guiding Robot for Visually Impaired People

Rajesh Kannan Megalingam, Souraj Vishnu, Vishnu Sasikumar and Sajikumar Sreekumar

Abstract This paper introduces an intelligent and efficient path guidance robot to assist the visually impaired people in their movements. This is a novel device for the replacement of strenuous guide dogs. The robot has the capability to move along multiple paths and then remember as well as retrace all of them, thus making it a perfect substitute for a guide dog which is often a luxury for the ninety percent of blind people living in low income settings. The robot is capable to guide the user to travel places which cannot be traced using GPS. Since most of the navigation systems that are developed so far for the blind people employ a complex conjunction of positioning systems, video cameras, location mapping and image processing algorithms, we have designed an affordable low-cost prototype navigation system which serves the purpose of guiding the visually impaired people both in indoor as well as outdoor environment.

Keywords Blind guiding · Obstacle avoiding · Navigation · Retrace

1 Introduction

Data from World Health Organization surveys shows that there are around 285 million people who are visually challenged worldwide, of whom 39 million are blind and 246 million have other kinds of visual challenges and these numbers will

R. K. Megalingam (✉) · S. Vishnu · V. Sasikumar · S. Sreekumar
Department of Electronics and Communication Engineering,
Amrita University, Amritapuri, India
e-mail: rajeshkannan@ieee.org

S. Vishnu
e-mail: sourajvishnup@gmail.com

V. Sasikumar
e-mail: vishnusasikumarpp@gmail.com

S. Sreekumar
e-mail: sksreekumar94@gmail.com

P. K. Mallick et al. (eds.), *Cognitive Informatics and Soft Computing*,
Advances in Intelligent Systems and Computing 768,
https://doi.org/10.1007/978-981-13-0617-4_25

rise to 75 million by the year 2020. It is not unknown to us the efforts and struggles put forth by a physically disabled person in their day-to-day life. The situation is even more complicated when it comes to a visually challenged person. It is needless to discuss the troubles they face when it comes to self-independent mobility, even if it is a small area like their backyard, neighbourhood, etc. They either depend on a cane or a guide dog.

Guide dogs need care throughout the day which means you must fit your life around their schedule as much as they do around yours. Guide dog training is a strenuous and time-consuming task. Moreover, Guide dogs only have a working life of around 8 years and then you have to start all over again with a new dog. Hence guide dogs are not a suitable choice to the 90% visually challenged people living in low income settings. A white cane though affordable does not provide adequate safety to the user. Other types of assistive devices like ETA's (Electronic Travel Aids) along with various other devices are limited in functionality to act as mere obstacle sensing and warning devices. The aim of this research paper is to implement a low-cost autonomous path guiding robot which is capable of assisting the blind and visually challenged people without the assistance of a sighted person and test the efficiency of the proposed prototype system. The paper is organized as follows: Sect. 1.2 describes the current research going on in this field. The system architecture and design approach are explained in Sect. 1.3. This is followed by the working of the robot in Sect. 1.4. Section 1.5 describes experiments, results, and discussions. Conclusion, future work and acknowledgement are presented in subsequent sections.

2 Related Work

A lot of ideas have been proposed in the field of robotics regarding travel aids for the blind people. Some of these are mentioned below. One such project is smart vision [1] which uses a camera fixed at the chest height, a portable computer and one earphone which helps the user to detect the path borders and obstacles along the path. In the intelligent guide stick [2] project, intelligent guide sticks which consist of displacement sensors were used. In the project i-path [3], a path guiding robot was developed. The robot is able to follow any particular path on the floor and is also smart enough to sense the motion of the user. In the work done on obstacle avoidance robot [4] at Amrita University, a three-wheeled self-navigating and obstacle avoiding robot was developed. The system further incorporates computer visioning using an on board computer and web camera. The project titled "High Precision Blind Navigation System Based on Haptic and Spatial Cognition" [5] used a system which combines both haptic and blind spatial perception. It is the ultra-wideband wireless positioning technology which gives them the precise positioning. The project "A Blind Guidance System Based on GCADSF Image Enhancement and Music Display" [6] address the problem of massive data, very low mapping efficiency and sound coding in two distinct way, one by introducing a system based on GCADSF image enhancement and music display. The project "Electronic Escort for the Visually Challenged" [7] uses a smart phone and a wearable RF module. The research work [8] introduces a blind cane which incorporates bluetooth module, haptic module, etc.

3 System Architecture

This prototype has been developed with emphasis of integrating advanced technologies which are economically affordable so that their benefits help to aid the visually challenged community. As shown in Fig. 1, the design of the system mainly consists of twelve parts. We used ATmega1280 Microcontroller. Matrix keypad is used as an input device through which different mode of operation is selected. A 4 $\times$ 4 matrix keypad has been used which provides the option to use 16 different keys. Joystick is used to navigate the robot. Joystick converts the X and Y axes into voltages. These values are then stored in an SD card. Arduino only has a flash memory of 256 KB which is inadequate for the robot to store data generated by the joystick. SD card helps in mass storage and data logging. The driving unit of the robot consists of a motor driver, two 12 V 45 rpm motors and four wheels. Motor driver also acts as the voltage regulator converting the 12 V received from the external rechargeable lead acid battery into a 5 V output which is in turn fed to the Arduino board. This navigational system uses sensors like ultrasonic sensors and infrared sensors. Ultrasonic sensor help in accurate measurement of distance within a range of 2 cm–3 m. Ultrasonic sensor is mounted on a servo motor in order to provide a 180° scan of the surroundings to detect the presence of obstacles. IR sensors mounted at the bottom of the robot body detects the presence of edges

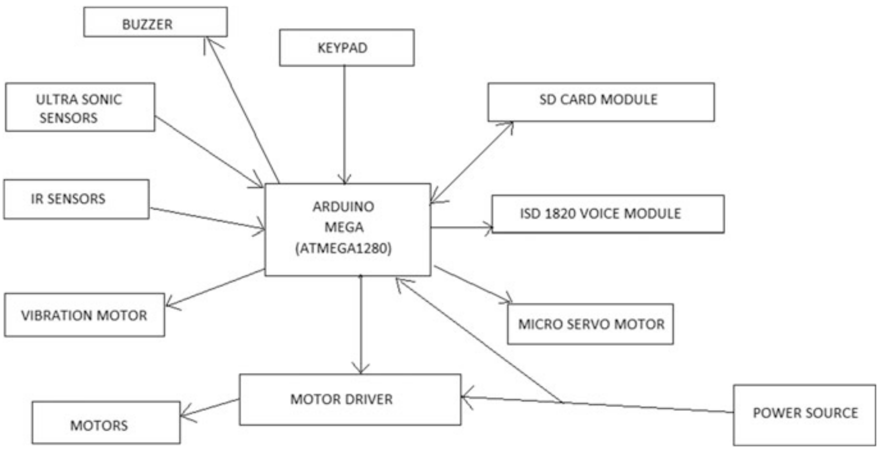

Fig. 1 System architecture

and pits below the horizontal level the robot. The audio module used is ISD 1820. Recordings are stored into on chip non-volatile memory, providing zero-power message storage. Figure 6 contains the design of the robot.

4 Working

The robot works in three basic modes. User can choose the modes with keypad which is mounted on the control panel. In the first mode, the robot can be driven through any path using the joystick attached on the control pad by a trainer. In this mode, the microcontroller processes the data from the joystick and directs the movement of the robot. Simultaneously the values are passed into an SD card where it is stored in an array format. The robot stops saving the path once the push button on the joystick is pressed. The second mode primarily focuses on the retrace of the path by retrieving the coordinates stored in the secure digital card. The values are taken one at a time from the array and passed to the microcontroller where it is processed to determine the direction of travel of the robot. Ultrasonic sensors acts as obstacle detectors while infrared sensors acts as depth and edge detectors. Ultrasonic sensors are located at a distance of 2–40 cm from the ground, each of these ultrasonic sensors can detect obstacles within a range of 20–100 cm respectively. One of the ultrasonic sensors takes a 180° sweep of the immediate surroundings.

Another useful function has been incorporated to the algorithm, which provides the user the freedom to stop in the middle of the process of path retracing and to come back to the starting point. By pressing a specific key on the keypad the user can instruct the system to go back to the starting point. As soon as the instruction reaches the system the further retrieval of values from the array ceases and then from that point in the array retrieval of values start to occur in the reverse direction till the beginning of the array. Since this retrieval of values happen in the reverse direction, the algorithm is developed in such a manner that wherever the instruction to turn left is encountered, the system is made to turn right and vice versa. As the last value stored in the SD card has been retraced and corresponding actions are executed the robots stops, by then it would have directed the user to the exact location. The robot also provides the user with an option for free navigation which can be accessed by pressing suitable key in the keypad. As mentioned in the other modes, movement of the robot is controlled by the joystick. As the robot moves the ultrasonic and edge sensors give simultaneous feedbacks to the robot. This enables the robot to avoid obstacles and edges and thus enhances the freedom of the user. Thus in this case the robot acts as an obstacle avoiding robot. The software algorithm for the working of the robot is given as follows.

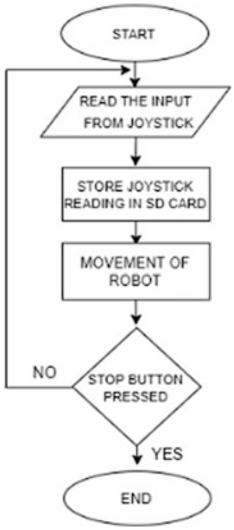

Fig. 2 System processing in learning mode

1. Start.
2. Prompt user to select the mode through keypad.
3. Obtain mode "n".
4. If n = 1, execute "learning mode".
5. If n = 2, execute "retrace mode".
6. If n = 3, execute "free mode".
7. Quit.

The robot works in three modes namely learning mode, retrace mode, and free moving mode. The working of the system when it is in either of the above three mentioned modes, i.e., learning, retrace or free mode is represented in Figs. 2, 3 and 4.

The analog joystick is made of two potentiometers, one each for the x-axis and y-axis. The input values from the joystick can vary from 0 to 1023 on both the axis. The center (x:512, y:512) is the rest position. If the joystick is moved along the x-axis from the two extreme points on the left and right, values ranging from 0 to 1023 are obtained, similar thing happens with the y-axis. Thus, the position of the joystick can be obtained from the (x, y) values. The joystick consists of a push button on the top which acts as a switch with an input either 1 or 0. The diagrammatic representation of the above description is given in Fig. 5.

5 Experiments, Results, and Discussions

The main function of the robot is to guide a visually impaired person through indoor as well as outdoor environment. The robot was tested in different scenario. The first environment was on a tar road. Tar road has rough and uneven surface.

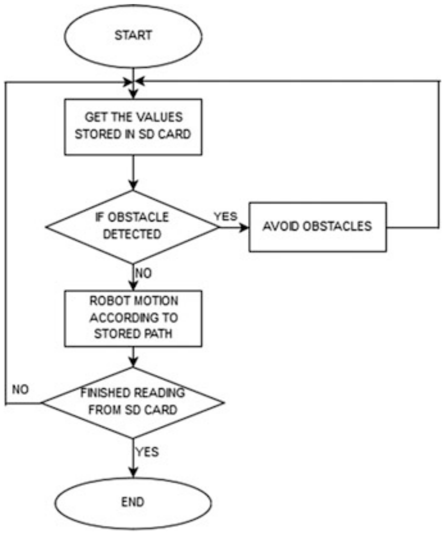

Fig. 3 System processing in retrace mode

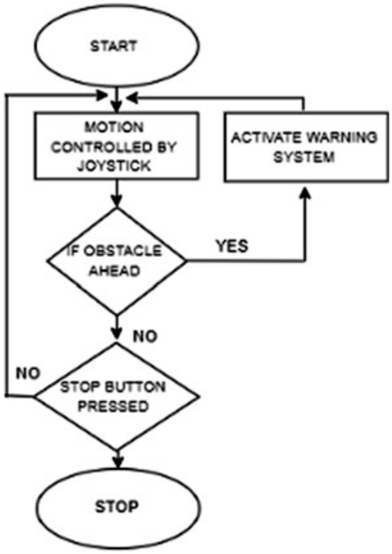

Fig. 4 System processing in free mode

The wheels of the robot should have high amount of torque in order to overcome the friction caused by the tar road. A user who was given a training course on the usage of the robot was instructed to walk towards a wall from a random distance. The user was instructed to inform as soon as he feels a vibration in his hands and then continue walking forward till he hears a warning sound. The threshold value that is given for the vibration of handle of the robot was the maximum range of the ultrasonic sensor, while twice of this value was given to generate a sound in order to

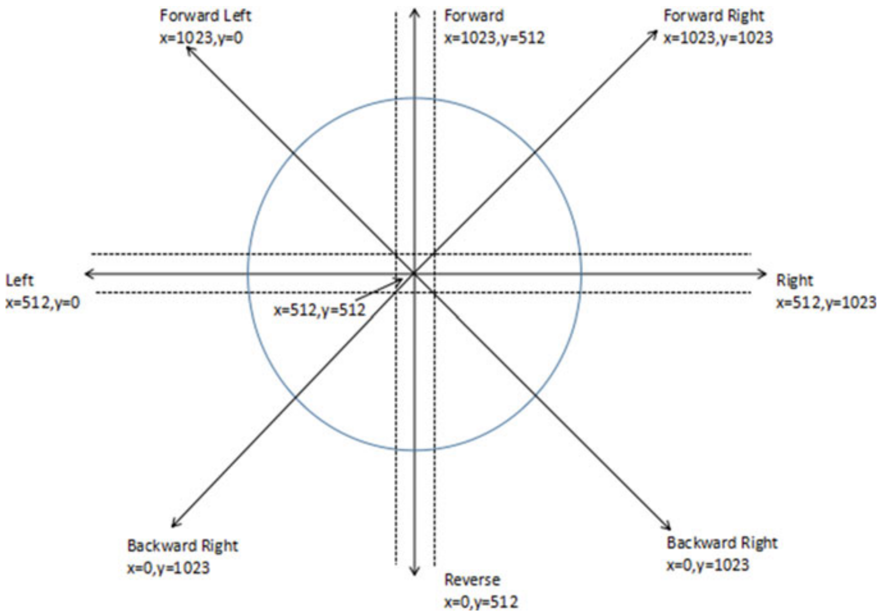

Fig. 5 Joystick position coordinates

Fig. 6 Robot design

indicate the risk of obstacles in the path of the robot. The user in this phase was able to infer the distance of obstacle from the vibratory and sound information. The user was instructed to go towards a pit which had a depth of 10 m. The robot was successful in detection of the pit. The robot stopped moving forward as soon as it detected the presence of the pit. At the end of this experiment, the user was asked to turn the robot left and right for purpose of detecting the presence of obstacles while turning.

For the second environment, the robot was tried on indoor environments like tiled floors and cement floors in the laboratory. Successful results were obtained in this experiment. In order to test the efficiency of the retracing mechanism, the robot was made to travel through a path ABCDEFG. A to B was a straight path of 50 m, after point B the robot was turned through an angle of 30° and moved 25 m to reach point C, path C to D was a semicircular path of circumference 35 m. From D the robot is moved through a straight path to reach E. At E robot is turned through an angle of 90° and moved 25 m to reach point F. From F the robot takes a left turn and travels a distance of 50 m to reach the destination G. Now the robot was switched to retrace mode and placed at point A. As expected the robot successfully moved along the path and reaches the point E. In order to test the efficiency of the sensors, an obstacle was placed along the path BC and a pit was dug along the path CD, the robot was able to detect the obstacle from a distance of 80 cm from it. Similar results were obtained when the robot encountered the pit on the path. The entire path was 60 cm broad.

To evaluate the response time of the system, two different paths were chosen. Path 1 was a 10 m long straight line path with a width of 50 cm, while path 2 was a straight line having a length of 15 m and width of 50 cm. The time taken by the robot to travel along the paths was recorded for the learning mode as well as the retracing mode. The observed values have been tabulated and shown in Tables 1 and 2 respectively. The mean response time for the learning mode in path 1 = 22.1919 s and in path 2 = 32.7878 s. The mean response time for the retrace mode in path 1 = 29.5458 s and in path 2 = 44.3501 s. Difference in response time of the two modes in path 1 = 7.3539 s and path 2 = 11.5623 s.

The deviation of the robot from a mean path was observed in the retrace mode for a number of trials and the variation in values have been plotted in the graph (Fig. 7) based on observed values given in Table 3. The analysis of the graph

Table 1 Calculation of response time in learning mode

S. No	Time (s)	
	Distance = 10 m	Distance = 15 m
1	21.22178	31.8326
2	19.70598	29.559
3	20.4639	30.6958
4	24.2527	36.379
5	25.31525	35.47287

Table 2 Calculation of response time in retrace mode

S. No	Time (s)	
	Distance = 10 m	Distance = 15 m
1	21.22178	31.8326
2	19.70598	29.559
3	20.4639	30.6958
4	24.2527	36.379
5	25.31525	35.47287

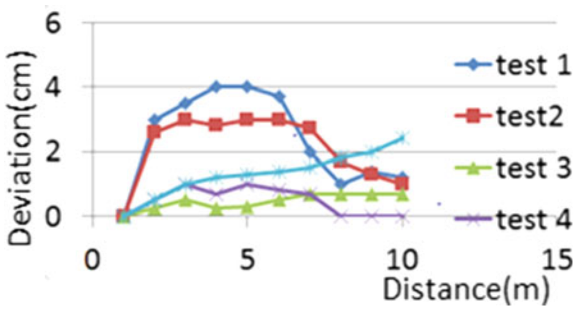

Fig. 7 Plot of distance versus deviation

Table 3 Calculation of deviation

Distance from origin in m	Deviation in cm from mean path				
	Test 1	Test 2	Test 3	Test 4	Test5
1	0	0	0	0	0
2	3	2.6	0.25	0.5	0.5
3	3.5	3	0.5	1	1
4	4	2.8	0.25	0.7	1.2
5	4	3	0.3	1	1.3
6	3.7	3	0.5	0.82	1.4
7	2	2.7	0.7	0.68	1.5
8	1	1.7	0.7	0	1.8
9	1.4	1.3	0.7	0	2
10	1.2	1	0.7	0	2.4
Mean deviation	2.38	2.11	0.46	0.47	1.31

shows the maximum deviation to be 4 cm from the mean value, the minimum deviation was observed to be 0 cm from the mean path and the maximum average deviation from the mean path was observed as 2.38 cm and the minimum average deviation was observed to be 0.46 cm from the mean path.

6 Conclusion and Future Work

Throughout our experiments and research we have tried to see how a simple technique of making a robot remember and retrace a path can be effectively applied in the field of humanitarian robotics to design a compact and user-friendly robot to assist the movements of a visually challenged person. With the use of SD card module, the memory of the system has been enhanced, so as to provide the provision to save multiple paths to the system. The safety of the user has been reinforced by the proper use of multiple sensors and simultaneous warning systems, which help the user to avoid any obstacles or similar threats along the path.

Acknowledgements We would like to thank all-powerful god for aiding us in the successful completion of our project. We recognize the help delivered to us by Amrita Vishwa Vidyapeetham and the Humanitarian Technology Lab for aiding us throughout the course of this project.

References

1. José, J., Farrajota, M., Rodrigues, J.M.F., du Buf, J.M.H.: The smart vision local navigation aid for blind and visually impaired persons. Int. J. Digital Content Technol Appl. **5**(5) 362–375 (2011)
2. Kang, S.J., Kim, Y.H., Moon, I.H.: Development of an intelligent guide-stick for the blind. In: Proceedings of the IEEE 2001 International Conference on Robotics 8, Automation, Seoul, 21–26 May 2001
3. Toha, S.F., Yusof, H.M., Razali, M.F., Halim, A.H.A.: Intelligent path guidance robot for blind person assistance. In: Informatics, Electronics and Vision (ICIEV), Fukuoka, 15–18 July 2015
4. Balasubramanian, K., Arunkumar, R., Jayachandran, J., Jayapal, V., Chundatt, B.A., Freeman, J.D.: Object recognition and obstacle avoidance robot. In: Control and Decision Conference (CCDC), 17–19 June 2009
5. Ma, J., Zheng, J.: High precision blind navigation system based on haptic and spatial cognition. In: 2nd International Conference on Image, Vision and Computing (ICIVC), Chengdu, China, 2–4 July 2017
6. Yanan, T., Hongwei, L., Jinghong, L.: A blind guidance system based on GCADSF image enhancement and music display. In: Control and Decision Conference (CCDC), Chongqing, China, 28–30 May 2017
7. Rao, S.N., Aswathy, V.R.: An electronic for the visually challenged. In: 2016 IEEE International conference on Computational Intelligence and computing research (ICCIC), 15–17 Dec 2016
8. Megalingam, R.K., Nambissan, A., Thambi, A.: Sound and touch based smart cane: better walking experience for visually challenged. In: IEEE Canada International Humanitarian Technology Conference, Montreal, Canada, 1–4 June 2014