International Journal of Scientific Research in Engineering and Management (IJSREM)
Volume: 05 Issue: 06 | June - 2021 ISSN: 2582-3930

Design and Implementation of a Path Guidance Ballbot for the Visually Impaired

Pranav K B[1], Rahul Murali[2], Ruchirkanth G[3], Vineet N[4], P Usha[5]

[1,2,3,4,5]*Department of Electrical and Electronics Engineering, Dayananda Sagar College of Engineering, Bengaluru 560078*

---***---

Abstract - Visually impaired people experience immense trouble when moving from one point to another and need to exert a lot of effort to ensure they do not run into any obstacle or get into dangerous situations, especially when they are in places unfamiliar to them. Hence, it is important that there is an effective solution that helps them navigate effortlessly, while preventing any untoward incidents. This paper presents the design of an autonomous assistive robot that uses a unique mode of motion, a sphere. The bot has the ability to follow a specified path by following a line on the floor and also, detect and avoid any obstacle on path. In addition, the hardware design for the robot is small and lightweight. Therefore, this ballbot can effectively provide assistance to visually impaired people in new environments and enhance their quality of life.

***Key Words*:** Ballbot, Guidance robot, Obstacle Detection, Visually Impaired, Line following.

1.INTRODUCTION

The faculty of vision is one of the most important methods through which humans perceive the environment. Almost all human beings are heavily dependent on the visual apparatus, i.e, the eyes, to perform all daily activities. Hence, it would be difficult to imagine a life without eyesight, which is unfortunately a reality for millions of people all around the world.

Blindness is a condition which renders a person incapable of visually perceiving their surroundings and can due to various physiological and neurological issues. It may happen in different ways resulting from either disease, injury, or congenital and degenerative conditions which may not be correctable by medication or surgery. According to the World Health Organization (WHO), almost 285 million people are approximated to be visually impaired globally; 39 million are completely blind whereas 246 million have low vision.

Due to this limitation, most of the visually impaired have enhanced their other senses such as hearing to have some form of awareness of their surroundings. However, studies show that if the visually impaired people relied strictly on their hearing , it would greatly endanger their lives[1]. Traditionally, a blind person requires the help of someone with normal eyesight to guide them around. They must act as assistance to the blind. In order to overcome this, the practice of using guide dogs was started. Though this method too has various drawbacks, it still continues to be in use. Hence, it is obvious that low-cost and efficient solutions driven by modern technologies were the need of the hour. Multiple inventions were made to assist the visually impaired, among which, the following stood out due to their effectiveness.

The Smart Walking Stick [2] introduced a method of assistance which was new in that period, and also provided a glimpse at electronic visual guidance. The Guide Cane [3] was developed in 1997 with the idea of mitigating risks to a visually impaired pedestrian. The NavBelt [4] was a wearable device that used audio feedback to guide a blind user, using techniques like stereophonic imaging. But the limitation of these devices is that they can only do a specific task, and more importantly, they can only be used when the user knew the route they were going to take. These devices would obviously be unable to detect various kinds of obstacles in the user's path and neither could it lead them on the right path to a destination in case they lost their bearings or enter a place which they are unfamiliar with.

This paper describes the developmental process of a blind assistive robot which can guide the user through a building or any space they are unfamiliar with while avoiding obstacles, along with the help of a novel mode of locomotion: a sphere. The robot has been developed based on the Arduino Mega (ATMega 2560 processor) which offers various advanced features for the robotic application. Considering all the limitations it is important to develop a system for the blind to move freely. To mitigate navigation complexity, the system is designed to follow a line and will detect obstacles, stairs, holes, and lead the person to the destined location[5]. The main goal of the project is to develop a cost effective prototype of an assistive robot for the visually impaired and also implement the concept of a ballbot instead of a two/four wheeled robot. A robot such as this, which performs not just line following but also moves using a sphere, requires a sturdy frame to attach all of the components while also ensuring that the rotation of the ball is not restricted in any direction and that the motion of the ball does not disturb the position and orientation of the sensors . There are various materials that can be used for the frame and the decision of choosing the right materials depends on the purpose of the robot, the size of the robot, strength and durability of the material and the power available on-board [6].

The project includes the implementation of a ballbot due to the significant advantage this design holds over the conventional wheeled robot [7][8]. Having a sphere as the mode of locomotion allows for 360 degree movement at any instant of time which is quite similar to the level of freedom humans have in their movement too. This implies that the robot can move in a versatile manner which is more organic to people and maneuver around obstacles with ease. Our design of the mechanically stabilized ballbot is also less susceptible to toppling over when moving on a slope or when there is a sudden change in direction of motion.

2. SYSTEM DESCRIPTION

2.1 BALLBOT STRUCTURE

The mechanically stabilized ballbot, shown in Fig. 1 and Fig. 3, consists mainly of a hollow polymer sphere with a diameter of 150 mm, which is held in place by four rubber coated steel rollers.

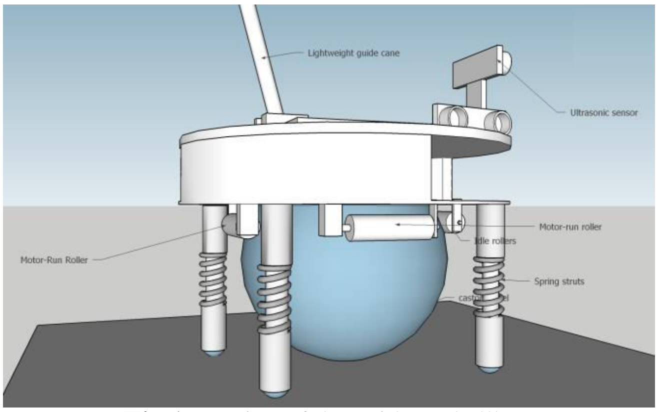

Fig-1 : Design of the guidance ballbot

The rollers were fabricated and customized for the purpose of our project and consists of a stainless-steel shaft, covered with a soft rubber cylinder. Of the four rollers, two are idle and are present to hold the sphere in place, while the other two are connected to the shafts of 12V DC motors, which are driven using a L28N H-bridge motor driver. This structure is a compromise since there is always some slip. For example, if one roller is powered, the orthogonal roller has to slip[9]. Therefore this implies the requirement of a material with both high-friction and low-friction for the ball. At the same time, it is best that there is significant friction between the ball and the floor. The robot is held erect with the help of four 150 mm spring loaded struts, fixed at the corners of the chassis. The ends of the struts are fitted with ball transfers to facilitate smooth rolling motion.

The housing for the various electronic components consists of two circular, acrylic sheets as shown in fig.2. The support structure for the rollers was developed in-house by using aluminium L-angles. A lightweight aluminium cane is attached to the top for the user to grasp, thus allowing them to be guided by the ballbot.

2.2 ELECTRONICS DESCRIPTION

The electronic system consists of the following components:

> Four HC-SR04 ultrasonic sensors

> Arduino Mega 2560 microcontroller

> 5-channel infrared sensor (IR) array

> Two 12V DC motors

> L298N H-bridge motor driver

> 14.8V Lithium-ion battery with Battery Management System board

> Two Buck converters

A. ULTRASONIC SENSOR

An ultrasonic sensor is a device that can measure distance or detect obstacles ahead of it by using high frequency sound waves. It measures distance by sending out an ultrasonic sound wave at a specific frequency and listening for that sound to bounce back. By measuring the time interval between transmission and receiving the echo, the distance between the robot and the object can be measured. The range of the sensor is 2cm to 400cm and the accuracy is 3mm.

The guidance ballbot uses 4 ultrasonic sensors pointing in the following directions, to obtain information about obstacles and holes:

> Forward facing sensor to detect obstacles in front of the bot.

> Sensors facing left and right to detect objects in the respective directions.

> Down facing sensor to identify the presence of any holes or pits in the floor.

B. INFRARED SENSOR

The Line tracking sensor array consists of four IR Transmitter-Receiver pairs. IR Sensors work by using a specific light sensor to detect light in the Infrared (IR) spectrum. When the transmitted infrared rays hit a white surface, they reflect to the receiver and the output pin of the receiver goes high. When the transmitted infrared ray hits a black surface , which absorbs IR, the receiver goes low, and so does the output pin.

The array board requires 5V to function and has an in-built signal processing unit that ensures the output is purely digital, i.e either 0 or 1.

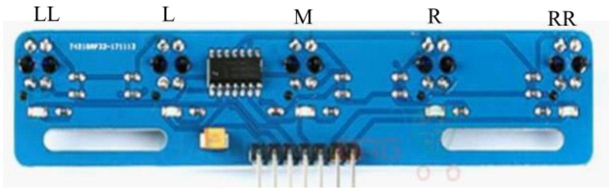

Fig-2: 5-Channel Line Tracking IR Sensor Array

The Arduino Mega microcontroller used in this project is based on the ATMega 2560 and has the code which governs the motion of the ballbot, by taking inputs from the line tracking array and the ultrasonic sensors, and driving the rollers through the motor driver.

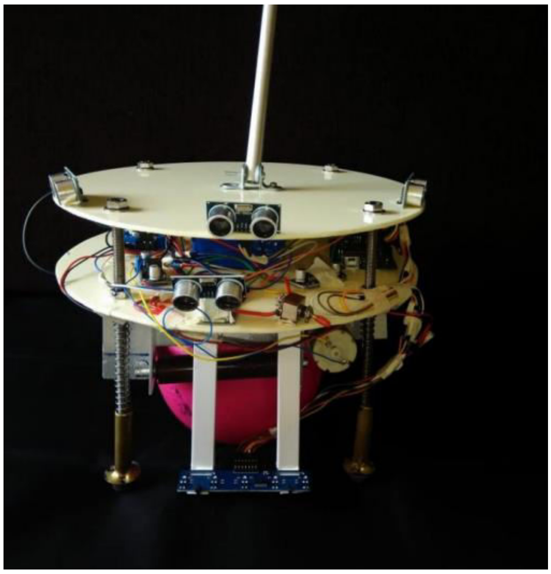

Fig-3 : Front view of Ballbot

Figure 3 shows the prototype guidance ballbot with the IR sensor array at the bottom, and the 4 ultrasonic sensors pointing in different directions. The aluminium cane is shown fixed to the top acrylic sheet.

International Journal of Scientific Research in Engineering and Management (IJSREM)
Volume: 05 Issue: 06 | June - 2021 ISSN: 2582-3930

The connection of the various components in the circuit are shown in the following schematic diagram.

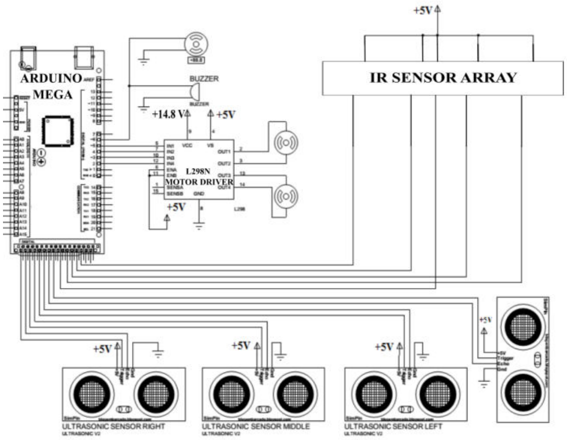

Fig-4: Schematic diagram of the circuit

The Arduino microcontroller, motors & their drivers, and sensors are powered by the on-board 14.8 V lithium-ion battery with built-in battery management circuitry. The required operating voltages for the various components is achieved through the use of DC-DC Buck converters with variable output voltage. The power flow in the system is depicted in Fig.5.

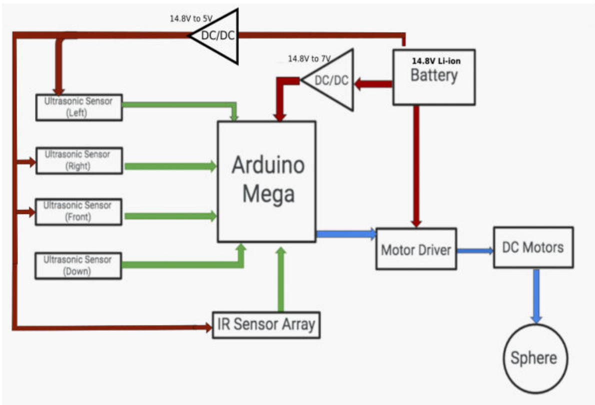

Fig-5: Block diagram of Power flow

2.3 BALLBOT MOTION

The locomotion of the robot is achieved by applying a force tangentially to the sphere on which the system rests, using a pair of geared DC motors via steel rollers. One motor handles the forward and backward motion, while the other handles the left and right motion. The drive mechanism is basically the inverse of a mouse-ball drive: instead of the mouse-ball driving the rollers to provide an input signal to the computer, the rollers drive the ball to move the robot in the required direction. A line-follower system using the IR sensor array is implemented to simplify navigation, while obstacle detection is achieved using the ultrasonic sensors. The principle of locomotion is to detect the black line on the ground and move along that line. To initiate motion in a particular direction, The values from the IR sensor array, as the one shown in Fig. 2, are used to decide in which direction the motion is supposed to happen, since the function of this component is to track the line to be followed.

The values from the ultrasonic sensors are used to ensure that there are no obstacles in the direction of motion and that there is enough space to move.

Suppose the line is pointing in the forward direction, only the middle sensor in the IR array goes low(i.e 0), while the others give a high output(i.e 1). The distance values are checked to ensure there is a space of a minimum of 0.5 meters upfront, and then the ballbot rolls forward. While moving forward, if an obstacle is detected, the distance values on the left and right are obtained to check if there is sufficient space on the sides to implement obstacle avoidance maneuvers. If yes, then the bot leads the user around the object and gets back on track to the line it was following. Figure 6 shows the simple mechanism followed to avoid the obstacles.

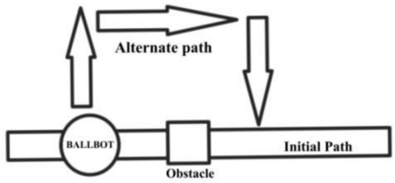

Fig-6: Block diagram of obstacle avoidance mechanism

When an obstacle is detected ahead, the forward motion is stopped and the ballbot moves to the left, given that there is space. It stops the left motion the moment the object is no longer in the ballbot's forward path. The time of motion to the left is recorded and once the ballbot passes the object, it rolls to the right for the same duration, thus returning to the original path. If there is no space on the left for obstacle avoidance, the same procedure is followed to overtake the obstacle from the right. The obstacle avoidance algorithm ensures that the ballbot overtakes the obstacle with sufficient space between the object and the bot, taking into consideration that there will be a person holding the cane attached to the ballbot.

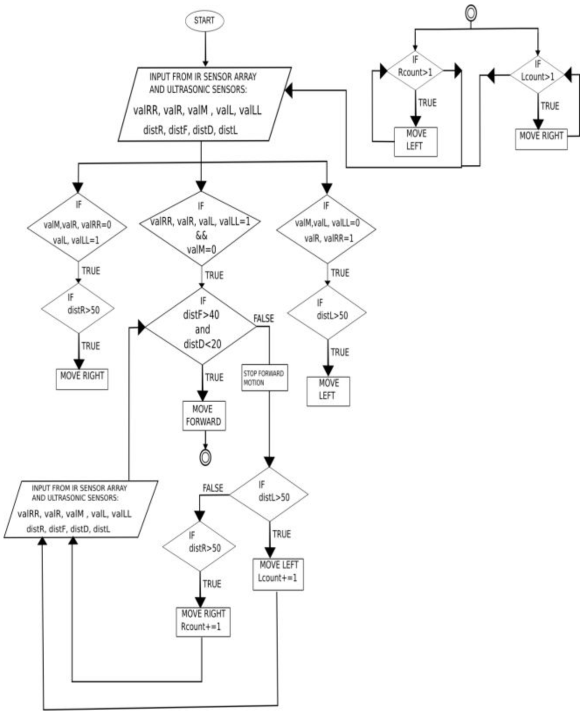

Fig-7: Flowchart of the code governing the ballbot's motion.

The flowchart in Fig. 7 shows the logic of the code in the microcontroller that governs the ballbot's motion.

3. RESULTS AND DISCUSSION

The working of the prototype of the ballbot was evaluated by running it through various situations, to test how the inputs from IR sensor array and the ultrasonic sensors is utilized by the microcontroller to create locomotion through the motor-driven rollers. The ballbot was run through multiple line-following tests to determine optimum placement of the IR sensor array and to fine-tune parameters in the Arduino code. The distance of the array from the ground for optimum accuracy was determined to be 2 centimeters, however this also depends on the type of the ground surface and its level of reflectivity.
The outputs of this array was also found to meet expectations, where the middle sensor, M, gave a high value (i.e 1) with the others giving zero, when the black line was leading forward, thus triggering forward motion. Similarly, when the line was leading to the left, the two IR sensors on the left, LL & L, and the middle sensor, M, (refer Fig. 3) gave a high signal, while the other two (R & RR) gave a low output (i.e 0), thereby triggering motion to the left; when the black line led to the right, the middle and two right side sensors gave a high signal while the two left side sensors produced a low output, causing the ballbot to roll to the right. The table below shows the outputs from the IR sensor for the three above discussed conditions.

Table-1: Output data from IR sensor array at various points

Condition of black line on the ground	Output of IR Sensor Array				
	LL	L	M	R	RR
Leading front	0	0	1	0	0
Leading to the left	1	1	1	0	0
Leading to the right	0	0	1	1	1

The ballbot's on-board ultrasonic sensors were also calibrated and the output data was obtained to compare the distance from the obstacle as measured by the sensor and the actual value.

Table-2: Actual distance vs output values of ultrasonic sensor

Distance (cm)	Output Value
50	52
100	99
120	124
160	145
200	175

To test the ballbot's response to the presence of obstacles, multiple objects were placed on the line at various points. It was noted that the ballbot was able to detect the presence of the obstacle and take evasive maneuvers once it was 0.5 meters away from the object. The serial output window of the Arduino IDE also showed that the ballbot continuously obtained distance readings from all the ultrasonic sensors so that it can overtake the obstacle from the sides and return to the initial path, while also providing sufficient clearance form the obstacle.

4. CONCLUSION AND FUTURE WORK

This project has been idealized after significant research of previous related work conducted across the world. The goal of the project is to mitigate difficulties of visually impaired people during navigating or travelling and also introduce a novel sphere based locomotion system for robots that are meant for assisting and interacting with humans. Using a sphere provides a higher degree of freedom, allowing for smoother movement in all directions, making the robot efficient and agile. It is much easier and faster to change directions in a ballbot as compared to a traditional four-wheeled robot. The device promises relatively smoother navigation and mobility since the user does not need to exert themselves trying to obtain their bearings and sensing for obstacles.
In its current form, the ballbot is capable enough to follow any line and lead the user to the intended destination correctly, while avoiding all obstacles. In instances where it is impractical to implement line following due to the area being large, a network of radio transmitters can be used to act as a positioning and guiding system for the robot, which would then track the signal for a specific destination and follow it. Another possibility would be to integrate with Google Maps, which would then provide the robot with navigation cues to reach a destination and the robot would use its ultrasonic sensors to avoid obstacles in the path.

ACKNOWLEDGEMENT

We would like to thank the Department of Electrical and Electronics Engineering, Dayananda Sagar College of Engineering, Bengaluru for their invaluable support during the development of this project.

REFERENCES

1. Adam Carey (2012, December 31). Risk for blind pedestrians on rise. The Age. Retrieved September 29, 2013 from http://www.theage.com.au/victoria/risks-for-blind- pedestrians-on-rise-20121230-2c1h8.html
2. S. Bunnan, G. Singh and S. Tondare, "ULTRASONIC BLIND WALKING STICK FOR THE VISUALLY IMPAIRED", International Journal of Research in Engineering and Technology, vol. 05, no. 05, pp. 350-352, 2016.
3. J. Borenstein and I. Ulrich, "The GuideCane — A Computerized Travel Aid for the Active Guidance of Blind Pedestrians", The University of Michigan, Advanced Technologies Lab, 1997.
4. S. Shoval, J. Borenstein and Y. Koren, "The NavBelt-a computerized travel aid for the blind based on mobile robotics technology", IEEE Transactions on Biomedical Engineering, vol. 45, no. 11, pp. 1376- 1386, 1998.

5. Nor Maniha Abdul Ghani, Tan Piow Yan and Faradila Naim (2011), Two Wheels Balancing Robot with Line Following Capability, World Academy of Science, Engineering and Technology, International Science Index 55, 5(7), pp 541-546.
6. Deepak Punetha, Neeraj Kumar and Vartika Mehta (2013). Development and Application of Line Following Robot Based Health Management System, International Journal of Advanced Research in Computer Engineering & Technology, 2(8), 2246-2450, vol.2, issue 8.
7. T. B. Lauwers, G. A. Kantor, and R. L. Hollis (2006). A Dynamically Stable Single- Wheeled Mobile Robot with Inverse Mouse-Ball Drive, IEEE Int'l. Conf. on Robotics and Automation.
8. M. Kumagai and T. Ochiai. Development of a robot balancing on a ball - application of passive motion to transport. In Proc. IEEE Int'l. Conf. on Robotics and Automation, pages 4106–4111, 2009.
9. U. Nagarajan, G. Kantor and R. Hollis, "The ballbot: An omnidirectional balancing mobile robot", The International Journal of Robotics Research, vol. 33, no. 6, pp. 917-930, 2013. Available: 10.1177/0278364913509126.
10. R.L. Hollis. Ballbots. Scientific American, pages 72–78, Oct 2006