DEVELOPMENT OF A SMART WALKING STICK FOR THE VISUALLY IMPAIRED

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Abstract*- The purpose of this paper is to design, construct and do a performance test of a smart walking stick with object detection and recognition. An ultrasonic sensor is used for object detection from a variable distance and a vibration actuator is attached with the handle of the stick to provide vibration feedback to the user depending upon the distance of the object. There is a camera sensor integrated with the stick that does image processing and can recognize up to 80 different objects. A headphone is used to inform the user that what the object is and also states the scenario within the range of the camera. A raspberry pi integrates all of these sensors and battery power it up. All of these are in an attachment that is installed on the walking stick. This smart device can help the visually impaired to be self-sufficient to a large extent.*

Keywords: Visually impaired, Obstacle Detection, Scenery Description, Location Tracking.

1. INTRODUCTION

Visual impairment refers to the term of not being able to use the eyesight properly. It includes complete and partial blindness. The visually impaired people suffer a lot due to their inability to detect objects ahead of them which they cannot touch. So, navigation for them is really difficult without any help from others. The idea of being self-reliant seems like a tough ask. Even if they could somehow detect an object ahead of them there is no way that they can say what the object is or how far the object is located.

Over the last decades, some researches have been done in this field. The researchers tried to accomplish easier ways for navigation of the visually impaired. Some really good works have been done and walking aid devices for the blind have been made. But there is still much work to be done to make the devices more feasible and cheaper.

The smart walking stick proposed in this work consists of some sensors for obstacle detection, object recognition, and location tracking. The ultrasonic sensor detects obstacles within the range of 0 to 13 feet from the stick. Through image processing with Pi Camera, the stick can detect what the object is and describe the scenario ahead. With the help of a GPS module, any guardian of the visually impaired can track his location. A raspberry pi processes all these signals and a 9-volt battery powers up the whole system. For the complete integration of all the components with a single stick, sufficient design considerations have been done. That is one of the main aspects of this paper. Here the complete design model of the stick and attachment for the integration of all the necessary components with the complete dimension will be given. Furthermore, the working result of the smart stick is also going to be discussed with the scopes of future modifications. Another important aspect of the design model is that it is going to be portable, lightweight, easy to use and cheaper than any other conventional devices present today.

Quite a bit of work has been done on this topic for the last decades. There has been work on wearable assistive devices like SVETA [1].

Fig.1: SVETA

Figure 1 shows that it consists of a computing device, stereo headphones, cameras. A stereo matching is performed over the transformed images to calculate the dense disparity image. Low texture filter and left/right consistency checks are carried out to remove the noises and to highlight the obstacles. A sonification procedure is used to know the situation in front of the user.
Shashank Chaurasia et al., (2014), presents a conceptual model of an electronic walking stick for the blind, where two ultrasonic sensors, two infrared sensors are used to detect an object in front of the blind person. Figure 2 shows that a vibration actuator and buzzer have been used to convey the message of the detected obstacle to the user. GSM module was used to send a pre-prepared message text to a specific number [2].

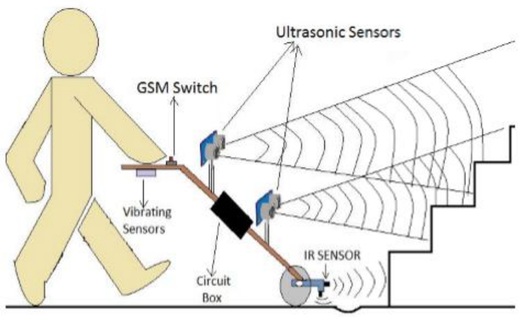

Fig. 2: Walking stick conceptual model with sensors.

Kher Chaitrali S et al., (2015), introduces a model of walking stick based on Radio-frequency identification (RFID). There is an RFID sensor placed on the stick. When that walking stick comes within the range of an RFID receiver, the sensor gets activated and it is connected to an android application system. The application then searches the database for the entry corresponding to the RFID tags and gives speech output about the location information stored. The application also updates the user's location on the cloud [3].

Ayat A. Nada et al., (2015), implemented a smart stick model that can detect obstacles based on IR sensors as shown in figure 3. Stair detection experiments and obstacle detection experiment was done with good results. The IR sensors were inclined at a certain angle to be able to detect obstacles situated at different heights. After detection, it gives warning messages based on how far the object is [4].

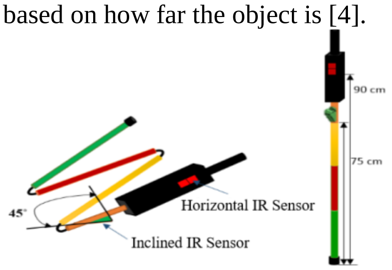

Fig. 3: Walking stick with IR sensor.

D. Sathya et al., (2018), presents an integrated smart stick with an ultra-sonic sensor, camera, water sensor as input and voice synthesizer, Rf receiver, buzzer, microphone as output. A Raspberry works as the processor of all these and a 9-volt DC battery powers up the system. A model diagram was given without any real-life model or any design consideration of the stick [5].

G.J. Pauline Jothi Kiruba et al., (2018), describes a smart walking stick with an ultrasonic sensor to measure obstacles in front, GSM & GPS system to track location. Arduino Uno is showed as the controlling unit. The addition of this model was integrating temperature and heartbeat sensors to know the health condition of the blind person. A circuit connecting all these components was designed and simulated. But o real-life model was done of the circuit or the stick to implementing in real-life scenarios [6].

Quite a lot of work has been done in this field. But there is still room for improvement. In this research, a proposed model with some selected sensors has been used because of certain advantages over the others. In this proposed model there will be an ultrasonic sensor, raspberry pi cam, GPS module will be used as input. The vibration actuator and Head-phone will be used as the output of the system. Raspberry pi will work as the controlling unit. A battery will power up the whole system.

Certain considerations were in mind while choosing these components. Firstly, the Ultrasonic sensor was chosen instead of IR sensors because Ultrasonic sensors are, for the most part, completely insensitive to hindering factors like light, dust, smoke, mist, vapor, lint. But IR sensors might get affected by these factors while using in outdoor environments.

The vibration actuator will be used instead of headphones in case of an ultrasonic sensor because it is easier to know instantaneously about the obstacles ahead. There will be a switch when the user wants to activate the pi cam. It will then take a picture, process it and then describe the scenario through the headphone. GPS module will be added to track the location of the user. A proper design model will be added to integrate all the components in a single unit.

2. MODEL & DESIGN

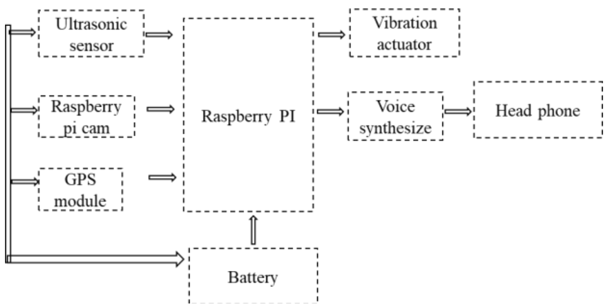

Fig. 4: Operation diagram of the sensors with the stick.

Figure 4 shows that there are 3 inputs to the whole system. A power source powers up the whole system and as output there is a vibration actuator and a headphone for voice feedback. A raspberry pi works as the processing unit for the whole system.

The rendered SolidWorks model is showing all the parts involved in the construction of the smart stick.

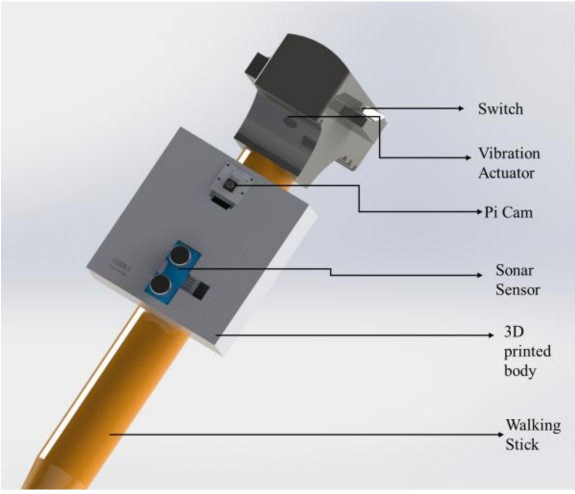

Fig. 5: Rendered Solidworks model of the stick.

Figure 5 is showing where each component is being integrated into the whole system. There are 2 switches at the top to operate the raspberry pi camera. One is for analyzing and another is for face learning. By pressing the analyzing button, the pi cam gets activated and starts detecting obstacles. After detection, it describes what is in front through the headphone. The other switch works as the face learning activator. By clicking this switch, it captures the person's face and then that person can be renamed through an offline website. So, next time if the blind person presses the analyze button it will be able to detect the person specifically.

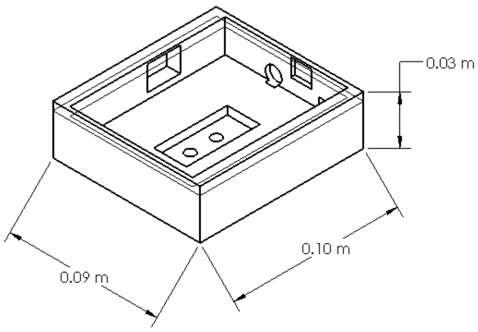

Fig. 6: Design model of the 3D printed sensor house.

Figure 6 is showing the inside of the 3D printed sensor house in which the raspberry pi and power source are installed. There is a section underneath through which nut can be inserted to attach the walking stick as there are holes drilled into the stick of the same diameter. The other gaps in Figure 6 are kept so that any external connection can be made with the raspberry pi inside it.

There is a QR code in the cover of the sensor house body. After the face learning, any person can scan the QR code and enter the website and update the person's name accordingly. There is also a cooling fan on top of the cover so that it can cool down the raspberry pi if necessary.

3. EXPERIMENT & RESULTS

At first, all the components were assembled together for conducting an experiment of the sonar sensor and camera. Then the stick was taken to different places and different objects were placed in front of it to see how the sonar is working and how much deviation is it giving from the real value.

Fig. 7: Experimental data collection for the sonar sensor for completely solid obstacles.

Figure 7 is showing one of the many experimental scenarios that were tested to see if the stick was working or not. Based on that at first, the deviation of distance calculation of the sonar sensor was done. This was repeated a lot of times with different obstacles each time. Human, wall, net and many more objects were set in front to experiment if the sonar was working correctly or not and based on the experimental data it was found that it was working effectively with very little error.

Table 1: Experimental data for distance vs vibration intensity for a solid plain obstacle.

Actual distance (in cm)	Distance measured by Sonar Sensor (in cm)	Intensity (%)
182.88	175.5	0
152.4	147.23	0
121.92	115.23	20.3
106.68	97.8	35.62
91.44	89.2	46.84
76.2	73.65	60.31
60.96	60.71	70.96
45.72	44.65	89.43
30.48	30.11	100

Table 1 is showing values for when there was a wall in front. The working range is within 30.48 cm to 121.92 cm. So, if any obstacle comes within this range it can be detected and vibration feedback is given accordingly. As the vibration actuator coin type vibration motor is being used which has a diameter of 8.00 mm and a thickness of 2.7 mm. So, it can be easily set with the stick. Since it is a coin type vibration motor, it can be rotated by supplying current and voltage to it. The rpm of the motor can be varied by varying the voltage level. That is what is being done here to control the intensity of vibration. At maximum speed, the rotation is about 3000 rpm.

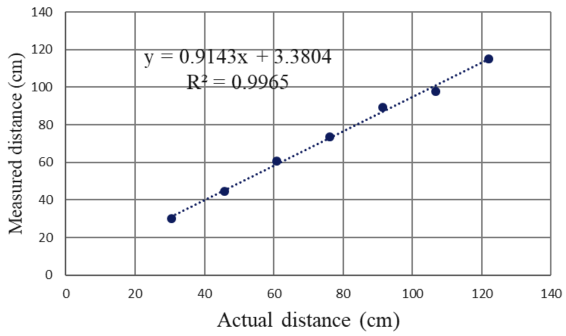

Fig. 8: Actual distance vs measured distance by sonar sensor for a plain solid obstacle.

Figure 8 shows a comparison between actual distance and measured distance. The actual distance was measured by measuring tape and the sonar sensor gave the measured distance. As is seen in figure 8 the trend line is linear and deviation is less than 1%. It indicates that the actual value of distance and the reading found in the sonar sensor are quite similar and accurate.

The working range is within 30 cm to 125 cm. So, any obstacle within this range can be detected and it will give a signal to the vibration actuator so that it can vibrate accordingly.

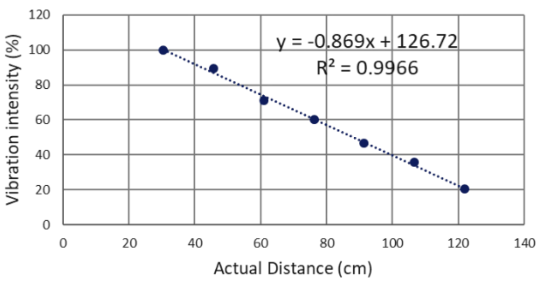

Fig. 9: Actual distance vs vibration intensity.

Figure 9 shows that the intensity of vibration is changing with the distance. The closer the object is the more the vibration is and the intensity of vibration decreases with increasing distance. This is just one of the many scenarios that have been tested and observed. For all the other cases similar graphs and accuracy were found.

Next, the experimental setup and performance test was done for the camera through image processing. For this experiment, a lot of objects were set in front of the pi cam to detect. This experiment was done at different times of the day because the brightness condition varies. The camera could detect the objects easily and give voice feedback accordingly.

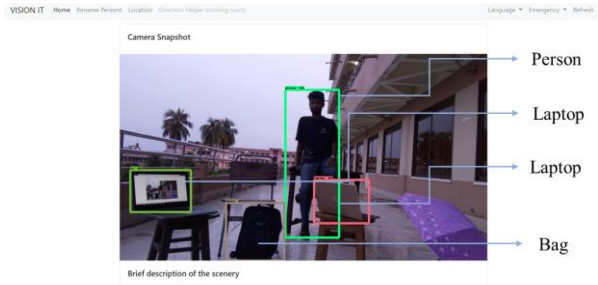

Fig. 10: Object detection experiment by pi cam.

Figure 10 is showing the object detection interface on the website. About 80 objects are in the tensor flow model and if there is any object within that 80 objects in front than the camera will identify it and give voice feedback about what it is. At first, the pi cam goes to a center point and then divides its whole frame into four zones, i.e, upper right, upper left, lower right, lower left. In the case of figure 10, it will generate a speech such as, “There is a person in front. There is a laptop on the lower right. There are a laptop and a bag on the lower left.” This is how the whole object detection is working and a Bluetooth headphone will be working as the voice feedback unit.

4. CONCLUSION

In this paper, a solution has been proposed for the easier movement of the visually impaired. A design model of the stick with the integration of all the sensors have been shown. The ultrasonic sensor is programmed to detect obstacles within the range of 30 cm to 120 cm and give a signal to the vibration actuator. The actuator vibrates intensely if the obstacle is close and less intensely if the object is far away. Pi cam can say what the object is in front of the blind person by describing the scenario. All these are integrated into a single place and can easily help the visually impaired move around easily. All these have been done maintaining the whole system cheap, lightweight and portable.

5. REFERENCES

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