The Voice Enabled Stick

An Embedded Device for Active Guidance of Visually Impaired Pedestrians

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***Abstract*— Now a day many visually impaired people face many problems when they walk on the roads or streets. These people need a device which is used in avoiding obstacle and helping in navigation. This paper introduces a novel embedded system device called voice enabled stick (VES) which is used to help the visually impaired people to navigate among the obstacles. This device is comprised of a long handle and three ultra-sonic sensors mounted at the end to extract the distance from the nearest obstacle. The output of the stick is in the form of voice to a head phone which gives commands to the user (visually impaired-person) to move right, turn left, and go straight or to stop. The user hears the voice commands from the device and navigates through the obstacles easily without any prior knowledge on the device. In this paper past existing devices have reviewed and the parameters related to these devices and VES are discussed. The improvement in different existing devices for blind people, their limitations and their advantages and disadvantages are examined. Comparison of different existing sticks with our proposed device is also recognized. Challenges issues and difficulties related to propose VES needs to be overcome have been highlighted.**

Keywords—Embedded system; Voice controlled module;Ultra-sonic sensors

I. INTRODUCTION

There are many guidance devices for the visually impaired people. These devices are used for obstacle avoidance, path planning and helping to navigate the persons quickly among other obstacles and hurdles. In the past century the visually impaired person was guided outdoor by a pet dog. The pet dog navigates the visually impaired person through the obstacles. However the visually impaired dog is very expensive and requires extra care.

Recent statistical information [1] provided the data that the population of the visually impaired persons in South Korea in the year 1999 is about 46,000. Generally the visually impaired person travels outdoor using a visually impaired stick or a guided dog. The use of visually impaired stick is easy and cheap bit it requires further information about the environmental situation. The most important information for the visually impaired person is to get the shape of the road and the position of the obstacles when they are in any other unknown places. With the help of this information, it is easier to them to move towards the final destination.

Finder [2] alarms the visually impaired person when any obstacle is detected within the threshold distance by means of acoustic difference waves. However this device provides inaccurate path planning of the obstacle.

MELDOG [3] uses the architecture of artificial intelligence technique and unlike path finding by the sonic waves. It provides accurate positioning of the obstacle using laser sensors and the ultrasound waves. The MELDOG in general is not only heavy, large, complex but it also requires a lot of training.

Nav-Belt [4] utilized an array of ultrasound sensors and instead of automatically steering the user, the robot controller transmit the acoustic cues to the traveler's headphone. But this device also requires a large amount of training at a fairly low speed.

Guide cane [5] utilizes an array of ultrasonic sensors similar to the Nav-Belt. It is compact, light-weight and easy to use. Guide Can utilizes both local and global path for path planning. MELDOG utilizes the local path for path planning. Global path planning is done when all the information such as global position or shapes of the obstacles is already known to the system. For the accomplishment of the local path planning, the information of the environment is not needed in advance.

Haptic based walking stick [6] is proposed for visually impaired people. Huang et al. [7] proposed the obstacle detection and warning for visually impaired people based on electrode matrix and mobile kinect. Tapu et al. [8] proposed a smartphone-based obstacle detection and classification system for assisting visually impaired people.

This paper proposes an embedded device to assist the visually impaired people by giving output signals in the form of voice commands. This device is named as Voice-Enabled Stick. It is compact, lightweight and has three ultrasonic sensors mounted at three different directions. The device uses arduino microcontroller and provides output in the headset.

A brief introduction of the past popular devices used by the visually impaired persons is given in section II. The proposed embedded device is explained in the section III. The software implementation is explained in section IV. The comparisons of existing techniques are mentioned in section V. Conclusion and Future work is discussed in section VI.

II. EXISTING DEVICES

A. Mobile Robot as a Guide for Visually impaired Persons

The mobile robots are used for centuries for the path planning, obstacle avoidance and motion planning purposes. The mobile robots are good choice for obstacle avoidance but they are unsuited for normal application because of large size, heavy weight, highly expensive. It is also extremely difficult for

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a visually impaired person to use the mobile robot for stair climbing and board walks.

B. The NAV-BELT

The Nav-Belt is a portable computer device with a series of ultrasonic sensors mounted on a belt to provide a 120 degree view. This device has a view angle very similar to the radar screen image. This image is given as an input to the portable computer which generates audio sounds to help the user navigate easily from the obstacles. This Nav-Belt is popular device for the persons to travel freely in any direction they want.

There is one Guidance mode in the Nav-Belt which gets the start and end geo-location information from the user and generates a simple path from the start point till end. It is much easier to follow the output signal given by the Nav-Belt and the normal walking speeds are achieved. The normal walking speed of humans is ranging from 0.6 m/sec to 0.9m/sec. The Figure 1 below demonstrates a successful test conducted by a visually impaired person from the Nav-Belt.

Fig. 1. Experimental Prototype of NAV-BELT [4]

C. Guide Cane

The Guide Cane is comprised of a simple cane with a pair of wheels with the servo motor mounted at the end. At distal end, a pair of wheels are attached which helps the visually impaired person to navigate easily through the obstacles. A steering servo motor is under the control of the computer and helps the user to steer right and left relative to the can. A series of ultrasonic sensors are mounted at the end at some height above the ground.

In the operating mode, the user holds a guide-cane with one hand and the guide cane guides the user. The guide wheels are ground contacted right in front of the user. The user controls the guide-can using a small portable joystick. The guide-can understands the direction relative to the current absolute direction from the compass fluxgate. Figure 2 below demonstrates an experiment performed on the guide-cane.

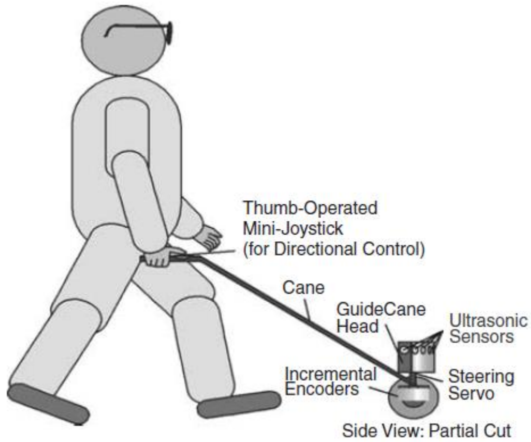

Fig. 2: Image Showing the functions of a Guide Cane [5]

III. PROPOSED EMBEDDED DEVICE

A. Hardware Implementation

The voice-enabled stick is made compact and light weight as much as possible so that the user has no difficulty in its operation. The user may use it indoor environment, outdoor environment, public transport or for coping with the stair steps. In the same way the electronic circuitry including the batteries are kept small, compact and light weight. For the mechanical portion, the stick is made up of hard and light wood. A small wooden box is made for enclosing the electronic circuitry. In addition, the three ultra-sonic sensors are mounted on the small wooden box for distance measurement. In addition to the mechanical and electrical hardware, the software task must also be designed for the real time performance with the limited power consumption. Two 12 AA rechargeable NiMH batteries are used that can power the circuitry up to 2 hours. The stick can also be controlled for a continuous 4-6 hours of operation. The final weight of the proposed device is 0.5 kg which is suitable for the customers and also competitive to the other commercially available visually impaired sticks. The image Figure 3 is showing the mechanical hardware of the voice enabled stick. It consists of three ultrasonic sensors and the enclosed box having battery and included circuitry.

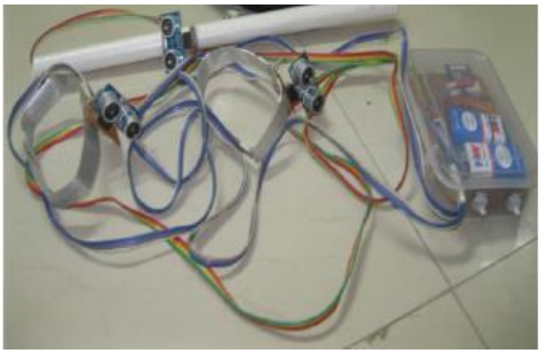

Fig. 3: Mechanical Prototype of Voice Enabled Stick

B. *Electronic Hardware*

Figure 4 shows the implementation of the electronic hardware components and their assembly. Arduino UNO is used as a microcontroller for computation purposes. Three ultrasonic sensors [7] are mounted in different directions and connected with the Arduino-UNO board. Each ultrasonic sensor has a transmitter as well as receiver. The transmitter sends the ultrasonic signals into the environment and the receiver receives the signals after bouncing back from the obstacle. The time is measured between the sending pulse and the receiving pulse.

$$Speed = \frac{Distance}{Time} \tag{1}$$

The computed time is converted to the distance by converting the accurate speed of the ultrasonic sensors.

$$Range = High\ level\ time * velocity\ (\frac{344m}{\text{sec}})/2 \tag{2}$$

The three mounted ultrasonic sensors operate at a same frequency. The alarm is generated when any obstacle is encountered in the threshold distance. A voice controlled module is enabled instead of using a buzzer or an LED for the alarm signals.

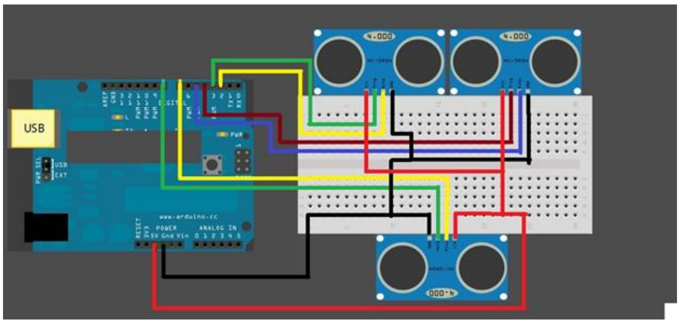

Fig. 4: UltraSonic Sensors Interface with Arduino Board

The voice-output module is the main contribution of this paper along with the development of commercial prototype of the visually impaired stick. The 8 bit digital port of the Arduino UNO board [6] is connected to an R2R resistor ladder. The purpose of the R-2R resistor ladder network is used to convert the digital signal of the arduino into analog signal. The speaker is connected to the analog pin of arduino along with some circuitry. In this proposed device headphone is used to listen the audio output of the arduino board. An R-2R ladder network is simple, cheap and easy to implement. Essentially, it takes incoming digital bits (0V and 5V) from the arduino, weights them from most significant bit to the least significant bit and then converts the analog voltage between 0V and 5V. The image shown below in the figure 5 is the digital to analog converter (DAC) implementation along with analog output to audio signal circuitry.

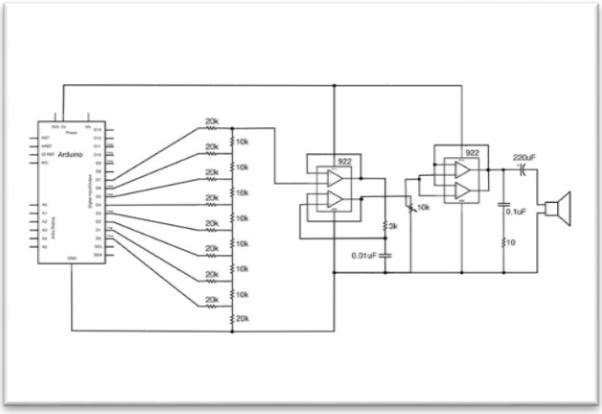

Fig. 5: Audio output with Arduino Board

Figure 6 shows the block diagram of the electronic circuitry which is used in proposed device. The input is taken from the three connected ultrasonic sensors and the ultrasonic sensors give the trigger signal which is then converted into the distance. If any obstacle is present then the voice module enables automatically. In the voice module the audio signals are taken from an secure digital (SD) card reader and then the output comes in the form of voice which can be heard by the user from the headphone.

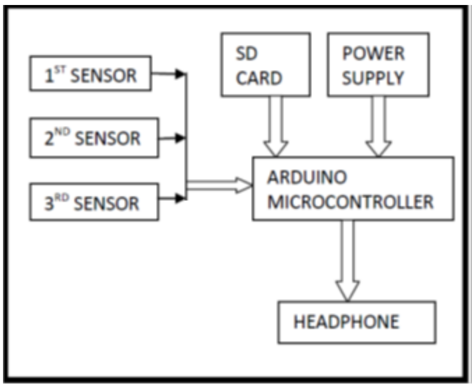

Fig. 6: Block Diagram of the electronic circuitry using Arduino Microcontroller

IV. SOFTWARE IMPLEMENTATION

The first step is to save the audio signals in the mini SD card. The mini SD card [8] can be easily interfaced with the arduino microcontroller. The audio file is first converted into 8 bit mono and then resampled at 20,000Hz. The audio file is saved in the SD card as a wav file. Each audio signal is saved in separate files. The flowchart of the implemented software is shown in the figure 7. The first step is to sense the obstacles through ultrasonic sensors. If the obstacle is present in the pre-defined distance threshold then the alarm situation is generated. In the alarm situation, the audio output module will thus be activated. In the audio output module, the cases will be activated to have either front obstacle, right obstacle, left obstacle, front and right obstacle, front and left obstacle and right and left obstacle. After generating the audio output, the system will automatically move to the initial phase and start sensing the obstacles from the ultrasonic sensors.

A. Cases and Their Corresponding Audio Output

When the obstacle is present on the front side of the visually impaired person the audio output will be “You have obstacle on the front side”.

When the obstacle is present on the right side of the visually impaired person the audio output will be “You have obstacle on the right side”.

When the obstacle is present on the left side of the visually impaired person the audio output will be “You have obstacle on the left side”.

When the obstacle is present on the right side and left side of the visually impaired person the audio output will be “You have obstacle on both right side and left side”.

When the obstacle is present on the right side and front side of the visually impaired person the audio output will be “You have obstacle on both on right side and front side”.

When the obstacle is present on the left side and front side of the visually impaired person the audio output will be “You have obstacle on both left side and front side”.

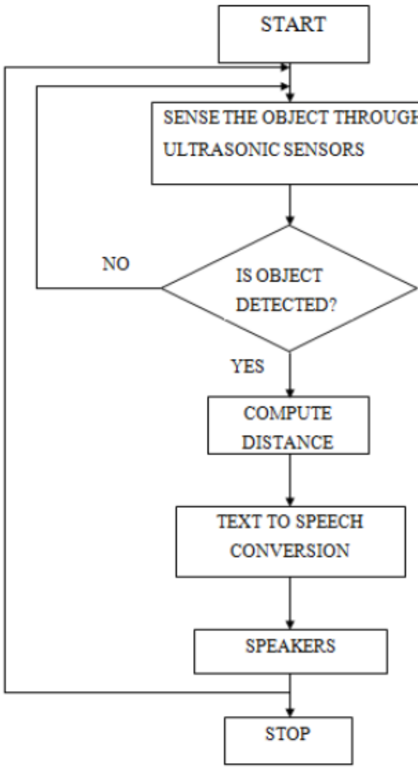

Fig. 7: Flow Chart of the developed module

V. COMPARISON OF DIFFERENT DEVICES

In this section, the popular existing devices are compared against the proposed device. The popular existing devices are Nav-Belt and Guide Cane. This comparison section is focused on power consumption, range, portability, invasiveness, response time and ease of use. Comparison of devices is shown in Table I.

There are many benefits of the proposed voice enabled stick against other devices which are as follows:

- Low production and design time.
- Low Non Engineering Recurring Cost.
- The proposed system is able to be used both in indoor and outdoor environments.
- The final design is light weight and occupies less space.
- The power-consumption of the proposed device is rated low.
- This device is easy to use and does not require training before using.
- The destination setting is quite easy in this proposed system.

TABLE I

COMPARISON OF DIFFERENT DEVICES

Systems	Power Consumption	Range	Response time
Nav-Belt	Medium	Low	Medium
Guide cane	High	Medium	Medium
Proposed Device	Low	Medium	Fast

VI. CONCLUSION AND FUTURE WORK

This paper introduces a novel embedded system device called voice enabled stick (VES) which is used to help the visually impaired people to navigate among the obstacles. This device is comprised of a long handle and three ultra-sonic sensors mounted at the end to extract the distance from the nearest obstacle. The output of the stick is in the form of voice to a head phone which gives commands to the user (visually impaired-person) to move right, turn left, and go straight or to stop.

The real time results of the intelligent stick are encouraging and it revealed an accuracy of 94 percent in detecting the obstacles and aiding the visually impaired people. This device is named as voice-enabled stick. It is compact, lightweight and has three ultrasonic sensors mounted at three different directions. The device uses arduino microcontroller and provides output in the headset.

The future work will involve in upgrading the proposed system. We are planning to replace the ultrasonic sensors with the RGB camera to guide the visually impaired through the obstacles

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