EMBEDDED GLOVE’ TO AID THE VISUALLY IMPAIRED

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Abstract: This paper presents a model of ‘Embedded Glove’, a hand mounted tactile (vibration mechanism) feedback Sound Navigation And Ranging (SONAR) obstacle avoidance system, by warning through vibration motors for visually impaired to whom traveling in indoor/outdoor environments is really a difficult task. This system acts as an Electronic Travelling Aid (ETA) providing independent mobility of the visually impaired. This model comprises of a glove strapped to the wrist, embedded with ultrasonic sensors, battery, microcontroller and vibrator motors. Along with being completely reliable, this system also provides to be a cost-effective guidance mechanism for the visually impaired. The system is designed to scan a wide area with a set of ultrasonic sensors which also provides a good range and speed in the detection of the obstacle. The detected obstacle is immediately notified to the possessor thereby the presence of obstacle along with its direction is conveyed to the visually impaired person by means of a tactile system. The energy consumption for the whole system is controlled by a Photovoltaic (PV) panel, making it more efficient. The analysis described in this paper helps to estimate the distance at which the obstacle is present based on the reliability of measurement performed with ultrasonic sensors. It is also possible to detect the speed of moving objects in addition to direction with increased accuracy, with the enhanced response timings and varying intensities in the vibration mechanism.

Keywords: visually impaired; Electronic Travelling Aid; obstacle avoidance system; ultrasonic sensors; vibration motors

I. INTRODUCTION

Disabled person can be categorized in some classes such as deaf, blind, physical disability etc. Of all disabilities, the person with visual impairment is of great danger. Vision is the main cue used by humans in obstacle avoidance, that is performed by the automatic processing of eyes with minimum cognitive effort and is seen as a trivial task to the visually able navigator. In contrast, for a visually impaired person, vision must be substituted by either auditory or tactile senses and it is a stressful and cumbersome process which is cognitively demanding. According to their motion properties, obstacles are categorized as static and dynamic. To avoid them and aid mobility, several traditional travel aids and electronic travel aids (ETA) are being introduced.

According to the WHO recent statistics, 314 million people are visually impaired worldwide. Among these 45 million people are blind and 269 million people have low vision conditions. About 90% of the world’s visually impaired live in developing countries in which only 15% are affordable to an ETA. The number has been estimated to increase highly in the forthcoming years. It is essential to help and assist the people with visual impairment using upgraded technology.

In the recent years, researches have been focusing their work in the area of health care. Exploring the outdoor environment has always been a challenge to the visually impaired person. The prevailing navigation systems have to be upgraded to provide a better precision to the visually impaired people. The method used for obstacle detection and the feedback scheme decides the exactness of the result of the system. A wrist mounted model of ETA, the ‘Embedded Glove’ is presented in this paper to assist and aid the visually impaired, to traverse the environment with increased confidence. This system can be used in indoor as well as outdoor environment with ease and high precision. It is embedded with the ultrasonic sensors (transmitter and receiver) for the obstacle detection and distance estimation. The ultrasonic sensors measures the distance by calculating the amount of time taken by a pulse of sound to travel to a destination and return as the reflected echo. The calculated information is given to the visually impaired person via a feedback system (vibratory mechanism or speech synthesizer). The intense of vibration illustrates the proximity of the obstacle from the visually impaired person.

II. NEED FOR THIS DEVICE

In the recent years several ETAs have been developed to assist the visually impaired in safety navigation. These include the Laser Cane, Mowat Sensor, Nav Belt, Sens Cap, Tylflos, Nottingham Obstacle Detector, Path sounder and Binaural Sonic Guide. The shortcomings of these ETAs include the masking effects due to auditory feedback, cost, reduction in walking speed of the user and energy consumption. Several available ETAs are not accepted by the visually impaired community due to the features of enhanced complexity and high cost.

Most of the ETAs are in the form of the White Cane. The cane is expensive, heavy and also can cover only a limited range in the detection of obstacles. The decision to move in the right direction is taken by the controller that commands the wheel to rotate as required which causes a hidden damage to the brain.

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A wrist mounted Electronic Travelling Aid (ETA) to assist the visually impaired while traversing the indoor and outdoor environment is presented.

Fig. 1(b) Sensor Glove design of Proposed System

The Block diagram and sensor glove design of the proposed system is shown in Fig. 1 (a) and (b).

1. Vibration Motors       2. Rechargeable Battery
5. Detection Range

The ultimate aim of this project is to develop a user-friendly cost effective warning system with more sensitivity in order to make the user comfortable in navigation. As initiative of this project, it is developed for the detection of obstacles present within the angular range of 180° with the arrangement of three ultrasonic pairs as shown in Fig.1(b) It provides a coverage of about 135° using three pairs of HC-SR04, providing 2 cm – 450 cm non-contact measurement function with a ranging accuracy till 0.3 cm. The module includes ultrasonic transmitter, receiver and control circuit.

III. PROPOSED SYSTEM

Fig. 1 (a) Block diagram of Proposed System

of the user. The other ETAs such as Nav Belt and Sens Cap are to be put on the head or waist of the user. This can cause damage to the neural system. The basic requirements of any assistive device are usability, portability, safety and handiness. The most important fact is that it should be affordable by the user.

Hence, a wrist mounted, user-friendly, cost effective, compact and low power consuming model, the ‘Embedded Glove’ is proposed. This is capable of providing a better coverage area for detection of obstacles and is affordable. Wearing the ‘Embedded Glove’, the visually impaired can traverse indoor as well as outdoor environment with confidence similar to a person with vision. This glove detects the obstacle and alerts the user, while the decision to move in the right direction is made only by the visually impaired person wearing the glove. The obstacle detection is made possible up to a range of about 5 m.

The choice of sensor is one of the important factors that decide the efficiency level of the ETA. It was found that infrared (IR) sensors were easily confused by the sunlight, remote control, absorbent surfaces and security cameras. Lasers would suffice the cause but is expensive. Also the obstacle detector does not have a satisfying range. But, ultrasonic sensors performed up to the satisfying range in less time and hence, it is decided to proceed with the ultrasonic sensors which proved to be a cost effective distance measurement system, the feedback given through microcontroller to the user either in the form of audio or vibration. The visually impaired depend on the sound from the external environment for safety navigation. Hence it is better to use tactile feedback by means of the vibration mechanism. The auditory signal via bone phone can be used as an alternative if required.

IV. EXPERIMENTAL SETUP

Fig. 2 shows the schematic diagram of the proposed warning system, which includes ultrasonic modules (Module 1-3), PIC microcontroller (PIC16F628A), motor driver (ULN 2003), vibrator motors (Vibrator 1-3) and a battery. In the first stage, three ultrasonic modules and vibrator motors are used to detect the obstacles in STRAIGHT, LEFT and RIGHT directions. The PIC16F628A utilized in the proposed system is made by Microchip as a main controller to control the entire system. The programming of PIC16F628A is developed using Flowcode (v4.2.3.58) for PIC, a PIC development environment with an intuitive graphical interface that allows developing programs for PIC microcontroller level block diagrams. This environment allows easy creation of programs by simply dragging and dropping icons on the required block diagram and the developed program has been burnt into PIC16F628A using PIC burner.
Embedded Glove’ To Aid The Visually Impaired

Fig. 2 Schematic diagram of proposed system

Ultrasonic module (HC-SR04) working:

There are 4 pins out of the module: VCC, Trig, Echo and GND. Using I/O, trigger the Trig pin to high level for more than 10µs impulse, then the module automatically sends eight 40 kHz and detect whether there is a pulse signal back. If any obstacle found in front, Echo pin will go high, and based on the different distance of the obstacles, the duration of high level differs, as shown in Fig. 3.

Vibrator motor module:
The concept of the vibration system used in the proposed system is that of the mobile phone when used in vibration mode. The sense of touch has proved to be the best feedback system to warn the visually impaired person. A flat coin type coreless vibration motor shown in Fig. 4 is used due to its fast response, low operating voltage range (between 2.7V and 3.3V), high speed at the rate of 12000 rpm, long life-time and high performance for a silent paging signal for the warning system. The speed of vibration motor is controlled by PIC16F628A controller through Pulse Width Modulation (PWM). The vibration motor is driven by a driver circuit developed with ULN 2003 in order to drive the vibration motor successfully.

Added feature of the device:

With the help of this high level duration, the distance (D) can be calculated for the range between 2 cm and 4.5 m using the following expression

\[ D = \text{Duration high level} \times \frac{340mS(\text{Velocity of sound})}{2} \]

The measured distance is proportional to the echo pulse width and the test performance shows 45° angle coverage, with the best coverage in 30° angle, which is shown Fig. 5.

Fig. 3 Behavior of input and Echo signals

Fig. 4 Coin type coreless vibration motor

Fig. 5 Performance characteristics

V. RESULTS AND FUTURE ENHANCEMENTS

Characteristic study of the ultrasonic module HC-SR04 is done. It is performed in the sense of distance versus frequency and angle versus frequency experimentally and the performance satisfies the expected level. The readings observed are tabulated.
which is given in the Table 1 and the corresponding characteristics curves are shown in Fig. 6.

The program has been developed based on the developed algorithm for Stage-I, burnt into PIC and the output is tested with LEDs in LEFT, STRAIGHT and RIGHT directions. The system performance is up to the expectation and satisfies all the conditions. Hence, the proposed system proves to be a cost-effective guidance mechanism to the visually impaired.

### Table 1: Performance of HC-SR04

<table>
<thead>
<tr>
<th>Distance (cm)</th>
<th>Frequency (Hz)</th>
<th>Angle (deg)</th>
<th>Frequency (Hz)</th>
</tr>
</thead>
<tbody>
<tr>
<td>10</td>
<td>2110</td>
<td>10</td>
<td>336</td>
</tr>
<tr>
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<tr>
<td>80</td>
<td>206</td>
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</tbody>
</table>

#### Developed Algorithm (Stage - I)

1. **Step 1:** Initialize Port A as input & Port B as output
2. **Step 2:** Apply trigger pulse of 100 KHz (10 us) to each module at regular interval
3. **Step 3:** Read Port A and verify the presence of obstacle using Masking Technique
4. **Step 4:** If the presence of obstacle is found, activate the corresponding vibrator(s) for a predefined time through Port B
5. **Step 5:** Go to Step 2

In the enhanced version of this system (Stage-II), with the help of repetitive distance measurement of the obstacle, provision will be made to indicate whether the obstacle is static or dynamic and corresponding indications will also be incorporated. As for as this module is concerned, charging the system is a major factor. In order to avoid such situations, a flexible PV panel could be attached on the top of the glove. Also, proposal is there to introduce one more ultrasonic sensor to convey the user about the presence of UPS and DOWNS while walking and a voice feedback system using speech synthesizer is to be used for the persons with normal hearing capacity and low vision condition.

### VI. FEATURES OF PROPOSED WORK

In the enhanced version of our proposed work, to make our system reliable in outdoor locations also, facilities such as measurement of the distance of object (Hurdle) and velocity of the moving object (Hurdle) are introduced because of the advantage of ultrasonic waves which can easily reflect from structures and also having the study of echolocation using ultrasonic sensors.

#### DISTANCE MEASUREMENT

The method of distance measurement using ultrasonic waves is based on the pulse-echo method, which determines the distance of an object by measurement of TIME-OF-FLIGHT (TOF), i.e., Elapsed time \( T_e \), as illustrated in Fig. 4. The TOF is the interval from transmission of an ultrasonic pulse to reception of an echo reflected from the object. The distance \( D \) is calculated from the product of Elapsed time and the acoustic velocity and dividing this product by two.

\[
D = \frac{\text{Elapsed Time} \times \text{Acoustic velocity}}{2}
\]

![Fig. 4 Distance measurement by the pulse-echo method](image-url)
**VELOCITY MEASUREMENT**

The method of velocity measurement using ultrasonic waves is based on the pulse-Doppler method. When the object is moving, due to the Doppler Effect introduced by the motion of the object, the reflected echo is Doppler-shifted. The frequency of Doppler-shifted echo is increased or decreased in proportion to the velocity of the object. Therefore, the pulse-Doppler method determines the velocity of the object by measurement of increase or decrease in the frequency, as illustrated in Fig. 5.

Furthermore, the TOF of the Doppler-shifted echo in Fig. 8 is different from the TOF of the echo in Fig. 7. The TOF is also Doppler-shifted in proportion to the velocity of the object. Velocity measurement with high resolution and calibration of the Doppler-shifted TOF is required to measure an accurate distance to the object.

In the proposed method of distance and velocity measurement, two LPM (Linear-period modulated) ultrasonic waves are continuously transmitted. The period of the LPM signal linearly increases with time as illustrated in Fig. 6.

The received signal, which includes the reflected echo, is correlated with the LPM signal, which is a cross-correlation operation, as illustrated in Fig. 7. Cross-correlation operation is the method for effective improvement of the resolution of the TOF. The cross-correlation function of the reflected echo, two continuous LPM signals, and the LPM signal has two peaks.

**CONCLUSION**

‘EMBEDDED GLOVE’, a wrist mounted assistive Electronic Travelling Aid for the visually impaired has been designed. Compact, affordable cost and the low power consumption are the striking features of the proposed device. The obstacle detection range and efficiency are reasonably more than the detection range of the existing ETAs. The proposed device can be extended to certain tasks such as rescue operation in mining. Mining is an activity in which people work in underground areas to extract valuable minerals or other geological materials from the earth from an ore body, lode, vein, seam, or reef, which forms the mineralized package of economic interest to the miner. People work in dark areas where finding the correct path is a difficult task. Hence, this device can be used by people working in dark underground areas.

**REFERENCES**


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