A vibrotactile obstacle avoidance system for visually challenged

Sameer P. Dhuri, NeerajKeskar, Devendra Pathak, Smriti Agarwal

Abstract— **As per WHO there are about 285 million visually impaired people around the globe out of which 39 million are blind and 246 million have low vision. This lack of vision reduces their manoeuvrability and make them accident prone. The project aims at developing a highly responsive vibrotactile feedback system to increase the awareness of the user about his surrounding environment. The system employs infrared sensors that are attached to the users stick which gather the information about the direction and speed of both stationary and moving obstacle in the user's path and provide proportional haptic sensation to the user. It also employs an ultrasonic sensor that is attached to the stick directed in upward direction so as to provide a binaural feedback proportional to the obstacle above the waist height of the user.**

Index Terms— **guidance; blinds; vibrotactile; obstacle avoidance**

I. INTRODUCTION

Blindness is a state of lacking the visual perception due to physiological or neurological factors. The partial blindness represents the lack of integration in the growth of optic nerve or visual centre of the eye, and total blindness is the full absence of the visual light perception [1]. People suffering from these impairments have inconvenience in navigating through unknown environments. Traditional way of navigating is using a white cane in which the user has to depend upon the tactile sensations obtained by touching the stick on the ground and the surrounding objects [6]. However, this can be inconvenience to the individuals in vicinity. Secondly it is limited by the length of the stick and is ineffective to detect moving objects. Another traditional method is by using guide dogs. The dog is trained to guide the user in a very complex environment. However it is not affordable and their average working lifetime is 7-8 years [10].

The approach discussed in this paper makes use of ultrasonic and IR sensor elements to obtain the distance information of the surrounding. This information is used to generate proportional vibrotactile feedback which give the user the information of the direction, proximity and speed of the obstacles. This ultimately enhances the manoeuvrability of the user and thus help him in reaching his destination with reduce risks of accidents and increased sense of independence.

The paper describes similar approaches that have been made to develop economical Electronic Traveling Aids (ETAs) for the visually challenged. It then describes the architecture used in developing the project and its potential benefits to the user, the various hardware and software that has been use to develop the project. It then concludes with the general discussions and plans for future research in the project.

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II. RELATED WORKS

A lot of research has been made to develop Electronic Travelling Aids (ETAs) for the visually challenged to help them interact with their surrounding environment. A variety of approaches like sonar, laser, camera etc are used to obtain information from the environment and provide either vibrotactile or audio feedback to the user.

One of the most initial research conducted was of the C-5 lase cane which used optical triangulation for obstacle detection by using by using three transmitters and three photodiodes as receivers [11]. Another approach called the Navbelt which consisted a series of ultrasonic sensors wore on the abdomen and a computer which processes the information from the sensors and provides audio output to the user was made [8]. However the device was bulky and was unable to determine presence of stairs. Borenstein and Ulrich developed a robotic guidance system which made the use of sonar as the sensor element and Vector Field Histogram Algorithm (VFH) for obstacle detection. The VFH method is based on information perceived by an array of ultrasonic sensors (also called "sonars" throughout this article) and a fast statistical analysis of that information. The VFH method builds and continuously updates a local map of its immediate surroundings based on the recent sonar data history. The algorithm then computes a momentary steering direction and travel speed and sends this information to the mobile robot.

In order to make the system wearable and eliminate the need of using a stick, a sonar sensor device was attached to the user's jacket and the necessary feedback for navigation was provided through vibrators which were also installed in the jacket [6]. One of the recent works in this field is CyARM [4] that allows users to perceive distance and other spatial information without interference with natural sound sources and without cognitive or mental loads. The CyARM is connected to a user's body by a wire and measures the distance to an object with ultrasonic waves. The tension of the wire is controlled according to the measured distance to the object. This also gives the user the independence of selecting the direction of which he wants information. In order to make use of the advances in the field of image processing a guidance system is developed which makes use of two cameras which are installed on the glasses of the user. Images obtained from these cameras are converted to binary format and the regions where there is a possibility of detection of the obstacle is determined, the resulting images then undergo normalized cross-correlation. If the result of the cross-correlation is 0.9 then it confirms the presence of the obstacle and an audio notification to the user is send.

III. System Architecture

A. Block Diagram:

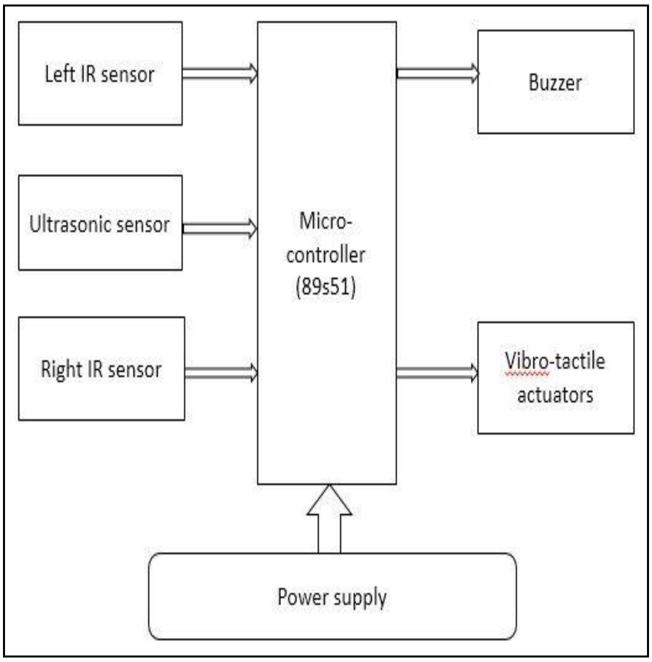

Fig 1: Block Diagram

Fig 1 represents the basic architecture of the system. We are using both IR sensors as well as the ultrasonic sensors as the sensing elements. The output of these sensors is given to the microcontroller 89s51. Vibrotactile actuators are attached to the handle of the stick which vibrate according to the distance information given by the IR sensors. An ultrasonic sensor is also used which helps the user to detect the obstacles above the waist height. The feedback to the obstacle above the waist height is given by the varying intensity of buzzer sound.

B. Sensors

Infrared Sensor:
The IR transmitter works at the carrier frequency of 38 KHz. The transmitter transmit for about 10ms after which the receiver module will start detecting any reflection from the nearby obstacle. The time of transmission is low compared to receiver module or else the receiver will treat any reflections as noise and avoid them. There are two such transmission and reception modules each covering an angle of about 45°. When an obstacle is detected the output of the IR receiver module becomes low. The time period between the transmission and reception of this pulse is used to detect the distance of the obstacle.

Ultrasonic Sensor:
The ultrasonic sensor is employed to detect the obstacle above the waist height. Whenever a 10µs pulse is applied to the trigger pin of the sensor the sensor emits 8 cycle burst at 40 KHz. It then waits until an echo is obtained. The distance from the obstacle will be proportional to the pulse width of the echo pulse. The timing diagram for the sensor is shown in fig 2.

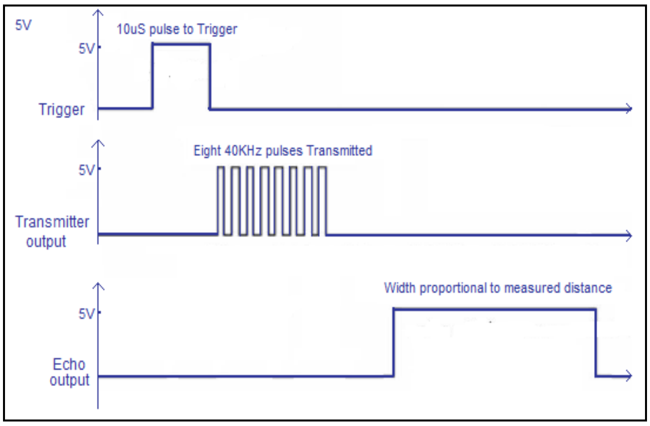

Fig 2.Timing diagram of Ultrasonic Sensor

C. Data treatment:

The microcontroller gathers the information from the ultrasonic transducers as Pulse Wide Modulation (PWM) signal directly proportional to the distance of the nearest obstacle. The microcontroller measures the width of the transmitted pulses and converts it into empiric distance. Similarly the time period is between the transmission and the low pulse from the IR receiver is calculated. The direction is given by comparison of the signal from both sensors. This distance is then converted into a voltage command for appropriate vibrating feedback. The system redirects this information to the actuators via Serial Peripheral Interface (SPI). A multichannel Digital Analog Converter (DAC) recovers 2 integers (address and data) and sends the desired output voltage to the appropriate vibrator [6].

D. Actuators

The actuators used to produce a vibrotactile sensation is composed of servo motors with an asymmetric mass attached to its axis. There are two such vibrators that are used each responding to the readings from IR sensor.

E. Buzzer

Buzzer responds to the output of the ultrasonic sensor which provides indication of any obstacle above the waist of the user. The intensity of the sound produced by the buzzer is proportional to the distance from the obstacle.

F. Power Requirement:

Each of the sensor employed in the project has a voltage requirement of 5 V and the current requirement of about 500 mA which enables the project to run with a standard 5 V NiMh battery for hours.

IV. Working:

The system employs two IR sensors that are present each having a field view of 45°. The horizontal field view of the sensor apparatus is given fig 4. Consider there is an obstacle to the right of the user the IR receiver will detect it and will make its output low. This will be use by the microcontroller to calculate the distance. Now the actuator to right side of the stick handle will vibrate providing the indication that there is an obstacle to the right. The intensity of the vibration is directly proportional to the distance from it. Even now if the user moves closer to the obstacle or the obstacle moves closer to the user the intensity of the vibration keeps increasing which helps the user to determine the motion of the obstacle.

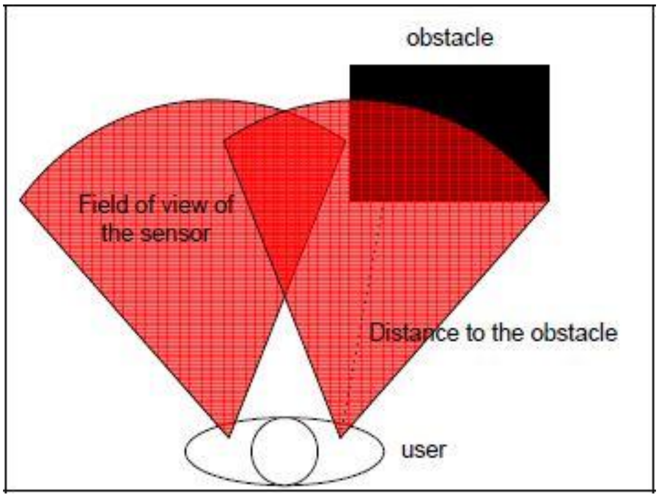

Fig 4. Field of view of IR sensor [6]

Fig 5 shows the detection of low hanging and above waist obstacles. Whenever there is a low hanging obstacle in front of the user the pulses send by the ultrasonic sensor gets reflected from them. This echo then will be used to calculate the distance of the obstacle by using the following formula

Range = high level time * velocity (340M/S) / 2

Similar to that in the case of the IR sensor the intensity of the sound from the buzzer increases as the user moves closer to the obstacle allowing him the necessary feedback to avoid the obstacles.

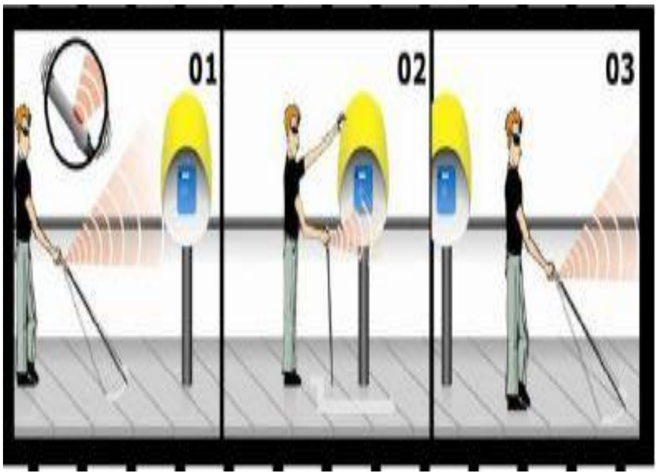

Fig 5. Ultrasonic sensor to detect above waist obstacles [2]

V. KEY COMPONENTS:

A. *AT89s51 Microcontroller:*

The AT89S51 is a 40 pin low-power, high-performance CMOS 8-bit microcontroller with 4K bytes of In-System Programmable Flash memory. By combining a versatile 8-bit CPU with In-System Programmable Flash on a monolithic chip, the Atmel AT89S51 is a powerful microcontroller which provides a highly-flexible and cost-effective solution to many embedded control applications.

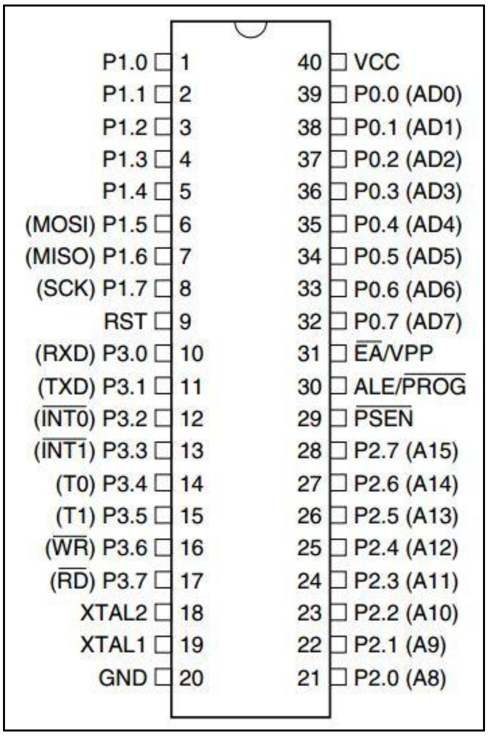

Fig Pin Diagram of 89s51 Microcontroller

Features:

- Compatible with MCS®-51 Products
- 4K Bytes of In-System Programmable (ISP) Flash Memory

– Endurance: 10,000 Write/Erase Cycles

- 4.0V to 5.5V Operating Range
- Fully Static Operation: 0 Hz to 33 MHz
- Three-level Program Memory Lock
- 128 x 8-bit Internal RAM
- 32 Programmable I/O Lines • Two 16-bit Timer/Counters
- Six Interrupt Sources
- Full Duplex UART Serial Channel
- Low-power Idle and Power-down Modes
- Interrupt Recovery from Power-down Mode
- Watchdog Timer
- Dual Data Pointer
- Power-off Flag
- Flexible ISP Programming (Byte and Page Mode)

B. *IR sensors*

IR transmitter output is modulated with a carrier frequency of 38 kHz carrier frequency. TSOP1738 acts as the IR receiver. It has an inbuilt pre-amplifier along with the photodetector. It is both TTL and CMOS compatible and consumes low power. The demodulated output can directly be decoded by a microprocessor.

C. *Ultrasonic HC-SR04:*

Ultrasonic ranging module HCSR04 provides 2 cm – 400 cm non-contact measurement function, the ranging accuracy can reach to 3mm.

VI. Future Scope:

The current device helps the user to navigate the obstacles in his path, however to increase the independence of the blinds it is necessary that they should be able to get information about the route to their desired location. This can be achieved by using GPS sensors and electronic maps like GoogleMaps. Further using the latest image processing techniques the user can also be able to detect what the object is.

VII. Conclusion:

The given system has been successfully tested in the indoors. In outdoors with medium crowd the system is found to be effective. In crowded places due to noise in surrounding there has been a lag in the response of the device leading to decrease in the performance. Although the device has been found to have significantly improved the manoeuvrability of the user.

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