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The Navaid –A Navigation System For Visually Challenged Obstacle Detection Using Ultrasonic Sensors

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Abstract: This paper presents an Electronic Travel Aid (ETA) for visually impaired and blind people. This device enables a blind user to quickly and safely walk through obstacle cluttered and unknown environments with a combination of eye glasses and waist belt. The foremost innovation of this device is its ability to actively guide the user around obstacles in pursuit of a given target direction. Using a network of ultrasonic sensors, this is possible. And special feature lets the system automatically determine the direction of travel when traveling alongside walls, sidewalks, etc. It effectively calculates the distance of the detected object from the subject and prepares navigation path accordingly avoiding obstacles. It uses speech feedback to aware the person about the detected obstacle and its distance. Such speech messages are conveyed to the subject using earphone.

Keywords: Electronic Travel Aid (ETA); Unknown Environments; Eye Glasses And Waist Belt; Ultrasonic Sensors; Feedback; Speech Messages.

I. INTRODUCTION

According to a survey conducted in 2009 by world health organization on disability, there are 300 million visually impaired and 50 million blind people worldwide. Aging populations and lifestyle changes mean that chronic blinding conditions such as diabetic retinopathy are projected to rise exponentially. Without effective major Intervention, the number of blind people worldwide has been projected to increase to 76 million by 2020 if current trends continue. Vision is by far the most important sense for most people, and trends in virtual reality and computer interfaces reflect this emphasis. Sighted people appreciate detailed images and are able to abstract relevant data from images with ease, and the challenge in virtual reality is not in abstracting the data but providing enough detail at sufficient speed. In contrast, the difficulty in presenting information to blind people is reducing information: non-visual channels are less direct and the available sensory channels have much lower bandwidth [1].

II. RELATED WORKS

In the existing systems, the device receives reflected waves and produces either an audio or vibration in response to detected obstacles. Recent navigation systems use digital video cameras as vision sensor along with other multiple sensors. These systems are quite bulky and involve physical interface with the subject [3]. In the recent system, images are captured using single or stereo video cameras mounted on a wearable system. Captured images are resized, processed further and converted to beeps, musical sound or vibrations. In such system frequency of sound shares, some relationship with the orientation of pixels, very few of them is in use [4]. With the concept of 'human-machine interface', an electric aid device was developed by using guiding orientation and locomotion [2]. The foremost disadvantage of the cane, however, is its failure to detect obstacles outside of its reach. Such obstacles include branches, signs, or any other obstacle protruding into the path above the user's waist [5]. Thus, the blind traveler is constantly in fear of collision and injury. Dog guides are considered the best travel aid available, but are very expensive, because of their extensive training. Thus, only a small percentage of blind people can benefit from dog guides [6]. We see two reasons for this. One is that the information is often presented as a continuous, or near continuous, tone, usually through headphones, whereas blind people need their ears to pick up other signals from the environment. The work on the auditory representation of the environment is encouraging as it shows the possibilities of using sound as a rich information system but does

not overcome this problem [7]. Furthermore, these devices must be used in a scanning function; a time-consuming task requiring a constant conscious effort by the user. Once an obstacle is detected, the conscious and active effort of the user is required to measure the relevant dimensions of the object and to plan a path around it; all the while scanning and looking out for additional obstacles. This procedure is time-consuming and straining, and does not permit fast travel. Some of these aids are Sonic pathfinder, Mowat-sensor, Guide-cane, sonic guide, Navi, Sveta, case lip.

III. PROPOSED DESIGN

An embedded system integrating some ultrasonic sensor pairs, APR9600 audio recording and playback flash memory, earphone with an AT89S52 microcontroller. In this wearable system, two ultrasonic pairs are mounted on the eyeglasses and rest of the pairs is mounted on the customized waist belt.

This system scans the environment with the sensor pairs and simultaneously calculates the distance between the obstacles. The strength of the obstacle detection is based on its gradual reduction of data complexity (from multiple sensors) to a level suitable for real-time guidance of human beings. It also has a button provided at the side of the system (belt) that alerts the nearby person in case of any emergency or help. A GPS is attached in this system so that whenever the person wants to send his/her location to someone (whose number is fed in advance). This device has its ability to actively guide the user around obstacles in any direction. The system automatically determines the direction of travel when traveling alongside walls, sidewalks, etc.

A. Abbreviations and Acronyms

- ETA: Electronic Travel Aid was mainly designed for physically challenged to aid them in navigating the routes or paths.
- GPS: Global Positioning System that provides the location and time information in all weather conditions anywhere on Earth.
- EPWHT: Echo Pulse Width high Time is the time required for the sound signal to travel twice between the source and obstacle.
- SV: Sound Velocity, the distance travelled per unit time.
- D: Distance
- PWM: pulse width modulation is a technique for getting analog results with digital means.

B. Units

- cm - Centimeter used for measuring distance.
- dc – Direct Current is the unidirectional flow of electric charge.
- mA – milliampere for measuring current.
- TTL-Transistor-transistor logic is a digital logic design in which bipolar transistors act on DC.

C. Equations

i) Obstacle Detection

Ultrasonic sensors are used for obstacle detection and calculation of its adaptive distance from the visually impaired person. Ultrasonic pairs are used in pairs as transceivers .one device which emits the sound waves is called transmitter and the other which receives the echo is called receiver. This sensor works on the principle similar to radar or sonar which detect the object with the help of echoes from sound waves rather than light for object detection, so can be comfortably used in the ambient outdoor application.

INPUT

Working voltage: 5v (DC)

Working current: 15mA

Input Trigger signal: 10 us impulse TTL

OUTPUT

Echo signal: PWM signal. The time required for a sound signal to travel twice between source and obstacle.

RANGE: 3 meters

ii) Distance Calculation:

For distance calculation following equation is used:

$$D = [(EPWHT) * (SV) / 2]$$

Before concluding the obstacle distance from the person, repeated information sampling and averaging are performed. As ambient light conditions do not affect ultrasonic sensors, object detection, and distance calculation can be performed accurately.

D. communicating Features For Navigation

The time of flight sonar sensors we have discussed throw away far too much information to be useful in feature recognition. In this section, we describe the ultrasound sensor, which is proving useful for extracting certain types of feature information. We describe the sensor briefly, the information which it provides and then possible interfaces to the user.

i) Principle of Operation

The sensor consists of a separate transmitter and receiver. The frequency of the transmitter is modulated in a known pattern, and the frequency of the signal being transmitted is compared to that of the signal at the receiver, which was transmitted some time ago and has now returned after reflection.

ii) Reception of transmitted signal and energy

Because of the long wavelength of ultrasound (a few mm), the amount of energy reflected back to the receiver depends strongly on an angle. When there is less energy, the peak spreads even for smooth surfaces because of the effects of noise. However work based on modeling following suggests that this can be exploited to determine the angle of the reflecting surface; for example the angle of a wall. This again could be a useful indicator for navigation.

IV. COMMUNICATION BETWEEN SYSTEM AND SUBJECT

This system can understand 3 meters distance object in any direction .this system announces calculated real time distance as it is in meters or centimeters using speech messages .to make distance understanding more appealing to the subject, speech message can be stored in a universal language.

A. Speech warning messages

Many systems uses vibration array, buzzer based audio frequency clips or text to speech conversion for announcing any detected condition to the subject [2] [3]. It uses APR9600 audio recording and playback flash memory. It can store variable duration speech message up to 60 seconds duration. A number of messages can be increased by reducing the duration of each message. AT89S52 microcontroller processes real-time data collected by the ultrasonic sensor array and take the correct decision. Based on processed data, the correct decision is taken and relevant message is invoked from the flash memory and conveyed to the subject through the earphone.

B. Flexibility to use any language

Many systems are converting the text into English language only. As this system uses APR9600 flash memory to store the prerecorded speech message there is no barrier for usage of any language. Any appealing universal language can be used for recording speech warning messages. This system offers a simple mechanism for recording and storing such speech warning messages.

C. Alerting System

The alert or emergency button is provided at the side of the system (belt) that alerts the nearby person in case of any emergency or help. It will be audible to nearby people.

V. SYSTEM DESIGN

Using this placement (fig 1.1) and alignment of ultrasonic sensor pairs, the subject can detect obstacles from waist level height to head level height in the range of 3m in any direction. These five pairs of ultrasonic sensors collect real-time data after 20ms and send it to microcontroller after processing this data, microcontroller invokes relevant speech message stored in flash memory is used for storing pre-recorded speech messages. Variable duration of speech messages up to 60 sec duration can be stored in this memory.

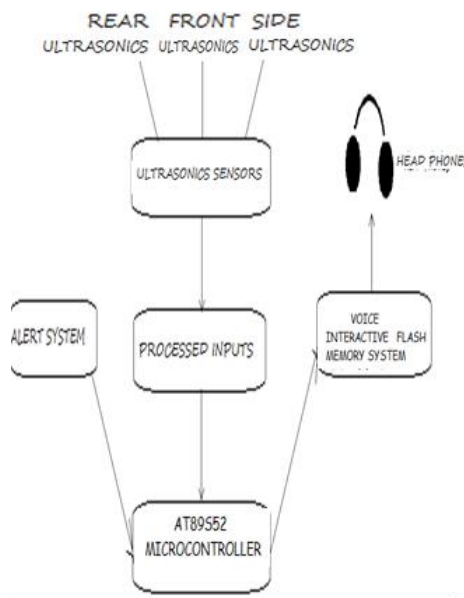


Fig 1: Shows the workflow of the system

AT89S52 microcontroller

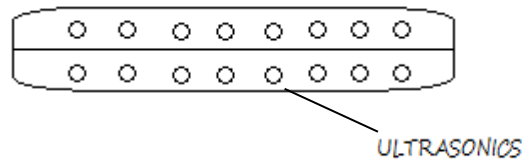


Fig 1.1 placement and alignment of ultrasonic sensors

Ultrasonic sensors as the testbed for our experiments. A blindfolded test was able to walk quickly fig1.2 (with the aid of this device) through a difficult obstacle course. The average speed of the system in a typical experiment was 0.51 m/sec, and the maximum speed was 0.78 m/sec (this is the maximum speed of the person). With this experimental setup, the test-person was completely unaware of how far he had driven and how much he had turned information considered crucial for efficient travel.

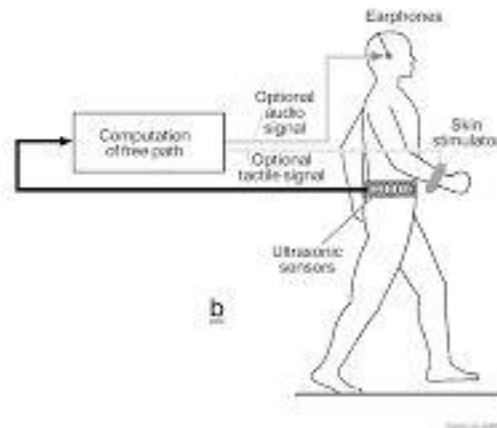


Fig 1.2 Testing done using blindfolded person

VI. RESULTS AND DISCUSSIONS

1) The table I shows the distance in centimeter and corresponding voice messages with the distance in meters. The distance is calculated irrespective of the speed in which the blind user walks.

TABLE I. DISTANCES MEASUREMENT

s.no	DISTANCE IN CENTIMETER	FORMAL DISTANCE SCALING (WITH SPEECH MESSAGE)
1	Less than 70 cm	Object is very close
2	70-99cm	Object is at 1m distance
3	100-199cm	Object is at 2 m distance
4	200-299cm	Object is at 3m distance
5	300-399cm	Object is at 4m distance
6	400-499cm	Object is at 5m distance

Ultrasonic sensors, AT89S52, and APR9600 are tested individually as well as an integrated system. As ultrasonic sensors work on the principle of echo, the study of its reflection properties on the different object surface is very important. Four such tests are carried on a concrete wall, static human body, wood, and metal. Surface smoothness plays a vital role in obstacle detection. The smooth surface object can be detected from a maximum detection range of ultrasonic sensors. Metal surface gives highest reflections and then the concrete wall, wood, and the human body. These four surfaces are considered for testing as a subject can come across any of them during navigation. We performed several experiments in order to assess the feasibility of our system. People are far better than computers at recognizing patterns, but the presentation of large amounts of raw data can overload the sensing systems available to the blind.

VII. FUTURE DEVELOPMENTS

This system encourages a great variety of future developments. The most obvious and immediate expansion of the system would aim at incorporating a global navigation aid (GNA) into the ETA. An integrated GNA/ETA system would work as follows: First, the user specifies his or her present location, as well as the target location (e.g., the grocery store on Main Street). Next, the GNA computes an optimal path between the starting position of the user and a known target location. The path comprises a list of via-points, typically vertices of straight line segments. This way, the OAS always receives a new target location (namely, the next GNA-generated via-point), and the guidance mode can be used. This is desirable since the guidance mode is easy to follow and allows for fast travel. In order to generate a path, a map of the environment must be known to the system. In urban environments,

regular street maps would be used. Computerized versions of such maps are already commercially available. For indoor applications, such map would comprise data on corridors, walls, doorways, etc. In the future, public buildings like hospitals, schools, government agencies, etc., may offer electronic map information at their entrances. This information can then be downloaded into the user's computer.

A GNA for optimal path planning has been one focus of our mobile robotics research [7] and is implemented on our mobile robot CARMEL [8]. Certain improvements can be made to the system. Detection of obstacles, Recognition of colors, Recognition of obstacles. Considering the expectations and requirements of the visually impaired and blind people, this system offers a low cost, reliable, portable, low power and robust solution for smooth navigation. Though the system is light weight, but hard wired with the sensor and other components. Further, it can be improved with wireless connectivity between the system components. This system is developed considering the visually impaired and blind people in developing countries.

CONCLUSIONS

This wearable electronic navigation system requires less training time; the system can be used for outdoor navigation. To show the feasibility of this transfer of technology, we have designed and tested the system suitable for real-time guidance of blind travelers. We have also investigated the commercial availability of components required for a portable system. We have further analyzed the electrical power requirements and weight and size constraints of these components. It was determined that the total power consumption of all necessary components is 18 W. The total weight of the portable system, including rechargeable batteries for 2.5 hours of continuous operation, is 1.2 Kg. All components can be packaged into a volume of 12"x6"x4".

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