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Dynamic Environment Exploration Tool: A Blind's Eye

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Abstract-One of the most challenging problems for visually impaired people is navigation. Usually they have to be dependent on other people to navigate their way. A wearable navigation system which can determine the obstacles and drop-offs can help blind people to walk with confidence even in unfamiliar outdoor environments. Many electronic travel aids have been developed recently to help them navigate independently even in unfamiliar or changing environments. Here, we propose an intuitive, economic and wearable device which focuses on removing the mobility problems of visually impaired people and thus replace the commonly used white cane.

Keywords: Electronic Travel Aid, white cane, sensor, actuator, microcontroller, navigation

1. Introduction

Vision plays a very important role in one's life. Most of the information which humans receive from the environment is obtained through eyes. Unfortunately a lot of people lack this ability due to different reasons. According to World Health Organization (WHO), around 285 million people are estimated to be visually impaired worldwide of which 39 million are blind and 246 have low vision [1]. In particular there are more than 7 million blind people in India. Without vision, visually impaired people suffer from various problems in their day to day activities. Blind people can use Braille to read the printed material but the biggest problem is to navigate around without hitting into obstacles [2]. Mostly they have to depend upon guide cane or someone to assist them to navigate their environment. Thus, this is a challenging task for scientific community to develop a device that can help visually impaired people to get information about the environment and navigate in known and unknown environments independently with confidence.
The category that we will focus in this work is the "vision substitution." It can be subdivided into following subcategories as Electronic travel aids (ETAs), Electronic orientation aids (EOAs) and Position locator devices (PLDs) [3].

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We are most interested in ETAs and more specifically in obstacle detection systems, not emphasizing in GPS features. The National Research Council has specified guidelines for ETAs [3] to be efficient and reliable. ETA's are the devices that transform information about the environment that would normally be relayed through vision into a form that can be conveyed through another sensor entity.

The most common aids used by blind people are white cane and guide dogs [4, 5]. The white cane is economical and long lasting but not all visually impaired people prefer the cane or are able to use it efficiently. The cane is not suited to social gathering or in public transportation, and in congested areas. The temporal and spatial resolution of a cane is poor and potential for error is correspondingly high. Guide dog is expensive and has a short span of life. The problem of navigation for blind can be efficiently solved by using ETA's.

The paper next the section 2 gives the details of similar products in the domain or the related work done in this domain. Section 3 is about the System Design with details of generic ETA design and design of proposed device. In section 4, the how the end product look like is shown. And finally paper is concluded in section 5.

2. Related Work

Many costly devices exist to assist visually impaired people for navigation. Number of software companies and research institutes are working on projects to provide navigation aids to visually impaired people. Navbelt, vOICe, NAVI and VAS are among popular navigation aids which employ image to sound conversion.

Navbelt: Navbelt is developed by Borenstein and coworkers in University of Michigan [6] as a guidance system, using a mobile robot obstacle avoidance system. It comprises of a belt with eight ultrasonic sensors mounted in front and a portable computer which are worn as backpack.

vOICe: vOICe used video camera as vision sensor [7]. When the scanner picks up across the image, a complicated dynamic sound with chords and melodies is produced [8, 9]. However, this system is very simple, lightweight, small, and cheap.

NAVI: NAVI's earlier system consists of two cameras as the vision system [10, 11, 12]. Object's size and location in the visual plane is relayed to the blind user in structured coded sound while the information of distance is represented by verbal sound. Improved NAVI's new methodology is to extract objects by using closed boundary extraction in color image and also add on noise elimination procedure. The mechanism of NAVI is alike voice but its image processing algorithms are fine developed.

VAS: VAS is a research and development project using the perception of space which uses sound [13]. This is a portable electronic prototype oriented to sensory substituted and allows human auditory capability of perceiving complex spatial patterns using a three-dimensional matrix of virtual sound sources, creating a virtual acoustic world.

Tyflos: Tyflos navigation system was conceived by Bourbakis and workers in the mid-1990s and various prototypes have been developed [14, 15, 16]. The Tyflos navigation system consisted of two basic modules: the Reader and the Navigator (ETA). The main goal for the Tyflos system is to integrate different navigation assistive technologies such as a wireless handheld computer, cameras, range sensors, GPS sensors, microphone, natural language processor, text-to-speech device, and a digital audio recorder, etc., and methodologies such as region-based segmentation, range data conversion, fusion, etc., in order to offer to the blind more independence during navigation and reading.

3. SYSTEM DESIGN

3.1 Generic Approach

Any kind of ETA involves 3 main phases of work, which thereby can be realized as three components of system. These are Sensation (Input), Processing and Actuation (Output).

Sensation: collect information from the environment. This information includes distance information of objects around the user, identification of objects or person in front and reading the text present if any available in his front. Information from environment can be collected using Infrared, Laser, Ultrasonic sensors and vision camera too.

Processing: It involves processing the information received from the range sensors. By using sensors, the information to be processed will be in the form of voltage signals by which we can get the distance information of obstacle pointed by the sensor. This distance calculation / processing can be done by microcontrollers as atmega, ARM and microchip PIC.

Actuation: This involves communicating the information obtained from the previous step to the visually impaired user. Here microcontroller will give signals as output and according to these output we will activate the vibration motor (an actuator). An actuator is a device which takes some form of energy and coverts into motion. This actuation or output generated in form of Audio / Speech signals for instructing blind person for moves to be performed. Audio-based output techniques are not suitable when the environment is noisy or when a user is hearing impaired too. Another mode of actuation could be Haptic interface. In this, textual directions can be provided to the user using a haptic glove approach where users wear six vibration-motors worn on fingers, such as Finger-Braille [19]. Haptic directions can be provided for example by using vibrotactors on a waist belt or in a backpack [20]. Some form of haptification (e.g, changes in frequency and intensity) is used to indicate the angle or distance between the user and the target destination.

3.2 Proposed Design

Having looked the available products in the domain, and various trades off in the design specifications, it is found that these products have some or other merits and/or demerits. The various design considerations generally taken while engineering a product or more specifically we had taken care are…

- Device should be truly useful to visually impaired people and capable of replacing the white cane altogether.
- Device should be capable of determining the obstacles within a range of at least 2 meters.
- It should detect steps and drop-offs efficiently.
- Device should be wearable i.e. it should not be too bulky or heavy and user must be comfortable in carrying the device.
- Device should be inexpensive and easily available. It should be open source so that anyone can assemble the device with basic electronic skills.
- Device should possess an intuitive interface that user can adapt quickly.
- Output should be provided in a form which visually impaired people can understand quickly.

The prototype proposed for this environment exploration tool consists of a microcontroller, range sensors and vibration motor or audio output. The position of obstacle with respect to the user is taken as the most important aspect for navigation using this tool. The user will be able to provide mobility help to the user in unknown environments because it collects the range information dynamically from the environment and gives tactile and audio output easy to understand. To collect the range information from environment user can swing the device around and thus can prepare a mental 3D image of the environment. For the best working of such a device it is necessary to consider the sensory qualities of the skin and comfort of the user. The sensory receptors of fingertips are quite good and therefore we try to give our tactile output near fingertips. Also it is easily accessible and user can swing around the device in a manner similar to traditional white cane.

As a generic approach our device has 3 components as Sensor, Processor and Actuator, working sequentially in a phases. A working model can be seen in Fig 1. The design description of each phase is discusses next.

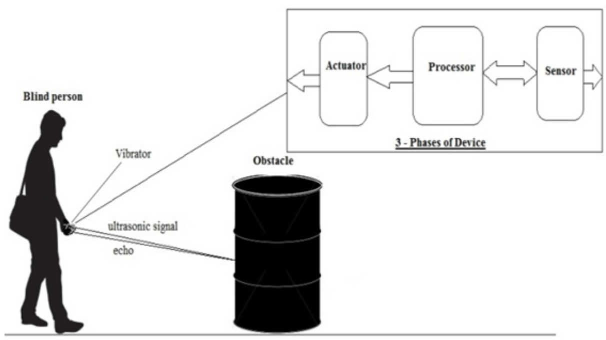

Fig 1 Working model of the Device

3.3 Sensor

By analyzing various sensors, we have chosen Ultrasonic sensors for our device. In Ultrasonic sensors, signal measurement is independent of material and color of obstacles. It works in all light conditions - bright, dark, glaring or dim. Suspended particles like dust, steam, smoke does not affect the measurements. These sensors are economical and easily available and also have better accuracy and range is up to 2-4 meters.

Pin configuration of an onboard SRF05 Ultrasonic sensor is shown here in Fig 2.

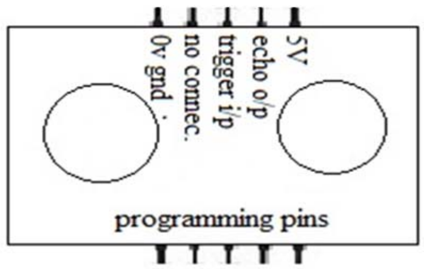

Fig 2: SRF05 Ultrasonic Sensor

3.4 Processor

We are using NXP LPC11U24 microcontroller for processing output from the sensor. This microcontroller is based on 32-bit ARM® Cortex™-M0 architecture and designed for prototyping battery powered applications and low cost USB devices. Some other features which make it more appropriate are low power and lightweight online compiler. NXP LPC11U24 includes a built-in USB programming interface that is as simple as using a USB flash drive.

Program can be written in embedded C or Assembly language. An online program editor and compiler is used for this microcontroller (mbed.org/compiler). After successful compilation of program, we just need to copy the compiled program (Hex format) in microcontroller's flash drive.

3.5 Interfacing between SRF05 and LPC11U24

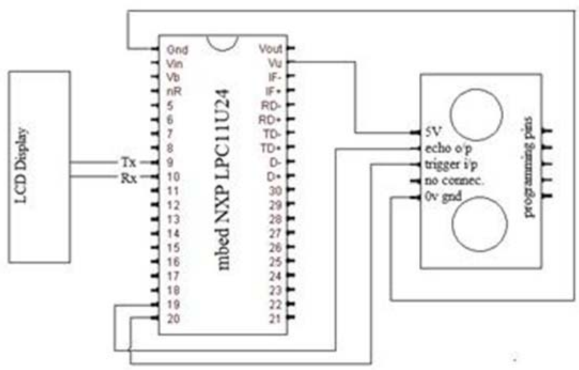

Fig 3: Interfacing

Fig 3 gives the schematic for the interfacing between microcontroller and ultrasonic sensor. Here, two analog I/O pins of NPC11U24 are configured to handle the Echo and Trigger lines of the SRF05. The ECHO output pin of sensor is wired up to pin 19 of microcontroller. This is the line that will receive the echoed pulses measured by the SRF05 ranger. The Trigger input pin is wired to the pin 19 of LPC11U24. This is the pin that will send a 20 µs pulse to initiate the sonic bursts by the ranger.

3.6 Distance Calculation

You only need to supply a short 20µS pulse to the trigger input to start the ranging. The SRF05 will send out an 8 cycle burst of ultrasound at 40 kHz and raise its echo line high. It then listens for an echo, and as soon as it detects one it lowers the echo line again. The echo line is therefore a pulse whose width is proportional to the distance to the object. By timing the pulse it is possible to calculate the range in inches/centimeters or anything else. If nothing is detected then the SRF05 will lower its echo line anyway after about 30mS.

The SRF05 provides an echo pulse proportional to distance. If the width of the pulse is measured in µS, then dividing by 58 will give you the distance in cm, or dividing by 148 will give the distance in inches.

µS/58=cm or µS/148=inches.

The SRF05 can be triggered as fast as every 50ms, or 20 times each second. You should wait 50ms before the next trigger, even if the SRF05 detects a close object and the echo pulse is shorter. This is to ensure the ultrasonic "beep" has faded away and will not cause a false echo on the next ranging.

3.7 Actuator

Audio and tactile stimuli are most suitable for giving output to the user. So for generating output in these two modes, actuators needed are speaker/buzzer for audio and vibration motor for tactile stimuli.

Vibration motor: This is the best way to warn the user about the presence of obstacles. Based on the distance of the obstacle we can divide the range into various levels. Now, the distance of obstacle determines the intensity of vibration to be given to user. Closer the obstacle vibration of higher intensity must be provided to the user.

Speaker/Buzzer: Buzzer can be used to identify different kind of threat to the visually impaired user. For example in case of a drop off or an object moving toward the user we can give a different output to the user so that immediate action can be taken by the user. Speech output can be used to sudden inform the person with some predefined words.

4. End Product

After analyzing the feasibility and availability of tool, a hand glove was selected as the most appropriate design for the tool. It will be having sensors, vibrator and a camera on its fingers. Glove is equipped with a microcontroller in the middle and a battery on wrist of it. Sensor will sense the obstacles in front of it, if present and will send signal to the microcontroller. Microcontroller will calculate the distance and vibrate the finger if distance if lesser than a threshold value. Threshold value may be set to 1 meter.

Fig 4 shows the end product in the expected shape.

Fig 4: The end product

5. Conclusion

The designed device is practically examined and found to possess the design constraints for an effective Electronic Travelling Aid. The device is capable of determining obstacles even in very small range. It is inexpensive, small, wearable and easy and comfortable to use. As well, the device is power efficient, which avoids the problems regular battery replacement.

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