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Design & development of a bone conduction based navigation aid for the visually impaired

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Abstract—Blind assistive technology has been a significant area of research and development over the last decade. This paper reports the design and development details of a navigation-aid for obstacle sensing and alerting the visually impaired via bone- conduction. This device can detect head-height obstacles, at distances ranging from 0.20 to 3 meters. A microcontroller ATMEGA 328 generates impulses as alert signals for a vibrating actuator, which communicates to the brain through bone conduction. The entire module is designed to be housed in a comfortable headband, which weighs around 300gm and operates at low power with a 400mAh battery. The device was tested on more than 100 visually impaired subjects and the false positives were zero.

Keywords—*Bone Conduction, Visually Impaired, Transceiver, Navigation, Audio Amplifier*

I. INTRODUCTION

Blindness is a sensory disability that demands paramount attention since visual disability governs one's lifestyle and connectivity with the rest of the world. As per the global data on visual impairment by WHO (2010), 285 million people are reported to be blind in the world, out of this a staggering 39 million are completely blind with irreversible damages to eye[1].

In the recent years, people with visual impairments have been assisted by well-trained dog-guides, white canes, and wearable devices[2]. Visual impairment limits a person's mobility and reduces travel-related activities [3]. The level of life's quality and self-confidence can be greatly enhanced if they are enabled to travel independently.

Locomotion by walk is integration of two segments; Sensing the environment for the detaction of obstables and hazards[4], and appropriate feedback. In this work, a navigation aid is developed to assist the visually impaired subjects. The methodology is based on detection of ultrasonic pulses reflected by the head-level obstacles using a transceiver module housed in a wearable headband.

The band additionally employs an inverse-transducer module to alert the user through appropriate tones via bone. As an additional feature, an audio player with arrangements for audio streaming is employed.

II. LITERATURE SURVEY

Several works on the development of assistive devices for the visually impaired have been reported, with varying Features. The distances to objects are typically measured using sonar principle in which ultrasonic transducer sets up a burst of echoes, which is sent and received back. The round trip time is taken as a measure of the distance.

When the visually impaired subject is alerted with tones via bone conduction (BC), the algorithm for speech enhancement supported by a BC microphone is reported in a work [5]. The utilization of a bone-conducting sensor worn on the neck appeared to enhance the performance of a codebook-based speech improvement framework for non-stationary noise suppression, while decreasing computational difficulty[6].

Guide Canes are useful in guiding the blind person, by incorporating ultrasonic principle[7]. Smart Cane is a modification of the traditionally used cane. Rechargeable batteries power the system. This eliminates the inconvenience of replacing batteries and dependence on others. Upon this work, feedback system became decisive movements for the visually impaired population[8].

III. IMPLEMENTATION

Since the visually impaired subjects depend heavily on their hearing senses, this work uses an alternative method of alerting them without disturbing the hearing canals. The special feature of this work is in terms of alerting through bone-conduction. Further, based on the measured distances, the tones of the alerts are varied to enable the subject better estimate the distances.

While the obstacles are detected based on the reflected ultrasonic pulses, the subjects are alerted by a vibrating actuator suitable integrated onto the wearable head-band. The entire module is controlled by microcontroller boards of small foot-prints which can be accommodated on the band. The user comfort is considered throughout the design and development work, and prototype model is discussed in the final section.

The block diagram of Figure 1 depicts the scheme of project implementation.

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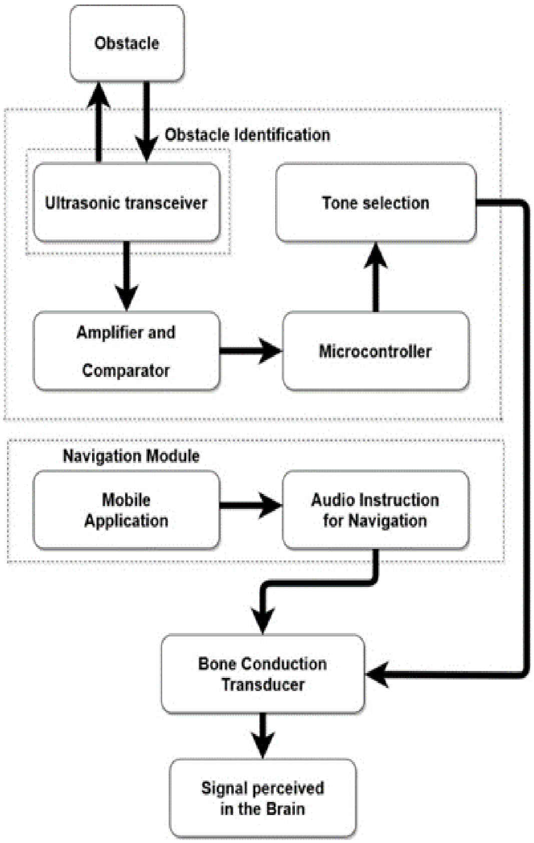

Figure 1: Project Implementation

Each block is explained with reference to Figure 1; Ultrasonic Transceiver sends out bursts of signals (20 pulses at 40 kHz frequency)with a time gap of 33ms. Received signal is fed to the amplifier, which gives a gain of 38 dB, subsequently, this signal is fed to an envelope detector and a comparator set to a threshold value of 2.3V (established on an experimental basis). When the comparator output goes high, the tone is streamed to the bone conducting module, and this alerts the user about obstacles [9]. This is depicted in Figure 2.

The waveform shown in blue color represents the echoes sent by ultrasonic module, the second echo is the received response which makes the comparator output high.

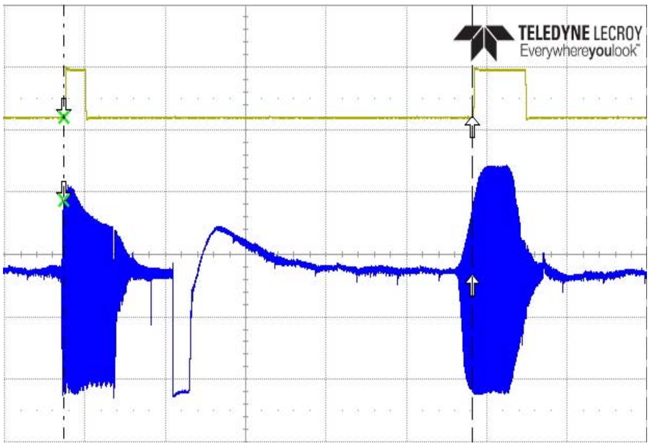

Figure 2: Transceiver and Comparator output waveform

Timing and voltage measurements made for a typical test case are depicted in Figure 3 and Figure 4. ΔX gives the time interval between echoes.

Figure 3: Voltage Specifications for transceiver and comparator

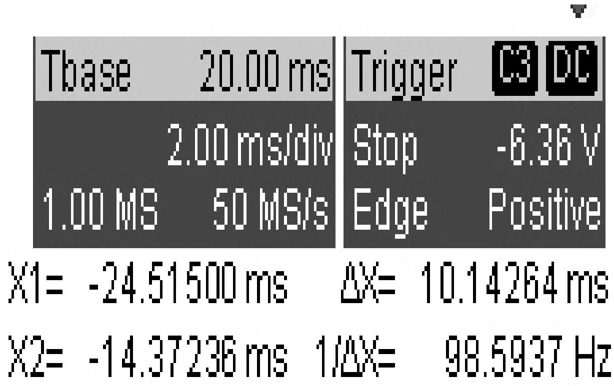

Figure 4: Timing details of ultrasonic pulse

Formula for distance calculation is provided in Equation 1:

$$D = \frac{time\ interval\ between\ echoes\ (ms) * speed\ of sound\left(\frac{m}{s}\right)}{(2*1000)} \quad (1)$$

In Equation 1, the factor of 1000 in the denominator is to get the distance value in meter, and ½ is representative of half the time taken by echo to hit the obstacle and reflect back to the transceiver [10].

Therefore, distance from obstacle for the typical measurement case mentioned earlier is found to be

$$D = \frac{10.14264 * 340}{2000} = 1.724\ m$$

Manual measurement using a standard measuring tape gave the distance value to an accuracy of 96%.

The microcontroller generates the input tones using PWM pins. LM386 is employed to amplify the signals and the circuit is shown in figure 5. The amplifier design helps in choosing a tone according to the obstacle detected; the level of alerting can be modified because the amplifier gain in audio frequency range is constant at 26dB as seen in Figure 6[7].

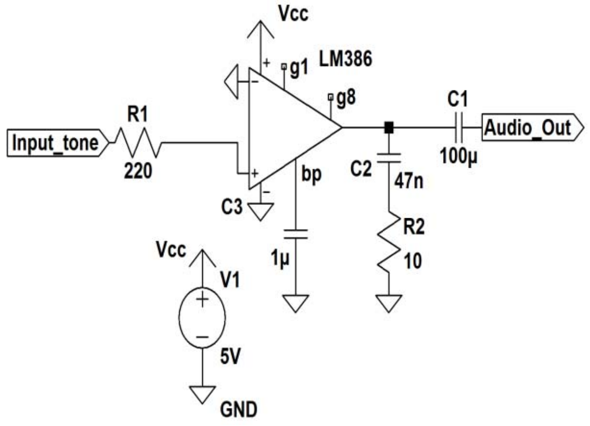

Figure 5: Audio amplifier

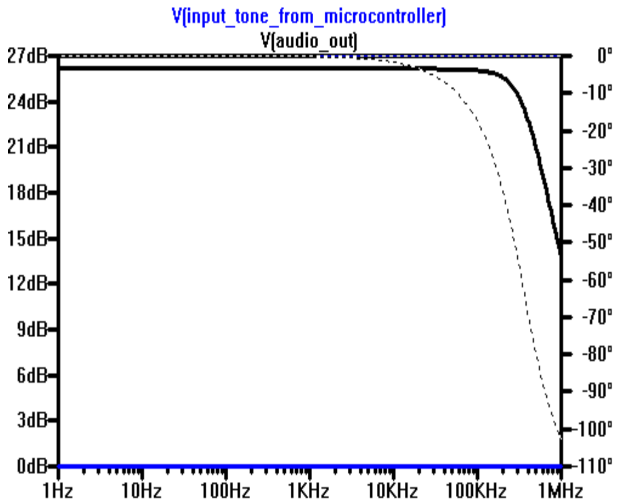

Figure 6: Gain obtained from Audio Amplifier

Navigation module has a mobile application which streams audio instructions that help the user to navigate. The application gives audio instruction to the user through bone conduction transducer[11].The instructions are simple and easy to understand.

Depending on the variations in the distance between user and obstacle, the intensity of the audio tone varies. The microcontroller is the decision-makingunit for varying the tone intensity[12].

Figure 7 illustrates the process flow from transceiver output to the amplifier stage. Based on the outcome of the decision (whether theobstacle is detected or not) the distance of the obstacle from the user is calculated to alert him accordingly.

For example, higherfrequency tones can be generated when the distance is less and vice versa[13].

The ultrasonic module scans the surrounding environment for obstacles if any. When the presence of an obstacle is sensed, the module sends out pulses to measure the actual distance from the obstacle. Then the microcontroller helps in deciding the tone to be played, selected tone is played by bone-conduction transducer.

Audio files were saved in SD card, and using 3.5mm jack; sounds were streamed to the bone-conduction transducer. This is a key highlight of the device and also of the prototype given in Figure 10.

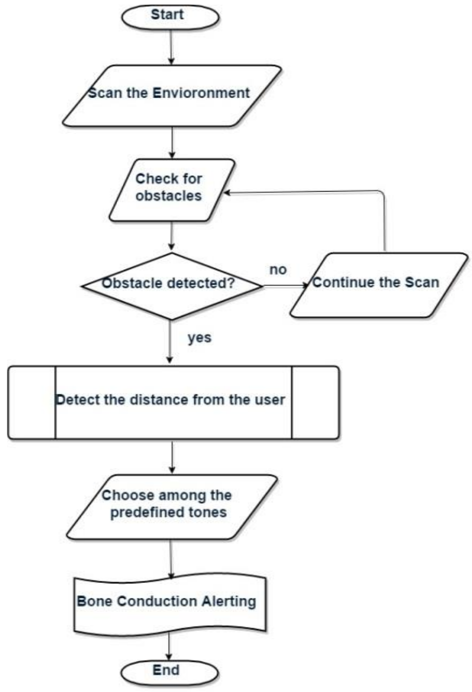

Figure 7: Flow chart for obstacle detection

IV. RESULTS AND DISCUSSIONS

Table 1 gives the various chosen notes and their characteristic values of frequency

TABLE 1: CHARACTERISTIC VALUES OF MUSICAL NOTES

Note	Frequency (Hz)
G_3	192
$A^{\#}{}_3/B^{b}{}_3$	228
B_3	242
C#4/Db4	272

These frequency values are used to activate the bone conduction alerting module. At these frequencies, the sound intensity remains constant since the amplifier gain is flat as depicted in figure 6. This is a desirable feature to have in the module.

Floor plan of the testing environment is given in Figure 8. As shown, the boundaries, walls, pillars, door, table corners and fridge are other obstacles

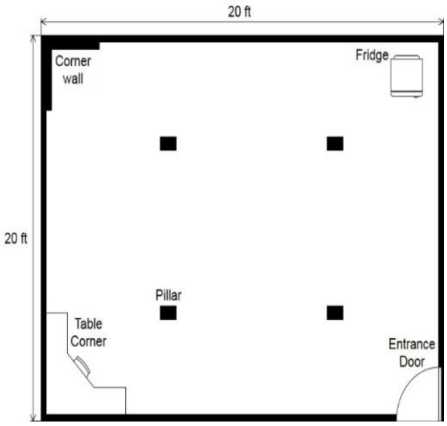

Figure 8: Floor plan of testing environment

Users were made to move around this environment either at normal speeds or at varying speeds towards the obstacles. The latter was required to measure the number of false alarm cases and were found to be zero .One observation made by this experiment was, the subjects with peripheral vision could detect the edges of obstacles far better than those who were completely blind, irrespective of the speed at which they moved towards that particular obstacle. Figure 9 is, the user testing out the prototype.

Figure 9: User testing

The complete working prototype of the wearable head-band is depicted in Figure 10.

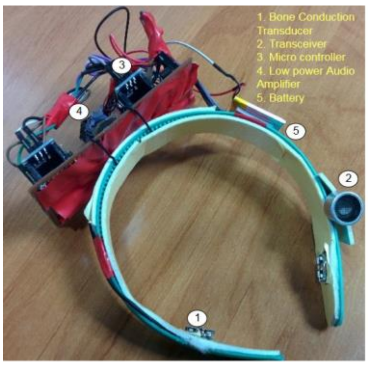

Figure 10: Working Prototype

Major advantages of this design are listed below:

- Upper body level obstacles are detected
- Alerting is reliable via bone-conduction
- The navigation alerting is easy to understand

CONCLUSION

The users were alerted well in advance before they could run into any obstacle. User testing was done in a trained environment with them wearing our prototype on their head.

The feedbacks obtained during the sessions were used to repeatedly iterate the testing in simulated conditions, such that the repeatability of the experiments was put to test and stability of the output was improved. Obstacles at distances ranging from 0.2 to 3 meters were detected. The vibrating actuator alerted the user about how close they were to the obstacles. The users also found the device to be easy to wear and use.

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