# Obstacle avoidance system for blind and deaf people

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***Abstract :*** In this paper, we have proposed a system of obstacle avoidance for blind and deaf people using ultrasonic range finding sensors and bone conduction technology. In our system, we have created an ultrasonic glove on which the ultrasonic range finder is mounted which communicates the presence of an obstacle to the person's android phone via Bluetooth communication protocol. The visually impaired person's phone has an app that communicates this message via the bone conduction headphones that is placed on his skull. as the person is hearing impaired due to malfunctioning of the eardrum, bone conduction technology directly excites his cochlea that gives him a sense of hearing.

***Index Terms*** **- Obstacle avoidance, bone conduction, Ultrasonic range finder, Bluetooth communication, Android application.**

## I. INTRODUCTION

Visually impaired people would like manual to facilitate for day to day locomotion in unknown surroundings. In alternative cases, they use sticks to come up with sounds that are typically not terribly reliable. So, we've designed a system for Obstacle turning away for blind individual's mistreatment supersonic sensing element module enforced in an exceedingly glove. The sensory receptor for blind with supersonic Glove, is intended to assist the blind to beat the shortage of sensory system, by mistreatment alternative senses like sound and bit. It uses string messages to advise the user concerning future hurdle. because the distance between glove and obstacle decreases below a specific level, a message is shipped to the phone via the Bluetooth module. Thus, the system helps to ease the navigation method for the poverty-stricken. For sensing the gap, the system uses a HC-SR04, associate degree supersonic vary Finder Distance sensing element Module. The sensing element module is intended to live the gap mistreatment the principle of asdic, mistreatment supersonic waves to see the gap of associate degree object. The system conjointly consists of a Bluetooth module to come up with messages that are communicated to the mobile app put in within the phone. HC-05 could be a Bluetooth module that is intended for wireless communication. This module is employed in a master or slave configuration. it's varied up to 100m that depends upon transmitter and receiver, atmosphere, geographic and concrete conditions. it's IEEE 802.15.1 standardized protocol, through that one will build wireless Personal space Network (PAN). It uses frequency-hopping unfold spectrum (FHSS) radio technology to send knowledge over air. It uses serial communication to speak with devices. It communicates with microcontroller mistreatment interface (USART). Bone conductivity is that the conduction of sound to the sense organ through the bones of the bone. Bone conductivity transmission is used with people with traditional or impaired hearing. unremarkably we tend to hear sounds conducted by vibrations within the air that cause vibrations on our tympanic membrane, that is thought to be external ear. These vibrations are sent to the tube-shaped structure that then sends signal to our brain. The tube-shaped structure is a component of the sense organ. as a result of the tube-shaped structure is embedded in bone It will capture vibrations from anyplace within the bone.

## II. RELATED WORK

Previously, many such solutions have been created and implemented where blind people are helped with their day to day locomotion with sensor feedback systems. Here is a list of the most important projects with a brief description for each one. We will study these systems taking the above guidelines into consideration and then give some comparative results to answer the questions of how advance, useful, and desirable each system is.

### 2.1 Echolocation

The main goal of this project, that started within the early Nineteen Nineties in Japan, was to style a replacement quality aid shapely when the bat's locating system [5]. 2 inaudible sensors are connected on standard eyeglasses and their information, employing a microchip and A/D convertor, are downconverted to a stereo audible sound, sent to the user via headphones. the various intensities and time variations of the mirrored ultrasound waves transmitted by the sensors indicate the different directions and sizes of obstacles, making a kind of localized sound pictures. Some preliminary experiments were performed to judge the user's capability to discriminate between objects before of the user's head, exploitation totally different ultrasound frequencies. The results provided show that the users will determine and discriminate objects in some restricted cases, however a lot of experiments and applied mathematics results are needed to support the viability of the project. The simplicity and movability of the paradigm is major blessings.

### 2.2 Navbelt

Navbelt is developed by Borenstein and coworkers in University of Michigan [6] as a system, employing a mobile golem obstacle rejection system. The paradigm as enforced in 1992 and it's consisted of inaudible vary sensors, a pc and earphones. the pc receives info from the eight inaudible sensors (Fig. 1) and creates a map of the angles (each for each sensor) and also the distance of any object at this angle. Then the obstacle rejection rule (including noise reduction algorithm EERUF) turn out sounds applicable for every mode Navbelt has 2 modes: the steerage mode and also the image mode. throughout the steerage mode, the pc is aware of the user's destination and with one continual beep guides him/her within the generated optimum direction of travel. however, in observe, a sensible (non-simulation) implementation would need a lot of sensors. within the image mode, eight tones

of various amplitudes are competing in fast succession from eight different virtual direction.(similar to a measuring device sweep). The pc interprets (depending on the mode) these maps to sounds that the user will listen from his earphones. The disadvantages of the systems are the utilization of audio feedback (exclusively), the large paradigm which the users are needed in depth coaching periods.

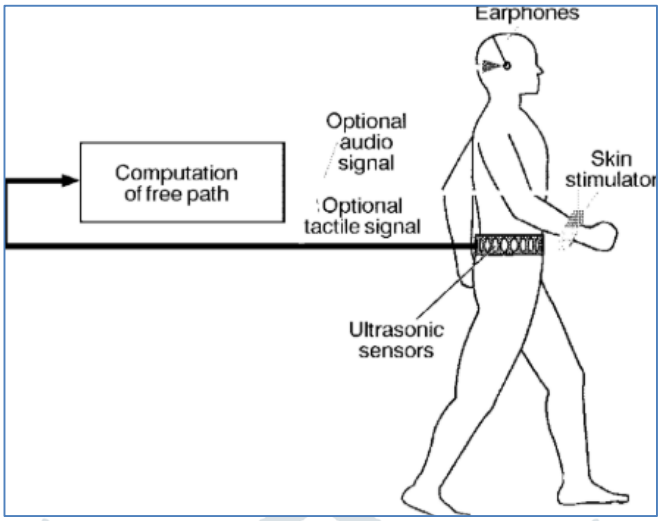


Fig 1: Navbelt system implementation

**2.3 vOICe**

Meijer [7] started a project having the essential argument that human hearing system is sort of capable of learning to method and interpret extraordinarily sophisticated and quickly ever-changing sound patterns. The paradigm consists of a camera connected to standard eyeglasses, headphones, and a transportable pc with the mandatory computer code. The camera captures pictures and also the pc uses a right away unfiltered, invertible matched image-to-sound mapping. The sound is then sent to the headphones. No filters were accustomed cut back the chance of filtering vital info since the most argument is that human brain is powerful enough to method advanced sound information. The system is incredibly straightforward, little light-weight, and cheap. Lately, the computer code was embedded on a radiophone, and so the user will use the cellphone's camera and earphones. additionally, measuring device extension is offered for higher illustration of the atmosphere and hyperbolic safety. several people tried the system returning terribly promising feedback, however they needed in depth coaching due to the sophisticated sound patterns.

**2.4 University of Stuttgart Project**

A portable– wearable framework that helps blind individuals situating themselves in indoor conditions was created by specialists in College of Stuttgart in Germany [8]. The model is comprised of a sensor module with a separable stick and a convenient PC. The sensor (Fig. 4) is furnished with two cameras, a console (like those in cellphones), an advanced compass, a 3-D inclinator, and an amplifier. It tends to be taken care of like an electric lamp and "By squeezing assigned keys, diverse arrangement and uproar choices can be picked and request concerning an item's highlights can be sent to the versatile PC. After effective assessment these requests are acoustically replied over a content to-discourse motor and the amplifier." The PC contains programming for discovery of shading identification separation and size of articles and remote neighborhood (WLAN) abilities. The gadget works nearly continuously. So as to improve the exhibition of the framework, a virtual 3-D model of nature was fabricated, so the data from the sensor can be coordinated with the information put away in the 3-D model. A coordinating calculation for sensor data and 3-D model's information and implanting the framework to Nexus system (a stage that permits a general depiction of discretionary physical genuine world and virtual items) are the future work proposition. Finishing up, the framework's positives are the heartiness of the sensor, the close constant task and the kind disposition to the client. The negatives are that the hold-and-output activity and the, until this minute, constrained, recreated testing.

**2.5 FIU Project**

This task from analysts in Florida Global College (FIU) [9] is a snag discovery framework that utilizes 3-D spatialized sounds dependent on readings from a multidirectional sonar framework. The model comprises of two subsystems: the sonar and compass control unit, which is comprised of six ultrasonic range sensors pointing in the six outspread ways around the client and a microcontroller; and the 3-D sound rendering motor, which is comprised of earphones and an individual advanced right hand (PDA) outfitted with programming fit for preparing data from the sonar and compass control. The calculation, utilizing head-related exchange capacities (HRTF), makes a 3-D sound condition that speaks to the obstructions recognized by the sensors. The client in that manner makes a psychological guide of the design of his/her environment with the goal that impediments can be maintained a strategic distance from and open entries can be considered for way arranging and route. The framework was tried on four visually impaired collapsed people, who were requested to explore in a structure. The outcomes were promising yet the route speed was moderate. As observed the structure of running unit isn't ergonomic however the framework is little and wearable.

**2.6 Bone Conduction devices**

To arrange all current BCDs for hearing restoration, the main division was made into "direct-drive" BCDs and "skin drive" BCDs. All immediate drive BCDs transmit vibrations legitimately to the skull bone, not through the skin. Skin-drive BCDs transmit vibrations through the skin and can be separated into ordinary and aloof transcutaneous BCDs. A comparative division could be made to coordinate drive BCDs, which are separated into percutaneous and dynamic transcutaneous gadgets. There is additionally a class of BCDs approached the-mouth gadgets which are neither direct-drive nor skin-drive BCDs, as they animate

the ear by transmitting vibrations by means of a tooth and its moderately hardened root associated with the skull. The regular skin-drive BCD was the first BCD available (see Figure 2). It is connected with a delicate headband (softband), a steel spring headband, or with displays for glasses. Today there are a couple of organizations that still assembling and offer traditional gadgets – for instance, BHM-Tech in Austria and Bruckhoff in Germany. What's more, BAHAs are here and there utilized with a softband/headband rather than titanium screw, in this manner acting as a customary skin-drive gadget. There are two producers of BAHAs, Oticon Restorative (Askim, Sweden) and Cochlear Bone Tied down Arrangements (Mölnlycke, Sweden), where the BAHAs are additionally accessible with softband/headband application. The utilization of BAHA on a softband (versatile texture) or headband (diadem type) is a profitable technique for hearing restoration in youngsters who are unreasonably youthful for implantation, 17,18 and it is the best quality level for preoperative evaluation. 19 Nonetheless, one should remember that the last hearing improvement with a percutaneous BAHA more often than not is superior to with a BAHA on a softband.20,21 specifically, Verstraeten et al22 have demonstrated that the consultation affectability through the skin, as contrasted and a skin entering projection, is somewhere in the range of 8 and 20 dB lower in the recurrence run from 1 to 4 kHz (see Figure 3 in Verstraeten et al22). This is in accordance with results introduced as of now during the 1980s by Håkansson et al,23 who analyzed the consultation limits utilizing a similar transducer connected first to a percutaneous embed and after that to the close-by skin. Moreover, ordinary BC is today utilized in correspondence frameworks of different sorts. One intriguing application is the Google Glass24 that utilizes a BC transducer as a reciprocal speaker to air-conduction recipients.

## III. Proposed System

Ultrasonic detecting is a standout amongst the most ideal approaches to detect nearness and distinguish levels with high dependability. An ultrasonic sensor is an instrument that estimates the separation to an item utilizing ultrasonic sound waves. An ultrasonic sensor utilizes a transducer to send and get ultrasonic heartbeats that hand-off back data about an item's closeness. High-recurrence sound waves reflect from limits to deliver unmistakable reverberation designs. Ultrasonic sound vibrates at a recurrence over the scope of human hearing. Transducers are the mouthpieces used to get and send the ultrasonic sound.

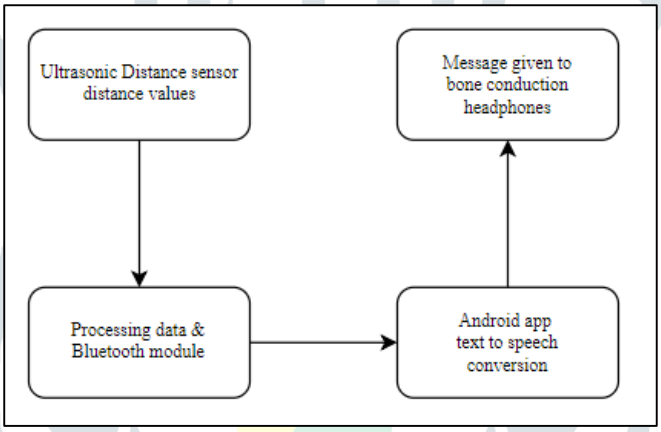


Fig 2: Block Diagram of the proposed system

Ultrasonic sensors utilize a solitary transducer to send a heartbeat and to get the reverberation. The sensor decides the separation to an objective by estimating the time slipped by among sending and accepting of the ultrasonic heartbeat. Ultrasound is dependable in any lighting condition and can be utilized inside or outside. Ultrasonic sensors can deal with crash shirking for a robot, and being moved regularly, as long as it isn't excessively quick. Ultra sonics are so broadly utilized, they can be dependably executed in grain container detecting applications, water level detecting, ramble applications and detecting autos at your neighborhood drive-through café or bank.

Ultrasonic rangefinders are normally utilized as gadgets to distinguish an impact. Ultrasonic sensors are best utilized in the non-contact discovery of quality, level, position and surmised separate. These sensor modules are autonomous of light, smoke, residue, shading and material aside from delicate surfaces like cotton or fleece on the grounds that such surfaces ingest ultrasonic sound waves and don't reflect sound. Ultrasonic sensors are better than infrared sensors since they aren't influenced by smoke or dark materials, be that as it may, delicate materials which don't mirror the sonar (ultrasonic) waves may cause issues. It is anything but an ideal framework, yet it's great and dependable. They are commonly utilized in ultrasonic separation estimation where this would be connected in a carport leaving application, detecting when a vehicle is maneuverer totally into a carport. They are additionally utilized for water level discovery tank level estimation, fuel checking and water system control. Ultrasonic sensors are a dependable, savvy answer for separation detecting, level estimation and hindrance discovery. The ultrasonic distance sensor provides stable and accurate distance measurements from 2cm to 450cm. It has a focus of less than 15 degrees and an accuracy of about 2mm. Sound travels at approximately 340 meters per second. This corresponds to about 29.412 microseconds per centimeter. To measure the distance the sound has travelled we use:

$$Distance = \frac{340(t_2 - t_1)}{2}$$

where $t_1$ is the instant at which the sensor sends the pulse and $t_2$ is the time at which the reflected pulse is received by the sensor. The 2 is in the formula because sound has to travel back and forth. First the sound travels away from the sensor, and then it bounces off of a surface and returns back.

We as a whole hear sounds through both our bones (bone-led or bone-transmitted) and our eardrums (air-directed or air-transmitted). Most sounds are heard by our eardrums. The eardrum changes over the sound waves to vibrations and transmits them to the cochlea (or inward ear). In any case, sometimes vibrations are heard straightforwardly by the internal ear bypassing your eardrums. Indeed, this is one of the manners in which you hear your own voice. This is likewise how whales hear. Typical sound waves are really minor vibrations noticeable all around. The vibrations go through the air to our eardrums. The eardrums thusly vibrate, deciphering these sound waves into an alternate sort of vibrations that are gotten by the Cochlea, otherwise called the internal ear. The Cochlea is associated with our sound-related nerve, which transmits the sounds to our cerebrum. Bone Conduction sidesteps the eardrums. In bone conduction tuning in, the bone conduction gadgets, (for example, earphones) play out the job of your eardrums. These gadgets decipher sound waves and convert them into vibrations that can be gotten straightforwardly by the Cochlea, so the eardrum is never included. The sound achieves the ears as vibrations through the bones (or skull) and skin. Most instances of hearing misfortune are because of harms to the eardrums. Since bone conduction does not utilize the eardrums, individuals with hearing troubles would almost certainly hear obviously again with bone conduction, gave that their cochlea is in solid and typical condition.

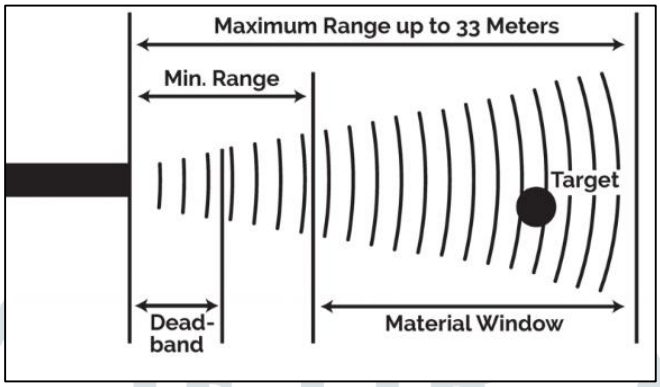


Fig 3: Ultrasonic distance sensing module

By and large, hearing misfortune could be portrayed into three classifications. That would be conductive hearing misfortune, insightful hearing misfortune and blended hearing misfortune. Conductive hearing misfortune is related with flawed transmission of sound and is for the most part because of harms to the eardrums. Bone conduction can help a conduction hearing misfortune in light of the fact that a bone conduction gadget plays out the job of the eardrums. Keen hearing misfortune is related with trouble in detecting the vibrations by the sound-related nerves at the cochlea. Bone conduction is less viable for discerning hearing misfortune. Concerning blended hearing misfortune, it is ideal to propose a preliminary ahead of time to see if bone conduction could be a guide to blended hearing misfortune since it contrasts among person. Bone conduction Portable hearing assistants are appropriate for individuals with conductive hearing as well as blended hearing misfortunes, and for individuals who have hearing misfortune in one ear (one-sided hearing misfortune). A bone conduction Listening devices assists individuals with a conductive or blended hearing misfortune by grabbing the sound, intensifying it, and transforming it to a vibration. The vibration is gotten by the cochlea as sound. A bone conduction Portable hearing assistant for the most part comprises of a BTE Listening devices that gets and intensifies sound over a bone director frequently consolidated into a headband or displays.

To start with, for frequencies under 1.5 kHz, the general development of the ossicular chain rules the bone conduction reaction; this is the inactivity of the centre ear ossicles. Indeed, even with harm to the centre ear and ossicles, nonetheless, there is a bone conduction reaction in the low frequencies in light of the fact that the skull moves like a strong body. Second, for frequencies more noteworthy than 1.5 kHz, the reaction is credited to the pressure of the maze. A third methods for bone conduction are because of the overall development of the mandible. Air in the outside ear is gotten under way and transmits sound through the unblemished drum and ossicles to the cochlea. A few different factors most likely additionally assume a job, for example, the oval and round window discharge, inward ear liquid dormancy, and cochlea water system impact. These variables are regularly interrelated, and it is hard to separate one from another. Practically paying little mind to the area of bone incitement, the floods of the basilar film travel from the base of the cochlea, where the layer is stiffer, at the helicotrema, similar to the case with air led sound. This implies the cochlea experiences issues in separating between bone directed and air led sound. Retraction tests have checked this trouble.

A Bluetooth innovation is a rapid low fuelled remote innovation interface that is intended to associate telephones or other convenient hardware together. It is a determination (IEEE 802.15.1) for the utilization of low power radio correspondences to interface telephones, PCs and other system gadgets over short separation without wires. Remote sign transmitted with Bluetooth spread short separations, commonly up to 30 feet (10 meters). It is accomplished by installed minimal effort handsets into the gadgets. It bolsters on the recurrence band of 2.45GHz and can bolster up to 721KBps alongside three voice channels. This recurrence band has been put aside by worldwide understanding for the utilization of mechanical, logical and restorative gadgets (ISM).rd-perfect with 1.0 gadgets. Bluetooth can associate up to "eight gadgets" all the while and every gadget offers a one of a kind 48-bit address from the IEEE 802 standard with the associations being made point to point or multipoint.

Fig 4: Bluetooth technology used in the system

Bluetooth System comprises of an Individual Zone System or a piconet which contains at least 2 to limit of 8 Bluetooth companion gadgets More often than not a solitary ace and up to 7 slaves. An ace is the gadget which starts correspondence with different gadgets. The ace gadget oversees the correspondences connection and traffic among itself and the slave gadgets related with it. A slave gadget is the gadget that reacts to the ace gadget. Slave gadgets are required to synchronize them transmit/get timing with that of the bosses. Also, transmissions by slave gadgets are administered by the ace gadget which implies that the ace gadget manages when a slave gadget may transmit. In particular, a slave may just start its transmissions in a schedule vacancy quickly following the availability in which it was tended to by the ace, or in a schedule vacancy expressly saved for use by the slave gadget. The recurrence jumping grouping is characterized by the Bluetooth gadget address $(BD-ADDR)$ of the ace gadget. The ace gadget initially sends a radio sign requesting reaction from the specific slave gadgets inside the scope of addresses. The slaves react and synchronize their jump recurrence just as clock with that of the ace gadget. Disperse nets are made when a gadget turns into a functioning individual from more than one piconet. Basically, the connecting gadget shares its availabilities among the diverse piconets.

The primary focal points of Bluetooth correspondence are that it evacuates the issue of radio obstruction by utilizing a strategy called Speed Recurrence Jumping. This system uses 79 channels of specific recurrence band, with every gadget getting to the channel for just 625 microseconds, for example the gadget must flip among transmitting and accepting information starting with one schedule opening then onto the next. This infers the transmitters change frequencies multiple times each second, implying that more gadgets can utilize a restricted cut of the radio range. This guarantees the obstruction won't occur as every transmitter will be on various frequencies. The power utilization of the chip (comprising of handset) is low, at about 0.3mW, which makes it feasible for least use of battery life. It ensures security at bit level. The validation is controlled utilizing a 128-piece key. It is conceivable to utilize Bluetooth for both exchanging of information and verbal correspondence as Bluetooth can bolster information channels of up to 3 comparative voice channels.

## IV. CONCLUSION

In this paper, we have proposed a system of obstacle avoidance for blind and deaf people using ultrasonic range finding sensors and bone conduction technology. In our system, we have created an ultrasonic glove on which the ultrasonic range finder is mounted which communicates the presence of an obstacle to the person's android phone via Bluetooth communication protocol. The visually impaired person's phone has an app that converts the distance readings and processes it with respect to a certain threshold value for obstacle presence warning and hence communicates this message to the individual via the bone conduction headphones that are placed on his skull. As the person is hearing impaired due to malfunctioning of the eardrum, bone conduction technology directly excites his cochlea that gives him a sense of hearing. By using this technology, the requirement of manual aid for such individuals is reduced greatly as the system is very reliable and is pretty accurate in detecting obstacles. This system was designed by considering the fact that the person might need help for indoor locomotion which is quite bothersome for the individual as well as his human-aid. The only drawback of this system is that it cannot be used in outdoors as it may fail to accurately detect the presence of multiple obstacles at the same time.

**REFERENCES**

[1] National Federation of the Blind. (2009, May 8). [Online]. Available: http://www.nfb.org/
[2] American Foundation for the Blind. (2009, May 8). [Online]. Available: http://www.afb.org/
[3] InternationalAgency for Prevention of Blindness. (2009, May 8). [Online]. Available: http://www.iapb.org/
[4] B. B. Blasch, W. R. Wiener, and R. L. Welsh, Foundations of Orientation and Mobility, 2nd ed. New York: AFB Press, 1997.
[5] T. Ifukube, T. Sasaki, and C. Peng, "A blind mobility aid modeled after echolocation of bats," IEEE Trans. Biomed. Eng., vol. 38, no. 5, pp. 461– 465, May 1991.
[6] S. Shoval, J. Borenstein, and Y. Koren, "Mobile robot obstacle avoidance in a computerized travel aid for the blind," in Proc. 1994 IEEE Robot. Autom. Conf., San Diego, CA, May 8 13, pp. 2023–2029.
[7] P. B. L. Meijer. (1992, Feb.). An experimental system for auditory image representations. IEEE Trans. Biomed. Eng. [Online]. 39(2), pp. 112–121. Available: http://www.seeingwithsound.com/
[8] A. Hub, J. Diepstraten, and T. Ertl, "Design and development of an indoor navigation and object identification system for the blind," in Proc. ACM SIGACCESS Accessibility Computing, Sep. 2003/Jan. 2004, no. 77–78, pp. 147–152.
[9] D.Aguerrevere,M.Choudhury, andA.Barreto, "Portable 3D sound / sonar navigation system for blind individuals," presented at the 2nd LACCEI Int. Latin Amer. Caribbean Conf. Eng. Technol. Miami, FL, Jun. 2–4 2004.
[10] J. L. Gonzalez-Mora, A. Rodriguez-Hernandez, L. F. Rodriguez Ramos, L. Diaz Saco, and N. Sosa. (2009, May 8). Development of a new space perception system for blind people, based on the creation of a virtual acoustic space. Tech. Rep. [Online]. Available: http://www.iac.es/proyect/eavi
[11] G. Sainarayanan, R. Nagarajan, and S. Yaacob, "Fuzzy image processing scheme for autonomous navigation of human blind," Appl. SoftwComput., vol. 7, no. 1, pp. 257–264, Jan. 2007.
[12] R. Audette, J. Balthazaar, C. Dunk, and J. Zelek, "A stereo-vision system for the visually impaired," Sch. Eng., Univ. Guelph, Guelph, ON, Canada, Tech. Rep. 2000-41x-1, 2000.
[13] I. Ulrich and J. Borenstein, "The guidecane – applying mobile robot technologies to assist the visually impaired people," IEEE Trans. Syst.,Man Cybern., A: Syst. Hum., vol. 31, no. 2, pp. 131–136, Mar. 2001.
[14] S. Meers and K. Ward, "A substitute vision system for providing 3D perception and GPS navigation via electro-tactile stimulation," presented at the 1st Int. Conf. Sens. Technol., Palmerston North, New Zealand, Nov. 21–23, 2005.
[15] K. Ito, M. Okamoto, J. Akita, T. Ono, I. Gyobu, T. Tagaki, T. Hoshi, and Y. Mishima, "CyARM: An alternative aid device for blind persons," in Proc. CHI05, Portland, OR, Apr. 2–7, 2005, pp. 1483–1488.
[16] M. Bouzit, A. Chaibi, K. J. De Laurentis, and C. Mavroidis, "Tactile feedback navigation handle for the visually impaired," presented at the 2004 ASME Int. Mech. Eng. Congr. RD and D Expo., Anaheim, CA, Nov. 13–19.
[17] C. Shah,M. Bouzit, M. Youssef, and L. Vasquez, "Evaluation of RU-netra– tactile feedback navigation system for the visually impaired," in Proc. Int. Workshop Virtual Rehabil., New York, 2006, pp. 71–77.
[18] L. A. Johnson and C. M. Higgins, "A navigation aid for the blind using tactile-visual sensory substitution," in Proc. 28th Annu. Int. Conf. IEEE Eng. Med. Biol. Soc., New York, 2006, pp. 6298–6292.
[19] S. Cardin, D. Thalmann, and F. Vexo, "A wearable system for mobility improvement of visually impaired people," Vis. Comput., vol. 23, no. 2, pp. 109–118, Jan. 2007.
[20] N. G. Bourbakis and D. Kavraki, "Intelligent assistants for handicapped people's independence: Case study," in Proc. 1996 IEEE Int. Joint Symp. Intell. Syst., Nov. 4–5, pp. 337–344