Computer Vision Based Travel Aid for Blind

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Abstract: - **Electronic travel aid, which convert visual environmental cues into another sensory modality, have proved to help blind people with a great degree of physiological comfort and independence. The main problem of blind people is to detect and avoid obstacles both during outdoor navigation and indoor navigation. Designing an obstacle detector for blind is a challenging task. Although there are many mobility aids available, there are very few which can detect dangerous obstacles. A comparative study of mobility aid for outdoor and indoor navigation purpose is presented in this paper. Computer vision based approach to design a travel aid for blind is discussed. The aim of the design is to develop a FPGA based travel aid that can be used for both outdoor and indoor navigation.**

Keywords: computer vision, blind, mobility aids, FPGA, navigation.

I. INTRODUCTION

Information of the environment enables humans to know various sources that are in many different directions. Proper source localization is very important for safety survival and navigation. Visual cues such as object detection, tracking and distance measurement play an important role while travelling. Loss of vision is often accompanied by loss of independence. Vision loss affects almost every activity of daily living. Walking, driving, reading and recognizing objects, places and people become difficult or impossible without vision.

Global data on visually impaired report submitted by world health organization estimate the total number of blind people in world [1]. According to this report, in world there are about 289 million people blind. This accounts to almost 4.7% of total world population. 289 million constitute both visually impaired and blind people. Out of 289 million people 246 million people have low vision, that is 86% of total blind population and 39 million people are completely blind.

As per this report [1] in India out of 1181.4 million population there 8.075 million people completely blind, 54.544 million people with low vision and 62.619 million people visually impaired. These figures indicates that out of total completely blind population approximate 20 % population and out of total people with low vision approximately 21 % population is in India. Figures from the report clearly indicate that there should be advanced electronic assistive aids that can help visually impaired people.

Mobility means moving safely, gracefully and comfortably [2]. It relies in large part in perceiving properties of immediate surroundings and avoiding obstacles, negotiating steps, drop-off etc. The need of mobility devices was and will always be constant. There are many mobility devices and navigation aids developed for visually impaired population. The most popular travel aid is guide cane, also called as white cane [3]. The long cane allows the user to extend touch and to preview the lower portion of the space in front of oneself. White cane is also cheapest, most reliable and thus most popular. Another popular travel aid is a dog guide. Dog guide helps to maintain a direct route, recognize and avoid obstacles and stops at all curbs and at bottom and top of staircase until told to proceed. Use of white cane or dog guide publicly identifies a pedestrian as blind. Moreover these devices cannot detect the obstacles which are at head height. White cane or dog guide does not inform the user about the dimensions of the obstacles. Though dog guide feels to be a cheap guidance aid, still the cost required to train a dog is very high.

The visually impaired community is very diverse in terms of degree of vision loss, age, and abilities. It is important to understand the various characteristics of this population if one is to design technology that is well fit to its potential customers. Since the needs of a low vision person and of a blind person can be very different, it is important not to overgeneralize the nature of visual impairment. Another important factor to be considered is the age of a VI person. Vision impairment is often due to conditions such as diabetic retinopathy, macular degeneration, and glaucoma that are prevalent at later age. Indeed, about one-fourth of those reporting significant vision loss are 65 years of age and older. It is important to note that multiple disabilities in addition to vision loss are also common at later age. The National Research Council's guidelines for ETAs are listed below [3]:

1. Detection obstacles in the travel path from ground level to head height for the full body width.
2. Travel surface information including textures and discontinuities.
3. Detection of objects bordering the travel path for shore lining and projection.
4. Distant object and cardinal direction information for projection of a straight line.
5. Landmark location and identification information.
6. Information enabling self-familiarization and mental mapping of an environment.

7.In addition: ergonomic, operate with minimal interface with natural sensory channels, single unit, reliable, user choice of auditory or tactile modalities, durable, easily repairable, robust, low power and cosmetically accepted.

II. REVIEW OF OUTDOOR MOBILITY AIDS

Foulke[1] defines term mobility as the ability to travel safely, comfortably, gracefully and independently through the environment .Electronic travel aid(ETA) system allow blind users to avoid obstacles. ETA system constitute a hope for blind community to travel safely and with confidence. There are many electronic mobility aids available for blind and visually impaired. Here we have discussed a few selected travel aids used for outdoor navigation

A) Navbelt

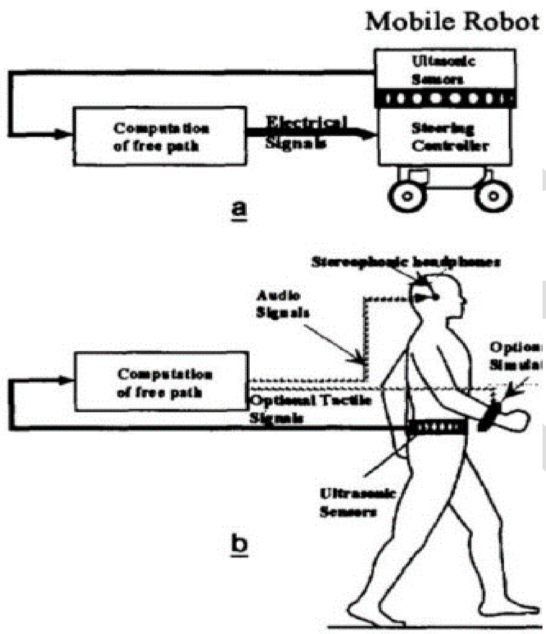

Figure 1: Comparison of mobile robot obstacle avoidance and blind navigation system

The research to develop Navbelt, ETA for blind started in University of Michigan in 1989[4]. The project aimed on using mobile robot obstacle avoidance system as a guidance device for blind and visually impaired people. Figure 1 shows the similarity between mobile robot guidance system and ETA developed for blind.
The Navbelt consist of a belt, portable computer and ultrasonic sensor. In this system computer processes the signals and applies the obstacle avoidance algorithm. The resulting signals are relayed to the user by stereophonic headphone, using stereo imaging technique. Navbelt has two modes: the guidance mode and the image mode. During the guidance mode, the computer knows the user's destination and with a single recurring beep guides him/her in the generated optimal direction of travel. In practice, a realistic (no simulation) implementation would require more sensors. In the image mode, eight tones of different amplitudes are played in quick succession from eight different virtual directions (similar to a radar sweep). The computer translates (depending on the mode) these maps to sounds that the user can listen from his earphones. The disadvantages of the systems are

- use of audio feedback.
- the bulky prototype.
- users require extensive training.

B) Guide cane

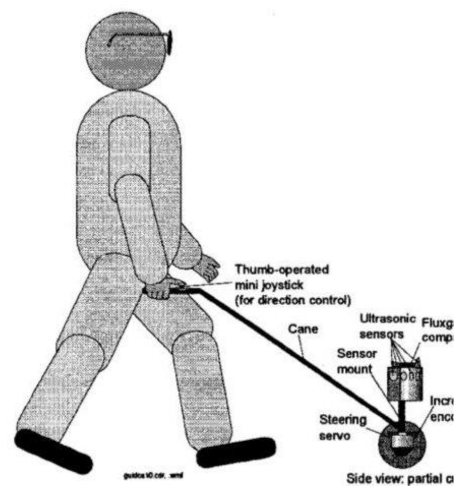

Figure 2: Prototype of guide cane

The research on developing guide cane [5] started at University of Michigan to overcome some of the drawbacks of Navbelt. The sketch of the prototype is shown in figure 2

A handle (cane) is connected to the main device. The main device has wheels, a steering mechanism, ultrasonic sensors, and a computer. The operation is simple: the user moves the Guidecane, and when an obstacle is detected the obstacle avoidance algorithm chooses an alternate direction until the obstacle is cleared and route is resumed (either in a parallel to the initial direction or in the same). There is also a thumb-operated joystick at the handle so that the user can change the direction of the cane (left or right). The sensors can detect small obstacles at the ground and sideways obstacles like walls.
Advantage of Guidecane are :

- Device does not block the users hearing with audio feedback

- computer automatically analyses the situation and guides the user without requiring him/her to manually scan the area,
- no need for extensive training.

There are a few drawbacks. They are :

- Limited scanning area.
- Small or overhanging objects like pavements or tables cannot be detected.
- Prototype is bulky difficult to hold or carry when needed.

C) Auditory image representation system

Electronic travel aid based on auditory image representation started in year 1992 [6]. Human hearing system is quite capable of learning to process and interpret extremely complicated and rapidly changing sound patterns such as speech or music in noisy environment. Visual input has some major advantage over the use of sonar beam reflection pattern. The short range of sonar makes it impossible to detect far way objects. Moreover visual input can also provide access to other data like road signs, reading material etc. which sonar system cannot do. The prototype of electronic travel aid contains one single camera, headphones and portable computer with necessary software. In this research[3][6] visual information captured by camera is converted

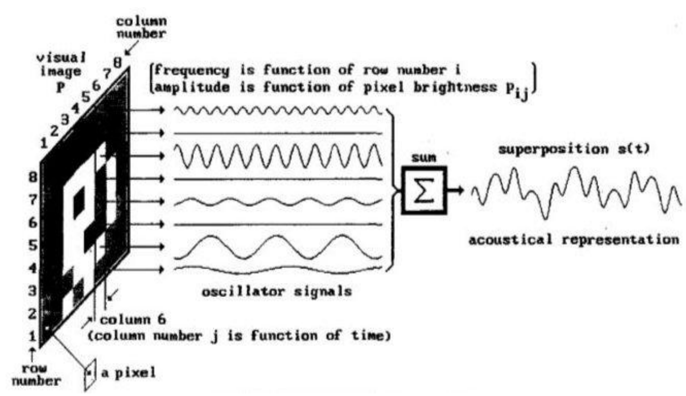

Figure 3: Conversion of image to auditory signal

into auditory signal i.e. two dimensional visual information is scanned and transformed into two dimensional map of oscillating amplitude as a function of time and frequency. This sound signal is given as feedback to the user through headphones.

This system was tried on many individuals. The results were promising but this system required extensive training because of complicated sound patterns. Principal of image to sound mapping is shown in figure 3

D) Real time navigation aid for blind

Figure 4: Real time navigation aid

The hardware consist of helmet fitted with stereo colour camera, headphones and a laptop to run the software. The software of this system includes the image and sound processing algorithm [9]. The stereo camera records the environment between the range -32º to 32º relative to user centre. Small stereo phone provides the acoustic feedback to the user. The device provides the user with the acoustic image of the environment. The distance up to which the camera can detect obstacles is 15 meters. Primary aim of artificial vision system is to detect known objects like humans, cars, buildings, trees etc. The software makes use of image segmentation, object recognition and bounding box estimation algorithm. For each image the depth map is generated, then segmentation algorithm is applied to extract the information from the image. This information is then converted into sound signal by using head related transfer function (HRTFs). Advantage of this design is only two sensors are required to capture complete information about the environment. The disadvantage is this system are

- Only detects the obstacles but does not suggest a path free of obstacles to the user.
- system is bulky and is not portable

III. REVIEW ON INDOOR NAVIGATION SYSTEM

Orientation (or way finding) can be defined as the capacity to know and track one's position with respect to the environment, and to find a route to a destination. Blind person moving in an unfamiliar environment faces a number of hurdles like accessing spatial information from a distance, obtaining directional cues to distant locations, keeping track of one's orientation and location; and obtaining positive identification once a location is reached.

For outdoor travellers, GPS represents an invaluable technology. Several companies offer GPS-based navigational systems specifically designed for VI people. None of these systems, however, can help the user in tasks such as find the entrance door of the building due to the low spatial resolution of GPS reading. In addition, GPS is viable only outdoors. Indoor positioning systems (for example, based on WiFi beacons) are gaining momentum, and it is expected they will provide interesting solutions for blind wayfinding.

A different approach to way finding, one that does not require a geographical database or map, is based on recognizing (via an appropriate sensor carried by the user) specific landmarks placed at key locations. Landmarks can be active (light, radio, or sound beacons) or passive (reflecting light or radio signals). Thus, rather than absolute positioning, the user is made aware of their own relative position and attitude with respect to the landmark. This may be sufficient for a number of navigational tasks, for example, when the landmark is placed near a location of interest. For guidance to destinations that are beyond the landmark's receptive field a route can be built as a set of waypoints that need to be reached in sequence. Contextual information about the environment can also be provided to the visually impaired user using digital map software and synthetic speech. The best-known beaconing system for the blind is Talking Signs. Already deployed in several cities, Talking Signs uses a directional beacon of infrared light, modulated by a speech signal. This can be received at a distance of several meters by a specialized handheld device. RFID technology has also been proposed recently in the context of landmark-based wayfinding for the blind. RFID technology uses matrices of RFID tags which guide the person through the shortest path using an algorithm. The main drawback of this design is its weight and size

A) Pocket PC navigation aid for blind

Pocket PC based navigation system for blind was basically designed to help blind or visually impaired people to navigate through indoor environment [10]. The system performs two major tasks in real time: Information gathering and information display. These two processes are performed in parallel by two independent circuits: the sensor control unit (SCU) and 3D sound rendering engine. The system design is as shown in figure below

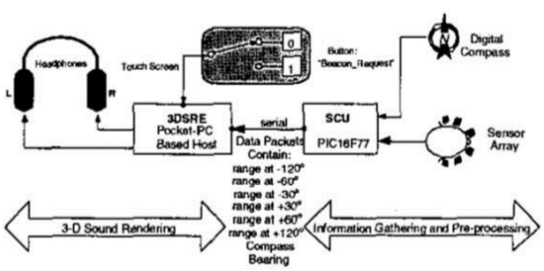

Figure 5: Block diagram of navigation system

In this system six ultrasonic sensors were used to detect indoor obstacles. The sensors were mounted on headgear such that they can scan area from -120º(left) to 120º(right). Sensor control unit (SCU) contains the trigger input for sensors and echo output. The system gives a trigger pulse. At the falling edge of the trigger pulse the module emits ultrasonic energy. Immediately after ultrasonic emission the system stars the timer and the system records the time required to receive the echo. This time is proportional to distance of the obstacle. The information of distance is converted into sound signal by 3D sound rendering engine.

B) Antenna to detect door location

Similar to RFID there is an indoor navigation system that makes use of specially designed antenna and a receiver, which allows the door identification and helps the person entering the room[11]
An antenna with a very tight radiation pattern and with a shape of a doughnut' is placed in a door casing. The user has a receiver to detect the power of antenna. The person is able to move until the maximum value of power emitted by the antenna is found. This maximum value of power measured through an appropriate receiver corresponds exactly to the middle of the door entrance. Concerning the resonant frequency, it has to be suitable for indoor environments, but other than that, there were no restrictions.

C) Roshni

IIT Delhi developed a portable and self-contained indoor navigation system for the visually impaired [12]. Comprising a network of wall mounted units and a user module coupled with a mobile application, the system downloads the map of the building, localizes the user within the building, takes the destination as input from the user, and then helps him/her to independently navigate to his destination using step-by-step navigational instructions. Protoype of the device is shown

Figure 6: Prototype pf the design

Figure 7 : Users trying device

Features of this device are: 1) Path-based navigation with active guidance for turns and important landmarks in the course of travel.

2) Update on position awareness information particularly obstacle warning instructions.3) Update on position correction information in case the user deviates from the path. 4)Use of minimal additional building augmentation while providing good accuracy.

IV. COMPUTER VISION BASED TRAVEL AID

Electronic travel aids (ETAs) have been available since the 1960s. There are many commercially available electronic travel aids and some are laboratory prototypes. All these wearable devices are based on either ultrasound or infrared. Indoor navigation technologies are based on Wi-Fi or RFID tags, Bluetooth, antennas etc. Despite of a couple of advantages, there are few drawbacks in the system. These drawbacks are stated below:

1.) Number of sensors required to acquire the information about the environment is large. Typically an ETA would require 6 to 8 sensors that includes ultrasound, metal detection, wet surface detection etc.

2.) As the number of sensors are large the amount of processing is also large. The data acquired is large. Hence the processing system is bulky as they require a large memory.

3.) These electronic travel aids can detect only the distance of the object but not the dimensions of the object. Dimensions are important because it helps visually impaired person to commute

4.) The obstacles that are at head height cannot be detected by many electronic travel aids.

5.) In case of indoor navigation systems, setting up the infrastructure for blind to commute is costly and the systems have to be maintained. Those services will be used only by blind people and are not useful to other humans.

6.) Maximum electronic travel aids used acoustic feedback to give indications to the person about the environment and/or probable obstacle. This reduces one sense of virtually impaired person.

Computer vision as a substitute for human vision constitutes a powerful tool for developing assistive technologies for the visually impaired and blind people. Applications based on computer vision enhance these persons mobility and orientation as well as object recognition and access to printed material. Computer vision systems are ripe for fine-tuning the intersection between human potential and advanced technology. This technology is helping researchers to develop useful travel aids that meet the guidelines given by National Research council. There are many advantages of using computer vision instead of ultrasonic or infrared technology. Some of the advantages are

1.) Number of sensors i.e. camera required to scan the environment is either 1or 2. Hence the power consumption is low and weight also reduces.

2.) By using computer vision, not only the relative depth of an obstacle, but also the dimension of the obstacles can be calculated and this information can be used to find a free path to travel.

3.) The same software and hardware can be used for outdoor as well as indoor navigation. Hence no extra cost for developing and maintaining infrastructure for blind people is required.

4.) Due to the development of smartphones, the same device can be used to process the images captured by cameras and give feedback to the user.

5.) Using computer vision can also give access to printed material, object detection.

Block diagram of proposed computer vision based device is as shown in figure below:

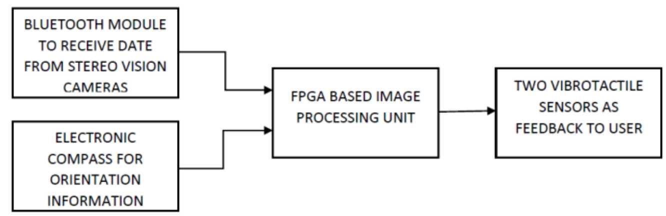

Figure 8: Block diagram of system

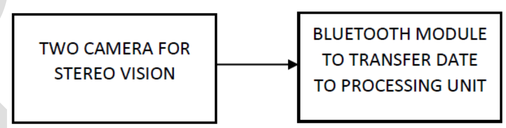

Figure 9 : Data acquisition system

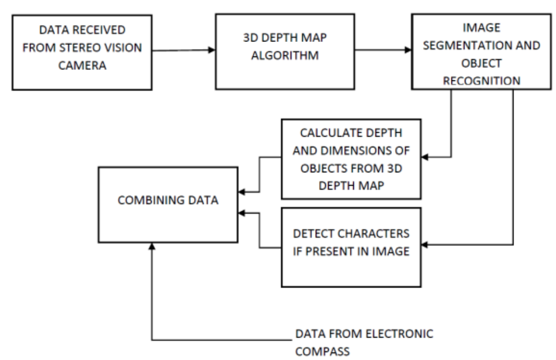

Figure 10 : FPGA internal block diagram

The stereo vision camera will capture images of the environment (these images will be similar to left eye and right eye image).

To transfer the data to processing device wireless communication device will be used. Bluetooth is a preferred method of transferring data.

At the processing end FPGA will be used. The advantage of using a FPGA is, hardware dedicated for a specific task can be developed, in this case, it is image processing. There are three tasks that will be done by FPGA:

1. From the two received images, FPGA will process the data and generate 3D map of the environment. Using stereo vision algorithms, it will detect various obstacles in the environment. Out of these obstacles, algorithm will locate the obstacles in front of the user and will calculate the relative distance of these obstacles. If the distance is less than threshold, then, algorithm will find an alternate path, free of obstacles. The method of feedback selected for this device are vibrotactile sensors. There are two vibrotactile sensors, one for left hand and other for right. If the path selected wants the user to move left, the left vibrotactile sensor will vibrate and if it wants the user to move right then right vibrotactile sensor will vibrate. The intensity of vibraion is inversely proportional to the distance of the obstacle. This algorithm can be used for both indoor as well as outdoor navigation system.

2. From the two received images, FPGA along with 3D map of the environment will develop a single image. FPGA will use this image to detect characters(letters) in the image. Machine learning algorithm will be used to train the device to classify between various letters. This algorithm will be used to detect road names, signs during outdoor navigation. In indoor navigation, the same algorithm will be used to understand the room numbers, name plates etc.

3. Image generated by FPGA will also be used to perform object recognition. The algorithm will detect basic objects like doors, elevators, stair case, which will help the user to commute.

V. CONCLUSION

A comparison of the state-of-the-art in the area of Electronic Travel Aid system for blind and visually impaired people is presented in this paper. The review was divided into two parts travel aids for outdoor navigation and travel aids for indoor navigation. The review shows that there is an improvement in the technology used in travel aids, but still these devices have a few drawbacks. Computer vision and mobile computing are powerful tools with great potential to enable a range of assistive technologies for growing population of visually impaired and blind people. The proposed design in this paper will help blind people to carry out outdoor and indoor activities with the same travel aid. This device is aimed at overcoming most of the limitations of current electronic travel aids.

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