Analytical Study of Intelligent Assistants to Help Blind People in Avoiding Dangerous Obstacles

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Abstract: This paper gives an overview of already developed devices for helping the blind or visually impaired people in obstacle avoidance. Different technologies are described on the basis of certain parameters. Although many gadgets are currently available to help blind people like GuideCane, NavBelt, Tom Pouce, Ultra Cane, etc. but in this paper we have analyzed four gadgets from which an optimal one is recommended for use, keeping in view the parameters. A system based on smart phone uses the camera as eyes and sends vibration and audio signal as feed-back to user. The Ultracane being an advance form of white cane has ultrasonic sensors and avoids the obstacles by steering action of the cane. The Stereo Vision based Electronic Travel Aid uses a stereo camera for obstacles detection and stereo sounds through headphone are used to intimate the user. The Wearable Jacket uses the sonar technique for obstacle detection and warns the user by vibro-tactile force. After analyzing all the gadgets on the selected parameters, wearable jacket for obstacle avoidance is the preferable option, because it satisfies most of the parameters as compared to other gadgets. It is ultra-portable, low power, user friendly, medium range, and non-invasive. The main focus of this work is to formulate a guideline for blind people by using of which they can select an intelligent assistant for themselves according to their economy, environment, and liking. [**Aslam Muhammad, Muhammad Umair Ahmad Khan, Haseeb Azhar, Ali Masood, Maliha Saleem Bakhshi**. Analytical Study of Intelligent Assistants to Help Blind People in Avoiding Dangerous Obstacles. Journal of American Science. 2011;7(9):480-485]. (ISSN: 1545-1003). http://www.americanscience.org

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1. Introduction

Blindness has haunted the people a lot in last 20 years or so. According to World Health Organization statistics the number of blind people in world is 39 million of which about 82% are over the age of 50years[1]. These blind people face a lot of difficulty in daily life. Moving through an unknown environment with dynamic obstacles is also a major challenge for them.

The first and the foremost assistance is the human guide, which is the most intelligent guide available but the blind person now have to depend on other person's assistance for his day to day affairs. White Cane is the mechanical device which is in use by blind people to avoid obstacle in their path. It has some major advantages that it is cheap, easily foldable, flexible, and light weight but the major disadvantage is that the user must have awareness about its use. The user first should be trained for some time about its use which is difficult task and one more disadvantage is its range which is just few feet. Another aid that was used by people commonly is the guide dog but its training and adoption for blind people is also a difficult task. Moreover the dog is also costly and a blind person who manages his own life hardly get another burden of taking care of the dog, which rather than easing over burdens his life.

In this modern age where technology has just revolutionized the way people live one should use technology for the help of the people also. Many devices have been made for helping people to avoid obstacles easily. However, some blinds remain indecisive when they have to choose any of such items. Normally, the price plays important role in the selection in addition to other considerations like, use, range, and invasiveness. Thus, a study is needed to analyze critically all such devices and finalize a precise guideline by using of which the vision impaired people can select their assistant easily.

Our main focus of this study is to suggest such a system which is the best among the present ones. We have evaluated different approaches for helping blind people in avoiding the obstacles by using different parameters. The main parameters are portability, user friendliness, range, power consumption, invasiveness, and response time. Portability and power consumption of different devices are important factors because heavy weight devices are difficult to use and also difficult to handle. Another reason for using the technology is that the cane used for obstacle avoidance makes contact with the hindrance and that can only be detected when it makes contact with the cane which can be harmful under different circumstances due to different terrain conditions.

The rest of the paper is organized as follows: in Section 2, we discuss gadgets for blinds. In Section 3, we discuss parameters of evaluation of several gadgets. Afterwards in Section 4, we present our parameters for evaluation and the comparison of different techniques on these parameters. From the comparison an optimal technique is suggested and the paper is concluded by giving some recommendation (Section 5 and 6) in the optimal technique to increase its functionality and effectiveness.

2. Related Work

Some analytical studies have previously been done on different techniques. In this section previous studies on gadgets are discussed as follows:

2.1 Computerized Obstacle Avoidance Systems for the Blind and Visually Impaired [2]

The use of ultrasonic sensors is now increasing to detect obstacles. The major purpose of their use is to measure the distance between the sensor and the obstacle. When this sonar sensor is activated it emits a short burst of ultrasound. When an object comes in the vicinity of sensor some of the ultrasound waves are reflected back to the sonar, which switches into a microphone mode immediately after activation. When the echo from the object is received at the sonar, an electrical signal is sent to the computer. The time elapsed between activating the sonar and received signal is calculated by the computer.

In both the NavBelt [3] and the GuideCane [4] an algorithm called Vector Field Histogram (VFH) [5], [6] is used, in this method a map is made of immediate surrounding which has the recent sonar history having both current and previous readings.

The NavBelt consists of three things i) a belt, ii) a small computer, and iii) ultrasonic sensors. The computer processes the signals from the sensors, uses the obstacle avoidance algorithms, and result would be sounded in the ears of user via stereophonic headphones, using so-called stereo imaging techniques. The acoustic signal carry the information of the new alternative path direction, NavBelt scans the environment by its eight sensors. When there is no obstacle in the path the direction from the device would be towards target but when an obstacle comes in front of the user a new path is calculated by the system so that user can avoid that obstacle. The earphones intimate the user in the following way, high pitch and increased volume represents shorter distance from the obstacle.

The GuideCane is heavier than white cane, it has wheels, a servomotor, built in computer, encoders, ten ultrasonic sensors, in this a user operates a mini joystick to specify target direction, computer takes decision on the basis of data from sensors, encoder and the input from user.

The user can push the joystick forward using thumb operated mini joystick, the user can prescribe a desired direction of motion. This directional command is understood according to the GuideCane's current direction of motion. The ultrasonic sensor can detect any obstacle or hurdle in 120° sector and the computer in the presence of hurdle prepares an alternative path for the user. In this case the user is notified by a physical force that is exerted on the handle and can be felt by the user, even though the GuideCane's wheels are unpowered, the GuideCane can apply a substantial amount of physical force on the user. The sideways motion of the wheels in the presence of the obstacle results in a rotation of the handle of the cane, this change is noticeable. Second force which can also be felt by the user is the increased pushing force that opposes the forward motion. Servomotor is used to rotate the wheelbase.

2.2 Electronic Travel Aids and Electronic Orientation Aids for Blind People [7]

In this paper, the researchers have compared three systems from technical, rehabilitation and beneficial point of views for visually impaired people. Two electronic travel aids (ETAs) and one Electronic Navigation Aid (EOA) are discussed. ETAs are gadgets which help blind people in avoiding obstacles while EOA are gadgets which help blind people in navigation in unknown environments. As we are discussing aids/gadgets which help blind people in avoiding obstacles so we are describing ETAs in this section only. The two ETAs are Tom Pouce and Teletact.

The Tom Pouce is basically a cane equipped with LEDs having a tactile feedback. The device has several collimated LEDs which emit Infra-red beams. These beams are reflected back after striking the obstacle and the distance is judged by the amount of light that is received by the detectors after reflecting back. A vibrator is clipped with the little finger whose vibration varies with the intensity of light reflected back. But this feedback is not the exact measure of distance of the obstacle from the blind. The device has a range of just 3 meters.

The Teletact is also a cane using the laser telemetry technique and have both audible and tactile feedbacks. The Teletact emits a laser beam which strikes the obstacle and the spot is seen through a lens on CCD (Charged couple device) line from where the distance between obstacle and user is known. After the distance is approximated either the audio or tactile feedback is given to the user. Two vibrators are incorporated in this system one is fixed on the first finger which vibrates when the distance is between 1.5-6 meters and the second finger vibrator vibrates only when the distance is less than 1.5meters. The intensity of vibration varies inverse-

ly with distance, as the object approaches closer the vibration becomes stronger. While in case of audible feedback, 28 different musical notes are used to alert the user. For shorter distances the tone of the musical note gets high.

From technical point of view, Teletact is an advancement of Tom pouce. Teletact has better accuracy of 1% as compared to Tom Pouce and have improved rate of distance measurement. The limitations of Tom Pouce are its small range, and late detection of small objects. The Teletact source of feedback is also easy to interpret than Tom Pouce.

From rehabilitation point of view, the user of white cane has to be trained on Tom Pouce for 3-4 months. It takes 3-4months for the user to get aware of sources of information and the sensory feedback of the time and then the system integrates with the user as a reflex. So the decision making and resulting action to be optimized takes a few months after complete training. For the user to use Teletact the use of Tom pouce was mandatory so that the user feels easiness in using this system also. Initially the features of Teletact are reduced so that the user gets the feeling of using Tom Pouce. But, as the user learns the effectiveness of the gadget all features are enabled so that maximum advantage can be taken from the features of the device.

From beneficial point of view in daily life, the responses are somewhat mixed up. Some user does not like the use of these gadgets and prefer conventional White cane. But users who feel comfortable with Tom Pouce and then Telectact never give up the use of Teletact.

3. Proposed Methodology

3.1 Methodology for Analytical Study

The analytical study of different gadgets focuses on following parameters:

3.1.1 Power consumption

Power consumption is one of the major parameter due to the obvious reason without power the device is not able to work, the power consumption in different devices vary with the load. In different devices techniques used are also different and because of the load variation some need more power and others need less. The system with minimum number of electric circuitry suits our requirement. In blind assistance devices the major requirement is to run for extended period of time without charging again and again.

Devices that need regular recharging or large batteries are only costly but provide no use to the user because if the user wants to go from one place to other and batteries end up, user will be stranded at that place. The system needs to work more and consume less power. The system should automatically controls wastage of energy like when the device is in use power is consumed but when the device is not in use it is not preferable to dissipate energy or consume power due to this a lot of energy is saved and it works for extended period of time.

3.1.2 Portability

The device or assistive technology needs to be portable so that user can easily carry the device with him. Portability is sometimes the main feature of the device because people choose the one which is easy to carry. In assistive technology blind needs light weight equipment or device rather than heavy equipment, so the equipment needs to have sensor and other electronic circuitry lighter as a result the user can easily wear or carry the device. The weight of device matters in selection of a device a lot because the user always prefers light weight, easy to handle devices.

3.1.3 User friendly

User friendliness determines the extent to which a device can be used by the user in achieving goals with effectiveness and efficiency. It also describes how easy the user interfaces are. The device should be easy to operate by the user and also easy to adopt. The device should be not only easy to use but also easy to learn and easy to remember.

As in case of complexity, the user will not feel easy in adopting the gadget and will not choose it accordingly. This parameter plays an important role in selection of any device if the device is complex with lot of sensors mounted on it and not easily accessible the device is not going to be the first choice by the user, in our case blind needs ease of operation in starting and stopping the device. Different types of system or devices are present in market and ease of use makes selection criteria easy for the user to select any device.

3.1.4 Range

Range describes to what extent a device can detect an obstacle. When choosing a particular device range plays an important role in selection of the device. Higher the range the more easy it is for user to change his path from the obstacle.

Blind assistance technology for obstacle avoidance depends on range due to the reason that blind want to avoid obstacles in much wider area, the devices having small range are not preferable and long range provide the user a facility to easily move around his environment. Range of the device should be such enough that it tackles the surrounding of the user.

3.1.5 Invasive and Non-Invasive

One of the important characteristic in the selection of technology in blind assistance is whether the device is in contact with the obstacle or is not. The user has to move around in different environments

and terrains so this parameter becomes an important one.

Invasive or non-invasive devices should be selected according to the environment specified by the user. If there is no danger to our device when the obstacle and device comes into contact, it is better to choose invasive otherwise non-invasive device should be preferred.

3.1.6 Response time

Response time is the time device takes in sending a signal to the user after detecting the obstacle. Blind people needs the device having a fast response time so that the blind after receiving the information from the device can easily change the path. The response time of the device is based on different technologies like whether an IR sensor is used or camera mounted system is used for obstacle detection. The response time also depends on the processing done on the information received from the sensors and then intimating the user through feedback. The faster the response the more time user has to make decision.

3.2 Technologies Considered for Analytical Study

Although there are many gadgets available for helping the blind people but we focus on following gadgets for this study:

3.2.1 A Smartphone-Based Obstacle Sensor for the Visually Impaired [8]

Smartphone has become a very common gadget nowadays. So this modern day gadget is also used to assist blind people. This system uses artificial intelligence techniques for detection of obstacles.

The camera of the smartphone is used as a primary imaging device for image acquisition. The image from camera is then processed using image processing techniques. First any area of interest is defined in which the camera has to scan for a dangerous object. After the definition of area of interest a histogram of the image is made. Initially a histogram of clear floor is stored and when the cane is used, a classifier which can differentiate between the floor and the obstacle is used to classify either 'floor' or 'obstacle'.

Making the histogram of a colored image takes a little time so the author suggested the use of threshold technique. In this method a threshold for clear floor is calculated and if the threshold does not match the threshold value then that area is marked as hazardous.

The smartphone in this technique is held at an angle of 45 degrees so that the area ahead of the user is scanned. If the smartphone is not kept at this angle then the working of the system is affected.

The user can either get sensational feeling or an audio signal in his ears through the speakers intimating of the danger facing him/her. The user has the option of either using the vibratory function or the sound feature. If an obstacle is detected then the user has to move the phone right or left to scan that area until no danger is sensed.

3.2.2 The Ultra Cane [9]

Infra-Red sensors having wide range of applications and accuracy are also used in obstacle detection devices. However, the use of IR sensors became obsolete.

The Ultra Cane is an enhanced version of I-cane. I-cane had two main parts handle and base. Base consists of electronic circuits, embedded chip and three IR sensors. The base of the cane also supports three wheels for movement of the cane. This device also has the feature of brake for its user. After the success of I-cane the Ultra cane was introduced, which have some advancements and increased efficiency as compared to I-cane.

The Ultra cane has a rotating disc on which the wheels are mounted, these wheels moves the cane to avoid the obstacles. Instead of three IR sensors two IR proximity sensors of bigger diameter are mounted on the rotating platform so that when the disc rotates the sensor again scan that area for obstacles. The stick also has another IR sensor which scans for the hurdles at head level. To avoid hurdles at ground level like holes or digs an ultrasonic sensor is used so that the user gets maximum safety, as an aid to user in case of obstruction the stick also has a vibrator whose intensity varies with the distance of obstacle from the user.

The sensors sense the obstruction and then the cane automatically moves to avoid it. The rays from the IR sensors are reflected back if an object is placed in the way of movement. The frequency of ultrasonic rays from the bottom sensors varies with the change of height from where the rays are reflected back. With the reflection of these rays the presence of an obstacle is judged by the stick and the user is intimated. When an obstacle is avoided then the front wheel of the stick which is connected with the motor rotates in a direction to avoid it.

The range of Ultra cane varies from 2-4 meters from the tip. The overhead range is 1.5 meters from handle.

3.2.3 Wearable Real-Time Stereo Vision for the Visually Impaired [10]

Stereo Vision and Stereo Sounds are the two latest techniques used for helping the blind people, these two techniques are incorporated in the said paper for the same purpose. The gadget was named as Stereo Vision based Electronic Travel Aid (SVETA).

SVETA has three main components i) Stereo Camera ii) Stereo headphones and iii) Compact Computing Device (CCD). Two stereo cameras are mounted on a helmet for the purpose of navigation act as virtual eyes for the user. With the help of these cameras, the distance of the hurdle can be calculated

by certain algorithms. As two cameras are mounted so the technique of stereo matching is to be used to mix the two images obtained from the cameras. Our brain also has a certain algorithm for mixing the two images obtained from our eyes so an artificial algorithm is developed to incorporate the same feature in the research. These algorithms are processed in Compact Computing device that has a 500MHz Intel processor and a 256MB RAM. The CCD is a small pouch which the user wears when using the gadget.

The CCD after processing the images converts it into a stereo sound that is then sent in the form of audio signal or voice command to the stereo headphones. These stereo headphones are also incorporated in the helmet. The sonification methodology is used for informing the user about the obstacle ahead of him. As our ears have the ability to differentiate between sound frequencies from 20Hz to 20 KHz, so in sonification methodology sounds of different frequencies are generated in various octaves. The information from the meshed image is used to generate sound of different frequencies by use of certain algorithm according to the distance of the obstacle and the user is then alerted of the hurdle ahead of him/her.

3.2.4 Wearable Obstacle Detection System for Visually Impaired People [11]

The system discussed is based on stereoscopic sonar technique and has a vibration based feedback system. In this system user is given jacket to wear with the whole system incorporated on it.

As the system is incorporated on a jacket so light weight equipment is used. The system consists of two sonar sensors, two cell phone vibrators, and microcontroller and a DAC. The sonar sensors have an ultrasonic sensor and an ultrasonic receiver incorporated on a single chip. These sensors are mounted on the left and right shoulders in the jacket to cover maximum area ahead. The ultrasonic sensor emits a wave and the receiver measures the echo reflected back. The difference in the emitted and reflected signal computes the distance between the obstacle and sensors. The microcontroller used receives the signal from transducers in the form of Pulse Width Modulation (PWM) which is directly proportional to the distance from the obstacle. The microcontroller measures the width of the pulse and calculates an empirical distance. The distance is then converted into a voltage which is sent to the appropriate vibrator through the Digital to Analog Converter (DAC).

First the direction and placement of obstacle is determined by Localization of horizontal plane and after calibration between the inputs from left and right sensors the feedback is given. If the obstacle is on the right side then the user feels the vibration in the right vibrator and same is the case for obstacle on left side. If the obstacle is in front of user then front of user then both the vibrators will vibrate simultaneously. The intensity of vibration will vary according to the distance of obstacle from the user.

4. Results

4.1 Parameters Specification

For evaluating the gadgets the parameters should be specified. For power consumption, a device consuming a power of 0-0.5W is considered as low power, 0.5-1W as medium power, and greater than 1W as high power. For range, a device which can detect obstacles in 0-2m is a low range device, 2-4m as medium range, and greater than 4m as high range. For response time, a device detecting and giving feedback 0-100ms is considered as fast, 100-200ms medium and greater than 200ms as slow. The device is portable if it is light in weight and the user can easily wear for extended period of time otherwise it is considered non-portable.

A user friendly device is easily accessible and easy to operate. Non-invasive devices do not come in contact with obstacle and become safe option dangerous environments like fire, water, etc. otherwise invasive devices are preferred.

Table 1: Comparison of Gadgets

Devices	Parameters							
	Power Consumption	Range	Portable	Non-Portable	Response Time	Invasive	Non-Invasive	User Friendly
Wearable Obstacle Detection System for Visually Impaired People	Low	Medium	Yes	No	Fast	No	Yes	Yes
A Smartphone-Based Obstacle Sensor for the Visually Impaired	Medium	Low	No	Yes	Medium	No	Yes	No
The Ultra Cane	High	Medium	No	Yes	Medium	Yes	No	No
Wearable Real-Time Stereo Vision for the Visually Impaired	High	High	No	Yes	Slow	No	Yes	No

5. Recommendations

After analyzing different gadgets on above described parameters in Table 1, Wearable Obstacle Detection System for Visually Impaired People satisfies most of the parameters and therefore is selected as optimal gadget compared to others due to less power consumption, faster response, ease of use and invasive behavior.

The existing technologies discussed are good but not a single device satisfies all parameters as some devices are light in weight but their range is not good etc.

To make Wearable Obstacle Detection System for Visually Impaired People respond faster, it should be equipped with advanced microcontroller to decrease computational complexity. One sensor can be mounted in between the two sensors to increase the detection rate. An advanced ultrasonic sensor LV-Max Sonar EZ-0 [12] having a range of 6.5m can be used instead of the conventional sensor to increase the range. Moreover the sensor has a maximum power consumption of 11mW, small in size, light weight, and have a wider beam. Power consumption can be effectively reduced by using the above mentioned sensor. To reduce power consumption, the device should be equipped with an interface which have stand-by mode in it to minimize the power dissipation, when the device is not in use.

To make the device easier in its use, the device should be equipped with an audio signal mechanism that intimates the user about the obstacles by using headphone. User friendliness can be increased by voice commands to alert the user.

6. Conclusion

Several intelligent and automatic assistant have been devised for visually impaired people. The market personnel want to sell their items without understanding the exact need of blinds therefore it lacks any guideline which can help blinds people to select an assist which is best suited to them. We conduct an analytical study of all such assistant on the basis of some parameters. We believe that this comprehensive information would help the impaired people to choose an optimal device for them. We intend to extend our study for several equipments used by deaf people.

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