SHRAVAN-The Indoor Navigation System For Visually Impaired Personnel

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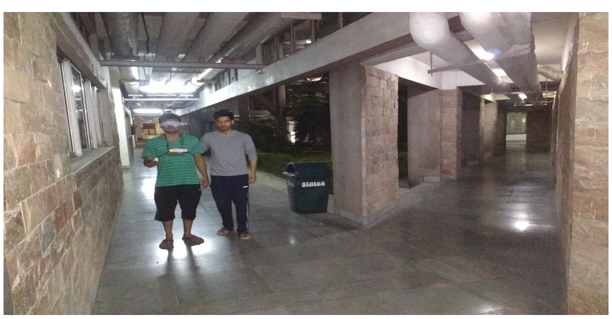
***Abstract*—The task of indoor navigation is central to the riddance of maximum problems of the visually impaired people who lack the capability of sensing directions. Blindness deeply affects the cognitive development of such people thereby further affecting their behavior in the immediate and unfamiliar environment. Artificial vision/Synthetic vision in terms of some outdoor/indoor navigation capability can drastically change the life of such specially abled person.**

The contemporary navigation systems largely depend upon the expensive sensing equipment or on expensive physical augmentation of the environment which is at times bulky. Our system is based on low cost smart phones which are available in the local markets in abundance and are very user friendly. Our system is a mobile smart phone based indoor way-finding navigational system for the visually impaired people. It provides stepby-step directions till the destination from any location in the building using minimal additional infrastructure. The carefully calibrated system provides audio instructions which help the user to navigate efficiently and unobtrusively in an unknown and unfamiliar environment. However, there is a limitation of this indoor navigation system. The irregularity in the wi-fi signal strength further adds up the errors in the output in terms of the current location of the user.

***Keywords*—Visually Impaired, Indoor Navigation, Mobile Smart Phones, Mobility, wi-fi, accelerometer and magnetometer**



I. Introduction

The task of navigation is mainly dependent on the orientation skills of a person and his/her mobility tendency in the immediate surroundings.[1] The primary and most common method of path integration is by orienting oneself with respect to a start point and thereafter employing certain landmarks en route till the destination is reached. This essentially requires individuals perception of the things and various external factors such as the cognitive map.

Thus, in order to visualize a path till a given destination in an unfamiliar environment, one requires to remember certain landmarks with the help of which the entire map can be built. This map building through cognition in case of normal sighted persons is done by means of their ability to see, whereas the visually impaired persons have to solely depend upon their other more developed abilities/senses like the ability to touch, feel, hear and smell.[2] Various studies have been carried out to observe the difference between the sighted people and the blind people in order to find out how they identify their ways and then carry out path integration. The studies show that there exists slight difference in doing so.[3] However, the kind of cognitive mapping required for this purpose is very retarded in case of blind persons which further retards their mobility significantly.[4]

The task of localization within enclosed environment requires tracking and positioning systems. There are various such indoor positioning systems available that employ either optical tracking or wireless concepts or ultrasonic techniques. Reconnaissance and Surveillance applications necessitate identification and detection of items and thereafter tracking them. Various methods exist for estimation of indoor and outdoor localization of objects.[5] These methods employ signals in the form of light, sound or radio to carry out triangulation techniques and give positional information as the output. Apart from the methods mentioned above, there are various other methods which employ calculations of relative positions and distances between objects in order to give their location. One of these methods is called Inertial Technique of Localization. However, over a period of time, the errors get accumulated and thus, after fixed time intervals, recalibration is required to be resorted to. Indoor localization can also be carried out using RF IDs, tags, tokens or labels.

Our indoor navigation system SHRAVAN which is implemented using a mobile smart phone has been an effective tool in aiding the visually impaired people in direction sensing. Its easy and user friendly interface allows the intended user in utilizing this app with much ease and with minimum possible error. The implementation of this application has been carried out with latest underlying technologies like wi-fi, use of mobile smart phone with android as the operating system having standard sensors like accelerometer and magnetometer.

II. RELATED WORK

Most of the recent navigation techniques which have been proposed for the blind persons employ outdoor navigation with

GPS as the underlying technology for positioning.[3] However, the walls of buildings in an enclosed environment block the GPS signals. Therefore, use of GPS for indoor navigation is not recommended. To overcome this problem, other positioning systems have been developed that employ different localization techniques.[1]

The first technique calculates a mobile users next location having known his/her initial/original/start location. This is possible because of the inbuilt sensors of the smart phone which the user carries along with him/her. The readings given by these sensors are utilized in calculating and thereby proposing the moving users current location. The next location is predicted with the knowledge of the previous known location and the sensor readings. This method, also known as the Dead-Reckoning technique requires minimum infrastructure and can be implemented using easily available sensors like magnetometers, accelerometers etc. which come with almost all the recent mobile smart phones. Thus, its initial cost is also limited. However, this localization technique is mainly governed by the precision and accuracy of the sensors which is generally not up to the mark in case of low cost devices. Moreover, since this process repeats over time, hence the errors are accumulative in nature.

The other method makes use of beacons which are placed in the indoor area where navigation is required to be carried out. Every portion of the physical area is augmented with identifiers having digital signatures which can be detected using RF IDs, infra red, cameras, sound identifiers etc. Each of these beacons are characterized by their own specific digital signatures. At times, the identification of beacons become difficult due to the human factor involved and the Line Of Sight nature of detection. The beacons should be near to the human beings carrying mobile smart phones. Thus, there are delays involved in the localization. On the other hand, other methods using beacons employ triangulation technique to find the exact location of the user. In case of localization techniques with wireless networks, location of base stations may be triangulated with the help of the signal strengths.[6][7] But there exists multi path fading and interference in such cases. A good model is one utilizing as less energy as possible. Lots of research has been done in this field describing which sensor of the mobile device consumes how much energy. Following table describes the consumption of energy by various sensors.[8]

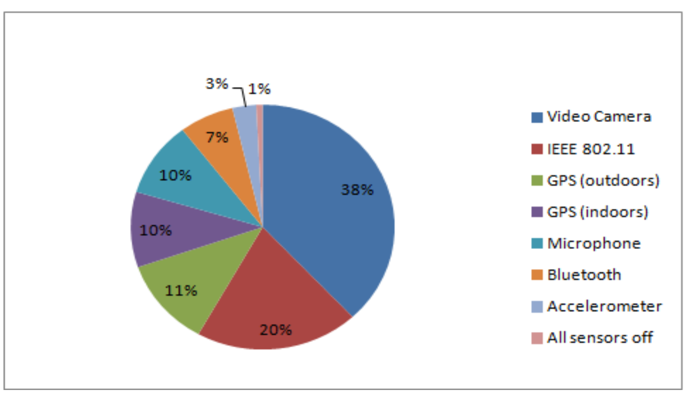


Fig. 1. Relative energy consumption of various sensors

III. BEHAVIORAL STUDY OF THE USERS

Visual impairment means reduced ability of a person to see which may be due to various reasons. The reasons might be any including non availability of lenses. When there is complete loss of vision, this hundred percent disability is termed as blindness. Thus, the visual impairment becomes blindness when a person cant see anything. There can be however various degrees of visual impairment. The routine activities of a visually impaired person gets affected because of this disability.

A. Causes

The most common causes of visual impairment globally are uncorrected refractive errors (43glaucoma (2hypermetropia and astigmatism. Cataracts are the most common cause of blindness. Other disorders that may cause visual problems include age related macular degeneration, diabetic retinopathy, corneal clouding, childhood blindness, and a number of infections. Visual impairment can also be caused by problems in the brain due to strokes, prematurity or trauma among others.

B. Mobility

There are various means available through which a visually impaired person can remain mobile. These means include a wide range of tools and techniques. There exist specialists who aid such people in travelling on their own with ease and confidence. These movements may be both indoors as well as outdoors including routes that are most frequented by such people. These orientation professionals instill a sense of independence amongst such lot by trying to familiarize the immediate surroundings to the visually impaired personnel.

The most common tool is the white cane with a red tip which has become the international symbol of blindness. All these tools aim at improving the orientation skills and mobility of a visually impaired person. Another tool comes in the form of a guide dog. The guide dogs help navigating these people in a real time and realistic manner. However, in complex situations, the guide dog may itself get lost. Various modern gadgets and devices have also been introduced in the market for use by the blind persons in order to help them navigate in an unfamiliar environment.

C. Communication

The visually impaired people communicate with others in a less confident way. Other normal persons also find it difficult in communicating with the visually impaired lot. The primary reason being the problem in being face-to-face with the visually impaired people. Thus, the communication barrier enlarges from both the ends.

D. Response To Surroundings

The visually impaired persons have their other senses more developed in order to compensate the loss of sight. They have to find improvised ways to navigate and communicate with the people. The compensatory senses include response to sound, touch and smell.

1) Sound: The primary sense that a blind person employs for navigation in absence of vision is the sound. Sound is used to identify and detect objects in their surroundings. The concept of Dopplers Effect is used by the visually impaired persons to locate objects. This can also be termed as a form of echolocation. The blind people do cane tapping due to which the sound waves emanate and are reflected off of objects and bounce back at the person giving them a rough idea of where the object is. This is done in order to avoid an item standing in their way.

2) Touch: Touch is the next important sense by which the blind or visually impaired people perceive the world. A lot of information is derived by mere touching ones surroundings. The blind people gain information about the shape, size, texture, temperature, and many other qualities of things by mere touch. Touch also helps with communication. Braille is a form of communication in which people use their fingers to feel elevated bumps on a surface and can understand what is meant to be interpreted. However, in some cases, touching may not be feasible.

3) Smell: Familiar areas have known smell patterns. Blind people associate certain areas by the kind of smell which comes from those areas. This helps them in navigating through those areas. Same thing is applicable for living things also. Each living being has some characteristic smell. Thus, on the basis of such smells, a blind person can identify the obstacles in his/her path.

E. Information Seeking Behavior Of The Users

Study has been carried out highlighting the behavior of the visually impaired personnel as to how they seek certain piece of information, what their information needs are, how they meet those needs, where they find the information they are seeking, how they use the information they have obtained and identify the barriers that they come across while seeking information.[9]

The theoretical framework for the study was Wilsons Model of Information Behavior which emphasized the need to explore information seeking in context and allowed people to be conceptualized as individuals and as socially constructed entities. This perspective was particularly important for the study because disability is a very personal, embodied yet contextual experience. Wilsons 1996 model allows a description of and explanation for information behavior.

F. Effect On Cognitive Development

The behavior of a person is primarily decided by the kind of visual inputs that person receives from the environment. If the visual inputs are nil, the perception about things drastically change. This factor becomes more predominant if a person is blind by birth. Thus, the understandings of cause and effect and the relationships between people and/or objects is severely reduced. Several studies have reported a high incidence of psychiatric disorder in blind children. However the criteria used in diagnoses are based on the sighted population. It is therefore difficult to tell if one is dealing with the outward symptoms of a psychiatric disorder or of the visual impairment itself. It is therefore very important that assessments regarding behavioral deviance are made by clinicians who are familiar with people who are visually impaired.[10]

G. Disorientation Factors

[11]

- Noise/traffic level
- Physical barriers that block landmarks
- Unavailability of braille signs
- Lack of availability of human help
- Human interference in the discovery process
- Lack of consistent building layout
- Large and empty open spaces
- Lighting levels

IV. SYSTEM OVERVIEW

A. Design Procedure

The problems faced by the visually impaired personnel in finding their way and in carrying out other routine chores motivated us to design an application which can aid them in indoor navigation without seeking much assistance from external agency. The problem was defined technically for further processing. An extensive study was carried of the intended users and a user centric application was planned to be designed. This application would give audio signals in the form of directions to a blind person using this application in an indoor environment.

Initial war-driving was carried out in the area under consideration wherein the received signal strength of the signals emanating from two wi-fi hotspots (access points) was measured and recorded. This was the initial step of the system design. After designing, the system was implemented. The final evaluation of the application was carried out by testing it with six blindfolded persons in an enclosed corridor having two diversions inside the CSE department of IIT Guwahati.

B. System Design

The system comprises of an android smart phone in which the designed application has to be installed. The blind person has to seek help from an external agency to feed the destination point where he/she intends to go indoors in an enclosed area. The scope of the trials was limited to an enclosed corridor inside the CSE department of IIT Guwahati which included two diversions and five rooms/halls where the visually impaired person intends to go.

The implementation testbed for SRAVAN was a mid cost mobile MOTOROLA G3 which has both accelerometer as well as magnetometer .It doesn't gives good accuracy for magnetometer readings even though accelerometer accuracy is reasonable. The interface will contain a text input box in which we will have to enter the height of the subject in cm. Then select the destination from the drop down menu and start the navigation application using the start button provided.The

Fig. 2. Testbed device(MOTO G3)

application automatically stops after reaching the destination and needs to be restarted again .

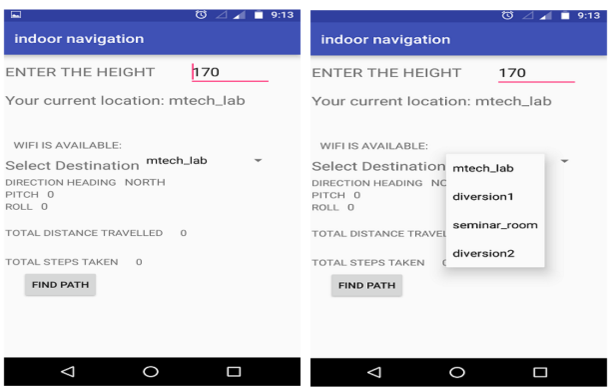


Fig. 3. User Interface

The subject is required to hang a very comfortable and light weight mounting through his neck in order to place the smart phone on it with the desired orientation. The same is required for meeting the constraint of keeping the smart phone in horizontal direction while using the application. Such orientation is required for both the sensors to function the way they are intended to. This hands free and user friendly mounting helps the subject to move around freely which considerably reduces his cognitive load.

1) Accelerometer: It is a measuring device which measures the actual acceleration of a body. For example, if we are falling freely towards the centre of the Earth, we shall get a reading equal to zero. But if a body is at rest, the accelerometer will give a reading of 9.8 m/s^2. In a mobile device, an accelerometer gives acceleration reading for three axes - X , Y and Z. Using these three axes acceleration, one can easily find out and sudden movement of the mobile device.

Fig. 4. Subject with the attachment support device

C. Implementation Of The Design

The design has been implemented by coding with Android Studio as the Integrated Development Environment. Standard sensors which come along with a mobile smart phone have been used mainly being accelerometer and the magnetometer. The accelerometer provides the sense of distance and magnetometer provides the sense of direction/angle.

Use of accelerometer in Shravan The main task in the system is to identify when a step has been taken and then to calculate the step distance.

1) Step detection: For step detection, the following procedure was used:-

- The square of the raw acceleration values for all the three axes given by the meter was summed up.
- A threshold value of 101 was decided upon and fixed accordingly. The same was received after carrying out several trials.
- It is considered as a step taken once the accelerometer value reaches or exceeds this threshold value.

2) Calculation of step distance: The step distance is being calculated as under:-

- Studies have shown that a persons step distance and the height ratio is between .40 to .45 depending on whether the person is walking slowly or is taking long steps while running.
- We therefore took a step threshold of .42 so as to match our applications specifications.
- Thus, Step distance=0.42*height of the user.

In the indoor navigation system, the Accelerometer is always kept on in order to detect any sudden movement/ acceleration produced due to any step taken.

3) Use of magnetometer in Shravan: The magnetometer in the mobile smart phone has been used in the following manner:-

- The magnetometer reading gives the current heading/direction in which one is heading (in degrees)
- This heading shown is the difference in angle from the magnetic North to our current facing direction.

- The headings reading ranges between -180 to 180 degrees. Here, the negative degree heading is obtained when our heading is towards left from the magnetic North. i.e - Westwards and it shows a positive degree heading when our heading is towards right from the magnetic north. i.e Eastwards.

4) Mathematical Model: We prepared a map of the building in which we intended to use our application - Shravan. We considered a corridor with two diversions inside our department for the demonstration. The map was represented in the form of a graph. The components of the graph include :-

- Nodes - Landmarks.
- Edges - Path between the landmarks.
- Edge Weights - Distance between the landmarks.

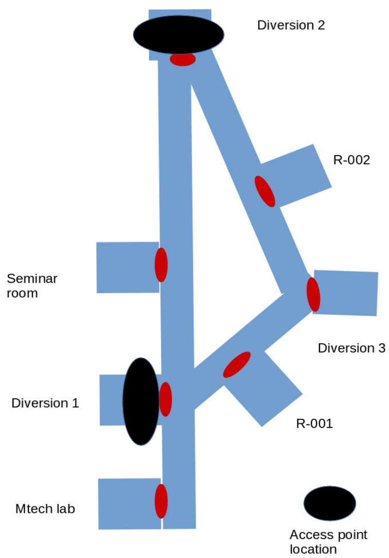


Fig. 5. Floor plan of the test area

After making the graph and adding edge weights, we run the Floyd Warshall algorithm on the graph. Floyd Warshall algorithm gives the shortest path between two points.

D. Wi-Fi

We used BSSID (Physical identification of the WIFI access point) and RSSI value (Signal strength of the device). RSSI values give the signal strength in the range between -100 and 0 dB. We converted this on a scale of 0 to 500, where 0 is the minimum strength and 500 is the maximum strength.

For mid course correction, we need the RSSI values of each access point at each landmark. So, we took the reading at each landmark for two minutes. We got approximately 500 readings at each point. Thereafter, we took an average of these values for each access point at each landmark. These values were stored in a database. This would help us identify the current landmark where user would be present. The current location of the user is thus found out by comparing the current RSSI value for each access point at each landmark with the already stored values. From this, we identify the current location.

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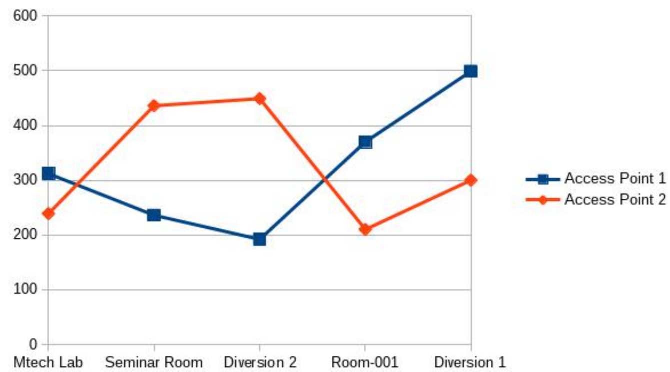

Fig. 6. RSSI values of Access points at the landmarks

E. System Evaluation

The trials were conducted with six persons duly blindfolding them. Both the wi-fi module and the accelerometer module were tested within the subjects in a repeated fashion. The obtained results were tabulated and charts were prepared accordingly. Due to paucity of time and non- availability of the desired class of subjects or the intended users (the blind people) the present trials have been carried out with the normal people duly blindfolding them. Thus, the endeavor has been to simulate the trials as realistically as possible. However, the actual users (blind people) can be pitched in for real trials and the results can be compiled and compared with the present results. Same are summarized in the succeeding

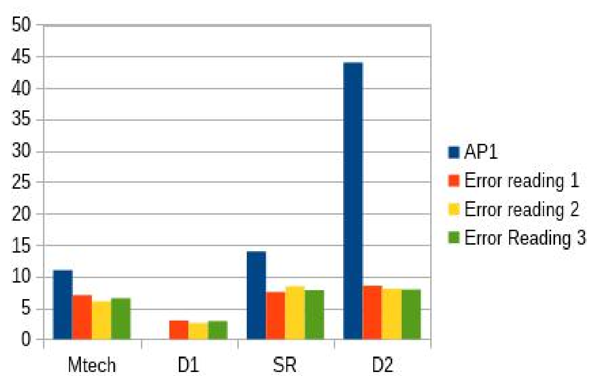

Fig. 7. Distance(m) vs Error(m) For AP-1

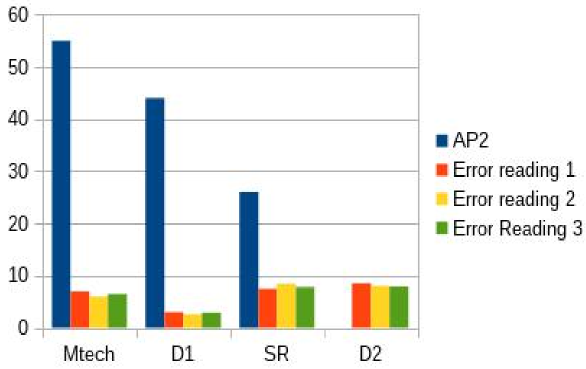

Fig. 8. Distance(m) vs Error(m) For AP-2

F. Observations

Firstly, it was observed that the system was giving high error rate with the wi-fi module. The wi-fi module was duty cycled for 50 % of the time. This ensured that the power consumption due to wi-fi do not exert much toll on the system. It was observed that the errors increased with the increase in the distance of the mobile phone from the Access Point. The use of accelerometer also provided audio directions to the user while navigating in the indoor environment. However, it was observed that the errors are getting accumulated over time and distance due to which 100 % accurate results were not obtained. In figure number 8 we are still getting comparable error in both case when the access point is near as well as far from the landmark because of the use of specialised access point device which has more operating power. slow performance of the application was detected while using both the wi-fi module and the accelerometer module of the system.

G. Advantages Of The Design

The sensors chosen for the application consume very less power and hence the overall power consumption of the system is minimal. The wi-fi module required for error correction has been suitably duty cycled so as to further reduce the power consumption. Thus, the main concern for a mobile smart phone with regards to its battery life has been taken into account and catered for. The mathematical modeling can be carried out for a separate building in a similar way and hence this model can be reused. Its user centricity renders it suitable to be fielded in enclosed environments for indoor navigation for a special class of the society. The main challenge faced by a visually impaired personnel in exploring his/her immediate surroundings in order to navigate in an indoor environment and reaching a desired location has been suitably dealt with by means of our system - SHRAVAN.

V. CONCLUSION

This system is quite useful for the visually impaired personnel. By virtue of its low cost, it is affordable and can be integrated with the existing infrastructure with minimal changes. The system is very user friendly and is therefore of potential use to low vision people as well as elderly people with limited vision. The system requires further refining in terms of calibration and audio interaction with the user. A prototype has been developed on the proposed system which is further available for research and improvement.

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