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Obstacles Detection Technique for Visually Impaired

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Abstract

World Health Organization (WHO) has estimated that there are about 45 million visually handicapped people worldwide. These visually impaired people experience serious difficulties in leading an independent life due to reduced perception of the environment. Most of them confront serious difficulties in mobility and navigation, when they find themselves in new, unknown environment. The visually impaired people greatly rely on vision aids to perform their daily activities. In this paper, we have discussed in detail all the design issues involved in the development of stereo vision based navigation technique for the blind people. In this paper, we have described a technique that automatically detects obstacles and help the blind user in navigation. The developed technique makes use of calibrated stereo cameras to acquire stereo images of an object from nearby viewpoints. The acquired stereo images are rectified to ease the stereo correspondence problem, which is computationally hard

Keywords: *Blindness, Obstacle Detection, Computer Vision, Stereo Vision*

1. Introduction

These days research is going on in the computer related fields like computer security, algorithm design, biometrics, network analysis, computer vision etc. Research in the area of computer vision has taken a serious shape in the last two decades. Computer vision is the area of research that focuses on how to make machine see. With the help of techniques used in the area of computer vision, we have developed a technique that will help visually impaired in navigation. To get the perception of the environment around them, humans depend upon five senses-vision, hearing, smell, touch and taste. Out of these, vision is undoubtedly the one that people depend upon the most for the performance of their everyday activities. Most people cannot even imagine what life would be like if they lose it – unable to read, requiring assistance for daily activities and difficulty in recognizing dear ones.

This is, however, a hardcore reality for nearly 45 million people worldwide, who are blind [Emmet T. Cunningham Jr. et. al (2001)]. A further 135 million people have severely impaired vision in both the eyes and additional 100 million people suffer from monocular vision loss [John. P. Whitcher et.al (2001)]. India has about 25 percent of world's blind population [3]. The Times of India report, dated 18 June 2000, draws attention towards the seriousness of this problem by stating that the number of blind would double by 2020 [4]. In the figure 1 given below, the causes of blindness and the percentage effect of each cause is shown:

These visually impaired people experience serious difficulties in leading an independent life, due to reduced perception of the environment [Vlad Coroama et. al (2004)]. Most of them confront serious difficulties in mobility and navigation when they find themselves in new, unknown environment. Many problems encountered by the visually impaired do not seem obvious to the sight people. The shopping malls have building maps, which are stationary displays that are useful only when one can locate and read the display. Many academic and medical buildings lack even this kind of navigation assistance. Challenging for a sighted person, the task of finding way in such a building for an unassisted person with visual impairment becomes nearly impossible.

The visually impaired people greatly rely on vision aids to perform their daily activities. The vision aids for blind have been under extensive research from the beginning of 1970's. Two low-technology aids for the blind, the white cane and the guide dog, have been used by the blind for many years. With the passage of time, the research to help visually impaired lead to the evolution of Electronic Travel Aids (ETA's). Early ETA use ultrasonic sensors for the obstacle detection and path finding. Some of the early Electronics Travel Aids are:

1. Ultra cane.

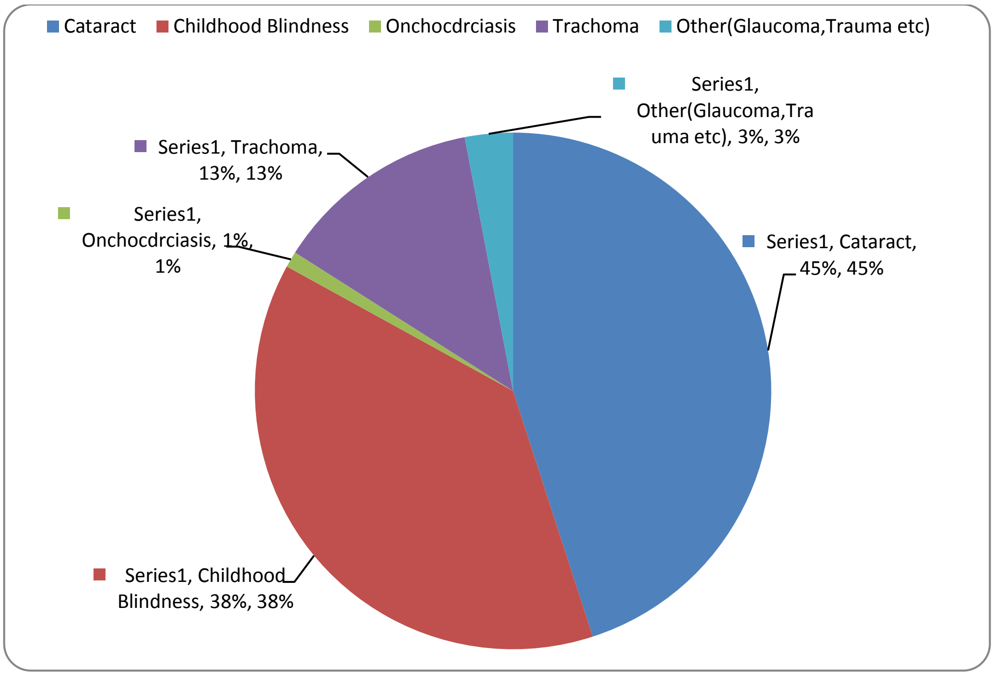

Figure 1: Classification of world blindness

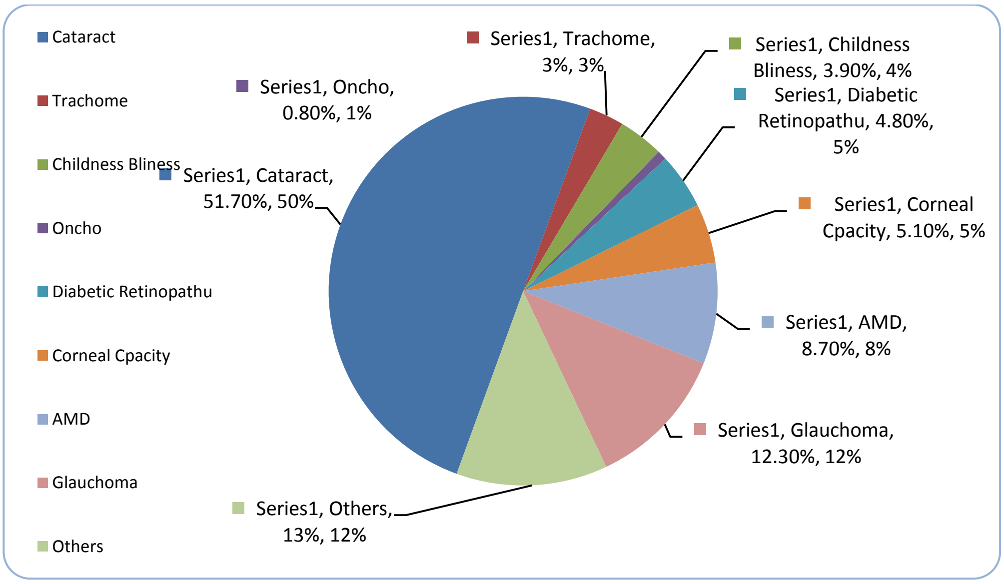

Figure 2: Global causes of blindness as a proportion of total blindness

2. BAT "K" Sensor cane.
3. Guide cane
4. MiniGuide.
5. Mowat Sensor.
6. Sensory.
7. Sonic Pathfinder.
8. Walkmate etc.

These aids proved to be of some help to the blind user but are not enough to enable them to lead a normal life. Today, **computer engineering, ophthalmology and biology are uniting in efforts to restore sight to the blind**. A number of researchers worldwide are united for a noble cause. They are attempting to develop ways to make the blind see. All research teams have one overall goal ***"Electronic sight should be available to those with no vision"*** [Robert Braham (1996)]. The research in the area of computer vision nowadays is extremely focused on developing applications for people with low vision and blindness. Day-by-day blindness is increasing because of diseases. The recent study on blindness and causes of blindness is presented in the next section.

2. Recent Studies on blindness and causes of blindness

Blindness is defined as 'visual acuity of less than 3/60 or

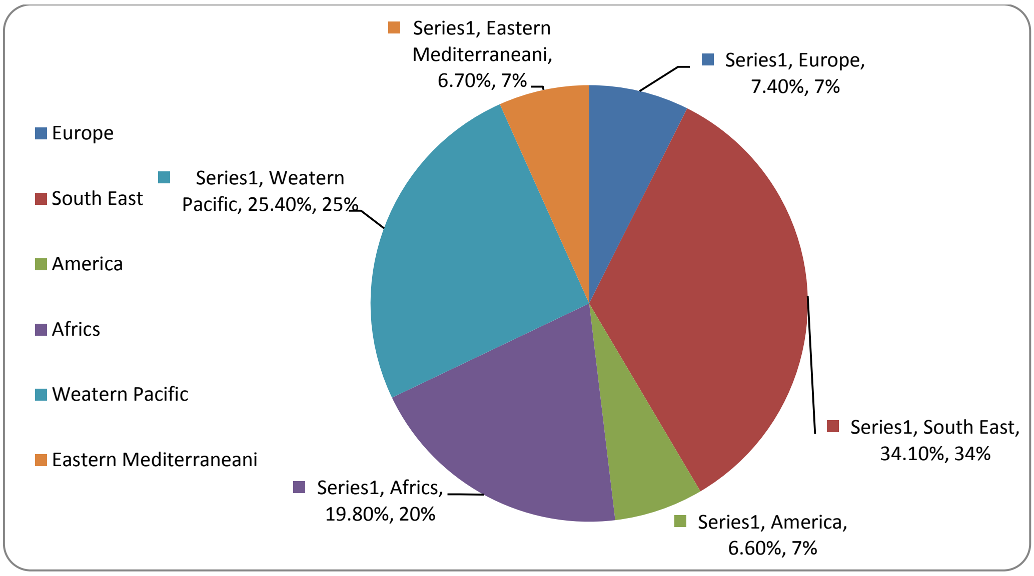

Figure 3: Geographical distribution of the world's blindness

corresponding visual field loss in the better eye with best possible correction'. Another simple definition of blindness refers to a loss of vision resulting in a person being unable to walk unaided. Low vision corresponds to visual acuity of less than 6/18, but equal or better than 3/60 in the better eye with best possible correction. A person affected by low vision is also defined as one who– after treatment and refractive correction– has impairment of visual function but is potentially able to use vision for the planning and/or execution of a task.

2.1 The Causes of Blindness

The main causes of blindness are- cataract (47.8%), glaucoma (12.3%) and age related macular degeneration (8.7%). Other causes include corneal opacity (5.1%), diabetic retinopathy (4.8%), childhood blindness (3.9%), trachoma (3.6%) and onchocerciasis (0.8%). Blindness is most prevalent in developing countries where malnutrition, inadequate health and education services, poor water quality and a lack of sanitation leads to a high incidence of eye disease. In India, there are approximately 293,000 blind and visually impaired people. Most blindness is caused by age-related conditions and the number of people affected is expected to double over the next 20 years as the population ages. The global cause of blindness as a proportion of total blindness is shown in the figure 2 given below:

2.2 Blindness Statistics

The following facts have been collected from the demographic studies of the blind:-

- Every five seconds one person in the world goes blind and a child goes blind every minute.
- According to the World Health Organization (WHO), in 2002 an estimated 161 million people worldwide were visually impaired, of whom 124 million people had low vision and 37 million were blind.(However, these figures do not include refractive error).
- More than 75% of the world's blindness is preventable or treatable.
- Approximately 90% of the world's blind people live in developing countries.
- Blindness more often affects older people. More than 83% of people who are blind are aged over 50 years (yet this age group represented only 19% of the world's population).
- An estimated 1.4 million children under the age of 15 are blind worldwide.
- In some developing countries, up to 60% of children die within a year of becoming blind, either from the condition that caused the blindness (such as measles and vitamin A deficiency) or from inadequate care as families affected by poverty struggle to look after a disabled child.
- Blindness is both a cause and a result of poverty. Adults and children living in poverty are more likely to suffer from malnutrition, poor water quality and inadequate sanitation. This places them at much higher risk of contracting eye disease.
- The annual global economic impact of blindness was estimated at US$42 billion in 2000. Around three-quarters of the world's blind children live in the developing countries in Asia and Africa. Distribution of blindness in the world is shown in the figure 3 given below:

2.3 Cataract Blindness

Cataract is the major source of blindness. The following are facts about Cataract Blindness:-

- On a global scale, cataracts are the leading cause of blindness. Of the 37 million people who are blind worldwide, approximately 48% (17.6 million) suffer from cataract blindness.
- Cataract blindness can be treated with surgery. Cataract surgery is considered to be one of the most cost-effective forms of health intervention.
- In some developing countries, the rate of cataract surgery is less than 250 operations per million people per year. This compares to a rate of up to 8,000 in some developed countries.
- In India, the condition which leads to the largest single direct eye health cost is cataract blindness. Around 122,000 cataract operations are performed in Australia each year and a further 29,800 people are visually impaired, to some degree, as a result of cataract.

2.3. Blindness in India

In India, so far as can be ascertained, the earliest school for the blind was founded rather more than fifty years ago at Amritsar by English missionaries, while schools at Calcutta and Ranchi followed some ten years later. Even today there are twenty organizations for the blind in the whole country, and of these, few have resources adequate to care for more than a dozen blind.The table 1 shown below presents the state wise survey of blind people:-

Table 1: Indian state-wise visually impaired

State	% of blind
Jammu & Kashmir	2.08
Haryana	2.01
Punjab	1.70
Gujarat	4.94
Rajasthan	7.53
Maharashtra	5.81
Kerala	3.35
Karnataka	4.41
Andhra Pradesh	5.82
Tamil Nadu	9.63
Assam	2.82
Orissa	5.13
West Bengal	8.62
Jharkhand	1.86
Bihar	10.05
Chhattisgarh	1.6
Madhya Pradesh	6.3
Utter Pradesh	18.52
Delhi	1.20

3. Obstacle detection challenges

The following are the major challenges below on obstacle detection system for the blind:-

- Typically, operating environment is irregular (off-road)
- Difficult to make assumptions concerning shape of the ground surface
- Real time requirements

4. Computer Vision

Computer vision is a field in which research is going on to help the blind people in scene. As a scientific discipline, computer vision is concerned with the theory for building artificial systems that obtain information from images. The image data can take many forms, such as a video sequence, views from multiple cameras, or multi-dimensional data from a medical scanner.

According to survey, 135 million people have severely impaired vision in both the eyes and additional 100 million people suffer from monocular vision loss [John et.al (2001)]. These people face many problems in their daily routine work. So proper attain is requires to help them. Computer vision is a field in which research is going on to help the blind people in scene. As a scientific discipline, computer vision is concerned with the theory for building artificial systems that obtain information from images. The image data can take many forms, such as a video sequence, views from multiple cameras, or multi-dimensional data from a medical scanner.

Computer vision is a discipline of programming a computer to process, and ultimately understands, images and video [Zollei (1999)]. It can be viewed as signal processing applied to 2-D (images), 3-D (videos), or higher dimensions. Computer vision can also be described as a complement (but not necessarily the opposite) of biological vision. In biological vision, the visual perception of humans and various animals are studied, resulting in models of how these systems operate in terms of physiological processes. Computer vision, on the other hand, studies and describes artificial vision system that is implemented in software and/or hardware. Interdisciplinary exchange between biological and computer vision has proven increasingly fruitful for both fields.

Computer vision is a relatively new science. Research from a variety of fields slowly evolved and formed into a new branch Computer Vision. Computer vision is intimately tied to:

- **Physics**
- **Artificial Intelligence(AI)**
- **Neurobiology and Optics**
- **Military**
- **And many More**

As a technological discipline, computer vision seeks to apply the theories and models of computer vision to the construction of computer vision systems.

4.1 Functions in computer vision system

- **Image acquisition**

For image acquisition several image sensors are used for producing a digital image. These image sensors various types of light-sensitive cameras, includes range sensors, tomography devices, radar, ultra-sonic cameras, etc. Depending on the type of sensor, the resulting image data is an ordinary 2-D image, a 3-D volume, or an image sequence. The pixel values typically correspond to light intensity in one or several spectral bands (gray images or color images), but can also be related to various physical measures, such as depth, absorption or reflectance of sonic or electromagnetic waves, or nuclear magnetic resonance.

- **Pre-processing**

In pre-processing, the data is firstly process for assuring that it satisfies certain assumption implied by the method. After that the second step comes of applying the computer vision method to image data for extracting the specific information. Examples are

  - Re-sampling in order to assure that the image coordinate system is correct.
  - Noise reduction in order to assure that sensor noise does not introduce false information.
  - Contrast enhancement to assure that relevant information can be detected.
  - Scale-space representation to enhance image structures at locally appropriate scales.

- **Feature extraction**

Image data is used for extracting image features at various levels of complexity. Typical examples of such features are

  - Lines, edges and ridges.
  - Localized interest points such as corners, blobs or points.

- **Detection/Segmentation**

In this step image points or regions of the image are relevant for further processing. Examples are:

  - Selection of a specific set of interest points.
  - Segmentation of one or multiple image regions which contain a specific object of interest.

- **High-level processing**

At this step the input so obtained is a small set of data, may be a set of points or an image region which is assumed to contain a specific object. The remaining processing deals with, for example:

  - Verification that the data satisfy model-based and application specific assumptions.
  - Estimation of application specific parameters, such as object poses or objects size.
  - Classifying a detected object into different categories.

As humans we are equipped with five senses - sight, sound, taste, touch and smell. Out of these five senses, most of us rely most heavily on our sight. We use our eyes to recognise objects and friends, read text, and to see where we put our feet in order not to fall over. The simple task of dressing becomes so much more difficult if you try it without using your eyes.

In computer vision, a camera is analogous to the human eye whilst the computer itself is analogous to the brain. The camera takes pictures of the world which is then fed into the computer for processing and interpretation. There are many ways in which these images may be processed and interpreted like segmentation, tracking, detection/ classification/ `recognition.

There are many subfields in the computer vision for example stereo vision, image processing, machine vision, signal processing etc. Henceforth, we concentrate on the area of stereo vision.

4.2 Stereo Vision

The word "stereo" comes from a Greek word "stereos" which means firm or solid. With stereo vision we can see an object as solid in three spatial dimensions-width, height and depth-or x, y and z. It is the added perception of the depth dimension that makes stereo vision so rich and special.

4.2.1 Advantages of Stereo Vision

Stereo vision or stereoscopic vision probably evolved as a mean of survival. With stereo vision, we can see where objects are, in relation to our own bodies with much greater precision-especially when those objects are moving toward or away from us in the depth dimension. We can see a little bit around solid objects without moving our heads and we can even perceive and measure "empty" space with our eyes and brain.

The greatest advantage of stereo vision with respect to other techniques (e.g. optical flow) is that the depth can be inferred with no prior knowledge of the observed scene (in particular the scene may contain unknown moving objects and not only motionless background elements).

5. Obstacles Detection Technique

We have developed a technique that automatically detects obstacles and help the blind person in navigation. The thesis work includes the following step:

- Rectification,
- Disparity map,
- Segmentation and
- Obstacle detection.

Basic concept behind each above mentioned step is described below:

5.1 Rectification

The first and the foremost task involved in the object detection is the parallelization of the epipolar lines. So, the first step is the rectification process which basically involves the removal of distortion from the images by allowing the use of simple epipolar geometry.

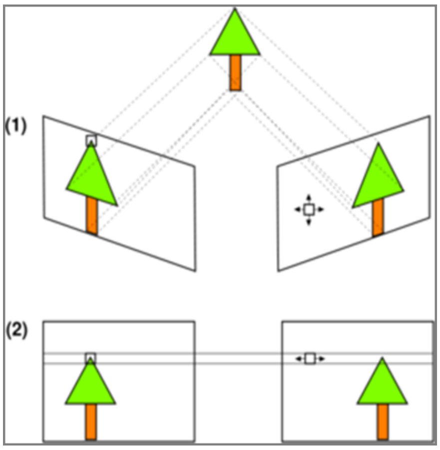

Figure 4: the search space (1) before rectification (2) after rectification

After rectification of two images, the matched points should have necessarily the same ordinate in the two images. The search of point in the second image corresponding to a given point in the first image is limited. Therefore to a one-dimensional search along a horizontal line in the second image situated to the same ordinate rather than a bi-dimensional search in a region of the second image. Rectification process is shown in figure 4.

5.2 Disparity Map

Two images at different viewpoints see an object at different positions and angles. This image difference is known as *disparity.* A stereo geometry is shown in figure 5 given below.

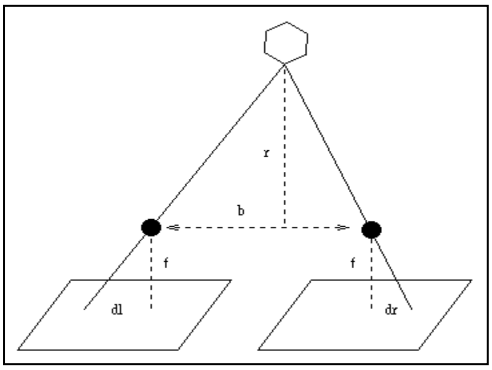

Figure 5: Stereo geometry

Two images of the same object are taken from different viewpoints. The distance between the viewpoints is called the baseline (b), given in above figure 5. The focal length of the lenses is f. The horizontal distance from the image center to the object image is dl for the left image, and dr for the right image. Normally, we set up the stereo cameras so that their image planes are embedded within the same plane. Under this condition, the difference between dl and dr is called the *disparity*, and is directly related to the distance r of the object normal to the image plane. The relationship is:

$r = \frac{b*f}{d}$ Where d = dl - dr .

Sensor noise and different transfer functions of the left and right imaging system introduce stochastic signal variations, whereas the varying view geometry leads to a variety of systematic image variations, including occlusion effects and foreshortening. In addition, since most object surfaces in real-world scenes display specular reflection, the intensities observed by the imaging systems are not directly correlated with the object surfaces, but nearly always have a viewpoint dependent component which moves independently of the surface.

Rectified images and epipolar geometry is a well-understood subject in computer vision. Given a suitable system for camera calibration, it is easy to produce rectified images [Hartley and Zisserman(2003)]. Stereo correspondence algorithms take two (or sometimes more) rectified grayscale images as input, and produce a disparity map *d*(*x*,*y*) for each pixel in one of the input images, typically stored as a grayscale image. Disparity map is shown in figure 6 given below.

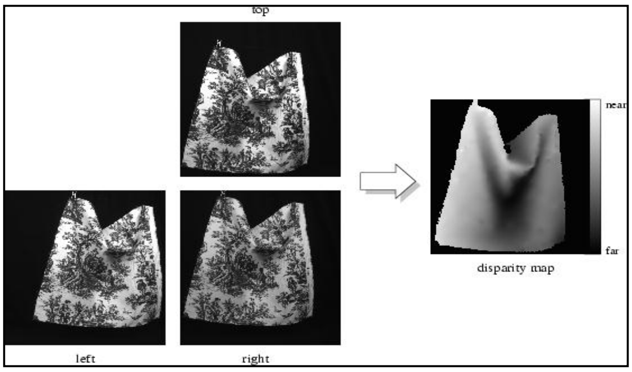

Figure 6: Stereo correspondence algorithm takes two (or more) rectified images as input.

5.3 Segmentation

In the analysis of the objects in images it is essential that we can distinguish between the objects of interest and "the rest." This latter group is also referred to as the background. The techniques that are used to find the objects of interest are usually referred to as segmentation techniques-segmenting the foreground from background. Image segmentation may be defined as the process of distinguishing objects in an image from the background. The purposes of segmentation in obstacle detection are quite obvious, since segments must be distinguished or separated first before they can be identified as obstacles. Typically several techniques are used to accomplish this task when dealing with images that are described by the intensity of each pixel (intensity images). A major goal of image segmentation is to identify structures in the image that are likely to correspond to scene objects It is important to understand that:

- There is no universally applicable segmentation technique that will work for all images, and,
- No segmentation technique is perfect.

The result of image segmentation is a set of segments that collectively cover the entire image, or a set of contours extracted from the image. Each of the pixels in a region is similar with respect to some characteristic or computed property, such as color, intensity, or texture. Adjacent regions are significantly different with respect to the same characteristic(s)[Dhond and Aggarwal(1989)].

5.4 Obstacle Definition

Obstacle is defined as something which prevents or delays an action. So, an obstacle is anything which stops your progression and/or requires the modification of current posture. From physiological and geometric points of view, an obstacle can be represented by an edge (a surface gradient) which prevents the evolution of the planned action [Linda and George(2001)] [Berthoz (1997)].

5.4.1 Blind people obstacle definition

For blind people, obstacles are defined by touch (feet and hand); sounds and proprioception provide other useful cues. It should be stressed that it’s often too late when a blind person has perceived an obstacle

5.4.2 Obstacle internal representation:

Cognitive map [Cierco (2002)] defends the theory of a brain cognitive map which is the internal representation of our environment via place and head orientation cells. These cells permit to have a useful and efficient representation of our environment with information on obstacles’ presence.

5.4.3 Obstacle avoidance task

The obstacle concept and its representation on any support, influence strongly the obstacle avoidance task. Detection of an obstacle in the environment is done by senses feedback, and brain analysis and the explanation.

- **Vision**

Visual perception is based upon physiological and psychological cues. Physiological cues, such as accommodation, convergence, binocular disparity, and movement parallax, directly influence the external world parameters selection and quantification by our brain. Psychological cues, such as image size, linear perspective, surface perspective, surface gradient, objects occlusions, shading and nuances, texture gradient, result from a subjective perception of the observed phenomenon and are related to image photometric formation, scene photometric and geometric analysis [O'Keefe and Burgess (1996)].

- **Hearing**

Sound of the environment is important for the correct understanding of its structure. Sound of objects, machines, and people help to understand space structure. Sound sources properties are linked to the sound they generate. Spatial localization can be calculated using stereophony principles and their distance can be induced from sound’s intensity level (the nearer the stronger: Doppler theorem).

- **Vestibule**

Even if vision is the dominant sense for global space structure analysis, other senses are involved in the analysis task as well. Indeed, the vestibular data stabilizes the gaze and permits to integrate translation and rotation information relevant to navigation. Moreover, vestibule allows establishing the link between human being and its position in the external world by providing the reference to the gravity.

- **Proprioception**

The fact that we have an internal (brain) representation of the structure of our body (proprioception) and their relative positions (referential) allow us to have a better understanding of our environment. Indeed, we can know how we interact with environment structure (haptic sense, motor), and we can understand the impact of the environment that forces us to adapt our body structure in order to achieve the aimed interaction [Gentaz and Streri (2003)].

- **Touch**

Physiology of the feeling (touch) sense shows that mainly Meissner’s and Pacini’s mechanoreceptors are involved in hand feeling . Meissner cells are in charge of the surface texture perception via a small pressure induced by the texture pattern, while Pacini’s cells detect vibrations. It seems that Meissner’s cells are mainly involved in surface gradient information registration.

Since the very first days of our life and before having a stabilized and exploitable visual perception, we have built first representations of our 3-D world from world’s tactile exploration.Tactile information can be provided to human in two ways: static and dynamic, both based upon local deformation of the skin corresponding to surface gradient. The active scanning of a tactile stimulating surface seems to be most efficient for perception and memorization.

Future Work

In this paper, we have described an efficient technique to rectify the problem of the visually impaired. In the future we can append more features in this system like System will work in hard real time.

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