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General Article

Obstacle Detection Sensors: A Survey

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Abstract

This paper gives a recent research on the statistic of blind person in world and obstacle detection systems. Obstacle detection is useful for the blind person in collision avoidance. This paper reviews the different techniques such as automated detection system and statistic of blind person in this world. The literature reviews is also condensed in tabular form for quick reference.

Keywords: *Obstacle detection systems, automated detection system, statistic of blind person*

1. Introduction

World Health Organization (WHO) estimates that approximately 38 million people worldwide are blind and more than 110 million having low vision. With the world's population estimated at 5.3 billion, this translates roughly into an overall blindness rate of 7 per 1000. More than 90% of all blind individuals live in developing countries. **By the year 2020, the number of blind people over 60 years of age will likely reach 54 million world-wide if current trends continue.** In 1987, it was estimated that 598,000 people in the United States met the legal definition of blindness. Of this number, 58% were over the age of 65 [Kirchner et al 1987]. In 1994-1995, 1.3 million Americans reported legal blindness[2].In November 2004 article Magnitude and causes of visual impairment, the WHO estimated that in 2002 there were 161 million (about 2.6% of the world population) visually impaired people in the world, of whom 124 million (about 2%) had low vision and 37 million (about 0.6%) were blind.[3]

Statistics on Blindness

- Worldwide, 42 million people are blind.
- Every 5 seconds: One person in our world goes blind
- Every minute: One child goes blind
- 75 million: People will be blind by 2020 (if trends continue)
- 37 million: People in the world are blind
- 124 million: People in the world are visually impaired
- 90 per cent: Of the world's blind people live in developing countries
- 33.3 million: Of the world's blind people live in developing countries
- More than half Of the world's blind live in India (9 million), Africa (7 million) and China (6 million)
- Five–10 times: People who live in the developing world more likely to go blind than
- people who live in highly industrialized countries.
- $28 billion (US): Per year direct economic loss due to global blindness.
- 100 million Americans are visually disabled without corrective lenses (70 million are myopic).
- 80 million people suffer from potentially blinding eye disease.
- 33,700,000 visits are made to doctors for eye care each year.
- 11,400,000 people have severe visual conditions not correctible by glasses.
- 6,400,000 new cases of eye disease occur each year.
- 2,800,000 people are visually handicapped from color blindness.
- 1,100,000 people are legally blind.
- 650,000 people are hospitalized each year for eye injury or disease.

2. Obstacles Representation

Obstacles detection task in the real environment requires obstacles representation, and constant feedbacks to any intermediate level of brain environment analysis based upon data provided by human exteroceptive sensors when moving[Bac01][Len98][Len00][Gen 03] [Ber97].

2.1 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,

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an obstacle can be represented by an edge (a surface gradient) which prevents the evolution of the planned action [Ber97][Cie02].

2.2 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

2.3 Obstacle internal representation: cognitive map

O'Keefe and al. defend 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.

2.4 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

2.4.1 Vision

Visual perception is based upon physiological and psychological cues. Physiological cues, such as accommodation, convergence, binocu lar 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 [Gre03].

2.4.2 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).

2.4.3Vestibule

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.

2.4.4 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 [Sac98].

2.4.5.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 3D 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 (if there is no purposely strong pressure). The active scanning of a tactile stimulating surface seems to be most efficient for perception and memorization (cf. Braille cell based devices).

3.Background

The vision aid for blinds had been under extensive research from the beginning of 1970's. It has been attempted in many ways with restricted achievement. Electronic Travel Aids (ETA) are electronic devices developed to assist the blind for autonomous navigation. Early ETA'S use **ultrasonic sensors** for the obstacle detection and path finding. But recent years,due to advanced development of the high speed computers and sensory devices, attempts for sophisticated equipment for the vision substitution are in progress [Wong et al,2000]. Recent research efforts are being directed to produce new navigation systems in which digital video cameras are used as vision sensors [Martin et al, 1998][Molton et al ,1998]. What has drawn so much interest into the subfield is perhaps the inexplicable ease and immaculate accuracy with which the human brain accomplishes certain tasks related to vision. Moving through an unknown environment becomes a real challenge when we can't rely on our own eyes [Espinosa et al,1998].

Since dynamic obstacles usually produce noise while moving, blind people develop their sense of hearing to localize them [Schmidt,1979]. However they are reduced to their sense of touch when the matter is to determine where an inanimate object exactly is. The common way for navigating of visionless person is using a white cane or walking cane. The walking cane is a simple and purely mechanical device dedicated to detect static obstacles on

Table 1:- Comparison b/w Automated system

System Characteristics Adequate field of view	Sonar	Radar	IR Intensity	Laser scanner	IR Time of Flight
	No	Yes	No	No	No
Range	1.5	3	1	100	1.3
Cost($AU)	60-649	App. 700	App. 50	App. 44000	App. 10000
Angular Resolution (degree)	10-125	180	180	0.5 along a single or multiple planes	1.25
Illumination	Emissive, work in dark	Active, work in dark, rain, fog	Active illumination, work in dark	Emissive , work in dark	Emissive work in dark

the ground, uneven surfaces, holes and steps via simple tactile-force feedback. This device is light, portable, but range limited to its own size and it is not usable for dynamic obstacles detection neither than obstacles not located on the floor. Another option that provides the best travel aid for the blind is the guide dogs.The dog is able to detect and analyze complex situations: cross walks, stairs, potential danger, know paths and more. Most of the information is pass through tactile feedback by the handle fixed on the animal.But guide dogs are still far from being affordable, around the price of a nice car, and their average working time is limited, an average of 7 years [Schmidt ,1979].

3.1. Automated Monitoring Systems

Systems are available that use sonar or radar to detect obstacles. In the event that a detected object comes too close to the rear of the blind person, the person is provided with an audio and/or a visual warning. While these approaches can be effective, certain situations exist where these systems can fail.

Another approach to reducing blind spot accidents is by using automated monitoring systems. These consist of a sensor to gather information from around the person, a processor to perform the necessary calculations to detect obstacles, and a device to notify the person of an impending collision, for example, with an audio and/or visual warning. These systems can be used to monitor areas, and also act as a secondary observer to ensure the person is aware of the presence of obstacles within time. We will now review the different types of sensors that have been used for automated monitoring.

3.1.1 Sonar

Sonar range sensors emit ultrasonic signals to determine the distance to an object. A sonar pulse is emitted from the device, and the time taken for the first echo to return is measured. Using knowledge of the measured time of light and the speed of sound in air, it is possible to infer the distance to the object rejecting the pulse.In Australia, Holden has released several system with rear park assist as a standard feature (Holden 2003).The Holden Commodore Acclaim has four ultrasonic sensors mounted in the front of the system.

Sonar devices are well known for the apparent unreliability of their readings (Dudek et al. 1996). These devices rely on sound waves traveling through air, rejecting of the surrounding objects. As a result there are several potential sources of error when calculating range from sonar measurements:

3.1.1.1. Low angular resolution: The angular resolution of a sonar sensor is denned by the beam cone angle. Outside this angle, the sonar pulse exists, but is too weak to return a measurable echo. It can range from about 10to 125centimeters (Polaroid OEM Components Group 1999).

3.1.1.2. Cross talk: Many vehicle reverse assistance systems utilize more than one sonar unit to help determine the angular position of an object. However this causes yet another problem which is known as cross talk. This is when a sensor receives a sonar pulse of the same frequency from another sensor, and confuses this with it's own signal. This can be solved by using sonars of different frequency or sound wave signatures. However, this requires the use of sensors with differing characteristics or a substantial amount of signal processing of the echos (Wijk 2001).

3.1.1.3. Specularity: Many surfaces act as specular surfaces at ultrasonic frequencies. This means that a sonar wave that hits the surface will follow the law of rejection – the angle of incidence is equal to the angle of reflection. It then follows that the surface needs to be almost facing the sonar sensor, otherwise the sonar beam will be rejected away from the sensor. In which case no echo will be detected, or an echo that has been rejected several times may be detected, providing an inaccurate reading.

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3.1.1.5. Diffraction: Another source of error in sonar measurements is due to diffraction. This happens when the sonar beam hits the corner of an object, which causes the echo wave to spread out cylindrically, with less energy. As a consequence, the corner is less likely to be detected and may not be detected at all.

3.1.1.6. Dead zone: There is also a minimum detection distance. When a sonar pulse is emitted by the sensor, any returning echos will be ignored because the device is still transmitting and not yet listening for the returning pulse. This distance is usually between 15 to 35 centimeters (Sensing and Control, Honeywell Inc. n.d.).

3.1.2.Radar

The MAA study (Paine & Henderson 2001) tested the Guardian Alert product by S & S Distributing, USA. This device had the longest range of the products tested, with a 3 meter maximum but this was reduced to 2.2 meters on the side opposite to the mounting. The main drawback of this system is the large vertical angular range, making it impossible to distinguish between objects of varying size and position. In September 2004, the automotive supplier Delphi gave a demonstration in Washington D.C. of their latest active safety technologies (Bishop Consulting 2004). One of the systems that was presented was the Dual Beam Back-Up Aid. This system uses radar sensors to detect obstacles up to a range of 5 metres. The Integrated Back-Up Aid with Camera is anticipated to be released on the market in 2008. There was no information provided indicating the accuracy of either system.

3.1.3. Infrared Intensity : Infrared sensors are another relatively cheap device that could be used. These sensors emit light from the infrared spectrum, and measure the distance to objects based on rejected light intensity. As a consequence, they give different results depending on the colour of an obstacles surface. This type of sensor is only effective for determining short range distances of no more than about 1 meter (Wijk 2001). The sensor characteristics make it unsuitable for any system.

3.1.4 Laser

Laser range sensors are quite effective at accurately determining ranges to objects in the environment. These sensors release a thin beam of light, and in a similar manner to sonar sensors, measure the time of light for the light beam to return. It can measure distances up to 100 meters away with centimeter precision. Laser range sensors are able to sample the environment much faster than a sonar sensor, as it relies on light rather than sound. A laser scanner:

- is quite expensive.
- can only detect objects within a single plane or possibly multiple planes (depending on the sensor), and will miss any object in between.
- has difficulty detecting transparent objects such as glass windows.
- is affected by dirt or water on the lenses, which can lead to false readings.

3.1.5 Infrared Time-of-Flight

This is another time-of-light sensor that uses an infrared light source to provide a burst of light. The device measures the time taken for the light to return to the sensor to determine the depth to surrounding objects. One of the leading technology providers is a company called Canesta (Canesta, Inc 2006). Depth and intensity images are generated up to a maximum rate of 30 Hz. The main disadvantages are as follows:

- When used outdoors, even with Canesta's patented CMR technology, the maximum
- range of the sensor is 1.3 metres.
- The range is also limited by the strength of the infrared source.
- The maximum field of view is 80 degrees.
- The sensor is currently only available to the general public as part of a development kit, which costs US$7 500.

4. Conclusion and Future Directions

This paper discussed the recent research on the obstacle detection using various sensors. A good obstacle detection system must be capable of the following:

1. to detect obstacles on a given space in good time
2. to detect and identify correct obstacles
3. to identify and ignore ground features that may appear as obstacles

These systems have low angular resolution and limited sensing volumes. Further improvement of performance would be possible by using proper combination of algorithms as well as sensor in order to improvement the detection techniques.

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