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Visual-tactile sensory substitution for blind with array of infrared sensors

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Abstract— **Considering blindness as the loss or decrease of the sense of sight, a possible palliative to this disability could be increasing the capacity to operate of two of the four other senses (taste, touch, smell and hearing). Most of the travel aids developed since white cane in 1921 are found within this line of thought. Some, as the mentioned cane, are extensions of the sense of touch, and others use the sense of hearing. The problem of this idea is that, both the sense of touch and hearing are not idle, and in visually disabled people the hearing sense is extremely necessary to overload it with more information. Some obstacle detectors have major problems because they have to be held by one hand, which is a limitation. This project explores the use of the sense of touch, but leaving the hands unoccupied, giving more freedom to blind people. A tactile radar that transmits information with a head band (Haptic Radar) is taken as reference, but powered with the use of a tactile stimuli, whenever an obstacle is detected. The proposed implementation uses the Sharp GP2D12 IR distance detector sensor, and the 18F46K20 Microchip microcontroller.**

Keywords— **Haptic radar, sensory substitution, blindness, DSP.**

1. INTRODUCTION

Since the invention of the white cane in 1921 by the Argentinian Jose Mario Fallï¿½tico, there have been many different kinds of navigation assistance devices for visually impaired people including electronic devices. This work emphasizes the evolution of the most recent ones.

Although the white cane is quite limited compared to vision, it has a big importance for visually impaired people because it is intuitive and allows disabled people to be identified within society. It is the reason why most of the technological help developed later, including the one presented in this work, is complementary to the cane [6][12]. Studies made in visual substitution have focused on both, tactile and auditory senses. Using both modalities, subjects have demonstrated the ability to localize and identify objects in the visual field [7].

Many technological aids have used visual-auditory substitution [2][3]. Within these developments it is possible to enumerate: the Mowat Sensor [2](hand held pocket-sized device containing an ultrasonic air sonar system), the Pathsounder [2](distance and position of a detected object is signaled using the eight tones of the musical scale), the Laser Cane [2](provides the user with advanced warning of obstacles in his/her path through an audible and tactual alarm system). However, the auditory sense substitutions mentioned before overload a sense that is already used in navigation, and the person may be in danger in the perception of urban traffic; and apparently it is not as intuitive and easy to use as people expected the method to be.

Taking into account this observation, this work will focus on visual-tactile substitution. The skin is an ideal location for tactile stimulation. The area of the skin is very extensive and it is minimally exploted during navigation. In addition, like the eye retina, the skin is capable of representing information in two dimensions and integrating signals over time[7][8]. Since 1960 there have been made many research works in this field. An example of these kind of developments is a device called TVS (Tactile Vision Substitution System)[9][10]. In spite of being conceptually new, it turned out to be inadequate for regular environments because of the large amount of information that it brings to the user. Following this line of research, in 2006 the Haptic Radar [5][11] appears, a device that allows the recipient to respond quickly and instinctively to spacial information. It uses an arrangement of infrared sensors that gather the information of the surroundings and translate it into a vibro-tactile stimuli. The problem with this device is its short range, but it turns out to be very intuitive for the user and training is not needed for its use.

This work focuses in the development of a visual-tactile substitution device, additional to white cane, that provides only the needed information, trying to keep costs as low as possible so that it is widely available for all disabled people. Then, the purpose of this study is to design a device of improved and appropriate range. In this way the user receives only the information he/she needs, resulting into a mechanism that can be easily used. With the aim of the implementation of this device, a variant of the Haptic Radar is chosen, but using an arrangement of infrared sensors that allows more range and information of the distance to the object.

This paper is organized as follows. Section 2.describes the obstacle detection system, indicating the involved processing and showing how the system will be implemented. The conclusions are drawn in Section 3.

2. METHODS

2. 1. Obstacles detection system

This study presents an own development which emulates the Haptic Radar, with an additional microcontroller that controls the vibrators. The microcontroller is used to activate and deactivate the vibrators as well as to measure the distance and the proportional response to it. Additionally, the microcontroller is needed to solve the situation when the user is resting in a position or seated next to an obstacle that is in the visual field (for example a wall). If the original Haptic system was used, vibrational information of the presence of the wall would be permanently sent to the person, which could be very annoying. That is why the system is designed not only to produce a distance proportional stimuli but also to analyze the relative modification of that distance. So, if a variation of the distance was not obtained, the system would not give information of that presence. As soon as a movement is detected, the vibrators would activate proportionally to distance and also to the distance variation. Figure1 shows the system taken as reference for the development.

Considering that the device is meant to be used for long periods and that it must allow the user to be independent, its parts must be tough and reliable. For this purpose many technologies of sensor arrays are evaluated so that the most convenient is chosen. Thus, the conclusion is that the most adequate sensor is the family of infrared sensors GP2D.

The GP2DXX line of sharp IR detectors [1][4] is a general purpose distance-measuring group of sensors which consists of a charge coupled device (solid-state silicon chip consisting of an array of individual light sensitive cells), an infrared emitting diode and a signal processing circuit. These sensors use triangulation to compute the distance to the object. A pulse of IR light emitted from the diode is reflected off any object in the field of view and returned to the CCD (charge coupled device). This creates a triangle between the points of reflection, the emitter and the detector. Finally, the distance to the object is proportional to the resulting angle. Depending on the sensor of the Sharp family, an analog or digital output proportional to the distance to the obstacle can be obtained:

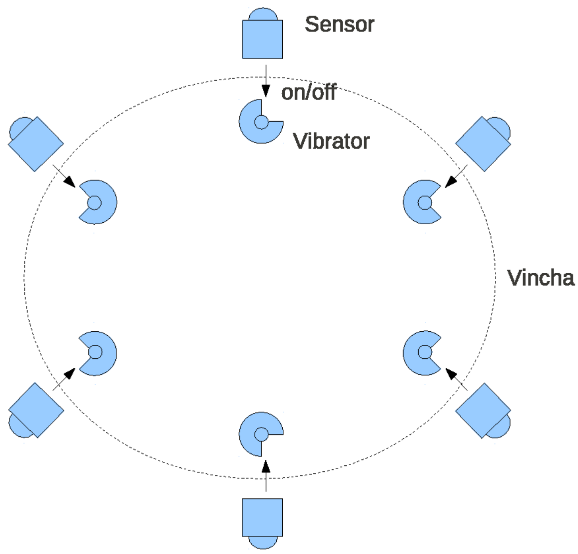

Figure 1: Scheme of Haptic Radar device.

- Analog. The output voltage is proportional to the measured distance.
- Digital. The output is a serial 8 bit reading with external clock.
- Boolean. The output is 1 bit, it shows the crossing through the hysteresis area of the sensor.

During device operation a LED radiates an infrared light. This light passes through a lens that produces a single ray as concentrated as possible to improve the directivity of the sensor. The light goes straight forward and when it finds an obstacle it is reflected and returns with a certain angle depending on the distance. The returning light is concentrated by other lenses, so that all the reflected beams impact in a single point of the charge coupled device. Figure 2 shows a scheme of this procedure. The most important characteristics of the family are presented in Table 1.

The sensor chosen is the GP2D12. The Sharp GP2D12 IR range sensor acquires a continuous distance and reports the distance as an analog voltage with a distance range of 100mm to 800mm. The output is continuously available and its value is updated every 32ms. This output can be connected directly to an analog circuit or to the input of an Analog-to-digital converter so that the microcontroller is able to use the digital equivalent value of the sensor output. The GP2D12 uses a single output line to communicate with the main processor. The sensor is shown in Fig.3.

Model	Characteristics	range(mm)
GP2D02	CCD [1] Infrared LED Signal processing, Digital output, 8 bits	100 a 800
GP2D021	CCD Infrared LED Signal processing, Digital output, 10 bits	40 a 300
GP2D05	CCD Infrared LED Signal processing, Digital output, 8 bits	100 a 800
GP2D12	CCD Infrared LED Signal processing, Analog output, 0-3V.	100 a 800
GP2D120	CCD Infrared LED Signal processing, Analog output, 0-3V.	40 a 300
GP2D150A	CCD Infrared LED Signal processing, Boolean	150 typ.
GP2D150T	CCD Infrared LED Signal processing, Boolean	220 typ.

Table 1: Characteristics of GP2DXX Sharp sensors.

As mentioned previously, this device uses triangulation to detect the presence and distance of objects in the visual field. The manner of functioning consists of an infrared light pulse emission transmitted through the visual field that impacts onto an object and reflects light. If it does not find any obstacle, the beam does not reflect and the reading made shows that situation. If it does find anything in the visual field, between the IR emitter, the point of reflection at the object the light hits, and then the detector, a triangle is formed. In this way the distance can be calculated. The angles in this triangle will change depending on the distance of the object and thus it is possible to calculate the distances using the angles. If the angle is big, the object is nearby (the triangle is wide), otherwise, the object is far away (the triangle is long and thin). The triangulation process is described in Fig. 4.

During the triangulation process, the infrared LED sends a light beam through a converging lens so that the emitter arrives parallel to the object. When the emitter hits an obstacle, certain amount of light reflects. If the obstacle was a perfect mirror, it would be impossible to measure the distance. Fortunately,

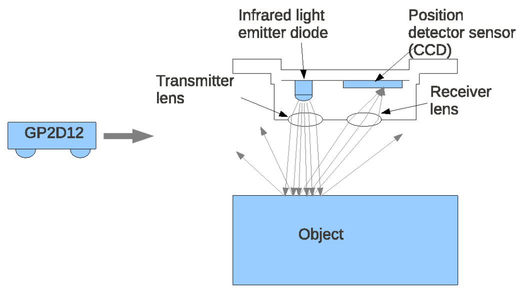

Figure 2: Operating method of the infrared sensor.

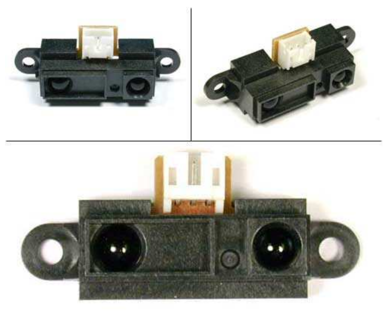

Figure 3: GP2D12 sensor.

all the substances have a high level of porosity, and thanks to the phenomena of dispersion, some of the beams of the infrared light coming from the emitting diode will reflect towards the sensor.

The pick up lens are also a convex lens, but they are used for a different purpose, because they work converting the position angle. If an object is standing in the focal plane of a convex lens and the other beams are parallel somewhere else, the beam that passes through the center of the lens crosses without change or points to the focal spot. In the focal plane we find the CCD (charged coupled device). As it was said this semiconductor device provides an output whose intensity is proportional to the position of the incident light respect to the center. The performance of the CCD in the output is proportional to the focal spot position. This processed analog signal is the sensor output.

Main characteristics of GPD212:

- Less influence of the reflexive objects color.
- Distance indicator line output/distance.
- Analog output to indicate the distance.
- Low cost.

2. 2. Processing

As already mentioned, the purpose of this project is not only to activate and deactivate vibrators in the presence of an obstacle, but also it aims to inform through the vibration intensity the position and distance to the obstacle. The microcontroller is needed to

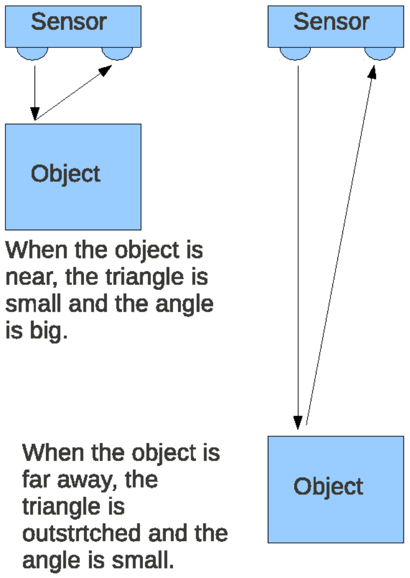

Figure 4: Triangulation process of the sensor.

carry out the analog to digital conversion (if actually the GP2D12 sensor was used), or the serial communication with the sensor if the one that has digital output is chosen. Such task of the microcontroller points out its versatility for a wide range of sensors.

Another desired feature is the possibility to control the tactile alert, not only by turning on and off the vibrators, but also changing its intensity accordingly. By using microcontrollers it is possible to generate software solutions in order to process sensor information and control the vibrators (turning them on and off, and producing proportional intensity). Nowadays, the best available technology for the purposes of this project is the one that PIC's (Microchip) provides.

In spite of being simple, the constructive structure of Microchip microcontrollers is very powerful. In this work, the 18F46K20 is used, providing appropriate memory space and adequate working frequencies. It also has suitable communication modules for serial data communication with sensors. This microcontroller also provides a range of possibilities that, when designing, allow to change sensors if necessary because it adapts to all the mentioned ones. Also, this family of microcontrollers has reduced the working voltage level. According to data sheets, this feature will produce a power saving when implemented.

2. 3. Implementation of the system

The diagram of the system to be implemented is shown in Fig. 5. The system can be divided in two stages. The first one receives environmental stimuli using the infrared sensors array, the information is converted into voltage variations that are processed. In case of the existence of an obstacle the vibrators will activate. The output stage consists of little motors with unbalanced axes, similar to the ones that cellphones use to emit a vibrating alert.

Regarding to the physical implementation of the device, infrared sensors are placed on adjustable elastic bands to cover a visual field of approximately one meter radius. In the head, a 360 degrees cover is implemented, and another 180 degrees cover is also placed in the rest of the body. In the back of each sensor, a vibrator motor is located. As it was said, the intensity of the vibration emitted will be proportional to the proximity of the objects. Also, depending on which vibrator activates it will indicate the direction of the approaching obstacle. Then, the user would be able to distinguish not only the distance to the object, but also its direction by perceiving a variable vibration in the part of the body that has a sensor pointing towards the obstacle.

The batteries that are used for energy supply and the additional circuitry can be transported in a small fabric container that is placed on the belt or directly as part of the device. In case of using the battery implementation in the head band the system would be similar to the one used in head lanterns.

The developed concept allows the user to put the bands with sensors in the place that better suites for him/her. However, studies show that there are areas of the body that have more sensitivity than others. Therefore, there are certain parts of the body that are ideal for the placement of the device. Figure 6 shows an image of the head-band model device implementation.

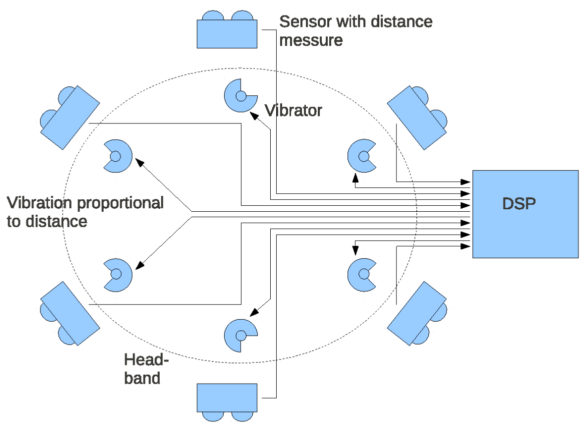

Figure 5: Diagram of the implemented system.

3. CONCLUSIONS

This work shows a system capable of assisting visually disabled people in their daily routines. The development has two distinctive characteristics. First, it allows the user to be helped by a travel aid without using his/her hands, that are already occupied with the cane. The second distinctive feature is even more important, because it enables the user to walk with-

Figure 6: Picture of the implemented system

out being afraid of hitting parts of the body with the surrounding obstacles. The characteristic mentioned before is the property of the travel aid to detect obstacles in an approximately one meter radius, in different heights. All that results in an improvement of users autonomy in daily life. Also, if the fact that this is a low cost device is taken into consideration and that it is safe for users, it can definitely be concluded that this development satisfy the three basic principles of bioethics: independence, equality and beneficence (not maleficence).

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