Wearable Obstacle Detection System for visually impaired People

Sylvain Cardin, Daniel Thalmann and Frederic Vexo
Virtual Reality Laboratory (VRlab)
Ecole Polytechnique Fédérale de Lausanne (EPFL)
CH-1015 Lausanne, Switzerland
{sylvain.cardin, daniel.thalmann, frederic.vexo}@epfl.ch

Abstract

This paper presents an obstacle detection system for visually impaired people. User can be alerted of closed obstacles in range while traveling in their environment. The system we propose detects the nearest obstacle via a stereoscopic sonar system and sends back vibro-tactile feedback to inform the user about its localization. The system aims at increasing the mobility of visually impaired people by offering new sensing abilities.

1 Introduction

The work we present in this paper is based on the use of new technologies to improve visually impair people mobility. Our research focuses on obstacle detection in order to reduce navigation difficulties for visually impaired people.

Moving through an unknown environment becomes a real challenge when we can't rely on our own eyes [5]. Since dynamic obstacles usually produce noise while moving, blind people develop their sense of hearing to localize them [6]. 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 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. Based on the symbiosis between the disabled owner and his dog, the training and the relationship to the animal are the keys to success. 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. The user is able to feel the attitude of his dog, analyze the situation and also give him appropriate orders. 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 [7].

The system we have designed consists in sensing the surrounding environment via sonar sensors and sending vibro-tactile feedback to the user of the position of the closest obstacles in range. The idea is to extend the senses of the user through a cyborgian interface. This means that the user should use it, after a training period, without any conscious effort, as an extension of its own body functions.

This paper describes the architecture and discusses the potential benefits of the system we have designed. One of the main contributions is the use of sonar based stereoscopic architecture of our system to give spatial information about the obstacles in the surrounding.

The rest of the article is organized as follows: next section overviews related works concerning blind people navigation aids. We analyze the advances done by new technologies in the area of handicap reduction for visually impaired. After we present our contribution in details: the design of the system architecture and the principle of the application. Then we present the test methodology and their analysis. The paper concludes with general discussion and our plans for future work.

2 Related Work

A deal of research has been performed to improve autonomy of visually impaired people and specially their ability to explore the environment. Wearable systems have been developed based on new technologies: laser, sonar or stereo camera vision for environment sensing and using audio or tactile stimuli for user feedback [1].

Some early examples about those systems can be illustrated by the C-5 Laser Cane [2] based on optical triangulation to detect obstacles up to a range of 3.5 m ahead. It requires environment scanning and provides information on one nearest obstacle at a time by means of acoustic feedback. The laser system measures the distance to the obstacle and a sound tone proportional to this distance is played. This system developed in the 70's is the precursor of a large series of devices trying to remove the cane of the blind user. More recent development using stereoscopic cameras coupled with a laser pointer and audio system have been developed at the University of Verona [3]. One of the main interests here consists in the translation of the 3D visual information into relevant stereoscopic audio stimuli. The sound generated on ear phones simulates a distant noise source according to the position of the obstacle. This system has been designed to be implemented on wearable device, like a pair of sun glasses equipped with two micro cameras and a PDA. Using audio signals may perturb the user's hearing, which is the main sense that let visually impaired people to perceive the dynamic distant environment. As a Camera vision based system, it can recover more information than only distance to the obstacle. With appropriate algorithm they can also compute information about the nature and specificities of the environment. The problem with vision algorithms is their need of huge computation power and their sensitivities to light exposition.

One other recent project, CyARM [4], is also based on wearable low cost devices but using slightly different approach. It uses ultrasonic transducers to detect the distance to the nearest obstacle. This information is passed to the user through variation of tension of the fixation wire attached to the belt. Higher tension means the proximity of the obstacle. The CyARM application offers an interesting solution. By using sonar sensing and tactile feedback it creates a new portable interface for navigation. However it is still not hand free and needs the user to constantly move the device to sense the environment.

Nowadays, some new commercial devices appear on the market, like the UltraCane [8] which uses a build-in sonar system and sends back vibrations through the handle according to the presence of obstacles. The ultra cane enhanced the traditional white cane by giving information about the obstacles before direct contact. But it doesn't provide any new functionality to the traditional cane and the localization is still done by movement of the cane and it doesn't detect objects at head height.

The mistrust of the visually impaired community against the new technologies is a major limitation of the large distribution of those systems. They often prefer rely on basic system like the cane. It is important for a usable electronic travel aid to let the user hand free in order to allow the use of traditional navigation tools. By letting the user hand free, the whole system has to be embedded in the clothes. Wearable constraint implies that all the system and computing power has to be implemented into small electronic system powered by battery. The system has to be low electrical consumer in order to be usable for several hours in a row. Even if camera based system offers more possibility in term of quantity of information, the computation power requested to treat this amount of data is too high for a proper miniaturization. Small sized, low power consumer in energy and computation, sonar based system seems to fit perfectly our needs for the application. By using vibro-tactile feedback we will not obstruct the hearing of the user while soliciting an unused sense. The next part will describe the system we developed based on those two relevant technologies: sonar sensors and vibrators.

.

3 System Architecture

3.1 General structure

Now we present the system architecture where its components are attached to a jacket. This wear cloth provides a natural way of carrying that facilitate its use (see figure 1). The components we integrate are: two sonar sensors, a microcontroller, and two vibrators.

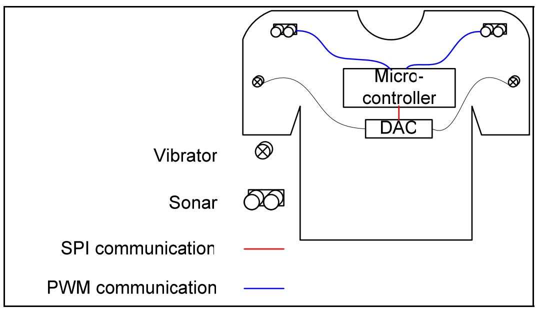

Figure1: Schema of the system architecture

The sensors are fixed on the shoulders to increase the field of sensing and side determination.

3.2 Sensor

The sonar system is based on two ultrasonic transducers mounted together. One emits an ultrasonic wave while the other measures the echo. By differentiation of the input and output signals, a microcontroller pic16F87 computes the distance to the nearest obstacle. Then this information is transmitted as a PWM signal to the receiver.

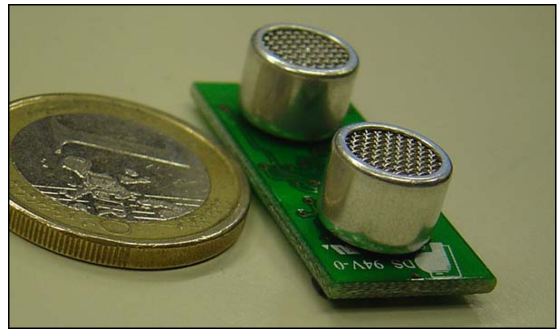

Figure2: sonar sensor

We are using sonar modules design for robotics and remote controlled unit applications. Those devices are accurate enough for our application around 1% of error. The range is limited from 3cm till 3m in a field of view of 60°, which perfectly fit our needs. The electrical consumption is really low (a few mW) allowing them to run for coupled of days on standard battery supply. The packaging of the two transducers is light and small enough (14x32x8mm) to be fixed on a jacket without any inconvenience.

3.3 Data treatment

The microcontroller gathers the information from the ultrasonic transducers as Pulse Wide Modulation (PWM) [9] signal directly proportional to the distance of the nearest obstacle. The microcontroller measures the width of the transmitted pulses and converts it into empiric distance. Following a calibration phase, we can determine the real distance between the sensor and the obstacle. The direction is given by comparison of the signal from both sensors. This distance is then converted into a voltage command for appropriate vibrating feedback. The system redirects this information to the actuators via Serial Peripheral Interface (SPI) [10]. A multi-channels Digital Analog Converter (DAC) recovers 2 integers (address and data) and sends the desired output voltage to the appropriate vibrator.

3.4 Actuator

The vibrators are composed by a miniaturized continuous current engine and an asymmetric mass lot fixed on its axis. The vibration is created by the rotation of the center of gravity of the mass around the axis of rotation.

Figure3: vibrator

We are using vibrators from mobile phone technology. Those devices are small and light enough to be fixed on cloth without any obstruction. The electrical consumption was also a major factor in this choice. With an electrical power consumption of 0.2W at 3.5V, they can run for hours using energy from standard battery. They are also produced in huge amounts so their price is really low.

3.5 Application relevance

With a maximum power consumption below the Watt, our system can run for hours out of a single battery supply. By its stereoscopic architecture, it allows positioning by telling the user from which side an obstacle is coming. Each part is small enough to be fixed on the cloth which ensures the whole system is wearable. It also let the user hands free for other purposes.

4 Working principle

This section presents how our system works and which patterns have been developed to inform the user of its own localization. Obstacle detection is one of the main problems to solve to ensure safe navigation for blind users. We use the stereoscopic architecture of our system to develop new obstacle sensing abilities.

First we determine from which direction the obstacles are coming from. Localization on the horizontal plane is done by appropriate combination of vibration between the left and the right side. If the user feels a vibration on its right it means that the obstacle is on his right. If the vibration is on both sides the obstacle is in front of him.

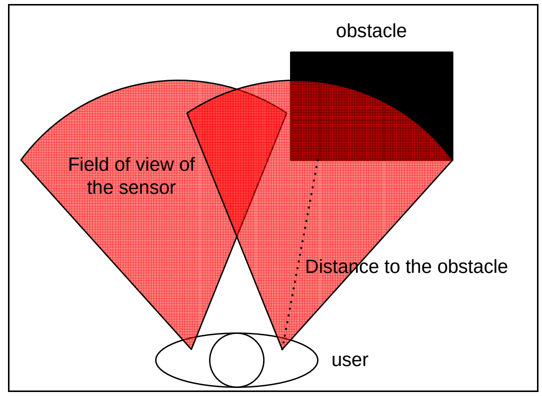

figure4: horizontal sensing map

The second point is to determine the height of an obstacle and specially if there's something on the floor. This is not directly detect by our system and requires mental effort from the user. It's important that the user keeps in mind that the sensor are locate on his shoulder and got 60° of field of view. If the object is at shoulder height then the vibration is increasing constantly while the user is moving toward it. If the obstacle is located on the floor at sufficient distance the user will feel a vibration corresponding to the obstacle. When he'll move towards it the vibration will stop according to the fact that the obstacle will pass below the field of view of the sensors. By memorizing this break of presence, the user can have an idea about the position of lower obstacles.

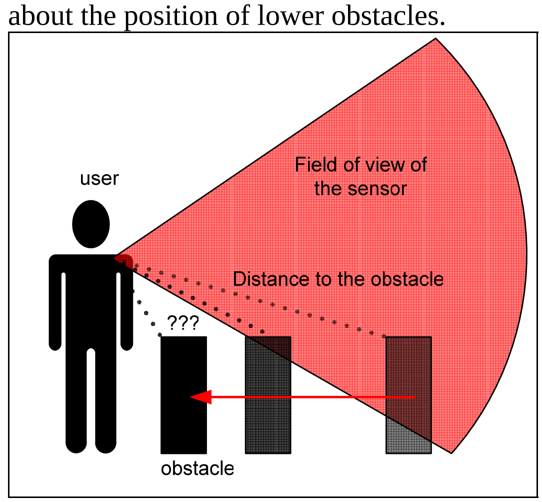

figure5: on floor obstacle detection

Moving obstacles can be localized using the same principles taking in account the user own displacement. The user will feel the dynamic changes into the vibro-tactile feedback. By this means, he will be able to estimate the position and the speed of the moving object.

Then the user of our system should be able to position himself/herself according to the environment and estimate moving object trajectories. The different methods presented for obstacle localization need now to be validated.

5 Discussion and results

5.1 Test methodology

To evaluate the system we have develop a small test method. By blind folding the user eyes, we simulate the deficiency of the visual system. Then we disorient the user by several rotations around him. It avoids him to have memorized the path through the environment. Then we ask him to navigate through a corridor without using his hand to touch the walls. The user only relies on the system to know at which distance he is from the walls.

For evaluating the dynamic obstacle avoidance, we use other people walking toward the user and doors opening or closing. This simulation is designed to be close to the real condition of application. To avoid the user to detect the moving obstacle by hearing them, he has been equipped with hear plugs.

The evaluation is made by an outside person who is judge of the performance of the user by his time to pass through the corridor, his improvement due to training and if the user have encounter collision with the environment.

5.2 Results

These results have been obtained by passing the same tests on five different users. We measure on the graph shown in Figure 6 the time of each user on their attempts. The reference time on the first column represents the time to pass through the stage in normal condition. The 3 others ones represents the successive performances of each user.

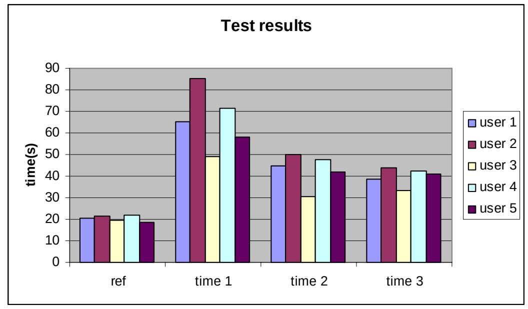

figure6: results for the validation test

The results show that our system is quite intuitive since we can observe a reduction of 50% of the time to pass through the obstacles. We observe only one collision by the third user on his second pass. The users sensed other people walking and avoiding them in the corridor. They had determined correctly on which side they have been passed.

5.3 Discussion

The results of the experience are really encouraging. The equipped user is able to walk through the corridor in a reasonable time after a bit of training. The collisions are perfectly avoided and the user is able to distinguish an obstacle from its left and right and to localize himself in his environment. Dynamic obstacle detection is still need to be improved. In fact the user approximates properly the distance to the obstacle but it still hard to localize it precisely. The main disadvantage comes from the blind angles which limit the field of action of such system.

Another disturbing phenomenon is coming from the occlusion of the sensor by the user hands. It becomes a really threshold for its usability at close range, because the natural attitude when approaching an obstacle is to interpose the hand between.

6 Conclusion & perspective

One main limitation of such sonar system is due to the principle of measurement. We are in fact measuring the distance to the “closest” obstacle in range, which could be an inconvenience when we are trying to map the environment. The problem becomes obvious when the system is used to sense the entrance to a room. We still have obstacle from both the left and the right and it can be interpreted as a continuous wall. A main improvement that can be done to the current system will be to incorporate a set of sensors with a narrow “field of view”. Coupled with a set of vibrators all around the user body, we will be able to make him sense more precisely the topology of the environment.

The system still be hardwired from the sensor to the actuators via the microcontroller. Each part of the system is also mounted on hard circuit board. It will be interesting to weave directly the wires inside the textile fiber and to use semi rigid support for the mounting of the electronic components. Another solution to improve the wearable aspect could be to design the system as a set of independent modules that can be fixed on the cloth and communicating via wireless connection. In order to accomplish a perfectly wearable system the miniaturization should be improved on the sensors and actuators. Those could never be, in a close future, perfectly wearable but could approximate the size of a standard button or clipper present on the most common vest.

This device has permit to reach a step forward the integration of visually impaired people or a precious help when the vision is reduced by harsh environment. The current system still need some improvement before a perfect fit to the application but demonstrates perfectly its usability.

References

[1] Strothotte T., Fritz S., *Development of dialogue systems for a mobility aid for blind people: initial design and usability testing.* In *Proceedings of the Second Annual ACM Conference on Assistive Technologies* (Vancouver, British Columbia, Canada, April 11 - 12, 1996). Assets '96. ACM Press, New York, NY, 139-144.

[2] Benjamin J. M., Ali N. A., *A laser cane for the blind* In Proceedings of *the San Diego Biomedical Symposium*, volume 12, pages 53-57, 1973

[3] Panuccio A., *A Multimodal Electronic Travel Aid Device*, ICMI 02: in proceedings of *the 4th IEEE International Conference on Multimodal Interfaces*, page 39, IEEE Computer society, Washington, DC, USA, 2002

[4] K. Ito, M. Okamoto, J. Akita, *CyARM: an alternative aid device for blind persons*, CHI '05: CHI '05 extended abstracts on Human factors in computing systems, pages 1483—1488, Portland, OR, USA, 2005.

[5] Espinosa, M.A., Ungar, S., Ochaíta, E., and Blades, Comparing Methods for *Introducing Blind and Visually Impaired People to Unfamiliar Urban Environments.*, pages 277-287, *Journal of Environmental Psychology* 18 (1998),

[6] Schmidt, F. (eds.). *Fundamentals of SensoryPhysiology*. Springer, New York, 1979.

*[7] The life of a guide dog, www.g*uidedogs.co.uk

[8] Ultracane™, www.soundforesight.co.uk

[9] PWM definition, www.elecdesign.com

[10] SPI how to, www.xilinx.com