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Blind Guide: an ultrasound sensor-based body area network for guiding blind people

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Abstract

Wireless Sensor Networks, in particular Wireless Body Area Networks, is a technology suggested by the research community as allowing elderly people, or people with some kind of disability, to live in a safer, responsive and comfortable environment while at their homes. One of the most active threats to the autonomous life of blind people is the quantity and variety of obstacles they face while moving, whether they are obstacles in the footpath or obstacles coming out from the walls of buildings. Hence, it is necessary to develop a solution that helps or assists blind people while moving either in indoor or outdoor scenarios, simultaneously allowing the use of the use of white cane or the Seeing Eye dog. In this article, the authors propose the use of an ultra-sound based body area network for obstacle detection and warning as a complementary and effective solution for aiding blind people when moving from place to place. According to the cost estimates of the solution and to the negligible setup time, this could be a real effective complementary solution for blind people.

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1. Introduction

According to the World Health Organization [1], there are about 285 million visually impaired people worldwide, 39 million who are completely blind and 246 million with low vision.

All this people, while moving from place to place, face limitations posed by obstacles such as infrastructures not compliant with blind people, bad localization of some facilities or even due to lots of obstacles present in the footpath like benches, big plant pots, badly parked cars that use large part of the footpath, etc. [2] [3] [4]. In order to move safely, blind people use devices or artifacts that aids them in the movement process. The most common artifact is the white cane that is used to find obstacles and to aid blind people to deviate from them. The white cane also promotes the acquisition of reference points that blind people use for orientation purposes. Another artifact used is the Seeing Eye dog, which helps blind people to deviate from several kinds of obstacles. In this case blind users don't acquire reference points as with the white cane. Hence, a blind person using a Seeing Eye dog must be more alert to signals from the dog than a person using a white cane. On the other hand, the white cane can only detect obstacles up to the waist level. There are several types of obstacles that the white cane cannot detect due to its dimension, shape or localization. Similarly, the Seeing Eye dog will not inform the blind user about the need to deviate from obstacles above the waist level. However, when compared to the white cane, the Seeing Eye dog is more effective dealing with obstacles bellow the waist. This paper presents a complementary solution of obstacle detection for blind people that usually use the white cane or the Seeing Eye dog, and a solution of obstacle detection for recently blind people that do not use the white cane or the Seeing Eye dog yet. This solution is based in a Body Area Network of ultrasound sensors that produces sound-based feedback. The Body area network is embedded in the clothing fabric, freeing blind people to continue using the white cane or Seeing Eye dog.

This document is organized as follows: section 2 presents some related work and section 3 describes the type of obstacles blind people usually face. Section 4 presents the Blind Guide solution and section 5 makes the qualitative analysis of the solution, highlighting advantages, disadvantages and some user opinions. Finally, section 6 presents some conclusions and future work.

2. Related Work

In the last years, the research community has tried to develop solutions in order to solve or, at least, minimize problems posed from obstacles when a blind person is moving from place to place. Brain Port V100 [5] is a solution that includes glasses with embedded camera and a tongue array that contains 400 electrodes and is connected to the glasses via a flexible cable. Glasses capture real time images and images are mapped into the tongue array in terms of gray scale. White level has a strong stimulation, gray level has a medium stimulation and black level has no stimulation at all. However, this solution is invasive and demands a big period of time for adaptation.

Ultracane [6] is presented as an augmented white cane that can detect objects at foot level, leg level, and chest level or even at head level by using ultrasound sensors. Unlike previous solutions the Ultracane is extremely ergonomic, but it is too expensive. Alternatively, Ray [7] is a handy device that complements the long white cane by detecting barriers up to 2,5 meters and announces them via acoustic signals or vibrations. Ray is a solution less expensive than Ultracane but it requires constant use of one of the blind user's hands. In our opinion this is not a good solution because using the Ray device and a white cane both hands of the blind person are monopolized. There are other solutions that try to guide user outside [8-10] or inside [11-14] but they are not strictly oriented for obstacle detection. These solutions usually use GPS for outside and an instrumented environment for inside. Unlike all these solutions, researchers of the SmartVision project have developed a system that combines the use of GPS with Radio Frequency Identification Technology (RFID) to estimate the location of the user. With the support of a specially designed Geographic Information System (GIS) this system is able to notify the user about contextual information, like the presence of obstacles or services in the vicinity. The system is also able to calculate routes to specific destinations taking the user's limitations into account. The interface with the RFID tags (planted in the floor) is made through an RFID reader placed on a specifically developed white cane. This instrumented white cane interfaces with a mobile device via Bluetooth. The interface with the user is made through haptic technology and text-to-speech [15][16]. Similarly, Blind Guide is targeted for both inside and outside scenarios, even for places blind people are addressing for the first time. It is non-invasive, and doesn't require the user's hands to be carried.

3. Obstacle Characterization

In order to detect obstacles, it is needed to segment them into small groups of obstacle types. Hence, from the point of view of a blind person, obstacles can be segmented in the following categories:

- Head level obstacles
- Chest level obstacles
- Foot level obstacles
- Obstacles where the lower part is farther than the higher part that is at waist level
- Obstacles where the lower part is nearer than the higher part of the obstacle

Head level obstacles are not detected either by the white cane or the Seeing Eye dog. Examples of head level obstacles can be tree branches, upper balconies, stair landings, etc. Chest level obstacles are not detected using the white cane but the Seeing Eye dog could detect them. Tables, chairs, vans, motorcycles, trees, electricity pylons are examples of chest level obstacles. Foot level obstacles such as plant pots, park benches, parking lot barriers, holes on the floor, fire hydrants, footpath step, etc. are all detectable using a white cane or the Seeing Eye dog. Apart from these types of obstacles, there are others that confuse blind people: i) the obstacles where the lower part is far than the higher part of the obstacles, such as tables and some types of cars (e.g. pickups) and ii) the obstacles where the lower part is nearer than the higher part of the obstacle such as stairs. All these kind of different obstacles need to be addressed by any solution that intents to aid blind persons.

4. The Blind Guide Solution

The Blind Guide solution is a prototype of an obstacle detection system to be used by blind people, without interfering with the use of the white cane or the Seeing Eye dog. Long term blind people won't put the white cane or Seeing Eye dog apart. However, recent blind people, probably due to a disease like diabetes, are not adapted to the white cane and probably would like to put the white cane apart.

Bling Guide is based in a set of wireless sensor nodes with ultrasound sensors strategically placed on the human body. It can detect the type of obstacles described in the last section. Figure 1 illustrates the Blind Guide prototype.

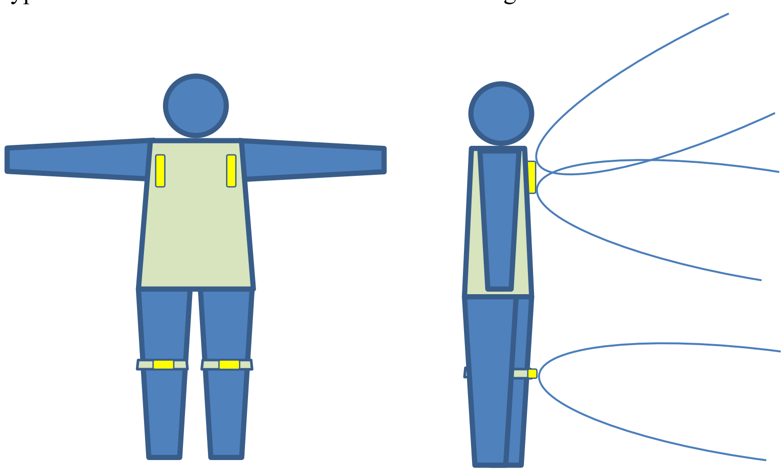

Fig. 1. (a) Blind guide represented by a jacket and two elastic bands; (b) Blind guide detection range and sources of ultrasonic waves.

The Blind Guide prototype is mounted on a wearable jacket with a set of elastic bands. The jacket includes hardware for head and chest level obstacle detection while the elastic bands include hardware for foot level obstacle detection. The elastic bands are to be used in the legs, near the knees, by blind people who don't use the white cane or the Seeing Eye dog. Blind people who use the Seeing Eye dog or the white cane should not use elastic bands otherwise sensors will detect the white cane or Seeing Eye dog as an obstacle.

4.1. The jacket module

The jacket is the Blind Guide system module that detects head and chest level obstacles and it is expected to be worn by any blind user, no matter if they want or not to use the white cane or Seeing Eye dog simultaneously. In the first jacket prototype we used two Mica2 motes, each one positioned in the front side of each shoulder as Figure 1 depicts. In order to connect each Mica2 mote to the ultrasonic sensors (one for chest level obstacles and another for head level obstacles), we also used the prototype board of the Mica2 mote, called MDA100CB. This prototype board includes a prototyping area with connection to all 51 pins on the expansion connector. Mica2 boards were programmed using C language, as we have adopted the MantisOS operating system. In order to save energy on each node, the ultrasonic sensors are polled periodically. Although our tests proved that a period of 1 second is enough to detect obstacles in-time, we adopted the 800 milliseconds as a tradeoff between safety and energy consumption. Besides ultrasonic sensors, a buzzer was also attached to the prototype board in order to warn user about approaching obstacles. In order to distinguish from head level and chest obstacles, different sound duration was adopted. Hence, when a head level obstacle is detected by the left shoulder sensor node, the buzzer sounds intermittently. However, if the obstacle is at chest level, the buzzer sounds intermittently but with a half period of the head level warning sound. If an obstacle is detected by both sensor nodes (e.g the obstacle is in front of the user) then both buzzers will sound.

4.2. The elastic bands

The elastic bands are the Blind Guide system module that detects foot level obstacles and they are expected to be worn by blind people who are not using the white cane nor the Seeing Eye dog. Each elastic band embeds a Mica2Dot sensor node and each sensor node has one ultrasound sensor connected through the MDA500CA data acquisition board. As with the case of Mica2 modules, the Mica2Dot modules were programmed using C language and the MantisOS kernel and an 800 millisecond period for ultrasound sensor pooling has been used. When an obstacle is detected by one of the Mica2Dot sensor nodes, a signal is sent to the related Mica2 sensor node in order to fire the buzzer (on the same side as the obstacle). The buzzer beeps with a different delay to warn user about a foot level obstacle.

5. Evaluation

The Blind Guide prototype was evaluated by both blind and non-blind people in scenarios similar to the ones described in section 3 such as, i) upper balcony as an example of a head level obstacle, ii) a van as a chest level obstacle, iii) a plant pot as a foot level obstacle, iv) a table as an obstacle where the lower part is farther than the higher part of the obstacle and finally v) stairs as an obstacle which has the lower part nearer than the higher part of the obstacle. However, due to safety reasons all these obstacles were simulated using Styrofoam models in a large and clear room.

Non-blind persons firstly evaluated the Blind Guide prototype and all obstacles were generally detected and announced to the user. However, the test user was using his hands in order to keep the jacket in good position and orientation. When two blind persons evaluated the Blind Guide prototype, the shoulder hardware was usually oriented to the floor, probably due to the jacket weight, and in the cases of head level obstacle (the upper balcony made of styrofoam) they were not detected. In spite of this problem, we think we got good results for the first prototype of the Blind Guide. We are already working in a second prototype which instead of using commercial sensor nodes, uses circuits drawn in plastic and lightweight batteries in order to hide both circuits, batteries and sensors into the fabric.

6. Conclusion and future work

This paper describes the first prototype of the Blind Guide. Blind Guide is a Body Area Network mainly used to help blind people to detect obstacles that the white cane or the Seeing Eye dog cannot detect. The target of the Blind Guide are both long term blind people who are already adapted to the white cane or the Seeing Eye dog and want to use these artifacts during their travel and for recent blind people who are not adapted to white cane or Seeing Eye dog yet.

The main aim of this first prototype was to address the different type of obstacles that could be detected. The evaluation results show very interesting results despite the fact that jacket tends to move a little around the users' bodies due to the hardware weight. The sensors tend to point to the floor instead of the head and chest position. However, when the jacket remains in a good position, obstacles are detected and the alerts are fired in time.

As future work, we will replace the Mica2 and Mica2Dot sensor nodes by plastic printed circuits in order to save weight but also to design a circuit board tailored to the jacket internal space. The ultrasound sensors will be also knit into the jacket fabric and jackets with a good size-to-fit mechanism will be used in order to adjust it to fat, slim or normal bodies. Another feature that will be added to the body area network is a mechanism to automatically turn off energy consumption when, for instance, the blind person sits quiet. We are already evaluating this feature using accelerometers sensors.

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