Blind Guide: anytime, anywhere

Daniel Vera Yánez
Departamento de Ciencias de la Computación, Universidad de las Fuerzas Armadas ESPE
Sangolquí, Ecuador
School of Technology and Management, Computer Science and Communication Research Centre, Polytechnic Institute of Leiria, Leiria, Portugal
(+593) 960 077 791
2152215@my.ipleiria.pt

Diego Marcillo
Grupo de Aplicaciones Móviles y Realidad Virtual, Departamento de Ciencias de la Computación,
Escuela Politécnica del Ejército, ESPE
Av. General Rumiñahui S/N, Sector Santa Clara, Valle de los Chillos Sangolquí - Ecuador
(+593) 992 720 003
dmmarcillo@espe.edu.ec

Hugo Fernandes
INESC TEC and Universidade de Trás-os-Montes e Alto Douro
School of Science and Engineering (ECT), Quinta de Prados, Apt.1013
5001-801, Vila Real, Portugal
(+351)259356380
hugof@utad.pt

João Barroso
INESC TEC and Universidade de Trás-os-Montes e Alto Douro
School of Science and Engineering (ECT), Quinta de Prados, Apt.1013
5001-801, Vila Real, Portugal
(+351)259356380
jbarroso@utad.pt

António Pereira
School of Technology and Management, Computer Science and Communication Research Centre, Polytechnic Institute of Leiria, Leiria, Portugal
INOV INESC INOVAÇÃO Institute of New Technologies – Leiria Office, Leiria, 2411-901, Portugal
(+351) 244 820 300
apereira@ipleiria.pt

ABSTRACT

Eyesight is an important sense that helps humans to avoid dangers and navigate in our world. Blind people usually have enhanced accuracy and sensibility of their other natural senses in order to sense their surroundings. But sometimes this is not enough because the human senses can be affected by external sources of noise or disease. That is why technology has been used to develop many assistive tools. Artifacts like white canes or braille compasses help blind people moving around in the environment. In this article, the use of a system that detects and recognize nearby objects or obstacles is proposed, giving an audible feedback to the user. It is designed as a wireless system in order to be comfortable to be carried by the user. The system helps visual impaired people to move around in indoor or outdoor scenarios. The goals of this blind guide system is to detect obstacles that white canes or dogs cannot, extending its detection range.

Keywords

Internet of things; Ambient assisted living; mobile technology; Blind; Ultra-sound.

1. INTRODUCTION

Worldwide there are 39 million people who are legally blind and 246 million people that have low vision, totaling 285 million people with visual impairment. More than half of the visual impaired are aged 50 and above and live in low-income settings [1].

The average visual impaired person is dependent on other people, or technology, in order to navigate in an unknown environment [2]. When in an unknown environment, blind people lack the knowledge about features and obstacles of the physical space around. They usually rely on tools like the white cane and the guide dog. However, these assistive tools have some limitations. The white cane has a maximum range of about 1,5 meters and only detects obstacles bellow the waist level. Guide dogs usually need long times for training, are very expensive and in most cases it is very difficult for the blind to take care of the living dogs appropriately.

The main goal of technology is to help people improve their quality of life. One such technology is the Internet of Things (IoT). IoT is based on a wireless network of sensors that communicate with each other in order to understand the environment and actuate when there is a change in their surroundings [3].

This paper presents a system that helps the navigation of visually impaired, based on the IoT. This blind guide uses ultra-sound sensors to detect obstacles. When a nearby obstacle is detected, the system takes a picture of the obstacle and sends the photo to an image recognition software that responds with audible warning to the user. This can help blind users to detect obstacles at a farther distance, in comparison with the traditional assistive tools, and also allows them to differentiate between the detected features.

Several other sensor-based solutions have already been made in the past and a selection of a few is presented in section 2. The rest of this article is structured as follows. In section 3, technologies related with the proposed system are discussed. Section 4 describes the Blind Guide implementation. In section 5, some preliminary tests and results are presented. Finally, in section 6 some final considerations are presented, as well as directions for future work.

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2. RELATED WORK

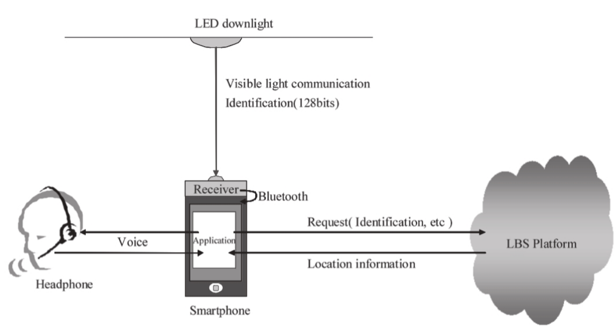
Research teams all over the world have developed different systems in order to help the visual impaired with their daily routines. One of these solutions is an indoor navigation system for visually impaired that uses visible light communication [4]. This system uses LED lighting and a common smartphone in order to estimate the current position, travel direction and distance of the user [4]. Although better directional accuracy is needed, the system proved to be a viable navigation solution for visually impaired people.

In [5] the authors created a virtual eye system for guiding users in indoor and outdoor. Their system consists of two cameras mounted in the forehead of the user. The cameras transmit real time video through an USB connection to a smart phone. The smart phone has a real time recognition software. The prototype can detect and identify obstacles in traffic situations. The authors tested the system and concluded that the system needs about two minutes of training. They tested the solution with visually impaired people and most of them gave a positive feedback. A small group said that the solution is loud and depriving.

BIOH uses ultra-sound in order to detect obstacles [6]. This ultra-sound system is placed in the forehead of the user. When an obstacle is detected, the system gives a pressure warning in the forehead of the user. The intensity of the pressure depends on the distance to the obstacle. The authors believe that the system can be improved using solar energy for places with lower accessibility.

Another indoor navigation system for visually impaired uses visible light communication [4]. The system employs LED lights and a geomagnetic correction method. In this system, LED lights, a smart-phone with integrated Bluetooth receiver and headphones where used for the implementation. [4] The LED light ID is sent via a light communication channel to the smart-phone receiver. The receiver transmits the ID of the LED light to the smart-phone via Bluetooth. With the LED light ID, the smart-phone receives the positional information from a cloud environment, via Wi-Fi. The positional information is combined with the guidance content into audio files and the transmitted to the headphones of the user. [4]

Figure 1. Indoor navigation system [5]



After the tests the authors concluded that the system needs a better directional accuracy and also a continuous feedback sound while the person is traveling.

Virtual Eye uses with GPS for helping blind people [7]. The system consists in a GPS receiver, GMS module, microcontroller (ATMEGA 328), ultrasonic sensor, speech IC and headphones. [7] The prototype works in the following form: The ultra-sound sensor looks for obstacles and sends the data to the microcontroller. Then the microcontroller processes the data and when an obstacle is found a signal is send to the speech IC. Speech IC gives a sound to inform the person that an obstacle is detected. The GPS continuously send the location information to the microcontroller. The microcontroller transmits the location through the GMS modem in SMS format to all the saved numbers.

The work presented in this paper is the continuation of the theme proposed in a previous paper entitled: Blind Guide: an ultrasound sensor-based body area network for guiding blind people [14]. Some of the authors of this article were the authors of this previous work. In this previous publication the authors addressed aspects like the different obstacles that visually impaired have to face in their daily life. The authors also explained the limitations of common tools that blind people may use and how the proposed system can be used as a complementary device [14].

There any many systems related to the work presented in this paper. We believe that the proposed blind guide solution is better than the rest as it uses an image recognition software that will help visually impaired to understand their surroundings. We also want to build a database that stores the location of the obstacles and make it available to the rest of the users of our system.

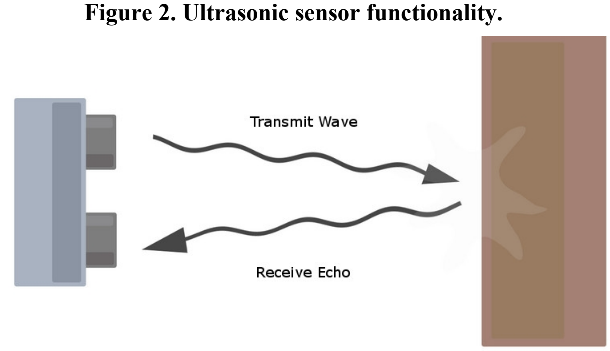
3. IMPLEMENTED TECHNOLOGIES

This section enumerates all the elements and technologies used in order to develop the blind guide prototype. The electronic elements used in the prototype are easy obtainable using affordable off-the-shelf components available in the market. The goal of this project is to create a system that can be available for everyone.

3.1 Ultrasonic sensor

In order to detect the obstacles, an ultrasonic sensor is used. The ultra-sound transmitter emits a 40KHz ultrasonic wave that travels through the air and immediately returns when it encounters an obstacle. [8] This effect is illustrated in Figure 2. The ultra-sound system calculates the distance between the sensor and the obstacle. The sensor range is between 2cm-400cm. [8] The sensor operates with a current of 15mA and the cost of acquisition is very low [8].

Figure 2. Ultrasonic sensor functionality.



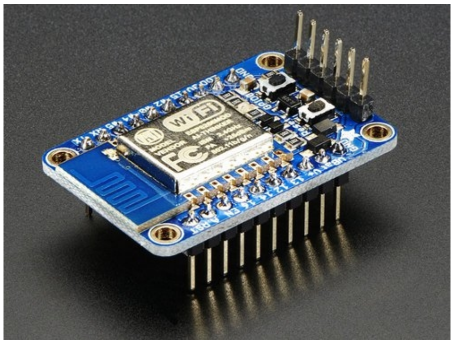
3.2 Wi-Fi microcontroller

For the purpose of the implementation of the communication between the sensor and the single-board computer, a microcontroller with a Wi-Fi module was used. The microcontroller uses an 80 MHz ESP8266 processor with a Wi-Fi front-end that supports TCP/IP and DNS [9]. The microcontroller has 3.3V out and a 500mA regulator. [9]

The Wi-Fi microcontroller receives the data from the ultra-sound sensor. When the microcontroller starts the communication with the single-board computer, the computer tells the microcontroller how close the obstacle must be in order to inform to the computer.

The reason for this configuration is because the ultra-sound sensor sends continuously data, and most of them is not relevant, so we want to limit the power consumption as much as possible.

Figure 3. Adafruit ESP8266. [9]

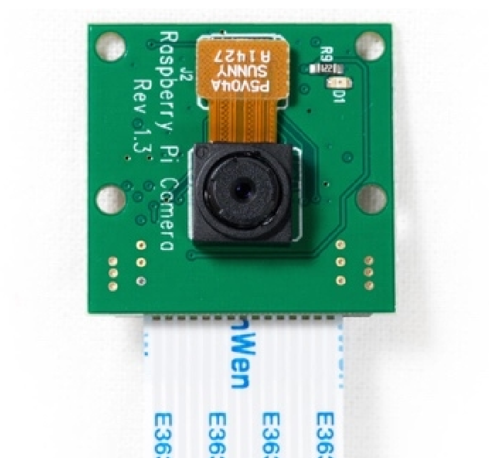


3.3 Camera module

When an obstacle is detected the single-board computer takes a photo of the object using a camera module. This camera module has a Sony IMX219 8-megapixel sensor. The camera module can take high definition videos or photographs. Its supports 10080p30, 720p60 and VGA90 video modes. [10]

The camera module may take high quality pictures because they are sent to a cloud image recognition server. Bad quality photos can affect the recognition and the audible warning.

Figure 4. Raspberry Pi camera module v2. [10]



3.4 Single-board computer

In order to process the data from the ultra-sound sensors, to take photos and communicate with the cloud image recognition server, a computer is needed. This computer also has to be portable and powerful. We chose the credit card-sized single-board computer called Raspberry Pi 3. The Raspberry Pi 3 has a 1.2GHz 64-bit quad-core ARMv8 CPU, 802.11n wireless LAN, Bluetooth low energy (BLE) and 1GB RAM. [11] Its runs a variety of operating systems. For this prototype we choose Raspbian OS.

Raspbian is a free operating system based on Debian which is optimized for the Raspberry Pi hardware. We prefer this operating system because of the great number of tutorials and examples that the community provides. The Figure 5 shows the Raspberry Pi v3 with the camera module v2 mounted.

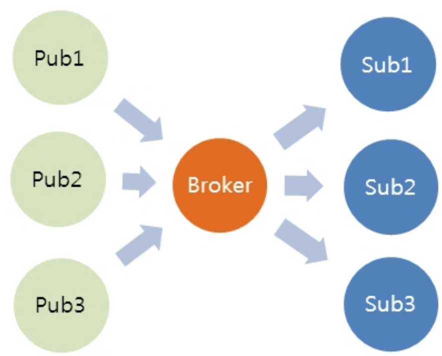
Figure 5. Raspberry Pi 3 with camera module.

3.5 Message Queue Telemetry Transport

Message Queue Telemetry Transport (MQTT) is an application layer protocol. This protocol was designed for resource-constrained devices [12]. It depends on the Transmission Control Protocol (TCP) and IP. MQTT uses a topic-based publish-subscribe architecture. This means that a client can send messages to a certain topic and all the clients subscribed to the same topic will receive the messages. The server that manages the communication is called the broker.

Quality of Service (QoS) is implemented in MQTT in three levels [12]. Level 0 means that the message is delivered once and no acknowledgement is required. Level 1 is a confirmation that the message reception is required. Finally, level 2 implements a four-way handshake for the delivery of the message..

Figure 6. MQTT scheme.

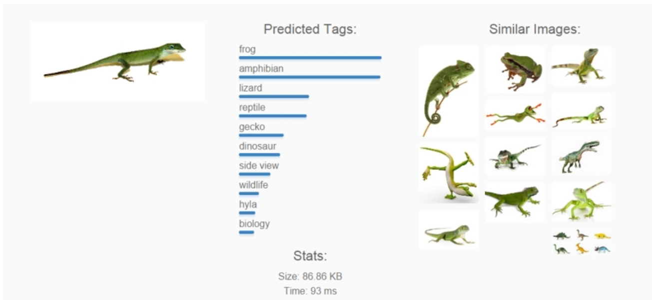


3.6 Cloud Image Recognition Server

In order to provide audible warnings to the user of the proposed prototype, we need an image recognition software. We tested many options but we decided to use a web service offered by the company Clarifai [13]. Clarifai offers an image recognition web service and it offers many APIs for different programing languages. Our main program, that runs in the single-board computer, has been made using Python. Clarifai offers an easy to use Python API for accessing their services [13].

The photo taken by the single-board computer is sent to the Clarifai web server using HTTPS (Hypertext Transfer Protocol Secure) protocol [13]. The server returns a message in JSON (JavaScript Object Notation) format. This JSON message contains the possible objects in the picture and the recognition probabilities for each object. The main program parses this information and chooses the object with the best recognition probability. This information is then transformed into an audio file and then transmitted over the headphones, or speaker.

Figure 7. Clarifai web service example. [13]



4. SYSTEM DESIGN

The proposed solution is a system that alerts the user about obstacles when he/she is navigating in indoor or outdoor.

Figure 8. Blind Guide prototype.

Blind Guide works in the following way: the system uses four ultra-sound sensors: one in the forehead, one in the chest and two in each leg. Each ultra-sound is connected to a Wi-Fi controller. The Wi-Fi controller communicates wirelessly to the single-board computer that is placed on the chest of the user.

Figure 9. Detection range of the ultra-sounds.

The communication uses the MQTT protocol and this results in a star topology. The single-board computer has a camera module. When an obstacle is detected, the single-board computer takes a picture and sends it to the cloud image recognition server. When the server responds, the result is transformed into an audible warning.

Figure 10. Blind guide system.

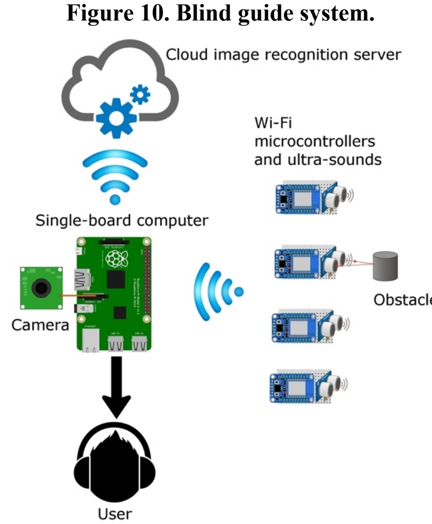
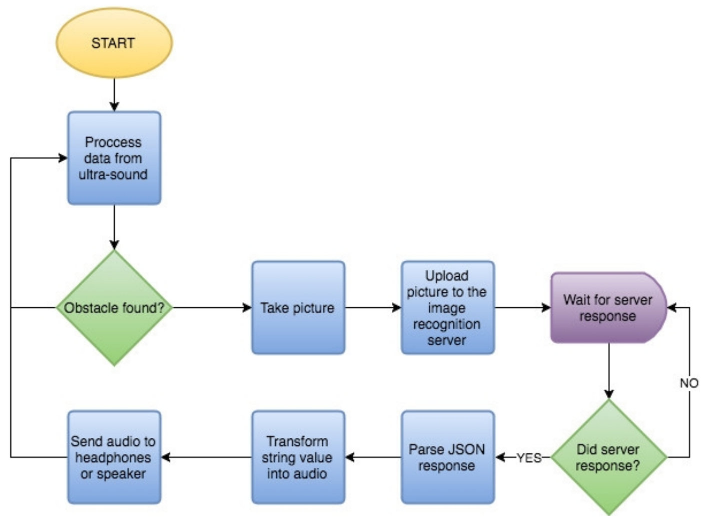


Figure 11 shows the information flow of the Blind guide system. Everything starts in the ultra-sound sensors. Then the Wi-Fi microcontroller parses the data in order to know if an obstacle has been found. If an obstacle appears, the Wi-Fi microcontroller sends a warning to the single-board computer. When the notifications arrive, the single-board computer takes a picture and uploads it to the image recognition cloud server. After that, the single-board computer waits for the server response. When the cloud service responds, the single-board computer parses the data. Then the resulting data is transformed into an audio file, which is transmitted into the headphones or speaker.

Figure 11. Blind guide information flow.



5. EVALUATION

A wireless prototype of the solution was tested with non-blind users (figure 12). The participants were informed about the objective of the experiments and instructed about how the prototype works. All the users gave consent regarding the publication of photos and other information related to the experiment. The tests were performed in a controlled environment and the obstacles present in the environment were chairs, tables and cardboard boxes. The objective of the proposed prototype is to detect and differentiate between obstacles that guidance dogs or white canes cannot.

We tested object detection in each ultra-sound sensor. We put an obstacle in front of the sensor at three different distances: 5 meters, 3 meters and 1 meter. The results of the test showed that each sensor detects the obstacle about 2 meters away (figure 13).
The test was also performed using tables and chairs. The table was detected only by the ultra-sound sensor placed in the chest. The chair was detected by the ultra-sound sensor placed in the legs.

Figure 12. Test subject using the wireless prototype.

Figure 13. Photo taken by the camera when the table were detected.

Another test was performed walking uphill and downhill (figures 14 and 15). A cardboard box was used as a random obstacle. The ultra-sound sensors in the legs successfully detected the cardboard box.

Figure 14. Uphill test.

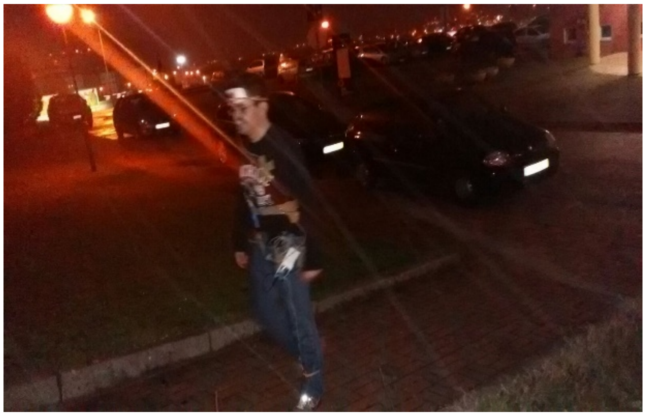


Figure 15. Downhill test.

6. CONCLUSIONS AND FUTURE WORK

We have developed a blind guide for helping visually impaired to navigate in indoor and outdoor scenarios. We have tested the prototype and we had successfully results. Using this tool, the user is now able to differentiate between the objects and features in their surroundings, which is very helpful especially in unknown scenarios. Also, with the materials used in this prototype we can assure that this is a low-cost solution for blind people.

In the future we want to make the prototype more portable and comfortable. Although the feedback from the sighted users was very good, tests with visually impaired are needed in order to get more feedback about the prototype in real life situations.

One of the mains limitations found was the system feedback, i.e., the way the system can interface with the user. For audible feedback, we want to test what is the best way to transmit it: over headphones or using a speaker. Which options is more comfortable for the blind people. We also want to test the different ways of alerting the user. Right now we are using audible warnings but it will be interesting to try haptic feedback.

Another limitation is that this prototype cannot geographically locate the user. On the other side, by describing the scene and the objects in it, the process of cognitive mapping the environment is greatly enhanced, contributing for a greater independency of the user and increase of confidence on exploring new areas.

We also want to try a different configuration of the camera or increase the number of cameras, with the purpose of increasing the effectiveness of the detection of the obstacles.

Regarding the recognition software, Google has a new Cloud Vision service available. It will be interesting to try this new service and compare it with the Clarifai web service.

7. ACKNOWLEDGMENTS

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