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Wearable Object Detection System for People with Blindness and IoT Monitoring

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***Abstract*—As technology advances, a wide variety of devices that aim to help people who suffer from blindness have been developed, since most of the time when this people leave their homes, they tend to be exposed to accidents if they do not have the necessary aid. Therefore, at present, devices have been created either with the objective of leisure such as products that read texts to individuals, also devices made to facilitate the movement of users such as those that make use of sensors or artificial vision and machine learning, even devices that have the objective of monitoring a blind person in case of emergencies, among others. At the same time, the cost of these new technological products is increasing, leading to an increase in the price of the devices used by blind people. This proposed system allows blind people to have access to a portable and affordable device, which informs them by vibrations if there are obstacles in front using ultrasonic sensors. Through a Wi-Fi module and making use of the IoT, acquaintances of the disabled person will be able to monitor their surroundings in live stream or through pictures.**

***Index Terms*—IoT, monitor, portable, ultrasonic sensors, visual impairment, Wi-Fi module**

I. Introduction

Blindness can be defined as the lack of vision and is considered a sensory disability. Most people with this disability do not count with the necessary resources to pay for an ophthalmologist and receive the required treatment to prevent the deterioration of their vision, so not much can be done without costly surgeries. Based on the aforementioned, it is necessary to implement the use of technologies so they can be the eyes of those people who do not have the opportunity to see with conventional medical treatments.

In Honduras, sometimes we can see blind people walking on the streets and guiding themselves simply by touching the walls or the objects around them, sometimes also with a cane, and on rare occasions with guide dogs, but will there ever be a day in which the blind can see without being able to see?

The present investigation intends to design a wearable object detection system in order to facilitate the movement of blind people in different environments and through the implementation of IoT, it aims to create a monitoring system that can be used by others to know where the user is. Making use of the V-Model, the systems and subsystems required for the operation of the prototype will be analyzed.

II. Background

A. History

Blindness is a disability that has existed since prehistoric times. In those times, people traveled in groups, so it was arduous to survive with any type of disability, the common thing was to abandon those who had one or they were forced to carry out specific jobs that did not require their constant mobilization. Depending on the region and the time, the treatment of blind people varied. At the time when the world was ruled by the bourgeoisie and royalty, blind people were considered defective, but in some Nordic countries these people were considered wise. As time progressed, possible factors were found, such as war or epidemics, that caused blindness and at the same time, ways to avoid going blind were being sought.

By the 18th century, awareness about people with disabilities began to be raised and the concept of social responsibility began to emerge. In 1784 the first institution for blind people was founded in France, later more educational centers for blind people were opened around the world. It is considered that in 1930 the first cane for blind people was created, which facilitated the movement of people who could acquire it. In 1971 Stanford University developed a device called "Optacon" (Telesensory), it consisted of exploring graphic or textual content whose visual design is preserved in the tactile representation [1].

By the 2000s onwards, the implementation of technology in common situations allowed the creation of products in order to facilitate daily life. Over the years, more inclusive ideas were also formed to allow blind people to enjoy everyday activities, such as audiobooks, Braille descriptions in museums, 3D books, apps, printers, among others. Just as technologies were developed for the leisure of people with blindness, products capable of allowing them to move freely by themselves were also created. Folding sticks and canes were developed, which are more practical to carry compared to a conventional one. Glasses with IoT functions that allow the recognition of the environment through sensors but that usually have high prices. Sensors and actuators have also been implemented in canes to make them more functional, however, their portability decreases.

B. Related Assistive Technology Projects

With the advance of technology, innovative projects that seek to help blind people have been created, such as in 2015 MIT's Media Labs introduced Finger Reader, which is a device used for text scanning and can read individual lines or blocks of text with feedback [2]. In the [3] research, they propose a system to avoid obstacles by locating them with a haptic interface for the visually impaired and blind people, implemented by means of a robotic operating system. Using a depth camera sensor they developed an algorithm capable of identifying obstacles at head level, left/right torso level, and ground level. It is a wearable and functional device, the design was taken into account for the prototype developed. We can also find projects that use GPS to help acquaintances locate the user or cameras to keep an eye on them.

One of the difficulties that blind people have when they walk is to identify if there are obstacles in the way they are going, based on this, the research by [4] proposes a product designed with the purpose of offering optimal protection to the user using his own mobile phone to facilitate its use and reduce costs. The prototype they designed was made with the goal of being worn at chest level, they use two ultrasonic sensors one of them point forward and the other has a downward inclination.

III. Theoretical Foundation

A. IoT

IoT stands for "Internet of Things" and refers to the stage of the Internet that allows "things or devices" to connect with each other and exchange information through the Internet fluently and in real time. According to [5] IoT can be oriented to three areas. The first area, oriented to the internet and focuses on the connectivity between objects; the second one, oriented to things and it centers on objects; and the latter, is knowledge-oriented and focuses on information organization, storage, and representation. The Internet of Things (IoT) creates a smarter world where everything is swiftly and easily accessible.

B. Wearable Devices

A few years ago the idea of smart gadgets worn close to the body, also known as wearable devices, emerged. Commonly these wearable devices possess sensors, tools that allow communication and/or computing units, in order to be able to perceive, process and exchange a wide variety of data and information continuously. From the term wearable devices, the idea behind the IoWT was created [6]. The IoWT (Internet of Wearable Things) can include a grand variety of accessories or garments that can be worn by a user, being more specific these devices can be smart watches, smart bracelets, smart shoes, smart rings and smart glasses, among others.

The use of wearable devices is not limited to a specific public, so they can help people perform their daily tasks more comfortably and efficiently, they can even use visual and auditory stimuli. Being able to answer incoming calls and messages, receive weather notifications, view your health information, etc. They are activities that can be done depending on the IoWT. There are a wide variety of applications that use these wearable devices, improving the quality of life of its user in general.

Another area of research closely related to IoWT is that made up of wireless body sensor networks (WBSN) [7], also known as wireless body area networks (WBAN). Body area sensor networks (BSN) consist of a series of interconnected sensors distributed around the human body in order to collect, process and analyze information for the function that it has been implemented for. They focus on portable and real-time monitoring systems with the aim of ensuring continuous monitoring of patients, while providing them with great freedom of movement [8].

C. Typhlotechnology

Tyflotechnology is known as the set of methods, knowledge and means aimed at providing blind and visually impaired people with the relevant resources for the proper use of technology, with the purpose of facilitating their independence in their lives [9]. The usefulness of assistive technologies, such as typhlotechnology, not only allows blind people to communicate with the digitized world of apps on computers or phones, but also with their senses it is possible for them to perform actions or activities in their daily life.

IV. Methodology

The methodology proposed for the research is the V-Method, which breakdown a complex prototype into a series of systems and subsystems [10]. It provides a practical tool for project development, allowing the researcher to integrate different engineering subsystems. For the development of this methodology there are two parts: 1) defining the project and 2) integration and testing. Following the diagram shown in Fig. 1, the project began by defining the systems that make up the prototype, followed by the subsystems and the parts, the second part involved the integration and testing of everything defined in the first part.

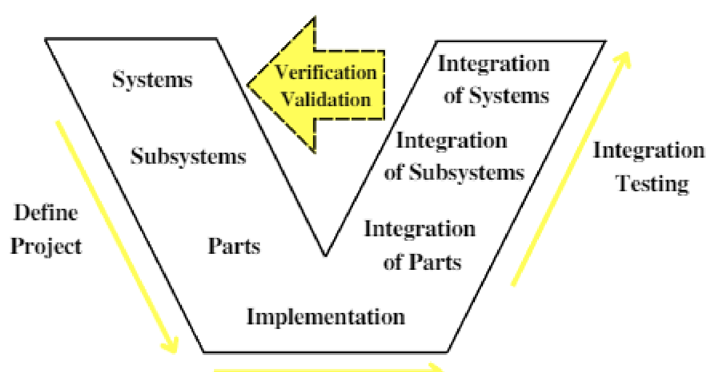

Fig. 1. V-Method diagram.

There is a wide variety of products created to be used by blind people, as mentioned above, there are from simple canes to canes with technological implementations. The research project focuses on the development of a device that must be simple and portable, it must facilitate the mobility of the individual without having to depend on someone else. For safety reasons, the prototype has a system that takes photographs every certain period of time to be capable of locating the user at any time. In case of being close to the user and using the same Wi-Fi network it will be possible to visualize what the camera is capturing at the time, through an application.

Ultrasonic sensors are used to detect obstacles in external environments, precisely obstacles/objects positioned in front of the individual, to then inform the user about their environment through a vibrating motor module that has two modes to distinguish where the obstacles are.

The development of the prototype was divided into three large systems: the electronic system, the structure system and the power system, each of these has its respective subsystems. Fig. 2 shows the distribution of systems and subsystems. Each subsystem is made up of individual parts or elements, which in the second part of the V-Method are integrated to form the device that will be displayed in the results.

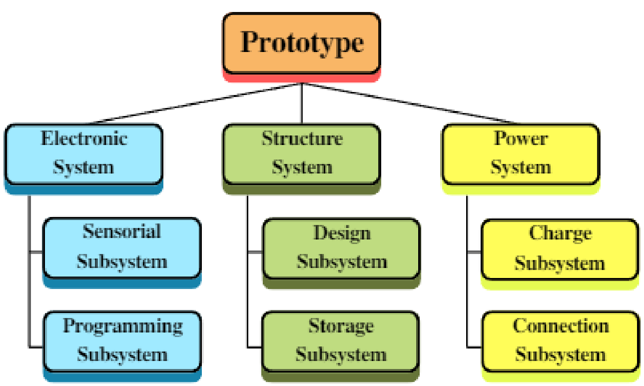

Fig. 2. Systems and subsystems diagram.

Once the systems and subsystems were established, by means of morphological matrices the individual components or part that were used in the project were selected. The essential characteristics for each one were analyzed and specified and from these, the ones that met the requirements were selected.

A. Electronic System

This system is in charge of collecting the data from the environment through the sensors, which in this case are the ultrasonic sensors. The data collected will go through a control phase and after the processing of this data, these will be communicated to the user through the selected actuator. This system contains most of the electronic components and is where code development takes place.

For this system, two elements were taken into account: 1) the sensors used to locate the obstacles and 2) the code that must be elaborated. Leaving two subsystems to work with:

a) Sensorial Subsystem: Is in charge of taking the physical variables of the environment, in this case the objects that are in front of the user, and transform them into data. As a requirement, the sensor must be able to capture the obstacles in the environment clearly in order to determine the location of the objects or at least detect the objects with a level of precision good enough to avoid the object when walking. The elaboration of the electronic board is also included. The main parts that make up this subsystem are:

- Ultrasonic sensors, which are in charge of detecting the obstacles. Two sensors will be used, one is positioned pointing forward and the other one tilted downward.
- Vibratory motor module, works as a notifier so the user can know if something is in front of them.
- PCB Bakelite, most of the electronic components will be soldered to it.
- Button, when pressed changes the mode of the device.
- Microcontrollers, they give instructions to the other components.

b) Programming Subsystem: Is in charge of preparing the code to be executed in the microcontrollers. The code in the microcontrollers is the one that will give the instructions to the electronic elements of the device to perform their function. Many factors were considered for the design of the code, from the signals it will receive to the output signals it sends, taking into account the selected Wi-Fi module. From this, two codes were developed, one for each microcontroller. It also takes in the creation of the app for monitoring. The main parts that make up this subsystem are:

- ATMEGA328P microcontroller, it gives instructions to other electronic elements.
- App, made with MIT App Inventor.
- ESP32CAM Wi-Fi microcontroller, works as the IoT monitoring system for the user acquaintances.

The ATMEGA328P was selected as it is less expensive compared to other microcontrollers and is relatively small which fits well with the size of the Bakelite purchased. C++ was the language utilized because of its facility, to connect with the sensors, it is necessary to declare the variables and libraries necessary. For the selection of the Wi-Fi module, the ESP8266 was considered, since it is cheap in Honduras and can establish the Wi-Fi communication necessary to work with an MQTT protocol [11], however, it does not provide the camera that the ESP32CAM does.

The user will need access to a phone, from [12] we can tell that in Honduras there are more users with internet access than cell phone access; to which a huge percent of users access internet through a mobile phone.

The two codes created are different, as one is for the microcontroller ATMEGA328P and the other for the ESP32CAM. In Fig. 3 the operation of the code for the ATMEGA328P is shown in a general way. Once the ultrasonic sensors are turned on, they begin to take measurements. The measurements taken are compared with the distance set in the code; if the measurement taken is less than the one set, the vibratory modules are activated. The preset distances for each sensor are different.

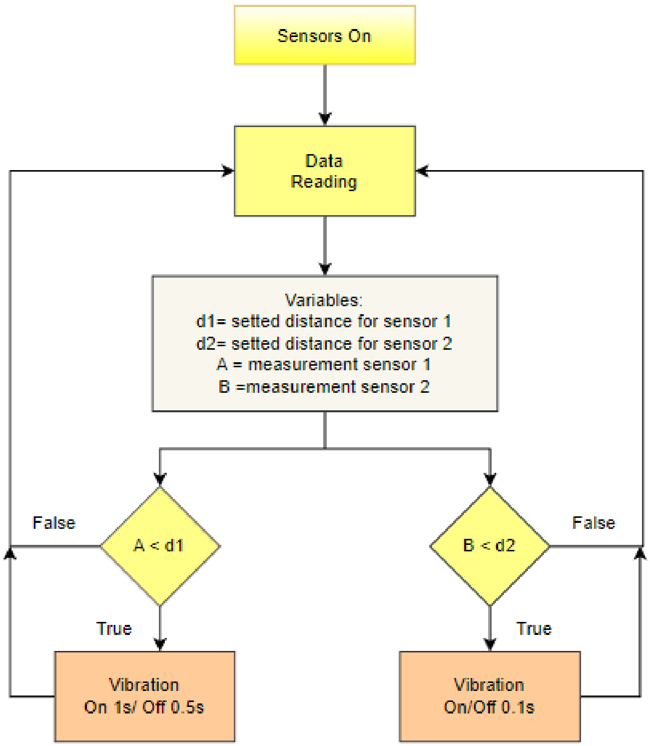

Fig. 3. ATMEGA328P flow chart.

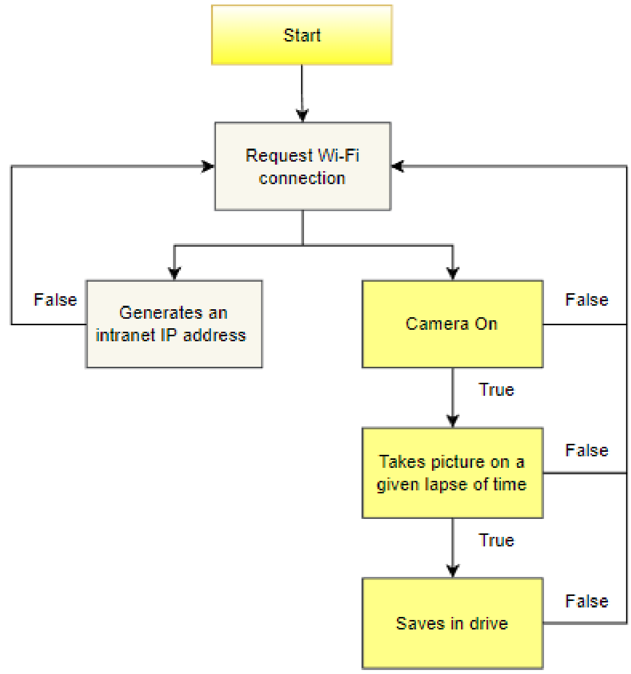

Fig. 4. ESP32CAM flow chart.

In Fig. 4 the operation of the ESP32CAM is shown. When starting the module, it immediately seeks to connect to the Wi-Fi network in the code. Once connected, it generates an IP address that will be used with the app and at the same time it takes pictures which are saved on a drive folder.

The code for the application is shown in Fig. 5. Upon entering the application it will allow the user to press the power button to view what the camera captures, pressing the off button stops the transmission, this happens if the IP address was found and the phone is connected to the same Wi-Fi network as the ESP32. Otherwise the app will not work.

B. Structure System

This system is in charge of finding the best option to store the electronic components of the product, it is also in charge of the prototype's visuals. One of its requirements to meet is that it must be easy to carry and handle. In this system the prototype design was selected; The material from which it was made was also chosen, taking into account different properties and characteristics of the materials.

The structural system was divided into the design subsystem and the storage subsystem, since these are the ones that make up the visual part of the project. In general it is what the user will use. For these subsystems, many factors related to the components, such as their dimensions, were taken into account.

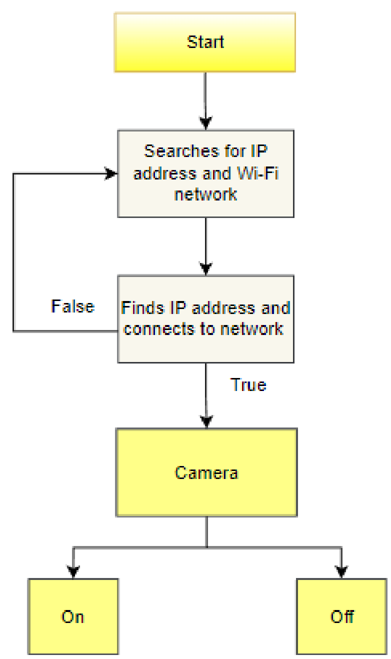

Fig. 5. App flow chart.

a) Design Subsystem: Is in charge of evaluating different designs for the elaboration of the final device. This must be able to contain the necessary elements for its functionality. In this subsystem, SolidWorks was used to develop the design. Factors such as the size and weight of the electronic components were taken into account for the dimensions of the prototype. In this, the materials from which the structure of the device can be made were selected. The main parts that make up this subsystem are:

- Solid cardboard, material selected for its strength, stiffness, food contact potential, water resistance and color.
- Design of structure, which was made in SolidWorks.
- How the device is going to be held.

b) Storage Subsystem: Seeks to find the best option to store the electronic components of the product. Having selected the preferred design, we sought to place the components within it. It has more focus on what would be in the inner part of the prototype, which is where the electronic components go. The main parts that make up this subsystem are:

- PCB with its components.
- Positioning of power source.

C. Power System

This system focuses on selecting the most practical way to power the electronic components of the prototype. In this system different ways to charge the components with the necessary voltage for their functionality were analyzed.

a) Charge Subsystem: Focuses on how the different electronic elements found in the prototype are powered. Factors such as: if the energy source can fully power the elements and the durability time that it has were taken into account. It focuses on analyzing those sources of energy. The main part that make up this subsystem is:

- Battery ICR 18650, as power supply.

b) Connection Subsystem: Also focuses on how the different electronic elements found in the prototype are powered, however, it is directed to the way in which this power/load source is connected to the electronic elements. The main part that make up this subsystem is:

- 18650 Shield 1 battery charger module, which allows the battery to be recharged.

V. Results and Analysis

Below are the results of the tests carried out and the operation of the device is shown. The results are displayed by system.

A. Electronic System

Five tests were performed to verify the accuracy of the ultrasonic sensors - HC-SR04 used. These sensors are ideally capable of measuring distances of up to 4 meters, but in non-idealistic terms they are capable of measuring distances of 2 meters approximately; therefore, a few tests were carried out to verify these data. In each of the tests, an attempt was made to use different objects to simulate different situations in which the user could be. Fig. 6 presents in a graph the results obtained through the tests. These shows that the closer the object is the better the accuracy of the sensor, however it also means that the user will have less time to avoid obstacles. The further away the object is, the measurement is less accurate.

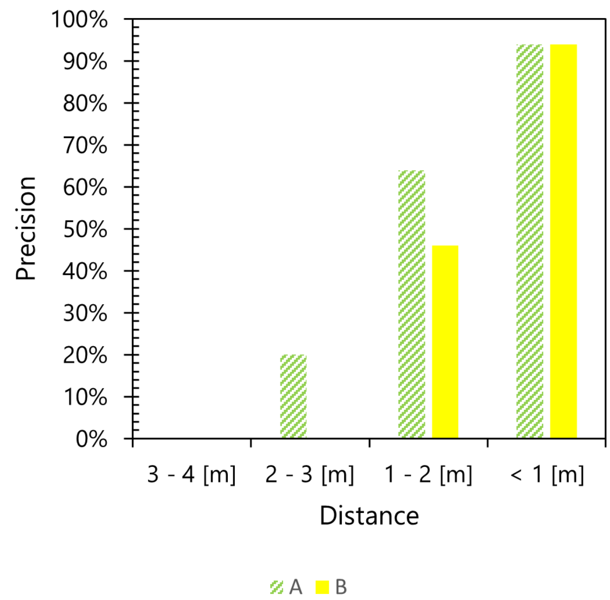

Fig. 6. Ultrasonic Sensors Accuracy.

Sensor A is facing forward and Sensor B is facing forward but is angled downward. These data were obtained by placing the prototype at a height of 1.10 [m], the recreated situations took place in a flat and closed space; so the results may vary when using it in outdoor places and with irregularities in the terrain.

The inclusion of the IoT through the Wi-Fi module allows the prototype to have a system that takes pictures from time to time to locate the user in an emergency. Tests were carried out to verify the operation of the camera, placing short time lapses to verify the storage of the photograph taken. Fig. 7 shows some of the pictures taken during the tests, they are saved in the drive folder established in the code.

When developing the application with MIT App Inventor, there was no problem to test each block of code added since now this program has a simulation option when scanning the QR code of our application on our mobiles. Once the programming has been tested, the application can be downloaded to our phones. All the devices that have the app and that are in the same wireless network configured in the ESP32CAM can see what the camera captures. Fig. 8 shows pictures of the test.

B. Power System

For the power system, it was taken into consideration that the ICR 18650 batteries can be recharged so the user would not have to be buying batteries every time they are spent.

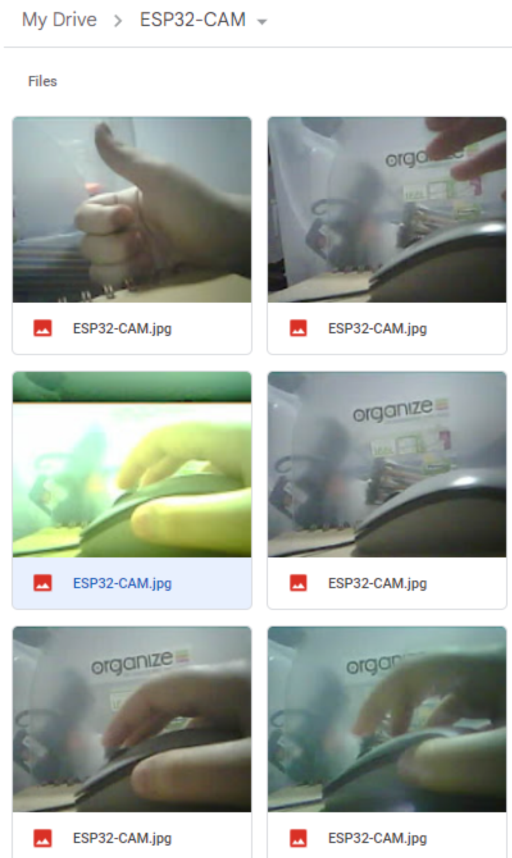

Fig. 7. Pictures taken by ESPCAM32.

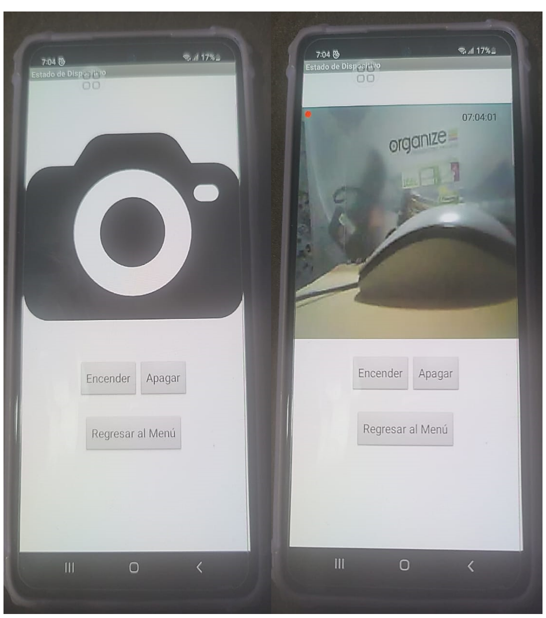

Fig. 8. Pictures of app.

The 18650 Shield 1 battery charger module allows the user to recharge this battery without problems, in addition to having three voltage outputs of 3.3V and three outputs of 5V. Fig. 9 shows the battery used.

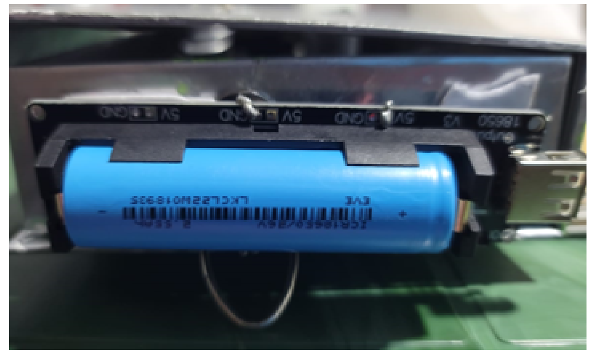

Fig. 9. Battery in charger module.

C. Structure System

Different designs were made for the external structure of the device, the design presented in Fig. 10 is the model of the final prototype. The different materials from which it could be made were evaluated, taking into account factors such as price and resistance to loads.

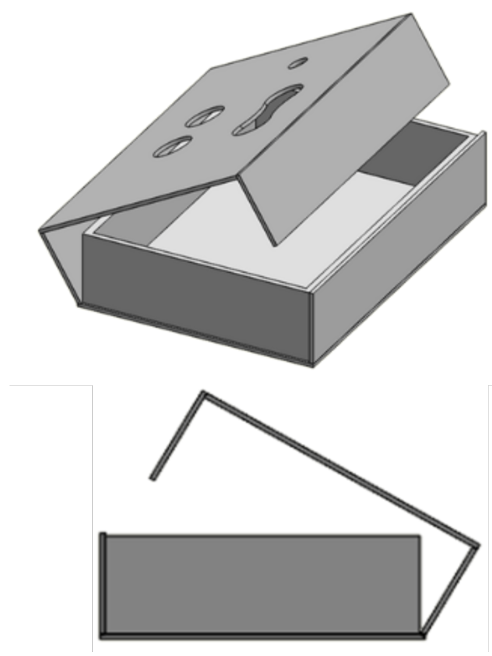

Fig. 10. Structure design.

D. Device

The integration of each part, subsystem and system contributed to the creation of the device. Fig. 11 shows how the device should be worn.

Fig. 11. Device.

VI. Conclusions

Making use of various electronic components, carrying out tests with the sensors and using design and simulation programs, an wearable object detection system for blind people and IoT monitoring system was created. Due to its size it is relatively easy to carry and by not having complicated instructions makes it easy to use. Using only two ultrasonic sensors limits the detection of objects in environments, so it is recommended to use more than two to allow the user to know more about their environment. However, care must be taken with the design of the structure since using more than two would reduce the portability of the device. It is recommended to use some other type of sensor that allows capturing the environment in a broader way, since with ultrasonic sensors you can only detect objects in a linear way.

The monitoring system is composed of the ESP32CAM and the app. If you are looking to obtain better quality images, it is recommended to change the camera of the Wi-Fi module since it has a resolution limit. The size of the camera influences the design of the prototype, so it is recommended to avoid large cameras in order not to lose portability.

For the selection of the material for the structure of the device, it is recommended to use a material with a solid texture to provide support to the components inside. It is recommended to use wireless modules that allow the transfer of information via Wi-Fi, since these allow various forms of communication and storage compared to Bluetooth modules.

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