FriendlyEyes

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***Abstract* — This paper outlines the design and testing of a system that helps visually impaired individuals walk with or without a pole using vibrating motor feedback. The system's calibration is done by considering the height of the user in the source code that calculates distance with respect to detection of stairs or floor elevations along with detection of objects coming directly in user's path. The system has demonstrated that with the integration of several algorithms and several different sensors the system can detect, track, and range objects traveling towards the it.**

***Index Terms* — Radar, Ultrasonic, Sensors, Li-Po, FriendlyEyes, MCU, JFET, AiP…**

I. Introduction

In most cases, range finding systems are used by engineers to take advantage of its characteristics of detecting objects in a certain range from the point of view of the observer, or user. Examples of such active range finding methods include radar, sonar, and laser-based approaches. While these methods are highly accurate, they do not appeal to every use case. That is because in FriendlyEyes, the system detects objects by zones and a sensor cannot do it by itself. Since the sensors can work in the system, FriendlyEyes have a combination of radar and ultrasonic sensors that working together, they can detect any object. For certain scenarios, the sensor cannot do its job by itself like detecting and stair, for that reason by using algorithms and sensors FriendlyEyes can do the job and keep the user safe by using the proper sensors and mathematics.

While sensors need to expose to send and receive signals, FriendlyEyes use a radar sensor that is inside an encloser to be more protected of heats. This sensor sends a signal that can go through the fabric of the case and detect not only the object but, also its trajectory to know if it is coming to the user or not. As a result of this, if the object is approaching the user, a feedback signal is sent to the motors to alert the user. This method is very efficient because instead of having all the sensors out and making the user unconfutable, the sensor is hidden and making the system look more like a bag that a piece of technology.

Our design is composed of set of subcomponents: the motors vibrators, the radar sensors, the ultrasonic sensor and a Lithium Polymer, Li-Po, battery that provides all the power that the system needs for up to eight hours. The power system is responsible for providing the correct voltage and current to each of the components in our system, FriendlyEyes. Also, we choose the MAX32625PICO board as our microprocessor, MCU, and finally a 3D printed case that keeps all the system together. The power portion of FriendlyEyes is composed by a 120V AC adaptor that converts the power to 12V DC and a DC-to-DC convertor that step it down to 4.7V to charge the Li-Po battery. After, the Li-Po battery is connected a group of Dc-to-DC regulators that adapt the voltage to the sensors, MCU, buzzers and motors.

The radar sensor, Acconeer A111-001-T&R, is connected to the MCU along with the XM122, and they work together to detect and alert the user of objects. Also, the MCU runs with the algorithm that process the information of the user and alert the system of incoming objects. With all the information that the MCU obtains from the sensor, it needs to be filtered to eliminate any noise or outliers that do not bring useful information to the system. After the information is filtered, the MCU analyses it and determinate if the object is coming or going away from the user and if it coming to the user, the MCU activates the GIO pins to turn in the motors and buzzers. However, the radar sensor not only detect one object at the time, but it also detects any object in the range and the MCU needs to determinate which object is coming faster to the user. Basically, the MCU creates a priority vector with all the objects and determinates which is more important.

The ultrasonic sensors, DFRobot SEN0388, are connected to the MCU and the send data in the same way as the radar sensor but, the different is that the ultrasonic sensors are expose, outside the bag to detect objects. The main function of the ultrasonic is that one detects any different of the elevation of the floor, like a stair coming, and the other detects any object that comes to the user and the radar did not pick it. Also, because we cannot limit the range directly of the sensor, the MCU needs to compare if the radar already detects that object or know because how the system works, the ultrasonic sensors have more priority than the radar.

All the sensors, buzzers and motors are powered by the Li-Po battery that last up to 8 hours. The battery has its own security system that avoids shorts, overvoltage, and reverse voltage problems. The motors are connected to the battery directly and by using an analog switch, the MCU determinates when the motors work or not. If the MCU wants to activate a motor, it will stop producing the 3.3V output of that pin to allow the current flow through the junction-gate field-effect transistor, JFET, and the motors start vibrating. , The goal of FriendlyEyes is to produce a system that can detect objects and stair and alert the user so, the person using FriendlyEyes can stop using a pole to determinate the location of objects and just feel the motors vibrating. Also, we want that FriendlyEyes can measure any object between 0.3 meters up to 7 meters, determinate distance and provide feedback in a 1/8 of a second, run for 8 hours, and support direct impacts. We feel that working within these bounds will allow us to realistically create a system that is usable in the field while also being achievable within the scope of this class.

II. Specifciations and Standards

The designing determinations we had were focused on the precision of the determined reach and the speed of the computation. The assessment speed will be more reliant upon the equipment, so we put forth an objective of one assessment each second as a baseline. We needed to be just about as exact as conceivable while additionally having the option to get the assessed esteem near the genuine worth, so we put forth an objective of the assessed range being inside a little level of the genuine reach. These two objectives conflict with one another because we could get a superior gauge with additional time, however we need to give as near a live worth as could really be expected. One more objective was to separate the objective in somewhere around one moment of the framework enacting and when another article shows up in the field of view. This is so then when something materializes of the camera, it begins following it immediately. We had a few stretch objectives we would have gotten a kick out of the chance to accomplish like a dissimilarity picture and speed assessments however coming up short on schedule to execute them into our plan.

Some of the standards we must follow include IPC-2220 (IPC-2221), UL 1642 as well as the standards set for the FLIR Tau 640, the Arducam MINI and the Jetson Nano. IPC-2220 and IPC-2221 are standards regarding printed circuit board design, and UL 1642 regards lithium ion batteries, which was a stretch goal of ours to make the system more portable. The standards set for the cameras are about safety and possible electromagnetic emissions. The Jetson Nano is compliant with the Federal Communications Commission.

III. Theory

In this section we will provide some concepts that will be helpful in understanding the inner workings of FriendlyEyes. We will introduce radar/ultrasonic sensors, motors, battery, 3D case, and the calibration process that the equipment needs to have before using.

A. Radar and Ultrasonic Sensors

Radar sensors are transformation gadgets that change microwave reverberation signals into electrical signs. They utilize remote detecting innovation to distinguish movement by sorting out the place of the item, shape, movement qualities, and movement direction. Not at all like different sensors, radar sensors are not impacted by light and obscurity and with the capacity to recognize obstacles like glass, it can see through dividers. When contrasted with other sensor innovation, like ultrasound, radar can detect longer distances and is safe for individuals and objects or persons approaching the user. [1]

Probably the greatest benefit radar sensors have over different sensors is its discovery of movement and speed. By recognizing the Doppler impact of an article, or change in wave recurrence, a radar sensor can figure that speed of the item alongside its bearing. They can likewise notice the development of the objective according to alternate points of view while utilizing multi-channel sensors. Looking at the development according to alternate points of view notwithstanding recently gathered estimations are utilized to decide complex developments. [1]

On the other hand, ultrasonic sensors work by conveying a sound wave at a recurrence over the scope of human hearing. The transducer of the sensor goes about as an amplifier to get and send the ultrasonic sound. Ultrasonic sensor utilize a solitary transducer to send a heartbeat and to get the reverberation. The sensor decides the distance to an objective by estimating time slips between the sending and getting of the ultrasonic heartbeat.

In FriendlyEyes, we use a combination of the sensors to create a three-zone system where any object will be picked by the sensors. That map can be seen in the Figure 1. In this combination, the radar picks any object that come from any direction and send a feedback signal to the user and by doing that the user can avoid the obstacle or person approaching the user.

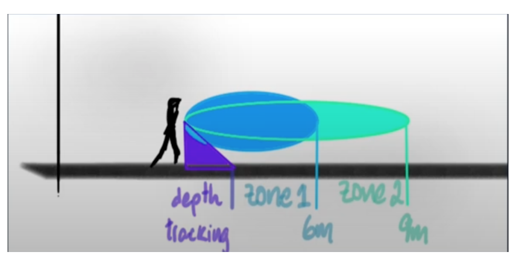

Figure 1: Zone Map of the Sensors

B. Lithium Polymer Battery

A battery-powered lithium-particle battery is made of at least one power-creating compartments called cells. Every phone has basically three parts: a positive terminal, a negative anode, and a synthetic called an electrolyte in the middle of them. The positive terminal is ordinarily produced using a synthetic compound called lithium-cobalt oxide (LiCoO2) or, in more current batteries, from lithium iron phosphate (LiFePO4). The negative anode is for the most part produced using graphite and the electrolyte changes starting with one sort of battery then onto the next.

All lithium-particle similarly. Whenever the battery is energizing, the lithium-cobalt oxide, positive terminal surrenders a portion of its lithium particles, which travel through the electrolyte to the negative, graphite anode and stay there. The battery takes in and stores energy during this interaction. Whenever the battery is releasing, the lithium particles move back across the electrolyte to the positive anode, creating the energy that drives the battery. In the two cases, electrons stream the other way to the particles around the external circuit. Electrons don't course through the electrolyte: it is a protecting hindrance, most.

The development of particles (through the electrolyte) and electrons (around the outside circuit, the other way) are interconnected cycles, and if stops so does the other. If particles quit traveling through the electrolyte on the grounds that the battery totally releases, electrons can't travel through the external circuit by the same token. Likewise, on the off chance that you switch off anything the battery is fueling, the progression of electrons stops thus does the progression of particles. The battery basically quits releasing at a high rate. Also, Li-Po batteries, which are a derivate of Lithium batteries, weight less and have more energy. For that reason, we choose Li-Po as the main battery for this project.

Figure 2: Lithium Polymer Battery

For FriendlyEyes, the battery is charge directly by a standard 120V AC to 12V DC transformer. In the PCB, we have a 12V input pin that connects to a voltage regulator that converts the 12V to 4.7V keeps the voltage constant without any deviation. Also, it provides security systems such as short circuit protection, overvoltage, and overcurrent protection. After, the system is connected to a MOSFET that controls the charging process of the battery and it avoids the battery to overcharge and heat during the process. Below, there is a power diagram explaining more in deep the charging process of the battery.

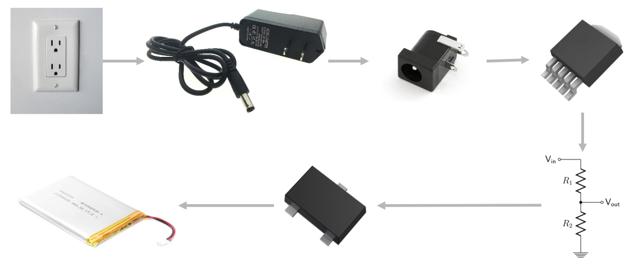

Figure 3: Overall Power Diagram

C. 3D Encloser for the System

For this project, we decided that 3-D printing an enclosure that will hold the PCB, and other parts of the project is going to be the best solution for this problem. However, we cannot use any type of filament to do this case, that is because some type of plastics can react to the wave that the sensor emits, and it can generate noise or problems to the project when we need to analyze the data. Below there is a table with a dielectric coefficient of different type of 3-D material and we can see there are a few types of material that work for these conditions. The problem is that the higher the dielectric constant is the behavior of the case approach more and more how a capacitor works. For that reason, we want to keep the dialectic constant as low as possible.

Material	Dielectric	Loss Tangent
Teflon	2.2	0.0002
Polypropylene	2.2	0.0005
Polyethylene	2.3	0.0003
Polystyrene	2.5	0.0004
ABS-M30	2.48	0.008
Acrylic Glass	2.5	0.0118
PLA	2.85	0.014
Fused Quartz	3.8	0.0015

Table 1: Dielectric and Loss Tangent Constants

Because we know this information now, we try to find a company that could use polypropylene or polyethylene as the material for the 3-D enclosure. After many intents, we finally got a case that we can use to hold the PCV on the sensors in one piece.

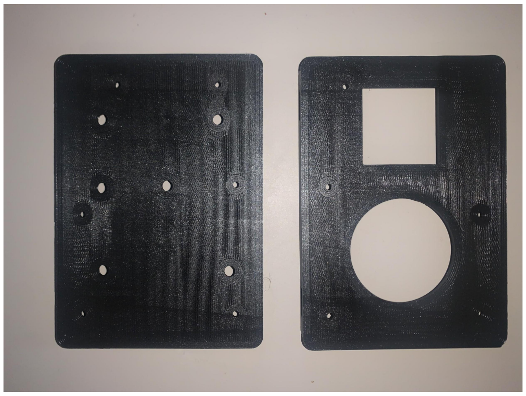

Figure 4: 3-D Encloser in Polypropylene

D. Vibrators Motors

The vibration engine is a coreless DC engine whose size is minimized. The first reason for this engine is to caution the client from getting the call without sound and vibrating. The fundamental component of this engine is, it has attractive properties, lightweight, and engine size is little. In light of these highlights, the engine execution is profoundly predictable.

The round and hollow shape is additionally called a pole type vibration engine. This vibration engine is basically inappropriately adjusted. As such, there is a whimsical load on the alternating shaft of the vibration engine, which produces radiating power when it pivots. This lopsided power uproots it. Its rapid uprooting makes it swing, which is classified "vibration". The wobble can be changed by the weight mass you connect, the weight's distance to the shaft, and the Speed at which the engine turns. Besides, the radiating power produced by the turn of the lopsided weight will make it vibrate along the two tomahawks (Z-hub and X-pivot).

In FriendlyEyes, the motors are activated when the sensor pick any object approaching the user. So, by doing that, the user can have feedback of where the object is coming and he or she can take an appropriate and save response to that.

E. Piezo Buzzer

Piezo buzzers are gadgets that can produce signals and tones. They work by utilizing a piezo crystal, a material that changes shape when voltage is applied to it. Assuming the gem pushes against a diaphragm, similar to a little speaker cone, it can produce a strain wave which the human ear gets as sound. Basic change the recurrence of the voltage shipped off the piezo and it will begin producing sounds by changing shape quick.

The buzzer is a piece that by applying a since or square wave using the MCU can produce a sound. In FriendlyEyes, we made the design so that the feedback that the user will get is vibration and sound. In order to power the buzzers, we are using the same circuit as the motors because they both work with a square wave.

IV. Design Components

A. Radar Sensor: A111 Acconeer

The A111 series of radar sensor of Acconeer is a versatile and small radar sensor strong enough for the application of FriendlyEyes. The A111 is a radar sensor fully integrated in a small package of 29 mm2. The sensor works at 60GHz, and it is optimized for high precision and ultra-low power, delivered as a one package solution with integrated Baseband, RF front-end and Antenna in Package (AiP). That make it easy to integrate to any portable battery or, in this case, the Li-Po rechargeable battery [2].

Another reason why A111 works perfectly with FriendlyEyes is the capacity to detects not only the objects but its motion and velocity to determinate if the person is approaching or distancing the user. This sensor is the one that we use for zone 1 in Figure 1 because of its short range.

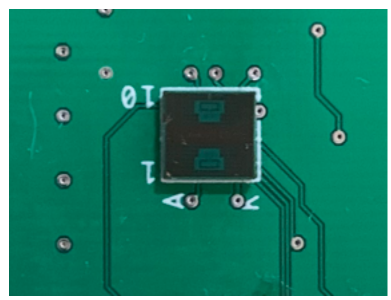

Figure 5: A111 Acconeer Sensor

B. Radar Sensor: XM122 Acconeer

The XM122 radar sensor is part of the family of the A111 that is previously mentioned with a few differences in its design that helps FriendlyEyes. XM122 works at 60GHz, and it also have a low power consumption with the characteristics of detecting and tracking objects to a distance up to 9 meters. For the high performance, XM122 is used to track any upcoming person from the distance to alter the user. The MX122 come with a optimize circle shape and small size around of the same area ass the A111 [4].

Figure 6: XM122 Acconeer Sensor Module

C. Ultrasonic Sensors: DFRobot SEN0388

The SEN0388 is a non-contact ultrasonic ranging sensor of high-performance that use an input voltage of between 3V to 5.5V and it has a maximum current load of 20mA. Also, the sensor has an effective range up to 5 meters with an accuracy of 1%. It works with a frequency of 25KHz, and this sensor is used for two scenarios in FriendlyEyes. The first is a stair detector where the sensor picks any increase or decrease in the elevation from the chest of the user in the deep tracking in Figure 1. Basically, by using trigonometry and the height of the chest of the user, FriendlyEyes can detect stairs and steps. The other function is to detect any incoming objects that the radars sensors did not pick and activate the feedback, or in this case, the motors. For this function, the SEN0388 works with the A111 sensor. The ultrasonic notify the MCU any object from 2 meters from the user that is when the A111 stops working properly [5].

Figure 7: SN0388 Ultrasonic Sensor

V. DESIGN AND IMPLEMENTATION

A. Calibration

The first step that we need to do was establishing the communication with the sensors. For the ultrasonic sensor, it is easy to program and to receive data due to its simplicity. Because we are using two of this kind and they have different functions, they have different codes. The first sensor is detecting proximity objects that we can do just by using the library to convert the information receive to distance and use an if function to discard any object that is more than two to three meters away from the user.

The second ultrasonic sensor is fixed with an angle of 60º looking down. The reason is that we are using Pythagoras theorem to detect stairs or steps. In order to do that, we know two angles (60º and 30º) and one side that is the height of the user. In a scenario where there are no steps and using a heigh from the from to the chest of 150cm the distance to the from the sensor is 300cm (Figure 8).

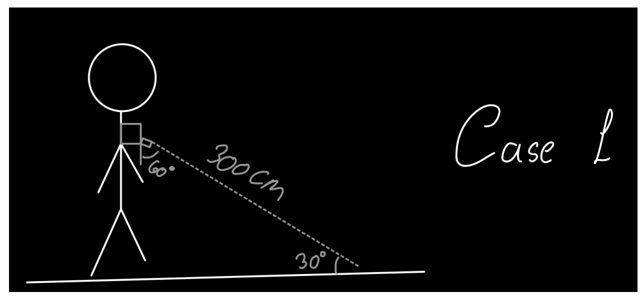

Figure 8: Ultrasonic - No stairs

If the distance is less or grater than 300cm, that means that a stair or sensor is approaching and a feedback must be sent to the motors to avoid an injury to the user. Those two cases can be seen in Figure 9 where the distance is not 300cm.

For those reasons, before the user wants to start using FriendlyEyes, the user will need to input his/her height. In this prototype, we change a parameter in the code but for future versions, a potentiometer with a legend will be implementeone-package it is not necessary that the user changes the code of the MCU and had the possibility to eliminate a function but also, it provides an easier access to change that variable.

The other two sensors are the radar A111 and XM122. Those sensors are harder to user than the ultrasonic. The first reason if that they need special libraries, and the communication protocol is hard to stablish. The XM122 has a MCU integrated that made it easier to flash and the calibration is writing the appropriate commands with its limitations. Also, because radars sensors can detect objects though fabric, FriendlyEyes will have those sensors lock inside the bag because there is no need to take them out or open the encloser.

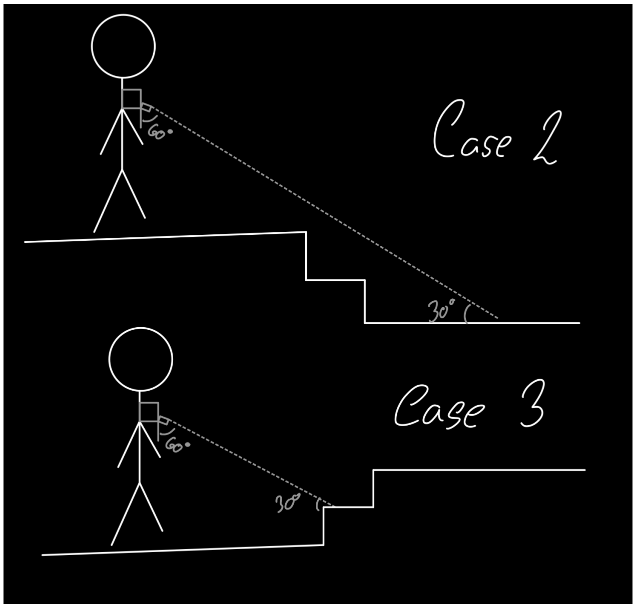

Figure 9: Ultrasonic - Stairs Present

The A111 is in the same family as the XM122 but with the main difference that it does not have an MCU integrated. That makes the process to flash the sensor harder because the computer needs to translate the code directly to the format that the sensor needs, and it is hard to set up.

B. Motors and Buzzers

To use the motors and the buzzers in FriendlyEyes we need to use a different approach. The Li-Po battery can provide enough power, but the MCU does not have the ability to provide enough current to the motors to work. For that reason, we designed a circuit with a motor driver chip that by using an external battery and the logic from the MCU, we made an analog switch that allows to turn on the motors and the buzzers at the same time. The MCU produces a square signal that turns on and off the buzzers and allows the motors to vibrate too.

C. Software Project Structure

In our code, we have several interrupts tied to sensors inputs, with the sensors being polled during a while loop running on the device.

When the device is powered on, many of the pins have requirements that have to be initialized. Our ultrasonic sensors and motor controller are all running at the 3.3V logic level, where the default is 1.8v on the microcontroller, and these pins also need to be set up as inputs or outputs. During the start-up process, a function calls each of these pins and sets them up into the proper modes. Once the pins are in their desired states, we can activate our ultrasonic sensors. After activation, our 'step' detection sensor undergoes calibration, forcing a quick check from that ultrasonic sensor and saving it to a variable that is used during step detection. We had previously wanted to use a potentiometer to set the height of the user, and then take that height and divide it by the cosine of the 60 degree angle we had set the ultrasonic sensor to. However, this method is not easly achievable by those visually impaired, as they would be unable to easily determine what the potentiometer is set at. By taking the distance read at start up, we can entirely bypass this issue.

We detect distance with the ultrasonic sensors using a two pin method. The sensor activates the trigger pin, and then waits the 10 microseconds it takes before we can receieve an output via echo. On the rising edge of the echo input, we start a timer. When the falling edge of the echo is reached, we stop the timer, count the length of time passed, and determine then determine the distance by dividing that time difference by six. After that we trigger the interrupt associated with that ultrasonic sensor.

The INS3330 and the ultrasonic sensors are tied to interrupts that force the motors to activate when the requirements for them are met. The step detector checks that the initialized 'distance from floor' value that was saved during calibration is within an offset of 20 cm. If the sensor detects that something has gotten closer or further than that, that is indicitave of a step and the corresponding motor will be triggered by the interrupt. The primary ultrasonic sensor detects when objects come within one meter of the user and triggers an interrupt causing a motor to commence vibration. Finally the INS radar sensor is constantly polling for approaching objects at a distance of 10 meters, and when one is detected it also triggers a motor's vibration indicating that an obstacle is oncoming. If the object is not approaching the user, the motor will not be triggered (the obstacle is not a threat).

VI. Demonstration (results)

A. Testing procedures

In order to test FriendlyEyes, we are going to test the system independently and after start combining every part to make sure all the integration of the system is easier. Also, because all the components are in a bag, it is easier than once a system work, we place it in the enclosure for final testing.

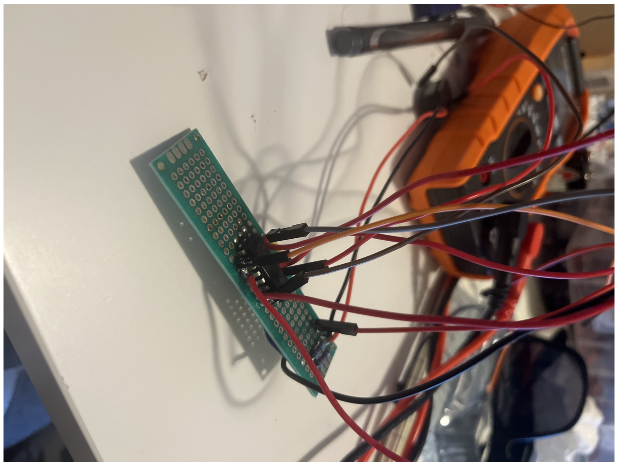

Figure 10: Motor and Buzzer Driver

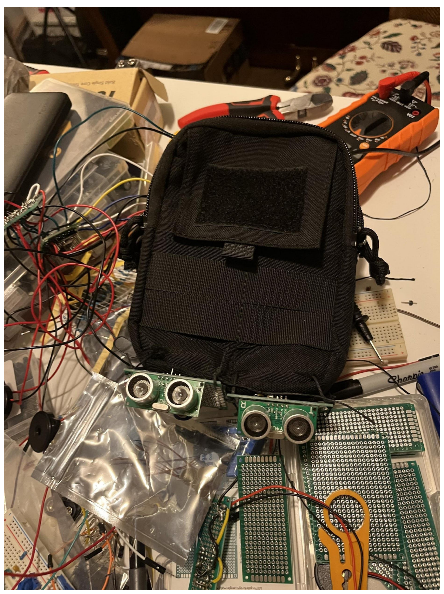

Figure 11: First Prototype of FriendlyEyes

B. Power Design

At the beginning of the project, we thought that a Li-Po battery will be enough to power everything but, due to the motor consumption, we need, to add a 9V battery that provides the power to the motor that is how they can get the ampere that thoutputsrs and buzzers need.

In Figure 12, we are powering the MCU and the 9V battery powers the motors. When the MCU set the GIO pins high, the motor module connects the motors to the battery and produce and output.

C. Ultrasonic Sensors

To test the ultrasonic sensors, we did it step by step. First, we prove that we could power the sensors with the MCU. After, we did all the connections for the trigger and the echo from the sensor to the MCU and make sure the MCU can process the information.

For the second sensor, we repeat the same process and make sure it worked and test if both ultrasonic sensors work together. Also, to see if the MCU can prioritize which sensor is more important, in this case, the second because it detects stairs.

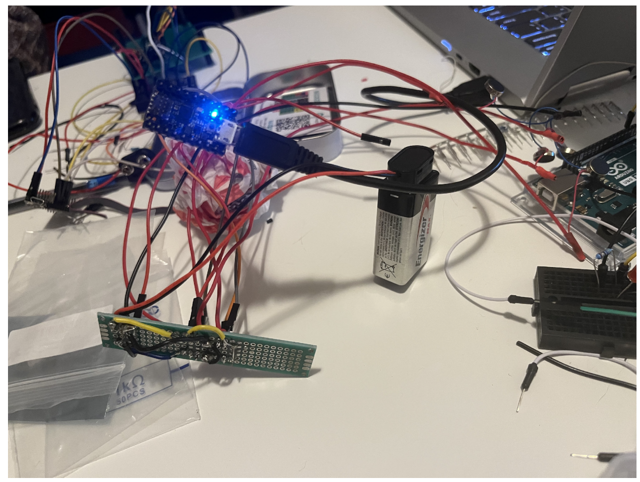

Figure 12: Power Design for the Motors

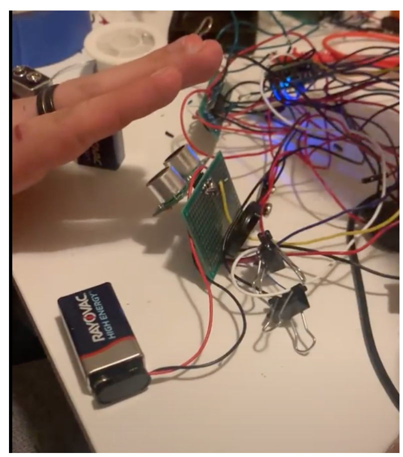

Figure 13: Ultrasonic Sensor turning on the LED

D. Radar Sensors

To test the radar sensor, is we use the same process as the ultrasonic, the main difference is that the sensor does not send a signal back to the MCU because it has an MCU integrated that does all the processing. For that reason, the sensor only turns on a GPIO pin that activates the motors.

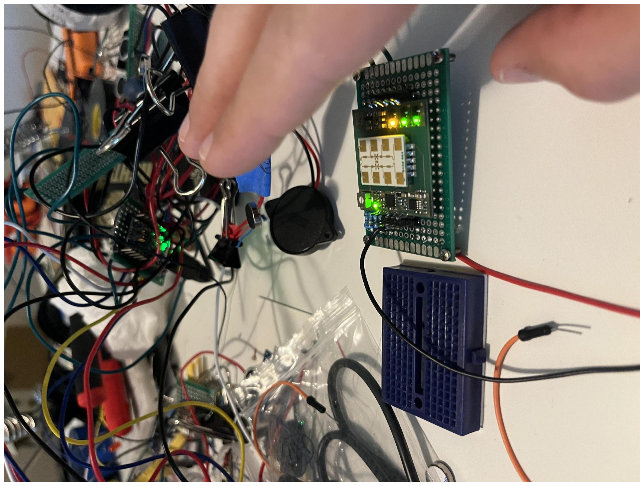

Figure 14: Testing the Radar Sensor

VII. Conclusion

This system was created to help people disability problems for blind people walk without the use of the stick. FriendlyEyes can help these people using three sensors, motors and buzzers. In the first prototype, we were able to attend stairs or change of elevation in front of the user, object approaching the user up to 10 meters away and, objects that are less than 1 meter from the user.

FriendlyEyes use the interaction of the three sensors (two ultrasonic and one radar sensor) to create feedback that will help the user to walk on the streets without the risk of hitting his/herself with an object.

By using 9V battery to solve our power problems we learn a lot about voltage dividers and how I reference load can affect all the calculations and supply voltage. Also, while testing the two ultrasonic sensors, we learned that our MCU most used a two-pin interface with the sensors because one pin is not fast enough to change from read to send information to get feedback to the motors.

In this project, we learn to work more as a team because we faced many difficulties such as supply chain with chips, sensors not working at the should and, and the motors not being able to work because of the MCU could not provide enough power to them.

Overall, FriendlyEyes can provide feedback in 1/8 of a second, use batteries so, it can be portable, detect objects up to 10 m away from the user, and detect motion of 7 m from the user. Those were the objective that we were looking from the beginning of the project, and we were able to make them work.

Acknowledgement

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Biography

Michelle Dubon is pursuing a bachelor's in electrical engineering in power track. Michelle is looking to graduate in Spring 2022 and graduating from FAMU Law College in Spring 2023. Michelle will begging a full-time position at WSP after an internship for a year as an Electrical Design Engineer.

Joseph Brown is pursuing a bachelor's in computer engineering, and Joseph is planning to graduate in Spring 2022. Currently, Joseph is looking for a position as an entry level in Computer Engineer.

Victor Lopes is pursuing a bachelor's in electrical engineering in power track. Victor is looking to graduate in Spring 2022. Victor will begging a full-time position at WSP after an internship for a year as an Electrical Design Engineer.

Manuel Parilli is pursuing a bachelor's in electrical engineering. Maule is looking to graduate in Spring of 2022. Manuel is looking waiting for an answer of a company to see if he got a full-time position in Colorado.

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