ECE 445 Senior Design Project

ALICE Sensors

Team 38
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Abstract

The ALICE in ALICE sensors are a short for Assessing Location In Current Environment. The ALICE sensors aim to reduce the number of people that fall from tripping over things as they walk. The ALICE sensors seek to accomplish this by using liDAR sensors to detect the present of potential trip hazards. The liDAR sensors are connected to a Bluetooth Low Energy chip, which will send a signal to a device worn by the user via Bluetooth Low Energy in real time. The Bluetooth Low Energy chip used in this project have a gyroscope in it, allowing it to determine if the feet are on the ground or not, preventing false alerts from detecting the ground while walking. When a potential trip hazard is detected, the eccentric mass vibration motor, mounted on the device worn by the user, will be activated, alerting the user of the potential trip hazard, so that they can be more careful in the area, and reduce the risk of tripping.

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1. Motivation

1.1 Problem Statement

Over 640,000 fatal falls happen each year. This makes falling the second most common cause of accidental death worldwide. Each year, about $50 billion is spent on injuries from falling. This is especially common among elderly [6]. As people grow older, their reflexes slow, and their natural senses grow duller. They also become weaker, so they fall more easily, and the falls hurt them more. This causes older adults to be unable to move about with the confidence they once had, back in the days when they were young, strong and reactive, so they could dodge most potential trip hazards, or maintain balance even if they do encounter the hazard, or be hurt less when falling from tripping. If an elderly person does fall, they can take significant damage that can traumatize a person. There are primarily three reasons as to why the elderly are more likely to fall and hurt themselves than a young person. The first reason is that their vision is weakened, so they fail to spot the trip hazard. The second is because the body is weaker, and their motor functions are slower. They react more slowly so they cannot balance themselves to catch themselves in time upon encountering a trip hazard, and even if they react in time, their bodies are not strong enough to stop the fall. Third is that their bodies are weaker, so they take more damage from the same impact. Unfortunately, the second and the third reasons cannot be resolved with the current strategy. The second reason is partially addressed by the use of canes or walkers, which help with balance. However, these are not for the elderly who have healthy legs and can walk just fine without any cane. They are bulky and a bother to carry around. Furthermore, the use of canes don't prevent falls due to trip hazards unless you swing them around to sweep for potential trip hazards. However, that action can be tiring, and may also bother surrounding people, and should be left for those with near no vision at all, in which case they should be accompanied by someone to guide them. Usually canes just help with balance, not trip hazards.

1.2 Solution

Our idea is to create an ALICE (Assessing Location In Current Environment) sensor, which would detect potential trip hazards and warn the user about them. The sensor would be located at the feet, so that it can detect potential trip hazards, and be able to detect anything a person could trip over as they walk. The idea is to forewarn the people about potential trip hazards, so they can avoid it and not trip. These sensors will be operated by battery power, as they are to be worn when the user is walking outside, and they will warn the user about a trip hazard if it is in the direction the user is traveling to. As it is to be worn on feet, they cannot be too heavy or clunky. According to the UK Health and Safety Executive, any obstruction that is 10mm or higher can be considered a potential trip hazard [5].

1.3 High-Level Requirements

- ALICE sensors must be able to detect potential trip hazards (any obstruction that is 10mm or higher) in 2m range.
- ALICE sensors must be able to warn the user upon detecting trip hazards.
- ALICE sensors must not alert the user mistaking the ground as a potential trip hazard as the user walks.

1.4 Visual Aid

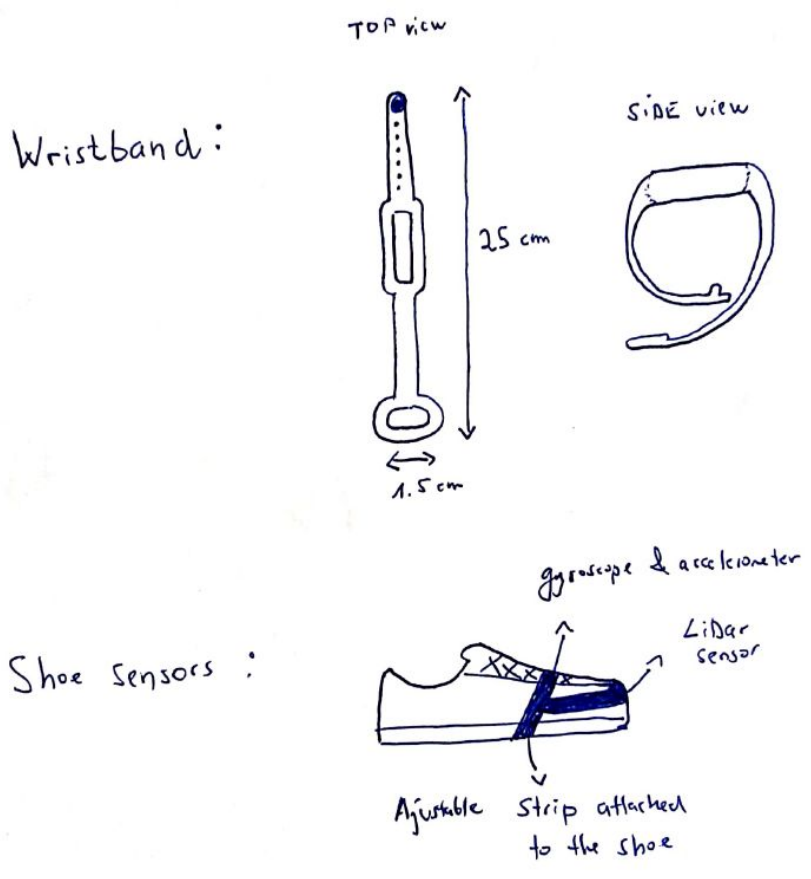


Figure 1

Figure 1 shows the a physical design of the completed product.

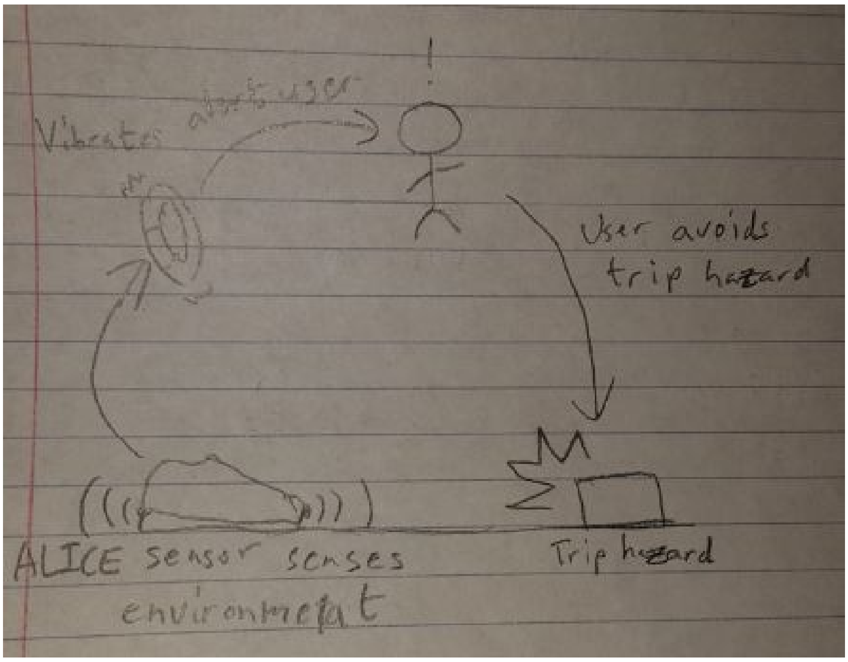


Figure 2

The figure 2 shows the conceptual design of the ALICE sensor. The ALICE sensors will be installed at the shoes, and be able to detect potential trip hazards. Upon detecting a potential trip hazard, it will send a signal to a device the user possesses, preferably a wristband, which will vibrate or make a sound to notify the user of the potential hazard. Upon receiving the warning, the user will be more cautious, and be able to spot and avoid the potential trip hazard.

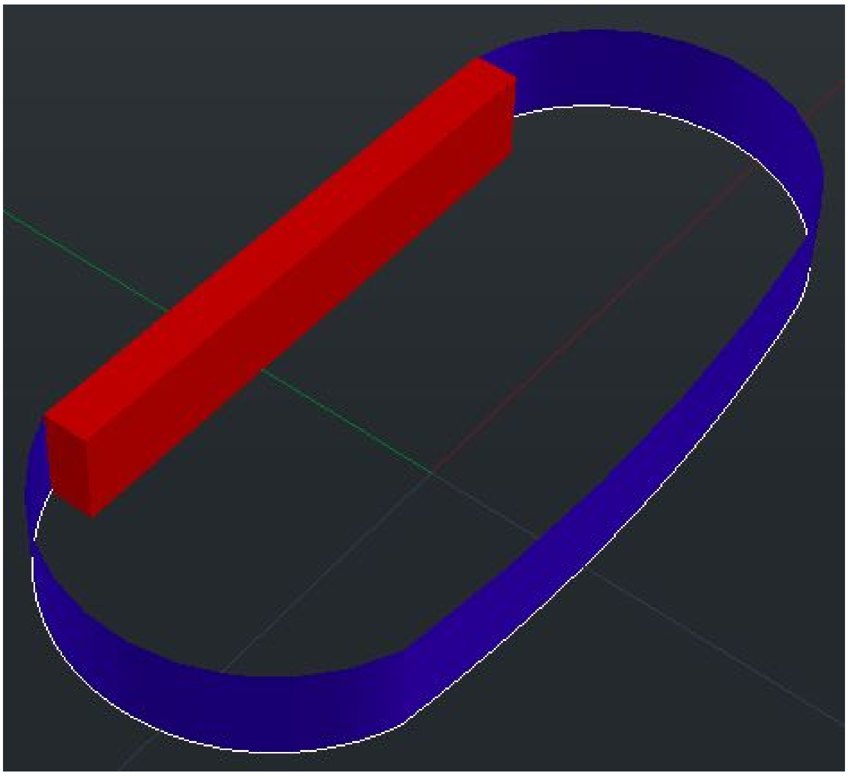


Figure 3: 3D model of User Notification Device

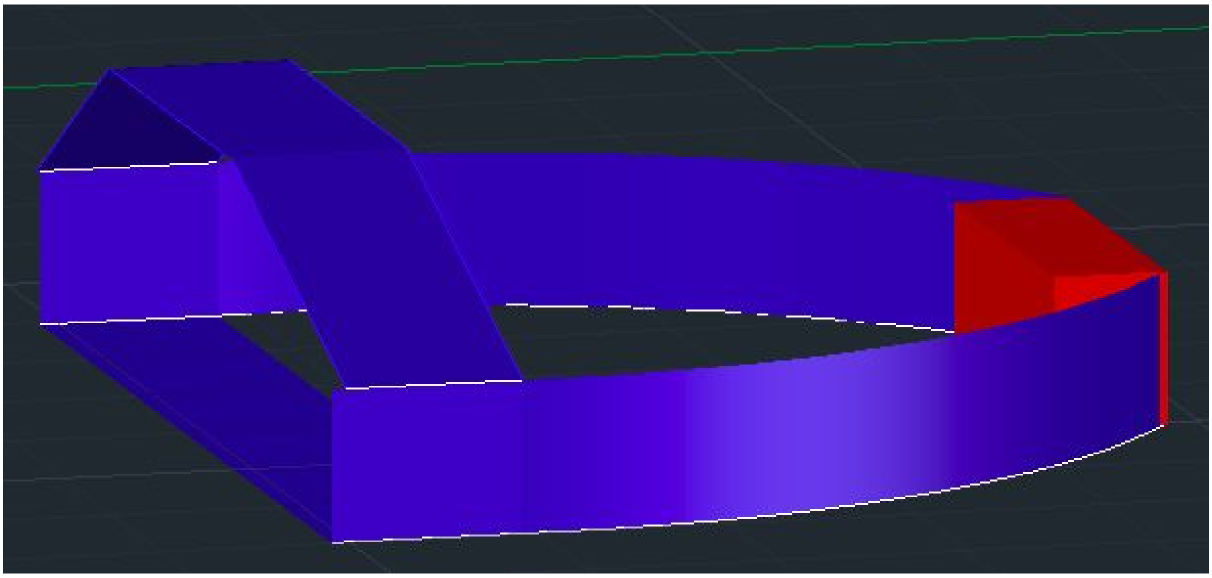


Figure 4: 3D Model of Shoe Sensor

1.5 Block Diagram

We will use sensors to detect potential trip disasters, and transmit the signal to a wearable device by bluetooth, and use an eccentric mass vibration motor to vibrate upon receiving the signal that claims that the sensors have detected a potential trip hazard. The sensors and the wearable device will be powered by battery, as they are for outside use. Bluetooth Low Energy sensors will be used to detect when the shoe is flat on the ground and allow signals from the distance sensor to pass through to the wearable device, so that the device doesn't go off every time the user walks and the sensor faces the ground. Figure 5 is the block diagram.

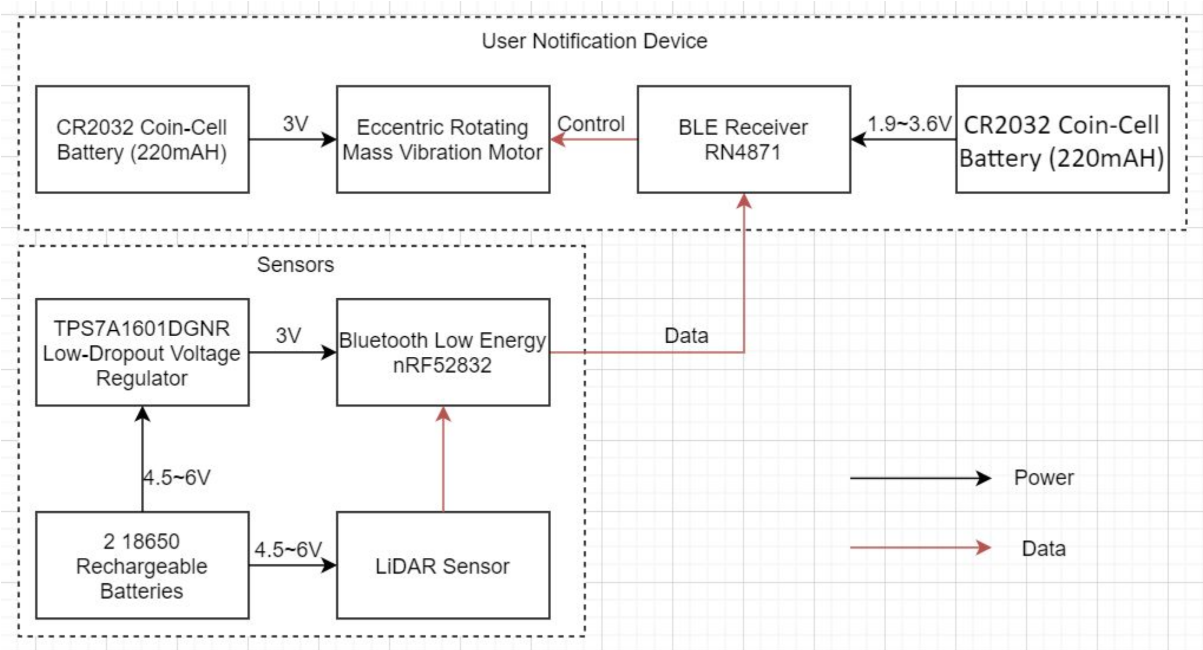


Figure 5

2. Implementation

2.1 Design Details

2.1.1 Sensor Module

LiDAR Sensor

Distance sensors will be installed at the front of the shoes, facing outwards to detect any potential trip hazards. For this project, we will use a small Light Detection And Ranging (LiDAR) sensor to detect the distance to a potential trip hazard, and if the trip hazard is near, it will send signals to the Bluetooth Low Energy device, which serves as a way to wirelessly transmit the data to the user notification device. Seeedstudio Grove - TF Mini LiDAR was chosen for its small size. The device can detect up to 12m, but we only need it to measure up to 2m. The requirements we have for the LiDAR sensor is for it to be able to sense objects that are higher than 10mm from the level ground where the user is standing, up to a 2m distance. This sensor requires a voltage from 4.5V~6V. It is powered by 18650 Rechargeable Battery, which provides a range of 2.5V~4.2V, which is sufficient power to the sensors if two are used. The LiDAR sends the data to the nRF52832 Bluetooth Low Energy. that it is connected to.

nRF52832 Bluetooth Low Energy

We will use a programmable Bluetooth Low Energy sensor (BLE) to act as a gyroscope as well as transmit data wirelessly to the user notification device. It is connected to the LiDAR sensor, and is powered by the rechargeable battery after it goes through the voltage regulator.

18650 Rechargeable Battery

Two of these batteries will be used to provide power to the distance sensor. They have 2300mAH to 3600mAH of power. Each battery has can provide a range from 2.5V~4.2V. These are rechargeable, and therefore can be reused over and over again. They power the LiDAR and the BLE after they go through voltage regulators. to provide sufficient power for each device.

TPS7A1601DGNR Low-Dropout Voltage Regulator

This voltage regulator takes in a wide range of input voltages, which can range from 3V to 60V. The output voltage can be controlled by .5V drops, ranging from 1.2V to 18.5V. With this voltage regulator, it is possible to adjust the voltage from the batteries so they suit the BLE as well.

2.1.2 User Notification Device

Eccentric Rotating Mass Vibration Motor

This motor is used to cause vibrations to notify the user of the potential trip hazard. It receives information from the BLE receiver, which only tells it to run when the gyroscope signal says the foot is on the ground and there is a potential trip hazard nearby. This one we will use is 2mm Mini Vibrating Disk Motor. which was chosen for its small size of 2mm thickness and 10mm diameter. It has a rated current of less than 80mA, so with a CR2032 Coin-Cell Battery, it can be used more than 2.5 hours non-stop. However, as it is not used constantly, and only used upon receiving a signal, 1 battery should last more than one day, depending on how often trip hazards are detected.

RN4871 BLE Receiver

This receives data from the BLE sensor. It is powered by a coin cell battery, and it will signal the eccentric rotating mass vibration motor to run when it gets the data that the foot is on ground and it detects a potential trip hazard.

CR2032 Coin-Cell Battery

This battery is used to power the BLE and the Eccentric Rotating Vibration Motor. Two a separate battery is used for each of the device to ensure longer operation hours. It is a cheap coin battery that can be easily replaced. This battery has 220mAH, which can power the BLE for more than a day. The battery is cheap. There are a variety of these batteries, most of them costing 25 cents per battery, and are cheaper if bought in bulk, some going down to mere 6 cents. Assuming the batteries were bought at 25 cents, that gives an upkeep of $7.5 per month. However, a CR2032 coin cell battery used to power a similar device has been shown to have a great divergence of battery life, ranging from 1 day to 14 days, which suggests that experiments need to be run to determine exactly how much power is consumed with the BLE.

2.2 Circuit Schematics

2.2.1 Sensor on Shoe

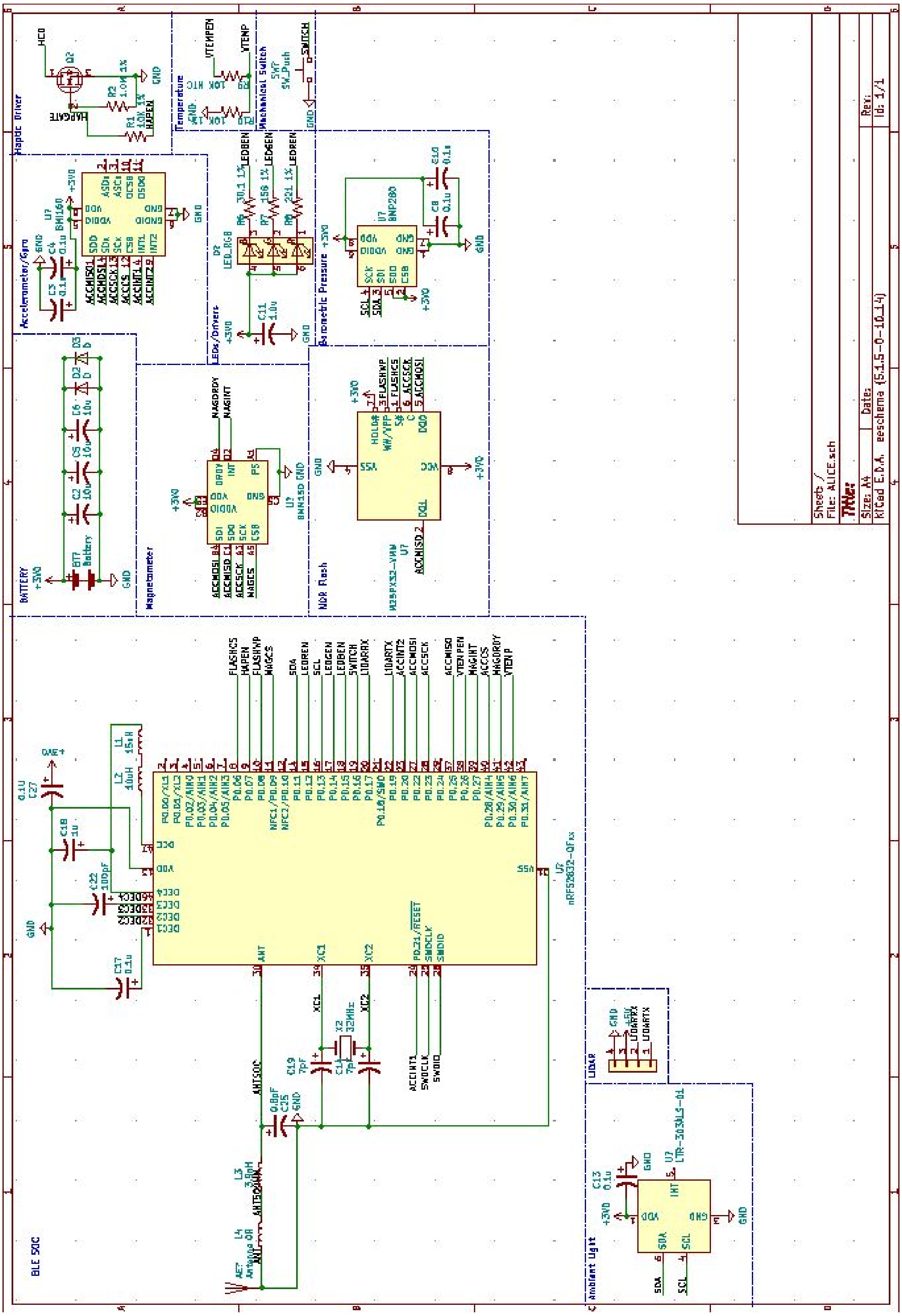


Figure 6

2.2.2 User Interface

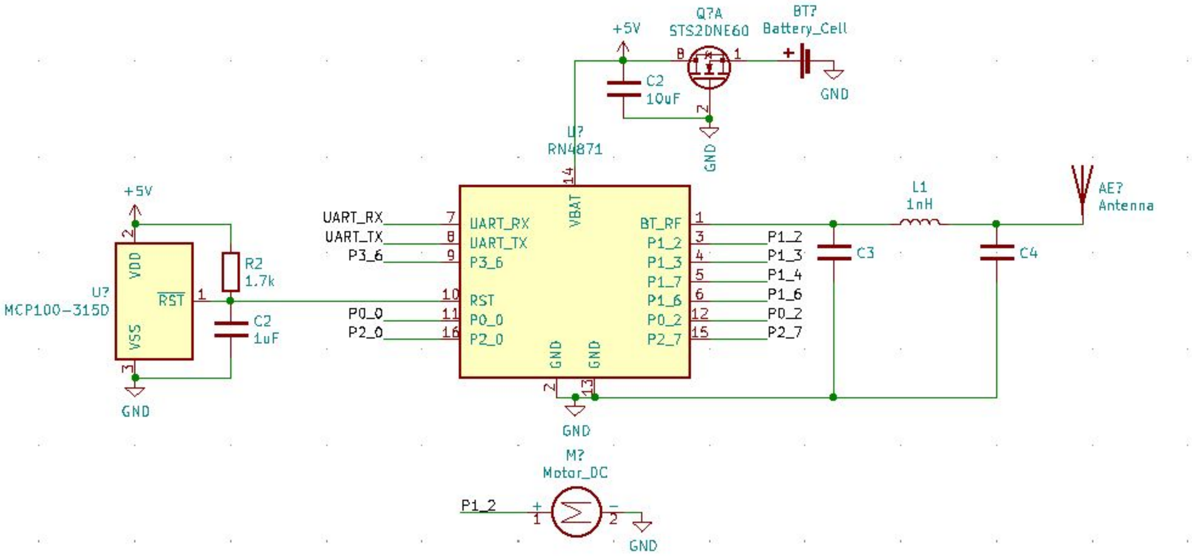


Figure 5

2.3 Calculations

In order to calculate the height of an obstacle, we require the following:

a) Distance measured by LiDAR.
b) Distance of LiDAR from the ground. This can be measured by the accelerometer (z axis).
c) Inclination of LiDAR (about y-axis). This can be measured by the gyroscope.

By combining the values of the above readings, we can find the height of the obstacle.

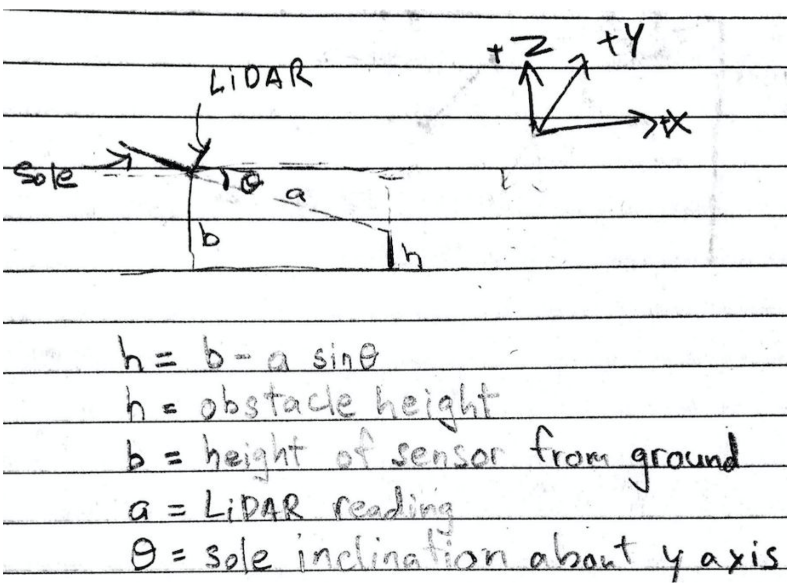


Figure 7

2.4 Schedule

Week	Task	Alejandro Diaz	Chulwon Choi	Karthikeyan Sundaram
03/30/20	Project Proposal	Cost and Schedule, Risk Analysis, Discussion of Ethics and Safety, Citations	Problem and Solution Overview, Visual Aid, High-Level requirements	Block Diagram, Subsystems, Tolerance Analysis
04/06/20		Select specific BLE	Select specific Vibration motor and batteries	Circuit schematics
04/13/20	Design Document	Cost and Schedule, Risk Analysis, Discussion of Ethics and Safety, Citations	Problem and Solution Overview, Visual Aid, High-Level requirements	Block Diagram, Subsystems, Tolerance Analysis
04/20/20	Design Review	Tolerance Analysis, Ethics and Safety, Conclusion	Schedule, Costs, requirements and verifications	Introduction and Overview, High Level requirements, requirements and verifications
04/27/20		Verification, Citations	Introduction, Costs	Design, PCB
05/04/20	Final Report	Review, cross examine other parts	Review, cross examine other parts	Review, cross examine other parts

2.5 Cost

2.5.1 Labor

Having 3 members in the group, assuming that one person gets paid \$30/hour, planning to work about 15 hours/week, and considering there were approximately 6 weeks from the time the project was changed to this one:

$$3\ teammates\ \times\ \$30/h\ \times 15h/week\ \times\ 8\ weeks\ =\ \$10,800$$

2.5.2 Parts

Part	Individual Cost (USD)	Number Ordered	Total Cost (Shipping fee and tax included)
MetaMotionC	75.99	1	84.09
Seeedstudio Grove - TF Mini LiDAR	39.95	1	45.63
BLE RN4871	7.03	2	26.60
Vibration ERM Motor 3V	1.22	1	10.41
220mAH CR2032 Coin Cell Batteries	.25	2	20.92
18650 Rechargeable batteries	3.99	2	16.78
TPS7A1601DGNR Low-Dropout Voltage Regulator	2.51	1	11.66
Total	13.85	----------------------	216.09

Summing the labor and parts costs, this project would require a funding of $11,016.09.

3. Conclusion

3.1 Implementation Summary

In this project, we picked out the TF Mini LiDAR sensor to use it to detect potential trip hazards within a 2 meter distance. The signal goes to the BLE, which is equipped with a gyroscope. The BLE sends the data when the gyroscope shows that the shoe is horizontal, meaning the signals from the LiDAR are not just detecting the ground. The data is sent to a BLE receiver on the user notification device, which turns on the eccentric mass rotation motor when a potential trip hazard is detected.

3.2 Uncertainties

Since we are going to design a wearable system that deals with the safety of people, we want to make sure that this device is safe for the people wearing it and that it works according to the specific goals we have proposed.

The risks we will have to face will mainly involve the accuracy of our system to predict the possible hazards. We believe it is as bad not to be able to detect a potential obstacle along the path of the user as well as to alert of a false positive. Both cases would put into risk the safety of the user and that is what we want to focus on.

SInce the system has two main components, the wristband and the sensors on the shoes, the connectivity between each other must be effective and as fast as possible. Time is one of the key components in our design because being able to effectively detect an obstacle is as important as letting the user know about it on time. The user has to be able to receive the notification on his/her wristband that there is an obstacle with enough anticipation so that he/she can make a decision on which path to take.

However, the main problem we have to face is to find a way of detecting obstacles just by using sensors on the shoes of the user. We want our system to be as universal as possible, so we will try to make it easy to add and remove from any shoes, however, we are sure that the shoes will have some specific requirements to work with the system, Therefore, we need to specify those requirements in order to identify the shoes that would be compatible with the ALICE system.

It is impossible to actually build and test these devices as we have no access to the lab. This means that any potential problems with the design are impossible to verify. One possible problem with the design may be that our design of the sensor strap may not be completely stable, and may allow the LiDAR to slip from the intended position as the user walks while wearing it. Such a problem is only addressable when you test it out by building it and trying it out. A potential method to complete this task may be trying it out using a makeshift strap with paper, rubber bands or strings, though this may be too unstable for a proper experiment.

3.3 Ethical Considerations and Safety Hazards

As engineers from the University of Illinois at Urbana-Champaign, we are committed to creating a project that is aligned with the values of the IEEE and ACM Code of Ethics [3],[4]. For that reason, these are our main ethical statements:

We will work in a safe environment in which we can avoid harm to any of the group members or other people while working. Due to the COVID-19 worldwide pandemic we will follow the OMS recommendations of practicing social distancing and we as team members of the project will meet via videoconference because we are aware of the risks that face to face meetings involve.

We are going to be honest about our work and results. We are going to respect the ideas and inventions of others, and in case we use an idea that does not belong to us we will mention the original author with a proper citation. It is important that we take into consideration the fact that no laboratories will be used for this project due to the closing of the facilities. Therefore, we will focus our project on simulations and we will try to make them as accurate as possible with the data we can use.

We want to maintain high standards of professional competence, conduct, and ethical practice. We will learn the technical knowledge required to develop the project and we will upgrade our skills through independent study, attending online conferences with professors, and asking experts on the matter.

3.4 Project Improvements

If we had an extra year to complete this project and we were actually able to build the project, we would research a design that would allow the ALICE sensors to be mounted on almost any type of shoes. This could be achieved contacting shoe companies and asking them for advice on the design, and testing out the design and making adjustments accordingly.

We may also configure the sensors to be active only when the user wants it to, so that when the user is location that constantly sets off the ALICE sensors, such as in front of a wall, or surrounded by trip hazards that the user knows of, it can be turned off to stop the constant vibration. This function would be useful when the user goes to places that require silence, such as the library, as it would stop the device from disturbing anyone.

We could also add an extra sensor so that the ALICE sensors can recognize the difference between walls and trip hazards, as the current design does not take walls into account, and would alert the user of anything that is above 10mm from the ground, including walls. We would also try to solve the problem of using LiDAR on glass objects, as glass is largely invisible to LiDAR. We have not addressed this problem in the current project because it is expected that people wouldn't just leave pure glass lying around, and any that do exist would probably be dirtied enough for the LiDAR to detect. This may be solved by using a different sensor, or some other method that has not occurred to us yet.

4. Progress made on First Project

We made good progress on the first project, Nannybot. The Nannybot is a robot designed to prevent robots that are learning to walk from falling. Starting from the basic idea provided by Professor Kim Joohyung, our team discussed many things at lengths, and made many changes to the incorporating different ideas. The final design had 3 omni-wheels as the chassis, with 2 step motors on the chassis to pull up the robot via strings when the robot had to be picked up. The final design looked like the Figure 8 below.

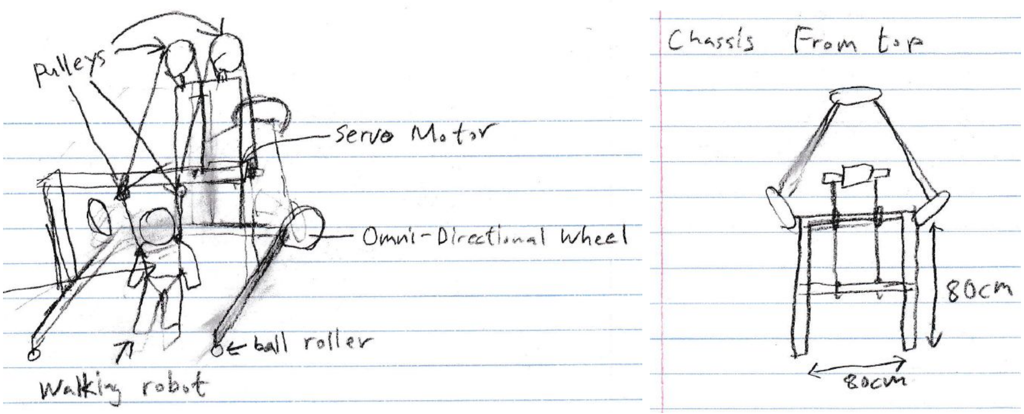
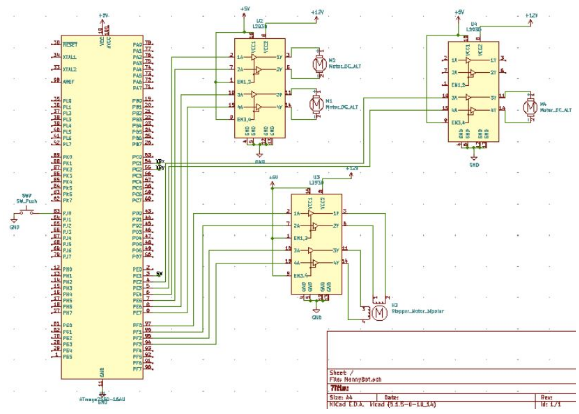


Figure 8

Karthikeyan made the PCB schematic, Alejandro determined which controller to use and the schedule, Chulwon acquired the components and kept in contact with the machine shop, making changes to the design. The final PCB made pass the review on PCBWay.com. The schematics and the PCB are below in Figures 9 and 10. The design was done and we handed in the materials the machine shop needed to start working on the frame, but that was the week before spring break, and the machine shop did not get far enough with the frame for us to complete it.



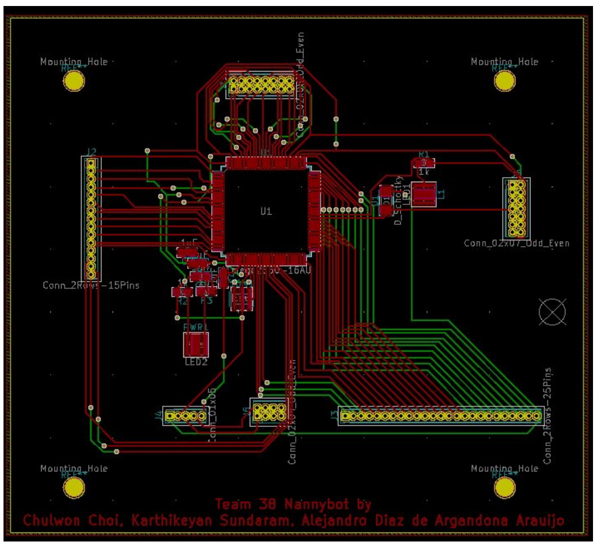


Figure 9, 10

5. References

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[2] “Falls Data,” *Centers for Disease Control and Prevention*, 17-Sep-2019. [Online]. Available: https://www.cdc.gov/homeandrecreationalsafety/falls/fallcost.html. [Accessed: 08-May-2020].

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[4] “The Code affirms an obligation of computing professionals to use their skills for the benefit of society.,” *Code of Ethics*. [Online]. Available: https://www.acm.org/code-of-ethics. [Accessed: 08-May-2020].

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Appendix A

Pseudocode of the program

AlicePseudocode.c

```c
/*
Pseudocode for ALICE sensors:

The goal is to determine with the sensors whether there is a potential hazard on the path and how close it is
Then the sensors will notify the user with a vibration that is regulable according to the proximity of the obstacle

Data available: LIDAR_distance, gyroscope_measure, accelerometer_measure
*/

int LIDAR_distance, gyroscope_measure, accelerometer_measure;
int calibrationFactor;
float proximity;

void function readMeasures();
int function calibrateSensors(int gyroscope_measure,int accelerometer_measure);
int function detectObstacle(int calibrationFactor, int gyroscope_measure, int accelerometer_measure);
void function sendNotification(int proximity);

int main (void) //Main program that runs constantly
{
    while(1)
    {
        readMeasures();
        calibrationFactor = calibrateSensors(gyroscope_measure, accelerometer_measure);
        proximity = detectObstacle(calibrationFactor, gyroscope_measure, accelerometer_measure);
        sendNotification(proximity);
    }
}

void function readMeasures() //Reads the measures of the sensors
{
    LIDAR_distance = readLIDAR();
    gyroscope_measure = readGyroscope();
    accelerometer_measure = readGyroscope();
}

int function calibrateSensors(int gyroscope_measure,int accelerometer_measure) //Calibrates the sensors to the specific user's type of walking
{
    if() //Here we set a range of the values received, then we compare them to calibrate the sensors)
    {
        //Here we compare measures received by a regular walking of the user to calibrate the sensors
        calibrationFactor = 1;
    } else if ()
    {
        //...
        calibrationFactor = 2;
    }//else if() ...

    return calibrationFactor;
}

int function detectObstacle(int calibrationFactor, int gyroscope_measure, int accelerometer_measure) // Obstacle detection
{
    //We use the calibration factor and the measures of the sensors to detect if there is an obstacle and how far it is from the user. The function returns a parameter with the proximity to the obstacle

    return proximity;
}

void function sendNotification(int proximity) //Sends an order to the vibration system to work according to the procximity of the obstacle
{
    sendVibration(proximity);
}
```