ALICE Sensors for Fall Prevention of Older Adults

Chulwon Choi, Alejandro Diaz De Argandona Araujo, Karthikeyan Sundaram

TA: Vassily Petrov

1. Introduction

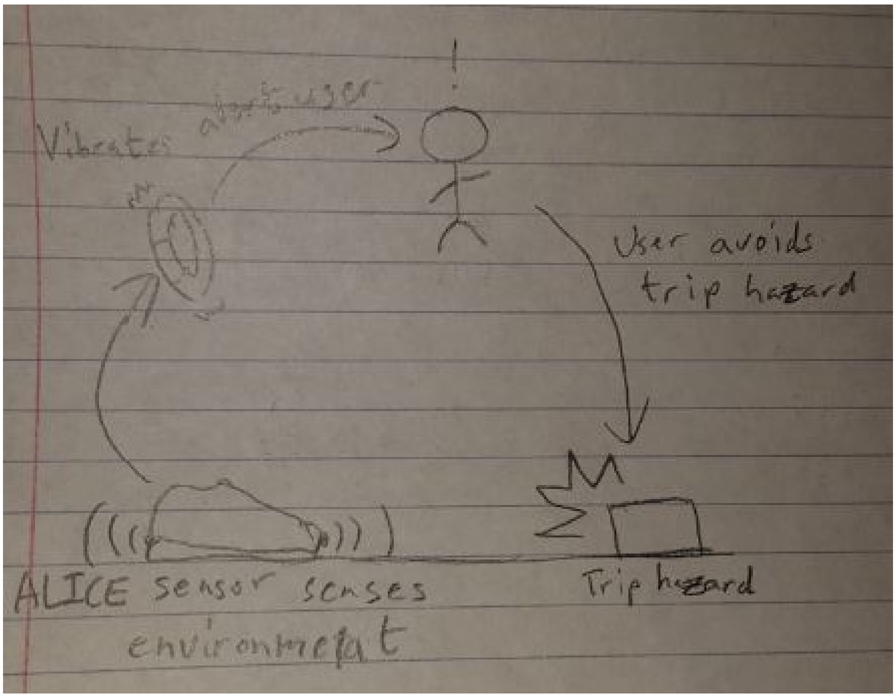
1.1 Objective

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. 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 UK Health and Safety Executive, any obstruction that is 10mm or higher can be considered a potential trip hazard.

1.2 Background

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. Unfortunately, the current fall prevention systems are focused on personal factors like gait and balance, or environmental factors by eliminating fall hazards. In other words, there's no technology that takes both the human and the environment into account.

1.3 Physical Design



The figure 1 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.

1.4 High-level requirements list

- 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.

2. Design

2.1 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 2 is the block diagram.

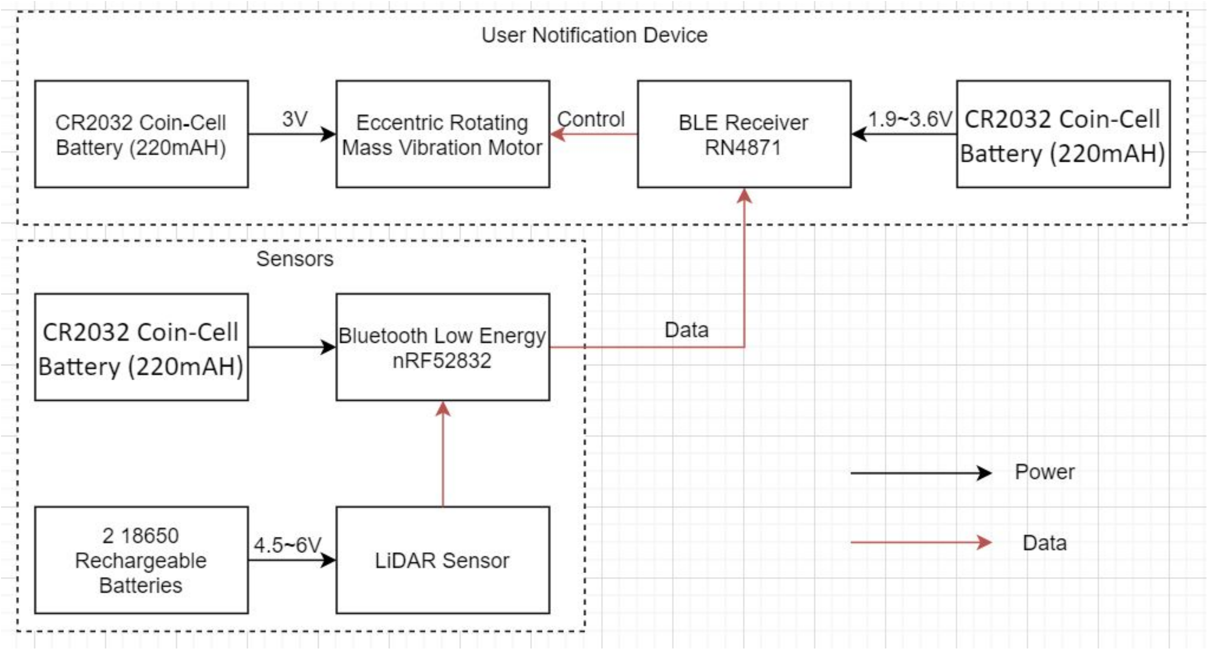


Figure 2

2.1 Functional Overview and Block Requirements

2.1.1 Sensors

2.1.1.1 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.

Requirements	Verification
- Sensor must be able to sense objects between 30cm and 2m.	- Set the sensor up, and move an object in front of it at 30cm and 2m. If the sensor detects them both, it passes.

2.1.1.2 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.

Requirements	Verification
- BLE must be able to tell when it is not horizontally oriented. - BLE must be able to send signals to the user notification device.	- Set the BLE up, and try rotating the BLE to see if it registers the change in orientation. - Test if the results from the first requirement can be transmitted to the user notification device.

2.1.1.3 18650 Rechargeable Battery

Two of these batteries will be used to provide power to the distance sensor. They have 2300mAH to 3600mAH.

Requirements	Verification
- It must provide voltage between 4.5V and 6V for - Device must be rechargeable	- Measure the battery's voltage with a voltmeter. - Try charging it.

2.1.1.4 CR2032 Coin-Cell Battery

This battery is used to power the BLE. 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 25cents, 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. This is usable for BLE in the user notification device as well.

Requirements	Verification
- The battery must be able to power the BLE for 8 hours at minimum.	- Try to power on the BLE with this battery. Leave it on for 8 hours.

2.1.2 User Notification Device

2.1.2.1 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 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.

Requirements	Verification
- The motor must vibrate strongly enough for a person to notice	- Try running it and feel the vibration

2.1.2.2 RN4871 BLE Receiver

This receives data from the BLE sensor. It is powered by a 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.

Requirements	Verification
- This must be able to receive data from the BLE sensor.	- Try having the BLE sensor send signals, and see if BLE receiver receives them.

2.1.2.3 Battery

The BLE Receiver and eccentric rotating vibration motor are powered by different batteries. The motor is powered by a battery with 2.5~3.5V, and the BLE receiver is powered by a battery with 1.7~3.6V.

Requirements	Verification
- Batteries must have respective voltages.	- Measure the batteries with a voltmeter.

2.1.2.4 CR2032 Coin-Cell Battery

This battery is used to power the BLE. 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 25cents, 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. This is usable for BLE in the sensor module as well.

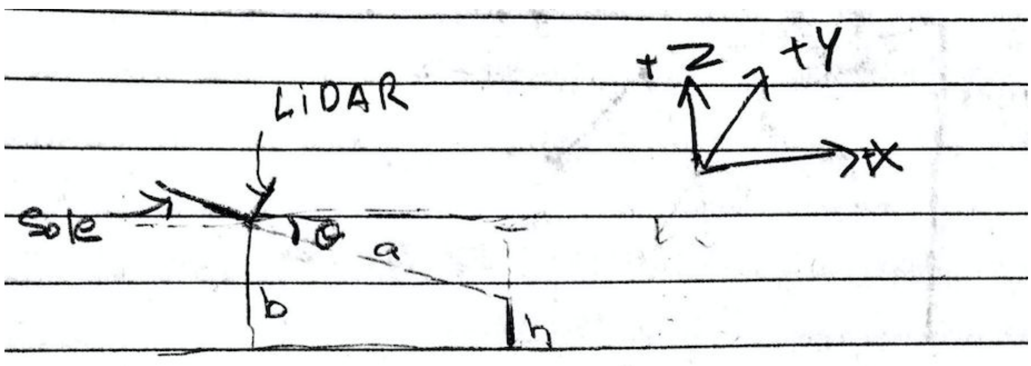
Requirements	Verification
- The battery must be able to power the BLE for 8 hours at minimum.	- Try to power on the BLE with this battery. Leave it on for 8 hours.

2.2 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.



$h = b - a \sin\theta$

h = obstacle height

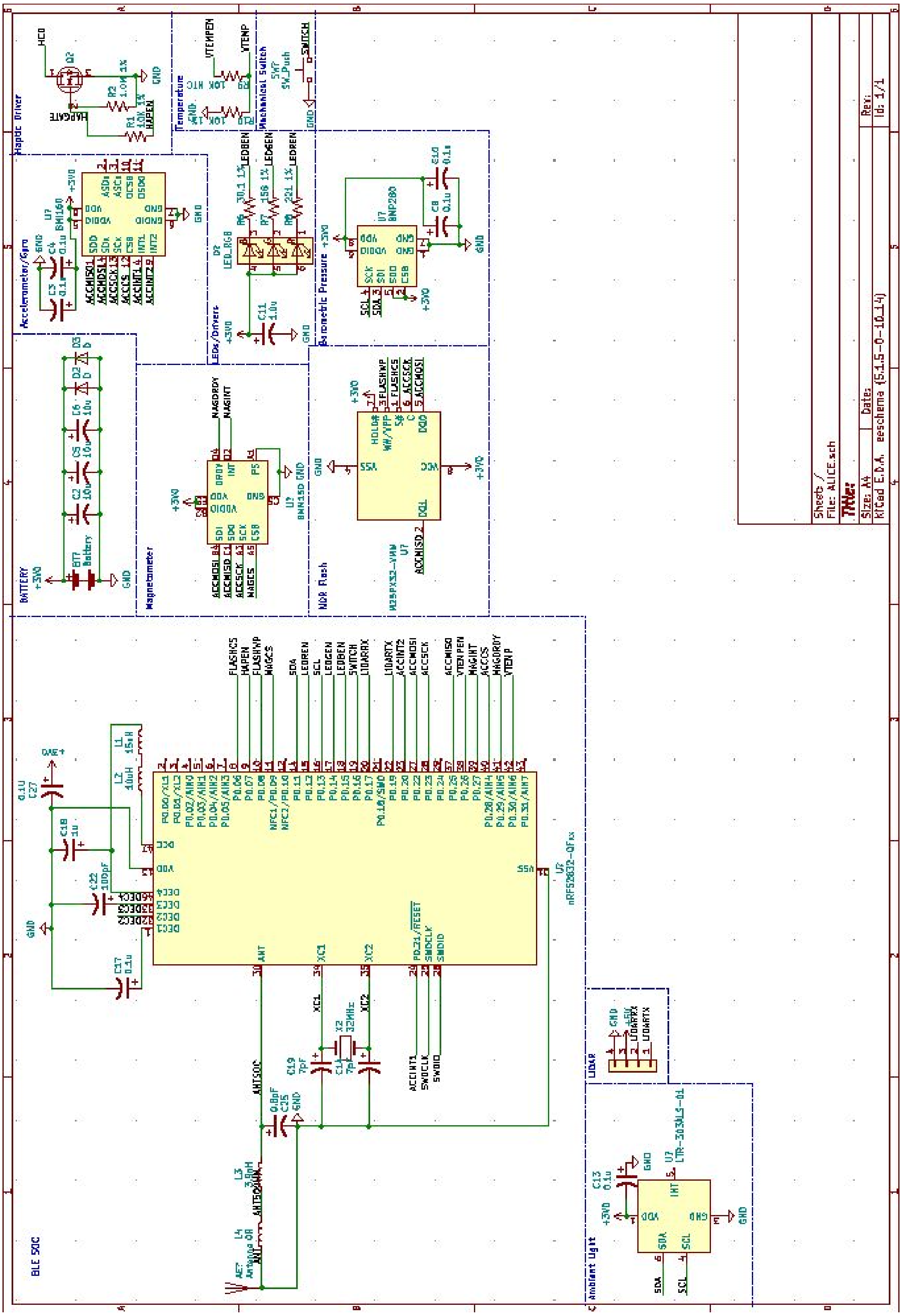
b = height of sensor from ground

a = LiDAR reading

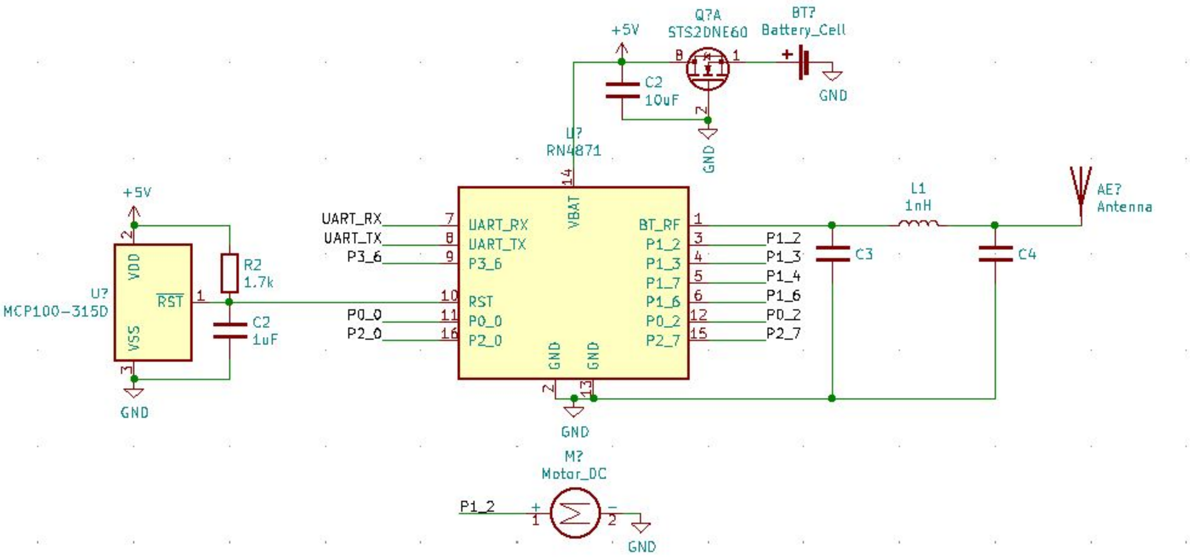
θ = sole inclination about y axis

2.3 Circuit Schematics

2.3.1 Sensor on Shoe



2.3.2 User Interface



3.1 Cost Analysis

3.1.1 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:

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

3.1.2 Parts

Part	Individual Cost ($)	Total Cost ($) (shipping fee and tax included)
MetaMotionC	75.99	84.09
Seeedstudio Grove - TF Mini LiDAR	39.95	45.63
BLE RN4871	7.03	14.45
Vibration ERM Motor 3V	1.22	10.41
10 200mAH CR2032 Coin Cell Batteries	.25*10	20.92
3 18650 Rechargeable batteries	3.99*3	16.78
Total	138.66	192.28

3.2 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

3.3 Risk Analysis

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.

3. Ethics and safety

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. 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.

References

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