THE CHINESE UNIVERSITY OF HONG KONG

DEPARTMENT OF ELECTRONIC ENGINEERING

Sport-climbing Electronic Wearable Assistor

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DEPARTMENT OF ELECTRONIC ENGINEERING

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1. Abstract

In this Final Year Project, the goal is to develop a smart electronic wearable that is specifically designed for rock climbers and outdoor athletes. As a rock climber myself, I find it frustrating that there are no any product in the market that can provide help in training as the format of training is quite different to other sports. And mostly because rock climbing is still considered as a niche sport. I discussed with some of my friends who are also climbers and they all share the same thought. It is clear that the rock climbing community is hoping for a product like that to exist. Therefore, I would like to use this chance to build a electronic gadgets for climbers, by climbers.

2. Acknowledgments

The completetion of this thesis could not have been possible without the help from Prof. Leung Ka Nang, my supervisor. I would also like to thank Prof. KK Cheng to be my associate examinar and taking time to examine my thesis. Also, I would like to thank my friend and fellow classmate Alvin, Lam Lok Hin for borrowing me an equipment which is crucial to the whole project.

Contents

3.Introduction

COVID-19 has been bringing enormous changes in people lifestyle from a variety of aspect. After the outbreak of COVID-19, instead of going to an in-door gym, people are starting exercise outdoor which is safer as the population density is low outside. People know appreciates going adventures into the wilderness more than ever. As a result, hiking and outdoor climbing have been gaining an increasing popularity. However, people might have forgotten that the nature itself can be dangerous in bad weather. It's difficult for beginner of outdoor sports to quickly sense danger and potential threats such as rainfall and extreme temperature.

In recent years, rock climbing is getting increasing popularity. There is more and more climbing gym in Hong Kong. In 2021, there's already 3 new climbing gym in different districts. In fact, it's now an Olympic sport. However, there's no product in the market to take care of climber's sophisticated needs. As a climber myself, I find it difficult to train and improve as a beginner. There is not much resource online for Hong Kong climbers. Personal training is unbelievably expensive. Even worse, rock climbing requires special training to train those muscles that aren't trained in daily life. I see many people giving up soon after they start climbing. Rock-climbing is

already a pain-related sport, the frustration of not improving fast as expected is making people lose interest to the sport.

For this wearable, I want to build a app-gadget comb that help people train, learn, and enjoy climbing. This is the initiation of this project. To offer a comprehensive service. I think the product should have acceleration monitor, route record, training helper and weather warning function. It will be wearable that is very flexible. It can be used as an belt, are band, wristband depends on users' choice to make sure it won’t block users movement in different routes. The app on smartphones provides GUI to control the wearable itself and take the role of data I/O processing center. In this stage of development, the product has two modes, standalone mode, and LCD augmented mode.

- Show the weather info of the surroundings (Temperature, humidity)
    - This is devastatingly essential for climbers as wet and slippery rock can ruin their whole session.
        - Can be done with the aid of implementation of API from weather services
- Warning of non-ideal weather for outdoor activities (Rain)
    - To warn them before they get into dangerous stuffs
        - Using LED light to warn the climbers as sound and vibration is hardly noticeable while doing sports and in outdoor environment
- Water resistance (Rain and sweat), Fast heat dissipation

    - Make sure the product to work in stressful conditions
        - The case of the wearable should block water from going in while the wearable can maintain a good working temperature
- Can be programmed to work automatically within one climb attempt
    - Free peoples' hand for climbing
        - This can be done by BLE(Bluetooth Low Energy) which has a connect range of 100m.
            - For most climbing route, the vertical height rarely exceeds 50m.
- Work with user's smartphone to record users training records.
    - By using BluetoothLE connection and accelerometer, training record can be detailly saved.

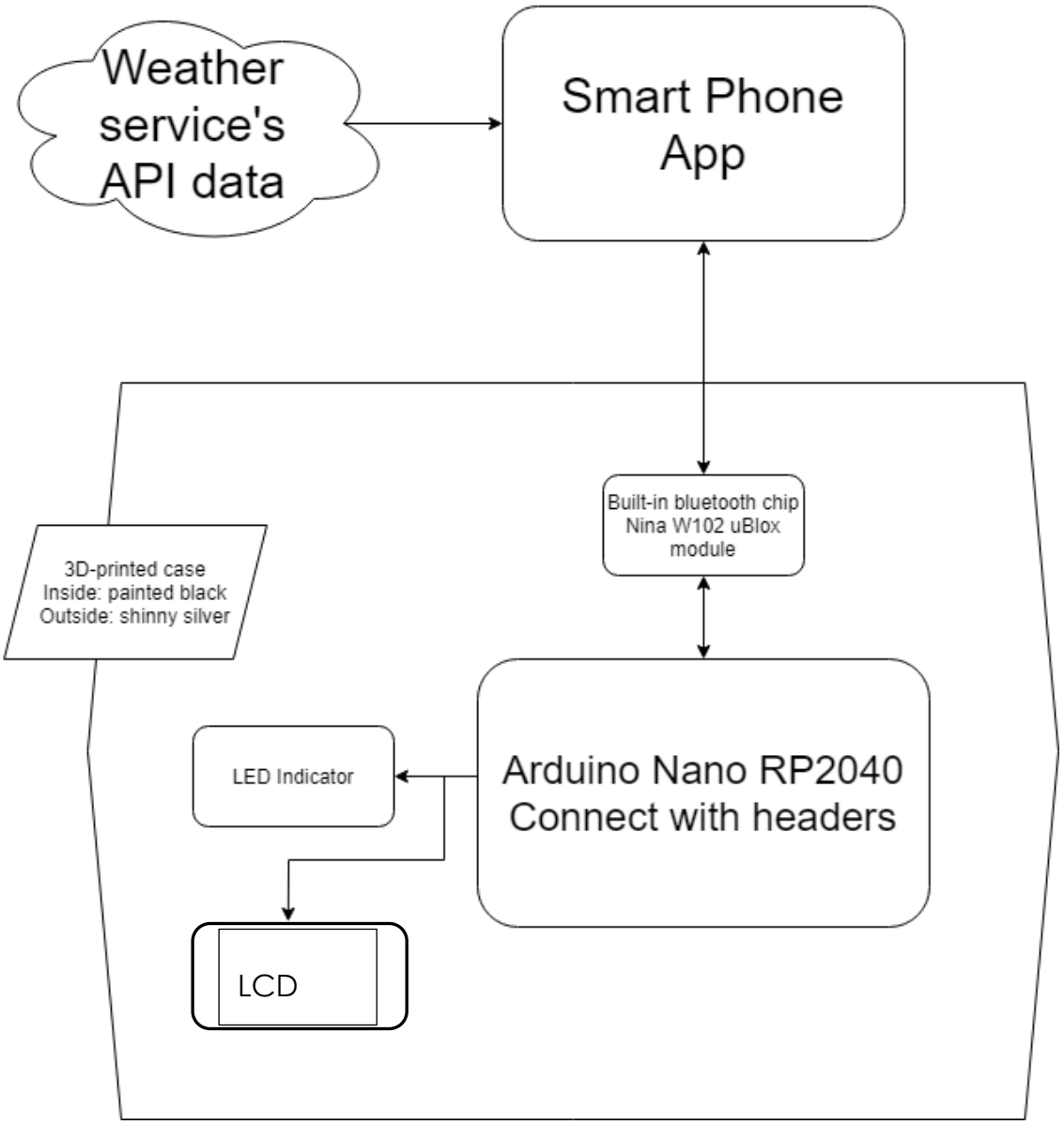


Figure 1 Simple chart that explains the project

4. Background

4.1 Background

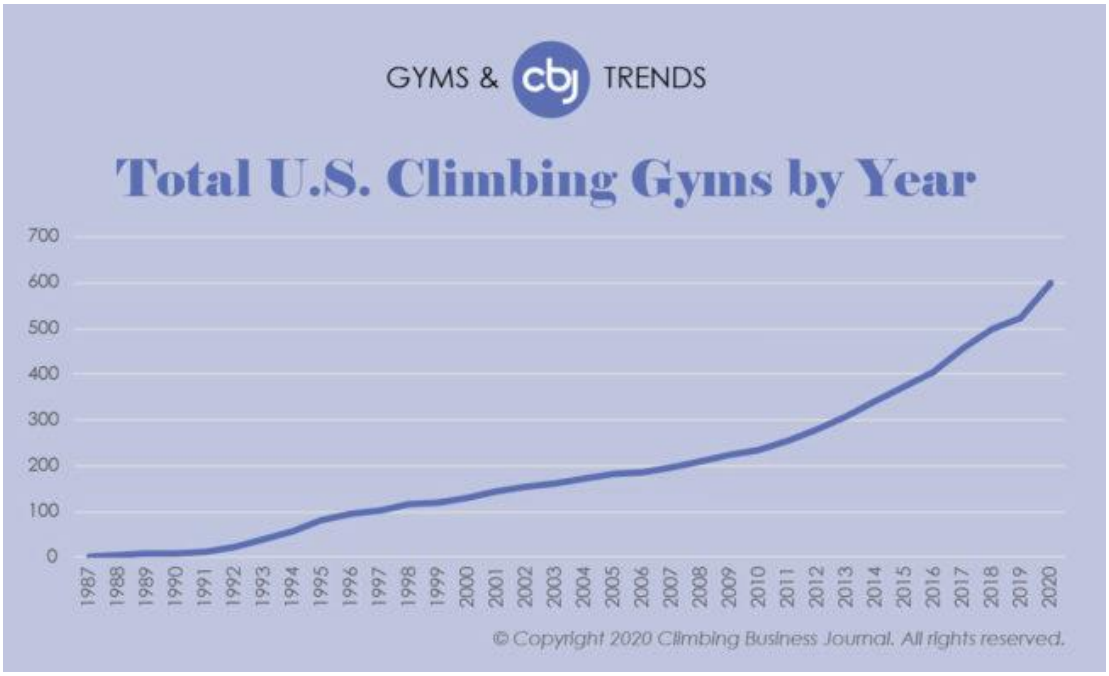


Figure 2 Total U.S. Climbin Gyms by Year [1]

Sports climbing is a newly emerged sport. Although its still not a mainstream sport, it is becoming something big. Figure 2 is a graph done by Climbing Business Journal [1] showing the total number of climbing gym in us by year. We can see that its is grwoing exponentially. Also similar circumstance is discovered in Hong Kong. It's very clear that sports climbing has a bright future. There is no doubt that the demand of climbing gears' will be enormous in the foreseeable future.I believe that after 2020 summer olympic, more and more people will learn about sports climbing. Results in increased popularity of the sport.

In the past, wearable electronics are only used by professional athletes and patients. With the advance of technology, wearable electronics are getting into everyone's life. According to my own research, out of 13 respondants, 72 have used wearable electronics, that is about 52%. For the people who have used or using health-related wearalbe electronics, the majority of them uses wearables in sports and for training purposes.

Figure 3 Pecentage of wearable users

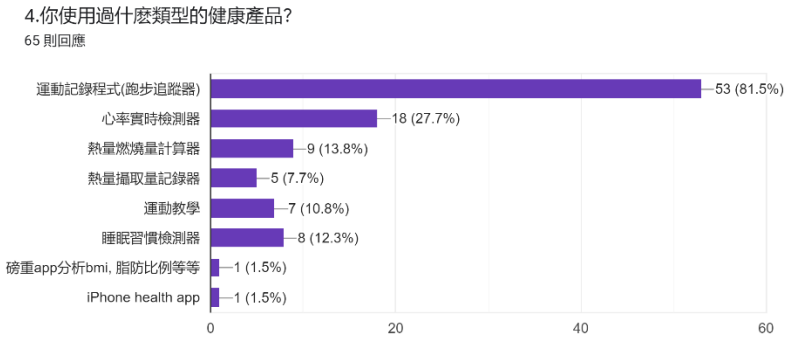


Figure 4 Purposes of wearables

It is comfirmed that people nowadays consider electronic wearables as a great tool to help them in sports. Perhaps improvinig their training quality. Meanwhile, rockclimbers and outdoor sports lovers are still struggling to find a wearable that is designed for them. Also, training and workout guiding app for rockclimbers on the market is very limited. The climbing community is craving for a wearable and app combo that could provide comprehensive support for them.

4.2 Main component

In order to build an electronic wearable, a board is needed.

I choosed the Arduino Nano RP2040 Connect with headers as it is one of the best board in this tiny size. It's micro controller is Raspberry Pi RP2040, which is a dual-core Arm Cortex M0+ in 133MHz. It's SRAM size is 264KB and it also have a 16MB flash memory.

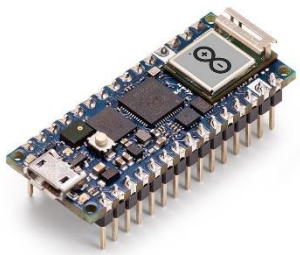


Figure 5 Arduino Nano RP2040

The another reason of choosing it is that it has a strong connectivity. It supports WiFi802.11b/g/n and mostly importantly, for this project, Bluetooth and BLE v4.2.

Also, it has a built-in micro phone, which is very useful for future development such as sound activation or even AI voice recognition.

The another main component is the app of the smartphone.

I choosed to use the MIT App Inventor to build the app in the android system. It's the leading app developing platform and I chose it because of its simplicity. MIT App Inventor has it own emulator so its easy for me to do testing and debugging.

Figure 6 MIT App inventor

5. Methodology and implementation

5.1 Plan

To start the project, I have to first find out the target audience in HK. My target is all sports climbers. Including indoor gym climbers who do speed climbing, or climbers who do bouldering and lead climbing both indoor and outdoor. Bouldering walls are usually under 5m in height and do not need rope for spot. Speed climbing is climbing a standardized route, just like sprinting. But vertical.

To sum up with, I would like to develope wearable for rock climbers which is able to keep track of their training records and warn them of bad weathers. It can also help climbers training in the app intergrated.

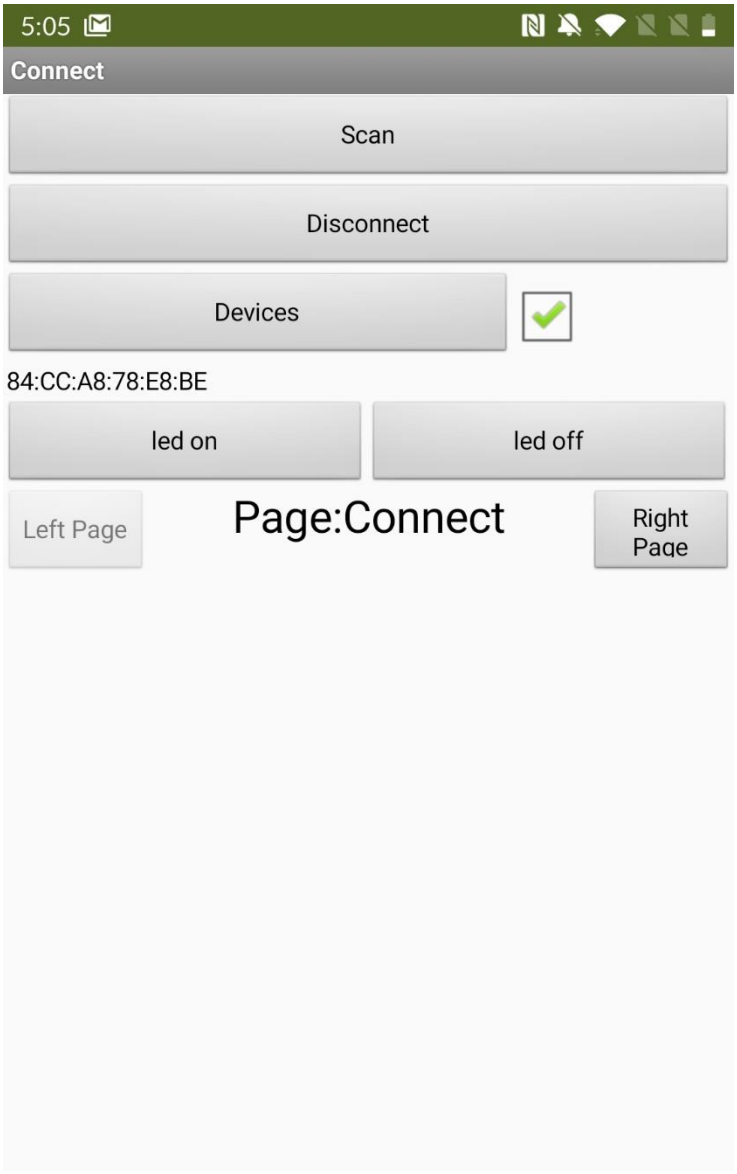
5.2. Preliminary concept

For the wearable itself, it is a arduino board connect to LED indicators. Which then can be connected to a smartphone with it's built BLE functions. It can receive signals from the smartphone and reacts upons the signal. Ideally, it should only has a negletable latency. For example, it's led light should blink when the smartphone received warning signal and transfer back to it. It should also install button modules for users to interact with it. For the app, it plays the role of the brain of the whole system. It should be programmed to collect data from the Arduino board and store them. It is also the UI that let the user give orders to the product.

5.3. Project designs

5.3.1. Alpha build

For the alpha stage of the app, I would like to first make a prototype that can connect the board via BLE and able to control its LED.



"Scan" button searches BLE devices nearby upon click.

"Devices" button shows a list of nearby devices upon click.

The checkbox indicates that the connection status.

Led on/off button send orders to the board upon click. Sending "1" and "0" upon clicking respectively.

Figure 7 Screen capture of my app

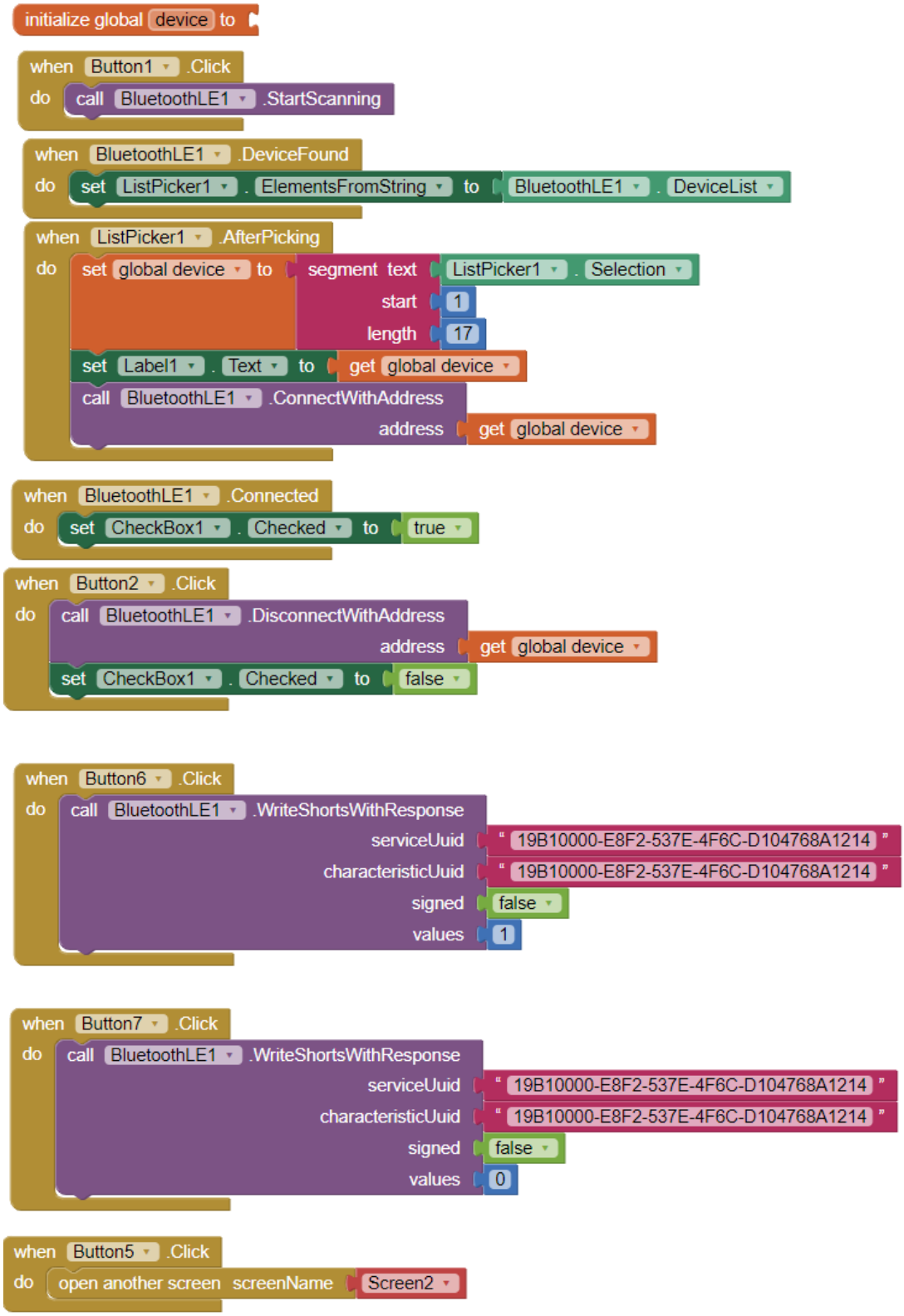


Figure 8 Program block view

For the Arduino code section, the code should make the Arduino board connectable to the smartphone. First, I must set up the BLE service with a local name, service UUID the characteristic to the service and the service itself. Next, I must set the built-in LED into output mode to allow upcoming controls.

```
#include <ArduinoBLE.h>

BLEService ledService("19B10000-E8F2-537E-4F6C-D104768A1214"); // BLE LED Service

// BLE LED Switch Characteristic - custom 128-bit UUID, read and writable by central
BLEByteCharacteristic switchCharacteristic("19B10000-E8F2-537E-4F6C-D104768A1214", BLERead | BLEWrite);

void setup() {
  Serial.begin(9600);

  // set LED's pin to output mode
  pinMode(LED_BUILTIN, OUTPUT);
  digitalWrite(LED_BUILTIN, LOW);         // turn off the LED

  // initialization
  if (!BLE.begin()) {
    Serial.println("starting BLE failed!");

    while (1);
  }

  // set advertised local name and service UUID:
  BLE.setLocalName("Nano RP2040");
  BLE.setAdvertisedService(ledService);

  // add the characteristic to the service and service itself
  ledService.addCharacteristic(switchCharacteristic);
  BLE.addService(ledService);

  // set the initial value for the characteristic:
  switchCharacteristic.writeValue(0);

  // start advertising
  BLE.advertise();

  Serial.println("BLE LED Peripheral");
}

```

After connected to the smartphone app with BLE, I use an if function to determine how the board will react to different command. In this case, when the board receives “1”, the LED with turn on. Vice versa, when “0” is received, the LED will be turned off. And finally, when the user disconnects the connection, the LED light will go off to save energy.

```
void loop() {
  // listen for BLE peripherals to connect:
  BLEDevice central = BLE.central();

  // if BLE connected:
  if (central) {
    Serial.print("Connected to central: ");
    // print the central's MAC address:
    Serial.println(central.address());

    // while connected:
    while (central.connected()) {
      // if received signal
      // react to the signal by the LED:
      if (switchCharacteristic.written()) {
        if (switchCharacteristic.value()) {   // any value other than 0
          Serial.println("LED on");
          digitalWrite(LED_BUILTIN, HIGH);          // will turn the LED on
        } else {                                // a 0 value
          Serial.println(F("LED off"));
          digitalWrite(LED_BUILTIN, LOW);           // will turn the LED off
        }
      }
    }

    // when the central disconnects, print it out:
    Serial.print(F("Disconnected from central: "));
    Serial.println(central.address());
    digitalWrite(LED_BUILTIN, LOW);         // when tdisconnects, turn off the LED
  }
}
```

Step 1: Use the “Scan” button.

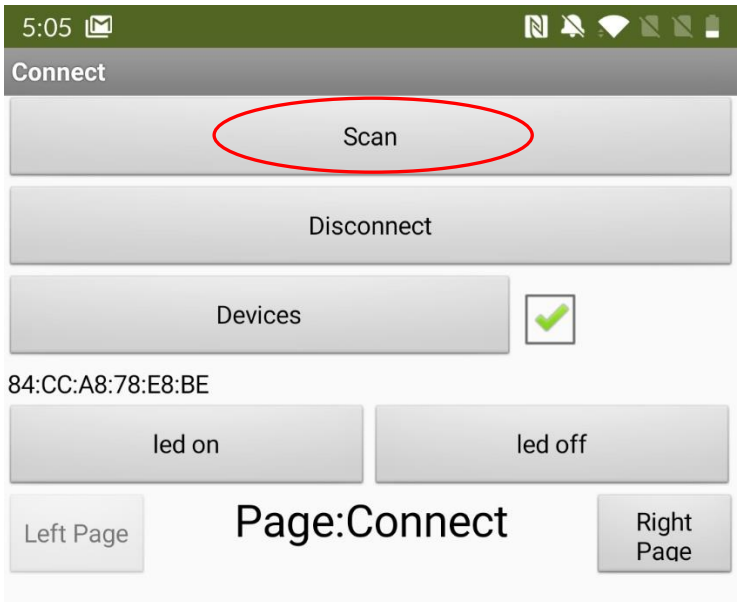


Figure 9 Connection Page: Scan

Step 2: Select this Arduino board from the list.

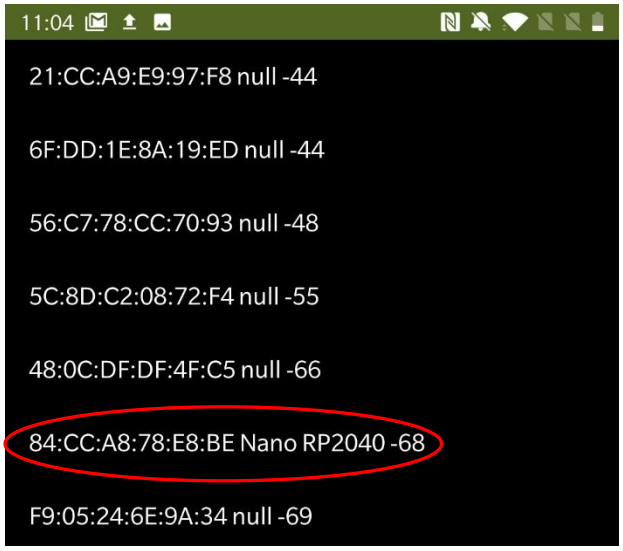


Figure 10 BluetoothBLE devices

Step 3: Check whether the connection is successful. If so, the checkbox would be checked.

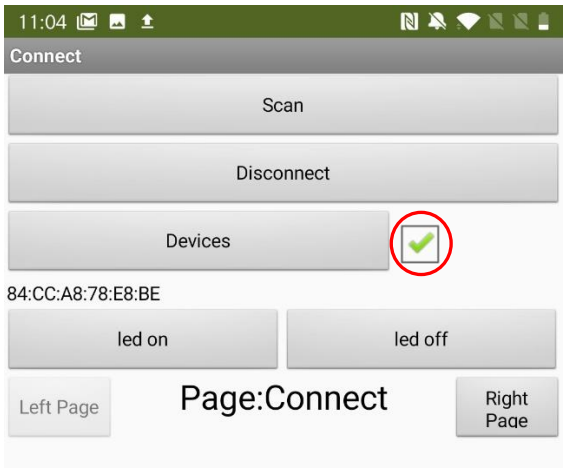


Figure 11 Connection Page: Checkbox

Step 4: Use the LED on and off button to control the built-in LED.

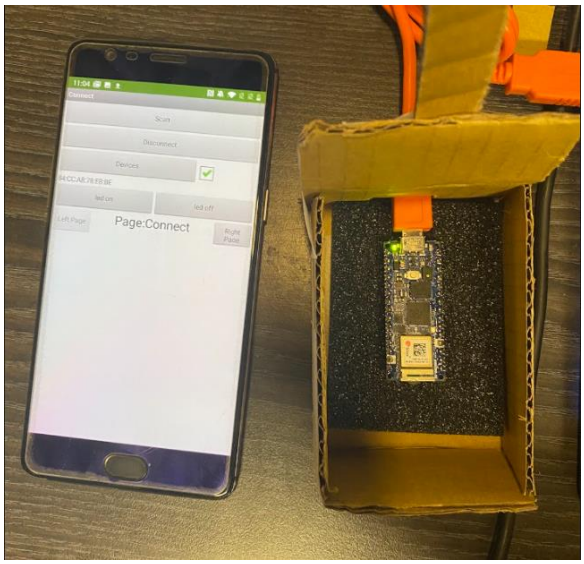


Figure 12 LED off

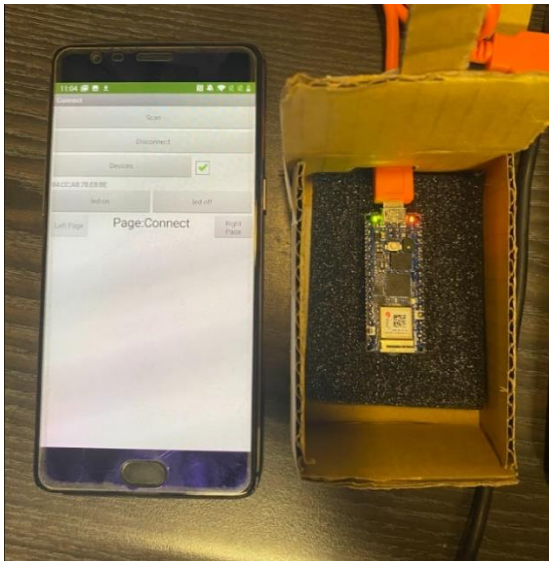


Figure 13 LED on

5.3.2. Beta build

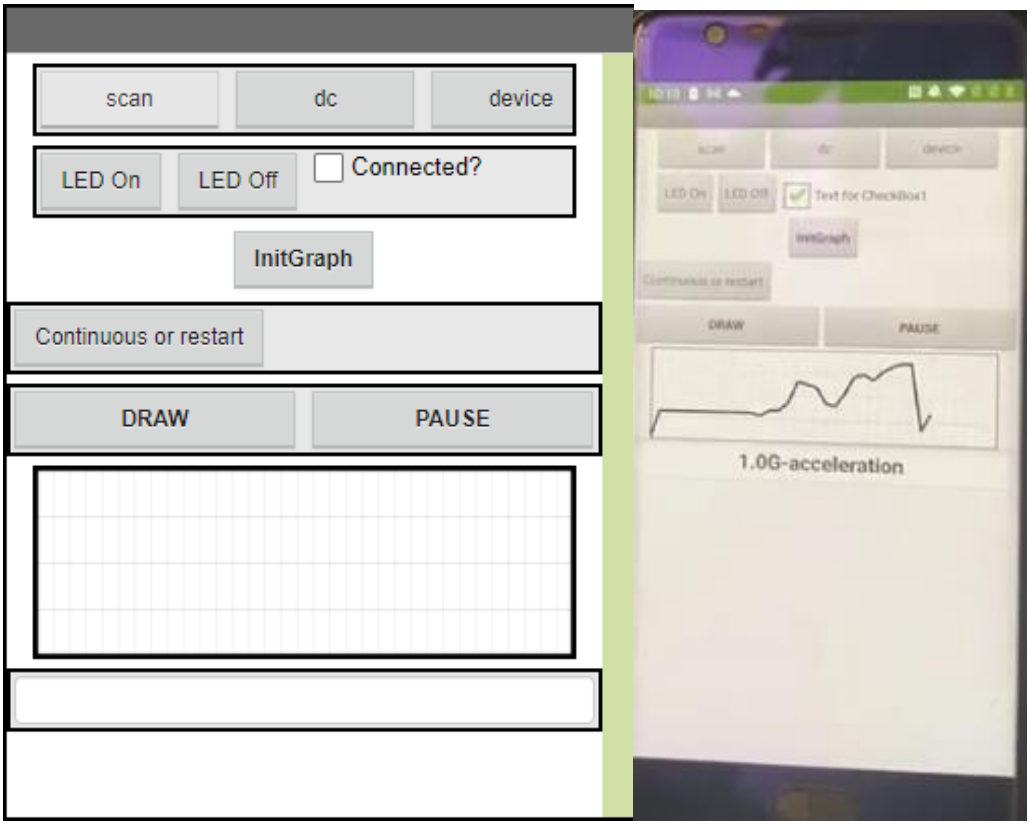


Figure 14 App user interface

In the beta build, the acceleration monitor function is added to the app. Data is collected be the inertial monitoring unit (accelerometer and gyroscope) built in the Arduino Nano. The app will then generate an acceleration to time graph for analysis purposes. In this build, LCD display and 3D model of the case is also implemented.

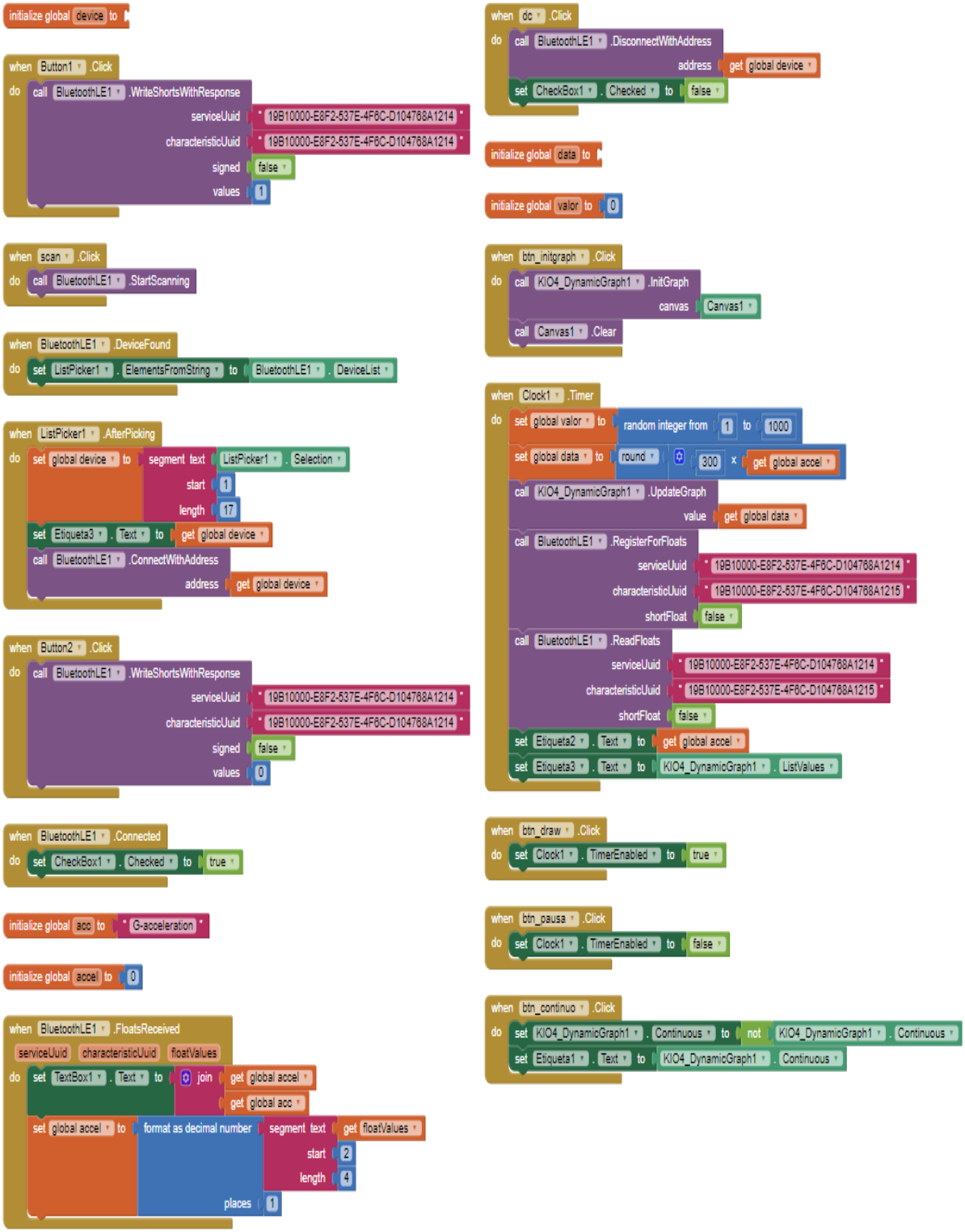


Figure 15 Block view

```
#include <ArduinoBLE.h>
#include <Arduino_LSM6DSOX.h>
#include <LiquidCrystal.h>

//BLE related

float data = 0;
BLEService customService("19B10000-E8F2-537E-4F6C-D104768A1214"); // BLE LED Service
// BLE LED Switch Characteristic - custom 128-bit UUID, read and writable by central
BLEByteCharacteristic switchCharacteristic("19B10000-E8F2-537E-4F6C-D104768A1214", BLERead | BLEWrite);
BLEFloatCharacteristic acc("19B10000-E8F2-537E-4F6C-D104768A1215", BLERead | BLENotify );


//LCD related
const int rs = 7, en = 6, d4 = 5, d5 = 4, d6 = 3, d7 = 2;
LiquidCrystal lcd(rs, en, d4, d5, d6, d7);
//End of starting


void setup() {
  Serial.begin(9600);

  // set LED's pin to output mode
  pinMode(LED_BUILTIN, OUTPUT);
  digitalWrite(LED_BUILTIN, LOW);         // turn off the LED

  // initialization of BLE
  if (!BLE.begin()) {
    Serial.println("starting BLE failed!");

    while (1);
  }

    // set advertised local name and service UUID:
  BLE.setLocalName("Nano RP2040");
  BLE.setAdvertisedService(customService);
```

```
    // add the characteristic to the service and service itself
  customService.addCharacteristic(switchCharacteristic);
  customService.addCharacteristic(acc);
  BLE.addService(customService);

    // set the initial value for the characteristic:
  switchCharacteristic.writeValue(0);

    // start advertising
  BLE.advertise();

  Serial.println("BLE LED Peripheral");
   digitalWrite(LED_BUILTIN, HIGH);

  //set up accelermeter
  if (!IMU.begin()) {
    Serial.println("Failed to initialize IMU!");

    while (1);
  }

   Serial.print("Accelerometer sample rate = ");
  Serial.print(IMU.accelerationSampleRate());
  Serial.println(" Hz");
  Serial.println();
  Serial.println("Acceleration in g's");
  Serial.println("X\tY\tZ");


  //set up LCD
  lcd.begin(16, 2);
  // Print a message to the LCD.
  lcd.print("Initialized");
}
```

```
void loop() {
  // listen for BLE peripherals to connect:
  BLEDevice central = BLE.central();

  // if BLE connected:
  if (central) {
    Serial.print("Connected to central: ");
    // print the central's MAC address:
    Serial.println(central.address());

    // while connected:
    while (central.connected()) {
      // if received signal
      // react to the signal by the LED:
      if (switchCharacteristic.written()) {
        if (switchCharacteristic.value()==1) {   // any value other than 0
          Serial.println("LED on");
          digitalWrite(LED_BUILTIN, HIGH);         // will turn the LED on
        } else {                                 // a 0 value
          Serial.println(F("LED off"));
          digitalWrite(LED_BUILTIN, LOW);          // will turn the LED off
        }
      }

      readAcc();

    acc.writeValue(data);
    }

    lcd.setCursor(0, 0);
    lcd.print("Current acc.");
    lcd.setCursor(0, 1);
    lcd.print(Acc);

    // when the central disconnects, print it out:
    Serial.print(F("Disconnected from central: "));
    Serial.println(central.address());
    digitalWrite(LED_BUILTIN, LOW);         // when tdisconnects, turn off the LED
  }
```

```
110
111   void readAcc(){
112     float x, y, z, acc;
113
114     if (IMU.accelerationAvailable()) {
115       IMU.readAcceleration(x, y, z);
116       acc=sqrt(x*x+y*y+z*z);
117       Serial.print(x);
118       Serial.print('\t');
119       Serial.print(y);
120       Serial.print('\t');
121       Serial.println(z);
122       Serial.print('\t');
123       Serial.print(acc);
124       Serial.print('\t');
125       data = acc;
126       Serial.print(data);
127
128     }
129   }
```

Figure 16 Arduino code

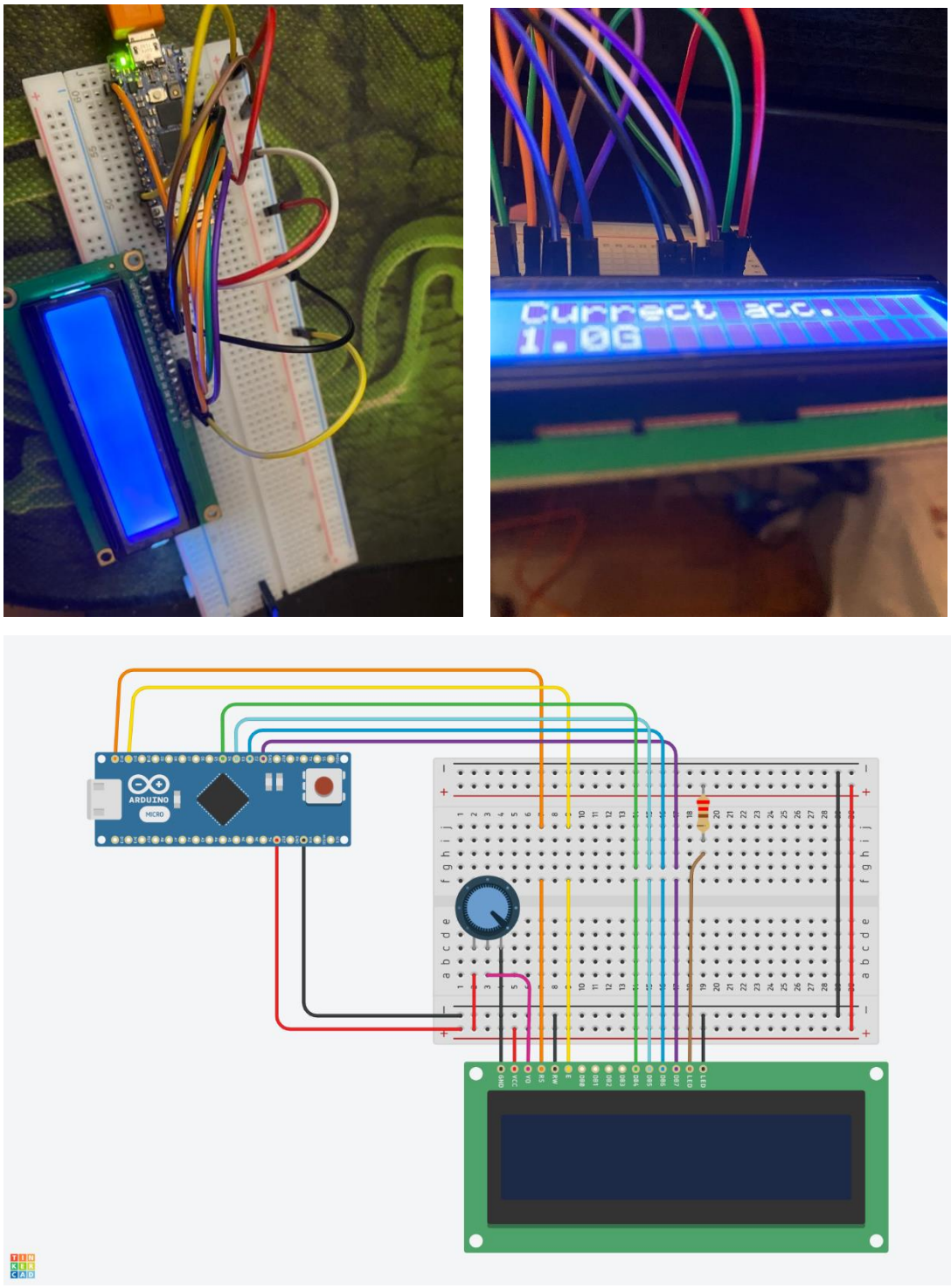
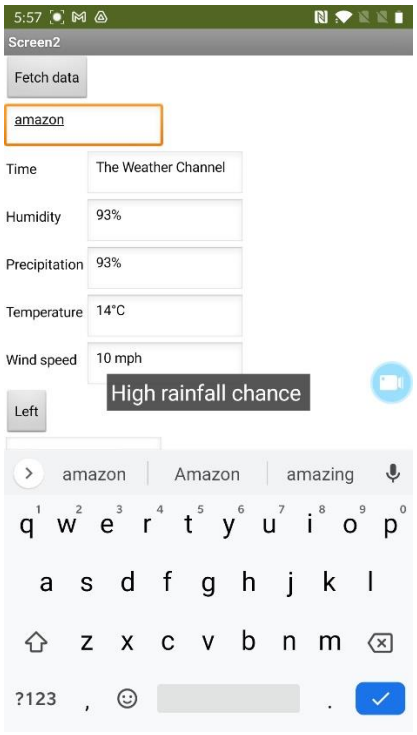
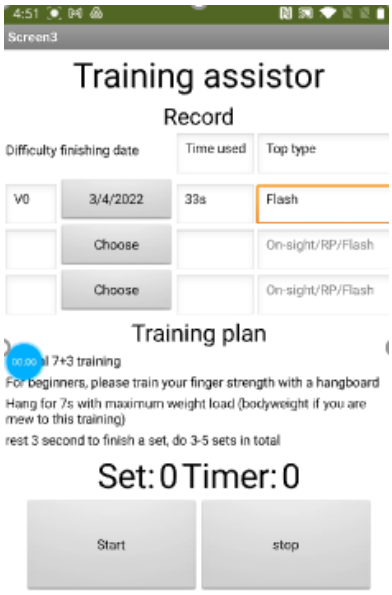


Figure 17 Breadboard wiring of LCD



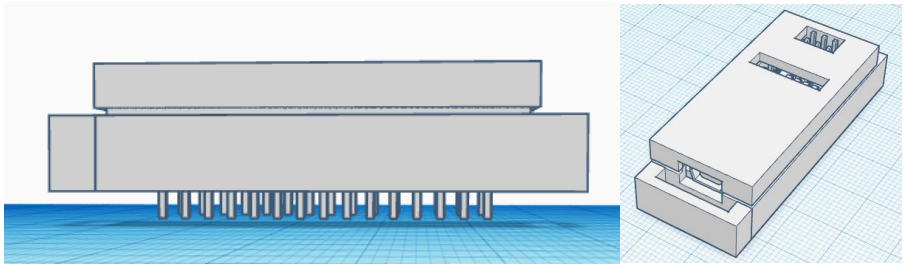
After the user input the location, the app will keep track of the weather info provided by the weather channel's API and refreshes every second. When there is some problem, the app will notify the users.

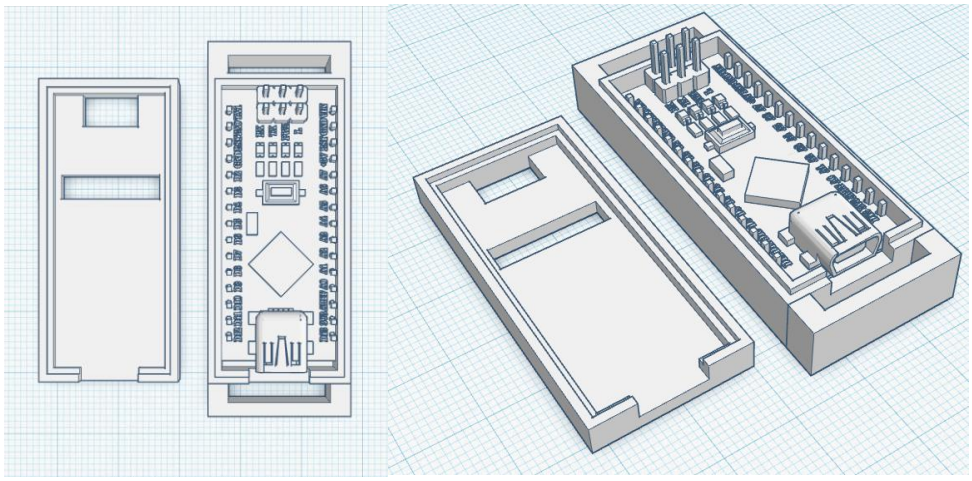
Figure 18 Weather service

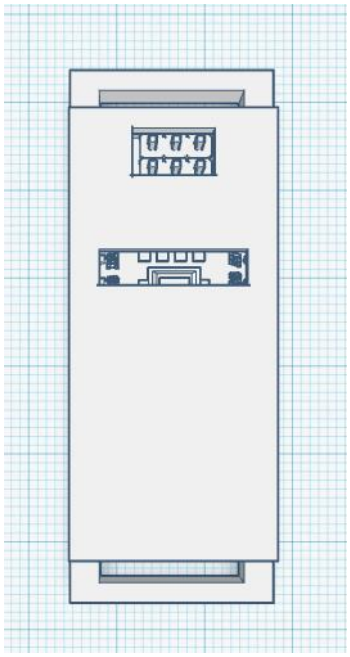


The training assistor provides two functions. One records the climbed routes. The second function is an interval training helper. It is a timer that automatically follows a 7+3 pattern training, specialized for finger strength.

Figure 19 Training assistor







There are slots in the front and the back of the case. So, it can easily put on straps in different size and lengths.

Figure 20 3D model of case

Symbol	Description	Min	Typ	Max	Unit
V_{IN}	Input voltage from VIN pad	4	5	20	V
V_{USB}	Input voltage from USB connector	4.75	5	5.25	V
V_{3V3}	3.3V output to user application	3.25	3.3	3.35	V
I_{3V3}	3.3V output current (including onboard IC)	-	-	800	mA
V_{IH}	Input high-level voltage	2.31	-	3.3	V
V_{IL}	Input low-level voltage	0	-	0.99	V
$I_{OH\ Max}$	Current at VDD-0.4 V, output set high			8	mA
$I_{OL\ Max}$	Current at VSS+0.4 V, output set low			8	mA
V_{OH}	Output high voltage, 8 mA	2.7	-	3.3	V
V_{OL}	Output low voltage, 8 mA	0	-	0.4	V
T_{OP}	Operating Temperature	-20	-	80	°C

Figure 21 Operating conditions[3]

Since the board works in 8mA, and the range of voltage is from 0 to 3.3V, the expected power consumption of the board will vary from 0 to 0.0264W depends on its mode. For example, when its connection with BLE, the power consumption will be slightly higher. 12V power supplier is recommended to provide enough voltage.

For the accuracy of the board, it is perfect. Out of 100 connections, 100 of them successfully interacted with the board's LED.

Then, for the temperature, the internal temperature increased from room temperature to 36° C after 20 minutes and maintain stable afterwards which is similar to normal human body temperature. Also, the working temperature of the board is from 0° C to 80° C so it will work fine.

6. Discussion

6.1.1 Product - Alpha

In this stage of the project, from the aspect of functionality, my app and Arduino board can successfully connect and interact with each other using BLE connection. The BLE connection works exceptionally together with the board's 133MHz core. It has an incredible data transfer speed. Further implementation such as weather warning is easy when there's already a working data I/O system.

Although the app is plain-looking, it works totally fine. There is almost no time delay in the BLE connection. The user interface is clear and straight forward.

Overall, the product is satisfying as it works quickly and efficiently, not only functional.

6.1.2 Problems and solutions - Alpha

During the development stage of the app, I found that not all smartphone supports BLE connection. Although the majority of smartphone nowadays supports BLE connection. But old smartphones do not support it. Also, I found that old android phone that doesn't have an android 5 or above update can't use the BLE connection either due to the lack of support of the BLE API. A USB connection could be added in the future to compensate these users.

6.2.1 Product - Beta

In this stage of development, practical functions have been implemented. The accelerometer, weather warning system and training assistor is working fine with a high competition rate. This prototype is successful to me as it is already very close to be a working product that can be used by athletes.

6.2.2 Problems and solutions – Beta

The LCD display is a bit too bulky for a wearable. Ideally, an OLED display can replace it in the future as is has a lower dimension and power consumption. Also, the app designed need improvement aesthetically to be more attractive. This is very important for a product.

6.3. Future development

Due to the limitation of time and technical knowledge. These features are not feasible to be developed in this stage. However, these functions could provide huge improvement in user experience. These functionalities may be developed when it’s doable.

A great idea is to collaborate with climbing gym in Hong Kong. Together with RFID function, the app can get the route data in the gym.

After that, as there is a build-in microphone in the chosen Arduino board, I can make use of it to build voice recognition functions to let user to control the system and give orders with their voice.

Besides, a better case would be developed shortly. The new case will be 3D printed with a small dimension, stronger structure and yet thinner. It will also be paint as I mentioned in Figure 1 to improve the heat dissipation by simple physics phenomenon.

Finally, a Traditional Chinese UI could be developed to widen the user base.

7. Conclusion

This project is a wearable that aim to satisfy rock climber's complicated need while also covering the demand of outdoor athletes.

The product can be controlled by BLE connections. The project has two parts. The app part and the Arduino board part. The user will download the app and connect it with the Arduino board. The app can send and receive signal, interacting with the board to do several functions. These are the main concept for the project.

In the beta build, the key functions and LCD display is developed. I believed that it is about 80% complete to be count as a mature product. After some adjustment and improvements, I think it will become the thing that I wanted it to be. A electronic gadget that can help people in climbing and make climbers' life easier.

I consider this project quite successful up to now. It fulfilled its job as a prototype. I can see the potential in this product. Although the function of my product is not something that is extraordinarily innovative to the world, it still accomplishing my goal that is to make people's life easier by integrating functions that are handy to climbers, contributing to people by practically making their life easily. Hopefully, rock climbing would be easier than ever with the aid of my wearable that design specially for climbers.

8. References

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9. List of figures