SMART INSOLE

Embedded Systems - Group Project

University of Kelaniya

By

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Abstract

Normally most of the people wearing their shoes. So we can introduce a smart insole that can be inserted into their shoe to identify some medical issues.

We are introducing an insole that can measure pressure distribution on foot and temperature inside the shoes. We can analyze those measured values and identify whether user's foot is healthy or not.

This insole can identify diseases like the diabetic neuropathy and chronic foot diseases (growth of microorganisms). Mainly we are targeting the audience of diabetic patients.

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Introduction

Diabetes is one of the major causes of illness and premature death worldwide. Diabetes causes neurovascular complications, which result in the development of high pressure areas in feet and hands.

Diabetic neuropathy causes nerve damage which can lead to amputation or ulceration. Locating abnormal pressure patterns under the foot enables early detection of neuropathy, preventing its serious consequences. [reference 1]

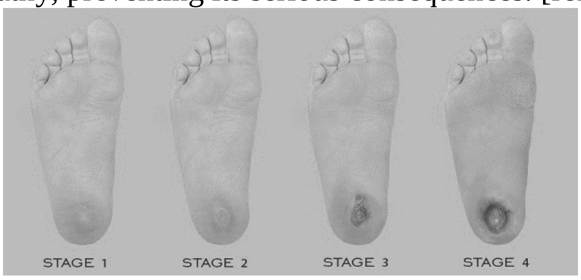


Fig1: Formation of ulcers from peripheral diabetic neuropathy

Another problem is, **High temperature and humidity** inside footwear. It has found that there is a correlation between planter foot temperature and diabetic neuropathy.

In addition, excessive humidity may promote the growth of microorganisms (fungi and bacteria) and cause chronic foot diseases. High temperature and humidity inside footwear also affect blood flow, putting a strain on the vascular system in the lower extremities.

Our objective in this project is to design and build a low-cost pressure & temperature measurement and analysis system based on an Arduino microcontroller, which a patient can use at home to measure his or her foot pressure distribution.

We have successfully designed and built a prototype system using a set of five Film Pressure sensors distributed on an insole. An Arduino microcontroller is used to measure the pressure sensor outputs and transmit the information through Bluetooth to a mobile application. The app can compare the pressure distribution against a reference distribution and show any anomalies.

Users can insert this insole to their shoes if they need to check anomalies and easily they can remove it when it is not using. The results show that such a device can be built at a low cost and can accurately measure the foot pressure distribution to detect anomalies.

Method

Materials Used

- Film Pressure Sensors[DF9-40]
- Dht11 temperature sensor
- Arduino Uno Microcontroller
- Hc5 Bluetooth Module
- Jumper wires

Methods Workflow:

1. **Analyzed the researched data about pressure distribution, temperature changes on human foot and identified the specific sensor placement points**

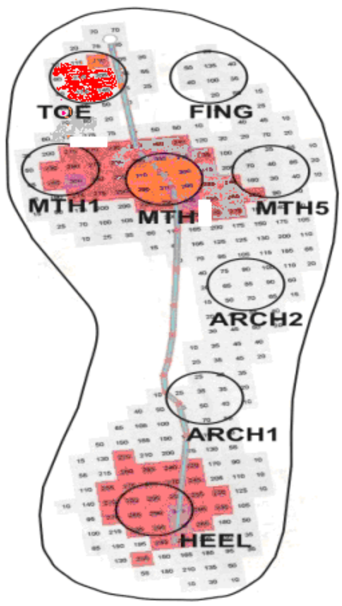
For Diabetic Neuropathy:

Abu-Faraj [reference 2] determined that sensors must be placed on eight areas of the foot to measure the pressure distribution accurately. These areas are categorized into high, medium and low-pressure areas.

- High-pressure areas: Heel, Metatarsal Head and Metatarsal Head 1
- Medium-pressure areas: Metatarsal Head 5, Toe and Arch 1
- Low-pressure areas: Fing and Arch 2

These areas are marked in the figure.

We placed the pressure sensors on a sole according to this layout.For the prototype selected 5 higher pressure points.[Heel, Metatarsal Head, Metatarsal Head 1, Metatarsal Head 5 and Toe]



8 standard pressure points

We have selected 5 pressure point for our prototype

For high temperature detection:

According to [reference 6], **Patients with diabetic neuropathy** (defined as vibration perception threshold (VPT) values on biothesiometry greater than 20 V) had a higher foot temperature (**32-35 °C**) compared to **patients without neuropathy** (**27-30 °C**).

According to referred research paper [reference 3], Under normal conditions of use, relative ***humidity*** inside footwear amounts to ***60–65 %.*** According to some research, humans experience a sensation of ***comfort at foot temperatures*** in the range of ***20 °C–33 °C*** and a sensation of discomfort at temperatures in the range 35 °C–38 °C.

According to above references we send warning to user when the temperature is more than 33°C.

2. Understanding the working of the force sensors

Selecting the force sensors:

We had many options for force measuring sensors. Film Pressure sensors, load cells, etc. We have selected the Film Pressure sensors because those sensors are low cost, small in size and high sensitivity.

Understanding the working principles of Film Pressure sensor:

According to data Sheet [reference: 4]. The Film Pressure sensor is based on a force-sensing resistor; whose resistance varies inversely with the applied force. With no load, the resistance is very high (more than 1 Mega Ohm). As load is applied, the resistance decreases as shown below.

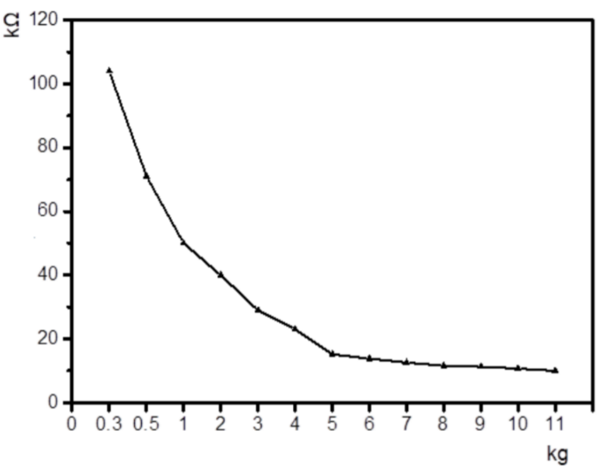
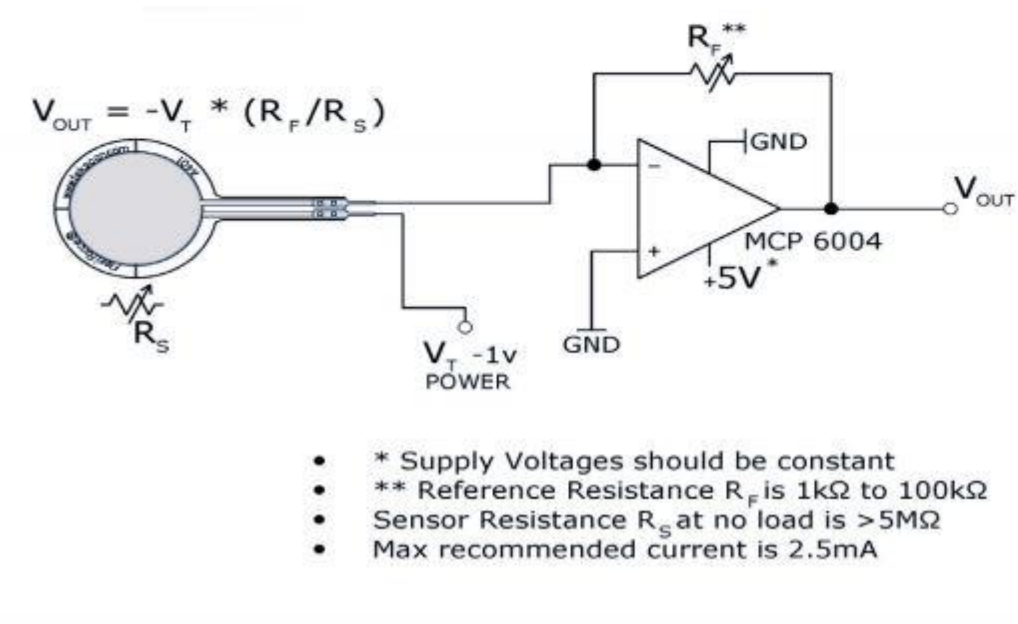


fig.3

By connecting it in an electrical circuit, the change in resistance can be converted to a change in voltage, which can then be sensed by the Arduino microcontroller. The following circuit can be used to convert the change in the resistance of the sensor to a change in voltage.



3. Connect sensors with Arduino Uno microcontroller

We have used 5 analog pins to read analog data values from pressure sensors and a single digital pin to read temperature data values. For the circuit diagram refer diagram [circuit diagram at page 9]

Through analog data pins microcontroller reads the voltage values through each sensor and convert it to a resistance presented in kilo ohms. According to the resistance force diagram[fig.3] we can calculate the force in newton. The resistance is infinite when there is no pressure. So we assign 999 default value when there is no pressure exerting on sensors. [999 means no pressure exerting]. When we exert pressure on sensors the resistance decreased.

Temperature value is read from a digital pin. We used the dht sensor library for that.

Then we send the 6 data values [5 pressure sensor values+ temperature] as a formatted string through the Bluetooth module.

Format: ***_FSensor1_Fsensor2_Fsensor3_Fsensor4_Fsensor5_tempertaureSensor***

For the full source code refer the code [in page 10 & 11], For the algorithm refer the flowchart [in page 13]

4. Selecting a communication media[Bluetooth]

We have selected the Bluetooth rather than Wi-Fi or any other medium because Bluetooth is,

Used for short range data transmission
Low power consumption

5. Designed the mobile application

We build the mobile app in android studio with java language. The application is able to display the healthy level of the users after connecting the insole system to it.

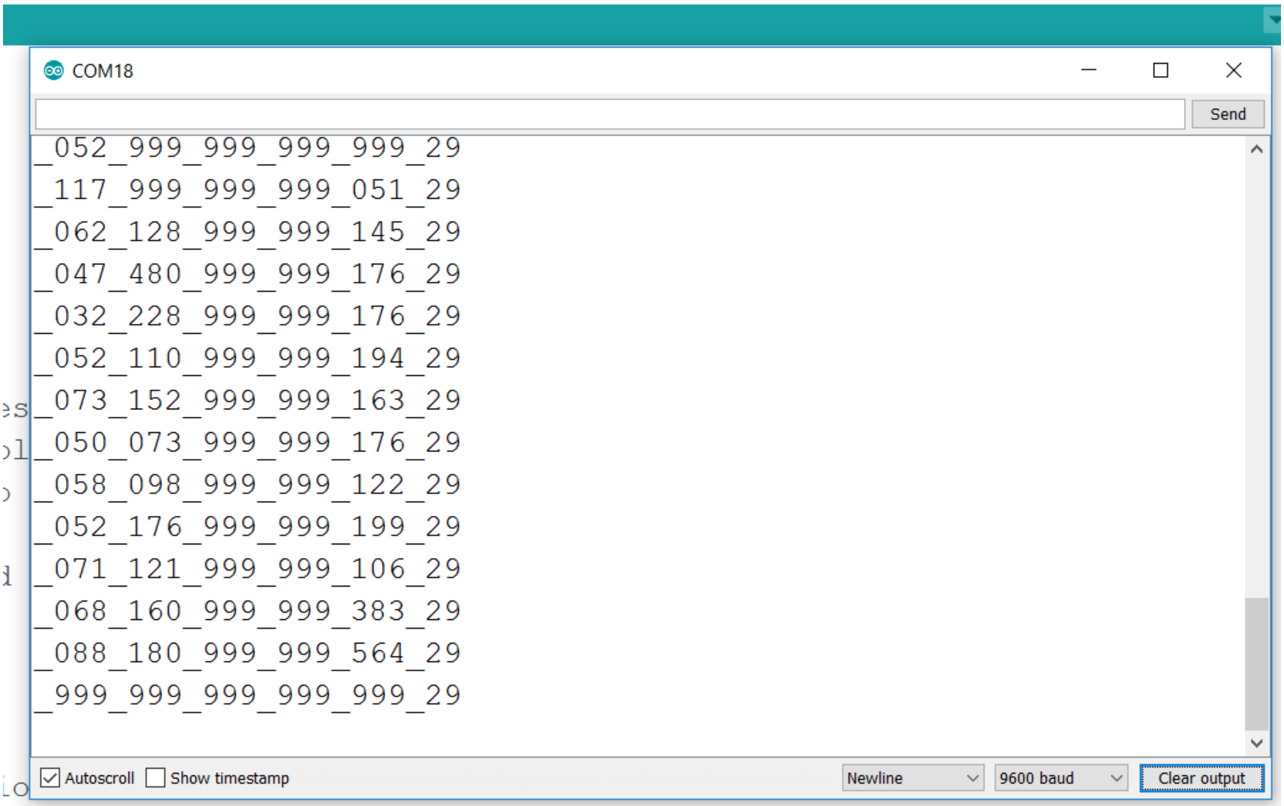
This application receives data string from Bluetooth and decompose the string to identify different sensor values. It gathers 5 data strings and get the average value. The average value is compared with the normal pressure and temperature values to predict the healthy status of user.

The flowchart diagram at [Flowchart at page 12] represents the algorithm that we used to build our mobile app.

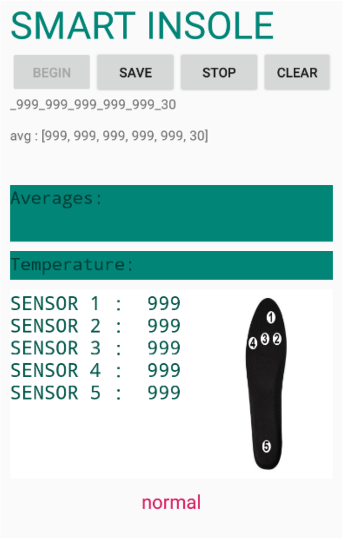
Results

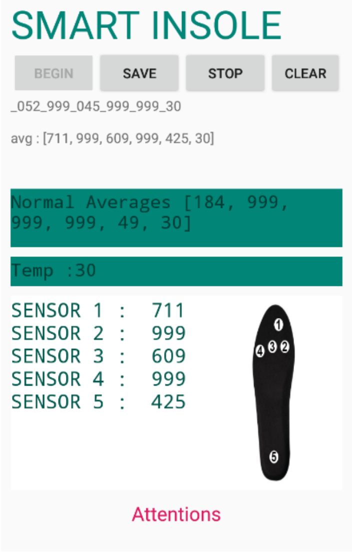
Serial print output from Arduino ide

Serial print results:



Results from the mobile application





Initial stage

Checking the current state by comparing with normal averages

budget

- Film Pressure Sensors[DF9-40] - Rs.1800($10.49)
- Dht11 temperature sensor - Rs.260
- Arduino Uno Microcontroller - Rs.1000
- Hc5 Bluetooth Module - Rs.650
- Jumper wires - Rs.80
- Rubber Insole - Rs.100

Total - Rs.3890

The price of a Diabetic Foot Ulcers Test Machine Bio Thesiometer VPT for Neuropathy Diagnosis from an online shop. The machine price is about $1350. So we can market out product with low price by further developing it. We can market our product to Rs.5000 with all production costs.

Conclusion & Discussions

We have successfully designed the smart insole porotype. It can identify the abnormal change of pressure and temperature. For further developments we need to do some practical trainings of the device with diabetic patients. After further analyzing of data with a machine learning models we can develop the product to identify users walking patterns, wrong postures of walking and to predict human body weight with pressure values.

Resources

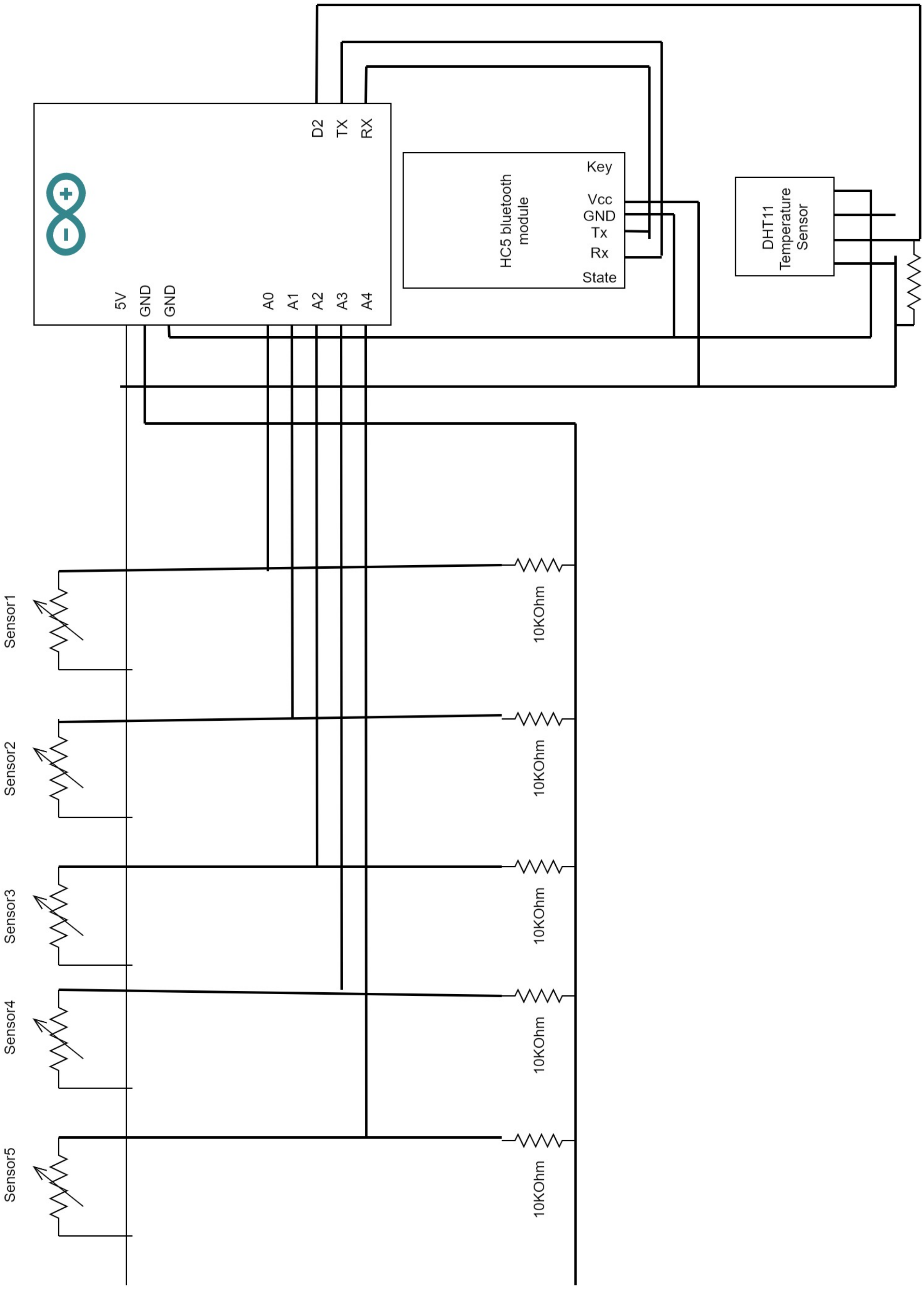
All the resources of project can be found at:
https://github.com/EANimesha/Healthy_Insole_Project

References

1. A Real Time Foot Pressure Measurement for Early Detection of Ulcer Formation in Diabetics Patients Using Labview. A.N.Nithyaa, R.Premkumar ,S.Dhivya ,M.Vennila[url: https://www.sciencedirect.com/science/article/pii/S1877705813017256]
2. Z. O. Abu-Faraj, G. F. Harris, A-H. Chang, M. J. Shereff, "Planter Pressure Alterations with Scphoid Pad," *IEEE Transactions on Rehabilitation Engineering*, Vol. 4, Dec. 1996,pp. 328–336.
3. AUTEX Research Journal, Vol. 16, No 2, June 2016, DOI: 10.1515/aut-2015-0030 © AUTEX," *THE MICROCLIMATE IN PROTECTIVE FIRE FIGHTER FOOTWEAR: FOOT TEMPERATURE AND AIR TEMPERATURE AND RELATIVE HUMIDITY*", Emilia Irzmańska[url: https://www.degruyter.com/downloadpdf/j/aut.2015.16.issue-2/aut-2015-0030/aut-2015-0030.pdf]
4. Film Pressure Sensor DF9-40@10kg V2.0 datasheet [url: https://www.winsen-sensor.com/d/files/df9-40%4010kg.pdf]
5. HC-05 -Bluetooth to Serial Port Module. Datasheet [url: http://www.electronicaestudio.com/docs/istd016A.pdf]
6. Correlation between plantar foot temperature and diabetic neuropathy: a case study by using an infrared thermal imaging technique. J Diabetes Sci Technol. [url: https://www.ncbi.nlm.nih.gov/pubmed/21129334]
7. Arduino-Based Foot Neuropathy Analyzer[url: https://learn.parallax.com/sites/default/files/inspiration/818/dl/Foot-Neuropathy-Analyzer-Report.pdf]

Schematics

Circuit diagrams

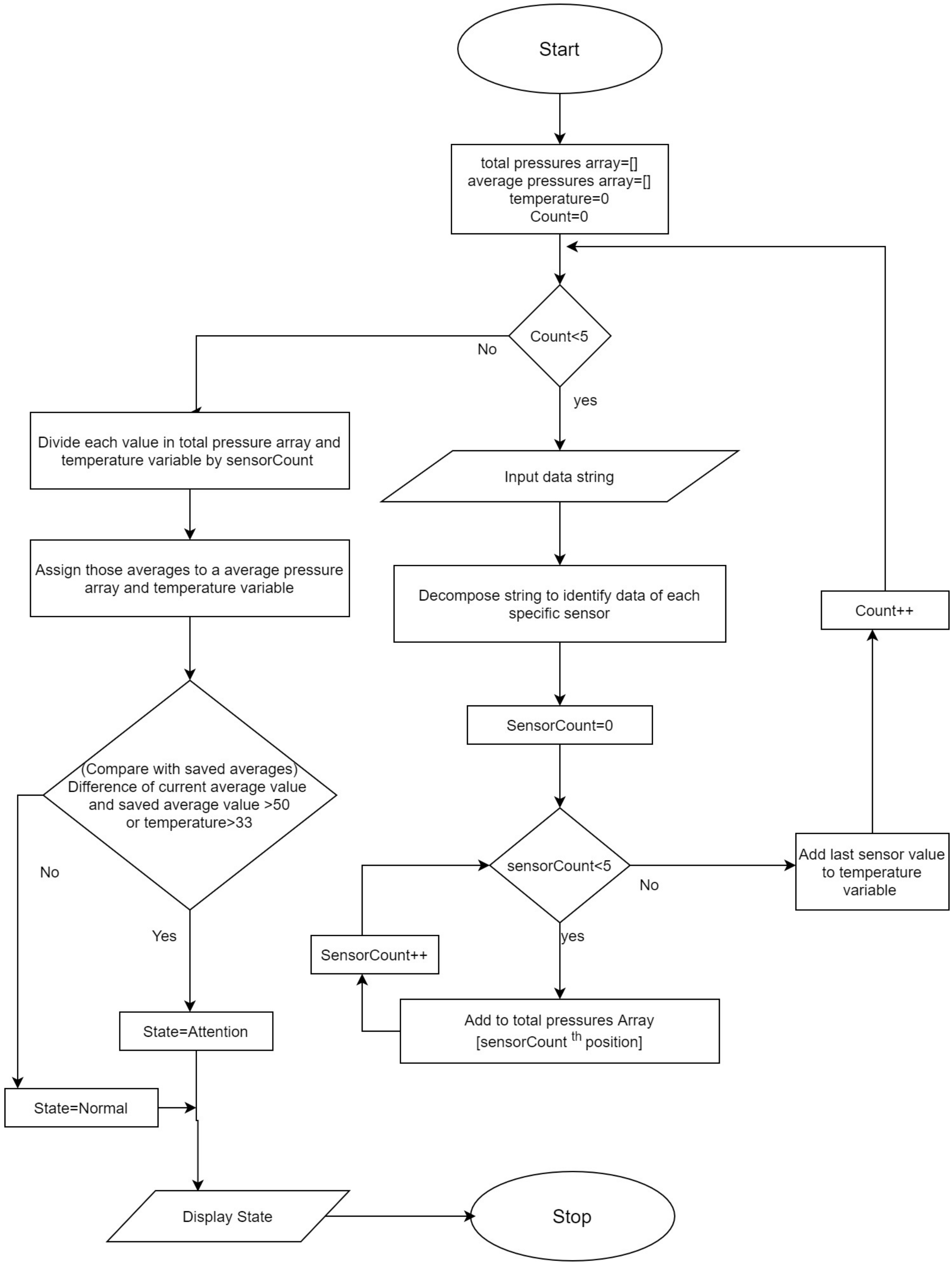


Source Code: Arduino Microcontroller

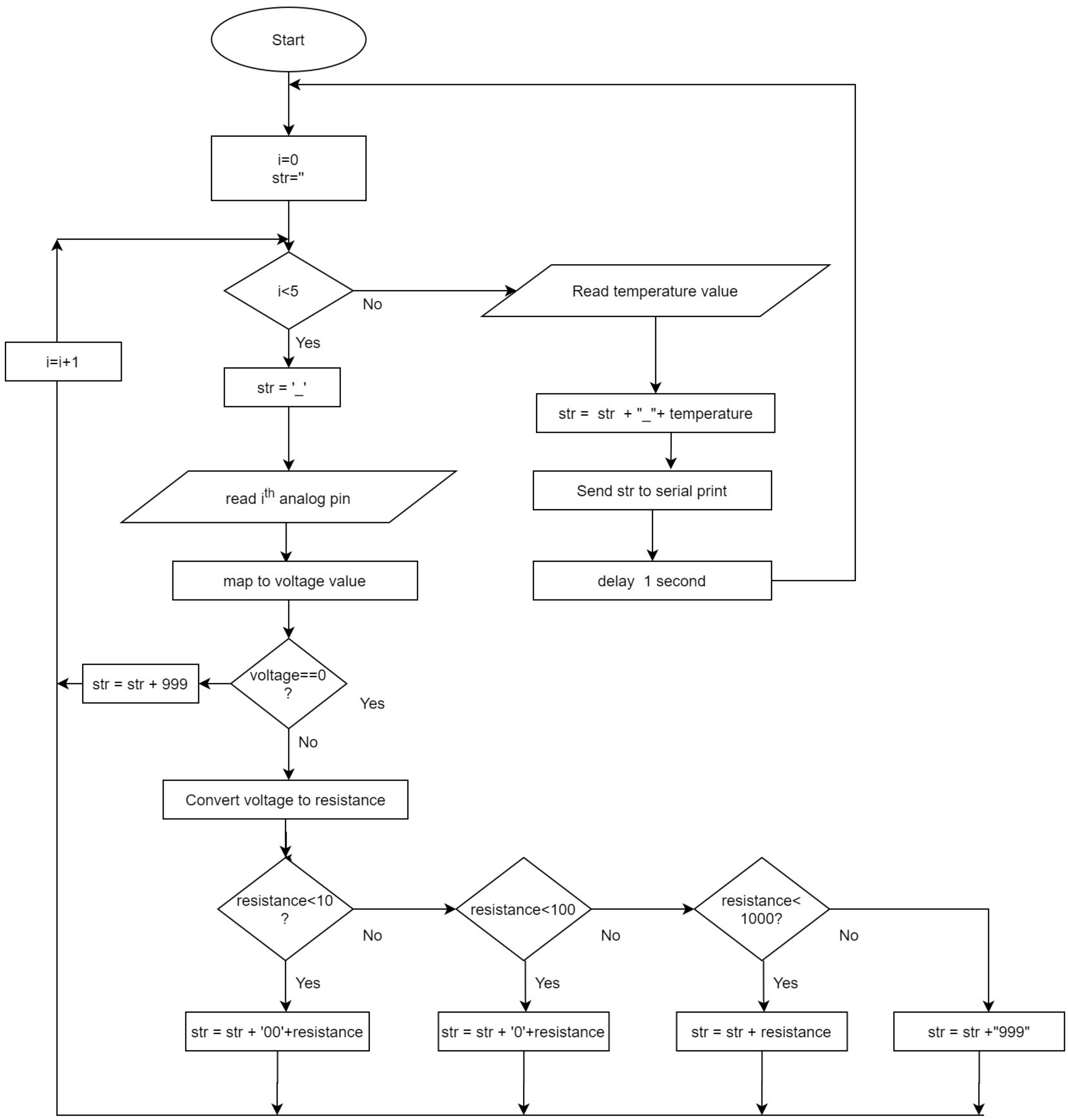
```
#include "DHT.h"
#define DHTPIN 2
#define DHTTYPE DHT11

DHT dht(DHTPIN, DHTTYPE);

int fsrPin[]={0,1,2,3,4};

int fsrReading;     // the analog reading from the FSR resistor divider
int fsrVoltage;     // the analog reading converted to voltage
unsigned long fsrResistance;  // The voltage converted to resistance, can be very big so
make "long"
unsigned long fsrConductance;
long fsrForce;       // Finally, the resistance converted to force
String str="";


void setup(void) {
  Serial.begin(9600);   // We'll send debugging information via the Serial monitor
  dht.begin();
}

void loop(void) {
    str="";
  for(byte i=0;i<5;i=i+1){
    str+="_";
    fsrReading = analogRead(fsrPin[i]);
    fsrVoltage = map(fsrReading, 0, 1023, 0, 5000);
    if (fsrVoltage == 0) {
//      Serial.println("No pressure");
        str+="999";
```

```
    } else {
      fsrResistance = 5000 - fsrVoltage;     // fsrVoltage is in millivolts so 5V = 5000mV
      fsrResistance *= 10000;                // 10K resistor
      fsrResistance /= fsrVoltage;
      fsrResistance /=1000;                  //to make it kiloohms
      if(fsrResistance<10){
        str+="00";
        str+=fsrResistance;
      }else if(fsrResistance<100){
        str+="0";
        str+=fsrResistance;
      }else if(fsrResistance<1000){
        str+=fsrResistance;
      }else{
        str+="999";
      }
    }
  }
//  float h = dht.readHumidity();
  int t = dht.readTemperature();
  int f = dht.readTemperature(true);

    str+="_";
    str+=t;
    Serial.println(str);
    delay(1000);
}
```

Flow charts for mobile app



Flow charts for Arduino Source Code



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