YEAR 2 PROJECT

Lie Detector

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Group 2P05

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Abstract

The aim of this project is to develop a low-cost and effective lie detector system for people to use. It monitors tester's temperature, sweating, heart rate, behavior (muscle state) and voice. Then, the system can print out all the results on the screen to help examiner judge the truth of tester's words.

Declaration

I confirm that I have read and understood the University's definitions of plagiarism and collusion from the Code of Practice on Assessment. I confirm that I have neither committed plagiarism in the completion of this work nor have I colluded with any other party in the preparation and production of this work. The work presented here is my own and in my own words except where I have clearly indicated and acknowledged that I have quoted or used figures from published or unpublished sources (including the web). I understand the consequences of engaging in plagiarism and collusion as described in the Code of Practice on Assessment (Appendix L).

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Chapter 1

Introduction

1.1 Background

Ever since humans deceived each other, people have been trying to develop techniques to detect deception and find the truth. With the development of technology for psychophysiological detection of deception in the 20th century, lie detection presents various aspects of modern science, most notably the lie detector test. Lie detector measures several physiological processes, such as temperature and heart rate, and changes in those measurement processes. Based on these measurement results of the lie test questions and observations provided by the lie detector, the examiner can infer the condition of mind as to whether a person is telling the truth or lying.

1.2 Introduction and Motivation

In recent years, a wide variety of types of lie detectors have been invented. However, many of them are very expensive. Thus, our group wants to develop a low-cost and effective lie detector system. Our group search several low-cost lie detector systems on the website. Although the cost is not high, the test result is not accurate. For instance, one of the lie detector systems found on the website is shown in Figure 1.1. It is based on the measurements heart rate sensor, which is not accurate. Therefore, our group wants to develop a more complex system. Due to this system using a heart rate sensor to detect, it is an idea to utilize more sensors to measure more physiological data. Thus, the result can be more accurate. According to this idea, our group carried out lots of research to find what kinds of information can be used to detect lies. Finally, five aspects are selected and corresponding methods to measure whether people tell lies. They are temperature, sweating, heart rate, behaviour and voice.

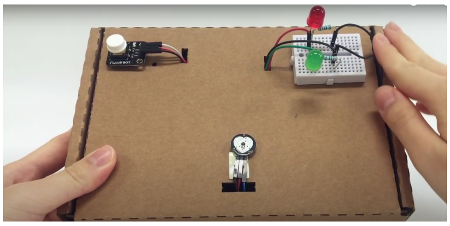

Figure 1.1: One kind of lie detector [1]

1.3 Objectives

Main objective: Build a Lie Detector which is powered by Arduino and MATLAB. This main objective can be separated into five different small objectives:

- Use the temperature sensor to measure the body temperature.
- Use the humidity sensor to monitor whether tester sweats.
- Use a behavior monitor sensor to observe the action of tester.
- Use a heart rate sensor to detect the heart rate of the tester.
- Utilize MATLAB to analyze the voice of the tester.

Combine all these measurement results together on one screen monitor to help examiner judge whether tester tells lies.

Chapter 2

Materials and Methods

2.1 Material list

1. Arduino Uno R3 board
2. SEN0240 analog EMG sensor
3. SEN0203 heart rate sensor
4. SHT1x Temperature and humidity sensor
5. LEDs
6. Bread board
7. 330Ω resistor
8. MATLAB
9. Arduino IDE

2.2 Details of materials

2.2.1 SEN0240 EMG Sensor

This sensor integrates amplifiers and filters, which can amplify small Surface electromyography (sEMG) within ±1.5 mV 1000 times. It also depresses noises (especially for power frequency interference) by analogue filter circuit and differential input. The strength of the signal depends on people's muscles activities. The output signal indicates the activities of the muscles, which assists us to analyse sEMG.

Figure 2.1: The diagram of EMG sensor [2]

2.2.2 SEN0203 heart rate sensor

This sensor uses photoplethysmography (PhotoPlethysmoGraphy, PPG) to measure the human heart rate parameter by measuring the change in blood haemoglobin absorbs oxygen with the beating of the heart. The module has two signal output modes: Analogue mode and Digital mode, and the output can be easily switched through the onboard switch.

Figure 2.2: The diagram of heart rate sensor [3]

2.2.3 STH1x Temperature and Humidity Sensor

The sensor consists of a capacitive polymer moisture measuring element and an energy gap temperature measuring element, and is seamlessly combined with a 14-bit A/D converter and a 2-wire digital interface in a single chip. Combined with Arduino, it is very easy to achieve interactive effects related to temperature and humidity sensing.

Figure 2.3: Temperature and Humidity sensor [4]

2.2.4 Arduino Board

Arduino board is the drive of the hardware. It provides 5V voltage to sensors so that they can operate normally. In this project, the Arduino boards are programmed according to the different functions of the sensors. The details can be seen in the Materials and Methods section.

Figure 2.4: Arduino Board [5]

2.2.5 Software

In this prject, Arduino IDE and MATLAB will be used for programming. Arduino IDE is used for driving the hardware sensors, while MATLAB is used for voice evaluation. The code can be seen in the Appedix section.

2.3 Theorey and Precdure

2.3.1 Hardware

1. **EMG sensor**

   According to the research carried out by M. Iwamoto [6], when people tells lies, they may have some subconscious actions like making a fist, rubbing fingers or other behaviours. These small behaviours can be captured by the EMG sensor. Therefore, we can know whether the tester tells lies.

Based on this theory, our group constructed the EMG sensor circuit in week 1. We connected the sensor to the Arduino and set the probe on the skin. The circuit is shown in Figure 2.5.

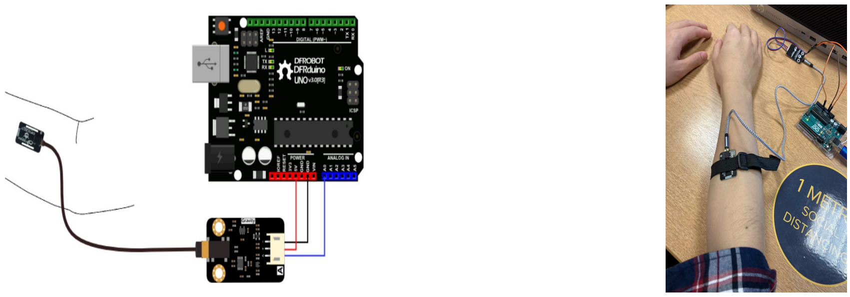

Figure 2.5: Circuit for EMG sensor

The working principle can be seen from Figure 2.6.

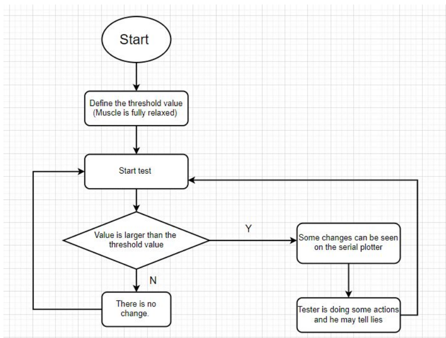

Figure 2.6: The flow chart of EMG sensor

2. **Heart Rate sensor**

   P. Vos [7] indicates that the heart rate rise repaidly when many people tell lies. That is because their brains are under high pressure and excite the sympothetic nervous system. The excitation of the sympothetic nervous system can increase the heart rate of the people. What is more, P. Vos [7] also point out that the more lies are inconsistent with the truth, the faster the heart rate increases.

   According to these research, we constructed the heart rate sensor circuit in week 2, which is shown in Figure 2.7. What is more, a LED was also added to help examiners determine whether the tester told lies. In order to take advantage of the two different working modes built in sensor, a switching circuit was designed. The working principle can be seen from Figure 2.8.

3. **Temperature and Humidity sensor**

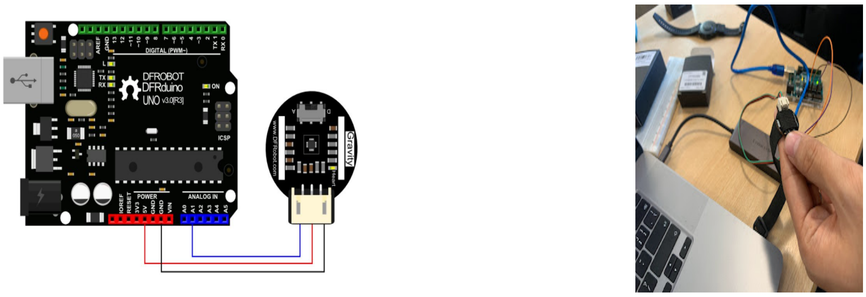

Figure 2.7: Circuit for heart rate sensor

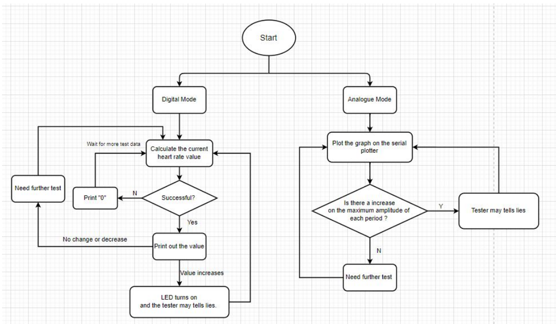

Figure 2.8: The flow chart of heart rate sensor

When people tell lies, the insular cortex (a brain hormone) in the brain is activated. The body temperature value will increase due to the increasing activity of the insular cortex, especially for the nose [8]. Increased body temperature may also lead to increased sweating.

Thus, we constructed the temperature and humidity sensor circuit in week 2 to measure the temperature and amount of sweat to test whether people tell lies. A LED was also added to help examiners judge the tester's words.

The circuit is shown in Figure 2.9.

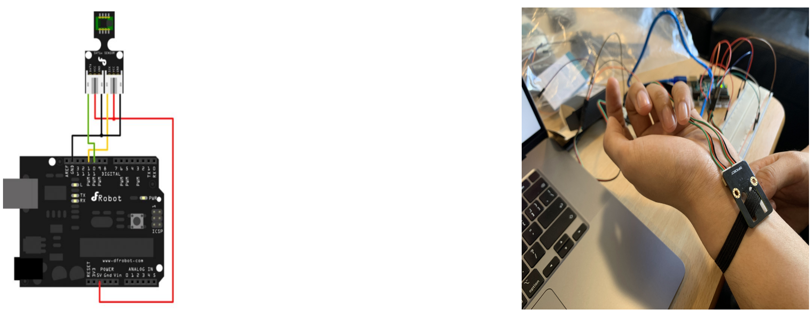

Figure 2.9: Circuit for temperature and humidity sensor

Based on the functions of this sensor, our group designed several methods to measure the values and display the results. The working principle can be seen from Figure 2.10.

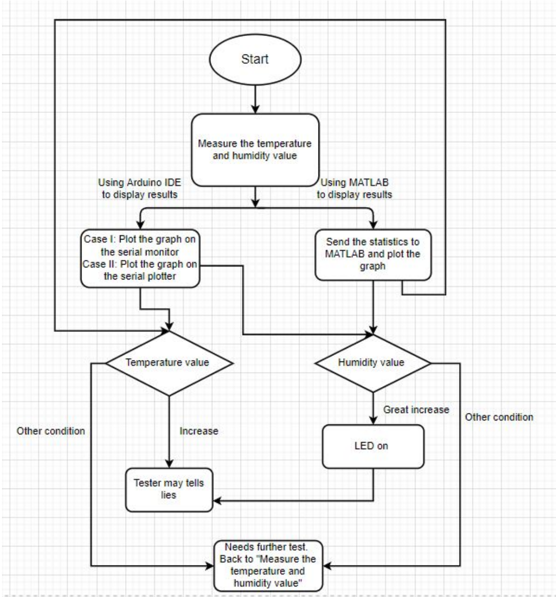

Figure 2.10: The flow chart of temperature and humidity sensor

2.3.2 The overall diagram

The entire hardware system is shown in Figure 2.11.

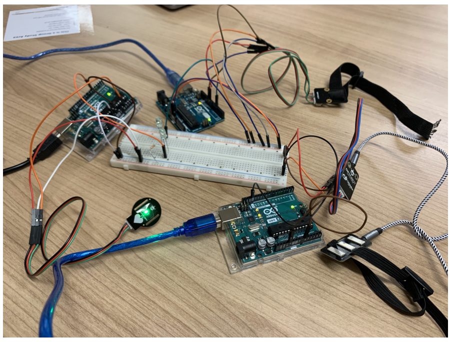

Figure 2.11: Hardware system

2.3.3 Software

Research shows that in as many as 95 percent of deceptive statements, a person's tone of voice deviates from the baseline [9]. It is one of the reliable factors of deception. Based on this theorey, MATLAB is used to do the voice evaluation.

The working principle is shown in Figure 2.12. The code for this part can be seen in the Appedix section.

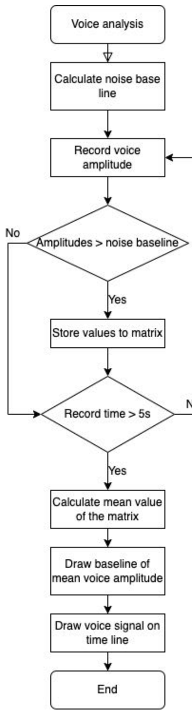

Figure 2.12: The flow chart of voice evaluation system

Chapter 3

Results

3.1 Theoretical results

The three sensor components of the lie detector record data and output it graphically on the computer screen. The results of this part will be shown in detail in the following sections.
The following describes the operating logic of the lights connected to the heart rate sensor and the temperature and humidity sensor and under what conditions the LEDs will be turned on.

Table 3.1: Heart rate sensor

a = The magnitude of heart rate change		
Heart rate changes	Judgment threshold	State of the LED
A significant increase	$a > 1$	Turn on
No significant rise	$0 < a < 1$	Turn off
No rise	$a < 0$	Turn off

Since the change in heart rate and humidity have inevitable fluctuations, that is to say; small variation cannot effectively reflect the tension of the subjects, so the judgment of changes is not to light up the LED when there is a small rise, but to trigger the LED when the magnitude of change is greater than 1.

Table 3.2: Temperature and humidity sensor

b = The Humidity change		
Humidity changes	Judgment threshold	State of the LED
A increase	$b > 1\%$	Turn on
No significant rise	$0 < b < 1\%$	Turn off
No rise	$b < 0$	Turn off

3.2 Component results

3.2.1 The heart rate sensor

This section shows the results of a separate test of the heart rate sensor. The heart rate can be output by placing your hand lightly on the sensor.

Since the heart rate sensor can be operated in two different modes, the output results in both cases are shown below. The figure 3.2 shows the values seen from the serial monitor in digital mode, where 0 indicates that the heart rate is not detected. Figure 3.1 shows the plot for digital mode.

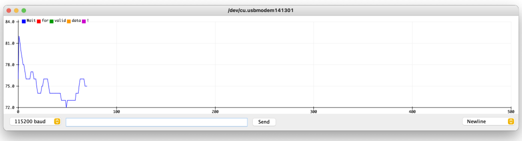

Figure 3.1: Image in digital mode

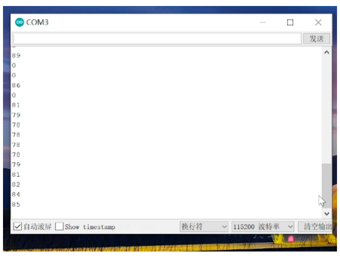

Figure 3.2: The digital mode

In analogue mode, data obtained from a serial port monitor is difficult to read. Figure 3.3 shows data obtained from a serial port plotter.

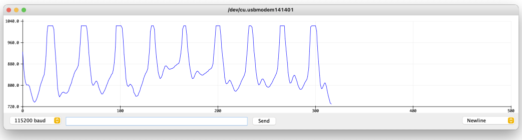

Figure 3.3: The analogue mode

3.2.2 Temperature and humidity sensor

When the temperature and humidity sensor is tested separately, the results are as follows:

The temperature and humidity output can be obtained from the serial port monitor. Figure 3.4 shows the output results.

Figure 3.4: Numerical output

At the same time, in order to see the output results more intuitively, MATLAB is used to read the returned data and draw in the research process of the project, which is shown in Figure 3.5.

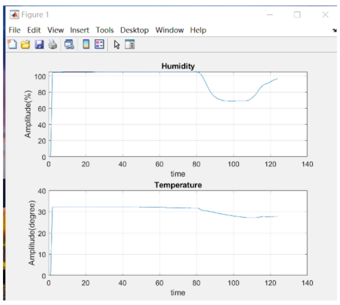

Figure 3.5: Matlab output

3.2.3 EMG sensor

The EMG sensor detects muscles movement by detecting the neural electrical signals produced by a person manipulating a muscle.
The output of the sensor on the serial port plotter is shown in the figure below.

When the muscles is fully relaxed, the cooresponding output is shown in Figure 3.6. As Figure 3.7 shows , the sharp wave peak in the output picture indicates that the EMG sensor has received an electrical signal, which indicates the presence of muscles movement.

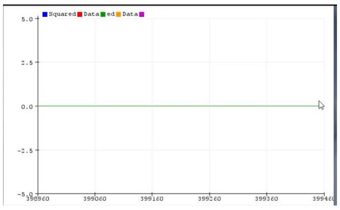

Figure 3.6: EMG sensor output

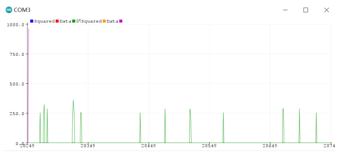

Figure 3.7: EMG sensor output

3.2.4 MATLAB sound detection

MATLAB is used to receive the measured voice in real-time and convert the received voice into an image for output. Observing the apparent changes of the voice image when lying allows the detection of lies. At the beginning of the design, the output image of sound is shown in the figure below. The upper part is the output spectrum, and the lower part is the output waveform in the time domain. The result is shown in Figure 3.8.

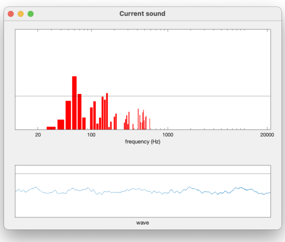

Figure 3.8: matlab sound output

However, since the baseline in this version can only be set to fixed values, but human voices are inherently unique, so it has been improved. The new sound monitoring system will record the sound in the first few seconds of operation, calculate the average amplitude and then output the waveform, as figure 3.9 shows.

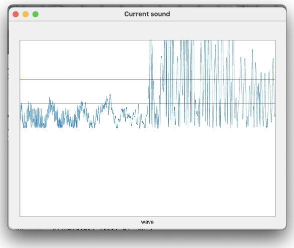

Figure 3.9: matlab sound output

3.2.5 The overall result

In conclusion, a total of three Arduino boards are used, and these components are connected together by a bread board. After connecting the three boards to the computer, the following four images were obtained with MATLAB sound detection on the computer, which are shown in Figure 3.10

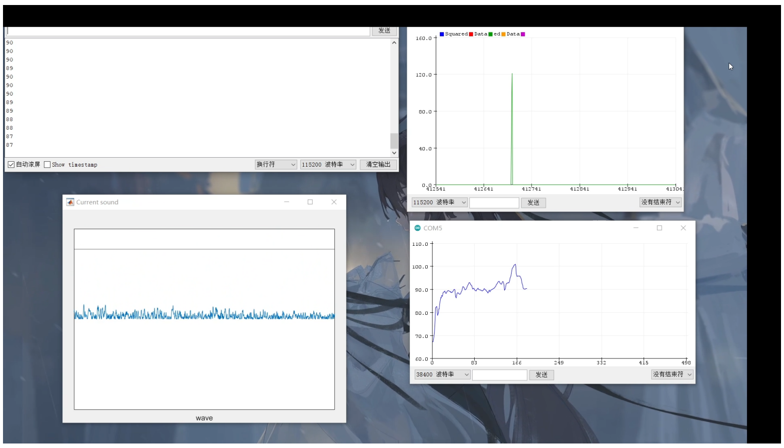

Figure 3.10: Lie Detector output

Chapter 4

Discussion and Conclusions

4.1 Achievement and Evaluation

There are some achievements made in this project and also some evaluation about them.

- Enable 3 sensors to work properly: Arduino IDE, which is based on C programming language, is used to drive these sensors successfully . For the EMG sensor, it is successfully calibrated through continuous testing, making it very sensitive and accurate, even able to detect slight bending of the finger. Humidity and heart rate sensors are also tested to make them work properly. When the values increase, their corresponding LED will light up. The debugging of these sensors was very successful, laying a foundation for the success of the project. The use of LED can more directly display the changes in humidity and heart rate of the subject, which is more conducive to the observer's judgment.

- Voice recognition and analysis can be carried out: The voice analysis MATLAB program uses the built-in Mic of the laptop to monitor the voice spectrum of the volunteer, records the volunteer's voice for 5 seconds and automatically calculates the mean baseline of his voice amplitude. It worked accurately and enabled the observers to judge the subjects during the whole procedure: by observing the difference between the subjects' voices when they answered questions and when they spoke normally.

4.2 Limitation and Reflection

There are some limitations existing in this project which will not affect the achievement of the project and there are some solutions to overcome these limitations.

- Firstly, due to the insufficient performance of the Arduino board, each sensor needs to use a sperate Arduino board, resulting in a waste of resources and the circuit is of large scale. If a more powerful board is used in the future, all the sensors can be integrated into one board, which could make the Lie Detector more portable and remove the redundant chips and wires.
- Secondly, because the sensors are driven by different Ardunio boards, in order to make the programs run synchronously on the same computer, some plans have to be discarded. For example: using MATLAB to output temperature and humidity images is not conducive to observation because it outputs data with a time delay.
- Thirdly, this Lie Detector can only provide the data for people to evaluate. It cannot make a judgement automatically. If the Artificial Intelligence is used to analyse the output data of the Lie Detector, the AI can help it determine if the person is lying through the training model.
- Finally, since the temperature sensor used in this project is greatly affected by the environment, it cannot be used to determine whether the person is lying. If more budget is provided to buy an infrared temperature sensor that is not affected by ambient temperature for this project, then temperature can also be used as a basis to lie detecting

4.3 Applications

This project can be applied in the following scenarios:

- The crime inspection: The Lie Detector measures and records physiological responses caused by sympathetic nerves, such as blood pressure, pulse, breathing and the electrical signal of the skin, to help the police determine whether the suspect lies.

- Patient monitoring: Due to the requirements of measuring heart rate, skin humidity and myoelectric response in this project, these biometrics are all related to the health of the human body. Therefore, another potential use of the system is to monitor the health condition. If more sophisticated and accurate sensors are applied in the future, it can be an efficient system to check the health status of patients in hospitals.

4.4 Ethical Considerations

The product is safe for most people, all the sensors and LEDs used in the lie detector are powered by just 5 volts, well below 36V safe voltage. In addition, the circuit connections are quite stable because most of the complex circuit internal integrated into the sensor, and only data and power wires are used for external links. The LED through the breadboard, and each LED has a resistor to protect it. Therefore, there is no danger due to this low power and stable connection.

4.5 Commercialisation and Intellectual Property

The total cost of the polygraph in the project is around £80. To make a polygraph into a product, we can unify the code and integrate all the sensors with a more powerful driving board rather than an Arduino board. Thus, it can promote the commercialization of products, save costs and maximize profits. The core code of the lie detector can be considered intellectual property, which can not be used commercially.

4.6 Future Work

As for future improvements of this project, possible ones are listed below:

- Integrate all the sensors: Two extra Arduino boards are required due to insufficient performance. To make the Detector more portable, more powerful hardware could be used to integrate all the sensors.

- Use Artificial Intelligence: To detect a lie automatically , the Artificial Intelligence could be used to analyse the output data.
- Develop a client: Since the Lie Detector requires to measure a lot of data, a client can be designed to display waveforms, making it easier for users to view the measured data.

4.7 Conclusions

In conclusion, most of the objectives are achieved. All the sensors' output can be displayed by Arduino IDE and the voice can be evaluated by using MATLAB. The circuit works properly while all the data are displayed perfectly. However, this project lacks an integrated design. Each sensor requires one Arduino board to drive, which is a waste of energy and efficiency. In addition, it cannot judge whether the person is lying by itself. In the future, Artificial Intelligence can be involved in the system to help it make a judgement automatically, and all the sensors can be integrated onto a more powerful board to make it more portable.

References

[1] C. CODING, “Let’s make lie detector with arduino,” https://www.youtube.com/watch?v=uYzXctqpSDA, YouTube, 2019.

[2] “Sen0240 emg sensor,” https://www.tme.eu/gb/details/df-sen0240/other-sensors/dfrobot/sen0240/.

[3] “Sen0203 heart rate sensor,” https://uk.farnell.com/dfrobot/sen0203/heart-rate-monitor-sensor-arduino/dp/3517882.

[4] “Sth1x temperature and humidity sensor,” https://www.mouser.co.uk/ProductDetail/DFRobot/DFR0066?qs=lqAf%2FiVYw9ivYrmVBnm2LQ%3D%3D.

[5] “Arduino uno rev3,” http://store.arduino.cc/products/arduino-uno-rev3.

[6] M. Iwamoto, A. Yuguchi, M. Yoshikawa, G. A. Garcia Ricardez, J. Takamatsu, and T. Ogasawara, “Human-like subconscious behaviors for an android when telling a lie,” in *2018 27th IEEE International Symposium on Robot and Human Interactive Communication (RO-MAN)*, 2018, pp. 390–395.

[7] P. Vos, P. De Cock, V. Munde, K. Petry, W. Van Den Noortgate, and B. Maes, “The tell-tale: What do heart rate; skin temperature and skin conductance reveal about emotions of people with severe and profound intellectual disabilities?” *Research in Developmental Disabilities*, vol. 33, no. 4, pp. 1117–1127, 2012. [Online]. Available: https://www.sciencedirect.com/science/article/pii/S0891422212000340

[8] S. Stewart-Steinberg, *The Pinocchio Effect: On Making Italians, 1860-1920.* University of Chicago Press, 2007.

[9] D. R. Fenstermacher, “Lie detector evidence-new mexico court of appeals holds voice-stress lie detector evidence conditionally admissible: Simon neustadt family center, inc. v. bludworth,” *NML Rev.*, vol. 13, p. 703, 1983.

Appendices

Appendix A

Project management forms

Year 2 Project (ELEC222/273) – *Supervisor meeting – Week 1*

Date: 2024.2.3 Supervisor: James . Bradley

Project Title: Lie Detector

Student Names /Attendees:	1. Qihang. Yao	2. Zhenyifan. Mao
3. Zhongpei. Wang	4. Tianyu. Yan	5.

Summary of week's activities:

Voice analysis by using MATLAB

Problem, issues and concerns:

No components

Tasks for next week/Actions for next meeting:

If components are delivered, we will start constructing circuit

Supervisor use only

Progress Assessment: ☐ Unsatisfactory ☒ Satisfactory ☐ Good

Comments/Recommendations:

— need components.

Year 2 Project (ELEC222/273) – *Supervisor meeting – Week 2*

Date: 2021.2.10 Supervisor: James . Bradley

Project Title: Lie Detector

Student Names /Attendees:	1. Qihang. Yao	2. Zhenyifan. Mao
3. Zhongpei. Wang	4. Tianyu. Yan	5.

Summary of week's activities:

Continue to do voice analysis using Matlab.
Construct the circuit for EMG and EKG.

Problem, issues and concerns:

We have not find a proper way to illustrate the expemential data

Tasks for next week/Actions for next meeting:

Construct the circuit for temperature sensor and continue to improve our system.

Supervisor use only

Progress Assessment: □ Unsatisfactory □ Satisfactory □ Good

Comments/Recommendations:

Year 2 Project (ELEC222/273) – *Supervisor meeting – Week 3*

Date: 2022.2.17 Supervisor: James . Bradley

Project Title: Lie Detector

Student Names /Attendees:	1. Qihang. Yao	2. Zhenyifan. Mao
3. Zhongpei. Wang	4. Tianyu. Yan	5.

Summary of week's activities:

① Continue to construct the circuit and combine all the sensors together.
② Design the poster

Problem, issues and concerns:

① The format of poster
② A more proper way to demonstrate data

Tasks for next week/Actions for next meeting:

① Design the poster
② Summary of the project
③ prepare for the presentation

Supervisor use only

Progress Assessment: □ Unsatisfactory □ Satisfactory □ Good

Comments/Recommendations:

Year 2 Project (ELEC222/273) – *Supervisor meeting – Week 4*

Date: 2022.2.24 Supervisor: James . Bradley

Project Title: Lie Detector

Student Names /Attendees:	1. Qihang. Yao	2. Zhenyifan. Mao
3. Zhongpei. Wang	4. Tianyu. Yan	5.

Summary of week's activities:

Improved the voice analysis to decrease the noise interference. Developed two working modes for heart beat sensor. Designed the poster.

Problem, issues and concerns:

EMG sensor is hard and time-consuming to calibrate.

Tasks for next week/Actions for next meeting:

Preparing for the bench inspection.

Supervisor use only

Progress Assessment: □ Unsatisfactory □ Satisfactory ☒ Good

Comments/Recommendations:

Y2 project (ELEC222/ELEC273) - *Contribution to project deliverables*

Notes:

- ***Assessors will request to see this sheet in the bench inspection day.***
- ***Typical deliverables include: Bench, Poster, Blog, Report, Code, Circuit, etc.***

	Member name	Deliverable(s)	Comments
1	Zhongpei Wang	Circuit, Poster, Report, Bench, Logbook	Contributed a lot to the sensor calibration (make EMG sensor work), Arduino coding. Managed the logbook very well.
2	Tianyu Yan	Circuit, MATLAB Code, Report	Did a great job on Arduino coding and circuits improvements (including adding LEDs to indicate rising sensor results)
3	Zhenyifan Mao	Blog, MATLAB Code, Report	Managed the online blog very well. Improved the MATLAB program (adding auto calibration function)
4	Qihang Yao	Circuit, MATLAB Code, Report	Did a great job on Arduino coding and circuits improvements (including adding LEDs to indicate rising sensor results)

Y2 project (ELEC222/ELEC273) – *Role allocation (responsibility matrix)*

Notes:

- ***Assessors will request to see this sheet in the bench inspection day.***
- ***See overleaf for details on titles and associated roles and responsibilities.***

	Member Name	**Title(s)**
1	Zhongpei Wang	Project Manager, Designer
2	Qihang Yao	Developer
3	Tianyu Yan	Developer
4	Zhenyifan Mao	Technical Writer

Responsibility Matrix

KEY:
R – Responsible (accountable) for completion of task. (Task can be delegated to this person.)
S – Supports task.
C – Requires communication about the task.

Title	Project Activity				Deliverables			
	Requirements/ Scope	Design	Implementing	Testing	Poster	Blog	Bench	Report
Project Manager	R	C	S	S	S	S	S	S/R
Designer	C	R	S	S	S	S	S	S
Implementer/ Developer	C	S	R	S	C	C	R	S
Technical Writer	C	S	S	S	R	R	C	R

<u>Typical Roles</u>

Title	Role	Responsibilities
Project Manager	Responsible for developing, in conjunction with the supervisor, the project scope. The Project Manager ensures that the project is delivered on time and to the required standards.	• Managing and lead the project team. • Managing the coordination of the partners and the working groups.
Designer	Designing the system (the circuit, the code, etc.).	• Creating the required block diagrams, circuit diagrams, flow charts, etc.
Implementer/Developer	Implementing the suggested design	• Connecting the systems/circuit • Writing the code
Technical Writer	Documenting the project progress and deliverables	• Recording and maintaining all meeting logs • Updating the logbook. • Creating project blog • Creating project poster • Writing project report

Y2 project (ELEC222/ELEC273) - *Attendance record*

Notes:

- ***This sheet should be updated by group members weekly when they meet to discuss the project.***
- ***Assessors will request to see this sheet in the bench inspection day.***

	Member name	Attended the weekly meeting? (Yes/No)					Comments
		Week 1	Week 2	Week 3	Week 4	Week 5	
1	Qihang Yao	Yes	Yes.	Yes	Yes	Yes	
2	Zhenyifan Mao	Yes	Yes.	Yes	Yes	Yes	
3	Zhongpei. Wang.	Yes	Yes	Yes.	Yes	Yes	
4	Tianyu Yan	Yes.	Yes.	Yes.	Yes	Yes.	
5							

Appendix B

Contributions to the project

Name	Contribution to this project
Zhongpei.Wang	Project leader. Mainly developed the EMG sensor circuit. Wrote the “Material and Method” part. Typeset the report. Designed the poster
Qihang.Yao	Developer. Mainly developed the heart rate sensor circuit Wrote “results” part for report. Reviewed lab reports. Designed the poster
Tianyu.Yan	Developer. Mainly developed the Temperature and Humidity sensor circuit. Wrote “Discussion and conclusion” part Helped Mao develop the voice analysis system Designed the poster
Zhengyifan.Mao	Developer. Mainly developed the voice analysis system Managed the web blog Reviewed the report Designed the poster

This table shows what each of us is primarily responsible for. In the process of doing the project, the team members helped each other, shared experience, and successfully completed the project

Appendix C

Program Listings

Listing C.1: Code for EMG sensor

```
#if defined(ARDUINO) && ARDUINO ≥ 100
#include "Arduino.h"
#else
#include "WProgram.h"
#endif
#include "EMGFilters.h"
#define TIMING_DEBUG 1
#define SensorInputPin A0 // input pin number

EMGFilters myFilter;
int sampleRate = SAMPLE_FREQ_1000HZ; //Define the ...
    sample frequency
int humFreq = NOTCH_FREQ_50HZ; //Power transmission ...
    frequency 50Hz //Calibration:
static int Threshold = 0;

unsigned long timeStamp;
unsigned long timeBudget;

void setup()
{
myFilter.init(sampleRate, humFreq, true, true, true);
// open serial
Serial.begin(115200);//define baud ratio
timeBudget = 1e6 / sampleRate; // micros will ...
    overflow and auto return to zero every 70 minutes
}

void loop()
```

```
{ // In order to make sure the ADC sample frequence ...
    on arduino,the time cost should be measured each ...
    loop
timeStamp = micros();
int Value = analogRead(SensorInputPin);
int DataAfterFilter = myFilter.update(Value);// ...
    filter processing
int envlope = sq(DataAfterFilter); // any value ...
    under threshold will be set to zero
envlope = (envlope > Threshold) ? envlope : 0;
timeStamp = micros() - timeStamp;
if (TIMING_DEBUG)
{
Serial.print("Squared Data: ");
Serial.println(envlope);
// the filter cost average around 520 us
}
delayMicroseconds(500);
}
```

Listing C.2: Code for heart rate sensor

```
#define heartratePin A1
#include "DFRobot_Heartrate.h"

DFRobot_Heartrate heartrate(DIGITAL_MODE);
int pin=5;
int mode=6;
int lastHeartRate;
void setup()
{
Serial.begin(115200);
pinMode(mode,INPUT);
pinMode(pin, OUTPUT);
}

void loop()
{
if (digitalRead(mode)==HIGH) ///< Work in digital mode
{
uint8_t rateValue;
heartrate.getValue(heartratePin);
rateValue = heartrate.getRate(); ///<get heart rate ...
    value
if (rateValue)
{
```

```
Serial.println(rateValue);
if(rateValue-lastHeartRate>1) ///<Determine whether ...
    the heart rate increased
{
digitalWrite(pin, HIGH); ///Ture, turn on the LED
}
else
{
digitalWrite(pin, LOW); ///<False, turn off the LED
}
lastHeartRate=rateValue; ///<Store the information
}
delay(20);
}
if (digitalRead(mode)==LOW)///<Work in analoge mode
{
int heartValue = analogRead(heartratePin);///get ...
    heart rate value Serial.println(heartValue); ...
    delay(20);
}
}
```

Listing C.3: Code for temperature and humidity sensor

```
#include <SHT1x.h>

// Specify data and clock connections and ...
    instantiate SHT1x object
#define dataPin  10
#define clockPin 11
SHT1x sht1x(dataPin, clockPin);
int pin=5;
int lastHumidity;
void setup()
{
   Serial.begin(38400);
   pinMode(pin, OUTPUT); //Set Pin mode
}
void loop()
{
  float temp_c;
  float humidity;
  // Read values from the sensor
  temp_c = sht1x.readTemperatureC();
  humidity = sht1x.readHumidity();
  // Print the output
```

```
  Serial.println(temp_c, DEC);
  Serial.println(humidity);
  if(humidity-lastHumidity>1)//Judge the humidity ...
     change
  {
    digitalWrite(pin, HIGH);//Ture, turn on the LED ...
       light
  }
  else{
    digitalWrite(pin, LOW);//False, turn off the LED ...
       light
  }
  lastHumidity=humidity;//Storage the humidity
   delay(2000);
}
```

Listing C.4: Code for voice evaluation

```
clear all;
%Set up built-in mic
mic = audioDeviceReader( ...
    'SamplesPerFrame',4410, ...
    'SampleRate',44100);
setup(mic)
totalOverrun = 0;
%Recording for noise cancellation
fprintf('DO NOT talk during noise cancellation.\n')
fprintf('Start recording.\n')
tic
while toc < 5
    [amplitude,numOverrun] = mic();
    totalOverrun = totalOverrun + numOverrun;
end
fprintf('Noice cancellation complete.\n')
framelength=1; %
length(amplitude);
framenumber=fix(length(amplitude)/framelength);
for i=1:framenumber
    framesignal=amplitude((i-1)*framelength+1:i*framelength);
    Amp(i)=0;
    for j=1:framelength
        Amp(i)=Amp(i)+abs(framesignal(j));
    end
end
noise=mean(Amp,'all');
fprintf('Please keep talking for at least 10 seconds.\n')
pause(5);
%Recording voice to find base line
fprintf('Start recording.\n')
tic
while toc < 5
    [amplitude,numOverrun] = mic();
```

```
    totalOverrun = totalOverrun + numOverrun;
end
fprintf('Recording complete.\n')
framelength=1;
length(amplitude);
framenumber=fix(length(amplitude)/framelength);
for i=1:framenumber
    framesignal=amplitude((i-1)*framelength+1:i*framelength);
    Amp(i)=0;
    for j=1:framelength
        Amp(i)=Amp(i)+abs(framesignal(j));
    end
end
Amp(Amp≤noise)=[];
baseLine=mean(Amp,'all');
%Draw live waveform of voice
%Set output figure parametres
timeLength=0.1;
samples=timeLength*44100;
[audioIn,¬] = step(mic);
figure('Name','Current sound','MenuBar'...
    ,'none','ToolBar','none','NumberTitle','off');
xdata=(1:1:samples/2)/timeLength;
axes= subplot(1,1,1);
pic= plot(axes, 1:1:samples, 2*audioIn); %Amplify the ...
    magnitude to fit the vertical axis
set(axes,'xlim', [0 samples], 'ylim', ...
    [-0.15 0.15],'XTick',[],'YTick',[] );
xlabel(axes,'wave');
yline(axes,2*baseLine);
yline(axes,2*baseLine*1.95,'-b')
axes.Position=[0.040 0.06 0.92 0.86];
drawnow;
%Always refresh the waveform
while 1
    [audioIn,¬] = step(mic);
    set(pic,'ydata',2*audioIn);
    drawnow;
end
```

Listing C.5: Code for plot the graph of temperature and humidity through MATLAB (not taken as the final result)

```
s=serial('COM5');%define the serial port
set(s,'BaudRate',115200);
fopen(s); %open serial port
interval=10000;
passo=1;
t=1;
x1=0;
x2=0;
while(t<interval)
    b=str2num(fgetl(s)); %read the data
    if b>40
```

```
        x1=[x1,b];
        subplot(2,1,1);
        plot(x1);
        title('Humidity');
        xlabel('time');
        ylabel('Amplitude(%)'); %plot the graph for Humidity
    elseif b≤40
        x2=[x2,b];
        subplot(2,1,2);
        plot(x2);
         title('Temperature');
        xlabel('time');
        ylabel('Amplitude(degree)'); %plot the graph for ...
            Temperature
    end
    grid on
    t=t+passo;
    drawnow;
end
fclose(s);
```

Listing C.6: Code for our group to study voice analysis by using MATLAB (not taken as the final result)

```
function sound()
timelength=0.1;              % set the sampling time
sample=timelength*44100;   % set the sampling frequency
S = dsp.AudioRecorder(...
    'NumChannels'   , 1,...                 % 1 channel
    'DeviceDataType', '16-bit integer',... % 16 bit
    'OutputNumOverrunSamples',true,...      % Over sampled
    'SamplesPerFrame', sample);
[audioin,¬] = step(S);                      % first time
figure('Name','Current sound','MenuBar'...
    ,'none','ToolBar','none','NumberTitle','off');
xdata=(1:1:sample/2)/timelength;
axes1= subplot(1,2,1);
axes2= subplot(1,2,2);
pic= plot(axes1, 1:1:sample, audioin);    % set the wave plot
pic2= bar(axes2,xdata, xdata*0,'r');
set(axes1,'xlim', [0 sample], 'ylim', ...
    [-0.15 0.15],'XTick',[],'YTick',[] );
set(axes2,'xlim', [min(xdata) max(xdata)], 'ylim',[0 6] , ...
     'xscale','log','XTick',[1 20 100 1e3 2*1e4],'YTick',[] );
xlabel(axes2,'frequency (Hz)');
xlabel(axes1,'wave');
yline(1);
yline(1);
axes2.Position=[0.040 0.48 00.92 0.50]; % left, right, width, ...
   height
axes1.Position=[0.040 0.06 0.94 0.26];
drawnow;
 while 3>2
   [audioin,Overrun] = step(S);        % sampling
```

```
    if Overrun > 0
       warning(' Overrun %d\n',Overrun);
    end
    ydata_fft=fft(audioin);               % Fourier transform
    ydata_abs=abs(ydata_fft(1:sample/2));% take absolute value
    set(pic, 'ydata',audioin);            % update the wave graph
    set(pic2, 'ydata',log(ydata_abs));    % update the spectrum plot
    drawnow;                              % refresh
end
end
```