Department of Electrical Engineering

EE4990

Summer Program for Overseas Students

Hovercraft Project

Group number: Group 2

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Abstract

The aim of the project was to create functional remote control vehicle – hovercraft. The project was scheduled to be done within 5 weeks. The work itself was split into two main sections. In the first section the students learnt how to put together the necessary electrical components of the hovercraft by using the soldering technique. They used the knowledge of basic electrical engineering. In the second section the students created the program for Arduino technology and mobile application in order to control motion of the hovercraft.

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1 Introduction

The aim of the project was to construct the functional remote control vehicle called hovercraft which would be competitive with other hovercrafts in a unique tournament. The main requirements were the properties such as the simple control of the motion, the speed adjustment and an airplane shooting. These were absolutely necessary in order to succeed in the tournament.

Before the beginning of the work students had been divided into 3-member international teams and each team made up a title of their own choice. Our team consisted of a Taiwanese, a Korean and a Czech. We gave us a name GP2 and our hovercraft's name was Battlecruiser.

The construction of the hovercraft was a process consisting of a few sections. Step by step we produced our project model. First of all, we had to build the physical body of the hovercraft - hardware. Then we created the Arduino code to communicate with the hardware component. Finally, we had to develop a mobile application in Thunkable in order to control the hovercraft.

2 Constraction of the hovercraft

2.1 Basic Electronic Theory

2.1.1 Ohm's Law

One of the most important and basic laws of electrical circuits is Ohm's law which states that the current passing through a conductor is proportional to the voltage over the resistance.

Description of the Ohm's Law by a simple equation:

$$\boldsymbol{I = \frac{V}{R}}$$

where *I = current in amps, V = voltage in volts and R = resistance in ohms*.

Ohm's law describes the way current flows through a resistance when a different electric potential (voltage) is applied at each end of the resistance. One way to think of this is as water flowing through a pipe. The voltage is the water pressure, the current is the amount of water flowing through the pipe, and the resistance is the size of the pipe. More water will flow through the pipe (current) the more pressure is applied (voltage) and the bigger the pipe is (lower the resistance). [1]

2.1.2 Circuit Diagram

A circuit diagram (also known as an electrical diagram) is a simple representation of an electrical circuit. A pictorial circuit diagram uses simple images of components, while a schematic diagram shows the components of the circuit. The Ohm's Law can be presented as such a diagram. [2]

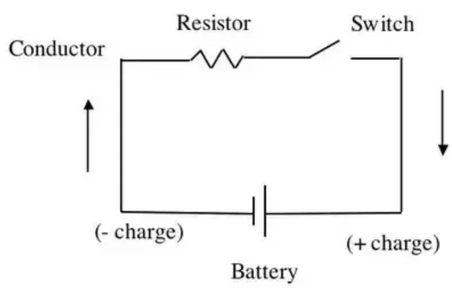


Figure 1: Basic Electrical Circuit Diagram

2.1.3 Electronic Components

Electronic Components are various components connected together in order to create an electronic system. Basic electronic components in our case are represented by a resistor, a capacitor, a motor, an integrated circuit and a printed circuit board.

Figure 2: Basic Electronic Components

Resistor

Resistor is an electrical component that reduces the electric current. The resistor's ability to reduce the current is called resistance and is measured in units of ohms. We can measure the resistance of it by a multimeter. In case of not having the multimeter we need to read the value from the color bands on the resistor directly according to a resistor color table. [3]

Capacitor

A capacitor is a two-terminal, electrical component which is capable to store energy in an electric field. They are one of the most fundamental passive components we use. It was the first known as an electric condenser in the past. The capacitance can be also measured by the multimeter as in the case of resistor. [4]

Motor

Motor is a device which transfers the energy to mechanical work. In our project we use a type KM-16A050 series DC Geared Motor. [5]

Integrated Circuit

An integrated circuit (IC) is a small semiconductor-based electronic device which consists of fabricated transistors, resistors and capacitors. Integrated circuits are the building blocks of most electronic devices and other equipment. [6]

Printed Circuit Board

A printed circuit board (PCB) is an electronic circuit used in devices to provide mechanical support and a track to its electronic components. It is made by combining different sheets of non-conductive material, such as fiberglass or plastic that easily holds copper circuitry.

A PCB works on the copper films/assembly/circuit that are placed inside of it to provide a pathway for the flow of current. A PCB can hold various electronic components that may be soldered without using visible wires, which facilitates its use.

We can find PCBs in nearly every electronic and computing device, including motherboards, network cards and graphics cards to internal circuitry found in hard/CD-ROM drives. [7]

2.1.4 Technique of Soldering

Soldering is the action of joining two or more electronic parts together by melting solder around the connection point. Solder is a metal alloy and when it cools it creates a strong electrical joint between the parts. Even though soldering can create a permanent connection, it can also be reversed using a desoldering tool. [8]

Soldering Tools (mostly common)

- *Soldering Iron*
- *Soldering Station*
- *Soldering Iron Tips*
- *Brass or Conventional Sponge*
- *Solder*

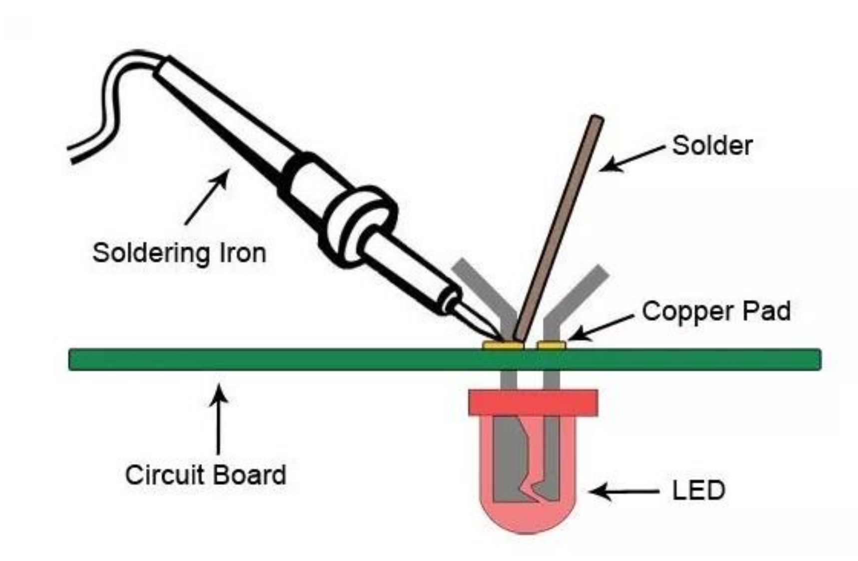


Figure 3: Soldering Process

2.2 Technology of 3D Print

The term "3D printing" represents a group of processes in which material is joined or solidified under computer control to create a three-dimensional object, with material being added together (such as liquid molecules or powder grains being fused together), typically layer by layer. 3D printing enables to create complex shapes using less material than traditional manufacturing methods. The most-commonly used 3D-printing process is a material extrusion technique called fused deposition modeling (FDM). [9]

Nowadays, the cost of 3D printing has significantly reduced due to the development of desktop 3D printers which has made the technology more accessible to small and mid-sized businesses and home users.

<u>Benefits of 3D Printing</u> [10]

- Geometric complexity at no extra cost
- Very low start-up costs
- Customization of each and every part
- Low-cost prototyping with very quick turnaround
- Large range of materials

<u>Limitations of 3D Printing</u> [10]

- Lower strength & anisotropic material properties
- Less cost-competitive at higher volumes
- Limited accuracy & tolerances
- Post-processing & support removal

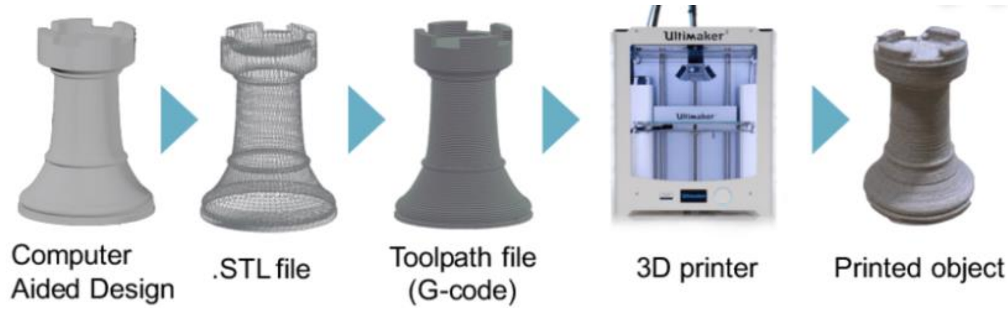


Figure 4: 3D Printing Process

2.2.1 3D Printer

Every 3D printer builds parts based on the same main principle: a digital model is turned into a physical three-dimensional object by adding material a layer at a time.

Picture a robot-controlled hot glue gun that uses plastic instead of glue, and you have the basics of a 3D printer. Strands of plastic are fed into a print head, which is heated up to melt the material. The print head moves around very precisely in three dimensions and drops lines of plastic onto the print bed—the table on which it prints. The printer does this over and over, building up layers of plastic until it forms a 3D part. [11]

Once the printer starts, everyone notices the main problem with 3D printing today: the process is very slow. While a 2D printer can print a whole book in a couple of minutes, most 3D prints will take several hours, if not days, to finish printing. And if a user messed up the settings, misconfigured the slicer, or just bumped into it a bit, he or she could lose the whole print. [11]

2.2.2 Modelling in DesignSpark Mechanical

3D printable models may be created with a computer-aided design (CAD) package, via a 3D scanner, or by a plain digital camera and photogrammetry software. 3D printed models created with CAD result in reduced errors and can be corrected before printing, allowing verification in the design of the object before it is printed.

One of the free CAD solid modelling software for 3D printing is DesignSpark Mechanical. This complex tool enables users to solid model in a 3D environment and create files for use with 3D printers. Users can mainly benefit from possibility to change frequently design of their models and use an intuitive set of tools. Although it is a payment free tool, it requires one-time registration to get full access.

Figure 5: DesignSpark Mechanical Logo

Each team got a task to use its imagination and draw in DS Mechanical environment an object of its choice for 3D printer. The reason for that was very simple. Such an element would be used as a special design element for their hovercraft. Our team decided to come up with 3 models – Creeper figure from the Minecraft videogame, Pikachu pokemon and title “EE4990”. All these objects were printed on the school 3D printer ArrayZC5C.

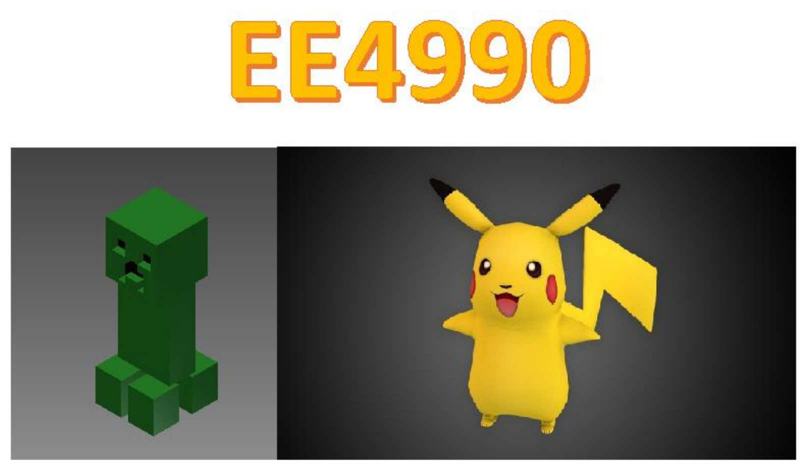


Figure 6: Our 3D models

3 Part II - Programming of the hovercraft

3.1 Arduino and Bluetooth technology

3.1.1 Arduino

Arduino is an open-source electronics platform based on easy-to-use hardware and software. Arduino boards are able to read inputs, such as light on a sensor, a finger on a button, or a Twitter message, and then turn it into an output like activating a motor, turning on an LED, or publishing something online. The way to control the Arduino is to use Arduino programming language to send a set of instructions to the microcontroller on the board.

Our project is using the Arduino Micro, which has 20 digital input/output pins (of which 7 can be used as PWM outputs and 12 as analog inputs).

Each of the 20 digital IO pins on the Micro can be used as an input or output, using, pinMode(), digitalWrite(), and digitalRead() functions. They operate at 5 volts. Each pin can provide or receive 20 mA as recommended operating condition and has an internal pull-up resistor (disconnected by default) of 20-50 k ohm. A maximum of 40mA is the value that must not be exceeded to avoid permanent damage to the microcontroller.

Arduino Micro also has a 16 MHz crystal oscillator, a micro USB connection, an ICSP header, and a reset button. It contains everything needed to support the microcontroller; simply connect it to a computer with a micro USB cable to get started. It has a form factor that enables it to be easily placed on a breadboard. [12]

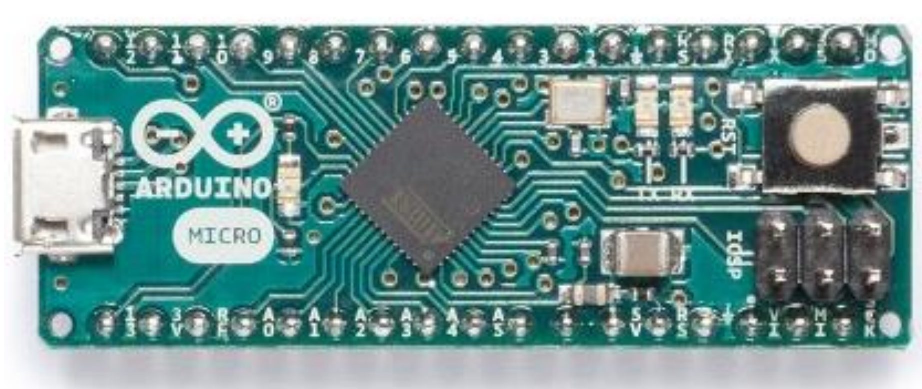


Figure 7: Arduino Micro

3.1.2 Communication between Arduino and Bluetooth

Figure 8: Bluetooth logo 1

Bluetooth is a wireless technology standard for exchanging data between fixed and mobile devices over short distances using short-wavelength UHF radio waves in the industrial, scientific and medical radio bands, from 2.400 to 2.485 GHz, and building personal area networks(PANs). It was originally conceived as a wireless alternative to RS-232 data cables. [13]

Figure 9: Bluetooth logo 2

In our project, we use Bluetooth Low Energy (BLE) to exchanging data. The reason we use it instead of BT is that BLE can help to reduce the power consumption. BLE can also ach-ieve short distance communication but is about 100 times less power than BT.

3.1.3 Arduino Code

```
gp2_adu.ino §
#define BT Serial1
#define left 10
#define right 9
#define leftDir 12
#define rightDir 8
#define shoot 4

char state,state1;
String cmd;
int SPEED2;


void setup() {
  Serial.begin(9600);
  BT.begin(9600);
  pinMode(left ,OUTPUT);
  pinMode(right,OUTPUT);
  pinMode(leftDir,OUTPUT);
  pinMode(rightDir,OUTPUT);
  pinMode(shoot,OUTPUT);
  SPEED2 = 0;
```

Figure 10: Arduino Code 1

For the First part of the Arduino Code which is show in the Figure 10. It shows the code before the loop(). First six line use #define to indicate what is the word mean. For example, BT will represent" Serial1", and left will represent "10". Left means the left propeller power control pin, which is number 10. Right is the number 9... The 'state' character is used to receive the signal from BLE, so as 'state1'. And "cmd" is used to achieve the slider fun-ction. Integer SPEED2 is used to tell the motor the power need to output. Go into the setup(). We first define the parameter of BT, which using the BT.begin(9600). Next, we define which pin is going to be the Output or Input by the function pinMode().

```
void loop() {
  state = BT.read();
  cmd = "";
  if(state == 'S'){
    SPEED2 = 0;
    digitalWrite(leftDir, LOW);
    digitalWrite(rightDir, LOW);
    analogWrite(left, 0);
    analogWrite(right, 0);
  }
  else{
      if(state == 'F')//FORWARD
      {
         digitalWrite(leftDir, LOW);
         digitalWrite(rightDir, LOW);
         analogWrite(left, SPEED2);
         analogWrite(right, SPEED2);
         state1 = 'F';
      }
else if(state == 'R')// RIGHT
{
   digitalWrite(leftDir, LOW);
   digitalWrite(rightDir, LOW);
   analogWrite(left, SPEED2);
   analogWrite(right, 0);
   state1 = 'R';
}
else if(state == 'L')// LEFT
{
   digitalWrite(leftDir, LOW);
   digitalWrite(rightDir, LOW);
   analogWrite(left, 0);
   analogWrite(right, SPEED2);
   state1 = 'L';
}

else if(state == 'B')//BACKWARD
{
   digitalWrite(leftDir, HIGH);
   digitalWrite(rightDir, HIGH);
   analogWrite(left, SPEED2);
   analogWrite(right, SPEED2);
   state1 = 'B';
}
```

Figure 11: Arduino Code 2

The next part is the code when setup() is already be done. The loop() function will be execute over and over again. The code is showing in Figure 11.

The first line indicate that 'state' is going to receive the BLE signal, using read() function. And the following code is to decide what signal BLE transmit into the Arduino board.

If the signal we type in is 'S', then (state =='S') will be true. And the following code is to make the hovercraft to STOP.

For the other words. 'F' means to go forward, 'R' means to turn right, 'L' means to turn left. 'B' means to go backward. This is the first system we used to control hovercraft. These four sections are only control the hovercraft dir-ection. As for the speed control will be explained on the next page.

Also, the "state1" which record the cuerent state is for the speed control. We will explain its work on next page as well.

```
else if(state == 'T'||state == 't')
{
  digitalWrite(shoot,HIGH);
  delay(1000);
  digitalWrite(shoot,LOW);
}
else if(state == 'P'){
  delay(10);
  for(int i=0;i<3;i++){
    char c = BT.read();
    cmd += c;
  }
  SPEED2 = cmd.toInt();
  BT.println(cmd);
  BT.println(SPEED2);
  if(state1 == 'F'||state1 == 'B'){
    analogWrite(left, SPEED2);
    analogWrite(right, SPEED2);
  }
  else if(state1 == 'R'){
    if(SPEED2+50<255){
      analogWrite(left, SPEED2+50);
    }
    else{
      analogWrite(left, 255);
    }
    if(SPEED2-50>0){
      analogWrite(right, SPEED2-100);
    }
    else{
       analogWrite(right, 0);
    }
  }
  else if(state1 == 'L'){
     if(SPEED2-50>0){
      analogWrite(left, SPEED2-100);
    }
    else{
      analogWrite(left, 0);
    }
    if(SPEED2+50<255){
      analogWrite(right, SPEED2+100);
    }
    else{
       analogWrite(right, 255);
    }
  }
  cmd = "";
}
```

Figure 12: Arduino Code 3

We set the signal 'T' or 't' as the signal to shoot the airplane. The code is showing in the Figure 12.

The next part is the speed control. When the (state == 'P') is true. It means we sent a set of speed signal to the Arduino board. We use the slider unit to change the speed.

When the slider's thumb position has changed. BLE will sent a message combine with 'P' and a number which is the speed we want to change. The state will receive the 'P', and "cmd" will receive the integer. After we change the String into the integer which means SPEED2.

Next step is to check what state1 repr-esent. If it is 'L', then it says we what to make it turn left. In this condition, we will make the left propeller's speed minus 100. At the same time, the right propeller's speed will plus 100, so the hovercraft will turn left.

By now, we have introduce the first system we control the hovercraft. That is using four buttons to decide the direction, and a slider to control the speed we want.

```
    }
    else if(state == 'O'){
      delay(10);
      for(int i=0;i<3;i++){
        char c = BT.read();
        cmd += c;
      }
      int SPEEDL = cmd.toInt();
      analogWrite(left, SPEEDL);
      cmd = "";
    }
    else if(state == 'N'){
      delay(10);
      for(int i=0;i<3;i++){
        char c = BT.read();
        cmd += c;
      }
      int SPEEDR = cmd.toInt();
      analogWrite(right, SPEEDR);
      cmd = "";
    }
  }
}
```

Figure 13: Arduino Code 4

The last part is showing in the figure 13.

The main idea is to control both propeller speed by two sliders. Same idea, when the left control slider is changing. The state will be 'O', and SPEEDL will be the speed we want left propeller is. As for the right propeller is the same.

So the second control system is directly control the propeller's speed sperate.

3.2 Control Mobile App

3.2.1 The background of Thunkable

Programming might be a difficult discipline, especially for new programmers. Fortunately, there is a program which allows to create a mobile app without knowledge of any coding language.

Thunkable is a web-based platform that enables users without programming experience to build apps for Android and iOS. The platform can be found at thunkable.com and it uses a Google account for registration and login. Then it is possible to start developing a new app.

Thunkable has a user-friendly interface with a palette of useful tools. The whole programming language is nothing more but set of visual blocks which need to be connected properly. The whole coding process seems more like building from puzzle rather than „serious software engineering". Despite that it is still very interesting and sometimes challenging. After the code is done and succesfully compiled, a user can export it as **.apk* file using also QR code or by downloading it directly to the mobile phone.

3.2.2 Creating the code

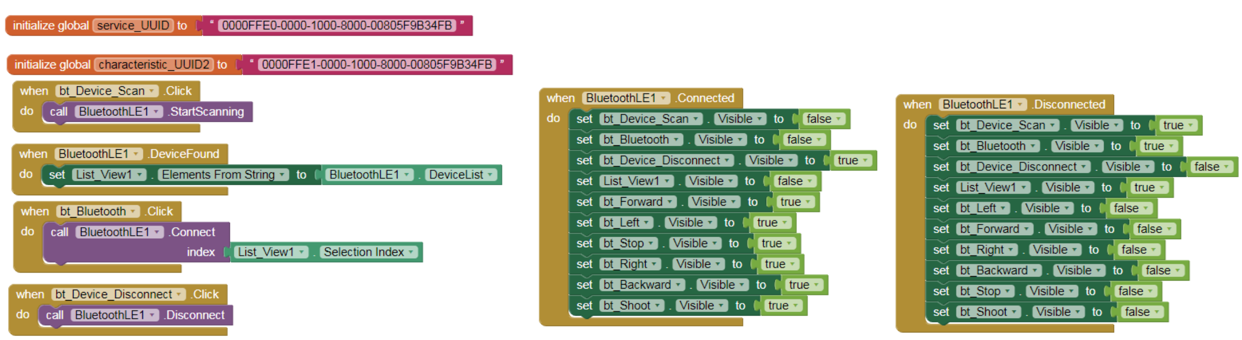


Figure 14: Thunkable Code 1

Figure 14 shows the code blocks to make the APP connect to the BLE. The first layout of APP is Figure 15. When clicking the Scan button, APP will start to search BT devices nearby. When picking the right device and click the BT image, the mobile phone will connect with the BT on Arduino board successfully.

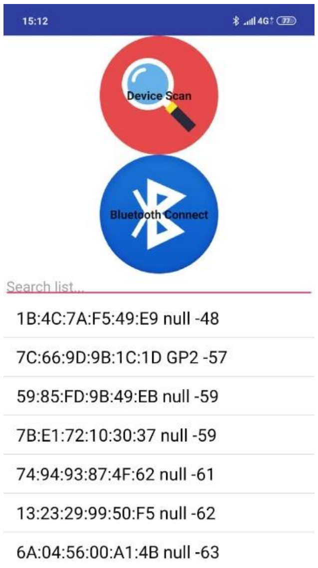


Figure 16: First layout

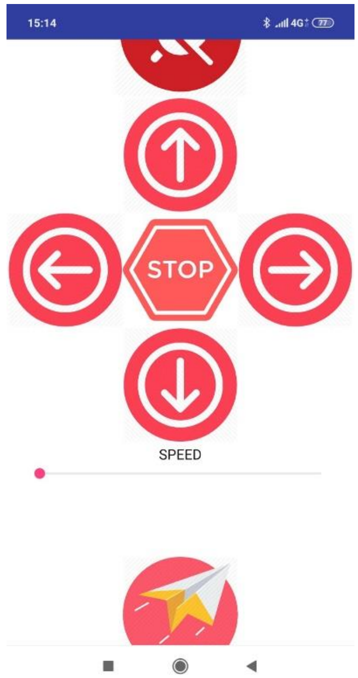


Figure 15: First control system layout

Figure 16 shows the first control system layout. The slider represents the speed control, and the up, down, right, left buttons control the direction.

Figure 17 shows the code blocks achieve the first control system.

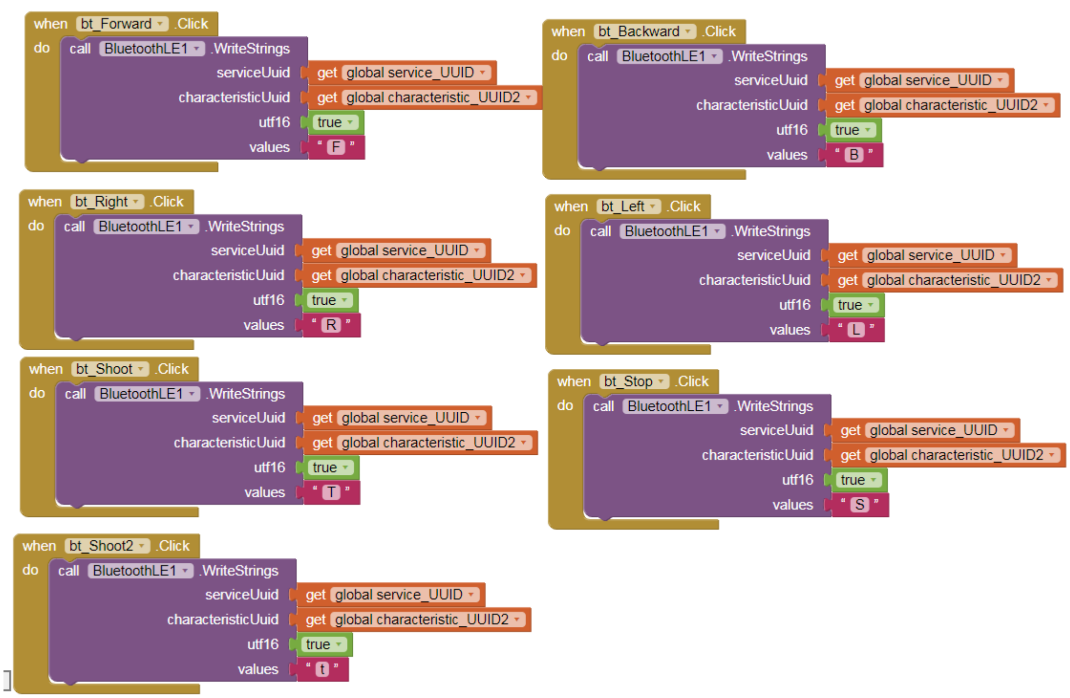


Figure 17: Code block

Figure 18 shows the second control system layout on the APP. The LEFT slider can change the speed of left propeller, and the RIGHT can change the right one. If we change the slider, then we can control the speed and direction by changing the speed separately.

Figure 19 shows the first and second control system using the slider to control speed's code blocks.

Figure 18: Second control system layout

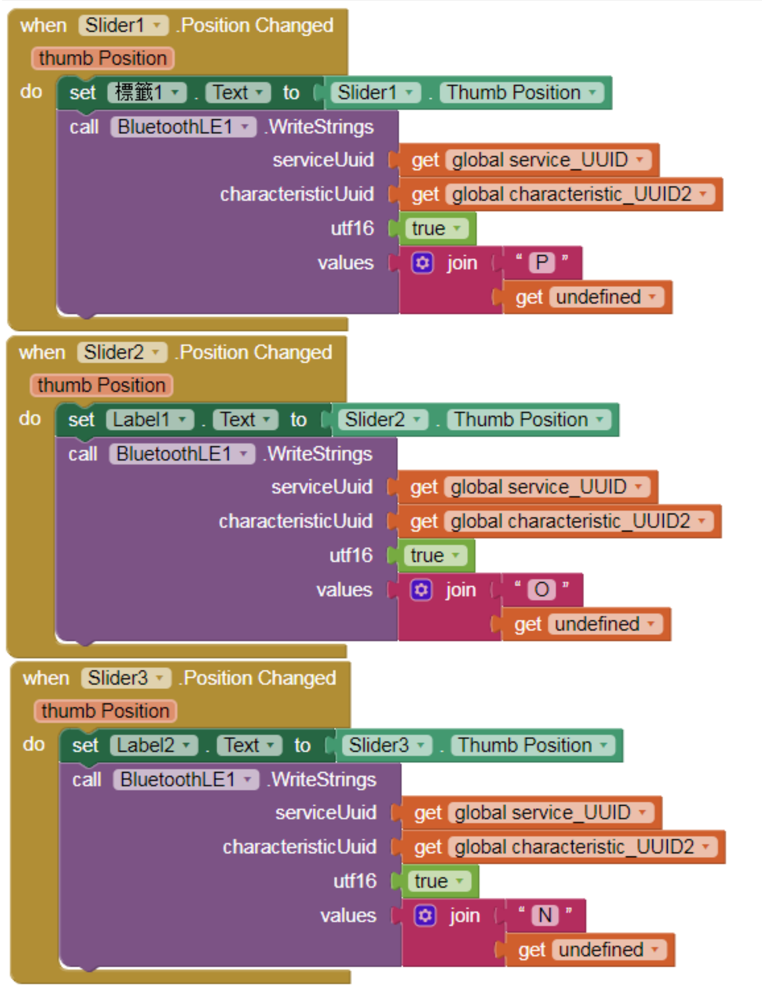


Figure 19: First and second layout with sliders

4 Conclusion

During the last five weeks our team did a lot of work. We started from zero and at the end of that period we reached a fully functional model of a remote control hovercraft. Step by step we had to deal with every small part which was necessary to accomplish the project. We have been challenged many times.

Project is finished. Our hovercraft is accessible by a smartphone and it is able to react on our commands in real time. Once establishing the Bluetooth connection the hovercraft has a function to move forward, backward, to turn right and left, to speed up or to slow down and to stop. Because of the handy user interface it is easy to adjust the power of the propellers and have the speed under control. In addition, the hovercraft carries an airplane which can be launched at will.

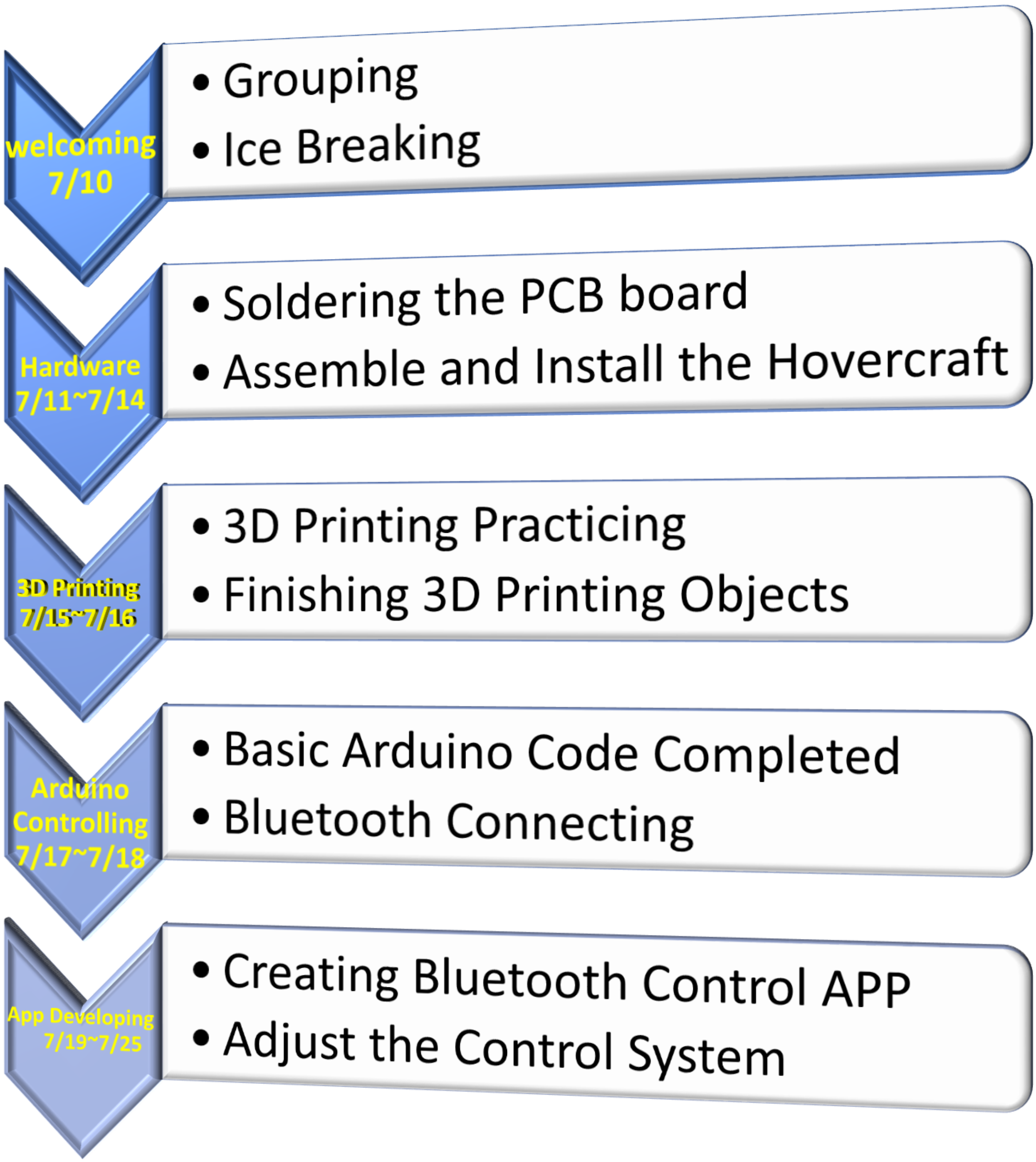
Now we would like to highlight the main branches in which we had to enlarge our knowledge and develop our abilities. They could be divided into two parts – hardware and software.

- Basic knowledge of electrical circuit and components (hardware)
- Soldering those small electrical parts on the PCB (hardware)
- Modelling objects in DesignSpark Mechanical (CAD) for the technology of 3D Printing (software)
- Establishing of the Arduino and Bluetooth communication path (hardware)
- Knowledge of the Arduino program language and creating code for control the hovercraft's engines (software)
- Learning the graphical programming language of the Thunkable software and creating GUI of a mobile app which has become a remote control tool for the hovercraft

Although it was sometimes hard to find the way how to move on with our project e.g. to plug in the correct cables or to find a bug in the code, thank to very well-composited manuals, understandable teachers' presentations and valuable tips or advice we were able to overcome every difficulty. We would like to thank to all professors, helpers and other CityU staff for the great organization of the whole project. We really enjoyed it and we learnt a lot. Good job!

5 Appendices

5.1 Appendice 1: Hovercraft Project Process Flow chart



Android Studio Learning 7/26~7/31

- Learning the Strcture of Android Studio

Report Writing 8/1~8/4

- Allocating the Report Task
- Finish Writing and Oral Reports

Finial Test 8/5

- Last Check the Hovercraft Function
- Practicing the Skill controlling the Hovercraft

Presentati on 8/6

- Oral Presentation

Competitio n 8/7

- Bumping Test
- Shooting Test

6 Reference

[1] „Fluke," [Online]. Available: https://www.fluke.com/en-us/learn/best-practices/measurement-basics/electricity/what-is-ohms-law. [Přístup získán 30 07 2019].

[2] „Electronics Club," [Online]. Available: https://electronicsclub.info/circuitdiagrams.htm. [Přístup získán 30 07 2019].

[3] Jimblom, „Sparkfun - Resistor," [Online]. Available: https://learn.sparkfun.com/tutorials/resistors/all. [Přístup získán 30 07 2019].

[4] Jimblom, „Sparkfun - Capacitor," [Online]. Available: https://learn.sparkfun.com/tutorials/capacitors/all. [Přístup získán 30 07 2019].

[5] Laboratory Manual for Hardware Component, Hong Kong: City University of Hong Kong, 2019.

[6] „Techopedia," [Online]. Available: https://www.techopedia.com/definition/2366/integrated-circuit-ic. [Přístup získán 30 07 2019].

[7] „Techopedia - PCB," [Online]. Available: https://www.techopedia.com/definition/2267/printed-circuit-board-pcb. [Přístup získán 31 07 2019].

[8] „Marketspaces - How To Solder: A Beginner's Guide," [Online]. Available: https://www.makerspaces.com/how-to-solder/. [Přístup získán 31 07 2019].

[9] „Wikipedia - 3D Printing," [Online]. Available: https://en.wikipedia.org/wiki/3D_printing. [Přístup získán 31 07 2019].

[10] „3DHubs," [Online]. Available: https://www.3dhubs.com/guides/3d-printing/. [Přístup získán 31 07 2019].

[11] „HowtoGeek," [Online]. Available: https://www.howtogeek.com/362939/how-does-3d-printing-work/. [Přístup získán 31 07 2019].

[12] „Arduino Micro," [Online]. Available: https://store.arduino.cc/usa/arduino-micro . [Přístup získán 31 07 2019].

[13] „Bluetooth - Wikipedia," [Online]. Available: https://en.wikipedia.org/wiki/Bluetooth. [Přístup získán 1 08 2019].