October 2018

Drone Movement Control using Gesture Recognition from Wearable Devices

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Drone Movement Control using Gesture Recognition from Wearable Devices

by

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A thesis submitted in partial fulfillment
of the requirements for the degree of
Master of Science in Computer Science
Department of Computer Science and Engineering
College of Engineering
University of South Florida

Date of Approval:
October 12, 2018.

Keywords: Gyroscope, Android, Moto 360, CrazyFlie, Crazyradio, Port-to-port

DEDICATION

To my parents, Someswara Rao and Pushpa Rama Devi for making me what I am now.

ACKNOWLEDGMENTS

I would like to express my heartiest gratitude to my supervisor, Dr. Sriram Chellappan for his never-ending support and encouragement during my research period. I would also like to thank Dr.Mehran Mozaffari Kermani and Dr. Tansel Yucelen to serve as my committee member and their valuable input and guidance. I thank my parents and friends for their consistent support, motivation and helping me through hard times. I am very grateful to my friend Kodhanda Karthik Siriyala for his constant support and advice all along my Master degree. I am very thankful to Gabriela Franco Munguia, Laura Owczarek, and Ryan Jose for supporting and helping me to solve my technical and non-technical issues. Lastly, I would like to thank Jesse Jaramillo and Tyler Wieczorek for helping me with the environment setup and help through the project.

TABLE OF CONTENTS

LIST OF TABLES ii

LIST OF FIGURES iii

ABSTRACT v

CHAPTER 1: INTRODUCTION 1

CHAPTER 2: PROJECT SETUP 3

CHAPTER 3: COMMUNICATION AMONG DEVICES 8
- 3.1 Using Bluetooth: Watch to Phone 8
- 3.2 Socket Programming: Phone to Computer 10
- 3.3 CrazyRadio: Computer to Quad-Copters 11

CHAPTER 4: CODING APPROACH 13
- 4.1 Android Application for Watch and Phone 13
- 4.2 Python for Communicating with the Drones 22

CHAPTER 5: ANALYSIS 25

CHAPTER 6: LIMITATIONS 33
- 6.1 Gestures Differ 33
- 6.2 Drone Drift 33
- 6.3 Maintaining Battery Life 34

CHAPTER 7: FUTURE WORK 35
- 7.1 Adding More Gestures for More Features 35
- 7.2 Implementing Drones to Pick Weights 35

CHAPTER 8: CONCLUSION 37

REFERENCES 39

ABOUT THE AUTHOR .... END PAGE

LIST OF TABLES

Table 2.1 Devices Used 7

Table 3.1 Communication Channels Used 12

Table 4.1 Libraries to Use Sensors 13

Table 4.2 Libraries to Send Data from Watch to Phone - Wearable. 16

Table 4.3 Libraries to Send Data from Watch to Phone - Tasks. 16

Table 5.1 Sensor Value Indices in the Array. 25

Table 5.2 Sensor Delay Options. 27

LIST OF FIGURES

Figure 2.1 Connection Between Watch and Phone. 4

Figure 2.2 Left to Right, Smart Watch and Phone used for the Project 5

Figure 2.3 A CrazyFlie Quad-Copter in Rest Position and Bitcraze Flow-Deck 6

Figure 2.4 A CrazyRadio with a USB Dongle Property. 7

Figure 3.1 Watch Sending Message to Phone via Bluetooth 8

Figure 3.2 Wear OS Application Home Screen and Settings Screen (Left to Right) 9

Figure 3.3 Phone and PC Communicating over WiFi 10

Figure 3.4 Computer Sending Signals to Drone via CrazyRadio 11

Figure 3.5 Computer Sending Signals to Multiple Drones over CrazyRadio 12

Figure 4.1 Code to Initialize and Use Gyroscope Sensor. 14

Figure 4.2 Handling Gyroscope Sensor's Data 15

Figure 4.3 Sensor Data Collection Control 16

Figure 4.4 Searching for Best Node and Updating Capability 17

Figure 4.5 Setting-up the Transfer to the Best Node. 18

Figure 4.6 Sending Messages Asynchronously in Background. 19

Figure 4.7 Method to Send Messages. 20

Figure 4.8 Methods of MessageClient. 21

Figure 4.9 Taking IP Address and Port Number as User Input. 22

Figure 4.10 Class Implementing Socket Programming. 23

Figure 4.11 Libraries for Drone Control. 23

Figure 4.12 Main Function of the Python Program. 24

Figure 4.13 Sending Signals to Drones According the Message Received. 24

Figure 5.1 Watch User Interface Initially. 28

Figure 5.2 Watch User Interface after Starting. 28

Figure 5.3 Watch User Interface While Capturing. 29

Figure 5.4 User Interface of Phone Initially. 30

Figure 5.5 User Interface of Phone after Data Entry. 31

Figure 5.6 User Interface of Phone While Capturing. 32

ABSTRACT

Gesture Recognition is a new and upcoming trend that is being widely used in wearable devices and mobile handheld devices. The sensors like Accelerometer, Gyroscope, Heart rate monitor, Barometer and Ambient Light are mostly being included within the device to detect the static or continuous motion, rotational velocity, heartbeat rate of the user, pressure and light conditions for the device respectively. Implementing algorithms to capture the readings of these sensors and implementing them in a necessary way allows a user to use the wearable devices for a wide variety of applications. One such application is controlling Drone that takes user input to determine their motion. A Drone can accept signals from a combination of computer and a radio dongle and would fly according to the accepted commands. The wearable device can detect the motion of the wearer's hand when moved left, right, up, down etc using the Gyroscope sensor. This information can be used to process and send the signals to the Drone to enable wireless and gesture-based movement control.

CHAPTER 1: INTRODUCTION

Gesture Recognition using wearable devices is an alternative to the existing method of giving inputs with devices such as a keyboard, mouse etc. It is a process in which sensors that are in the wearable device would be to capture a human movement or an action and would be converted into mathematical input using a device with computational capabilities. The human movements might be of hand or face when combined with facial recognition, eye tracking, voice recognition, etc is called perceptual user interface also known as PUI. PUI focuses on improving the ease of use and efficiency of the intended program of the software that increases the usability.

The concept of gesture recognition is already implemented in the computational field since the last few years in which the user has to interact with a screen by touching it or using a mouse. In recent times, in pursuit of making more natural and three dimensional, the above-mentioned sensors have been deployed in the devices. These sensors are being used along with cameras to achieve PUI. These approaches can be applied to a variety of causes like understanding sign language, 3-D gaming, wireless control etc. Our current project focuses more on using the sensors to wirelessly control a Drone.

Wearable and handheld mobile devices nowadays come with a variety of sensors. Hand-held devices like smartphones have a number of sensors when compared to the wearable device due to the limited architecture of wearable devices. The sensors that most popularly are in wearable are the accelerometer, Gyroscope, step counter, light, wrist tilt, rotation vector, orientation, gravity etc.

This basically means that the device has been packed with all the sensors which would detect a good number of movements made by the user. The sensors have properties depending upon their type. For example, the light sensor has a sensitivity meter toward the light and step counter has the property "value" which gives the number of steps taken by the user. In [1], the usage of the sensor properties of accelerometer, Gyroscope, and magnetometer sensors are collaboratively used and termed as "9-axis" sensors. The techniques like Principle Component Analysis and Linear Discriminant Analysis in order to extract the feature in an effective way. With the help of the support vector machine, the machine focuses on achieving the task of extraction with less computation time and higher accuracy.

All this process can be easily implemented using a development IDE (Integrated Development Environment) known as "Android studio", a tool developed by "IntelliJ IDEA" as stated in [2]. This IDE enables the user to write code for handheld or wearable devices that run with the Android operating system. At [3] the documentation of the IDE usage and support is provided to ease the programmer's usage. We have chosen the Android platform in as we have more flexibility to implement the desired features and modify the functionality according to our necessity.

CHAPTER 2: PROJECT SETUP

The current project focuses on controlling one or many drones at a time. In order to achieve this, we need the following devices: 1) Smartwatch with Android support. 2) Smartphone with Android studio. 3) Computer with Dongle setup. 4) One to 4 drones. In [4], a Robot Operation System has been implemented to achieve the drone control with gesture recognition. There are other systems in which the drone has a camera in which the gesture recognition would be detected using that camera implementing pattern recognition techniques.

In this situation given the limited feature set of the drones, we can use the proposed method of gesture recognition using wearable devices. The watch determines the readings of the Gyroscope sensor that is embedded in it which detects rotational motion. It is an efficient sensor that has the most sensitive readings toward the rotational hand movements of the user by calculating its angular velocity.

In [5], a study has been conducted over how the Gyroscope's multi-axial readings behave towards each motion of user's hand. This sensor is commonly made of crystal, ceramic and silicon. The angular velocity is calculated using Coriolis force [6] that is applied to an object which is vibrating. We selected a wearable smartwatch which has a good Gyroscope has been included. For our project, we selected "Moto 360 2nd Gen" watch which has the sensors Accelerometer, Ambient Light Sensor, Gyroscope and Vibration/ Haptics engine and comes with a battery of 300mAh (1.5 days). It runs on Android Wear 2.0 version operating system which has the good architecture to

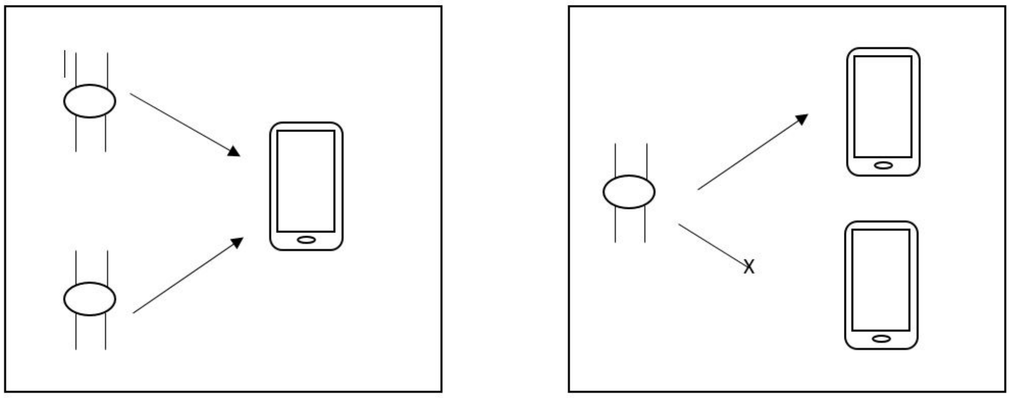


Figure 2.1: Connection Between Watch and Phone.

send and receive messages and data to a paired phone.

In order to take the signals from the watch, we need an and Android handheld device like a tablet or a phone. Since a mobile phone is handier, lighter and faster than a tablet, we had chosen to use an android phone. Compared to any other operating system, even android phones have more flexibility. In the current setup, a phone can be paired with one or more watches while a watch can be paired with only one phone at a time as shown in figure 2.1. Also, the watch can communicate only with the phone. Though there are architectures in which a watch can be connected to a computer, we have used a basic model of the watch and phone setup as we wanted the application to be a lightweight application without a bulky environment.

The phone can handle more data and has a quicker processing speed. Hence we have broken down the logic and code handling part into the phone. The Figure 2.2 shows the smartwatch and phone used for this project. Android provides an application in which one can control, monitor and troubleshoot a watch connected to a phone with "Wear OS" application. In this application,

Figure 2.2: Left to Right, Smart Watch and Phone used for the Project

we can check the battery life, the developer options for the watch. We can connect the watch and phone from this application and also while installing the custom application that we built, we can send the code from phone to watch via Bluetooth by turning the debugging over Bluetooth option in the wear OS application. The Figures in 3.2 show how the app looks like and what settings are available in it.

The quad-copter we used is called CrazyFlie 2.0 shown in figure 2.3, and the company that made it is called Bitcraze [7]. It weighs 27 grams, has a flight time of around 7 minutes. Uses a Lithium-Polymer battery. Below are three links for more information on it. Each CrazyFlie has a unique address that is set in the CrazyFlie PC client (version: Cfclient 2018.01.3). For example, the address is in the form 'radio://0/80/2M/E7E7E7E7E7', where the number 80 can be changed

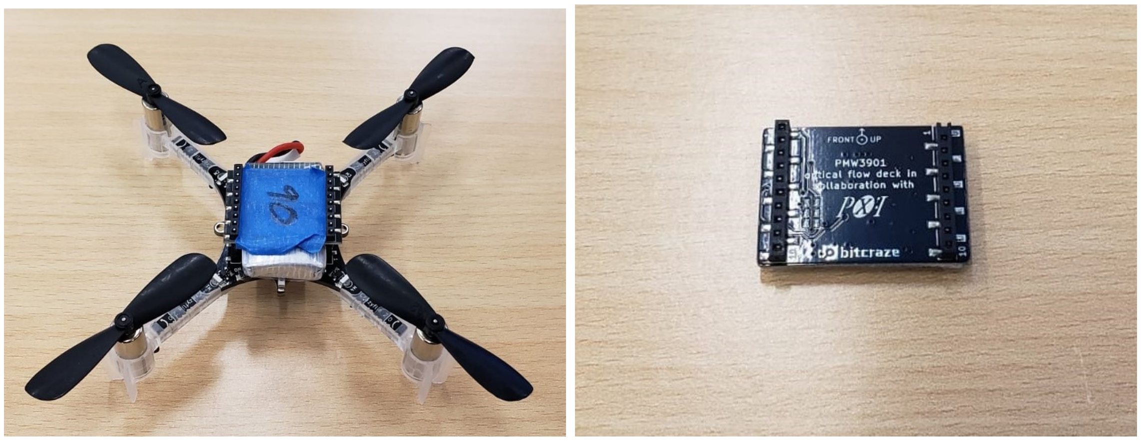


Figure 2.3: A CrazyFlie Quad-Copter in Rest Position and Bitcraze Flow-Deck

to identify different CrazyFlies.

For the project, we used four different CrazyFlies. On board, there is a gyro and accelerometer (MPU-6050) for moving along XY positioning. A sensor called 'Bitcraze Flow-deck' [8] shown in figure 2.3 is used for altitude. It has two sensors. The first is a Time of flight (ToF) sensor, which measures the distance to the ground. The second is an optical flow sensor that measures movements in relation to the ground. [8].

Information gets sent from the computer to the CrazyFlie, through the CrazyRadio [9]. It is a radio dongle that can be connected using USB port of the computer and has a capacity of 2.4 GHz. The computer must be installed with a CrazyRadio driver that is available from Windows Operating systems version XP to 10. The CrazyRadio is for now used only to communicate with the above mentioned Quad-Copter.

However, CrazyRadio has the capability to be flexible enough to be worked on other applications. The dongle is designed with economic 2.4 GHz chips of Nordic Semiconductor. The CrazyRadio has quite a few attractive properties. The USB BootLoader that comes with it, enables

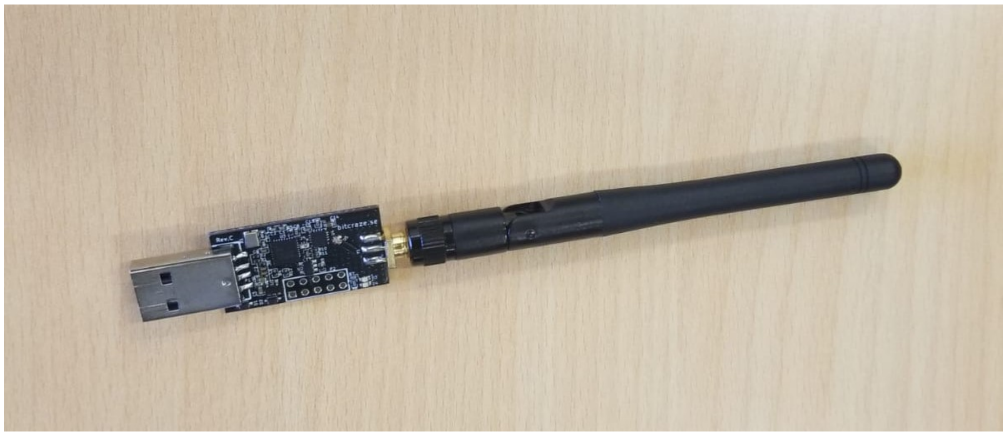


Figure 2.4: A CrazyRadio with a USB Dongle Property.

Table 2.1: Devices Used

Sno.	Device	Name
1	Wearable Smart Watch with Android support	Moto 360
2	Smart-phone with Android Support	Samsung S6
3	Computer with Drivers Installed	Acer Predator
4	Dongle that communicates with Drones	CrazyRadio
5	Single or Multiple quad-copters	CrazyFlie

upgrades with USB cable. The application can be made a stand-alone one if paired with an expansion header. It has a range of 1 kilometer which means it can send signals to drones which are as far as one kilometer. The figure, 2.4 shows that CrazyRadio that has been used for the project. The Dongle connects to the PC over USB and sends signals to the quad-copters. The table 2.1 shows the list of devices we had for this project.

CHAPTER 3: COMMUNICATION AMONG DEVICES

The whole project is designed to be wireless. Hence, the communication among the devices has also been set up to be wireless.

3.1 Using Bluetooth: Watch to Phone

The watch communicates with the phone using the Bluetooth connection that is established when the watch gets paired with the phone. It uses this connection to send and receive messages, data and even syncing the data it has. As discussed in 2, the watch can only pair with one phone at a time. This is because the watch is connected to the phone via Bluetooth which has a master and slave system, the phone being the master Bluetooth device. The master device would be having many slaves but the slave device has only one master device at a time.

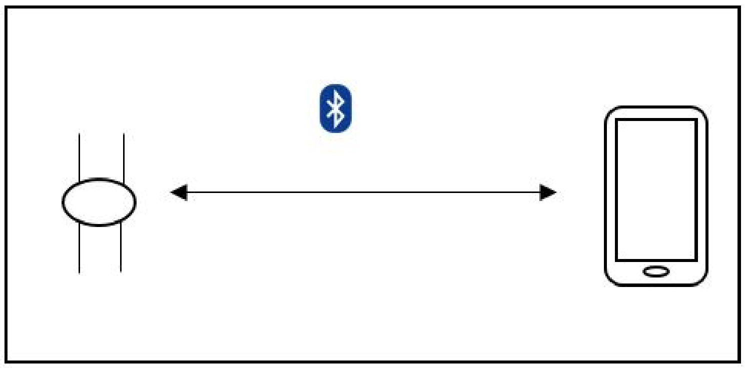
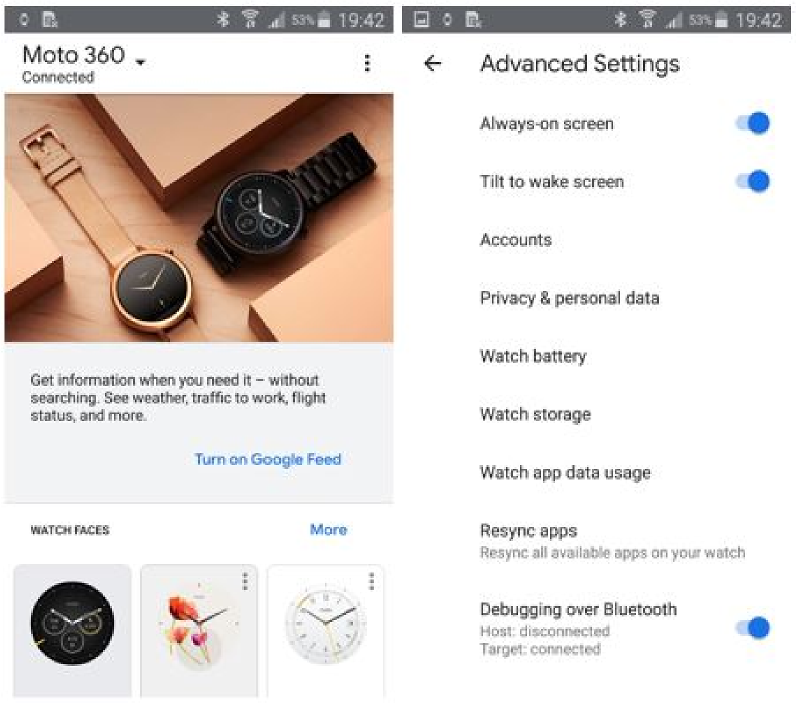


Figure 3.1: Watch Sending Message to Phone via Bluetooth



Get information when you need it – without searching. See weather, traffic to work, flight status, and more.

Always-on screen ●
Tilt to wake screen ●
Accounts
Privacy & personal data
Watch battery
Watch storage
Watch app data usage
Resync apps
Resync all available apps on your watch
Debugging over Bluetooth ●
Host: disconnected
Target: connected

Figure 3.2: Wear OS Application Home Screen and Settings Screen (Left to Right)

However, while the master device is connected to one slave device, it can communicate only with that particular slave device. The wearable device which we have has a Bluetooth 4.0 version embedded in it. Additional research on how Bluetooth works in wearable devices and their applications have been conducted in [10].

As represented in figure 3.1, the watch connects with the phone. This is done using the application called Wear OS. This application is available for all android phones and is free to download. The figure 3.2 shows the screenshots of the wear OS application. The first screen shows how the home screen after connecting to the watch. The second screen shows the settings of the watch which could be controlled over the phone. Enabling the last option, "Debugging Bluetooth", enables the app to be installed over Bluetooth.

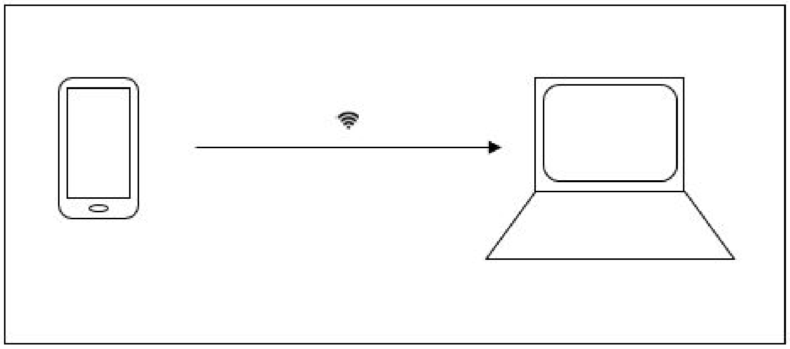


Figure 3.3: Phone and PC Communicating over WiFi

Once the application is installed, we wanted a system in which as soon as the user makes a movement, the device must be able to immediately take the action and send it to the phone. For this, we use Bluetooth as specified. The watch checks its gyro scope's values and determines the movement of the hand i.e., left or right or up or down. Then the watch sends this information as a message using the Bluetooth channel that it has already established. The watch and phone use "MessageAPI" API to send and receive messages.

3.2 Socket Programming: Phone to Computer

Now as the phone's Bluetooth has already been connected to the watch, the phone can no longer use the Bluetooth port to use for communication. In case, it wishes to use it, the phone's operating system has to switch the Bluetooth connection between the devices. In order to avoid that, we use socket programming. Detailed elaboration as in [11] gives more insight into this. A socket is a two-way communication's endpoint for two different programs that run on a network. These programs can be on the same system or a different system. Socket Programming is a technique where the devices can communicate among themselves over the wireless network or internet using

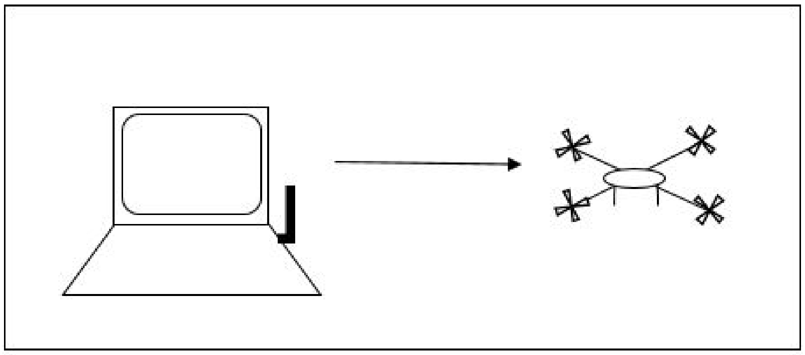


Figure 3.4: Computer Sending Signals to Drone via CrazyRadio

these sockets. The service need not be available the two devices have to be known about each others IP addresses. This would be done by knowing the network location. For this project, we record the network location manually. A socket has an identifier called "Port number" which enables the TCP layer to recognize the destination and sends the data to it.

In the current setup, in order to enable the socket programming, we need to have the phone and the PC on the same network. To achieve that, we have set up the phone and the PC to be on the Wireless network, WiFi. Shown in 3.3, the phone sends the signals to the computer over WiFi by using "Socket.Net" library in Java.

3.3 CrazyRadio: Computer to Quad-Copters

This part would be flawlessly handled by the CrazyRadio of which we discussed in 2. CrazyRadio can be connected to PC as an add-on hardware using the USB port. Now it acts similar to a WiFi dongle. This instead connects to the drones. As shown in figure 3.4, the PC has a dongle connected to it to communicate with the drone.

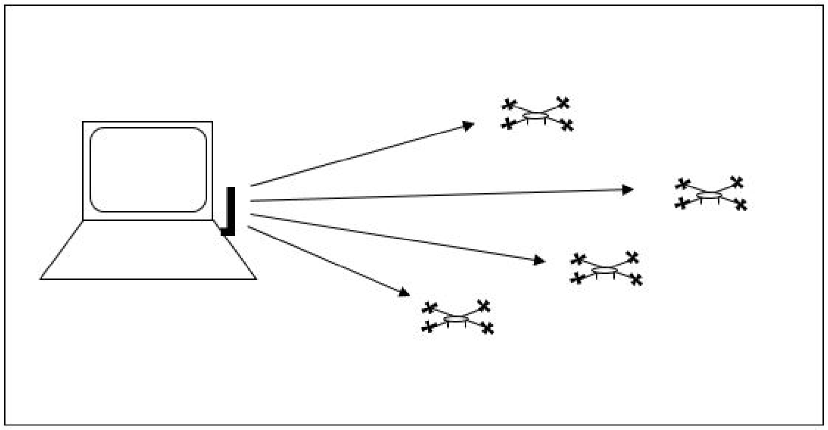


Figure 3.5: Computer Sending Signals to Multiple Drones over CrazyRadio

Table 3.1: Communication Channels Used

Sno.	Scenario	Communication Channel
1	Watch to Phone	Bluetooth
2	Phone to Computer	Socket Programming
3	Computer to Drone(s)	Dongle a.k.a CrazyRadio

This CrazyRadio would also keep track of the drones with the help of their unique IDs. It also coordinates the signals while controlling multiple drones. As shown in figure 3.5, even if there are multiple drones, a single CrazyRadio is sufficient to communicate with all of them. This step uses Python code which includes the Unique ID of the drones given in it. The CrazyRadio uses this ID to register them into the working model and sends signals to each one. It would send one signal at a time. Which means all four drones wouldn't be getting signal at the same time. There would be a gap of a millisecond or two in sending signal one by one. Hence the total communication could be broke down into different parts as shown in Table 3.1

CHAPTER 4: CODING APPROACH

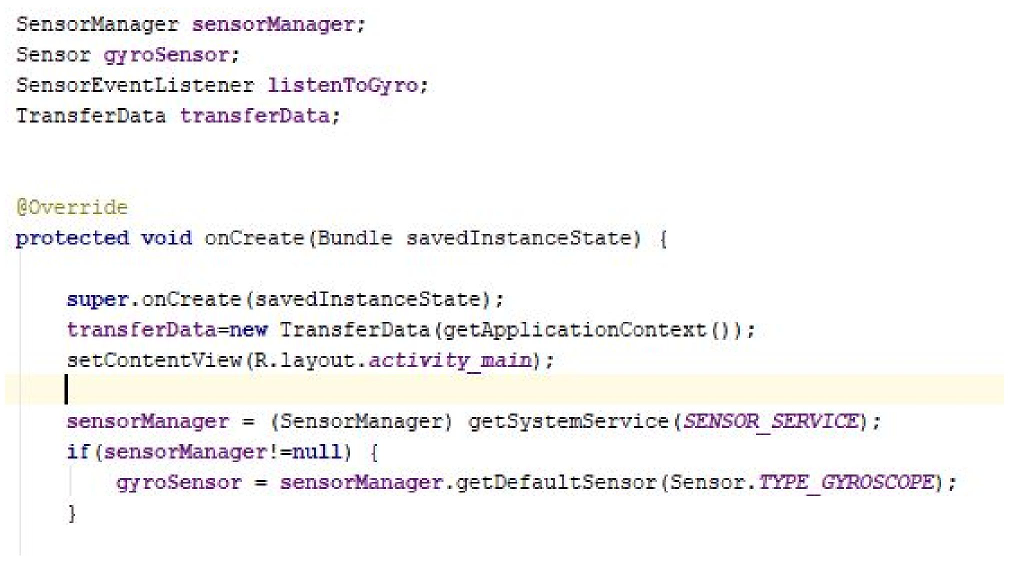
In order to make the application work as per the requirements, we need to deploy a piece of code into them. The platforms we chose and the programming languages we used for this project are all quite flexible and open source. This enabled us to easily modify the code and rebuild a working system according to our requirements.

4.1 Android Application for Watch and Phone

As mentioned and discussed previously, an application has been developed for both watch and phone that establishes a coordination among them. Let us first consider looking at the wear's application. We have used a library called "android.hardware" which allows us to use the hardware resources that the android device has. The Classes used and their uses are stated in table 4.1. In order to use this, we need to specify the "<uses-feature>" tag in the manifest file of the project.

Table 4.1: Libraries to Use Sensors

Sno.	Classes	Description
1	Sensor	Class that represents sensors
2	Sensor Event	Class that represents a sensor and also holds
		information about sensors (type, data, accuracy etc)
3	Sensor Manager	Gives Access to use device's sensors
4	SensorEventListener	An interface that Receives alerts from Sensor Manager
		on new Sensor Data or the sensor's data change.



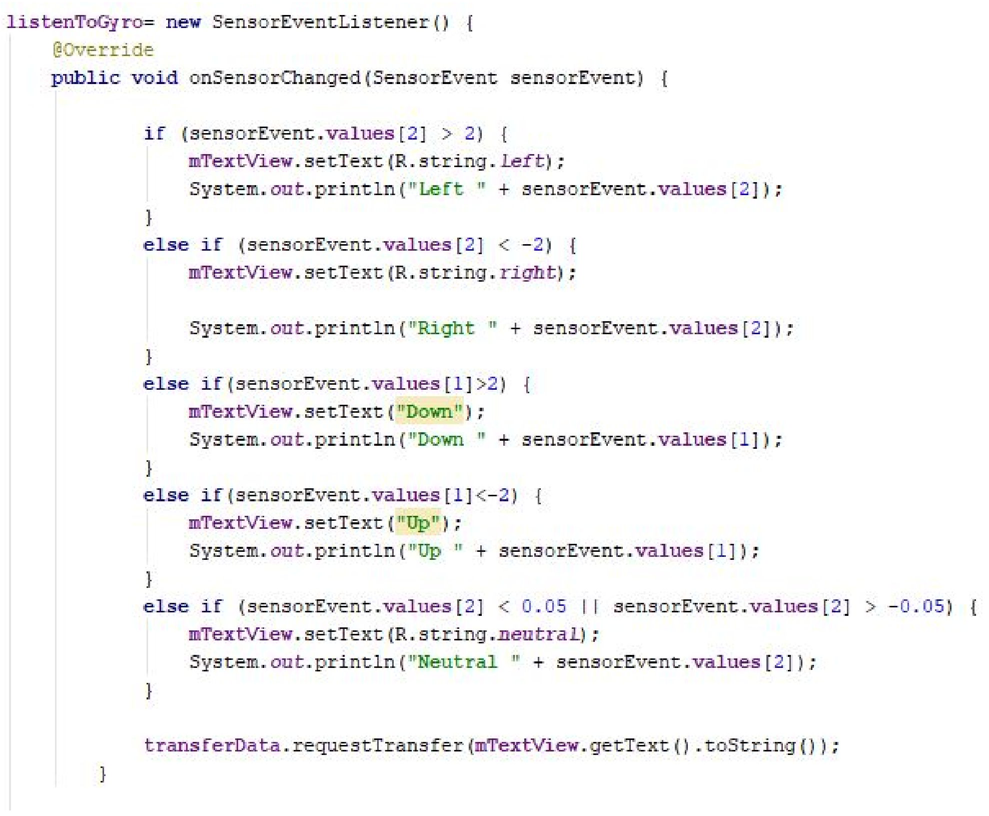
```
SensorManager sensorManager;
Sensor gyroSensor;
SensorEventListener listenToGyro;
TransferData transferData;


@Override
protected void onCreate(Bundle savedInstanceState) {

    super.onCreate(savedInstanceState);
    transferData=new TransferData(getApplicationContext());
    setContentView(R.layout.activity_main);

    sensorManager = (SensorManager) getSystemService(SENSOR_SERVICE);
    if(sensorManager!=null) {
        gyroSensor = sensorManager.getDefaultSensor(Sensor.TYPE_GYROSCOPE);
    }
```

Figure 4.1: Code to Initialize and Use Gyroscope Sensor

Once the classes are used, we can use their methods to access the sensor's data. The sensor class could be used to register the gyroscope sensor which we intend to use. In figure 4.1, we can see that the sensor class is used to get the gyroscope sensor, where the sensor manager has helped to get the gyroscope sensor registered to the current usage.

As we have the sensor now, we need to get an action listener which uses the sensor manager to get notifications whenever there is a change in the sensor's data. The listener is an interface which implements methods that constantly look for any notifications, in specific, events. Sensor Manager gives a notification whenever there is a change in the form of a SensorEvent object which has all the information about the sensor.

The listener interface takes this SensorEvent and lets the user program it according to his wish. Since the listener is an event, it has methods that have to be overridden in order to use them. The first method is "onSensorChanged" method. This method is called in when the listener receives an alert with SensorEvent as input. This means that the sensor's state has been changed.

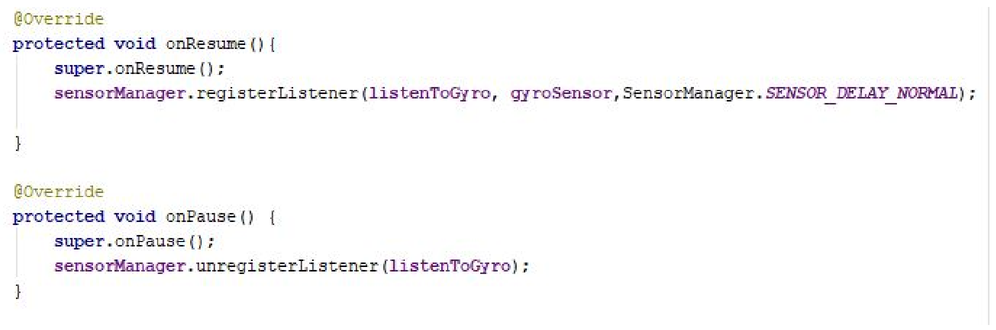


```
listenToGyro= new SensorEventListener() {
    @Override
    public void onSensorChanged(SensorEvent sensorEvent) {

            if (sensorEvent.values[2] > 2) {
                mTextView.setText(R.string.left);
                System.out.println("Left " + sensorEvent.values[2]);
            }
            else if (sensorEvent.values[2] < -2) {
                mTextView.setText(R.string.right);

                System.out.println("Right " + sensorEvent.values[2]);
            }
            else if(sensorEvent.values[1]>2) {
                mTextView.setText("Down");
                System.out.println("Down " + sensorEvent.values[1]);
            }
            else if(sensorEvent.values[1]<-2) {
                mTextView.setText("Up");
                System.out.println("Up " + sensorEvent.values[1]);
            }
            else if (sensorEvent.values[2] < 0.05 || sensorEvent.values[2] > -0.05) {
                mTextView.setText(R.string.neutral);
                System.out.println("Neutral " + sensorEvent.values[2]);
            }

            transferData.requestTransfer(mTextView.getText().toString());
        }
```

Figure 4.2: Handling Gyroscope Sensor's Data

The second method is "onAccuracyChanged" which has a sensor object and int as input which is triggered when the registered sensor's accuracy has been changed. We haven't used the second method in our project.

The figure 4.2 shows the usage of the "onSensorChanged" method in reading the gyroscope sensor's data and the SensorEvent object has been handled as required. The SensorEvent object also has the properties of the sensor which could be used while handling the sensor event and using the sensor's properties. The property ".values" returns all the properties of the sensor that is in use. In the current scenario, the gyroscope has the properties of "x-axis", "y-axis" and "z-axis". These values change when the sensor's direction, orientation is changed and hold a decimal value.



```
@Override
protected void onResume(){
    super.onResume();
    sensorManager.registerListener(listenToGyro, gyroSensor,SensorManager.SENSOR_DELAY_NORMAL);

}

@Override
protected void onPause() {
    super.onPause();
    sensorManager.unregisterListener(listenToGyro);
}
```

Figure 4.3: Sensor Data Collection Control

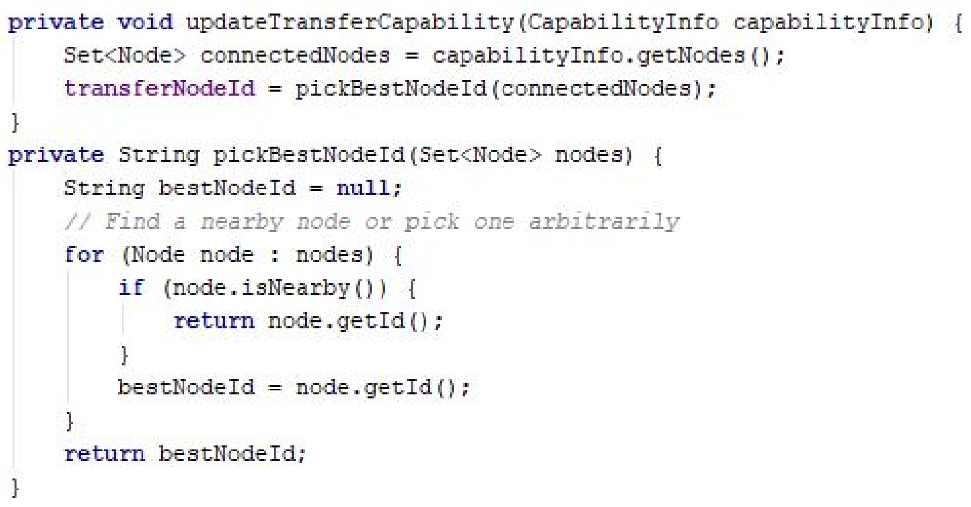
The wearable code also extends a WearableActivity, an abstract class which helps keeps track of the registering and de-registering the sensor. This makes sure that the algorithm doesn't run when it is not required to. It provides the access to "onResume" and "onPause" classes when extended. "onResume" is executed when the sensor is to run and "onPause" when the sensor doesn't have to. The implementation is given in figure 4.3.

Table 4.2: Libraries to Send Data from Watch to Phone - Wearable.

Sno.	Classes and Interfaces	Description
1	Capability client	API to learn the capabilities by a node on network
2	Capability Info	Provides information about capability on network
3	Node	Gives information about a node on network
4	Wearable	API that gives access to Wear Platform in Android

Table 4.3: Libraries to Send Data from Watch to Phone - Tasks.

Sno.	Classes and Interfaces	Description
1	Task	Shows an asynchronous action
2	Tasks	A utility for the Task object
3	OnFailureListener	This listener is called when a failure occurs
4	OnSuccessListener	This listener is called when the execution is successful



```
private void updateTransferCapability(CapabilityInfo capabilityInfo) {
    Set<Node> connectedNodes = capabilityInfo.getNodes();
    transferNodeId = pickBestNodeId(connectedNodes);
}
private String pickBestNodeId(Set<Node> nodes) {
    String bestNodeId = null;
    // Find a nearby node or pick one arbitrarily
    for (Node node : nodes) {
        if (node.isNearby()) {
            return node.getId();
        }
        bestNodeId = node.getId();
    }
    return bestNodeId;
}
```

Figure 4.4: Searching for Best Node and Updating Capability

Now that we have a way to get the sensor's data and the method to capture it, we need to send this to the phone over Bluetooth. To achieve this, we use "MessageClient" and "CapabilityClient". We used "Wearable" and "Task" library for this. Wearable library deals with the communication between the phone and the watch where Task library deals with maintaining the message or data in a synchronized way, in this case, immediately.

All these are available in "com.google.android.gms.wearable" and "google.android.gms.taskS" library. The table 4.2 shows the classes of wearable and uses while the table 4.3 shows the same of classes of Tasks. The watch has a capability that has to be entered in the values. The watch when requested to transfer the data, looks for the all the nodes nearby that have the same capability.

Here the nodes are the processes running on one phone or different phones. This can be done by implementing the functions as in figure 4.5. We have to also specify that the phone to uses this capability by specifying the same in the values field. This way the phone's application registers itself into the list of devices with the capability.

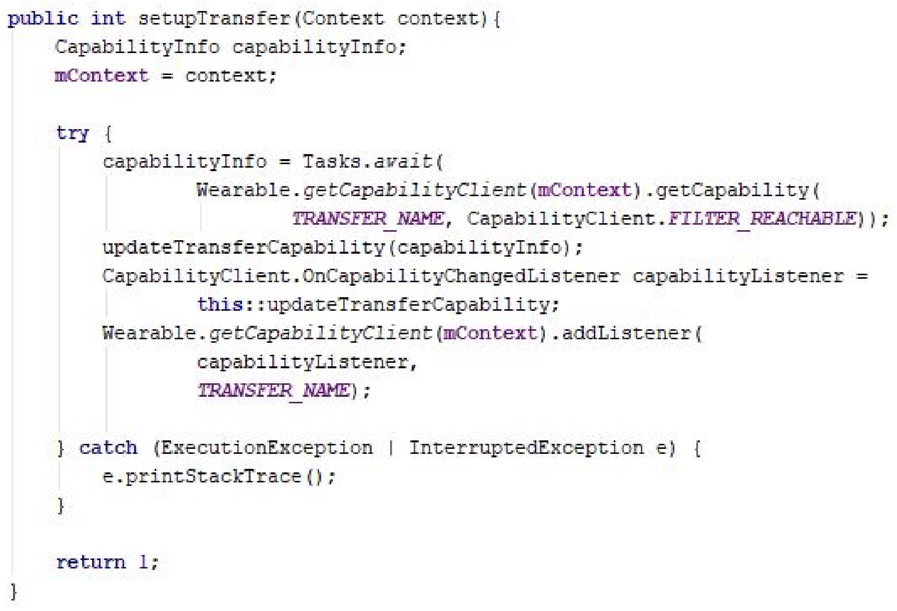
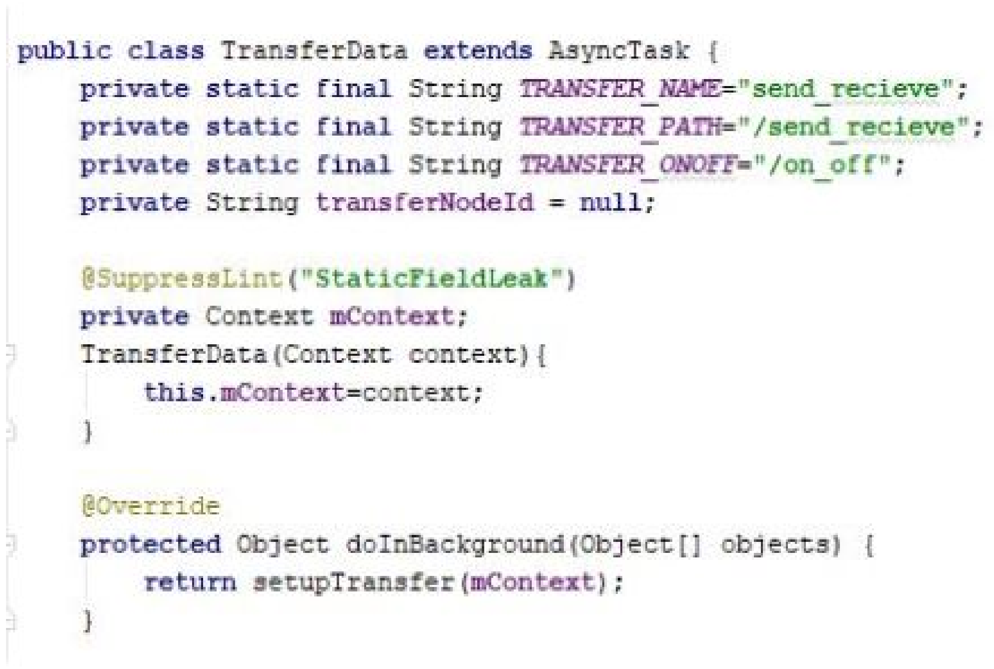

```java
public int setupTransfer(Context context){
    CapabilityInfo capabilityInfo;
    mContext = context;

    try {
        capabilityInfo = Tasks.await(
                Wearable.getCapabilityClient(mContext).getCapability(
                        TRANSFER_NAME, CapabilityClient.FILTER_REACHABLE));
        updateTransferCapability(capabilityInfo);
        CapabilityClient.OnCapabilityChangedListener capabilityListener =
                this::updateTransferCapability;
        Wearable.getCapabilityClient(mContext).addListener(
                capabilityListener,
                TRANSFER_NAME);

    } catch (ExecutionException | InterruptedException e) {
        e.printStackTrace();
    }

    return 1;
}
```

Figure 4.5: Setting-up the Transfer to the Best Node.

This best node that has the capability can be used to set up the transfer. Here, the CapabilityClient and Wearable are used to get the information and establish the connection between the phone with the specified capability and the Wearable device i.e, the watch. The Tasks class is used to make the process wait when there is no node with such capability.

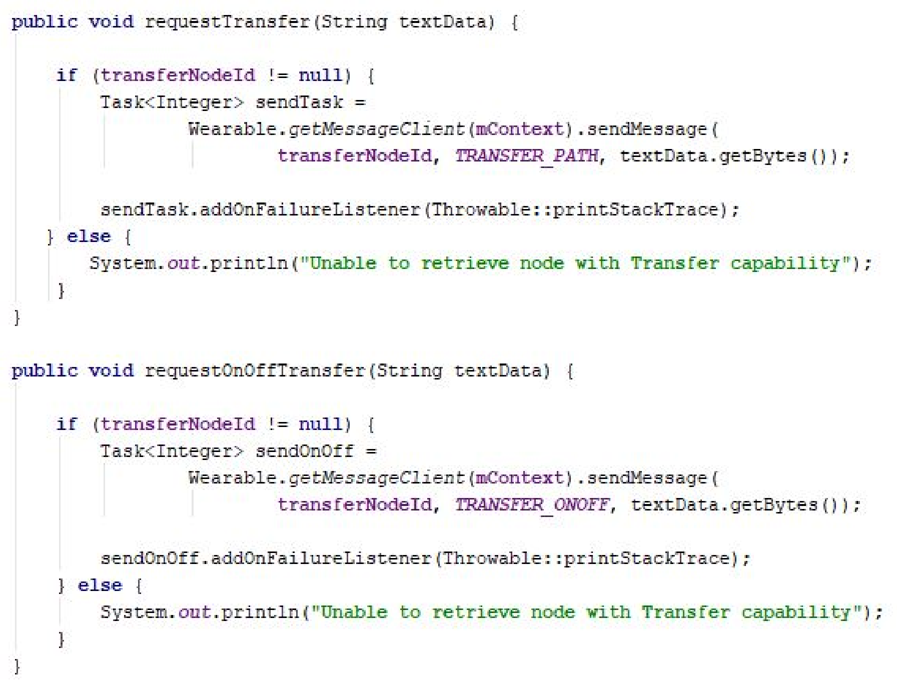
We can now create a class to Transfer the data from watch to phone as shown in 4.6. In this class, the transfer has to be done immediately when the sensor data has been changed. Hence we would be using the AsyncTask Interface to achieve this. This interface helps us define the tasks that have to be done in the background. In 4.6 we can also see that the TRANSFER NAME and TRANSFER PATH are defined as static strings which are none other than the capability name and the path that helps the phone to cross check if the message that it has received is intended to it or not. Also, The string TRANSFER ONOFF is the capability for the button that we have to stop or start recording the sensor data.



```java
public class TransferData extends AsyncTask {
    private static final String TRANSFER_NAME="send_recieve";
    private static final String TRANSFER_PATH="/send_recieve";
    private static final String TRANSFER_ONOFF="/on_off";
    private String transferNodeId = null;

    @SuppressLint("StaticFieldLeak")
    private Context mContext;
    TransferData(Context context){
        this.mContext=context;
    }

    @Override
    protected Object doInBackground(Object[] objects) {
        return setupTransfer(mContext);
    }
```

Figure 4.6: Sending Messages Asynchronously in Background.

The AsyncTask, when implemented, has to have "doInBackground" method which executes in the background. This method is pretty simple as it takes an object as input and gives an object as output. So we can be versatile to use any input and get an output. As we are done setting up, we just need to now request the transfer of data which is done in figure 4.7. We can use the AsyncTask interface by importing the "android.OS" library. The request transfer method that we have created would first check if there is a node or not. If there is no node, then the function would throw an error to the user regarding the same else it would use the Task object to initialize a task. After initializing the task, we use the Wearable class to obtain the message client. The message client can be used to send the message to the phone and it takes three inputs. First is the node ID, which we get from the setup transfer function. The second input is the path which we defined it as a static string and would help the phone authenticating its message. The third input is the data or

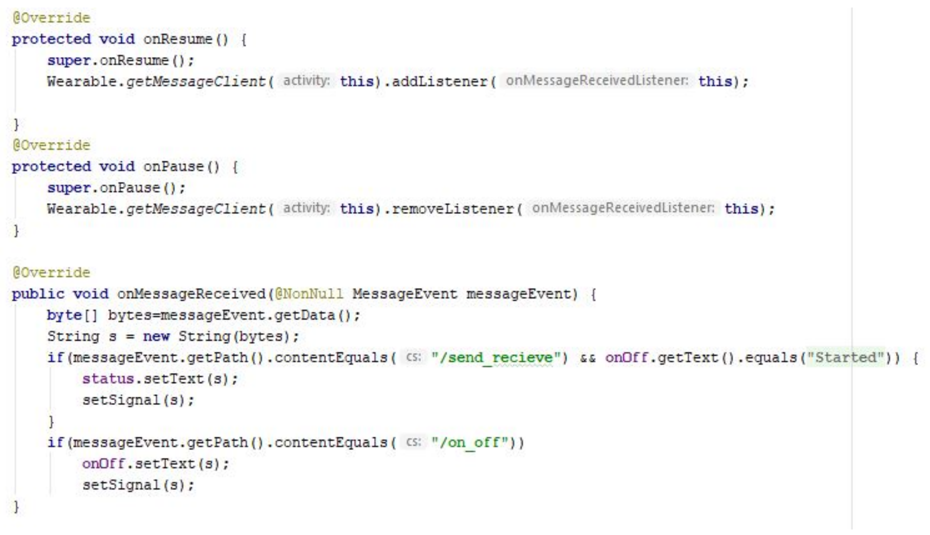


```
public void requestTransfer(String textData) {

    if (transferNodeId != null) {
        Task<Integer> sendTask =
                Wearable.getMessageClient(mContext).sendMessage(
                        transferNodeId, TRANSFER_PATH, textData.getBytes());

        sendTask.addOnFailureListener(Throwable::printStackTrace);
   } else {
       System.out.println("Unable to retrieve node with Transfer capability");
    }
}

public void requestOnOffTransfer(String textData) {

    if (transferNodeId != null) {
        Task<Integer> sendOnOff =
                Wearable.getMessageClient(mContext).sendMessage(
                        transferNodeId, TRANSFER_ONOFF, textData.getBytes());

        sendOnOff.addOnFailureListener(Throwable::printStackTrace);
    } else {
        System.out.println("Unable to retrieve node with Transfer capability");
    }
}
```

Figure 4.7: Method to Send Messages.

the content of the message which we intend to send over the established connection channel. The second function in 4.7 is to send the messages regarding the sleep state or active state of the sensor.

As now we are done by the code at the watch side, let us look at how these messages have to received and handled on the phone side. The phone activity would implement the "MessageClient" interface and use the "OnMessageRecievedListerner". The listener has to be initialized and registered. The interface needs three methods to be implemented. The first method is "onResume", which should use the resume method in the parent class. This method lets the listener know when to start expecting a message. The second method. "onPause" is quite opposite to the "onResume" method on when it is called. The "onPause" method also overrides the parent's method and calls it. This method is executed when the application has no longer need to receive the messages. The third method is "onMessageRecieve" method. This message is executed when a message is received



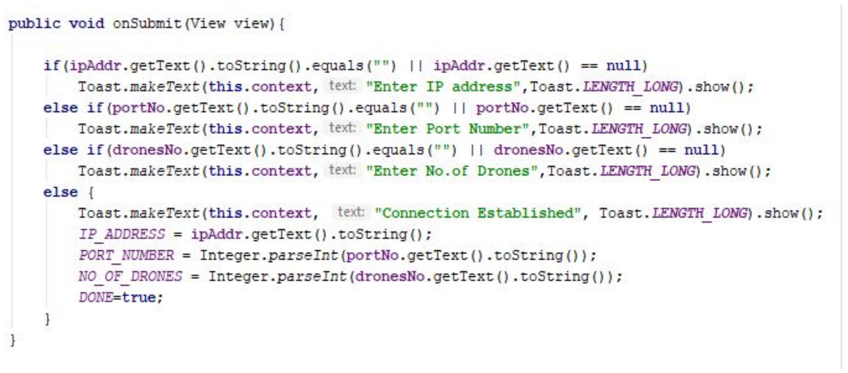
```
@Override
protected void onResume() {
    super.onResume();
    Wearable.getMessageClient( activity: this).addListener( onMessageReceivedListener: this);

}
@Override
protected void onPause() {
    super.onPause();
    Wearable.getMessageClient( activity: this).removeListener( onMessageReceivedListener: this);
}

@Override
public void onMessageReceived(@NonNull MessageEvent messageEvent) {
    byte[] bytes=messageEvent.getData();
    String s = new String(bytes);
    if(messageEvent.getPath().contentEquals( cs: "/send_recieve") && onOff.getText().equals("Started")) {
        status.setText(s);
        setSignal(s);
    }
    if(messageEvent.getPath().contentEquals( cs: "/on_off"))
        onOff.setText(s);
        setSignal(s);
}
```

Figure 4.8: Methods of MessageClient.

by the application. As we can see in figure 4.8, we can see all the three methods being implemented and being overridden.

While receiving a message, the "onMessageRecieved" function gets a MessageEvent object. This object has the message data in it. The message data is in the form of bytes which we have to convert into a string. Then this message is authenticated using the message path property. After authentication, we can add the custom set of code lines which we want to.

SetSignal is a custom, user-written function which is intended to convert the string that is extracted from a stream of bytes to a desirable data. For example, if the watch sends the signal saying "up", the stream of bytes when converted to string would be "up". For the Drone to fly in the upward direction, we need to send the signal 0. Hence, we used "SetSignal" function to convert the strings to Drone-understandable signals. Now as we have the signals ready, we need to send them to the phone. For that, we need to use socket programming. As discussed, we need an IP address of the device in order to communicate with it over TCP using the port numbers. Hence



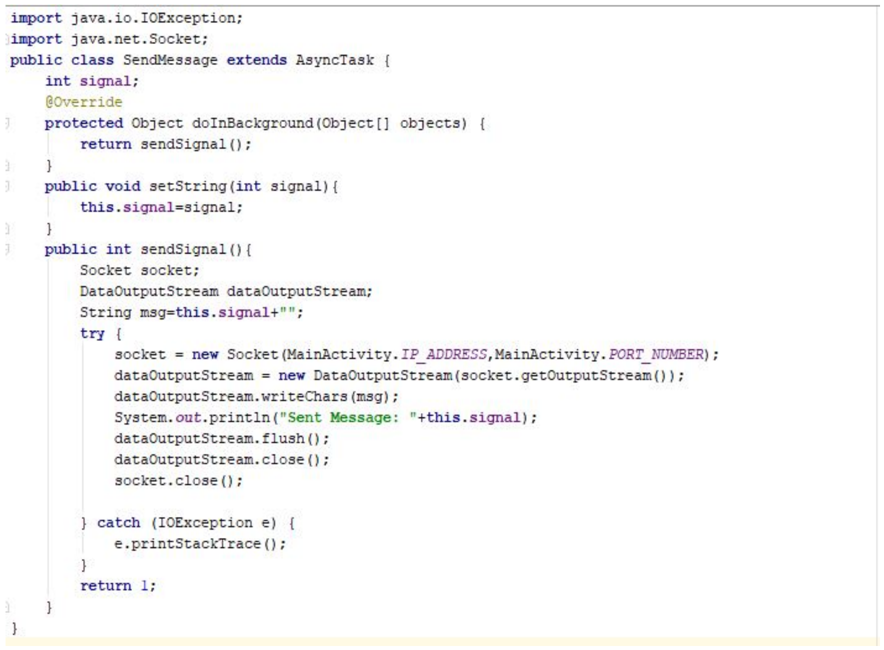
```
public void onSubmit(View view){

    if(ipAddr.getText().toString().equals("") || ipAddr.getText() == null)
        Toast.makeText(this.context, text: "Enter IP address",Toast.LENGTH_LONG).show();
    else if(portNo.getText().toString().equals("") || portNo.getText() == null)
        Toast.makeText(this.context, text: "Enter Port Number",Toast.LENGTH_LONG).show();
    else if(dronesNo.getText().toString().equals("") || dronesNo.getText() == null)
        Toast.makeText(this.context, text: "Enter No.of Drones",Toast.LENGTH_LONG).show();
    else {
        Toast.makeText(this.context,  text: "Connection Established", Toast.LENGTH_LONG).show();
        IP_ADDRESS = ipAddr.getText().toString();
        PORT_NUMBER = Integer.parseInt(portNo.getText().toString());
        NO_OF_DRONES = Integer.parseInt(dronesNo.getText().toString());
        DONE=true;
    }
}
```

Figure 4.9: Taking IP Address and Port Number as User Input.

we use the user interface to let the user put in the IP address and port number as in figure 4.9. We have also added the input for no of Drones are about to be controlled so that the signal can be sent. The message that has to be sent to the Computer has to be done in the background and simultaneously. Hence we use a class that implements AsyncTask for this too as we did before. The "doInBackground" function sends the signal. "DataOutputStream" is an object which sends the signal as a stream of bytes to the given socket object which has to be created and initialized with an IP address and a port number. This can be seen in figure 4.10.

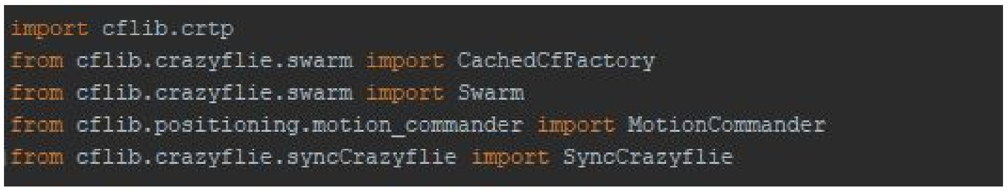
4.2 Python for Communicating with the Drones

The computer uses Python code to Control the Drones. This code is in integration with the CrazyRadio and uses the libraries as in 4.11 . The code is executed in the python shell and is quite fast and flexible. It has the list of IDs of all the Drones that are possibly about to fly. It also has the functionalists like a "Run sequence" which executes in a loop, "reset estimator" and the main function. The reset estimator function handles the parameters of the Drones. Here, we declare few global variables which are uniform across the program. They are: IP address, Port



```java
import java.io.IOException;
import java.net.Socket;
public class SendMessage extends AsyncTask {
    int signal;
    @Override
    protected Object doInBackground(Object[] objects) {
        return sendSignal();
    }
    public void setString(int signal){
        this.signal=signal;
    }
    public int sendSignal(){
        Socket socket;
        DataOutputStream dataOutputStream;
        String msg=this.signal+"";
        try {
            socket = new Socket(MainActivity.IP_ADDRESS,MainActivity.PORT_NUMBER);
            dataOutputStream = new DataOutputStream(socket.getOutputStream());
            dataOutputStream.writeChars(msg);
            System.out.println("Sent Message: "+this.signal);
            dataOutputStream.flush();
            dataOutputStream.close();
            socket.close();

        } catch (IOException e) {
            e.printStackTrace();
        }
        return 1;
    }
}
```

Figure 4.10: Class Implementing Socket Programming.

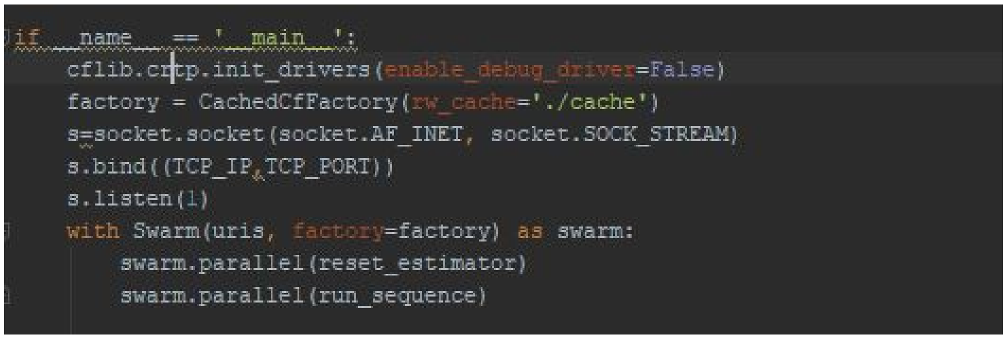


```python
import cflib.crtp
from cflib.crazyflie.swarm import CachedCfFactory
from cflib.crazyflie.swarm import Swarm
from cflib.positioning.motion_commander import MotionCommander
from cflib.crazyflie.syncCrazyflie import SyncCrazyflie
```

Figure 4.11: Libraries for Drone Control.

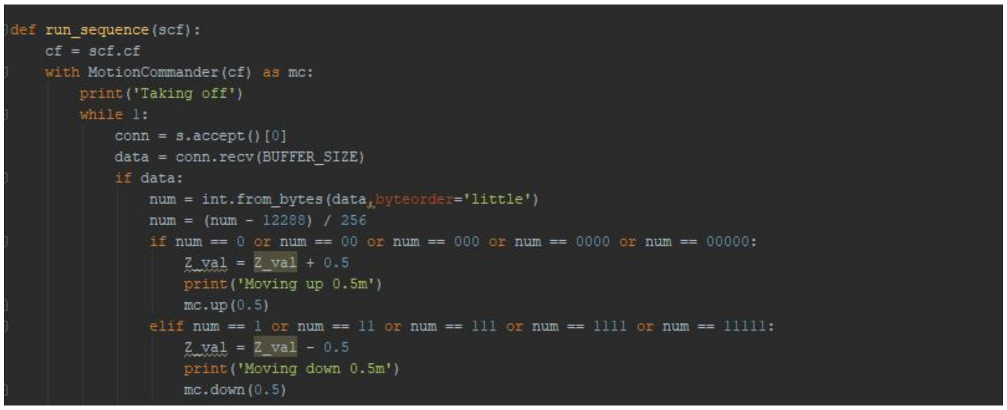
number, URIs (IDs) of the Drones, Buffer size, which means the largest number of bytes that can be transferred. This Program uses the Socket and time libraries to handle the data transfer and asynchronous execution respectively.

The figure 4.12 is the main function of the program where the execution starts. In this function, we register the socket by creating a socket object using the IP address and the port number. This socket is then started for listening which means it constantly checks for messages. This function also implements the "run sequence" and "reset estimator" to be run constantly. The



```python
if __name__ == '__main__':
    cflib.crtp.init_drivers(enable_debug_driver=False)
    factory = CachedCfFactory(rw_cache='./cache')
    s=socket.socket(socket.AF_INET, socket.SOCK_STREAM)
    s.bind((TCP_IP,TCP_PORT))
    s.listen(1)
    with Swarm(uris, factory=factory) as swarm:
        swarm.parallel(reset_estimator)
        swarm.parallel(run_sequence)
```

Figure 4.12: Main Function of the Python Program.



```python
def run_sequence(scf):
    cf = scf.cf
    with MotionCommander(cf) as mc:
        print('Taking off')
        while 1:
            conn = s.accept()[0]
            data = conn.recv(BUFFER_SIZE)
            if data:
                num = int.from_bytes(data,byteorder='little')
                num = (num - 12288) / 256
                if num == 0 or num == 00 or num == 000 or num == 0000 or num == 00000:
                    Z_val = Z_val + 0.5
                    print('Moving up 0.5m')
                    mc.up(0.5)
                elif num == 1 or num == 11 or num == 111 or num == 1111 or num == 11111:
                    Z_val = Z_val - 0.5
                    print('Moving down 0.5m')
                    mc.down(0.5)
```

Figure 4.13: Sending Signals to Drones According the Message Received.

"run sequence" function converts the received messages into the signals and sends them to the Drones. In the figure 4.13, the half implementation of the run sequence function. It opens a connection with the socket we initialized and started receiving the messages at the beginning and closes the connection at the end of the function. Also, it can be observed the connection object also receives data in the form of bytes which is later converted into integers. After the conversion, these integers are used to send signals to the Drone through the dongle.

CHAPTER 5: ANALYSIS

There are many interesting points that this project has given out. This chapter discusses these points and draws out the deductions from them and the outcomes of the project that we constructed in 2 and 4. These deductions have been applied to overcome the real-time challenges that are faced.

The first deduction that was made is about the properties of the gyroscope. As we see that the gyroscope's properties have been used in the code which is represented in figure 4.2. The code uses the property called "values" which as discussed contains the properties of the sensor. The properties are an array of these values object. For the gyroscope, we have the "x-axis" value of the sensor in the zeroth index of the "values" array. The value can be access using the statement as shown in the code line, 5.1.

$$sensor.values[index] \tag{5.1}$$

Table 5.1: Sensor Value Indices in the Array.

Property	Index	Usage	Return Value	Unit of Measure
X-axis	0	sensor.values[0]	float	rad/s
Y-axis	1	sensor.values[1]	float	rad/s
Z-axis	2	sensor.values[2]	float	rad/s

To use the "y-axis" and "z-axis", the indexes would be 1 and 2 respectively. Hence, as a whole, the usage statements would be as shown in the table 5.1. The values that are returned by these statements are integer values, to be specific, they a signed floating point values which are decimal numbers that might be positive or negative.

Another deduction we can be made on this sensor property is that the z-axis value could be used to track the horizontal movement of the wearer's hand. Which means the z-axis property would help us to track if the user has moved their hand to left or right based on its value that it has returned when used the "values" feature on it.

The verdict is that when the hand is moved left, the z-axis reading of the sensor readings is positive. When the hand is moved to the right, the z-axis readings give negative values. Similar to the y-axis readings. They are negative when the hands have moved upward and the values are positive when the hand is moved downward. If the user would make a movement parallel to the ground, but perpendicular to him, which depicts the motion of "punching", the x-axis would be helpful in tracking this motion. This project didn't require such a movement as we haven't planned to use it in the current setting. Hence the x-axis behavior is yet to be studied.

The sensor senses when there is a movement in the hand. It would record even the slightest movement in it. For example, the user has worn a watch and is standing with the hand raised perpendicular to him, the sensor values would still change as it is not a practically a rest position. Human hand makes a very slight movement even when the person tries to stay still in a practical situation.

$$SensorManager.SENSOR\_DELAY\_NORMAL \tag{5.2}$$

Table 5.2: Sensor Delay Options.

S.no	Value Name	Delay Time in ms	Usage
1	SENSOR_DELAY_FASTEST	0	gets value as soon as possible
2	SENSOR_DELAY_GAME	1	Suitable for Games
3	SENSOR_DELAY_UI	2	Suitable for User Interface
4	SENSOR_DELAY_NORMAL	3	Suitable for Orientation changes

In order to control the sensitivity of this gesture recognition, with the code line as in the code line 5.2. There are three values of sensor delay which are given in table 5.2. The sensitivity can be controlled by implementing the necessary value to the sensor manager and it would capture the values with that delay. Since SENSOR_DELAY_NORMAL is the best for this case, it has been used to adjust the sensitivity.

This delay can be further handled in the code by giving certain thresholds when the algorithm has to process. For example, as we see in figure 4.2, the code only handles when the sensor values that are greater than 2 and less than -2. These values are reached only when a user makes a complete left or right rotation respectively. The Drones are sensitive to the immediate signals. Which draws a situation in where the user could make an accidental minute left or right movement which the sensor reads and the project would send a signal to the Drones. But, The Drones need a little delay between the signals else they would crash. These accidental or unintentional movements might cause these crashes in order to avoid that, we need to handle the sensitivity of the sensors.

The User Interface has been designed to be simple, user-friendly as well as aesthetic. The color choices and backgrounds have been selected keeping in mind that this project would be used or demonstrated in an area with brighter conditions. The functionality that has been included is intended to make the process simpler for the user.

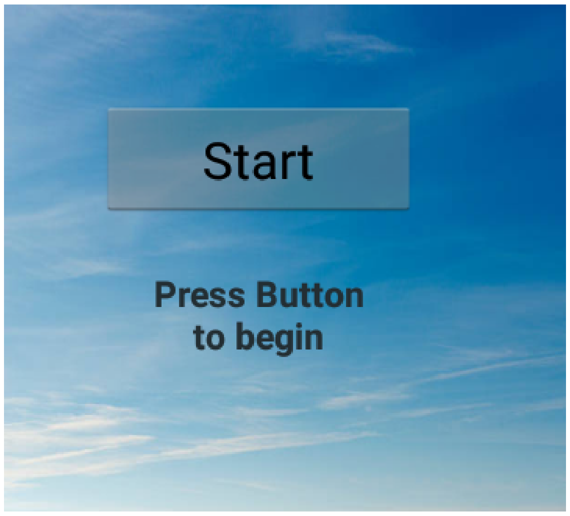


Figure 5.1: Watch User Interface Initially.

As shown in figure 5.1, the initial screen of the watch interface looks like a plain screen with a button on it and an instruction below it to click the button to start the process. The Start button when clicked would start capturing the sensor data. This would also start the process of sending the signals. The screen would then look like figure 5.2.

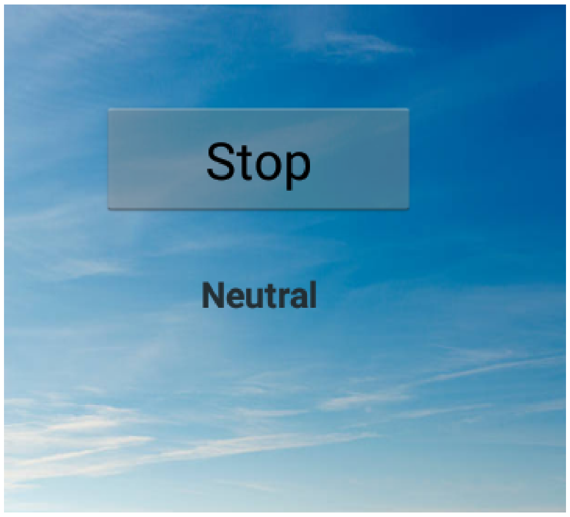


Figure 5.2: Watch User Interface after Starting.

Once the start button is clicked, the button changes to a "stop button" and the text below would also change according to the movement. As it is shown in figure 5.2, the start button has now been changed to stop which means that the process has started and the user could click on the stop button whenever he wishes to stop the capture.

Clicking the stop button would also send a signal which would make the Drones land safely to the ground. In this case, sending the signal, "8" to the Drones makes them land safely on the ground. This is a more convenient way for the user as he only needs to click a button on the watch instead of the traditional method of force stopping the python program.

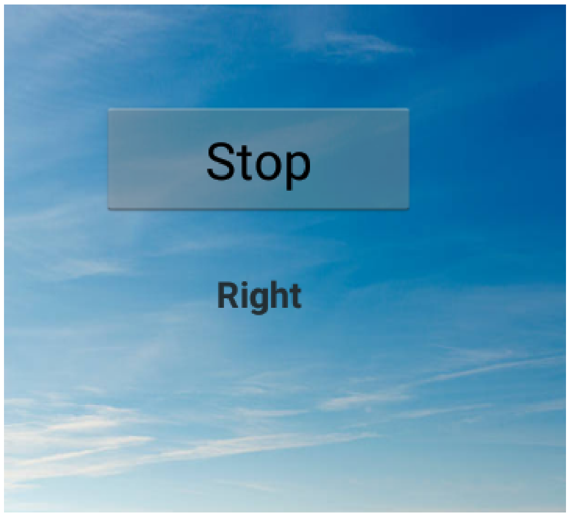


Figure 5.3: Watch User Interface While Capturing.

The Text below the button would change according to the process. At first, it is an instruction but later, after turning the capture on, this text shows the visual feedback of the movements the user has made. This enables the cross-checking and immediate feedback facilities to the user. This text would be left, right, up, down or neutral which are the textual representation of the user's hand movement as shown in figure 5.3.

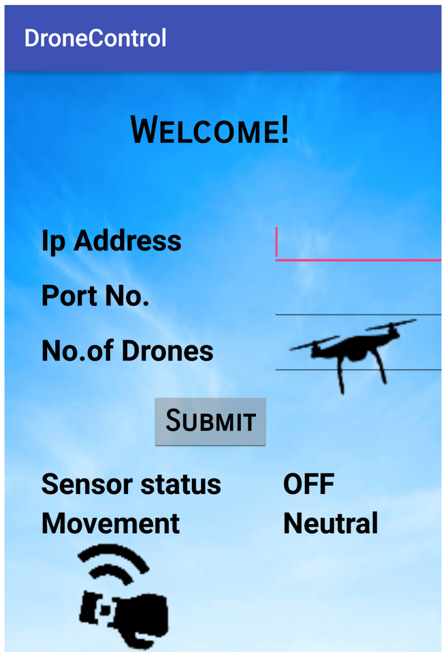
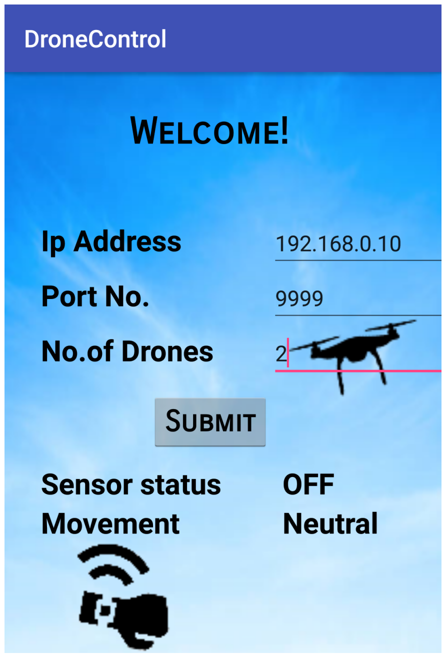


Figure 5.4: User Interface of Phone Initially.

Since we have seen the watch interface and how it works, we can now jump onto the phone's interface and its working. The figure 5.4 shows the initial screen of the application. It has the input for IP address, Port number and the Number of Drones. Since the IP address and Port number are not always constant and rather tend to change with the change in the network, this would be a better way for the user to enter them in runtime than making changes in the code.

The IP address field is intended to take the IP address of the computer which is on the same network. The Port number field accepts the port number for the socket communications. The number of Drones field takes a single integer which represents the count of the Drones that is taken for the current setting of the project. These fields when entered and hit submit, the values get stored to the variables as we have seen in the figure 4.10. In the figure5.5, see a sample input being given to the application



Ip Address 192.168.0.10

Port No. 9999

No.of Drones 2

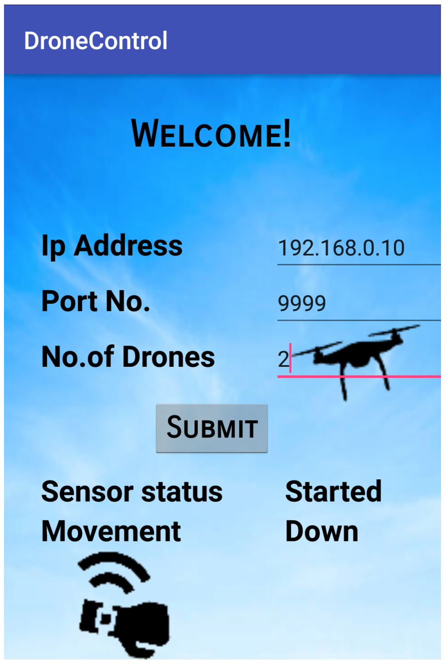
Sensor status OFF

Movement Neutral

Figure 5.5: User Interface of Phone after Data Entry.

The submit button calls a function internally that binds the entries in the user interface to the underlying variables. This is basically the first step of our project set up. Once we have all the devices charged and turned on, the computer's IP address has to be determined. This IP address has to be given in this application as an input.

At the computer side, in the python program, we must update the IP address and assign a port number which can be a combination of any 4 random digits, ranging from 0001 to 9999. After this, we need to register the unique IDs of the Drones into the python program. After that, we can start the capture by clicking on the start button of the watch. After Clicking on "Submit" button, the user would be given a toast message i.e., a pop-up message on the screen saying, "Connection Established" giving them a feedback that the connect has been established successfully and the system is ready for a data capture.


DroneControl

WELCOME!

Ip Address 192.168.0.10

Port No. 9999

No.of Drones 2

SUBMIT

Sensor status Started

Movement Down

Figure 5.6: User Interface of Phone While Capturing.

Once the start button is clicked on the watch, the text against the "Sensor Status" would change to start. It would say "Stopped" if the stop button is clicked. But initially, it would be "OFF". The text against the "Movement" label shows that same feedback as of the watch. It stays "Neutral" when the capture is not running, but when the capture has started, it would show the same value which is on the watch that represents the captured hand movement. This can be seen in figure 5.6 where the sensor has been started and the user has moved down which could be seen on the screen.

CHAPTER 6: LIMITATIONS

Though the sensitivity levels are checked and all other care is taken, this system has some limitations which have to be addressed in order to get a foolproof system.

6.1 Gestures Differ

There is always a possibility that a movement may be done totally different by another person. A person may move their arm just from their elbow when someone asks them to move their arm upward while some might move his or her whole arm until the shoulder to do the same. In these cases, the readings of the sensors, differ a lot. Some might move their arm pretty quickly while someone might take a while to do it. All these gestures need to be understood by the algorithm which needs a lot of data to learn from.

6.2 Drone Drift

The Drones have sometimes experienced a drift while positioning themselves. This has been added as they would avoid colliding with one another and would move farther when there is an obstacle but this sometimes causes a problem when the user actually wants the two Drones to be nearer to one another. Also if these Drones are used in a windy environment they would be vulnerable to loss and damage. They should always be used in a supervised and a controlled condition which is under a Drone protector nets and a drift detector.

6.3 Maintaining Battery Life

The current setup needs four devices to be charged and maintained. The watch has to be kept turned on all the time while the project is being carried out and which would consume a lot of battery. Turning the screen off would cause the application to go sleep and we would not be able to get the reading. The same case with the phone and the computer. Hence the devices should be charged and maintained throughout the process. The Drones also have evidently lesser charging life. They have the flight time of seven minutes and the batteries have to be replaced when they run out of power.

CHAPTER 7: FUTURE WORK

The future works of this project may include the following ideas.

7.1 Adding More Gestures for More Features

A Drone may have many features. Some might have a camera access while some may have a GPS enabled on them. We can extend the algorithm in such a way that a gesture made by the user can control these abilities. Like a wave may make the camera turn on. We can also make the Drones to form a certain shape with the gestures. For example, consider 5 Drones have been taken and four of them (Drone numbers, 1,2,3,4) have been arranged as a square and the fifth one is placed at the center. When the user makes a gesture, say, two consecutive upward movements quickly, the Drones 1,2,3,4 move one step upward and the Drone 5 moves two steps upward. This forms a pyramid structure of Drones. Complex applications of this can be used in many ways.

7.2 Implementing Drones to Pick Weights

The given model when implemented with Drones of higher capability which can carry larger weights, can be used by people with challenges and difficulty in lifting weights to easily relocate object around them. When studied the sensitivity of the sensors with people having different health conditions with difficulty in movement, and the sensors are tuned to it, the algorithm can be used to enable them in an easy relocation of objects. This can be implemented in large scale by implementing the algorithm over micro-integrated chips to the wheels of trolley bags or trolleys carrying goods so that human effort could be reduced in shifting them as one may be able to do it with a simple gesture. Another application of this technique would be to achieve a complex task. For example, an object has to placed on a high altitude place, we can use Drones to do that.

CHAPTER 8: CONCLUSION

This project is a demonstration of how a simple setup can be made to use a gesture recognition pattern to apply in a real-world scenario. All the equipment that is used in this experiment is so lightweight and economic. They are also flexible and easily personalized. Usually, materials that are economic do not come with a good flexibility of customization. But with the implementation of algorithms in a good way, makes this task easier. The algorithm need not be complex or use extra libraries and utilities to work. For this project, we have considered using the existing resources to the fullest the achieve the output.

Gesture recognition as it evolves, would bring down new challenges and new possibilities as one goes on exploring it. Once all these cases are served and we know how to deal with them, we can develop a foolproof system and could be used in many applications. There was development in which the devices were made wireless in every possible way. Now the systems that are hands-free are more evolving as they are less stressful and easy to handle.

As discussed, the applications could be very large and could be used for noble causes and in helping challenged individuals. This could also be a next big thing in the security and surveillance systems. Likewise, when used with care and security, these systems could be having a wide application. Although, these systems are highly risked towards hacking and unauthorized controls. Once evolved, these systems would be highly relied on. At that stage, once hacked, the hacker can have control over a major part of the victims routine. Avoiding such complications would help us make the most effective usage of the gesture recognition. Recent times, machine learning and Artificial Intelligence have been popular and we could see the application in every other application. Researches being conducted which would include the gesture recognition with machine learning and Artificial intelligence in which the habits and mannerisms could be captured by the system and could be reproduced by the Artificial Intelligence and could recreate them. Projects like the current one would be stepping stones for the future more stabilized in which the outcomes could be used and recreated to achieve a similar or more complex task.

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