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Development of Smart UAV (Drone) ozone (O_3) monitoring system in Port Harcourt, Rivers State, Nigeria

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Abstract

We hereby report a detailed design and fabrication of our indigenously developed smart UAV (drone) Ozone, O_3, monitoring system, using locally sourced materials in Nigeria. Our device is locally built from scratch to finish using materials available to us. Our design comprises a small lightweight (Polystyrene), Rotors, Arduino Joystick, Arduino Nano Board, 434 MHz Transmitter Module, 1 KΩ Resistor, Vero Board, Connecting wires, 9 Volts Battery, Antenna, simple and cost-effective multi-sensor system for multiple measurements of atmospheric phenomena and related climate information. We have used a long-range wireless communication module with real-time monitoring and visualizing software applications embedded on our device to access live data, track trends, and archive historical data for comparisons (data logger). We have also obtained original ozone datasets after conducting test flight measurement experiments at the launch site (Rivers State University Campus) Port Harcourt, Nigeria.

Keywords: Drone; Ozone; Monitoring; Transmitter; Receiver

1. Introduction

Unmanned aerial vehicle (UAV), most often referred to as *drones*, is an aircraft that is controlled remotely or autonomously and contains sensors, target designators, offensive weapons, or electronic transmitters with an intended target objective [1]. These target objectives could be in areas of military endeavors [2, 3], civil engineering [4, 5], search and rescue [6-8], construction and infrastructure inspection [9, 10], remote sensing [11, 12], precision agriculture [13, 14], and even photography [15, 16]. UAVs can be astonishingly effective, delivering significantly more range and endurance than equivalent manned systems since they are not constrained by a crew, life-support equipment, or the design-safety standards of manned aircraft [17]. Due to their versatility, standoff capability, and ease of deployment, unmanned aerial vehicles (UAVs) are being used in a wide range of military and civilian applications [18, 19]. UAVs have recently seen significant growth and investment. By 2025, it is anticipated that UAVs, will generate annual sales of more than $82.1 billion [20].

Irrespective of certain drawbacks [21-23], UAVs have grown in popularity. The development of drone systems with enhanced and refined systems has been made possible by technology advances in sectors like blockchain, artificial intelligence, and machine learning [24, 25]. These systems give more security, safety, and efficiency to help drone missions succeed.

The control system of most robust UAVs has been designed to regulate and navigate tiny, unmanned, jet-turbine steam-powered rotary-wing craft so as to permit the craft to keep up controlled flight, and come back to its original position, with none operator involvement using waypoint design technology [26, 27]. Operator error has been one of the primary causes of UAV mishaps in the current environment [28], which calls for rigorous human monitoring of UAV operations

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[29]. The non-linear model for predictive tracking control (NMPTC) is widely used to promulgate efficient network algorithm, using gradient-descent method to control the motion path in connection with an autonomous online optimization to track and investigate the working principles of UAVs [30].

The availability of high-quality atmospheric measurements over extended spatial and temporal domains provides unquestionable value to meteorological studies. Despite the need for such data, these measurements are not necessarily easy to acquire, especially within the atmospheric boundary layer (ABL) [31]. Therefore, this research was geared towards the development of a smart UAV for monitoring the Ozone (O_3) in part of Port Harcourt, Rivers State, Nigeria.

2. Material and methods

The system developed is made up of two main units; the UAV system transmitter and the UAV system receiver units.

2.1. The UAV System Transmitter Unit

The components used for fabrication of the Drone transmitter system are Arduino Joystick, Arduino Nano Board, 434 MHz Transmitter Module, 1 KΩ Resistor, Vero Board, Connecting wires, 9 Volts battery, and antenna. The transmitter part of the drone consists of Joystick, Arduino Nano Board and the 434 MHz Transmitter module as the main components that creates the connection between the control pad and the Drone. To implement the desired plan, we connected all VCC and V+ on all modules with the 5V pin on the Arduino board and connected GND pin on all module with the GND on the Arduino. We also connected the VER pin on the joystick with the A0 on the Arduino and linked the HOR pin on the joystick with the A1 embedded to the Arduino. The SEL pin was connected to the joystick with the Vin on the Arduino before connecting the Data pins on the RF-TX and RF-RX together and both were further linked with D10 on Arduino.

We further connected ANT pins on RF-TX and RF-RX together and also linked both of them to the D1/TX on Arduino followed by connecting the first two legs of the potentiometer between GND and A3 on Arduino. When this was successfully fitted, we connected the third leg of potentiometer to the negative terminal of the 9V battery and finally connected the battery to the power input on the Arduino. After these connections, we merged the circuit to our laptop and launched the Arduino integrated developer experience (IDE) to respond to our written computer program suitable for each of the components using C++ programing language (See appendix A.1). After writing the program, we uploaded it to the Arduino board for automation.

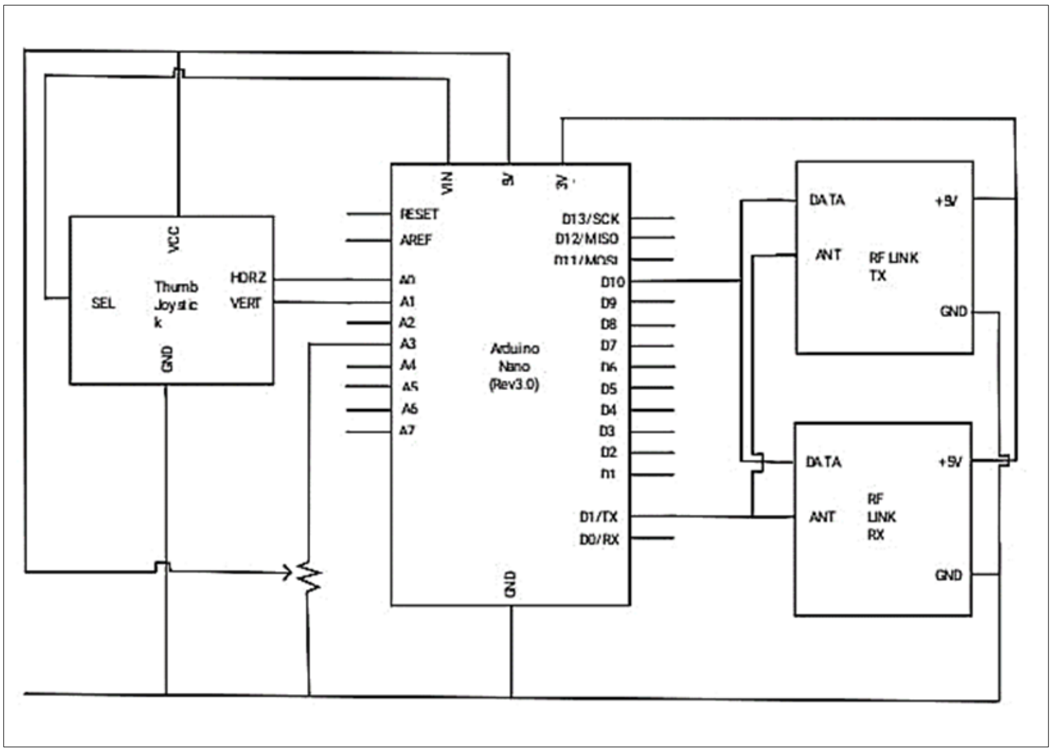


Figure 1 Block diagram for the control pad circuits

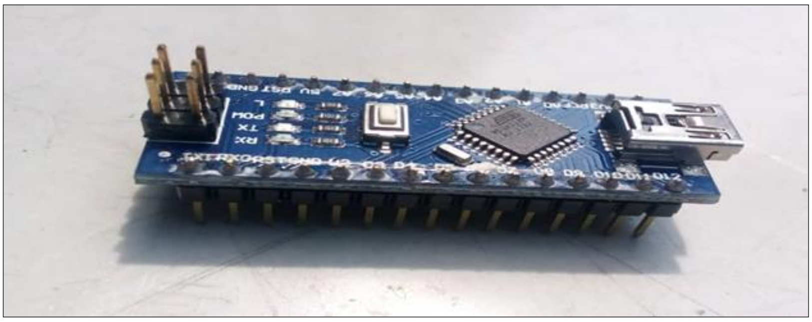


Figure 2 Procured Arduino Board

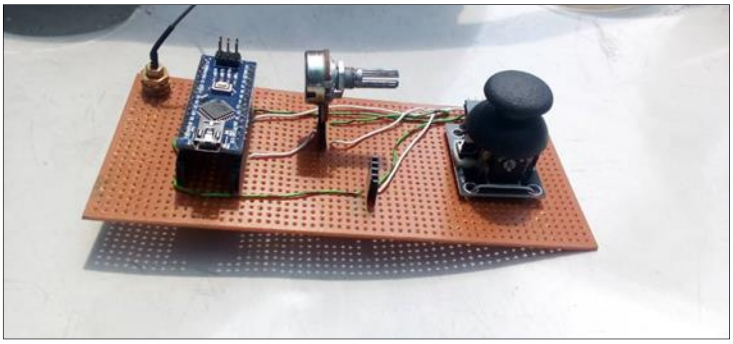


Figure 3 Layout of our control pad circuits

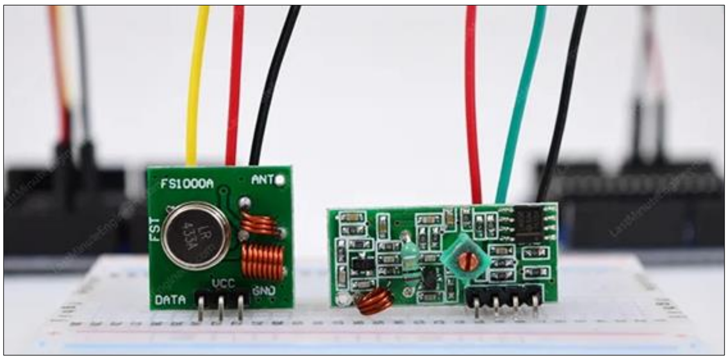


Figure 4 433MHz RF (Radio-Frequency) Module TX/RX

2.2. The UAV System Receiver Unit (Drone Unit)

The components used for fabrication of the Drone receiver system are, Arduino nano board, 434 MHz receiver module, 1 KΩ Resistor, Vero board, connecting wires, Lipo battery, antenna, SD micro adapter board, and MQ131 Ozone sensor.

To implement this part of the fabrication, we connected the black wire on both the servo motors with the GND on the Arduino and linked the red wire on both the servo motors with the 5V pin on the Arduino. The yellow wire on the first motor was connected with pin 8 on the Arduino while the yellow wire on the second motor was connected with pin 9 on the Arduino and all GND was connected to GND on the Arduino. We hanged the Antenna in an open space, and connect it to ANT with the RF-TX module before connecting the Data pin on RF-TX module with D12/MESO on Arduino. The Data line on RF-TX module was also connected with D12 on Arduino while all 5v and VCC were connected with 5v on Arduino. The A0 on MQ131 were connected with A0 on Arduino while the D0 on MQ131 were connected with D1/RX on Arduino. We ensured a firm connection of the DIG on the servo with D3 on Arduino and also a connection of Vin on Arduino to the DS LiPo Battery. After these connections, we linked the Arduino board, being the central processing unit of the system, to our computer and wrote a computer program corresponding to the previous program written for control using C++ (See appendix A.2). After laying out the circuit board, we embedded the components into a thick polystyrene of 5cm wide, 30cm long 3cm thick. We placed both motors at both ends of the cork unto of the servo brackets firmly, while the servos brackets are firmly fastened to the mechanical part of the servo motor. The MQ131 sensor is placed on top of the cork (base) for it to be exposed to the surrounding air.

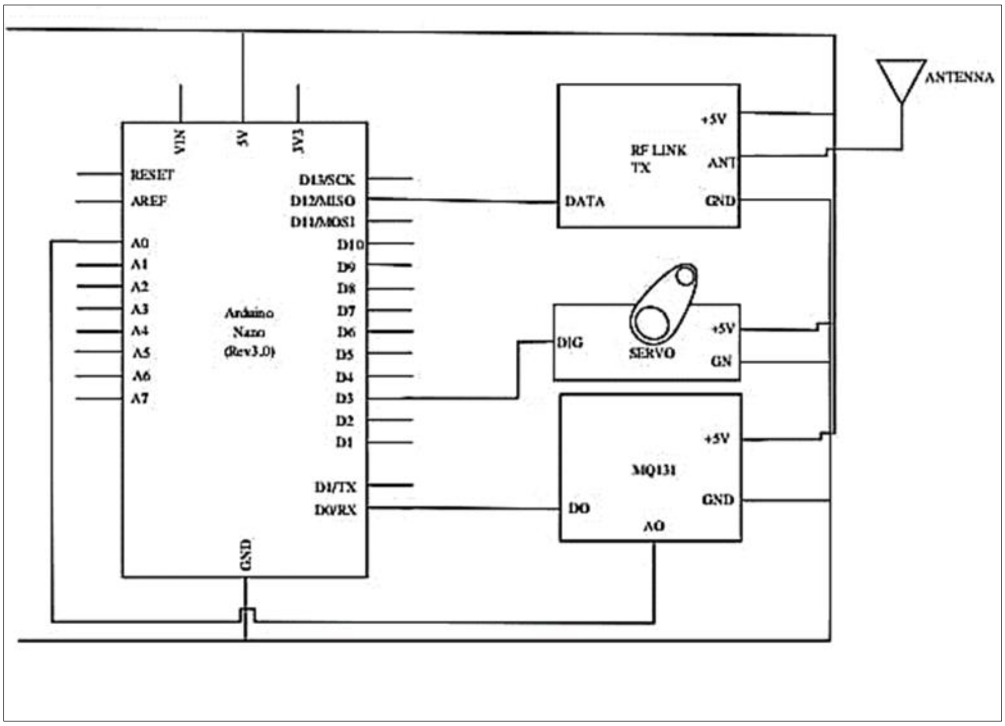


Figure 5 Block diagram for the Drone

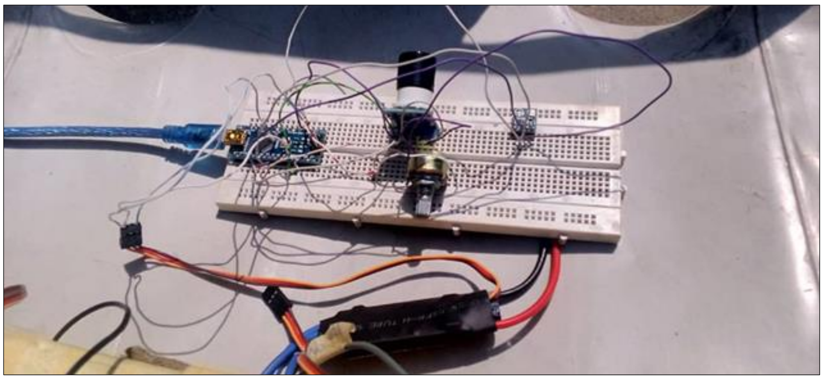


Figure 6 Layout of the control pad circuits on the breadboard

Having successfully set up the circuits for both the Drone and the control pad, we inserted an eternal memory in the SD card module before launch. When we powered the circuit, the MQ131 sensor automatically turns on and starts collecting air sample from the surrounding and ready for analysis. These analyses are not dependent on the flight of the Drone. We wrote the computer program such that the MQ131 sensor takes the average of the surrounding Ozone and logs them into the memory card through the SD card module and stores the numeric at 5munites interval in parts per million (ppm), parts per billion (ppb), milligram per meter cube (mg/m^{-3}), and nanogram per meter cube (ng/m^{-3}).

3. Results and discussion

Figure 7 below show the completed package of our drone ready for deployment. We used a 2200mAh (milliampere hour) which is a 1000th of an ampere hour (Ah) needed for long flight duration during launch and data collection. In order to have a stable flight, force analysis plays an important role, all the loads were calculated to support gravity. The payload was located between both rotors between the leading edge of the front rotor and the trailing edge of the bottom rotor was fifteen inches. Our UAV was designed such that the payload does not affect or determine the centre of gravity. Hence, the centre of gravity was adjusted towards the centre of the payload to certify equilibrium during take-off launch. The centre of gravity of both rotors were calculated using Win Laengs V 2.7 software.

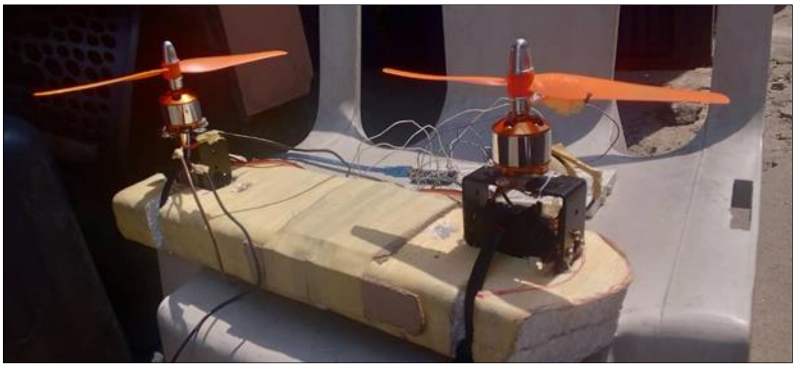
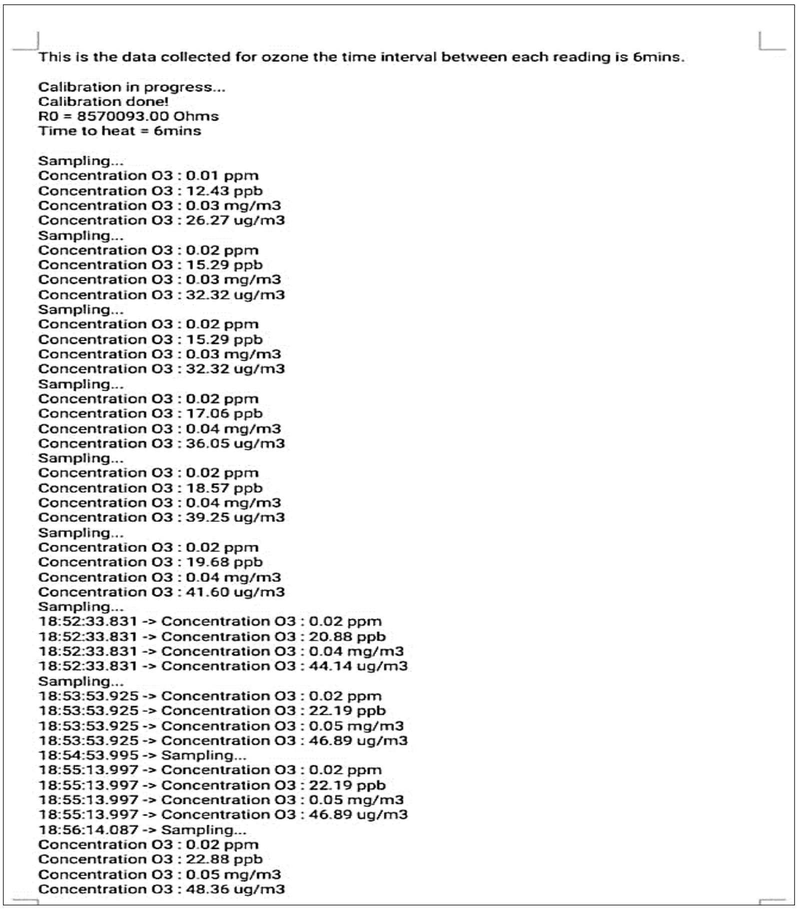


Figure 7 The assembled Drone

At the end of the data collection process after the Drone launch, we removed the memory card and inserted in a computer SD card slot to extract the data as shown in Figure. 8 below.



This is the data collected for ozone the time interval between each reading is 6mins.

Calibration in progress...
Calibration done!
R0 = 8570093.00 Ohms
Time to heat = 6mins

Sampling...
Concentration O3 : 0.01 ppm
Concentration O3 : 12.43 ppb
Concentration O3 : 0.03 mg/m3
Concentration O3 : 26.27 ug/m3
Sampling...
Concentration O3 : 0.02 ppm
Concentration O3 : 15.29 ppb
Concentration O3 : 0.03 mg/m3
Concentration O3 : 32.32 ug/m3
Sampling...
Concentration O3 : 0.02 ppm
Concentration O3 : 15.29 ppb
Concentration O3 : 0.03 mg/m3
Concentration O3 : 32.32 ug/m3
Sampling...
Concentration O3 : 0.02 ppm
Concentration O3 : 17.06 ppb
Concentration O3 : 0.04 mg/m3
Concentration O3 : 36.05 ug/m3
Sampling...
Concentration O3 : 0.02 ppm
Concentration O3 : 18.57 ppb
Concentration O3 : 0.04 mg/m3
Concentration O3 : 39.25 ug/m3
Sampling...
Concentration O3 : 0.02 ppm
Concentration O3 : 19.68 ppb
Concentration O3 : 0.04 mg/m3
Concentration O3 : 41.60 ug/m3
Sampling...
18:52:33.831 -> Concentration O3 : 0.02 ppm
18:52:33.831 -> Concentration O3 : 20.88 ppb
18:52:33.831 -> Concentration O3 : 0.04 mg/m3
18:52:33.831 -> Concentration O3 : 44.14 ug/m3
Sampling...
18:53:53.925 -> Concentration O3 : 0.02 ppm
18:53:53.925 -> Concentration O3 : 22.19 ppb
18:53:53.925 -> Concentration O3 : 0.05 mg/m3
18:53:53.925 -> Concentration O3 : 46.89 ug/m3
18:54:53.995 -> Sampling...
18:55:13.997 -> Concentration O3 : 0.02 ppm
18:55:13.997 -> Concentration O3 : 22.19 ppb
18:55:13.997 -> Concentration O3 : 0.05 mg/m3
18:55:13.997 -> Concentration O3 : 46.89 ug/m3
18:56:14.087 -> Sampling...
Concentration O3 : 0.02 ppm
Concentration O3 : 22.88 ppb
Concentration O3 : 0.05 mg/m3
Concentration O3 : 48.36 ug/m3

Figure 8 Raw data extracted from the data archive

4. Conclusion

We have successfully designed and fabricated an indigenous Smart UAV Drone for monitoring Ozone in Nigeria using some locally sourced materials. We have developed a small, lightweight, simple, and cost-effective multi-sensor system for multiple measurements of atmospheric phenomena and related climate information. We have also used a long-range wireless communication module with real-time monitoring and visualizing software applications to access live data, track trends, and archive historical data from our device for comparisons with other data sources. We also obtained original Ozone datasets after conducting flight measurement experiments at the launch site and used the data for simple research.

Compliance with ethical standards

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Disclosure of conflict of interest

The authors declare that there are no conflicts of interest.

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Appendix

A.1 C++ Script for the UAV System Transmitter Unit

```
#include <LiquidCrystal.h>
int sensorValue;

// moisture
int sensorPin = A5;
int sensorValue1;
int limit = 700;
//moisture

//Ldr
int ldr=A3;//Set A0(Analog Input) for LDR.
int value=0;
//Ldr

//rain
const int capteur_D = 4;
const int capteur_A = A2;
int val_analogique;
//rain

//const int rs = 12, en = 11, d4 = 5, d5 = 4, d6 = 3, d7 = 2;
//LiquidCrystal lcd(rs, en, d4, d5, d6, d7);

void setup(){  //lcd.begin(16, 2);
Serial.begin(9600);                    // sets the serial port to 9600
//moisturepin
pinMode(2, OUTPUT);
//moisturepin

//Ldr indicator
pinMode(3,OUTPUT);
//Ldr indicator

//rain
const int capteur_D = 4;
const int capteur_A = A2;
int val_analogique;
//rain
}
void loop(){sensorValue = analogRead(4);      // read analog input pin 0
Serial.print("AirQua=");
Serial.print(sensorValue, DEC);            // prints the value read
Serial.println(" PPM");

//moisture
```

```
sensorValue1 = analogRead(sensorPin);
Serial.println("Analog Value : ");
Serial.println(sensorValue);

if (sensorValue1<limit) {
digitalWrite(2, HIGH);
Serial.println ("Soil is WET");
}
else {
digitalWrite(2, LOW);
Serial.println ("Soil is DRY");
}
//moisture

//Ldr
value=analogRead(ldr);//Reads the Value of LDR(light).
Serial.println("LDR value is :");//Prints the value of LDR to Serial Monitor.
Serial.println(value);
if(value<300)
 {
  digitalWrite(3,HIGH);//Makes the LED glow in Dark.
  Serial.println ("Enviroment DARK ");

 }
 else
 {
  digitalWrite(3,LOW);//Turns the LED OFF in Light.
  Serial.println ("Enviroment is BRIGHT");
 }
//Ldr

//rain
if(digitalRead(capteur_D) == LOW)
 {
  Serial.println("Digital value : wet");
  delay(10);
 }
else
 {
  Serial.println("Digital value : dry");
  delay(10);
 }
val_analogique=analogRead(capteur_A);
Serial.print("Analog value : ");
Serial.println(val_analogique);
Serial.println("");
//rain
```

```
delay(500);                    // wait 100ms for next reading

if (sensorValue > 51)
   Serial.print("Enough quality Oxygen!");

   Serial.println();
}

//drone code starts here

#include <Servo.h>

#define MIN_PULSE_LENGTH 1148
#define MAX_PULSE_LENGTH 1832

Servo motA;

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

  motA.attach(11, MIN_PULSE_LENGTH, MAX_PULSE_LENGTH);
motA.writeMicroseconds(MIN_PULSE_LENGTH);
}

void loop() {
  if(Serial.available()){
   char data = Serial.read();
   if(data == 't'){
    test();
   }
  }
}

void test()
{
  for (int i = MIN_PULSE_LENGTH; i <= MAX_PULSE_LENGTH; i += 5) {
    setESC(i);
    delay(20);
  }
  for (int i = MAX_PULSE_LENGTH; i > MIN_PULSE_LENGTH; i -= 5) {
    setESC(i);
    delay(20);
  }

  Serial.println("STOP");
  motA.writeMicroseconds(MIN_PULSE_LENGTH);
}
void setESC(int val){
    Serial.print("Pulse length = ");
```

```
    Serial.println(val);
    motA.writeMicroseconds(val);
}
```

A.2 C++ Script for the UAV Receiver Unit (Drone Unit)

```
#include <Servo.h>

#define MIN_PULSE_LENGTH 1148
#define MAX_PULSE_LENGTH 1832

Servo motA;

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

  motA.attach(11, MIN_PULSE_LENGTH, MAX_PULSE_LENGTH);
motA.writeMicroseconds(MIN_PULSE_LENGTH);
}

void loop() {
  if(Serial.available()){
   char data = Serial.read();
   if(data == 't'){
    test();
   }
  }
}

void test()
{
  for (int i = MIN_PULSE_LENGTH; i <= MAX_PULSE_LENGTH; i += 5) {
    setESC(i);
    delay(20);
  }
  for (int i = MAX_PULSE_LENGTH; i > MIN_PULSE_LENGTH; i -= 5) {
    setESC(i);
    delay(20);
  }

  Serial.println("STOP");
  motA.writeMicroseconds(MIN_PULSE_LENGTH);
}
void setESC(int val){
    Serial.print("Pulse length = ");
    Serial.println(val);
    motA.writeMicroseconds(val);
}
```