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An Affordable Airborne Weather Observation Platform

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Research Article

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Abstract

This paper presents the culmination of the "Low-Cost Weather Forecasting Blimp" study, focusing on the design, development, and evaluation of a low-cost weather monitoring blimp tailored for agricultural applications. With accurate and localized weather forecasting being crucial for sustainable farming practices, especially in remote and developing regions, the Low-Cost Weather Forecasting Blimp system aims to address this challenge by providing real-time atmospheric data at an affordable price point. The Low-Cost Weather Forecasting Blimp system is designed as a multirotor aerial platform equipped with a customized sensor array to measure essential weather parameters such as temperature, humidity, wind speed, and precipitation. Leveraging IoT technology, the blimp transmits the collected sensor data via cellular networks to a ground station for real-time analysis using machine learning algorithms. These algorithms are specifically tailored to detect trends, anomalies, patterns in the data, enabling the generation of precise short-term forecasts relevant to farmer's needs.

Keywords: Agricultural Viability, IoT, Low-cost, multirotor aerial platform, Sensor Array, weather forecasting

I. Introduction

In today's connected world, with the proliferation of high-speed internet, the Internet of Things (IoT) has become a revolutionary force that transforms non-human interactions for the better, but there is also communication between electronic devices. As the price of Wi-Fi-enabled devices continues to drop, adoption of the IoT will accelerate, enabling unprecedented connectivity and data availability. The principle behind the IoT is to connect various electronic devices over the internet to collect and share data generated by sensors. This data can be sent to a cloud service such as IBM Bluemix or ThingSpeak for analysis and processing. The potential of IoT spans many sectors, including transportation, logistics, energy, healthcare, and agriculture.

In the energy sector, the IoT is changing the process by creating intelligent plans that can respond to changes in energy consumption patterns. The IoT holds great promise in many areas besides energy, including smart homes, technology, and connected healthcare. The market is expected to grow exponentially as global electronics giants such as Intel, Rockwell Automation, Siemens, Cisco, and General Electric invest heavily in IoT infrastructure. Analysts predict that the number of connected devices worldwide will reach 26 billion, or four devices per person, and the economic value should reach $19 trillion.

However, with the emergence of this new technology, managers faced great difficulties and began to use their management and the large amount of data produced by IoT products. The integration of Aerial Robots is designed to meet

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the urgent need for aerial monitoring in agriculture.

The program aims to provide farmers with accurate and regional weather information for sustainable agriculture, using a low-cost weather monitoring platform equipped with customized sensor arrays. The basis of the system is the ESP8266-based NodeMCU, a low-cost Wi-Fi module and the integration of various sensors used to measure the environment such as temperature, humidity, pressure, and the lamp. The collected data is transferred to the ThingSpeak IoT platform, facilitating instant analysis, and visualization to make informed decisions in smart agriculture. The program aims to provide farmers with answers and backgrounds to increase agricultural productivity through the integration of IoT technology and weather monitoring.

II. Literature Survey

Demonstrated cost-effective indoor flight control via Bluetooth using an Android application [1]. The aircraft uses three servo motors, lithium-ion batteries, and helium for propulsion and keeps its weight below 12 grams, making it suitable for indoor observation.

Authors [2] proposed a low-cost UAV using an aircraft carrier (equipment drawn on each aircraft). Advanced models of the entire system and a 3D simulator that serves as a testbed for physical use are provided. A trajectory planning algorithm based on ant colony metaheuristics is also described.

The review highlights aerial platforms utilized for flood monitoring in Malaysia, with a preference for helikites due to their resilience in extreme weather conditions [3]. However, it also notes limitations in their coverage capacity due to mobility constraints, indicating a need for further assessment.

The weather station identifies temperature, humidity, pressure, light intensity, and rain [4]. At its core is the ESP8266-based Wi-Fi module NodeMCU, which connects to various sensors such as DHT11, BMP180, raindrop module, and LDR. It is designed to allow users to take timely action by sending automatic notifications via SMS, e-mail, and tweets when pre-determined limits are exceeded.

Described IoT-based real-time weather monitoring system using NodeMCU ESP8266, connected with DHT11, BMP180, and FC37 sensors [5]. The system measures humidity, temperature, air pressure, and precipitation and sends the data to a web server. Once downloaded, the NodeMCU's IP address can be accessed from the monitor, allowing data to be viewed in a web browser for remote monitoring; this is especially useful in restricted areas such as remote areas.

III. Airship Design Structure Selection

Airships come in many models. Simple models rely on air pressure in the hull to maintain its shape. We also offer a robust system that provides a metal frame, making it stronger and more reliable, but at the expense of additional weight. We used balloons made of latex, which are inexpensive and not difficult to obtain. Compared with other flying robots, if the flying robot is flying or damaged during operation, it needs to be made from scratch, when damaged, it can be easily replaced. The code only needs to be loaded once.

Aerodynamics, weight distribution, and payload capacity are important considerations during design. Create accurate 3D models for virtual testing and optimization with Cero Parametric 8.0. The aim is to reduce drag, increase body pressure, and increase stability for good flight in different weather conditions. Additionally, the design seamlessly integrates sensors and communications equipment to ensure air quality. Through modelling and simulation, the aircraft achieved optimal performance in terms of durability, maneuverability, and functionality according to the study's objectives.

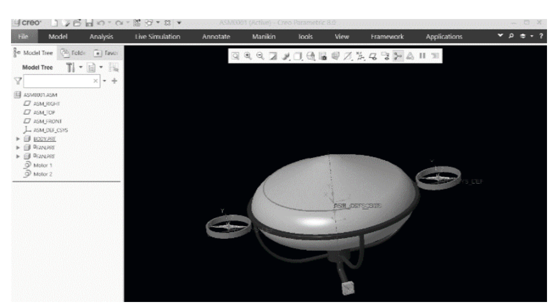

Fig 1. Design in Creo parametric 8.0 tool

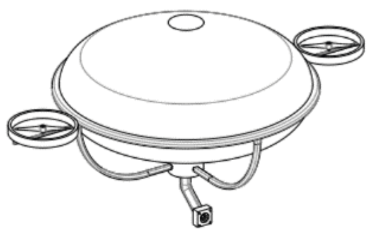

Fig 2. Isometric view of the blimp

IV. Lifting Agent

The first airships used hydrogen as fuel, which was the lightest at the time. It is usually produced by reacting dilute sulfuric acid with metal shavings. While hydrogen made from metal shavings was used in the first hydrogen balloons in 1783, zinc was used in British balloons. The disadvantage of using hydrogen is that it is flammable and in the event of a fire, the entire aircraft is at risk. The discovery of noble helium gas caused an explosion because it was lighter than air, non-flammable, easy to produce, and non-toxic. Helium is 92.7% more buoyant than hydrogen, making it a better choice. That is why we use helium as fuel in airships because it has many advantages over other fuels.

Fig 3. Helium cylinder

V. Implementation Set up

A. components required- "hardware for weather station"

1) ESP8266-based Wi-Fi module NodeMCU
2) Temperature and Humidity Sensor (DHT11)
3) Barometric Pressure Sensor (BMP180)
4) Raindrop Module
5) Laptop (through the ThingSpeak platform) to receive data
6) Power supply using "Li-Po Battery" (100 mAh)

B. components required- "hardware for flight controller"

1) Four coreless motors
2) R/C transmitter
3) Receiver board JJRC H29C
4) Four propellers
5) Power supply using "Li-Po Battery" (100 mAh)

C. components required- "Software"

1) Arduino IDE
2) Accessible Wi-Fi
3) ThingSpeak platform

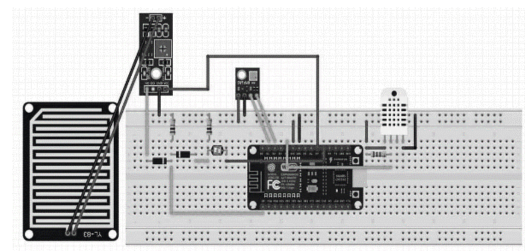

Fig 4. 3D view of building a weather station

VI. Methodology

A. NodeMCU

It is the heart of the device. It provides a platform for the IoT. It is a Wi-Fi module with Esp8266 firmware. All other sensors are connected to this microcontroller. They send their measurements to it and it uploads all the results to the cloud where they are analyzed. The developer of this development board is the ESP8266 open-source community. There is an operating system called XTOS. The CPU is ESP8266 (LX106). It has 128 KB internal memory and 4 MByte storage capacity.

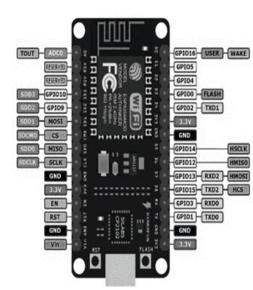

Fig 5. ESP8266

B. Temperature and Humidity Sensor (DHT11)

It feels the heat and the cold. It is a 4-pin device. We need to connect a 10 k resistor between pins 1 and 2. Pin 4 is connected to GND. Pin 2 is the output pin and input to NodeMCU pin D4. Leave pin 3 empty.

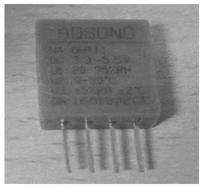

Fig 6. DHT11

C. Barometric Pressure Sensor (BMP180)

It feels the air around itself. BMP180 is an I2C standard. It is a 4-pin device such as SDA, SCL, VIN, and GND. Vin and GND are connected to 3.3V and GND respectively. SDA is connected to the D2 pin of NodeMCU and SCL is connected to the D3 pin of NodeMCU.

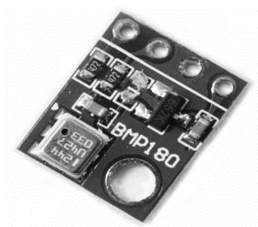

Fig 7. BMP180

D. Raindrop Module:

It is used for the detection of rain. It can also be used for measuring the intensity of the rain. The module measures humidity via the analogue output pin and provides a digital output when the humidity is too high. The higher or lower the resistance, the lower the output voltage, and less water means more resistance at the analogue pin and more output. For example, a completely dry card will cause the module to output five volts. The analogue output of the module is connected to the A0 pin of the NodeMCU.

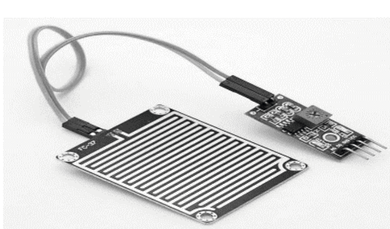

Fig 8. Raindrop module

E. Power supply (Li-Po Battery):

The aircraft's power choice is a lightweight lithium polymer battery known for its current output. The optional battery is 100 mAh and the working voltage is 3.7 V.

Fig 9. Li-Po Battery

F. Coreless Motors

These motors provide the power needed for the aircraft to climb, descend, and operate in various directions. Each inertial body is connected to the receiver plate and placed parallel to the aircraft, ensuring stable flight. Two motors are used for vertical lift, and the other two motors control forward, reverse, and rotation. The motor speed is controlled by the PWM signal from the receiver board, which receives commands from the remote-controlled transmitter.

G. Propellers

The propeller converts the rotational motion of the engine into thrust force, allowing the airship to move. Each motor has a fan attached to it to ensure it is securely attached and oriented correctly to push or pull air in the desired direction. The fan is matched to the engine in size and sound, providing powerful thrust.

Fig 10. Coreless motors and propellers

H. R/C Transmitter

The remote-control transmitter served as the pilot's interface for controlling the blimp. Before the flight, the R/C transmitter was paired with the receiver board on the blimp to ensure a secure communication link. The transmitter's joysticks were used to control the blimp's altitude and direction, adjusting thrust and motor direction as needed.

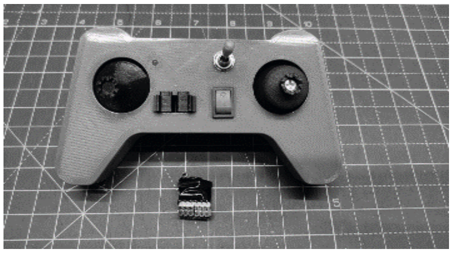

Fig 11. Transmitter

I. Receiver Board JJRC H29C

As the blimp's brain, it receives signals from the remote-control transmitter and converts them into motion by controlling the engine. The receiver board is securely mounted inside the airship to ensure that it is well protected, and its antenna is positioned for visible signal reception. All motors and electronics are connected to the receiver. The board's built-in gyroscope helps stabilize the airship during flight.

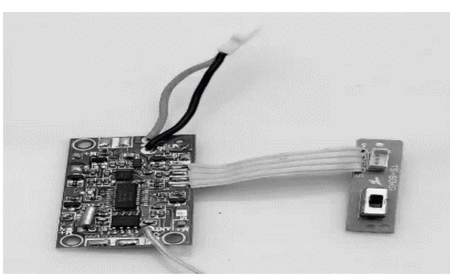

Fig 12. Receiver

J. IOT coding using Arduino IDE

During the software development phase, NodeMCU is first programmed using Arduino IDE or a similar environment. The purpose of this code is to initialize the sensor module, read the sensor data, and send the data to the ThingSpeak platform via Wi-Fi. This data is then formatted and sent to the ThingSpeak platform using the ESP8266's Wi-Fi capabilities. The MQTT protocol or HTTP GET/POST requests are typically used for this data.

1) Algorithm 1:

```
/*Weather monitoring system with
Thingspeak.*/
#include <SFE_BMP180.h>
#include <Wire.h>
#include <ESP8266WiFi.h>
#include "DHT.h"

DHT dht(D3, DHT11);
SFE_BMP180 bmp;
double T, P;
char status;
WiFiClient client;

String apiKey = "";
const char *ssid =  "";
const char *pass =  "";
const char* server = "api.thingspeak.com";

void setup() {
Serial.begin(115200);
delay(10);
bmp.begin();
Wire.begin();
dht.begin();
WiFi.begin(ssid, pass);

 while (WiFi.status() != WL_CONNECTED)
{
   delay(500);
   Serial.print(".");
}
  Serial.println("");
  Serial.println("WiFi connected");
}

void loop()
{
 //BMP180 sensor
   status =  bmp.startTemperature();
  if (status != 0)
{
   delay(status);
   status = bmp.getTemperature(T);

   status = bmp.startPressure(3);// 0 to 3
   if (status != 0)
{
   delay(status);
   status = bmp.getPressure(P, T);
   if (status != 0)
{
```

```
}
}
}

//DHT11 sensor
float h = dht.readHumidity();
float t = dht.readTemperature();

if (isnan(h) || isnan(t)) {
Serial.println("Failed to read from DHT
sensor!");
return;
}

//Rain sensor
int r = analogRead(A0);
r = map(r, 0, 1024, 0, 100);

if (client.connect(server, 80)) {
String postStr = apiKey;
postStr += "&field1=";
postStr += String(t);
postStr += "&field2=";
postStr += String(h);
postStr += "&field3=";
postStr += String(P, 2);
postStr += "&field4=";
postStr += String(r);
postStr += "\r\n\r\n\r\n\r\n";

client.print("POST /update HTTP/1.1\n");
client.print("Host: api.thingspeak.com\n");
client.print("Connection: close\n");
client.print("X-THINGSPEAKAPIKEY: " + apiKey
+ "\n");
client.print("Content-Type:application/x-www-
form-  urlencoded\n");
client.print("Content-Length: ");
client.print(postStr.length());
client.print("\n\n\n\n");
client.print(postStr);

Serial.print("Temperature: ");
Serial.println(t);
Serial.print("Humidity: ");
Serial.println(h);
Serial.print("absolute pressure: ");
Serial.print(P, 2);
Serial.println("mb");
Serial.print("Rain");
Serial.println(r);

}
client.stop();
delay(1000);
}
```

K. ThingSpeak Channel Setup

Create a ThingSpeak channel to receive and store weather data transmitted by NodeMCU. Each area in the channel is configured to correspond to some type of measurement data (e.g. temperature, humidity, precipitation, and barometric pressure). The ThingSpeak platform provides tools to review the product received. The platform's visualization capabilities allow this information to be presented in readable formats such as graphs and charts that can be accessed online.

VII. Results and Discussion

The ESP8266 microcontroller successfully controlled weather sensors including DHT11 (temperature, humidity), BMP180 (barometric pressure), and rain sensors. The system is powered via a USB cable, the coding sketch is loaded into the ESP8266, and the sensor data is displayed on the serial monitor of the Arduino IDE. The ESP8266 connects to a Wi-Fi access point so a web server can be created to display sensor data. Communication is established between the sensor station and the weather station via Wi-Fi, and the data is displayed in ThingSpeak. ThingSpeak achieves the goal of the study by storing and disseminating sensor data, allowing users to monitor air quality through the website.

SL NO.	PARAMETERS	TIME	VALUE
I	Temperature	10 AM	24 ~28
II	Temperature	1 PM	28 ~31
III	Temperature	10 PM	27 ~28
IV	Humidity	10 AM	78
V	Humidity	1 PM	76
VI	Humidity	10 PM	77
VII	Pressure	10 AM	1001 ~1800
VIII	Pressure	1 PM	1006~1829
IX	Pressure	10 PM	997~1560

SL NO.	PARAMETERS	TIME	VALUE
X	Rainfall	10 AM	0.25
XI	Rainfall	1 PM	0.15
XII	Rainfall	10 PM	0.35

Table 1: Weather Parameters Measurements at Different Times of the Day

Note 1: "The units used for measuring the parameters are degrees Celsius for temperature, percentage for humidity, millibars for pressure, and inches for raindrop amounts."

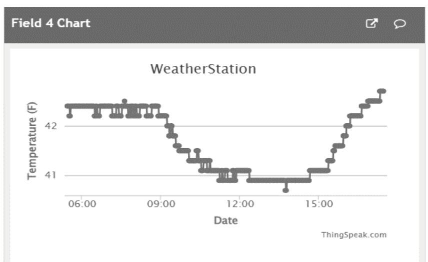

Fig 13. Graph for Temperature

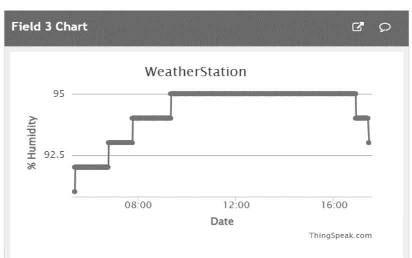

Fig 14. Graph for Humidity

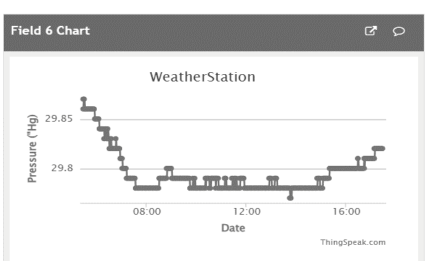

Fig 15. Graph for Pressure

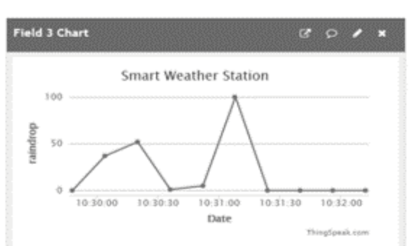

Fig 16. Graph for Rainfall

VIII. Future Scope

Improvements in this study include extending the communication range through multiple models, adding GPS for self-management, and supporting models for outdoor use. Additionally, weather stations can be equipped with OLED displays for real-time data visualization and GPS modules for location tracking. These changes aim to expand the benefits of the program and increase its applicability in various fields such as agricultural aviation and environmental protection.

IX. Conclusion

Although its limitation is low resolution, in-flight tests have shown it to be effective, especially for indoor use. Offering a suitable alternative to other drones with a control range of up to 10 metres, the drone has many customizable applications in different areas. Additionally, the study achieved its goal of using a wireless IoT system to monitor air quality. The system provides real-time data collection and analysis by communicating between the sensor and the weather station via a Wi-Fi hotspot. Comparison of recorded data with weather forecast and forecast shows the accuracy of the weather forecast and reveals its reliability in monitoring the environment. The integration of ThingSpeak and IFTTT increases the efficiency and effectiveness of the system by supporting data storage and further analysis. Overall, this program lays the foundation for the future development of wireless weather monitoring and highlights the importance of exposure to environmental data for a variety of applications.

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