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A Drone Based Crop Monitoring System in Precision Agriculture using RF Remote Control

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Abstract: *This paper presents Drone-Based Crop Monitoring System in Precision Agriculture using RF Remote Control. The nurturing processes of crops in the farm are very tedious and time consuming. Many factors affect the developmental stages of crops in the farm. Farmers suffer a lot to manually monitor the progress of these crops in order to avoid malnutrition, lack of irrigation, weed control and Insects attack. This system is aimed to assist farmers successfully monitor their farms and records accurate measurement of the soil state for urgent attention and further improvement. The prototyping and Waterfall design approaches were used to build the drone-based system with sensors underneath to capture the temperature, pressure and soil humidity. The drone system comprises of the Hardware and Software units. The hardware of the drone is made up of various components such as the electronic speed controllers, microcontroller, camera, the ESP-32 Wi-Fi module, and so on. The RF remote control device is designed to control the drone movement during operation. The microcontroller codes were written in Arduino IDE using C++ language. The prototype device was tested successfully at the Teaching and Research Farm in the University of Port Harcourt.*

Keyword: *Drone; Crop monitoring; Precision Agriculture; Farmer; RF remote; embedded system*

1. INTRODUCTION

With the expansion of cultivation to wider fields, manual intervention to monitor and diagnose insect and pest infestations is becoming increasingly difficult. Failure to apply on time fertilizers and pesticides results in more crop loss and so lower output.

Farmers are putting in greater effort to conserve crops, but they are failing most of the time because they are unable to adequately monitor the crops when they are infected by pests and insects. Pest infestation is also difficult to predict because it is not evenly distributed [1]. In recent years unmanned aerial vehicles (UAVs) have emerged as a popular and cost-effective technology to capture high spatial and temporal resolution remote sensing (RS) images for a wide range of precision agriculture applications. This technique can help reduce costs and environmental impacts by providing detailed agricultural information to optimize field practices. Furthermore, deep learning (DL) has been successfully applied in agricultural applications such as weed detection, crop pest and disease detection, etc. as an intelligent tool. However, most DL-based methods place high computation, memory and network demands on resources. Cloud computing can increase processing efficiency with high scalability and low cost, but results in high latency and great pressure on the network bandwidth. The emerging of edge intelligence, although still in the early stages, provides a promising solution for artificial intelli-

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gence (AI) applications on intelligent edge devices at the edge of the network close to data sources. These devices are with built-in processors enabling onboard analytics or AI (e.g., UAVs and Internet of Things gateways) [2]. Smart farming technologies are becoming increasingly common in modern agriculture to assist in optimizing agricultural and livestock production and minimizing the wastes and costs [3]. Precision Agriculture offers the opportunity for a farmer to apply the right amount of treatment at the right time and at the right location in the farm. However, in order to collect timely high-resolution data, drone-based sensing and image interpretation is required. These high-resolution images can give detailed information about the soil and crop condition, which can be used for farm management purposes. Leaf area index, normalized difference vegetation index, photochemical reflectance index, crop water stress index, and other such vegetation indices can provide important information on crop health [4].

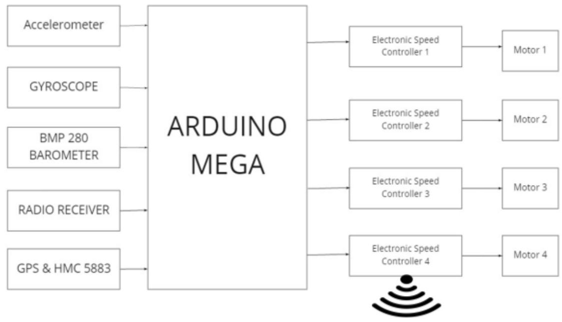
2. REVIEW OF RELATED WORKS

The development of an Unmanned Aerial Vehicle-Borne Crop-Growth Monitoring System is discussed in [5]. The system is capable of real-time online acquisition of various major indexes, like, the normalized difference vegetation index (NDVI) of the crop canopy, ratio vegetation index (RVI), leaf nitrogen accumulation (LNA), leaf area index (LAI), and leaf dry weight (LDW). Based on the flow-field characteristics and geometrical dimensions, a UAV-borne crop-growth sensor was designed. In [6, 7], GSM-Based Agricultural Monitoring System Using Drone was developed. Pixhawk flight controller was used to maintain stability and sustained operation. The drone is used for enhancing agricultural activities like spraying pesticides and water. In [8], High Yield Farming using IoT based UAV was developed.

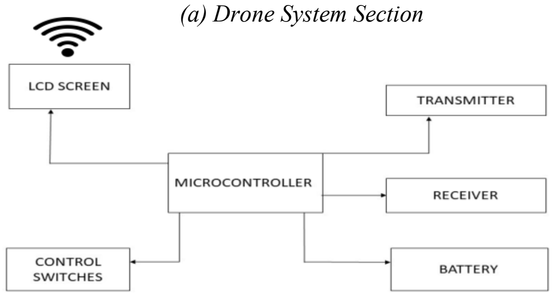
They integrated various sensors with Internet of Things in drone for crop production enhancement using Raspberry Pi 3B module. Drone based Precision Agriculture System was discussed in [9]. An automated elevated vehicle (UAV) was utilized to catch the influenced plants pictures (diseased leaves) while an improved k-mean grouping calculation was applied to anticipate the tainted zone of the leaves. In [10], Agricultural Drone for Plant Health Analysis was developed. An autonomous flying quadcopter, equipped with a GPS tracking system and programmed to be able to fly autonomously from one location to a different location using GPS coordinates was built and tested. In [11], Smart IoT-Based CNN Technique for Harmful Maize Insects Recognition in Precision Agriculture was developed. The system has three sections namely IoT, Maize app, and deep learning CNN. Each of the sections was properly designed and implemented. The results show that the developed system can work excellent in Nigeria's farms by monitoring the maize moths and providing accurate predictions to the farmers. IoT based Unmanned Aerial Vehicle system for Agriculture applications were explained in [12]. They explained remote controlled drone-based sprayer system used in precision agriculture which avoids the direct spraying by humans. Their paper further explained the advantage of reducing labor workers, spraying time and resources like water and chemicals over conventional spraying methods which can also improve yield and crop health.

3. SYSTEM DESIGN METHOD

The drone-based system with remote control is made up of Internet of Things (IoT) hardware and Software. The Drone system is divided into IoT and Remote-control systems. The IoT system design uses hardware prototyping approach while the software section of the system design uses agile methodology. The entire system block diagram is shown in Figure 1.



(a) Drone System Section



(b) Remote Control Section

Figure 1: Drone System with remote control block

3.1 Drone Hardware System

Drone system comprises of sensors, camera, microcontroller, solar power panel, microcontroller, Actuators, Xbee RF module, and FPV transmitter as shown in Figure 2.

3.1.1 Sensors

Different sensors were integrated into drone system to help it perform optimally. Such sensors are accelerometer, barometer, and camera. The Micro Electro-Mechanical System (MEMS-MPU6050) was used to measure the acceleration, velocity, orientation, dis-

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placement and other motion-related parameters of the drone. MS5611 Barometer sensor provides a precise digital 24 Bit pressure and temperature value and different operation modes that allow the user to optimize for conversion speed and current consumption. The camera used for the quadcopter drone is Foxeer Razer Camera because of its clarity in low light environment.

3.1.2 Xbee RF module

XBee S2C is an RF module used to provide wireless communication between the drone and remote-control unit over distance up to 10 meters.

3.1.3 Actuator and Propeller

A2212 1000KV Brushless Motor and propeller are used to propel the drone to the expected height in the sky. 40A Brushless ESC provides enough current used to drive the motor to a desired distance.

3.1.4 Microcontroller (Arduino Mega 2560)

The Arduino Mega is deployed to process signals received from remote control unit, manage, and control the entire behavior of the system.

3.1.5 First Person View (FPV) Drone Radio Receiver

This helps drone to receive commands wirelessly from remote control unit through a set radio frequency.

Figure 2: Drone Hardware Components [13-15]

4 3.1.6 Limskey 6000mah 11.1V Lipo battery

The Limskey 6000mah 11.1V Lipo battery is a powerful battery used for Drones Quadcopters. It is basically used to supply required voltages to the various units of the drone and sustain it within set hours of operation. Its voltage per cell is 3.7V and voltage per pack is 12.6V.

3.1.7 HC-05 Bluetooth module

The HC-05 is a module that helps to establish communicate between two microcontrollers used. These microcontrollers communicate via Bluetooth functionality with smart phone or laptop. The HC-05 Bluetooth module communicates using USART at a 9600 baud rate.

3.1.8 Solar Powered Battery Charger

The Solar panel supplies a dc voltage of 18V maximum and this value is been monitored by the LM 317T comparator and BC 548 Transistor which must be maintained within the period of operation. The comparator compares the voltage output from the solar panel and sends the prescribed voltage value to turn on the BC 548 Transistor. The voltage value produced is been adjusted to the expected magnitude with the aid of the voltage divider and variable resistor. To ensure a precise stabilization in the output voltage, a zener diode is connected which safe guards the lead acid battery from voltage fluctuation. A complete designed circuit diagram is presented in Figure 3.

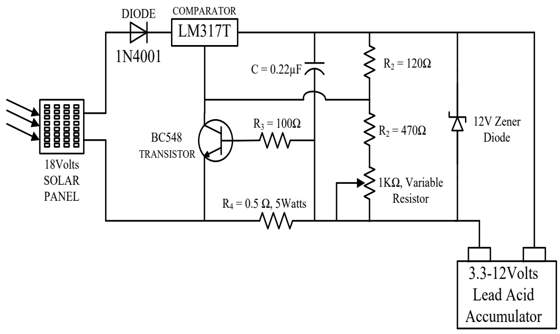

Figure 3: Circuit diagram of Solar Powered Battery Charger

3.2 Remote Control System

This panel is used to control the movement of drone in the air and to perform its duty during operation. The panel comprises of First Person View (FPV) transmitter and microzone remote as shown in Figure 4. FPV Drone Radio Transmitter helps to transmit commands wirelessly from remote control unit through a set radio frequency to the drone radio receiver. Microzone remote was programmed to be used in controlling the movement and operation of the drone.

Figure 4: Drone Remote Control system

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3.3 Drone Hardware Simulation Circuit

The simulation is done using PROTEUS environment and the simulated circuit is shown in Figure 5. The input unit includes the sensors, camera, battery, receiver and the Gyroscope/accelerometer. These sensors are used to monitor the environment. The sensors scan the soil once the drone gets down to the soil and performs a data gathering operation for the users. The camera is used for proximity areas and in determining what part of the soil that the analysis is needed. The gyroscope helps to maintain steady orientation and angular velocity while the drone is in flight to reach the farm area and collect the most accurate samples. The controller, Arduino Mega Pro is connected to the input unit and the output unit, and it receives signals from both units. Output from the sensors is signal-conditioned and processed by the micro-controller.

It gives out signals based on the inputted algorithm. The written code in C language is compiled and sent to the Arduino mega pro micro-controller with the aid of a USB connector. The output unit includes the motors and the electronic speed controllers which controls and regulates the speed of brushless motor. Four (4) motors on the drone help to control the speed, start/ stop the rotation of the motor in a more accurate way.

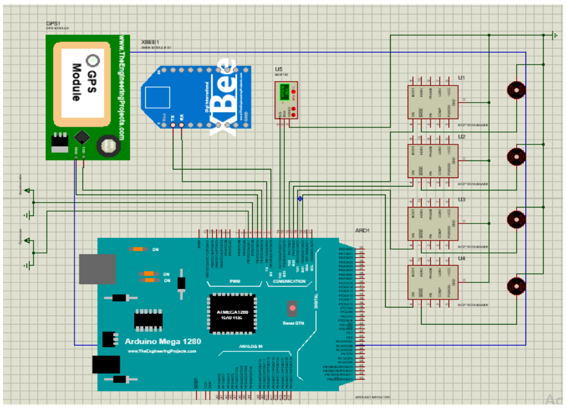

Figure 5: Drone Hardware System simulation in PROTEUS

3.4 Drone System Flow Chart

The drone system initializes all the sections immediately it is turned on. It turns on the cameras and activates the GoFPV for surveillance. It checks if the GoFPV synchronizes with the camera and if it does not, it starts the process again. After camera synchronization has been done, it connects to the mobile device and flies to the farm via remote control to take readings using the sensors underneath. After taking readings in the farm, it checks connection to the Wi-Fi and sends data to the connected mobile device using the web interface. The flowchart of the drone system is shown in Figure 6.

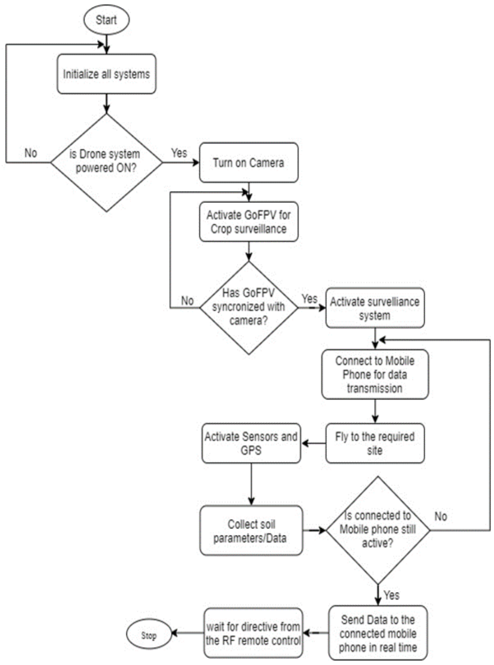

Figure 6: Drone system flow chart to get parameters from the farm

3.5 Drone Programming Software

The Arduino Integrated Development Environment (IDE) is a cross-platform application that was used to write and upload programs to Arduino boards. The program was written in C language. The Arduino IDE uses a program called avrdude (AVR downloader uploader) to convert the executable code into a text file in hexadecimal encoding that is loaded into the Arduino board by a loader program in the board's firmware.

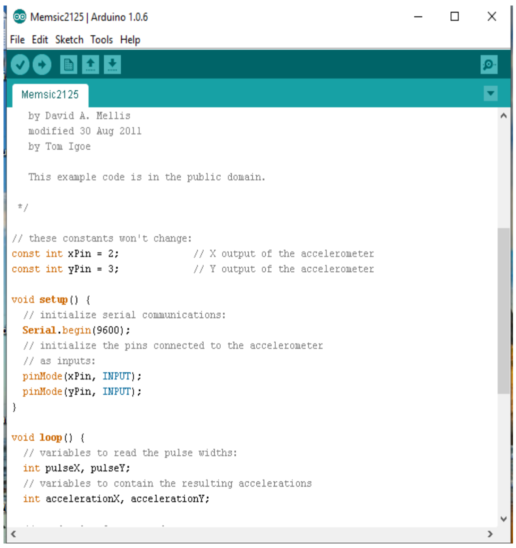

Figure 7: Arduino IDE Programming environment

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3.6 Packaged Drone System

Drone based system packaging consists of two parts namely, the drone system and the Remote-control system. The Drone has the main casing that consists of the Arduino Mega Microcontroller and other components such as the Battery, Electronic Speed Controllers, Brushless motors, Camera, and other electrical conductors. All sensors are attached underneath the drone. It was packaged on a plastic chassis for ease of flight. The plastic measured 30 cm in height with a width of 33cm. The remote control is a factory made microzone remote that was programmed. It also measured 5cm by 7cm.

For the drone to work, it is charged and booted up first, then, the remote control is turned on to fully arm the motors and propellers. Once the drone is fully turned on, all the cameras and monitoring sensors system would be activated. The mobile device in use would secure connection to the ESP chip on the drone. The data would be transmitted through an IP address 192.168.43.35 to read all the data coming from the drone. Using the RF controlled remote; the drone is flown to a farm area. The camera monitors the farm area for any inconsistency. After this, it lands, and takes the temperature, pressure, and soil moisture content of the soil. The Drone reads the data in real-time, and communicates to the mobile device through the IP address. The implemented prototype drone system is shown in Figure 8.

Figure 8: The implemented Prototype Drone System

4. TEST AND RESULTS OBTAINED

Various drone components and units were tested. Each component result was discussed in the subsequent sections.

4.1. Drone Test

The drone panel features were tested as indicated and results discussed.

4.1.1 Camera Test

The brightness and quality of the drone was tested in various brightness levels to ensure that it works properly and captures the drone in the best possible ways. The FPV receiver helps to process the images and brings out the best results possible.

4.1.2 Motors Test

The motors on the Drone were tested when the drone was armed. This was done to ensure that enough power enters into the drone for it to take off properly.

4.1.3 Soil Moisture Sensor Test

The soil moisture sensor was properly tested to see how it connects to the ESP micro-controller to get the moisture content and display it on the mobile application. In the mobile Application, the moisture content was set to a percentage value to show the farmer the water level in the soil.

4.1.4 Temperature and Pressure Sensor Test

These were tested during the flight process which shows the temperature and the pressure successfully.
Battery Test: The Limsey 6000mah 11.1V battery was tested during the overall flight test. During the test, the battery lasted for 45 minutes. With the introduction of solar powered battery charger, operation time extended more than two hours.

4.2. Drone Flies to Farm

During the testing period, the button attached on the drone was switched on. The drone system energized and voltages supplied to various components. The drone synchronized with the remote control and four propellers start rotating as shown in Figure 9.

Figure 9: Drone propeller rotate on power ON

The RF remote control is used to control the movement of the drone on air to the targeted farm site as shown in Figure 11.

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Figure 11: Drone controlled with RF remote

The drone flies to the farm to collect required soil data as shown in Figure 12.

Figure 12: Drone on air to collect Soil data

4.3. Software Tests

Mobile Interface Test: The Web interface that is used to collect the data is tested. The ESP 32 connected to the mobile device through hotspot establishment and the data accessed through an IP address of 192.168.43.35.

The result values of the atmospheric temperature, pressure, and soil moisture of the drone-based crop monitoring system when tested within 1-minute interval is shown in Figure 9. The result shows that the web interface displays all the necessary values farmer needs from the drone. The soil moisture content is measured in percentage to show the level of water in the soil. This shows that the drone collected different soil parameters and sends the data in real-time to the mobile phone. The pressure in bar is also displayed.

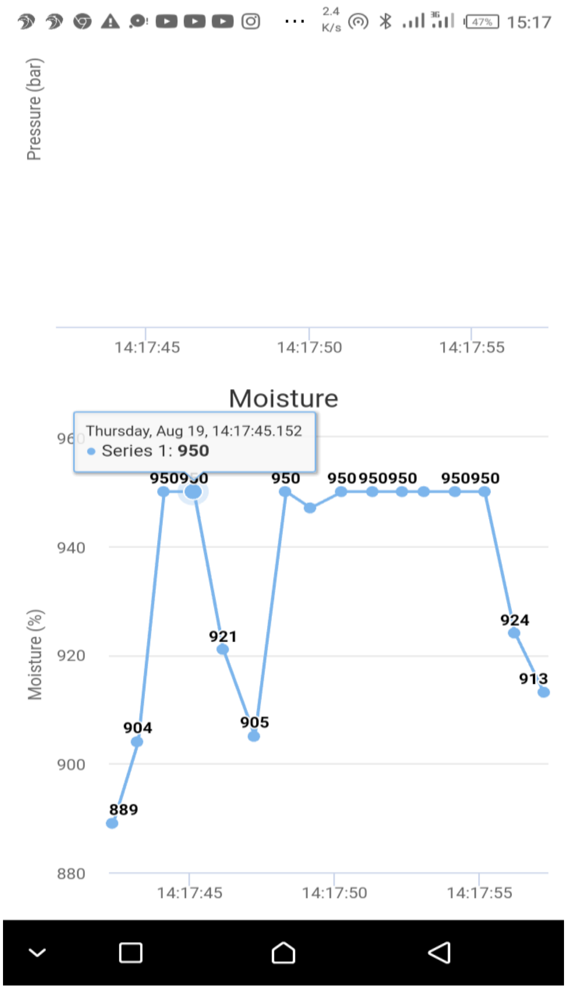

Figure 9: Soil parameters test results obtained by the Drone

5. CONCLUSION

The Drone based Crop monitoring system with RF remote control in Precision Agriculture has been designed, implemented and tested successfully. The drone system can now be operated and controlled via RF remote control. This product supersedes the manual processes used by the farmers to monitor the developmental stages of crops in the farm. Also, part of improving the power sustainability during drone operation, solar powered battery charger was introduced. This makes the drone battery to stay longer during operation without being discharged.

For future enhancement on this work, researchers are recommended to deploy machine learning and train a model to handle soil parameters predictions to help farmers take appropriate actions.

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