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AUTONOMOUS SPRAY SYSTEM FOR AGRICULTURAL UTILIZATION IN NIGERIA

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Abstract

The deployment of crop production equipment is a pertinent part of the surging productivity in Europe and American agriculture. Agricultural chemical utilization is often required at particular periods and locations for optimal site management of crop infested with pests. Basically, piloted agricultural planes are typically deployed to handle large, continuous land areas, crops, unobstructed and are not competent enough when being used over small plots. An Unmanned Aerial Vehicle (UAC) is remotely controlled based on preprogrammed flight plans and can be deployed to do timely and efficient utilization over small area designs. This paper describes the implementation of spray-system and its incorporation with flight control system having a complete autonomous, unmanned landing and vertical take-off helicopter. Sprayer actuation can be triggered by the preset positional coordinates as monitored by the equipped Global Positioning System (GPS). The developed spray system has the potential to provide accurate, site-specific crop management when coupled with UAV systems. It also has enormous potential for vector control in areas not easily accessible by personnel or equipment.

Keywords: Spray-System, Autonomous Flight, GPS, Unmanned Aerial Vehicle

Introduction

The point of concern about the Nigerian economy is the diversification of the mono-economy away from oil production. Agriculture as a major popular alternative provides the leverage for man's emancipation from poverty to wealth; however, the method currently deployed is responsible for 70% poverty level (Uche & Audu, 2021). Hence, there is need for paradigm adjustments in the use of agriculture as the most viable option for wealth creation and national economic development. Agricultural mechanization is viable and reliable alternative to youth empowerment (Yawson & Frimpong-Wiafe, 2018). Agriculture entails animal husbandry, soil study and cultivation, crop planting and processing. Ploughing, sowing and harvesting are necessary for all crops as part of the process that it must undergo. Application of fertilizer and pesticides in agriculture are difficult procedures that are undertaken to ensure maximum crop yield. In the face of this challenge, drones could be deployed to implement the application of insecticides in modern times. Applying pesticides by manual means exposes the spraying person to some quantum negative side effects (Joseph, Onyebuchi, & Obinna, 2021). Some of these side effects ranges from minor skin irritation to congenital abnormalities and malignancies. Deploying drone technology to spraying farms or agricultural ecosystems has become indispensable. Drone's capability of Vertical Take-Off and Landing (VTOL) provides it a distinctive kinematic as an Unmanned Area vehicle (UAV). UAV is equipped with sensors, automatic control and communications systems as well as data processing units for autonomous flight missions (Uche & Audu, 2021). At precise intervals and places, fertilizers, pesticides and site-specific management of crop pests must be applied often for reliable outcomes.

Usually, aerial application equipment, chemigation equipment, or ground sprayers are employed. These methods may be effective for large acreage systems cropping, but may be burdensome for small plot production systems. Unmanned aerial vehicles (UAVs), which are more maneuverable, less expensive to operate, and require lower capital expenses, may be able to meet this demand.

Prevalently application of UAVs by military and civilian has been in use and will continue so for some time to come (Blyenburgh, 1999). Some areas of applications include archaeological searching (Eisenbeiss, 2004), rangeland management (Hardin & Jackson, 2005) and control, assessment of grain crop features (Hunt, Walthall, & Daughtry, 2005, Jensen *et al.*, 2003), and vineyard management [Hunt, Walthall, & Daughtry, 2005, Jensen *et al.*, 2003, Johnson *et al.*, 2001). Most rice fields, wheat and soybeans plantation are beguiled by pests; hence, the Japan Yamaha model helicopter was designed to provide control mechanism for agricultural applications. In 1997, RMAX model was presented to the world and much later the model was advanced with azimuth and differential GPS sensor systems (Yamaha, 2004) for optimal performance. (Miller, 2005) presented a provisional experiment to test the worth of using UAV to spray insecticides in order to reduce human effect (disease) caused by pests. The aerial spray assists in the control of arthropod vectors, particularly the mosquito breeds. UAVs enables vector spraying easy and convenient. Fully autonomous UAVs technology in regard to vector control spraying mechanism and agricultural systems are limited in literature. The UAV spray system produces a moving space spray aimed at hovering mosquitoes. Also, the vector control spray shields against disease-carrying arthropods. The study aims to design and optimize spray application systems (UAV) in Nigerian scenario.

Several studies have been carried out to determine the superlative droplet-size for vector control spray (Curtis & Beidler. 1996, Eisenbeiss, 2004, Matthews, 1988, Himel, 1969). As established by studies, the vector control spray application makes best use of least harmful chemical techniques to salvage pests and disease vectors control. Distance between the sprayer and the measuring device can spontaneously affect droplet-size measurements. Any Aerosol droplets that is more significant than 50m have a tendency to to "settle out" or drops on the ground (Matthews, 1988). (Hoffmann, 2007) opined that distant samplers measure lesser droplets when enormous droplets settle out.

In order to preserve crops and control pests, this paper proposes the development of a low-volume spray system for a completely autonomous UAV. This research is proposed to control vectors.

Methodology

Figures 1 and 2 depict the developed UAV that will eventually act as the foundation for the created application system. The following elements will make up the hardware system: The KK 2.1 Multi-Rotor controller and this manages the flight of multi-rotor Aircraft (Quadcopters, Tricopters, Hex copters etc.) (Aigbe, 2022). It uses signals from the onboard gyroscopes to steady the aircraft while it is in flight (roll, pitch and yaw). It transmits these signals to the Atmega324PA processor, which interprets the signals in accordance with the user's chosen firmware (such as a quadcopter), and provides the installed Electronic Speed Controllers (ESCs) with the control signals. These impulses are combined to tell the ESCs how to fine-tune the rotational speeds of the motors, which stabilizes the craft. CT6B RC Transmitter and Receiver: Hand-held (hobby) RC transmitters and receivers are primarily used in Radio Control (RC) communication. RC airplane propellers are modified to work as multi-rotor aircraft propellers. Size of UAV (Drone) From "nano," which is smaller than the size of your hand, to "mega," which can only be hauled in the bed of a truck, UAVs come in a variety of sizes. A 3D printer and various fiber materials are used to construct the drone body components. The Drone's primary rotor diameter is 1 and its maximum payload is 3.15 kg.

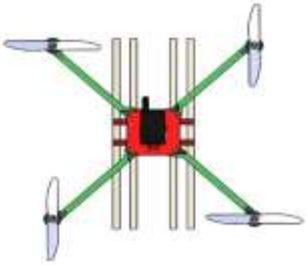

Figure 1: Top View of the Designed Drone (Aigbe, 2022)

Figure 2: Drone Construction Phase

Flight Control System and Telemetry

A Drone's AFCS is an integrated module. The AFCS has a 3-axis, 6 degrees-of-freedom Inertial Measurement Unit (IMU), a 3-axis magnetometer, a GPS, and a proprietary radio receiver with servo interface and safety pilot override. The AFCS controls the Drone using signals from a ground transmitter. A C++ API allowed the AFCS to communicate commands to the transmitter and ground station. Using software and shell commands, unique Internet Protocol (IP) addresses for each UAV pushed from the ground control system such as RunSim, Flyto, Ground and GCS can be used to control UAV flight operations.

Onboard Sprayer

An easy-to-install spray system was designed and built for the drone. Based on preprogrammed GPS coordinates and spray sites, the spray system interfaced directly with the UAV's electrical control systems to initiate spray release. The spray system had four key parts: a boom arm with spray nozzles attached, a tank to store the spray material, a liquid gear pump, and a control device to activate the spray. These parts must be lighter than the Drone's 3kilogram maximum payload. For the best spray mission efficacy, a technique has been developed to aid in component selection and maximize available mission payload capabilities.

Sprayer Component Selection and Payload Configuration

The sprayer on the UAV spray 0.15 ha (1500 sqm) of land on the double load and at low volume sprayed at a rate of 0.0015 L/ha. A net useable payload of 3.5 kg was achieved at a 1.5-kg standard undercarriage. Given this payload, the high-performance telemetry was taken. The 1.9 kg payload of electronic and mechanical components of the sprayer were left, such as the pump speed controller, chemical tank, spray pump, tubing, chemical and nozzles. Table 1 gives weights of the sprayer components and UAV attachments. The boom tubing together with the nozzles weighed 0.3 kg. The spray pump weighed 0.2 kg. The spray tank weighed 0.2 kg and 0.2 kg (0.2 litres) of chemicals.

Table1: Weights of UAV Attachments and Sprayer Components

		Weight (Kg/Litre)
UAV Attachments	Standard Undercarriage	1.50
	Motors	0.45
	Telemetry Unit	0.45
	Tank tubing and Nozzles	0.30
Sprayer Components	Spray Pump	0.20
	Control Box	0.20
	Spray Tank	0.20
	Chemical	0.20
	Total	3.50

Nozzles, Spray Material Tank, Pump and Motor Assembly

The droplet size and flow rate of two misting nozzles, ASABE standard 250067 nozzles, and Micronair UltraLow Volume (ULV) -A+ nozzles (Micron Sprayers Ltd, Bromyard, Herefordshire, UK) were evaluated (Orbit Irrigation Prod. Inc., B. U. & Ecologic Tech. Inc., Pas. Md.). A designed spray tank weighing 0.2 kg and measuring 1.4 x 1.8 x 1.4 cm was created using a 3D printer. A pipe fitting was installed into the 0.5 cm deep channel created by the bottom tank's slope toward the center to deliver the spray mixture to the pump assembly. The DC pump motor received a pulsed voltage, with the modulated pulse width controlling the pump speed. The spray material load sloshing during flight was lessened by two interior baffle plates (1.4 x 1.8 cm). In addition to the tank, there were 0.2 kg of chemicals. The liquid was pumped from the tank to the nozzles using an all-plastic, low-volume, variable speed DC gear pump. The sprayer's electrical parts are weatherproof and electrically protected (Figure 3).

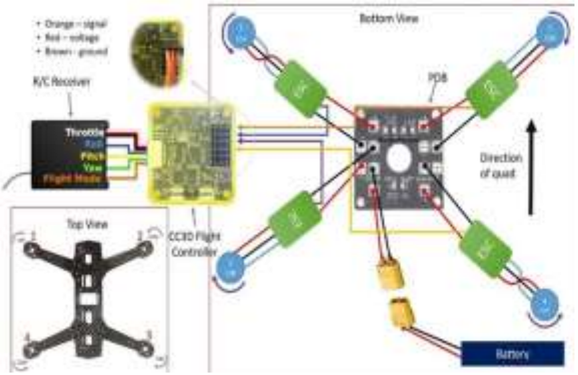

Figure 3: The Block Diagram for The Circuit Connection of The Drone (Aigbe, 2022)

Results and Discussion

The testing of the designed spray system's integration as well as the testing of nozzle droplet size and flow rate, is described below.

Nozzle Study

The droplet spectra from the four water-operated nozzles are shown in Table 2. The findings of a chemical (spray solution) measurement of the droplet size spectra indicated that the misting nozzles created the smallest droplet sizes. Yet, the Micro nozzles exhibited a better spray atomization plume pattern when spraying fine substances at greater altitudes. The original opening into the nozzle was closed, and a 220μm cavity was drilled in the metering insert for the nozzle since the flow rate through the nozzle for vector control was higher than required.

Spray System Integration with UAV And Flight Control System

According to preliminary field testing, the UAV was anticipated to have an effective spray swath of 10m when spraying at 3m. The system sprayed 0.15 ha/min with the anticipated swath width (30m) and speed (2.4 m/s). The flow rate of herbicide oil was tested using a vector control nozzle that was chosen and a pump with a range of pump pressures. With a 10m swath width, 1.3 m/s airspeed, and 0.15 L/ha spray rate, the number of nozzles required on the spray system were calculated using the measured flow rates. The outcomes demonstrated that 2, 3, or 4 nozzles are required for the desired spray rate, depending on the applied pump voltage.

Table 2: Flow rate measurement and number of nozzles needed

Pump Voltage (V)	Flow Rate (mL/min)	No of Nozzles Needed
10	30	4
8	36	3
6	40	3
4	44	3
2	48	2

Conclusions

The construction of an effective spray system for a UAV application platform is demonstrated in this study. An autonomous spray system that may be utilized for pest management and vector control is produced by the integration of the spray system with the UAV. In the PWM control range of the spray pump speed, this UAV's spray system performs particularly well when spraying for vector control ((<50μm droplet size) with a number of nozzles (2, 3, and 4). In order to achieve very precise site-specific application in Nigeria, the development of this UAV system with the sprayer has a huge potential to improve pest management over small agricultural plots or areas within a vast crop field.

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