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Design and Fabrication of a Locally Made Unmanned Aerial Vehicle

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Abstract - Unmanned Aerial Vehicle (UAV) popularly known as drone is a type of robot that autonomously moves in the air. Basically the essences of robots are to assist humans especially in hazardous and/or heavy duty tasks since they cannot be fatigued. Drones are used in Nigeria today in areas such as journalism, media, and entertainment but come at quite a huge cost due to various factors such as importation, as drones are not produced locally, complexities of the machine itself amongst others. Also, they usually come customised to restricted functionalities. This paper therefore looks into using locally available materials to build a locally made drone which potentially can lower the cost of purchase and also employs a different idea/concept in communicating with the drone for on-ground control. The method conceptualised for control is the use of Wi-Fi medium from an android application on a smart phone to provide control to the drones. Also, the functionalities that are targeted are aerial survey and spraying of chemicals in Agriculture circles.

Keywords: Agriculture, Drone, Frame, Gyroscope, Military, Payload, Robot, Unmanned Aerial Vehicle (UAV).

1.0 Introduction

Robots are machines built for helping humans achieve task that seems almost impossible. Being a machine, they are able to reach hazardous (but essential) places that human will ordinary will not visit but needful for the benefit of society to progress. Since then, robots have found more usage in other societal and industrial activities such as industrial automation, car assembling factory and so on.

Robots have existed in various forms one of which is an Unmanned Aerial flying Vehicle (UAV). The UAVs are popularly referred to as drones. A drone is an unmanned aircraft or ship that can navigate autonomously, without human control or beyond the line of sight. Basically, a drone can be said to be the conventional aircraft with the difference of one being a manned controlled system and the other being an unmanned controlled system.

A drone is of high importance due to inability of humans to have access to some places that can be dangerous, hazardous or in crowded areas which if a drone is not employed, necessary crucial tasks will be left undone. This is the major problem drone is solving, making otherwise inaccessible areas accessible. Drones are of practical importance in security surveillance, in Agriculture for monitoring and spraying, in journalism for getting live news feed in an area otherwise inaccessible to journalists amongst others. However, some have employed it to do bad things. Having acknowledged that the sinister, evil, perverted and criminal element will always remain (Bartsch, Coyn, & Gray, 2017), government have come to place some rules and regulations in the fabrication and use of drone.

Acquiring a drone for use in Nigeria costs some fortunes and therefore makes it hardly used by many. Also the drones are customised to meet the needs of the advance country from where they are produced and sometimes find it difficult to adapts some of its functionality to Nigeria context. In view of this. this study aims to design and construct an Unmanned Aerial Vehicle (UAV), this is done by designing an appropriate frame suitable for flight, designing the flight mechanics and perform important tests of the

flight operation of the designed system. The work is expected to achieve lower cost of production and the system to fit into the Nigeria needs.

1. Components of UAV

There are various components, systems and sub-systems that are popularly used in the construction of a drone and are discussed as follows:

1.1. Electronic Speed Control (ESC)

The ESC receives signals from the flight control board and processes the signal gotten to determine the power it delivers to control the speed of motors. Each motor has attached to it an ESC, and each ESC has a processor, a firmware and other electronics for managing the task of rapidly switching on and off the power supplied to the monitor and as well changing direction of motors.

1.2. Battery and Power Supply

UAV's need a source of power supply for running it's engine and since it's active work is when it's in the air, a battery is the logical source of power supply, Lithium battery are commonly used because of its lightweight and higher charge density, the battery must be attached to a protection circuitry. Batteries are the heaviest item on a UAV so they are usually mounted on the dead centre of the drone to subject the motors to the same load. (Ralf and Georg, 2012).

1.3. Flight Controller

Flight controllers are the brains and the coordinator of UAV, they help stabilize the motors and synchronize them so that even if the motors give a different output of thrust the UAV can steady itself. Depending on the flight controller being used, some can be programmed to take off and fly to waypoints. (Ralf & Georg, 2012).

Flight controllers are a huge part of the UAV design since it connects all of the pieces together. Because of this flight controllers can range from user programmed Arduino to autopilot systems. It is important to know what the purpose of the UAV is in order to give it the right amount of processing power. (Ralf and Georg, 2012)

1.4. Microcontrollers

Microcontrollers are computers on a single chip. A microcontroller is basically a microprocessor. It differs in the fact that rather than getting a microprocessor a RAM, a ROM and other core components required to having a fully functional computer; all these major components have all being embedded as a single Integrated circuit (IC) entity. Even though a microcontroller may not be embedded with a RAM or ROM that will be sufficient for a particular intended task, it provides a capability to connect external memory components to complement the ones inside the single chip or to work in isolation or to work as a backup to the internal ones.

Various microcontrollers exist today and there usage depends on the developer and ultimately the task it is intended for. The most popular around here in Nigeria is the PIC by microchip and AT Mega others are Motorola, Cypress Psoc, EPSON, Infineon e.t.c.

1.5. Development Boards

Microcontroller development boards are already made circuits, designed to overcome or to eliminate the hassles involved in soldering and interconnecting components required for operation of a microprocessor or microcontroller. Instead of getting a microcontroller, an oscillator or a crystal, resistors, capacitors and other components separately and interconnecting them using soldering iron and other electronic workshop devices, development board has enabled electronic enthusiasts to go fast in their project endeavours by skipping those steps. There are various development boards that have helped electronic circuit designers to make their work more efficient and with less stress. Most commonly used ones in Nigeria are the Arduino boards (of different flavours: UNO, Mega, NANO, etc.) and the Raspberry pi. Others are Beagle Bone Black, Intel Joule 570X obviously by Intel, DECA board, Thunder board React, NRF52-DK by Nordic Semi, S7 Synergy Starter Kit, Freedom Board, etc. (Griffith, 2017).

1.6. Servo-Motor

Servo-motors are used in applications requiring precise position control like the UAV, it is controlled by a signal known as the pulse-width modulator. Servo-motor is one of my motors. Motors differs according to how they are powered which can are AC motor because they are powered by AC or DC motors because they are powered by DC. The DC powered motor can be furthered classified into Brushed DC motors, Brushless DC motors (which is typically a servo-motor) and Stepper motor (Renasas, 2016). While the DC powered one delivers high powered output, the AC powered one delivers a low power output though more stable. Motors basically consists of stator which is the stationery field and a rotor which is the rotating field also known as the armature and they operate through the interaction of magnetic flux and electric current to produce rotational speed and torque (Chen, 2017).

1.7. Gyroscope

A gyroscope is a device used for measuring or maintaining orientation and angular velocity. It is a spinning wheel or disc in which the axis of rotation is free to assume any orientation by it. A gyroscope helps with orientation of an aircraft while flying thus used to guide UAV's. There are different kinds of gyroscopes based on their operating principle.

1.8. Propellers

A propeller is firmly attached to a motor. With the aid of a motor driven by a rotational force called torque, a propeller helps to generate a force called thrust which acts towards an object and therefore causing a motion of the object in the opposite direction of the line of action of the force (i.e thrust). This follows the newton's third law of motion which states that "To every action there is always and opposed and equal reaction" (Lenzen, 1937).

The thrust is a mechanical force generated by way of the propellers accelerating a mass of air fluid around the drone (Hall, 2015). The equation of thrust is as expressed below:

Force = change in momentum with time

The equation depicting force and the acceleration of air mass is depicted below:

1 (1)

If the mass is kept constant and the velocity is changed with time, the simple force equation is obtained.

$$F = m \times a \tag{2}$$

The equation (2) above is obtainable for a solid body.
However for a moving fluid (liquid or gas), keeping track of mass is difficult, therefore the important parameter is the mass flow rate which is the amount of mass moving through a given plane over a period of time. This is expressed in equation (3). The unit is kilogram per second (kg/s) or slug per second (slug/s).

$$\text{mass flow rate } (\dot{m}) = \frac{mass\ of\ air\ (m)}{time} \tag{3}$$

$$\dot{m} = r \times V \times A \tag{4}$$

- Where r = density of the air
- V = Velocity of the air accelerated by the propeller
- A = Area

Therefore for a moving liquid, the change in momentum across a propelling device can be expressed in terms of mass flow rate ($\dot{m}$) rather than mass. Denoting the end or exit of a propelling device with e and 0 to denote the free stream, then we can have the equation expressed in (5).

$$F = (\dot{m}V)_e - (\dot{m}V)_0 \tag{5}$$

An additional effect that must be accounted for if the pressure P of the exit is different from that of the free stream. The fluid pressure is related to the momentum of the gas molecules and acts perpendicular to any boundary that is imposed. If there is a net change of pressure in the flow rate, ther is an additional change in momentum. Across the exit area, an additional force term may be encountered. This force equals the exit area Ae times the exit pressure minus the free stream pressure.

$$A_e \times (P_e - P_0) \tag{6}$$

The momentum equation in this case is expressed below (i.e $P_e \neq P_0$)

$$F = \dot{m}_e V_e - \dot{m}_0 V_0 + (P_e - P_0) A_e \tag{7}$$

But if $P_e = P_0$ then our momentum equation is expressed thus

$$F = \dot{m}_e V_e - \dot{m}_0 V_0 \tag{8}$$

(Hall, 2015)

1.9. Areas and possible areas of UAV application

UAVs were traditionally deployed in military missions but are increasingly being adopted in civil

applications such as in fire fighting, law enforcement, assessment of natural disasters and environmental monitoring (Lumenera, 2007 - 2012). The increased use of it has inaugurated a new phase in modern warfare (Christi, 2012). There is a special type of UAV designed for military which is called Unmanned Combat Aerial Vehicle; it contains aircraft that is highly manoeuvrable and are able to engage in air to air combat and also provide precision weapon delivery to surface targets (Udeanu, Dobrescu, & Oltean, 2016). One of the most notable use of UAV is in combatting terrorism (Udeanu, Dobrescu, & Oltean, 2016). The United States of America Military had used and is still using it to combat terrorism in the middle-east.

In Nigeria where the country is faced with the challenge of conquering, boko haram and other terrorist group, the use of a drone (UAV) can assist in easily overpowering the terrorist strong hold. Since UAVs can be equipped with tools to perform Intelligence, Surveillance, and Reconnaissance (ISR) (Udeanu, Dobrescu, & Oltean, 2016). With a UAV armed with weapons, an attack can easily be launched at the boko haram sect without endangering our military personnel in Nigeria.

2.0 Methods

2.1 Design and Measurement of the Drone

Using a locally sourced material of aluminium, the frame for the UAV was made. The following measurements were made as detailed below:
The four (4) arms each have a length of 0.3 metres. Each of the four arms extends out of a square cubicle that houses the major components that drives the UAV's accessories.

2.2 The flight controller components

The components that can be found inside the square cubicle base are; a LiPo (Lithium Polymer) battery, two arduino board (arduino UNO), MPU-6050 3 axis accelerometer with gyroscope, and ESP 8266 Wi-Fi module. The arduino board serves as a central processing unit for the UAV, the arduino board uses an ATmega 328P microcontroller.

The measurements for the base cubicle that houses the components are as follows:

- It has a height of 0.2 metres;
- It has width of 0.15 metres each.

Components that resides external to the base are four (4) 1000KV brushless motors, four (4) 9045 carbon fibre propellers and four (4) 30-ampere electronic speed controllers (ESCs).

2.3 Connection Procedures for the electronic circuitry of the UAV system.

- The Red, Black and Yellow terminal of the servo motors are connected to the three Blue terminal of the ESC (Electronic Speed Controller).
- The Red, White and Black terminals of the ESC are connected to the 5V output port, port 9 and Ground (GND) port respectively. Precaution is taken in ensuring the 5V is not connected to the Red wire of the ESC while the board is connected to the PC, otherwise the USB port of the PC will end up burnt.
- The same point where the ESC (i.e. Red and Black Wires) connects LiPo battery is connected to the Vin and GND ports of the Ardunio board.

When connecting of ESC to the Arduino the black is for the GND, White is for 9V, while the Red is for 5V but it's optional because it is either the ESC is controlling it or the power is directly gotten from its source (Lipo Battery).

2.4 Tools Used in Fabricating the UAV Frame

i. Shear Cutter: For cutting the aluminium sink.
ii. Hack Saw: For cutting of aluminium rod.
iii. Hammer: Making a flat surface on the aluminium sink.
iv. Riveting Pin: Joining the aluminium rod and sink together.
v. Working table: For carrying out the work.
vi. Tee-Square: For taking accurate measurement tape rule.
vii. Manual Drilling machine: used for making hole in the aluminium.
viii. Riveting Gun: Driving riveting pin inside of aluminium.
ix. Plier : For holding of nail to punch the aluminium sink.
x. Table Vice or Bench vice: For holding of material firm.
xi. Table Grinding Machine: For filling.

2.5 Program logic

The logic in the program code applied to the arduino microcontroller board is depicted below:

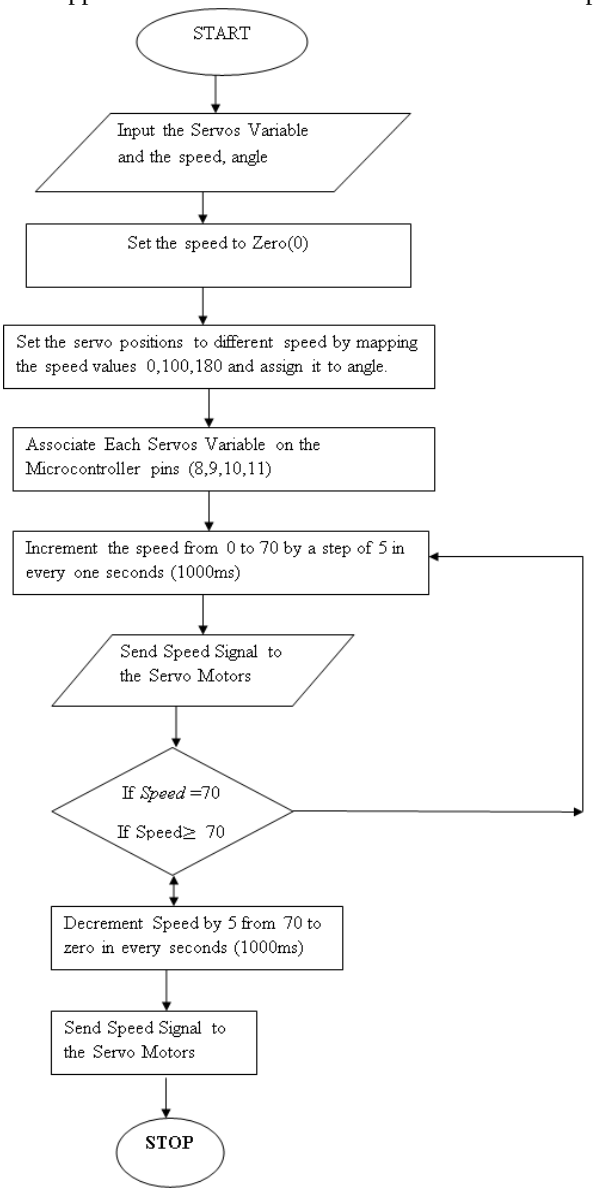

Fig. 1. The drone system control program

2.6 Operation of the System

Pin 8,9,10 and 11 of the Atmel328 microcontroller on the arduino board were programmed to send control signals to the servo motors through the electronic speed controllers. The flowchart below depicts the control program used on the arduino microcontroller.
The plates below shows the constructed frame

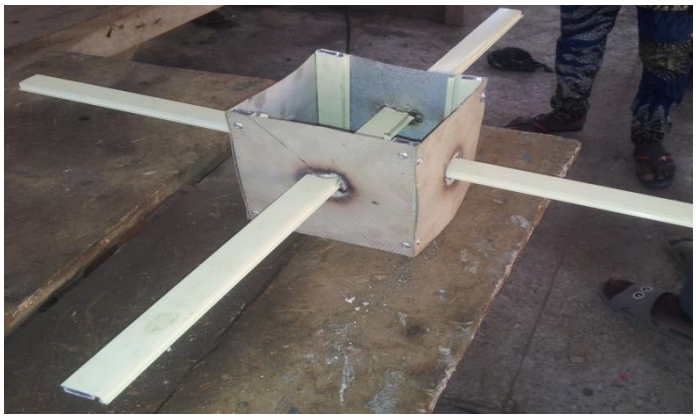

Fig. 2. The Drone Construction Phase

Fig. 3. The drone phase construction with mounted accessories

3.0 Conclusion

The proper running of this UAV is a clear indication that the set aims and objectives have not been achieved because of time constraints and in terms of cost implication and hampered by limited availability of resources.

The design and construction is based on the theoretical knowledge gain so far. It was constructed with considerable cost available and reliable components rather than the more exorbitant unavailable once.

The practical knowledge of the multipurpose use of the arduino microcontroller, gyroscope Wi-Fi module, etc. makes the project interesting, captivating and educating.

4.0 Recommendations

The major work done on the system was the construction of drone frame and to ensure its lifting up off the earth's surface. As discussed in chapter One, the drone consist of two parts which are the drone frame itself which is the flying entity, and the payload which are the systems attached to it to perform specified action. For example, a camera attached to the drone to capture an event is the payload. Therefore it is recommended that further work should be done to ensure a payload such as chemical spraying devices,

aerial survey equipment are attached to the system.

Also, since the major thing the project is aiming at is the cost, the project ended up being expensive as most of the tools used were foreign made components and subsystems. It is therefore recommended that components like the electronic speed controllers be researched into and be built from the ground up.

In the realities of the terrorism being perpetrated here and there in Nigeria, the use of this system can help to combat them by means of surveillance to investigate or monitor the movements of the offenders/terrorist and can also be used to launch an attack by loading the UAV with weapons. This will save our military personnel from grave risk of confronting the deadly terrorists. It is recommended that government should support the design and local fabrication of this system so that the military can be aided with adequate tools without having to rely on selfish international organisation and foreign nationals for sophisticated combat equipment such as the UAVs.

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