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Stable Flight Mode for Quadcopter Drone for Campus Monitoring and Surveillance

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ABSTRACT: This paper work presents the stabilization of a quadcopter flight mode during the implementation of a Quadcopter drone in Nnamdi Azikiwe University Awka for monitoring and surveillance, The implementation of this work allows for remote view of the suburbs of Nnamdi Azikiwe University Awkaclearly from an aerial view, at altitude of 65m and also the flight characteristics were obtained. In this paper, the mission planner was used to configure flight parameters, synchronization and also the flight dynamics of the quadcopter were employed to achieve a stable flight mode. It is of utmost importance to know the parameters associated with this paperwork as they are important for flight operation. The flight time was calculated to be 16mins 30secs using 2200mAH Lithium Polymer battery, the speed of the blades measured as 11040rpm with the power dissipated by the propulsion unit as 5.81watts, and torque generated at $132\mathrm{n/m^3}$.

KEYWORDS: Stable Flight ,Motion, Thrust, Propellers, BLDC, Quadcopter, UAV, Mission Planner.

I. INTRODUCTION

Quadcopter is a device with an intense mixture of electronics, and mechanical components. It is based mainly on the principle of flight with dynamic stability. The Quadcopter can be customized and sized according to our own convenience. It can be implemented as much small as we want by using the small sized components we need to make it.The applications of Unmanned Aerial Vehicles for civil purposes have expanded in recent times as a result of growing research and technological advancements in the development of drones. These applications include surveillance, emergency situations, agricultural and industrial applications as well as package delivery. As more benefits are been unearthed, there remains a major limitation in terms of the battery life span which imposes a restriction to a longer flight time for various missions.
The Unmanned Aerial Vehicle (UAV) is a remotely driven or sensing aircraft that has no pilot on board it. It can also fly on its own. Drones are also referred to as Remote Piloted Aircraft Systems (RPAS), Unmanned Aircraft Systems (UAS), Small Unmanned Aircraft (SUA), Small Unmanned Surveillance Aircraft (SUSA), Multi-rotors and Quadcopter.
In recent times, drones have been used for teaching and research purposes. Although they have enormous benefits, their operation still has to be regulated under a legal framework as it can cause harm to people and property.Unmanned Aerial Vehicle has a lot of applications in various fields and they include: UAV Navigation, UAV controller design, cooperative air and ground surveillance, volcano monitoring, photography of real estates, Anti-piracy operations and controlling of sand miningBloor,2016 [1]

With recent technological advancements,the use of drones as unmanned aerial vehicle has increased in recent years for surveying, facility management and other relevant fields. The planning and monitoring of activities is one of the key areas that needs proper attention in the school, this projectwill play a very important role in NnamdiAzikiwe University Awka, as the manual way of monitoring events in the school premises can never be reliable enough, ranging from functional occasions, to extracurricular activities. Indecent and immoral activities within the school such as cultism and social unrest can be monitored and information recorded from a central point. This will also serve a useful purpose in examination and conferences if not for the size.

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II. REVIEW OF LITERATURE

In [2], during the 10th International Conference of Environmental Engineering, as stated, the UAV platform's flight controller is designed to provide smooth and stable flight performance.Mainly, the flight controller is designed to perform automatic control of angular stabilization, angular position and trajectory during flight phases (operation modes) from take-off to landing(Ardupilot 2016). Basically, the drone stabilization is controlled in loop feedback mechanism, used in control systems, named PID controller (proportional-integral-derivative controller). In this particular system PID controller receives data measured by the sensors on the flight controller's gyros and accelerometers and compares that against expected values to alter the speed of the motors to compensate for any differences and maintain balance. The PID controller calculation algorithm involves three separate constant parameters, the proportional, the integral and the derivative values that are to be tuned for a specified construction. The Arducopter firmware 3.4.3 installed on board Pixhawk flight controller allows for the performing of auto tuning mode in which PIDs parameters for the platform can be tuned automatically. This procedure takes few minutes, and the copter during flight attempts to automatically tune PID rates to provide the highest response without significant overshoot, although this procedure can overshoot parameters, causing copter to be too responsive for input, or a "wobbling" effect, which must be corrected manually.

In [3], within this particular firmware, there are 14 built-in flight modes, 10 of which are regularly used. There are modes to support different levels/types of flight stabilization, a sophisticated autopilot, or follow-me system. 6 of them were programmed for the research tasks (Stabilize, Alt Hold, Loiter, Return-to-Launch, Auto and Circle). Flight modes are controlled through the radio (via RC transmitter switch), via mission commands, or using commands from a ground station (GCS) or companion computer (Ardupilot 2016). The Pixhawk flight controller is responsible purely for a flight control, and its processor (168 MHz Cortex M4F CPU) is unable to perform complicated computation. For testing and developing photogrammetry and remote sensing algorithm other commutation devices are to be used. For this reason, this project configuration enables to use a companion computer, in order to perform complicated calculation and pass only a navigation decision to the Flight controller.

Also in [4], another work titled "Quadcopter Summer project" which is a summer PCB design class project. The aim was to design a PCB based quadcopter from scratch using a 4.2V lithium battery that can supply 4A current to power the quadcopter, including microcontroller power, mpu6050 sensor power and the motors. STM32F4 microcontroller on this board runs at 168MHz, with its FPU (Float Point Unit) module, it could easily process data from mpu6050 to get the board's orientation with complementary filter. An RTOS named ChibiOS is running on STM32F4, it is compact, fast and well documented. It is written in C; so many C libraries could be used, or ported. For the wireless communication, XBee module was used. This module only need simple setup with provided software and only 4 pins are enough for the purpose. But in comparison to this project's wireless communication which uses RF module and the ATMEG microcontroller section, this work will be an upgrade considering the fact that the STM32F4 microcontroller pin used for the XBee module transmitter port can easily go wrong during stabilization adjustment as itwill always requires swapping of pins.

Stafford Jesse, in [5] explains the procedure of a working quadcopter. It uses two pairs of identical fixed pitched propellers in which two rotate clockwise (CW) and remaining two counterclockwise (CCW). These use independent variation of the speed of each rotor to achieve control. By changing the speed of each rotor it is possible to specifically generate a desired total thrust. Quadcopter differ from conventional helicopters, which use rotors that are able to vary the pitch of their blades dynamically as they move around the rotor hub.

Gordon Ononiwu, ArinzeOkoye, et al. [6], this paper presents the design and implementation of an aerial surveillance quadcopter for search and rescue applications. The first phase of the paper considered modelling of the quadcopter while the second phase involved system implementation and simulation. It results in surveillance and reconnaissance quadcopter which can take the photographs from environment captured through the aid of the on board mounted camera while live streaming with the help of laptop during flight.

In Ganeshwaret al, [7], a drone system that could be used for surveillance and security management was proposed. This system was going to reduce the labour in finding bombs in a forest area thereby reducing loss of lives to the barest minimum. The system is expected to carry out the surveillance of an individual by loading the person's image into the processor interfaced with the drone. This would make it easy for a person to be tracked in his location without any manpower. The Global-positioning system (GPS) gives the location of the system and the Global System for Mobile Communications (GSM) sends the message of the location.

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The GPS location of the system can also be used to track a vehicle's location which is sent to a cloud receive location using a mobile application, in order to curb car theft. This proposed system was found to be much more better than previous surveillance methods as it consumes less power, has less human error, possess sophisticated security, is safe and cost effective.

In Farlik*et al*,[8] an analysis was carried out on the possibility of detecting UAVs in various electromagnetic spectrum bands. At first, they used calculation and simulation methods as well as experiments in laboratories where external measurements were taken.

III. PROBLEM DEFINITION

During the research, it occurred that NnamdiAzikiwe University boasts of over 250acres of land mass, and of which is evenly spread with different faculties, utility buildings and other strategic locations. It is obvious that monitoring and coverage of these points have always been done manually and of which is not totally dependable and reliable.

This paper utilizes the quadcopter drone as surveillance device for monitoring operation in the school premises, and will also help curb immoral and indecent operations.

Over the years, the coverage of most activities done within the school was inefficient, as it provides a view from one angle, which on some occasions do not give detailed information nor proffer the expected outcome. Oftentimes during an event within the school, the viewer or the Camera personnel will have to cover a lot of ground distance to capture a scene, and still emerge with slow and poor output performance.

Secondly, as these platforms are situated at rather remote or inaccessible areas, the flight endurance and maneuverability of the quadcopter drone will be significant, excluding during windy weather, because of its struggle against forces attributed by the wind.

IV. APPLICATIONS OF 4G AND 5G IN DRONES TECHNOLOGY

4G and 5G could also advance live drone video capability in leaps and bounds. Their enhanced ability to transmit data may increase the potential for their use in broadcast television, video surveillance and video mapping. Any industry which requires aerial video to be fed back in real-time can benefit hugely from 5G networks – meaning that 5G has implementations in everything from construction to traffic flow analysis. We may see drones go from being an occasional tool used by the video to capture an interesting shot, to being a common place feature in broadcasting other applications includeaerial photography, .shipping and delivery, geographic mapping, disaster management, precision agriculture, weather forecast, wildlife monitoring, entertainment and in law enforcement with this huge market in place if well deployed and implemented.

V. METHODOLOGY

The methodology used follows a structured implementation process that requires a systematic approach. The overall system encompasses various sections of hardware and software implementation. These methods play an important role in achieving the intended system. In this research, each unit is developed separately from the other units and thereafter all the units are integrated together to implement the stability of the whole system. Quite a number of properly laid out steps were followed to achieve the objectives of the project. Each step is carried out with careful articulation, because the success of any phase of the project is dependent on the success of the preceding phase. The stability mode of this system is determined using the mission planner application.

VI. QUADCOPTER FLIGHT DYNAMICS

It is important to be knowledgeable with the flight dynamics of a quadcopter in order to obtain a stable flight mode. This is achieved by varying the spin (revolution per minute RPM) of the four rotors so as to control lift and torque. During flight operation such as monitoring exercise, the thrust is determined using altitude, pitch, and roll angles and this is obtained from the ratio of the angles. The thrust plays a key role in maneuvering, and enables the user to perform flying routine which includes aerial maneuvers. To achieve angular orientation along with takeoff, landing and hovering at an altitude, there are four major directions to move the quadcopter for the aerial monitoring of events. These directions are Roll, Yaw, Pitch and Throttle.

Guide to flying the Quadcopter for monitoring event:

1. Roll moves your quadcopter left or right. It's done by pushing the right stick on the transmitter to the left or to the right. It's called "roll" because it literally rolls the quadcopter. For example, as you push the right stick to the right, the quadcopter will angle diagonally downwards to the right.

2. Pitch is done by pushing the right stick on the transmitter forwards or backwards. This will tilt the quadcopter, resulting in forwards or backwards movement.
3. Yaw is done by pushing the left stick to the left or to the right. Rotates the quadcopter left or right. Points the front of the copter different directions and helps with changing directions while flying.
4. Throttle is engaged by pushing the left stick forwards. Disengaged by pulling the left stick backwards. This adjusts the altitude, or height, of the quadcopter.
5. Maneuvering is a consistent circular turn in either the clockwise or counter clockwise direction.
6. Hovering is simply staying in the same position while airborne. Done by controlling the throttle.

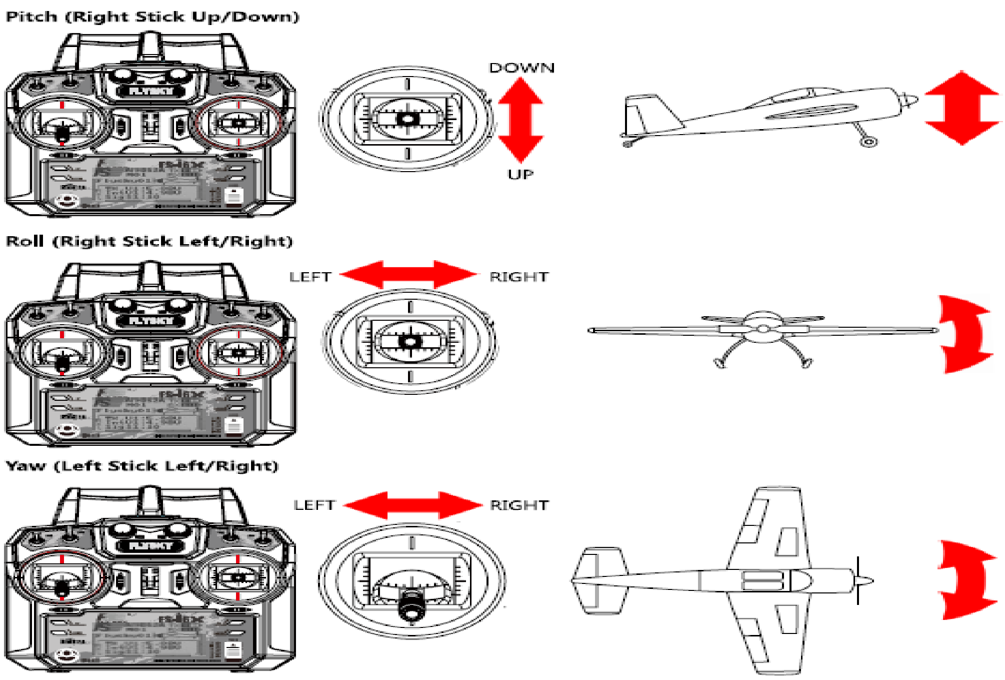

Fig .1: Flight control of a Quadcopter
Source: Fly Sky FS-i6X manual

VII. PROPOSED WORK

For this vehicle to have a smooth and stable flight operation without so much wobbling the quadcopter is properly armed and accel calibrated. This method was used to achieve the stability of this project. It is done using the mission planner application software and little skill of observation. The arming of the quadcopter involves the uniform synchronization of the four motors to have the same starting torque and the same rpm. Prior to this, it is ensured that the motors are well axially positioned and fastened, then using the mission planner under initial set up and accel calibration, the gyro sensor is equipped with the eight required directions to obey for a stable flight mode which are reference level, right side level, left side level, nose down, nose up, left side bend, right side bend and flat back. These major positions are now saved in the arducopter gyro sensor, and the radio and ESC calibrations are done subsequently to synchronize with full throttle, pitch, raw and yaw with the gyro sensor and the accelerometer.

VIII. SYSTEM ARCHITECTURE

Each quadcopter can have a very different hardware component which mostly depends on application in which it will be implemented. Standard components are: microcontroller, sensors, motors, power supply and telemetry devices. The basic component of each quadcopter is frame. In this project, the arms and center plate of the quadcopter frame is in made of glass fiber. Connections between the center plates and arms, as well as the motor mounts are made of aluminum. The modular integration of the frame allows components to be replaced easily if necessary. Another important part of this quadcopter is the propulsion unit. The propulsion unit for the quadrotor consists of four brushless DC motors and four electronic speed controllers. The power source for the system is a cell lithium polymer battery. Propellers mounted on the motors are several cm lengths and have a fixed pitch angle. This propulsion configuration

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allows safe operations of the frame and ensures excellent lift and thrust performance for all of the flight. Within the Flight controller unit which is the heart of the system contains the microprocessor and inertial measurement unit with accelerometers, magnetometer and gyroscopes responsible for sensing and stabilization. Interfaced to the power distribution unit is also a video graphic unit which consists of a high definition camera for imagery.

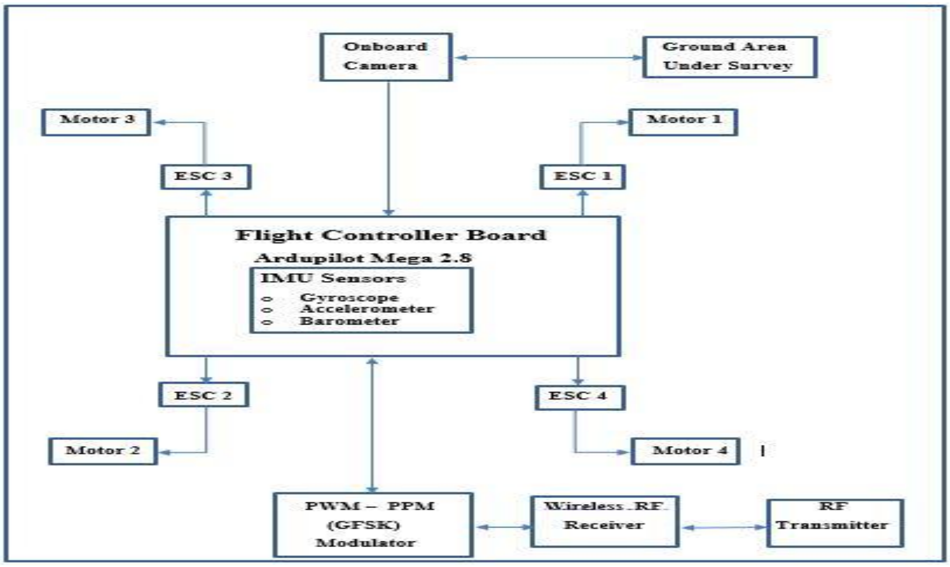

Fig 2: Block diagram of a Quadcopter

IX. TECHNOLOGY

In radio frequency communication, there are several modulation techniques available, such as the Pulse amplitude quadrature (PAQ), Phase shift keying (PSK), Amplitude shift keying (ASK) etc. But in this work, the technology adopted is of Gaussian Frequency shift Keying (GFSK) due to its filter capabilities and compatibility with the transmission protocol employed. The transmission protocol which is Automatic Frequency Hopping Digital System (AFHDS-2A) is a multi-channel Hopping Frequency. This protocol’s bandwidth ranges from 2.4055GHz to 2.475GHz. This band is divided in 135 channels. Each transmitter hops between 16 channels in order to reduce interference from other transmitters.

X. FLY SKY TRANSMITTER AND RECEIVER

The excitation and response states of this project are demonstrated using Fly Sky Transmitter and Receiver. In this work, we use FS-IA6 model transmitter which has 6 channels and operates at frequency of 2.4GHz. A personal computeris used to change the channel variables, and servo reversing. The radio transmitter and receiver allow you to control the quadcopter. There are many suitable models available, but you will need at least four channels for a basic quadcopter. In electronics and telecommunications, a radio transmitter is an electronic device which, with the aid of an antenna, emits radio waves and propagates them into the medium towards a compatible receiver (Fly Sky FS-i6X).

The transmitter when energized generates a radio frequency signal, alternating current, which is modulated and applied to the antenna. When excited by this alternating current, the antenna radiates radio waves. The term transmitter is usually limited to equipment that generates radio waves for communication purposes; or radiolocation, such as radar and navigational transmitters.

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XI. DESIGN APPROACH OF THE QUADCOPTER

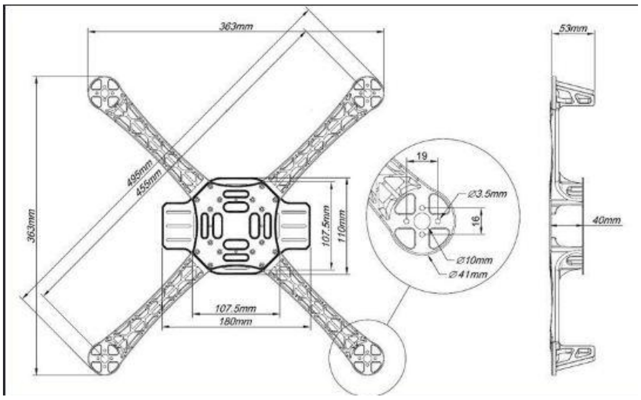

Fig 3: Architectural Design of F450 Frame

The quadcopter design is based on the embedded system platform. It consists of microcontrollers which control the overall performance of the quadcopter such as flying mechanism. After the microcontroller, the Electronic speed controller (ESC) is used to control the propeller speed depending on the signal from the controller. The power supply of the quadcopter is achieved by the LIPO battery. These requirements make sure that the quadcopter maintains stable flight while moving or hovering.

This quadcopter drone was implemented using a different and more suitable modulation technique from most conventional drones. The modulation technique used is of Gaussian frequency shift keying (GFSK) which is a modulation method for digital communication, basically the standard for AFHDS 2A (Automatic frequency hopping digital system), Bluetooth and other wireless communication. A Gaussian frequency shift keying (GFSK) modulator differs from an ordinary Frequency shift keying (FSK) modulator in that before the baseband waveform goes into the FSK, it is passed through a Gaussian filter which makes its transition smoother, this also limits its spectral width; it is simply called pulse shaping. This method has an advantage of reducing sideband power, reducing interference with neighboring channels [5].

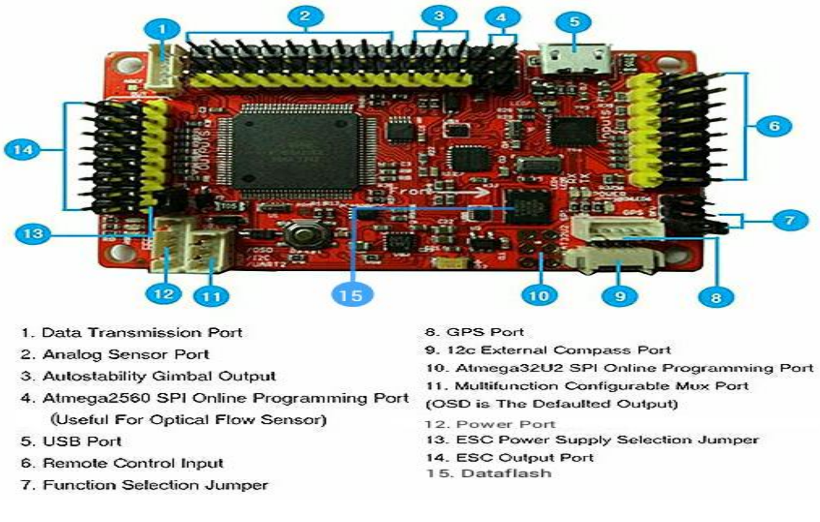

Fig 4: Pin Configuration of an APM flight controller board

In this work the flight controller which serves as the heartbeat of this device interacts with the transmitter ground station using this technique. The flight controller board is used for different operations performed by the quadcopter like roll, pitch and yaw.In this quadcopterArdupilot Mega 2.8 (APM) which is a single chip autopilot was used, it consists of two microcontrollers, Atmel's ATMEGA2560 and ATMEGA32U-2 chips for processing and usb functions respectively.

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XII. ARDUCOPTER ARDUINO SOFTWARE CONTROL PROGRAM

In the Mission Planner, these commands are dependent on C++ programming language, using an Arduino IDE. The Arduino project provides an open source electronic platform that uses sets of robust microcontrollers, Atmel's ATMEGA2560 and ATMEGA32U-2 chips for processing and USB functions respectively. The safe flying and safe landing of this quadcopter can be assured by implementing a written computer algorithm which runs the flight controller, and gives it instructions in form of a software command. These software commands are encoded into the microcontrollers of the flight controller, the flight controller in turn using the arduino hardware compatible platform to activate the corresponding servos and sensors to achieve a desired flight and safe landing. These algorithms represent series of steps and codes that controls the entire system.

XIII. ARDUPILOT MEGA CONFIGURATION USING THE MISSION PLANNER APPLICATION

Having already installed Mission Planner software, ensure that the battery source of the Apm is disconnected. Using a micro USB cable, the Apm is connected to the computer, this was automatically detected by windows, and its drivers were downloaded by manually installing Arduino Mega 2560 drivers. Then the mission planner software was opened, with the computer connected to the internet. Clicking on the Initial setup tab in the menu, the firmware option is opened and Quad X option selected because the frame in use is an X-frame. The firmware for this Quad X was automatically downloaded and installed on the Apm.

After the above procedure, the configuration setup was done, starting by opening the control panel then devices and printers in order to take note of the COM port which the Apm is connected to. Going back to the home page of the mission planner, at the top right, this noted COM port was selected and set to a baud rate of 115200.

After this was done, the next step is going to the Mandatory Hardware under Initial set up for the configuration the individual Quadcopter components. Under frame type, the option 2 is selected for X orientation, then under Accelerometer calibration, Calibrate Accel is clicked and selected. The Quadcopter is moved left, right, back, level in different directions, this allows it to sense and save the movements. Then under the Radio calibration, all the sticks and switches are moved to extreme positions and then back to mean positions and again calibrate radio was clicked. This saves the maximum and mean ranges of the sticks.

Then the Failsafe mode was enabled, this allows the quadcopter to return to its original position if connection was lost between the transmitter and the receiver or if the battery gets low.

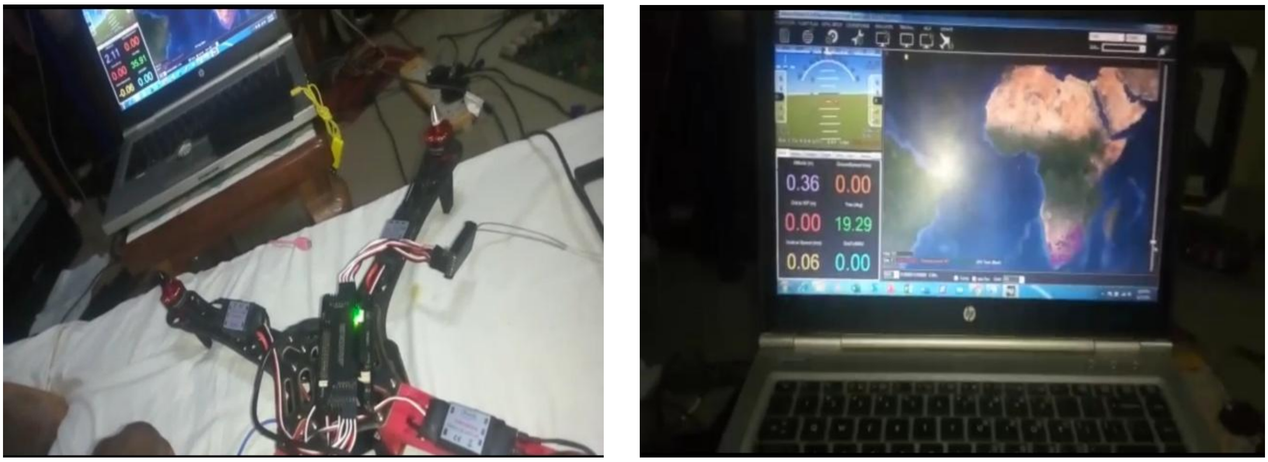

Fig 5. Configuration of Flight controller using Mission planner

XIV. TORQUE ANALYSIS OF THE MOTORS

Brushless motors are used for all quadcopter applications. For the electric motors, the torqueproduced is given by

$\tau = Kt\ (I - Io)$; $Kt = (0.01794) * Kv$

Max current drawn by Motors =

$No\ of\ Motors\ \times Max\ current\ drawn\ by\ a\ single\ motor$(1)

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Where *t*is the motor torque, I is the input current, Io is the current when there is no load on the motor, and Kt is the torque proportionality constant and is obtained using electromechanical relationship. The voltage across the motor is the sum of the back-EMF and some resistive loss:

$$V = IRm + Kvw \qquad (2)$$

Where V is the voltage drop across the motor, Rm is the motor resistance, *w* is the angular velocity of the motor, and Kv is proportionality constant (indicating back-EMF generated per RPM). We can use this description of our motor to calculate the power it consumes. The power is

$$P = \frac{(\tau + \mathrm{Kt\ Io})(\mathrm{Kt\ IoRm} + t\mathrm{Rm} + \mathrm{KtKv}w)}{Kt^2} (3)$$

For the purpose of simple model, anassumption of a negligible motor resistance is made. Then, thepower becomes proportional to the angular velocity:

$$P = \frac{(\tau + KtIo)Kvw}{Kt} = \frac{Kv}{Kt}\tau w (4)$$

Calculating the Torque generated in this quadcopter,

$$\tau = Kt\ (I - Io)$$

*Where Kt = (0.01794) * Kv*

$$\gg Imax\ for\ a\ single\ BLDC\ motor = 2A$$

*Total I drawn = Imax * number of motors*

*I = 2A * 4 = 8Amps*

*Since torque proportionality constant Kt is = (0.01794) * Kv rating*

*Kt = (0.01794) * 920kv = 16.504*

Therefore,

$Torque\ \tau = I * Kt$

$= 8 * 16.504 = 132\ n/m^3$

For Further simplification of this model, assume that Kt I0 <<*t*, since I0 is the current when there is no load, and is thus rather small. In practice, this approximation holds well enough. Therefore, a final expression is obtained in a more simplified equation for power using propeller constant:

$P = Kp * D^4 * P * N^3 (5)$

Where Kp = Propeller constant = 1.11

P = pitch of the propellers in metres

N = Kv * Voltage input is the speed in RPM (Revolution per minute)

D = diameter of propeller

The total power(watts) dissipated by the propulsion unitof this quadcoptercan be calculated,

Given Kp = Propeller constant = 1.11

P = 0.114m

N = 11040r rpm

D = 0.254m

(For 1045/1045RC Drone propeller)

$$\boldsymbol{P = (1.11) * (0.254^4) * (0.114) * (11040) = 5.815 watts}$$

XV. FLIGHT TIME

This is the total time elapsed during flight operation and it is dependent of the battery capacity and power consumed within the quadcopter.

To calculate flight time, it is necessary to know the average amperage drawn by the quadcopter.

$$flight\ time = \frac{(Battery\ capacity\ in\ Ah) * 60}{Average\ amp\ drawn}$$

$$Average\ amp\ drawn\ by\ Quadcopter = amps\ per\ motor * Number\ of\ motors \qquad (6)$$

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Since the battery capacity is given as = 36000mAh / 12V

$$Flight\ time = \frac{3600 * 60}{1000 * (2A\ per\ motor * 4pcs)} = 16minutes\ 30secs$$

XVI. QUADCOPTER FLIGHT TEST

Having done the complete implementation, the Quadcopter was tested for a stable flight mode in an open field where there are no passers-by. The flight was tested for the three major motions, hovering and maneuverability using the control sticks and switches as explained under quadcopter flight dynamics.

Fig 6: Picture of the Quadcopter during Flight

XVII. CONCLUSION AND DISCUSSION

In conclusion, the implementation of quad copter drones for monitoring and surveillance in NnamdiAzikiwe university awka , the paper x ray a new dimension technology for aerial coverage in data collection and analysis. Thus when well implemented will solve the problem of security, examination monitoring and mapping of the school environment at ease. It is recommended that for efficient operation of this quadcopter, its flight operation should be done only at line of sight (LOS), and not near power lines to avoid frequency interference from large objects. Outside this, there would be loss of control. It is also advisable to fly the vehicle within a ground distance of 500m and 90m altitude under a favorable condition as moist or windy weather will degrade the signal quality.Due to impairment such as total stability issue generated from damping effect as observed during flight test, the work is open to further research so as to completely eliminate damping in the system and at the same time maintain equilibrium and complete stability

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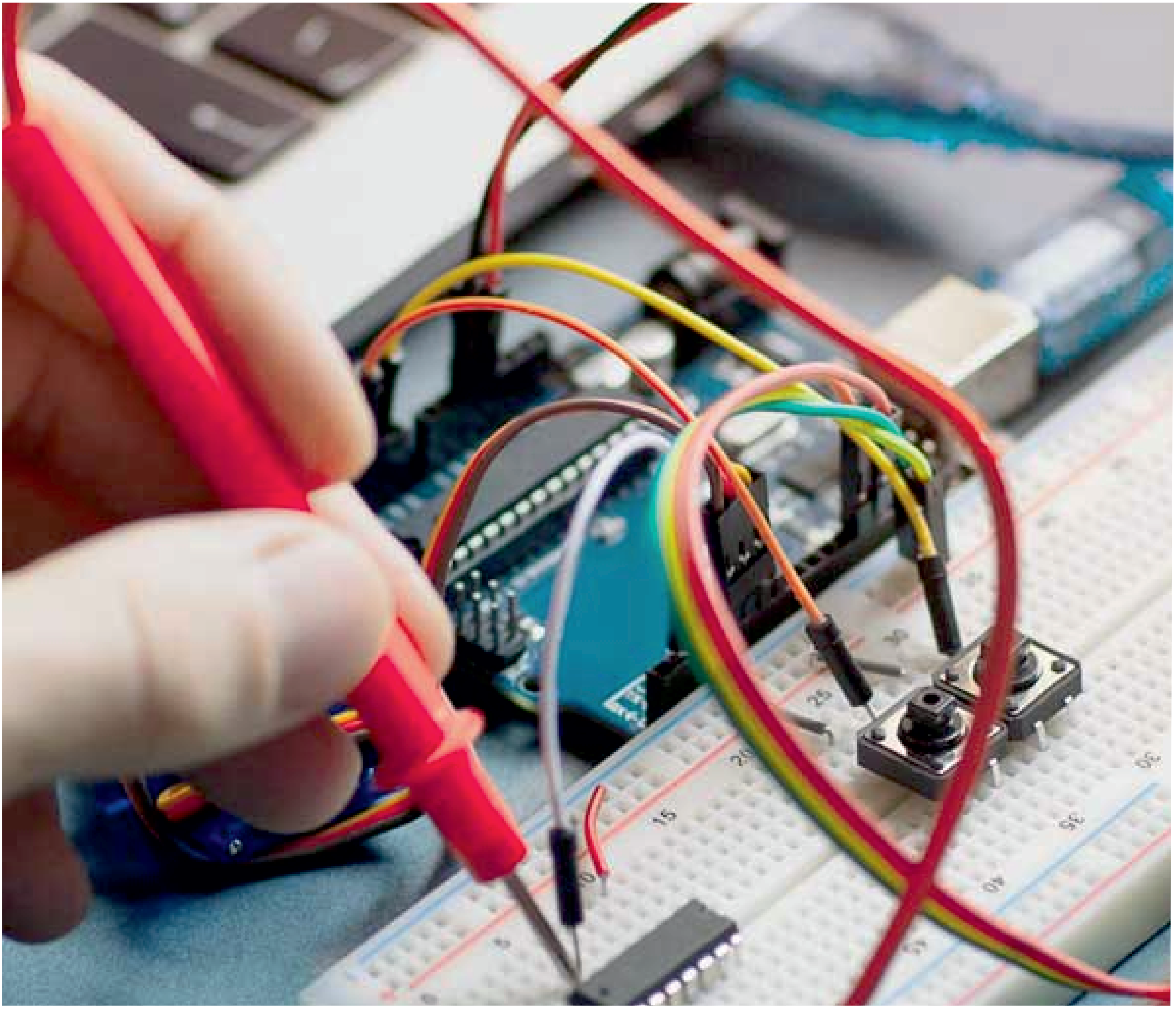

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