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"Mini Surveillance Quad-copter"

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Abstract:- Conventional drones are not only large in size but also heavy and high-priced. We aim to develop a small quadcopter, with fewer payloads which is not only cheap but also can be used for short time surveillance with features like obstacle detection and failure resistance. Our aspiration is to design a light weight, mini sized quadcopter system for surveillance purposes. We aim to attain obstacle avoidance apart from designing a safe landing mechanism during emergency/ system failure to achieve better performance. We intend to accomplish the desired goals by integrating IR sensors in our drone along with studying battery life versus flight time study for a fail-safe operation.

Keywords- Quad-copter, MultiWii, Flight Controller, Surveillance.

1 Introduction

Recently we have seen a massive growth in the manufacture and sales of remote control airborne vehicles known as Quad-copters. Unmanned Aerial Vehicles (UAV) usually have four arms and fixed pitch propellers. The propellers are typically positioned in an X shape or + (plus) configuration. More often than not, placement in an X shape, is the favoured configuration. These UAV's are also referred to as Drones, Quadrocopters or in short Quad-copters. In quad's two of the propellers spin in a clockwise direction while the other two spins in an anticlockwise direction, This arrangement allows the drone to ascend vertically, flit around in the air and flutter in a designated direction. Remote control enthusiasts are widely using Quad-copters as an effective aerial photographic platform [1]. We have added four motors and four propellers to a lightweight carbon fibre frame, which is in turn, connected to a remote control transmitter via a small control board, which is fitted with a gyroscopic stabilization system along with a Li-Po battery. This construction is relatively simple to assemble. Proliferation of Quad-copter designs can be attributed to the rapid advancements in computational power, tinier microprocessors, improvement in batteries, efficiency of the coreless or brushless motors, and gyroscopic and accelerometer technology.

2 Components

2.1 Body and structure

The physical structure for the entire aircraft is provided by the frame of the quad-copter. It not only connects the motors to the rest of the quad-copter but also houses all of the other components. The only consideration while choosing the frame is that it must allow all the four propellers to spin without collision and also it must not be bulky for the motors either. The centre plate is usually of light weight material and has four arms made of light plastic attached to it. The overall dimension of our quad-copter is mere 150mm, measured from motor to motor.

2.2 Flight Controller

Arduino Nano- The ATmega328 provides a UART TTL serial communication, which is availableon digital pins RX (0) and TX (1).An FTDIFT232RL on the boards channels the serial communication over USB. The FTDI drivers provide a virtual com port to software on a computer. The Arduino software comprises of serial monitor which enables simple text data to be sent to and from the Arduino board.

Voltage Elevator- The MT3608 2A Max DC-DC Step up Power Module has a clever boostcircuit with an inductor to convert a low input voltage into a usable higher output voltage. This module features the MT3608 2 Amp step up (boost) converter. It can take input voltages as low as 2V and step up the output to as high as 28V. It features automatic shifting to pulse frequency modulation mode at lesser loads. It includes under-voltage lockout, current limiting, and thermal overload protection.

MPU 6050- The MPU 6050 is a six-axis IMU sensor, which means that it gives six values asoutput consisting of three values from the accelerometer and three from the gyroscope. It is a sensor based on MEMS (micro electro mechanical systems) technology [2]. In this project, accelerometer is used to determine position and orientation of a drone in flight. It detects the change in acceleration due to gravity whenever the drone performs a movement along x-axis (forward and backward) or along y-axis(sideward). Gyroscope determines angular velocity of the drone.

ESC (Electronic Speed Controllers)- These devices are basically used to control the speed of motors. Each motor is associated with an exclusive electronic speed controller. These PWM based speed controllers receive commands in the form of signals and adjust motor speeds accordingly. Its purpose is to vary an electric motor's speed, its direction and also braking. Here we have used NPN122 transistors along with zener diodes for the same. It has a Darlington pair configuration giving a high DC current gain and operates on the Collector current of 5A which gives a low switching speed and thus controlling the motors.

2.3 Wi-Fi Module (ESP8266-01)

The ESP8266 ESP-01 is a Wi-Fi module that allows microcontrollers access to a Wi-Fi network. It is interfaced with Arduino with the help of AT commands. It handles all the necessary overhead for communicating with TCP/IP stack and 802.11 networks [3]. It is completely addressable over SPI and UART protocols.

2.4 Coreless motors

They are economical and simple to use and their Speed is linear to the applied voltage. We have used 8.5x20 mm coreless motors with 50,000 rpm and the 75mm propellers generating 35gm of thrust per motor resulting in a total thrust of 140gm.

2.5 IR sensors

The Infrared Sensor which is used as Obstacle detector is to transmit an infrared signal, this infrared signal bounces from the surface of an object and the signal is received at the infrared receiver notifying by beeper and thus avoiding collision.

2.6 Camera

As mini drone requires a camera that can be used for low level surveillance, aerial photography and this type of camera are called FPV. First Person view is a concept in the drone hobby where alive video stream from the drone is sent to a display in the pilot's view.

2.7 Battery

As our miniature quad-copter has less payload and sensors it requires lithium polymer battery of 3.7v 850mah with 20C rating for distributing power to components and having more flight time

[4]. *C Rating* is an indicator of the continuous discharge rate of a Li-Po. It allows users to easilycalculate the maximum constant current you can draw from the Li-Po pack safely without harming the battery.

3. Methodology

At the very onset, we created a frame where our primary component, the Arduino, would be mounted. We are specifically using Lithium batteries as their ratio of weight to power is paramount in the group. Motors are used to whirl the propellers. Controlling of the four motors is done through the accelerometer and gyroscope of the Electronic Speed Controller (ESC) unit. This unit actually provides stability to the quad-copter. Quad-copter is constantly connected to Wi-Fi for receiving the signals.

3.1 Quad-copter flight dynamics

In the quad-copter, there are four motors placed at the edge of four arms of the frame. The direction of each motor's rotation is such that it balances the torque generated by the motor that is placed at the opposite side. This prevents the quad-copter from spinning due to torque effect. It has two opposite motors spinning clockwise and two opposite motors spinning anti clockwise. The torque generated by each of the motors cancels out and thus it is lifted upwards. For the quad-copter to hover in place, it is necessary to ensure that all the motors rotate at the same speed (or RPM). The rotation speed of the motors must be sufficient enough for the quad-copter to generate a 'lift', counteracting its own weight, but not so much that the quad-copter keeps gaining altitude.

Gaining and losing altitude:

In order for the quad-copter to gain altitude, all the four of motors must increase the speed of rotation simultaneously. Also to descend, all four of the motors must decrease speed of its rotation simultaneously.

Pitch: The 'pitch' control signals the quad-copter whether to fly forward or backward. In order topitch forward, the speed of the motors at the rear end of the quad-copter must increase, in relative to the speed of the motors on the front. This pitches the nose of the quad-copter down, resulting in the forward movement. Conversely, in order to pitch backwards, the speed of the motors at the nose of the quad-copter must increase relative to the speed of the motors at the rear end.

Roll:The 'roll' controlsignals the quad-copter to move side by side.In order to 'roll' to the right,the motors on the left of the quad-copter must have higher speed as compared to the speed of the motors positioned to the right side of the vehicle. Conversely, in order to 'roll' left, the relative speed of the right located motors of the quad-copter should be more than the speed of the motors towards the left.

Yaw: The 'yaw' also known as 'rudder' is a rotational movement of the quad-copter. Here, the rotation speed of diametrically opposite pairs of motors are increased or decreased, varying their torque in the direction of rotation of that pair, causing the quad-copter to rotate in the direction of the increased torque.

The efficiency of the overall drone with respect to the flight dynamics values are calculated using the formulas:

Equation 1 relates Power using air density and air velocity

$$P=(\rho A v^3)/4$$

Eq. (1)

Equation 2 describes Upward Thrust using air density and air velocity

$$F\_thrust = (dp_{air})/dt=(\rho A v^2)/2$$

Eq. (2)

Rotor area is A and the density of air is ρ, then this would be an expression for the thrust force (magnitude) as a function of air speed v and P is power.

4. System Architecture

The following block diagram is the system architecture of the quad-copter:

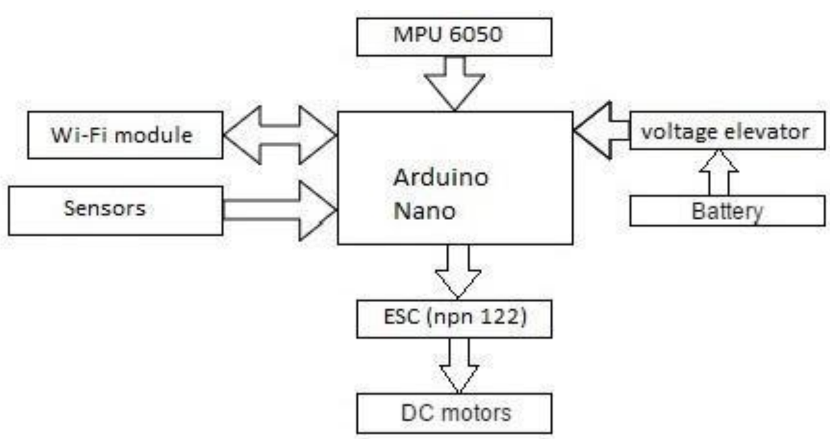

Fig.1 Block diagram of our Quad-copter

We intend to control our quad-copter using an Andriod application remotely. Arduino, the brain of the quad-copter, controls the movement. The commands received through the Arduino from the Mobile, guides the vehicle. The command signal is wirelessly transmitted to the Wi-Fi module via the Andriod application to manoeuvre the quad-copter. Usually, an unmanned flying device works on the principle of proper *PID tuning* [5].

Flight controller software has *PID* (Proportional Integral Derivative) which receives the incoming data from the connected sensors and analyses the readings to ensure that the speed of motors is such that the desired rotation speed of the aircraft is constantly maintained. This will be implemented with the help of 'MultiWii' firmware which calibrates the values according to the payload and various other factors to ensure a stable flight. In order to obtain these all, the overall weight of the drone has to be kept in check. For this reason minimal wiring has been done to reduce extra weight and protrusions that would might hamper in flight. The battery is mounted below and chosen in accordance to the weight. Traditionally, the weight of the battery (capacity) and the efficiency of the thrust developed by the motors controls the flight duration. The two factors contributing to efficiency of the thrust are primarily, the propeller design and the efficiency of the motor itself.

The quad-copter also includes some features like camera, fail safe operation and obstacle detection. Obstacle Detection is done with the help of ultrasonic/infrared sensors which are interfaced with Arduino and mounted on the drone and connected to a beeper to warn for the same.

4.1 Setting up Arduino and ESP8266-01

For proper stability and controlling quad-copter the accurate values from MPU6050 must be obtained. This data further processed by our microcontroller gives us best stability, efficiency and cheap way other than any microcontroller.

The connection of Arduino and ESP8266 is shown below:

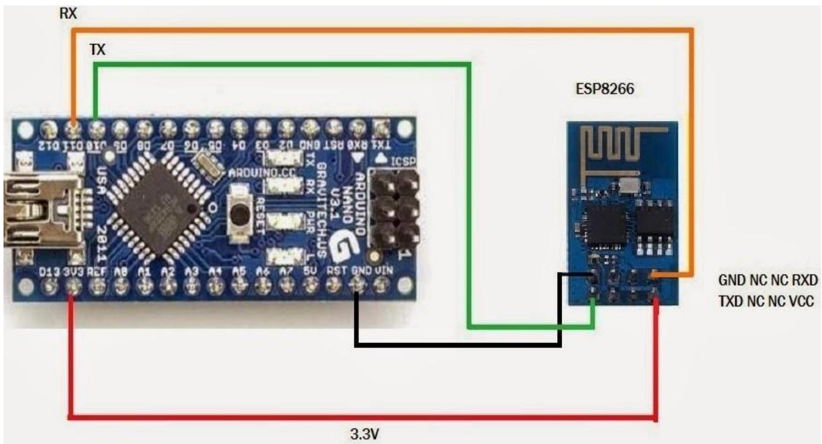

Fig. 2 Interfacing Arduino Nano with Wi-Fi module (Source:www.Google.com)

A constant 3.3 V is given to Wi-Fi module by Arduino and Rx pin is connected to Tx pin of Arduino and vice versa. Then by using AT commands we configure the Wi-Fi module forming TCP/IP connection between Wi-Fi module and Web server. The data gathered in web server is accessed by an Andriod application thus this data helps us to control the quad-copter.

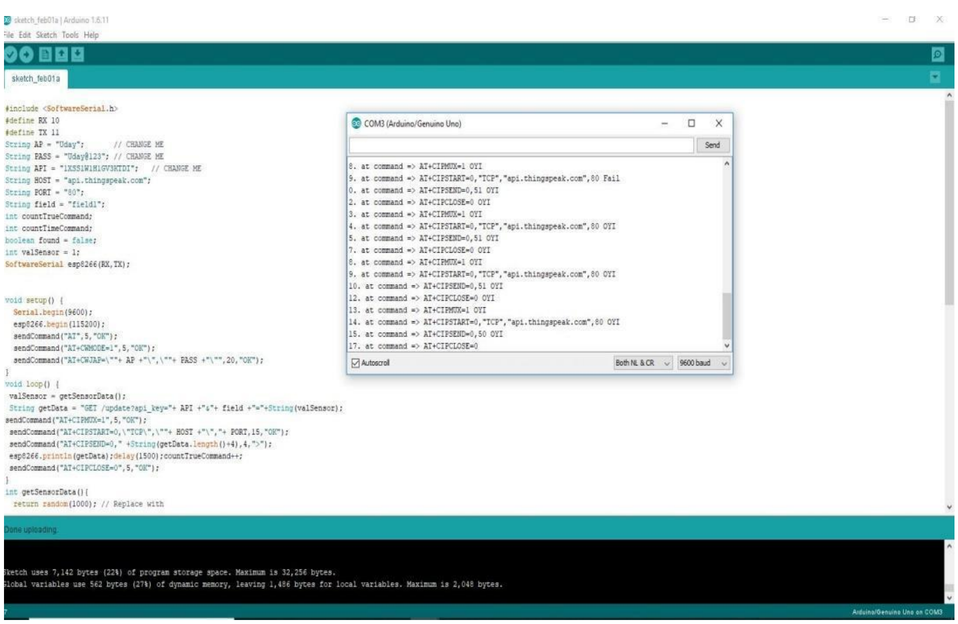

Fig. 3 Set up of the Wi-Fi interface on Arduino IDE serial monitor.

4.2 Configuring Mobile Application

The EZGUI application is used in which the server address and port number are required to control the quad-copter. This data is obtained when we configured Wi-Fi module with Arduino in the serial monitor. As we fill up this data, data that is gathered on web server is collected by this application. Further in application, with help of virtual joysticks on an android platform , the control of quadcopter is done as shown in figure 4.

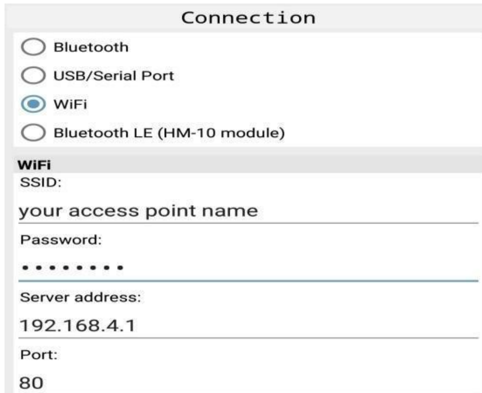

Fig. 4 Set up of APN

4.3 Interfacing MPU6050 with Arduino

The MPU 6050 supports only I2C communication and hence, it must be connected only to the I2C pins of the Arduino. The I2C pins of Arduino are multiplexed with the analog input pins A4 and A5 i.e. A4 is SDA and A5 is SCL as shown in figure 5.

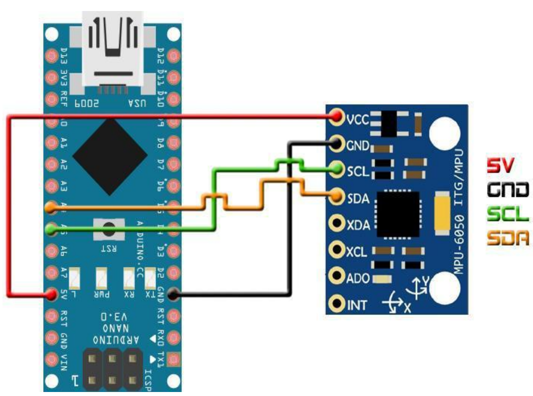

Fig. 5 Interfacing Arduino Nano with MPU 6050 (Source: www.google.com)

At last the setup code of quad-copter which contains flight parameters that have been observed with respect to PID tuning along with roll, pitch and full gyroscope sensitivity with horizon detection. Then the Calibration of gyroscope and accelerometer is done by MultiwiiConf application as shown in figure 6.

Fig.6. Gyroscope and Accelerometer calibration using MultiWiiConf application.

5 Applications

The applications of our drone are that this build can be used as a toy, for aerial photography and low altitude surveillance. It can be used for beginners to learn how to fly or control the drone. It can be also used for battery manufactures (Li-Po) to test their battery longevity & performance.

6 Result

The final product as per the plan executed, has resulted in a stable and miniaturized quad-copter shown in figure 7. This project finally has a frame (structure), where every component is mounted, movement controlled through motors and propellers is implemented using Arduino. The end result is a steady flight platform that meets all the required parameters for safe landing and obstacle detection. The overall system can be used in various surveillance applications such as traffic monitoring.

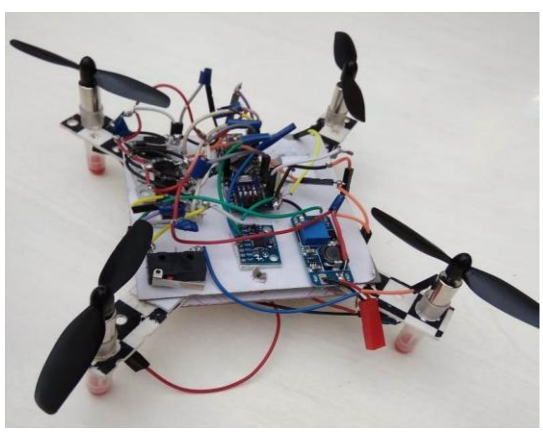

Fig.7. Quadcopter Prototype

7 Conclusion and Future scope

This paper presents an approach which could be used for developing a small and compact sized quad-copter which can be used to carry out surveillance operation to increase the security. It could also be used for performing live video streaming.

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