Development Of Arduino Based Hexacopter

Cherry Tin, Zaw Myo Tun, Hla Myo Tun, Zaw Min Naing, Win Khine Moe

Abstract: In the world of photography, surveillance of larger areas and military operations, Unmanned Aerial Vehicles (UAV) are increasingly used. Many fixed wing Unmanned Aerial Vehicles are designed and used for these applications and much analysis is performed for such cases. To solve the disadvantages of fixed wing Unmanned Aerial Vehicles, rotary wing Unmanned Aerial Vehicle can be used. Again, among the rotary wing Unmanned Aerial Vehicles, hexacopter is an attractive alternative. Hexacopters are more stable than tri-copter and quad-copter. This paper represents the design and fabrication of a hexacopter and flight control unit by using Arduino Uno.

Keywords: surveillance, military,unmanned, fabrication, hexacopter, Arduino.

1 INTRODUCTION

THE hexacopter is an under-actuated, dynamic vehicle with six input forces and six degrees of freedom which uses six rotors to push air downwards and to create a thrust force for keeping the hexacopter on the air. It is a six-rotor helicopter. Unlike regular helicopters, a hexacopter has six fixed-pitch blades. In helicopters, complex variable pitch rotors whose pitch varies as the blade rotates for flight stability and control are used. The fixed-rotor blades of hexacopter is simpler rotor mechanics for flight control process than helicopter. The hexacopter has six motors arranged in a 'X' shape and they work as in clockwise and counter-clockwise manners. In Hexacopter, the flight control unit (FCU) is the heart of its control system. The FCU will control the different motor speeds with its different PWM outputs. The FCU will balance the vehicle in air by reacting the rate on each axis and by taking information from sensors such as barometer, magnetometer, gyro and GPS. Radio remote control is used to control the vehicle manually. In communication terms, radio remote control is transmitter and flight control unit (FCU) is receiver. The communication between the two units is I^2C technology**.** Overall control process of hexacopter is described in this paper. In the basic control system of a hexacopter, the flight control unit (FCU), sensors and radio remote control are included. In this system, if the FCU receives the command from the ground station, it can be able to place the vehicle at the exact positions.

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2 SYSTEM ARCHITECTURE

2.1 System Architecture and its Description

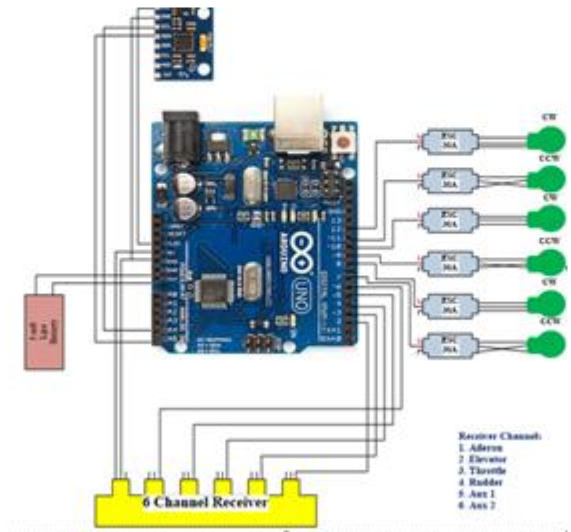

Figure1. *System Architecture*

The above figure shows the system architecture comprising of Arduino UNO development board consisting of Atmel Atmega328P IC as the main brain of the hexacopter. The other interfaces to it are gyroscope, four BLDC (Brushless DC) motors connected through corresponding Electronic speed controller (ESC), LiPo (Lithium Polymer) battery which is of 11.1V when fully charged and six-channel receiver. The Receiver Channels are:

1. Aileron
2. Elevator
3. Throttle
4. Rudder
5. Aux 1
6. Aux 2

O**ut of six** BLDC **motors, two** motors facing each other are connected in such a manner that they will rotate CW (Clockwise) while the rest of two facing each other will rotate CCW (Counter Clockwise). Thus, this the basic arrangements on the **Hexa- copter** frame.

2.2 System Flow Chart

Initial process: This stage performs at once when the hex-copter starts working to calibrate accelerometer, gyroscope and calibrates ESC for all motors.

Receive command: We will receive different commands that indicate the behavior of hex- copter.

1. Up and down
2. Left and Right
3. accepted Forward and backward

Read current parameters from data sensor: Read data from inertial measurement unit (IMU), by sending addresses for each accelerometer and gyroscope, using fast I2C mode (400 kHz)

Current parameter: PID parameter and IMU data and set point for roll, pitch and yaw.

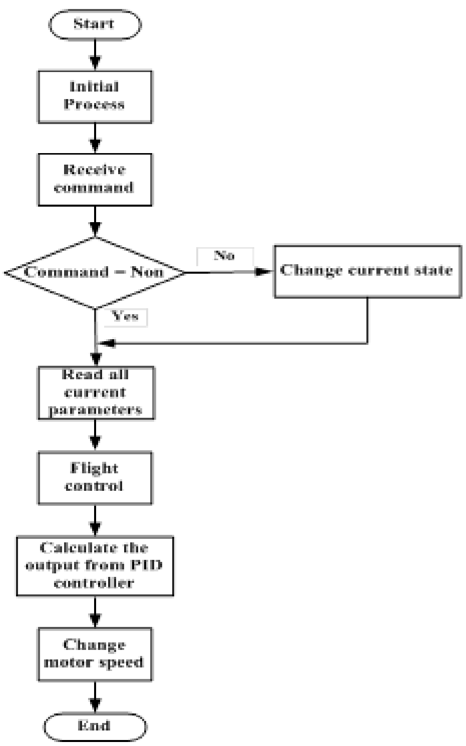

Figure2. *System Flowchart*

3 HARDWARE IMPLEMENTATION

In hardware implementation, component selection plays an important role. In component selection of this research, six brushless outrunner motors, six (30A) electronic speed controllers, a 2200 mAhlipo battery, frame, six propellers, a flight controller, MPU-6050 sensor and transmitter and receiver are selected. The innovation of this research is Arduino based flight controller with MPU- 6050 sensor. The advantages of this controller are cheaper than other flight controllers, open-source project and easy to configure.

1.1 Flight Controller

The core of the hardware is the flight controller. In this research, Arduino Uno is designed and used as flight controller. It contains two central processing units (CPUs) responsible for control, communication and sensor data processing. A bunch of sensors are used as inertial measurement unit (IMU); three-axis accelerometers and three-axis gyroscopes. The system can receive flight commands through a radio controller (RC) or through a ground station control and starts its operation to motors.

1.2 Arduino Uno

Arduino is an open-source prototyping platform based on easy-to-use hardware and software. It is based on ATmega 328P. It has 14 digital input/ output pins, 6 analog inputs, a 16 MHz quartz crystal, a USB connection, a power jack, an ISP header and a reset button. Arduino reads inputs by light on sensor and turn it into an output by activating motors. Arduino IDE (Integrated Development Environment) is used to upload programs to the ArduinoBoards and these microcontroller boards can be used to perform intended tasks.

Figure 3. *Arduino Uno Microcontroller Board*

1.3 Atmel Atmega 328/ P

ATmega328/P is a single-chip 8-bit microcontroller created by Atmel in the megaAVR family. This microcontroller provides a highly flexible and cost effective solution to many embedded control applications. The ATmega328/P AVR iscan be supported with programs and system development tools including: C Compilers, Macro Assemblers, Program Debugger/Simulators, In-Circuit Emulators and Evaluation.

Figure 4. *Pin connections of Atmega 328/P*

3.4 Transmitter and Receiver

To maintain all the systems, a 6 channel transmitter is needed. The 1st four channels are generally used for flight controls and the last two are for other operations. In this case, the 5th channel was used to switch between flight modes (i.e. manual control, stabilize mode, Return to Home mode, etc.

Figure 5. *Transmitter and Receiver*

3.5Hex-copter Frame

In order to withstand payloads which have to be lifted and suitable for the propellers, the HF-550 hexacopter frame is used.

Figure 6. *HJ 550 (Diagonal distance= 550 mm) Frame*

3.6 MPU- 6050 Sensor

The MPU- 6050 is the world's first integrated 6-axis Motion Tracking Device. It combines a 3-axis gyroscope, 3-axis accelerometer and a Digital Motion Processor (DMP) all in a small 4×4×0.9mm package.

Figure7. *MPU 6050 sensor*

Precision and accuracy is important when it comes to accelerometer and gyroscope measurements. MPU-6050 is very accurate as it contains 16-bits analog-to-digital conversion hardware for each channel. It includes a sensing element and an IC interface able to provide the measured angular rate to the external computer through digital interface (I2C/SPI).

4 Propulsion System

Each propulsion system consists of brushless motors, Electronic Speed Controllers (ESC) and propellers.To achieve higher efficiency, the motor had to be of low RPM but high torque, i.e. power. In this kind of motors, 1000Kv (rpm per volt), BL 2217/9 Brushless Out runner Motor s (BLDC) are compatible with hexacopter. They are capable of rotating up to 18400 rpm without any load. A brushless motor cannot be driven directly by a PWM signal. It is instead controlled by an ESC. Electronic Speed Controllers (ESC) are used to control the voltage applied to the BLDC motor as per the PWM signals it receives from Microcontroller digital pins. They control the motors by rapidly turning on and off the current to the different poles in the motor. In order to achieve a good performance and good efficiency, the propeller has to be of a good twist angle, followed by a variable chord design to maintain boundary layer over the surface of the aero foil of the blades. And, many research evident that long propellers are more efficient than short propellers. Thus, three 9.5" diameter CW and CCW counter rotating propeller pairs are chosen to get more efficiency. Maximum thrust achieved was 950 g per motor and the current required to generate maximum thrust was 14.5 A.

5 PID CONTROL

Proportional Integral Derivative (PID) is one of the most commonly used control system because of its simplicity and reliability. PID (proportional- integral- derivative) is a closed-loop control system that try to get the actual result closer to the desired result by adjusting the input. Multicopters use PID controller to achieve stability. There are three algorithms in a PID controller; P, I and D."P" depends on the present error; "I" on the accumulation of the past errors; while "D" is the prediction of future errors based on the current rate of change. To have any kind of control over the hexacopter, we first need to measure the hexacopter's sensor output (For example, what angle the hexacopter is on each axis).Knowing what desired angle wanted to be, we can estimate error. By applying the 3 control algorithms to the errors, one can get the next outputs for the motors aiming to correct the error. Therefore, PID tuning is an essential part in multicopter flight control process.

5.1Effect of each parameters

On a multicopter, there are 3 axis and in each axis, there is a PID controller. That means we will have a separate set of PID coefficients for each axis (Pitch, Roll and Yaw). Generally, altering PID values have the following effect on a Hexacopter's behavior.

- Proportional Gain Coefficient- Hexacopter can fly with just P gain even without the other 2 parameters. This coefficient determines which is more important, human control or the sensor measurement from Gyroscopes. The higher the coefficient, the more sensitive and stronger the hexacopter reacts to angular change. If it is too low, the hexacopter will appear to be more sluggish and offer, and harder to stay steady. One negative impact when P gain is too high is oscillation and over-correcting
- Integral Gain Coefficient – This coefficient influence the precision of the angular position. It is especially useful in windy situation, with low "I gain, the hexacopter will simply drift away with the wind.

However, when the "I" value gets too high, the hexacopter might begin to have slow reaction and a decrease effect of the Proportional gain as consequence. It will also start to oscillate like having P gain, but with a lower frequency

- Derivative Gain Coefficient – In a hexacopter, this coefficient works as a dampener and reduces over-correcting and overshoots caused by P term.

5.2 PID Tuning According to Required Flight

1. Aerobatic Flight

- Requires a slighter higher P gain
- Requires a slightly lower I
- Higher D to compensate for P

2 Gentle Smooth Flight

- Requires a slightly lower P
- Requires a slightly higher I
- Lower D

6 PID TUNING

PID algorithm is simple andeasy to understand but PID tuning on hexacopter is a difficult task. PID constants (K_p,K_i,K_d) are difficult to tune stable due to their effects on flight.. By tuning these constants, we will ensure that the system behaves in a desired manner byreducing the errors as small as possible. There are two methods in which PID can be tuned, namely, (1) Trial and Error method and (2) Ziegler Nichols (Open and Closed loop) method. Trial and error method is very simple, easy to use and it can be done on the stand or string with the help of Graphical User Interface (GUI) before flying. It is simple and less damage tuning on hexacopter. .After the PID tuning before flying, it is required to tune the PID controller while flying in the air. By doing this, thehexacopterwill be able to face or response the disturbances in the air.

Figure 8. *Hexacopter tuning GUI written in visual basic*

Figure 9. *PID tuning with flight controller by the help of GUI before flying*

At first, P gain is higher and so there are noises in the PID graph description and so by gradually tuning P, I, D gains, we get a stable curve. But this result is not absolutely stable due to other magnetic effects. This is the optimal curve of the stable condition.

7 ARDUINO AS FLIGHT CONTROLLER

The flight controller may be Resbery-Pi, PIC microcontroller, KK controller, Arduino and etc. In this paper, Arduino is used as flight controller. Arduino based flight controller can do many things such as wireless PID tuning, orientation lock and attitude hold and even a position lock with the help of a GPS. Arduino projects can be stand-alone or can communicate with software running on a computer. It is simple to make, easy to program and is a great project for experienced hobbyists. Moreover, Arduino program is open-source and easy to configure. This flight controller will have features like those of NAZA and APM, the only difference is the PID where in you will need to be patient in getting the hexacopter tuned. The main advantage of Arduino flight controller is cheaper and easy to configure due to its open-source platform.

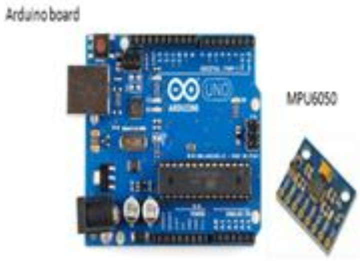

Figure 10.*Arduino board and MPU 6050 sensor to build flight controller*

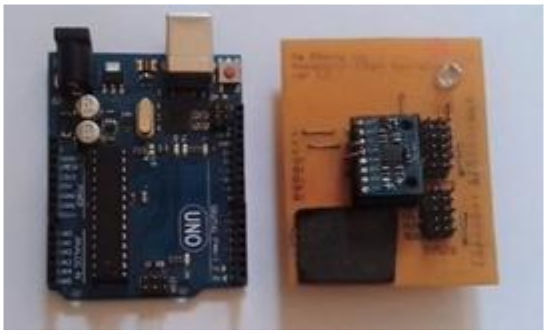

Figure 11.*PCB of Arduino Based Flight Controller*

In this circuit, Arduino can be used as flight controller with the help of MPU-6050. Printed Circuit Board (PCB) is used to connect the pins clearly between the MPU-6050 sensor and Arduino board. Firstly, Vccfrom sensor is connected to 3.3V of Arduino and ground pin is connected to other ground pin. The clock and data pins (SCL) and (SDA) of MPU-6050 sensor are connected to A4 and A5 of Arduino Uno board.

8. Arduino Based Hexacopter With MPU-6050 Sensor

Hexacopter project by using MPU 6050 and Arduino is shown in figure. This project includes hardware components and Graphical User Interface (GUI) for PID tuning and real-time debugging and radio remote control.

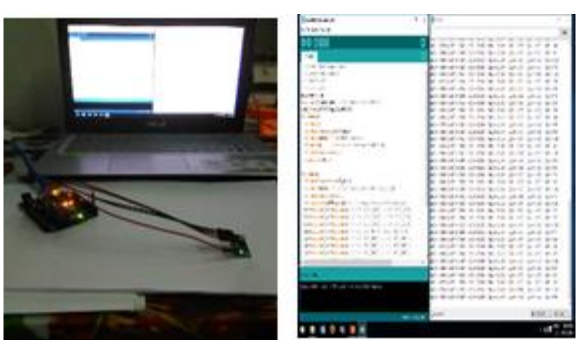

Figure 12.*Testing of MPU-6050 sensor*

Figure 13.*Development of Arduino Based Hexacopter*

9 Conclusion

Nowadays, there has been a lot of increasing interest in hexacopter due to its high endurance and more lifting payload. Exciting videos have been published on the Internet by many research groups and have attracted much attention from the public. This journal is proposed the overview of Arduino platform and the basic of Arduino based flight control system, so no GPS and other effective sensors are not included. The effective changes in hardware and software can give high stability and reliability in UAV system. The stability of hexacopter will depend on the PID Tuning. It is need to be tuned the flight controller with each different body frame. Testing the flight controller with manual control cannot give the correct PID gain because of its friction on each joint and other magnetic forces such as mobile phones, laptop, etc.

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