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Unmanned Aerial Vehicle for Reconnaissance

[1]Shadab Hussain, [2]Rahil Husain, [3]Prasad Aditya Jugesh,

[4]Sanjeev, [5]Anil Kumar Chaudhary

[1,2,3,4] U.G Students, Electronics & Communication,
Buddha Institute of Technology, Gorakhpur, Uttar Pradesh, (India)
[5] Head of Department, Electronics & Communication,
Buddha Institute of Technology, Gorakhpur, Uttar Pradesh, (India)

ABSTRACT

The military use of Unmanned Aerial Vehicles (UAVs) has grown because of their ability to operate in dangerous locations while keeping their human operators at a safe distance. The UAVs provide a reliable long duration, cost effective, platform for reconnaissance. They have grown to become an indispensable tool for the military. The question we posed in this paper was whether small UAVs also had utility in military and commercial as well as industrial applications. We postulated that smaller UAVs serve more tactical operations such as searching a village or a building for enemy positions. They should be able to handle military tactical operations as well as the emerging commercial and industrial. To validate this proposal, we considered many different UAV designs before we settled on creating a quadcopter.

Keywords- Quadcopter, Unmanned Aerial Vehicle (UAV), vertical take-off and landing (VTOL).

I.INTRODUCTION

The development of small autonomous unmanned aerial vehicles is an area of interest that many researches wish to explore. There is currently a large range of projects and research topics emerging in this field.

Autonomous aerial vehicles are true mechatronic systems that combine elements of mechanical, electronic, electrical, software and control engineering.

Preliminary research has shown that the most versatile and mechanically easy to construct autonomous aerial vehicle is a quadrotor helicopter. This is due to the fact that quadrotors can be fully controlled solely by varying the speed of the four rotors and no mechanical linkages are required to vary the rotor blade pitch angles as with a conventional helicopter. Quadrotor aerial robot is an automatic system which is an unmanned VTOL (vertical take-off and landing) helicopter.

The quadcopter consist of four rotors constituted at the four end of the cross intersection. Each rotor/propeller is driven by a brushless motors [1] attached to electronic motor controllers in order to communicate with the microcontroller, with which we can control the speed of each individual motor. The speed of each motor will determine the upward and downward acceleration. Using a four motor quadcopter design we are able to change directions, elevation, and tilt by simply manipulating how much voltage goes into the motors while it is in the

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air. We can also integrate an array of sensors onto our quadcopter that can measure the temperature and guide it away from obstacles.

Quad-rotor comprises of four motors in total, with two pairs of counter-rotating, fixed-pitch blades located at the four corners. Quadcopter do not require complex mechanical control linkages for motor actuation, relying instead on fixed pitch rotors and using variation in motor speed for vehicle control. It simplifies both the design and maintenance of the vehicle. The use of four rotors ensures that individual rotors are smaller in diameter than the equivalent main rotor on a helicopter, relative to the airframe size. The individual rotors, therefore, store less kinetic energy during flight [2].

In a quad-rotor there are four rotors with fixed angles which represent four input forces that are basically the thrust generated by each propeller. The collective input is the sum of the thrusts of each motor.

Quadcopter theory

The Quadcopter uses four propellers, each controlled by its own motor and electronic speed controller. Accelerometers will measure the angle of the Quadcopter in terms of X, Y, and Z axis and accordingly adjust the RPM of each motor in order to self-stabilize its self. The Quadcopter platform provides stability as a result of the counter rotating motors which result in a net moment of zero at the centre of the quadcopter as shown in (figure 1).

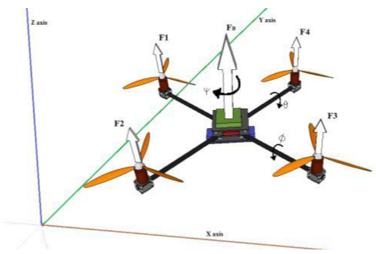

Fig 1. Net Momentum

Using this principle we are able to adjust the speed (RPM as a function of the voltage provided to the motor) of each individual motor in order to correctly manipulate Quadcopter's yaw, tilt, and roll. Tilt and roll can be controlled by changing the speed of the appropriate motors, while yaw control involves delicate balancing of all four motor functions in order to change the moment force applied to the quad. Controlling the Quadrotor involves four different states [3]:

U1 - Upward motion z-direction (Thrust): (figure 2) it controls the vertical up and down motion of the drone. Positive thrust will make the drone fly higher and negative thrust will make the drone fly lower.

U2 - Roll motion Φ: (figure 3) it is the side to side tilt of the drone. Positive roll will make the drone tilt to the right and negative roll will make the drone tilt to the left.

U3 - Pitch motion θ: (figure 4) it is the forward and backward tilt of the drone. Positive pitch will make the drone tilt and move forward and negative pitch will make the drone tilt and move backwards.

U4 - Yaw motion ψ: (figure 5) it is the left and right rotation of the drone. Positive yaw will make the drone turn to the right and negative yaw make the drone turn to the left.

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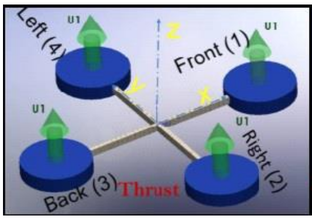


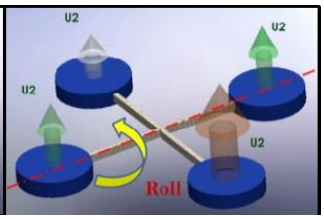
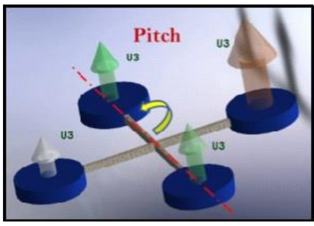


Fig.2 Thrust Fig.3 Roll



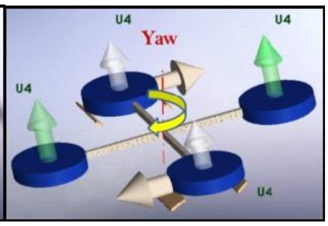


Fig.4 Pitch Fig.5 Yaw

II. LITERATURE REVIEW

At a glance the website of abc NEWS posted an article by Rheana Murray on 8th August 2014, headlined, “How Drones will Replace Humans in the Workplace” to which Mary Cummings, a drones expert who teaches at MIT and Duke University says, “Maybe if you’re a cargo pilot for FedEx or UPS, drones will augment the delivery world and one could argue that they would be much more environmentally friendly since they could take cars off the road for last mile delivery and help reduce congestion.” She further adds, “Jobs like delivery for which cargo planes are used currently and crop dusting should be turned over to drones immediately. Crop dusting is the most dangerous job in general aviation with a high accident rate. Drones can not only do that job better, but much safer. This will happen in the next 10 to 20 years. Ultimately, drones will create more jobs than they replace, they will save lives, and they will give us capabilities we only dream about – like everyone owning our own flying cars.” [6]

In a website known as www.farmingdrones.com, an article headlined “Farming Takes Flight Drones save IL Farmers Time and Money was posted. It explains how drones are used in agriculture to give a crystal clear view of their fields. Dennis Bowman, a crop sciences educator with the University of Illinois Extension, is using two drones to take aerial snapshots of crops in the research plots on the university’s South Farms. He says, “It offers a quick and easy way to check on the plants‟ progress and determine if they need more attention. It does allow the opportunity to get an overall survey of the area and make a better use of your time, rather than just walking out blindly into a field of corn that’s taller than your head, and hoping that you stumble across any of the problem areas that might be out there. People think about drones and a lot of times, the negative connotations come to mind, privacy issues and those kinds of things. But in the agricultural community, we’re out in the middle of nowhere most of the time, flying them over fields of crops”. He further says that the agriculture industry is expected to be one of the largest markets for drone usage. [7]

III. SYSTEM DESCRIPTION

The control signal generated by remote using FS-CT6B 2.4 GHz frequency transmitter and receiver. The microcontroller decodes the data frame sent and process it. It also has input signals from sensors in IMU board. The IMU board consists of 3-axis gyroscope and 3-axis accelerometer on it. Data from these sensors will be helpful in stabilizing and balancing the quadcopter. The microcontroller is governed by the program written in its memory. According to the data received from the remote and from the sensors. The controller sends appropriate signals to the ESCs. This would be achieved by the PWM channels available in it as shown in (figure 6).

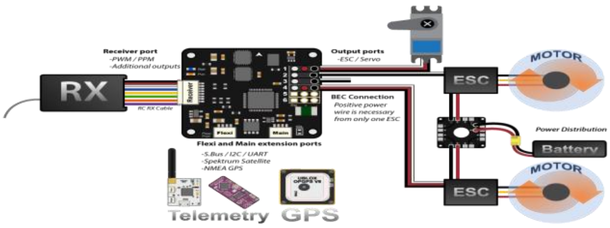


Fig-6 System Model

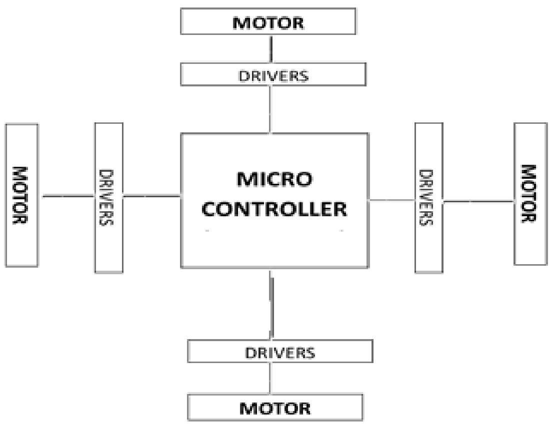


Fig.7 Block diagram

Yaw motion is achieved by supplying more voltage to M1 and M3 which moves the Quadcopter in left direction. Supplying more voltage to M2 and M4 which moves the Quadcopter in right direction. (figure 7) shows the basic building block diagram of connection between microcontroller and motors and drivers.

Frame design and construction

The components of our quadcopter are framed together on a frame. The main design consideration for the frame, as for most aircraft, is minimizing weight. Because this is a multi-rotor vehicle a separation gap of 25.4 mm must be maintained between propeller tips to avoid wake interference [14]. Additional considerations specifically for this project are robustness and the ability to easily adjust and mount new devices.

The early attempts at designing a conceptual layout of the quadcopter as shown in (figure 8) began with an approximate parametric designed structure for analysis and procurement of components.

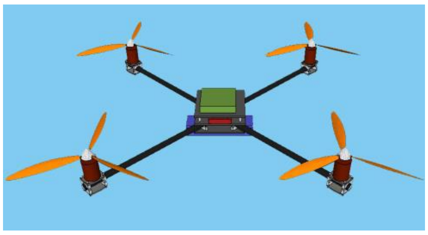


Fig.8 Conceptual design

Libre Pilot offers a range of tools to enable the generation of a complete digital representation of the product being designed. This section shows and highlights the final configuration that will be fabricated for each quadcopter assembly, the weight of the total quadcopter (less batteries, and other components) as well as the weight of each component/subassembly consumes of the entire structure.

Final design

The second design as shown in (figure 9) consisted of a hollow C-section arms, motor base etc. The weight of other electrical components is constant hence the changes are made in the chassis of the Quadcopter. The weight was reduced to a considerable degree. The circular section arm needed extra clamps and motor bases to hold the motors in horizontal position.

Fig-9 Quadcopter Structure

IV. DESIGN METHODOLOGY

Sensor selection

The control and balancing of quadcopter is achieved by the use of sensors that communicate to the control system. The control system performs calculates to work out the outputs required to move the quadcopter to a desired position as well as maintain stability. In the UAV and the MAV project the size and the weight of the employed components play a dominant role, it would be preferable to develop still smaller and more lightweight attitude determination systems than the ones available on the market. Attitude determination systems normally consist of gyroscopes, accelerometers and magnetometers, whereat a device, containing gyroscopes and accelerometers, is commonly called Inertial Measurement Unit (IMU). We will be using MPU6050 breakout board, which has 3-axis accelerometer and 3- axis gyroscope. An accelerometer is an electromechanical device that will measure acceleration forces. These forces may be static, like the constant force of gravity pulling at your feet, or they could be dynamic - caused by moving or vibrating the accelerometer. A gyroscope is a device used primarily for navigation and measurement of angular velocity [15]. 3-axis gyroscopes are often implemented with a 3-axis accelerometer to provide a full 6 degree-of-freedom (DOF) motion tracking system. Gyroscopes have evolved from mechanical-inertial spinning devices consisting of rotors, axles, and gimbals to various incarnations of electronic and optical devices. In more complex systems such as the International Space Station or satellites, a combined form of the gyroscopes and accelerometers is used called the Inertial Navigation System (INS) [16].

Brushless DC motors

Brushless motors are more advantageous to quadcopter over brushed DC motor. Brushless motors have more torque per weight, have more efficiency, reduced noise factor, reliability, elimination of ionizing sparks from commutator, longer life span, more power and overall reduction of electromagnetic interface.

Propellers

Propellers transduce the rotary motion to aerodynamic lift force. Two pair of counter rotating propellers make the aerodynamic torque is zero. We will be using 11 inch diameter with a pitch of 4.7 inch/revolution.

Electronic speed control (ESC)

An ESC controls the brushless motor by converting the supplied DC from the battery into three phased AC. ESC is an electronic circuit with the purpose to vary an electric motor's speed, its direction and possibly also to act as a dynamic brake. We selected Turnigy Basic 25A v3.1 Brushless Speed Controller.

Battery (LiPo)

Lithium polymer batteries (LiPo) are increasingly popular for powering remote control aircraft; due to light weight, energy density, longer run times and the ability to be recharged. We selected Zippy 11.1V 25C 5000mah battery.

KK2.1.5 Flight Controller (figure 10)

It is an updated gyro system with a very sensitive 6050 MPU system. It also uses an Atmel Mega 644PA 8-bit AVR RISC-based microcontroller with 64k of memory. It has large LCD screen and built-in software and includes buzzer. It has input voltage of 4.8-6.0 volts, a 6 pin standard AVR interface, and it provides signal to ESC of 1520us.

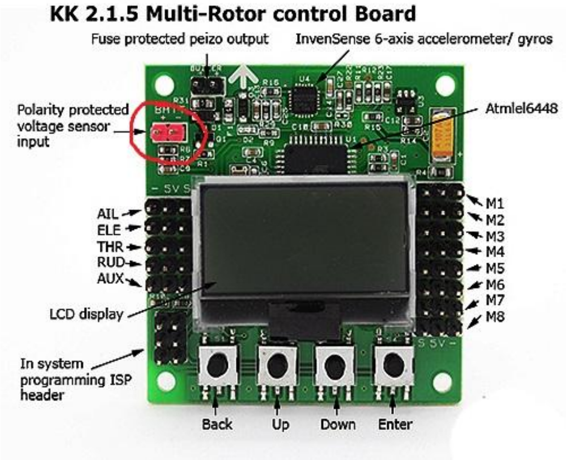


Fig.10 KK 2.1.5 Multi-Rotor control Board

Receiver

For radio controlled (RC) systems we need a transmitter and receiver. One or more output devices such as an ESC/motor combo or servos. These are plugged into the receiver and are usually used to spin wheels or move control surfaces such as a steering mechanism. We will be using 2.4GHz FHSS 6 channel transmitter and receiver.

Camera (figure 11)

The camera which provides surveillance capability for the Quadcopter is a Linksprite JPEG color camera that employs a transistor-transistor-level (TTL) logic signal. The camera has the ability to display a series of images through a serial communication output as well as 30 frames per second (fps) National Television System Committee (NTSC) formatted output. All of the sensors and electronic hardware used in this project communicate over a TTL serial connection, including the wireless telemetry module we are using. The ability to integrate the video over the serial connection seamlessly was the main reason that we chose this camera.

Fig.11 Link sprite Jpeg Color Camera

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USB TV Tuner (figure 12)

A TV tuner card is a kind of television tuner that allows television signals to be received by computer. Most TV tuner functions as a video capture cards, allowing them to record television programs onto hard disk much like the digital video recorder does. The interfaces for TV tuner cards are most commonly either PCI bus expansion card or the newer PCI Express bus for many modern programs.

Fig.12 Easy CAP USB TV tuner card

V. CONCLUSION

The core intention of our project is to familiarize ourselves with the complete design process from engineering requirement to finished product. We aim at making a robust design of a quadcopter which can be used in the market for both military and commercial use. With the aid of our faculty advisor we have the resources and technical knowledge to successfully complete this project. We chose the quadcopter for our UAV design since it has interesting design elements and potential for marketable gains. At this point the project could go in a variety of directions since the platform seems to be as flexible. This flexibility allows changing the functions it performs and also allows integration of any technology that would prove to be useful. This project will clearly demonstrated the goals of proving that small scale UAVs are useful across a broad range of applications.

Application of a quadcopter other than reconnaissance are listed below:

- Safety inspection tool in construction industry
- Traffic monitoring
- Locating forest fires or frost conditions in farmlands
- Visual tracking and control using camera system
- Object identification and avoiding using fuzzy control
- Temperature and altitude estimation
- Weather forecasting
- Scenic photography
- Post natural disasters
- Agriculture surveying

- Crowd management
- Perimeter surveillance
- Search and rescue operations

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