Project Report

QAUDCOPTER

Project Aim: To build a stable remote controlled Qaudcopter(UAV).

Project Objective: The **objective** of this project is to build a remote controlled **quadcopter** that is capable stable flight.

Project guide:

Group members:

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Abstract

Quadcopter is an unmanned aerial vehicle (UAV), which can be implemented in different applications. In paper it will be represented a development of a quadcopter system and potential application in which it can be implemented. Quadcopter structure model, basic components with block diagram, hovering stability, dimensions, and description of basic movements will be represented and discussed. Control algorithms with steps in empirical methodology will also be presented. Current civil and military application will be examined, and future applications will be suggested.

***Keywords** : qaudcopter,design,application,control*

Introduction

An **unmanned aerial vehicle** (**UAV**) (or **uncrewed aerial vehicle**,commonly known as a **drone**) is an aircraft without a human pilot on board and a type of unmanned vehicle. UAVs are a component of an unmanned aircraft system (UAS); which include a UAV, a ground-based controller, and a system of communications between the two. The flight of UAVs may operate with various degrees of autonomy: either under remote control by a human operator, autonomously by onboard computers or piloted by an autonomous robot.

Compared to crewed aircraft, UAVs were originally used for missions too "dull, dirty or dangerous" for humans. While they originated mostly in military applications, their use is rapidly expanding to commercial, scientific,recreational, agricultural, and other applications, such as policing and surveillance, product deliveries, aerial photography, infrastructure inspections, smuggling and drone racing.

A quadcopter or quadrotor is a type of helicopter with four rotors. Although quadrotor helicopters and convertiplanes have long been flown experimentally, the configuration remained a curiosity until the arrival of the modern UAV or drone. The small size and low inertia of drones allows use of a particularly simple flight control system, which has greatly increased the practicality of the small quadrotor in this application.

The four-rotor design allows quadcopters to be relatively simple in design yet highly reliable and maneuverable. Research is continuing to increase the abilities of quadcopters by making advances in multi-craft communication, environment exploration, and maneuverability. If these developing qualities can be combined, quadcopters would be capable of advanced autonomous missions that are currently not possible with other vehicles.

For small drones, quadcopters are cheaper and more durable than conventional helicopters due to their mechanical simplicity. Their smaller blades are also advantageous because they possess less kinetic energy, reducing their ability to cause damage. For small-scale quadcopters, this makes the vehicles safer for close interaction. It is also possible to fit quadcopters with guards that enclose the rotors, further reducing the potential for damage. However, as size increases, fixed propeller quadcopters develop disadvantages relative to conventional helicopters. Increasing blade size increases their momentum. This means that changes in blade speed take longer, which negatively impacts control.

Design

Quadcopter is a kind of unmanned aerial vehicle (UAV).UAV can generally be defined as a device used or intended to be used for flight in the air that has no onboard pilot. These devices are sometimes referred to as drones, which are programmed for autonomous flight, and remotely piloted vehicles (RPVs), which are flown remotely by a ground control operator. This fact in many cases can result in high maintenance and deployment costs particularly speaking in the industrial domain applications. Some applications implement an autonomous flight mode, however the autonomy here is intended as a simple path planning through several given points. Such type of many applications can be implemed using drone. But here just for beginner purpose we are making a simple qaudcopter to study how it is designed, how it works and many more.
Dimensions of quadcopters can vary from the size of an insect to a size of a professional aerial vehicle. Dimensions differ according to the type of application inwhich this UAV are going to be implemented and the equipment they are taking. For example in application where there is a need for detecting toxic substances in the air, quadcopter needs to be equipped with sensors(in most cases

they are light) so the quadcopter can be small. And in the case of drones used in military region are bigger in size because of more sensors and other required module takes more space.
In our project we had made a normal sized drone which can be easily seen from naked eyes from a long distance.
A quadcopter is a multirotor UAV that is lifted and propelled by four rotors. Quadcopters are classified as rotorcraft, as opposed to fixed-wing aircraft, because their lift is generated by a set of rotors (vertically oriented propellers). A quadcopter uses four propellers for thrust and has them configured in either a cross or plus format. The quadcopter robot can take off and land vertically which is a big advantage as it lowers the requirements for a landing platform. Also, it allows the quadcopter to hover in place with considerable stability. Hover stability prevents the quadcopter from crashing in the event of strong wind or due to its weight.

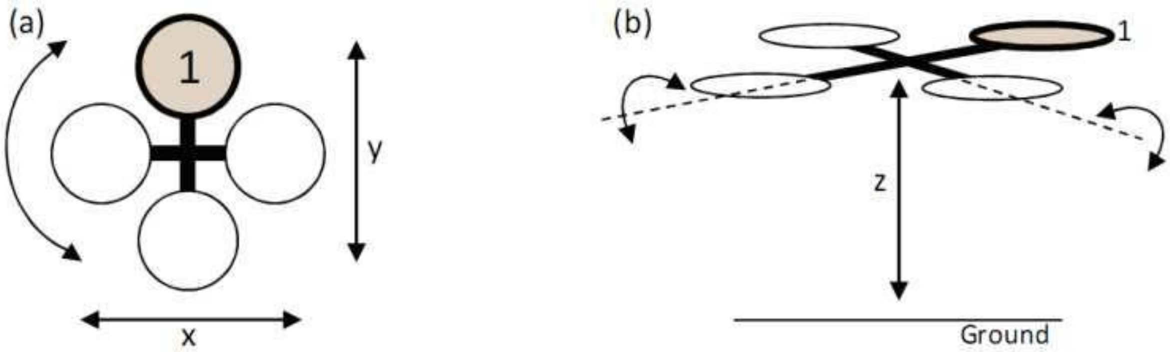

Figure 1. The six degrees of freedom of the quadcopter

Fig. 1 shows the six degrees of freedom of the quadcopter. In Fig. 1(a) (birds eye view), x and y represents the translational motion along the x- and y-axes respectively and ψ represents yaw, the rotational motion about the z-axis, while in Fig. 1(b) (frontal view), θ represents roll, the rotational motion about the xaxis, ϕ represents pitch, the rotational motion about the y-axis and z represents the translational motion in the direction per pendicular to ground. The label '1' signifies the front propeller. With a hover control unit, the quadcopter can hover at aconstant height z (see Fig. 1(b)), with its roll and pitch angles stabilised by the gyroscope. The person at the command base will only need to control the quadcopter's motion along the x- and y-axes and also its rotation about the z-axis (to turn corners), reducing the degree of complexity from six to only three.

Quadcopter model

Quadcopters use 2 sets of identical fixed pitched propellers; 2 clockwise (CW) and 2 counter-clockwise (CCW). These use variation of RPM to control lift and torque. Control of vehicle motion is achieved by altering the rotation rate of one or more rotor discs, thereby changing its torque load and thrust/lift characteristics. The front and the rear propellers rotate counterclockwise, while the left and the right ones turn clockwise. This configuration of opposite pairs directions re-moves the need for a tail rotor (needed instead in the standard helicopter structure). Fig. 2 shows the structure model in hovering condition, where all the propellers have the same speed.

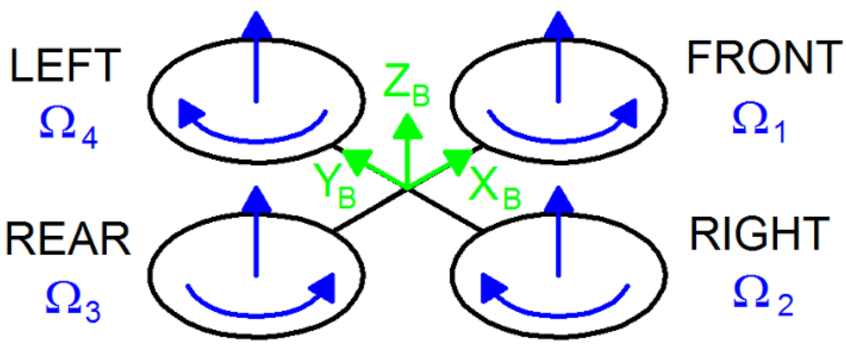

Figure 2. The quadcopter structure model in hovering condition.

In Fig.2 a fixed-body B-frame of quadcopter is shown X_B, Y_B, Z_B). Also the angular speed of the propellers is represented. In addition to the name of the velocity variable, for each propeller, two arrows are drawn: the curved one represents the direction of rotation, the other one represents the velocity. This last vector always points upwards hence it doesn't follow the right hand rule (for clockwise rotation) because it also models a vertical thrust and it would be confusing to have two speed vectors pointing upwards and the other two pointing downwards. All four propellers rotate at the same speed which is represented as Ω [rad s_{-1}] to counterbalance the acceleration due to gravity. Even though the quadcopter has 6 DOF, it is equipped just with four propellers. Thanks to its structure, four best controllable variables can be chosen related to the four basic movements which allow the quadcoper to reach a certain height and attitude. It follows the description of these basic movements:

- Throttle (U_1 [N]) - increasing (or decreasing) all the propeller speeds by the same amount. It leads to a vertical force which raises or lowers the quadcopter. If the quadcopter is in horizontal position, the vertical direction of the inertial frame coincide. Otherwise the provided thrust generates both vertical and horizontal accelerations in the inertial frame.
- Roll (U_2 [N m]) - increasing (or decreasing) the left propeller speed and by decreasing (or increasing) the right one. It leads to a torque with respect to the X_B axis (Fig. 2) which makes the quadcopter turn. The overall vertical thrust is the same as in hovering, hence this leads only to a roll angle acceleration (infirst approximation).
- Pitch (U_3 [N m]) - similar to the roll and is provided by increasing (or decreasing) the rear propeller speed and by decreasing (or increasing) the front one. It leads to a torque with respect to the Y_B axis (Fig. 2) which makes the quadcopter turn. The overall vertical thrust is the same as in hovering, hence this leads only to a pitch angle acceleration (in first approximation).
- Yaw (U_4 [N m]) - increasing (or decreasing) the frontrear propellers' speed and by decreasing (or increasing) that of the left-right couple. It leads to a torque with respect to the Z_B axis (Fig. 2) which makes the quadcopter turn. The yaw movement is generated thanks to the fact that the left-right propellers rotate clockwise while the front-rear ones rotate counter clockwise. When the overall torque is unbalanced, the quadcopter turns on itself around Z_B. The total vertical thrust is the same as in hovering, hence this leads only to a yaw angle acceleration (in first approximation).

Control algorithms

The PID (Proportional-Integral-Derivative) control algorithm has been considered and implemented in literature to control the hover altitude of the quadcopter. PID control is a type of linear control that is widely used in the robotics and automation industry. The PID algorithm is popularly used mainly because:

· It has a simple structure
· It provides good performance
· It can be tuned even if the specific model of the controlled plant or system is not available.

A PID controller functions by calculating the error, ordifference between a measured output and a desired setpoint and adjusts the system control inputs such that the calculated error is minimised. The PID algorithm consists mainly of three control parameters, P – Proportional, I – Integral and D – Derivative. The mathematical expression of the discrete-time PID algorithm is given in (1). P determines the reaction to the current error, I determines the reaction based on a sum of recent errors while D responds to the rate at which the error has been changing.
Calculation of the control input by control algorithms such as PID control may return a control input gain which may be too high for the quadcopter system. This results in a large control input magnitude which may be out of the limits recognisable by the system. To solve this problem, the linear quadratic regulation (LQR) method can be employed. LQR is a form of linear optimal control regulation which aims to reduce the magnitude of the control input without affecting the performance of the control algorithm. The LQR algorithm is used to obtain the parameter settings that will minimise the undesired deviations (in this research, altitude) while at the same time limiting the energy expended by the control action by using a mathematical algorithm that minimises a cost function or performance index with weighting factors. The cost function or performance index refers to the sum of deviations of measured values from its desired values. For a discrete-time LQR, the performance index is defined as (1). By adjusting the weight parameters Q and R, the optimal control sequence that minimises the performance index is given by (2).

$$J = \sum_{k=0}^{N} (x_k^T Q x_k + u_k^T R u_k) \qquad (1)$$

$$u_k = -F_k x_{k-1} \qquad (2)$$

The steps involved in the empirical methodology to obtain control parameters are shown in Fig. 3.

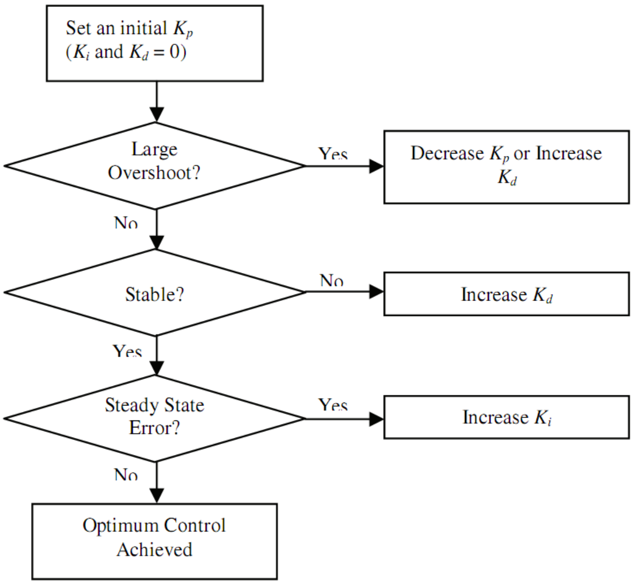

Figure 3. Steps in empirical methodology.

Different approaches have been developed for formation of flight control. Linear formation flight controller has been discussed in. The advantage of the linear control is that it is intuitive and easy to synthesize, but it cannot handle the constraints directly and may not be valid for large operation range since it is designed around a fixed operating point. Some researchers addressed the nonlinear formation flight control problem by using feedback linearization and adaptive control. Although these nonlinear control methods can deal with the unmodelled dynamics, they cannot handle the constraints directly and the implementation of such controller may result in ill-defined control inputs.

HARDWARE COMPONENTS OF QUADCOPTER

Each quadcopter can have a very different hardware component which mostly depends on application in which it will be implemented. Standard components are: flightcontroller, motors, power supply and telemetry devices.
Basic component of each quadcopter is frame. The arms and centre plate of the quadcopter frame is in most cases are made of carbon fiber, but in our case it is madeup of aluminium. Connections between the centre plates and arms, as well as the motor mounts can be made of aluminium. The modular integration of the frame allows components to be replaced easily if necessary. The frame, is 22inches long from motor to motor(diagonally) and weighs approximately 900 g. The propulsion system is mounted directly onto this frame.

Another important part of quadcopter is 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 can be cell lithium polymer battery. Propellers mounted on the motors must be several cm lengths and have a fixed pitch angle. This propulsion configuration allows safe operations of the frame and ensures excellent lift and thrust performance for all of the flight.

Figure 4: This are the front view and the side of the quadcopter respectively.

For the safety purpose of the frame and the battery attach make a stand for the copter and take care the copter is in balanced condition after standing on a stand.
Following is a YouTube link which will help in setting the actual values and settings and also will help in connections of motors, esc,power distribution panel and flight controller.
https://youtu.be/gQf9zIhR4hQ

APPLICATIONS OF QUADCOPTER

Quadcopters have been used, are being used or are actively being considered for different applications all over the world. They have range of potential environmental or commercial applications (emergency response, pollution detection, crop spraying, etc.). Also, they can be deployed in surveillance applications against civilians, such as applications in policing and border surveillance. Some police departments in Europe and North America have been using quadcopters since 2006. At least five police forces in the UK (Essex, Merseyside, Staffordshire, Derbyshire and the British Transport police) have purchased or used micro-quadcopters. The range of potential applications is clear to police forces, where, for example, the South Coast Partnership between Kent Police and five other police forces in the UK is seeking to introduce drones (quadcopters) ‘into the routine work of the police, border authorities and other government agencies’ across the UK.

Police forces use quadcopters to monitor large crowds, prevent or detect crime and assist in incident responses. UK police have used quadcopters to monitor festivals, to monitor protests and to monitor the Olympic ceremony. In 2007, quadcopters were reported over political rallies in New York and Washington, DC. The CannaChopper has been deployed in the Netherlands and Switzerland against cannabis smokers, football fans at the European football championship in 2008 and “troublemakers” at the NATO summit in 2009. India has also recently begun using quadcopters to help secure sensitive sites and events. A North Carolina county is using quadcopters with infrared cameras to monitor gatherings of motorcycle riders and to detect marijuana fields. In this deployment, the quadcopters flies a few hundred feet in the air, which is close enough to identify faces. Six police departments in Canada are using quadcopters in populated areas to record crime scenes and Canadian police are responsible for the first photographs taken by a quadcopters being admitted as evidence in court after the local police force used a quadcopters to photograph a homicide scene in 2007.
In India this copters are used mainly in Police cops, in wedding ceremony, agriculture, delivery system, for industrial purpose and many more.

CONCLUSION

Quadcopter is a special kind of vehicle, which can be implemented in different applications. In this paper basic principles of quadcopter design as well as current applications are represented. In the future applications, quadcopter could be used for a variety of new policing functions. Quadcopter could be used for safety inspections, perimeter patrols around prisons and thermal imaging to check for cannabis being grown in roof lofts and other not easy to access locations. The police could use them to capture number plates of speeding drivers, for detecting theft from cash machines, railway monitoring, combat fly-posting, flytipping, abandoned vehicles, waste management. Future research will be in field of search and rescue.

Future Scope.

In future an effort will be directed to development of a system for defining evacuation/safe path in case of natural disasters and accidents. The system will consists of quadcopter which is equipped with a camera to capture different terrain (land or water) and a processing unit for processing the recorded condition which is placed on the vehicle/vessel or in form of handheld device. In addition to the situations of natural disasters and accidents it is possible to use this system in cases of climatic changes that affect the safety and health of the population, or in cases where it is endangering the functionality of different economic systems.

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