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A Review on a Quad-rotor Unmanned Air Vehicle

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ABSTRACT: This paper presents the review on quad-rotor unmanned air vehicle. The paper gives just information about quad- rotor, its parts, its functions and various applications of quad rotor. The dynamic model of the quad-rotor which is an under actuated aircraft with fixed four pitch angle rotors, will be described. The controlling of a quad-rotor vehicle is not an easy task because of its complex structure. The aim is to give information about this because it a very useful in now these days. In model there four input forces which are basically the thrust provided by each propeller connected to each rotor with fixed angle. Forward (backward) motion is going to maintain by increasing (decreasing) speed of front (rear) rotor speed while decreasing (increasing) rear (front) rotor speed simultaneously. The aim of this paper is to give information about enhance performance of quad-rotor.

Keywords: Quad-rotor, vertical take-off and landing (VTOL), Unmanned aerial vehicles (UAV).

I. INTRODUCTION

Quad-rotor aerial robot is a automatic system which is an unmanned VTOL (vertical take-off and landing) helicopter. The main features of this structure is a cross intersection rigid body, cross intersection poles which have been composed of two diagonals of a square. Four rotors has been configured at the four end of the cross intersection. Each rotor is driven by a motor [1]. The quad-rotor is very well modeled with a four rotors in a cross configuration. This cross structure is quite thin and light. However it shows robustness by linking mechanically the motors (which are heavier than the structure). Each propeller is connected to the motor through the reduction gears. All the propellers axes of rotation are fixed and parallel. Furthermore, they have fixed-pitch blades and their air flows points downwards (to get an upward lift). These considerations point out that the structure is quite rigid. And the only things that can vary are the propeller speeds.

Unmanned Aerial Vehicles can be defined as Automatic aircraft. it is mostly used to perform intelligence, surveillance, and reconnaissance missions. These Vehicles have several basic advantages over manned systems because of its increased manoeuvrability, reduced cost, reduced radar signatures, longer endurance, and less risk to crews. Such vehicles are to require little human intervention from take-off to landing. Unmanned aerial vehicles (UAVs) are fulfilling many civil and military applications including surveillance, intervention in hostile environments, air pollution monitoring, and area mapping [3]. These Unmanned aerial vehicles (UAVs) have a wide area of possible applications large outdoor UAVs can be used for military and commercial purposes.

In Indoor flight it requires a suitable type of vehicle which requires suitable control. One helicopter-like vehicle with the additional advantage of a simple construction and rotor mechanics is the quad-rotor [2] here we are studying the behaviour of the quad-rotor. This flying vehicle presents the main advantage of having quite simple dynamic features. The quad-rotor is a small vehicle with four propellers placed around a main body.

The main body has power source and control hardware. Here the four rotors are used to controlling the vehicle. The rotational speeds of the four rotors are independent so it's possible to control the pitch, roll and yaw attitude of the vehicle. And its displacement is produced by the total thrust of the four rotors whose direction varies according to the attitude of the quad-rotor. The vehicle motion can thus be controlled.

Existing quad-rotor dynamic system is composed of five rigid bodies: four rotors and a crossing body frame. This makes the explanation of several aspects, like gyroscopic effects, very difficult [3].

Quad-rotor consists of four rotors in total, with two pairs of counter-rotating, fixed-pitch blades located at the four corners of the aircraft. Quad-rotors do not require complex mechanical control linkages for rotor 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 [4].

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 (*u1*) is the sum of the thrusts of each motor. Pitch movement can be obtained by increasing (reducing) the speed of the rear motor while reducing (increasing) the speed of the front motor. The roll movement can be obtained by increasing (reducing) the speed of the right motor while reducing (increasing) the speed of the left motor. The yaw movement can be obtained by increasing (decreasing) the speed of the front and rear motors together while decreasing (increasing) the speed of the lateral motors together. This should be done while keeping the total thrust constant.

II. MATHEMATICAL MODELLING

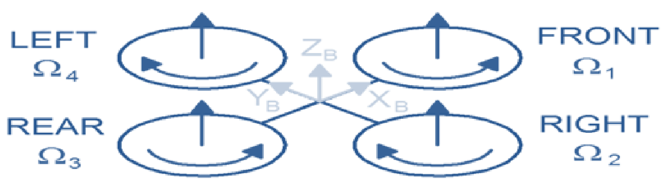

Fig. 1. Quad-rotor motor.

The equations of motion can be written using the force and moment balance.

$$\ddot{X} = U1(Cos\varphi Sin\theta Cos\Psi + Sin\varphi Sin\Psi) - K1\dot{x}/m$$

$$\ddot{y} = U1(Sin\varphi Sin\Psi Cos\Psi - Cos\varphi Cos\Psi) - K2\dot{y}/m$$

$$\ddot{z} = U1(Cos\varphi Cos\Psi) - g - K3z/m$$

Where,

x: Forward position in earth axes

y: Lateral position in earth axes

z: Vertical position in earth axes

Ki: The Drag Coefficients for the system

The center of gravity is assumed to be at the middle of the connecting link. As the center of gravity moves up (or down) units, then the angular acceleration becomes less sensitive to the forces, therefore stability is increased. Stability can also be increased by tilting the rotor forces towards the center. This will decrease the roll and pitch moments as well as the total vertical thrust.

For convenience, we will define the inputs to be

U1 = (Th1+Th2+Th3+Th4)/m

U2 = l(-Th1-Th2+Th3+Th4)/I1

U3 = l(-Th1+Th2+Th3-Th4)/I2

U4 = C(Th1+Th2+Th3+Th4)/I3

Where,

u1 : Vertical thrust generated by the four rotors

u2 : Pitching moment

u3 : Yawing moment

u4 : Rolling moment

Thi : The thrusts generated by four rotors

Ii : The moments of inertia with respect to the axes

Where Thi's are thrusts generated by four rotors and can be considered as the real control inputs to the system, and C the force to moment scaling factor. And Ii's are the moment of inertia with respect to the axes. Therefore the equations of Euler angles become:

$$\ddot{\theta} = u_2 - lk4\dot{\theta}/I1$$

$$\ddot{\Psi} = u_3 - lk5\dot{\Psi}/I2$$

$$\ddot{\varphi} = u_4 - lk5\dot{\varphi}/I3$$

where (*x*, *y*, *z*) are three positions; (θ, φ ,ψ) three Euler angles, representing pitch, roll and yaw respectively; *g* the acceleration of gravity; *l* the half length of the helicopter; *m* the total mass of the helicopter; *Ii's* the moments of inertia with respect to the axes; *Ki*'s the drag coefficients.

III. SYSTEM ARCHITECTURE

This last section provides an overview of the architecture presenting the devices and their connections. The quad-rotor structure is equipped with a RF receiver, a Micro Controller Unit (MCU), four motor's power boards and several sensors to provide a stable autonomous system. A general block diagram of the architecture is shown in Fig. 2 [5].

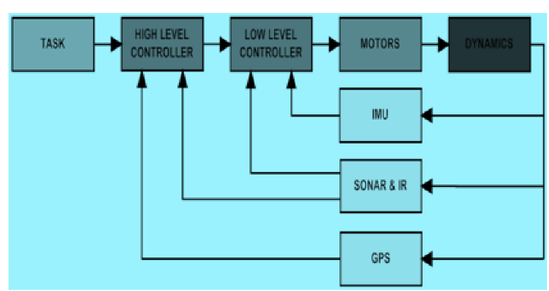

Fig. 2. System architecture.

The goal of the quad-rotor is presented by the task block. It can be burned in the MCU's ROM or provided by the user through a wireless communication. In the first case the robot will behave to follow its (fixed) high level task and no external communication is required. In the second case, the task can be changed by the user.

This configuration is more flexible and is the one implemented in this work. The interface between the user and the quad-rotor is fulfilled by a Remote Controller (RC) equipped with a RF transmitter which sends the task information to a RF receiver mounted on the quad-rotor.

From Fig.2 it shows that the input of this block is not only the task, but also the GPS and the SONAR & IR. With this information the algorithm is able to provide a trajectory, send the references to the low level controller and verify the progress of the motion through the sensors in feedback. In this work, the task is directly given in a low level format; therefore this block is not implemented. However it can be added in future through software upgrades. Even the low level controller block represents an algorithm on the MCU, but its purpose is to stabilize the quad rotor. This program is also indirectly composed of the description of the dynamics of the robot. Hence it is possible to define a control law which bind the motors' inputs to the quad-rotor linear and angular position.

The inputs of this block are the high level controller, the Inertial Measurement Unit (IMU) and the SONAR & IR blocks. Through the sensors it is possible to have a feedback on the position and provide autonomous stabilization.

The motors block is composed of the motor's power boards and the motor propeller systems. The power boards are essential to supply the voltage and current needed by the motor. It also provide a current feedback to a MCU's ADC to observe the state of the motor. The IMU block represents the physical device which provides information about the quad-rotor's attitude and heading. It is composed of three accelerometers, three magnetometers, three gyroscopes, a barometer and a temperature sensor. Thanks to all these components, the IMU calculates the roll-pitch-yaw angle and it sends them to a MCU's UART.

The communication is provided through a digital RS-232 interface. Furthermore, the three gyroscopes, it is possible to have a feedback about the quad-rotor's angular speeds in the fixed-body frame. The IMU is therefore an essential device for UAVs. The GPS block represents the device which provides information about the quad-rotor's global position. It is physically built in the IMU, but its information is not provided by inertial sensors. The GPS has a position accuracy of about 10 meters, hence it is not used in the low level controller because the error is too large. Furthermore the GPS doesn't work properly in indoor applications. However it can be connected to the high level controller as a feedback for the desired outdoor global trajectory.

The SONAR & IR block represents the devices involved to estimate the distance from the quad-rotor to an obstacle in a certain direction. Two different systems have been mounted: the SONAR and the IR module.

The SONAR detect the distance of an obstacle thanks to ultrasound waves. It's beam width is quite wide: 55 degrees. Furthermore the SONAR is mounted on a PCB which provide an I2C digital communication to the MCU. The IR module uses instead light waves and has a narrower beam. It is also mounted on a PCB, but it is connected to the MCU thanks to a MCU's ADC since the information is analog.

These devices are used to estimate the height of the quad-rotor from the ground and to provide information on the availability of the space around itself.

For the controlling of system there are many techniques: PID controlling technique, Fuzzy logic Controlling Technique and many more.

IV. CONCLUSION

This paper represented review on quad-rotor system. In this paper we have seen basic structure of quad-rotor, it's functioning and applications. It is very useful system for these days especially in defence purposes.

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