# Tri-Rotor UAV Stabilisation and Control

[1]A.Sundar Raj, [2]V. Muthumani, [3]V. Anusuya
[1]Associate Professor,
[1]E.G.S. Pillay Engineering College, Nagapattinam, India
[2,3] E.G.S. Pillay Engineering College, Nagapattinam, India

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***Abstract-*** **In the present times unmanned vehicles are commonly used for remote Ariel surveillance especially in the field of military application. One of the major advantages of a Tri-rotor UAV is its Vertical Take-off and Landing (VTOL) capability. The aim of our project is to develop a Tri-rotor UAV and its control mechanism that can be used for remote Ariel surveillance. The project thus involves designing and implementation of an effective communication mechanism between a ground station and the UAV and an effective flight control algorithm to control the flight of the UAV. The control signals are transmitted from the ground station to the UAV by using ASK modulation. A wireless camera attached to the UAV transmits the live video of the terrain and this video can be viewed directly on an LCD display or monitored using a PC. This video enables a controller to continuously monitor the path of flight of the UAV.**

***Keywords*— Tri-Rotor UAV, Stabilisation, Surveillance.**

## I. *Introduction*

Camera based surveillance has long been used for security and observation purposes. Surveillance cameras are typically fixed at known positions and cover a circumscribed area defined by the field of view of cameras. Although some recent vision work has addressed autonomous surveillance, in most cases humans perform the sensory processing, either in real time or by reviewing footage. Likewise, humans have performed reconnaissance, or scouting, for centuries in military and other applications in order to inspect terrain and identify and classify activities in the environment. In this UAV project, we combine the sensory capabilities of surveillance with the mobility of reconnaissance by mounting cameras on mobile robotic platforms. The resulting groups of collaborating reconnaissance and surveillance robots pose interesting challenges in vision-based surveillance algorithms and mission planning.

The first question that one asks about the Tri-rotor UAV is how it stands out from the traditional one. Hence a short introduction about the Tri-rotor UAV construction and steering principle is necessary. The tri-rotor UAV is a mechatronic system with three rotors that provide the lift and control. With respect to hover, the main difference is best explained by considering how the helicopters compensate from gyroscopic torques. Traditional helicopters basically compensate from the torque generated by the main rotor through the tail rotor. However the tail rotor compensation conducts a sideways displacement of the helicopter, thus counter steering by tilting the main rotor blades is necessary. In this way hover is an ongoing and complex process. Similar is the case with a Tri-rotor UAV.

This paper primarily describes the UAV stabilisation and control mechanisms. Section II gives a brief overview of the UAV system. Fig. 1 shows the architecture of the surveillance system within our UAV system. The UAV is the mobile unit in which a wireless camera is attached. The wireless camera takes live video and transmits the video from the UAV to a receiver located on the ground. These video can be used for live monitoring of a militant active region in military application and other spy works. The position of view of the camera can be adjusted using the signals from the camera position control circuit which is monitored by a controller. The proposed processor for our application is PIC 18F4550. The processor processes the control signals from a ground transmitter and controls the position of the camera and the direction of flight of the UAV. Ground station is a portable unit. A user could use this unit to monitor the live images from the UAV through an attached LCD display or using a TV. The user can use the controls on this module to generate the control signals necessary for monitoring and directing the path of flight of the UAV and also adjust the position of the camera.

Sections III describes about the hardware components used in our system and section IV gives an explanation about the communication between the copter and the ground station and also describes about the synchronisation between them.

## II. *System overview*

In our project we have two modules such as copter and user control unit called ground station. The main part of the UAV is nothing but a flight control board. The main function of the flight control board is to process the control signals transmitted by the ground station and to control the direction and stability of the copter. The ground station is a portable unit which is handled by the user to control the copter. We also have an LCD display to watch the video picked by the camera in the copter.

### *A) Basic layout*

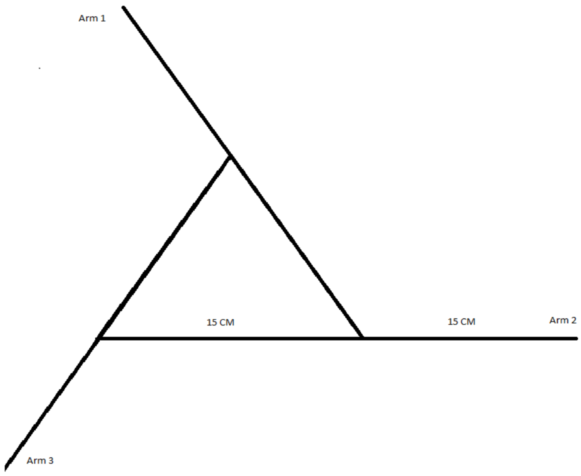


Fig 1: Basic layout of UAV

The UAV has a size of 650×650×220mm (L×W×H) and a weight of 590 g. With fully loaded batteries (3200mAh) it can operate for approx. 20 min. Its maximum payload is 500 g. The UAV is controlled either by the UGV or a human operator. It can be programmed for working in autopilot mode also for constant surveillance purposes. Figure 1 shows the basic layout of the UAV. Here each arm is placed $120^0$ each other. The length of each arm is more than 15 cm to avoid the flapping due to wind from the propellers. The whole body is made with Aluminium and each arm is made with hollow aluminium square section.

### *B) Flight control board*

Flight control board is the most important part of the copter since it controls the direction and stability of the copter. Its flight control board is equipped with an inertial measurement unit consisting of gyroscopes, speed control unit and servos to control direction. Fusion of these sensors as well as the control of the three motors is done by means of an on-board 40MHz microcontroller (Pic 18F4550) and three brushless motor control boards. The on-board microcontroller controls the three brushless controllers via PWM. Figure 2 shows the functional diagram of the UAV used in the project.

The back born of the flight control board is pic microcontroller. The microcontroller controls the switching circuit and also provides signals to the gyros. The control signals send by the user from the ground station is applied to a switching circuit which determines which signal is to be given to which gyro. The switching of this circuit is controlled by the microcontroller. The head lock gyro is nothing but a device that senses the tilt of the copter. It produces output voltage corresponding to the tilt and is applied to brushless DC motor via speed control unit. Piezo gyro controls the servo motor mounted on an arm and is used to stabilize and to control the direction of the copter. A 3-axis accelerometer is also provided for continuous monitoring of acceleration. The accelerometer output is given to microcontroller which produces necessary control signals to the motor.

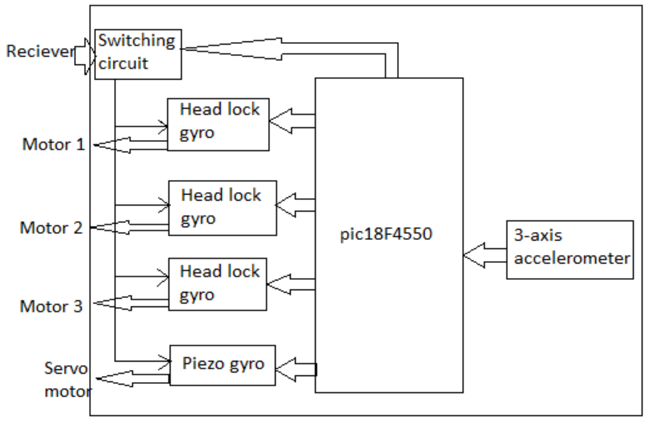


Fig 2: Architecture of flight control board

### *C) Ground station*

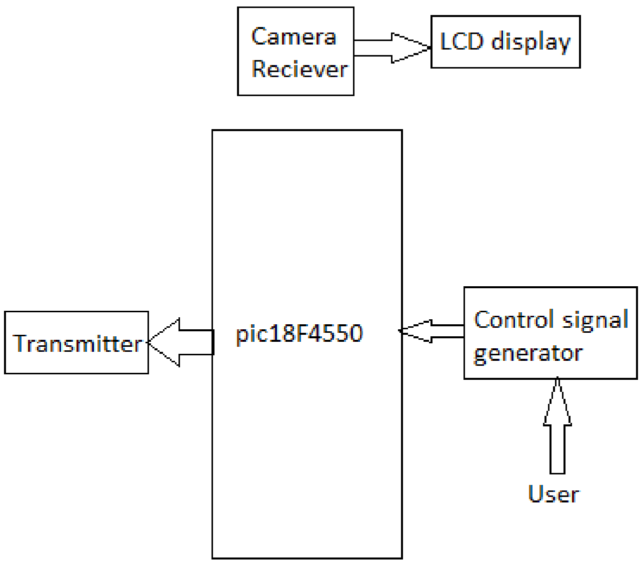


Fig 3: Ground station block diagram

The basic block diagram of the ground station is shown in the figure 3. Ground station is a portable unit which has user interface. The control signals are generated by the user through control signal generator and are given to the microcontroller. The microcontroller converts the signals digital and process and then applied to the transmitter. The transmitter transmits the control signals to the copter. The ground station is also equipped with a LCD display to watch the real-time video picked by the camera in the copter. Video transmitted from the copter is received and directly given to the on-board LCD display.

## III. HARDWARE ARCHITECTURE

Before the UAV components are assembled to the frame of the UAV, the frame must be balanced. The weight to the three arms must be equal for a stable flight. Otherwise unbalanced forces will result in extra energy loss, the mechanism of which is described in the Gyroscope section.

### A) *Body Design*

For the stable operation of UAV the body must be designed and balanced. The final length of the arms will determine the size of the UAV radius. The longer the arms the more stable the UAV will be. We are choosing 20 inch as our UAV radius. The arms can be made from any number of materials from wood, carbon fibre, or aluminium. The three arms are place 120 degree apart in a circular manner. The motor and the blades are placed at the end of each arm. Speed control unit is placed just near to the motor. Head hold gyro is placed in each of the arm. To balance the centrifugal forces, the circuitry and power supply unit is placed at the exact centre.

### *B) PIC Microcontroller*

The PIC 18F4550 microcontroller was chosen to obtain data from sensors, input from a pilot, perform control calculations, and control the motors on the UAV. This PIC microcontroller has several hardware features that are very useful for use in a UAV and simplify the interfacing of sensors and motors with the microcontroller, such as an analog to digital converter (ADC), interrupts, timers, and capture/compare/pulse width modulation (CCP) channels. In addition, the microcontroller requires low current. Devices in the PIC18F2455/2550/4455/4550 family incorporate a fully featured Universal Serial Bus communications module that is compliant with the USB Specification Revision 2.0.

### *C) Electronic speed control unit*

As the name suggests this element is used for the speed control of the brushless DC motors. An *electronic* speed control works by applying full voltage to the motor, but turning it on and off rapidly. By varying the ratio of on time to off time, the speed control varies the average voltage that the motor sees. Since at any given instant, the control is either fully of or fully on this kind of control is theoretically 100% efficient, but in actual scenarios there is a reduction in efficiency.

### *D) Head hold Gyro*

Flight is made stable by monitoring the signals from the Head Lock Gyro. The Gyro placed in each arms of the copter. The Gyro produces an analog- voltage with respect to the tilt in each arm. The controller then varies the power to the Electronic speed control unit for making the copter stable.

The Gyro measures angular velocity along the pitch and yaw axes with a full scale of ±300°/s. Digital outputs are provided for tilt along its orientated axis. A regulated voltage 5VDC should be supplied to the power pins. We are using an external gyro module for preciseness, in that module we have the filtering circuits all set up; and it is just need to connect the outputs to an ADC, for the proper operation of head hold gyro.

### *E) Yaw control arrangements*

A Yaw rotation is a movement around the yaw axis of a vehicle. It is commonly measured in degrees per second or radians per second. In case of a helicopter or a flight it is the rotation in the horizontal plane. It is mainly generated due to the unbalancing forces acting on the UAV like frictional force. It causes the copter to rotate in the horizontal plane. To minimize the effect of yaw the propellers are rotated in different directions. Any unbalanced yaw can be monitored by the yaw gyro. A servo motor is provided in the tail arm to counteract any unbalanced yaw.

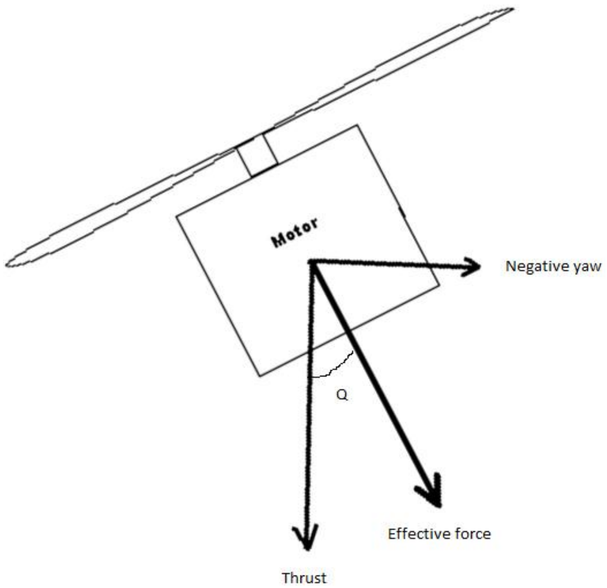


Fig 4: Yaw and direction control

At the front arm a servomotor is connected which is able to tilt the brushless motor according to the signals from a piezo gyro. The piezo gyro senses the yaw of the UAV and produces analog voltage. The tilt in the plane of rotation of the brushless motor resolves the total force into two. Thus one component of the resolved force counteracts the yaw force.

## IV. COMMUNICATION

The communication between the Tri-rotor UAV is accomplished by using a 433MHz transmitter at the ground station which transmits digital signals to the UAV and a receiver at the UAV.

### A) *Transmitter*

The transmitter consists of a control panel which acts as an interface for the controller to control the UAV. The pic 18f4550 is used to generate the control signals. The control signal transmitted is a signal of 50Hz frequency. The time period of 20ms is divided into 4 slots of 5ms. The first slot transmits the synchronizing bit which indicates the starting of the 20ms cycle. The next three slots transmit the signal to the three motors of arm1, arm2 and arm 3 respectively. The last bit is used to control the servomotor.

The time duration of each bit is varied with respect to the analog voltage signals from the control panel. The first bit transmitted is a .5ms wide high pulse. It is used to indicate the beginning of a 20ms cycle. The transmitted signal is shown in the figure3 and is generated by the micro-controller in the ground station based on the user input.

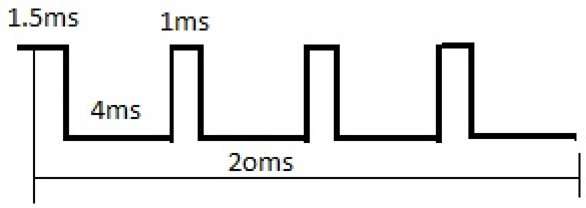


Fig 5: Control signals transmitted

The ground station board consists of variable resistors which produces the analog voltage corresponding to the variations in the resistance produced by the user. This analog voltage is converted into digital form and the appropriate control signals are generated by the micro-controller.

## V. CONCLUSION

In this paper we presented a Tri-rotor UAV which can be used for remote aerial surveillance especially in military applications. This device can be used for continuous monitoring of a particular area. This Tri-rotor UAV has two parts such as the copter and the ground station with user interface to control the motion of the copter. Ground station is a portable unit. The main advantages of this system are vertical take-off and landing, maneuverability, low cost and small size. The applications of the system are in remote surveillance, in military field and for spy works etc. The major problems of our Tri-rotor UAV is its battery back-up and range of communication. We are planning to develop a system with better battery back-up and range in future.

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