International Journal on Recent Technologies in Mechanical and Electrical Engineering (IJRMEE) ISSN: 2349-7947
Volume: 2 Issue: 10 047 - 050

Gesture and Stability Control of A Quadcopter Using 3-Axis Accelerometer

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ABSTRACT - Usually, the copter's position and stability are sensed using an "Indoor Global positioning System". In this method, reflectors are fixed on the quadcopter and they are continuously sensed by IR, motion sensors and cameras. But if an accelerometer is used in a quadcopter, the need for the cameras and motion sensors is removed. An accelerometer placed on the quadcopter can be used to maintain the copter's stability. This accelerometer constantly monitors the position of the quadcopter in flight. The signals from the accelerometer are monitored by a microcontroller. If the controller senses any disturbance in the flight position of the quadcopter, it automatically generates necessary signals to bring back the quadcopter to stable state. The XBee module is used to receive data wirelessly from another module present in the user's hand. The controller on board, reads the serial data from the XBee receiver and executes the respective commands from user gestures. Thus, the controller on board uses the data to control the quadcopter. This paper is presented to explain the control methodology and realization of stability of a quadcopter using accelerometers. The main aim of this paper is to reduce the cost of the control system by using onboard position sensors i.e. accelerometers and to control the quadcopter via hand gestures.

Index Terms – *Quadcopter, Global Positioning System, Accelerometer, XBee module, stability and control.*

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I. INTRODUCTION

An unmanned aerial vehicle also known as UAV is an unpiloted aircraft which can either be remotely operated or flown autonomously based on pre-programmed flight plans. Usually these types of vehicles are used in military applications for missions that are too dangerous for manned aircraft. They are also used in a growing number of civil applications such as aerial photography and the transport of various goods.

A quadcopter, also called a quadrotor helicopter, is a multicopter that is lifted and propelled by four rotors. Unlike most helicopters, quadcopters generally use symmetrically pitched blades; these can be adjusted as a group, a property known as 'collective', but not individually based upon the blade's position in the rotor disc, which is called 'cyclic'. Control of vehicle motion is achieved by altering the pitch and/or rotation rate of one or more rotor discs, thereby changing its torque load and thrust/lift characteristics.

Fig 1.1 Typical Quadcopter

A quadcopter, also called a quadrotor helicopter, is a multicopter that is lifted and propelled by four rotors. Unlike most helicopters, quadcopters generally use symmetrically pitched blades; these can be adjusted as a group, a property known as 'collective', but not individually based upon the blade's position in the rotor disc, which is called 'cyclic'. Control of vehicle motion is achieved by altering the pitch and/or rotation rate of one or more rotor discs, thereby changing its torque load and thrust-lift characteristics.

There are several advantages to quadcopters over comparably-scaled helicopters. First, quadcopters do not require mechanical linkages to vary the rotor blade pitch angle as they spin. This simplifies the design and maintenance of the vehicle. Second, the use of four rotors allows each individual rotor to have a smaller diameter than the equivalent helicopter rotor, allowing them to possess less kinetic energy during flight. This reduces the damage caused should the rotors hit anything. For small-scale UAVs, this makes the vehicles safer for close interaction. Some small-scale quadcopters have frames that enclose the rotors, permitting flights through more challenging environments, with lower risk of damaging the vehicle or its surroundings. Due to their ease of both construction and control, quadcopter aircraft are frequently used as amateur model aircraft projects.

II. SYSTEM ANALYSIS

2.1 QUADCOPTER DYNAMICS AND THEORY

They are quad rotor helicopters that are lifted and propelled by four rotors. Unlike helicopters, they use symmetrically pitched blades. Each rotorproduces both a thrust and torque about its center of rotation, as well as a drag force opposite to the vehicle's direction of flight.

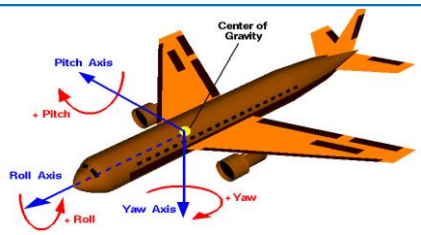

Fig 2.1 3-Axes of Flight

There are three main axes in flight. They are Yaw, Pitch and Roll. To control these three axes, a minimum of four rotors with symmetrically pitched blades must be present. Given that the front and rear motors both rotate counter-clockwise and the other two rotate clockwise, resulting in a net torque of zero due to the rotational axis.

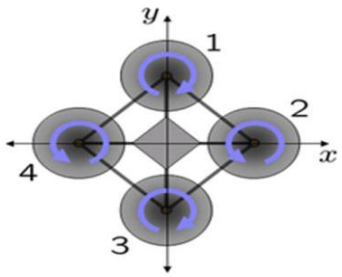

Fig 2.2 Quadcopter Dynamics

Lastly, the quad rotors symmetrical design allows for easier control of the overall stability of the aircraft. To control this axis, diagonal rotors should be increased in speed. For example, if the copter is to be rotated clockwise, then the speeds of rotors 2 & 4 (which rotate in anticlockwise directions) should be increased. The Pitch and Roll axes in a quadcopter are same as the quadcopter is symmetrical in both directions. In order to increase a copter's pitch, the respective rotor's speed should be increased and simultaneously, the speed of the diagonally opposite rotor should be decreased. For example, if the speed of the rotor '1' is increased and simultaneously, the speed of the rotor '3' is decreased, then the quadcopter would be positioned such that rotor '1' is in a higher altitude and rotor '3' is in a lower altitude. The control strategy is given in the tabular column below.

We can see that the quadcopter needs any two of the rotors to be controlled in any given time. Based on certain assumptions, the control design or strategy has been proposed.

Table 2.1 Quadcopter Axes Control

Control Axes	Control Procedure
Yaw	Speed of the rotors 1 & 3 or 2 & 4 are increased for anticlockwise or clockwise rotations
Pitch	Speed of respective rotor is increased while the speed of the diagonally opposite rotor is decreased
Roll	Due to symmetrical spacing, Pitch and Roll axes are the same in a quadcopter.

2.2 Existing Concept

To stabilize the quadcopter, the position of the copter in 3 dimensional space should be known. This is calculated by creating an '**Indoor Global Positioning System**'.

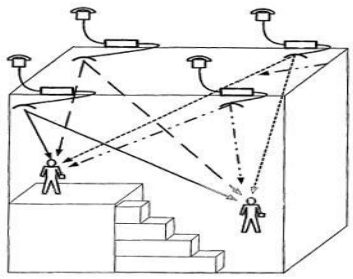

Fig. 2.3 Indoor Global Positioning System

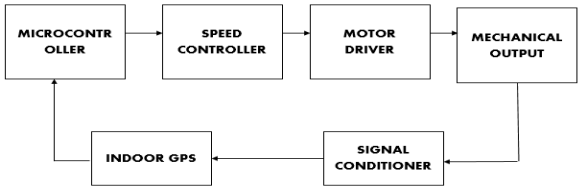

Fig. 2.4 Block Diagram of Existing System

The Indoor GPS is nothing but an array of cameras continuously monitoring the motion of the copter and feeding its location, in 3 dimensional space, to the processor. The cameras detect the copter with the help of a reflector mounted on the copter. This reflector denotes the position of the copter inside the room. So based on the motions of the copter, the stability of the copter can be determined. Reflector denotes the position of the copter inside the room. So based on the motions of the copter, the stability of the copter can be determined. Say, the stability's', of the copter is taken in a scale from 0 to 1, where, '1' being the copter's stable state and '0' being the unstable state. If the processor senses that copter is in state 0, then it follows a certain algorithm to stabilize the copter through wireless transmission by controlling the 4 rotors of the copter.

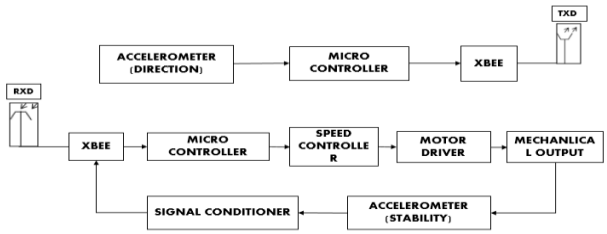

Fig. 2.5 Block Diagram of Proposed System

While stabilizing the copter, the motion of the copter is continuously monitored and counter directional forces are supplied such that the net force on the copter is zero.

2.3 Problem Statement

In this type of controlling "indoor global positioning system" they used many number of cameras for control and to stabilize the copter .Even though this is one of the good method of controlling copter but the cost of entire system was so high. And we can use this copter only in fixed

location this was the major drawback we faced when we exposed this existing concept. This are the problem's we overcome in our project. Then system faced some of difficulty on controlling of copter. It is difficult to control copter by using the old buttons. This above problem's are over come in our project.

2.4 Proposed Concept

The proposed concept contains no cameras and detectors. Two accelerometers are used to control the quadcopter. First accelerometer, mounted on the user's hand, is used to control the quadcopter's motions. This accelerometer detects the motion of the user's hand and signals the copter to move respectively. Thus the motions of the user's hand are replicated by the copter. The second accelerometer is mounted on the quadcopter. This accelerometer is used to monitor the quadcopter's position. The signal from this accelerometer is sent to an on-board microcontroller so that the quadcopter can itself understand its motion and control the respective rotors so that the quadcopter is in equilibrium.

The block diagram in Fig 2.5 explains the working of the control system.

III. System Explanation

(This paper does not explain the working of individual components. The main aim of the paper is to explain the concepts in controlling the quadcopter using an accelerometer.)

The main components specific to this project are,

- BLDC motors (1120 Kv)
- Electronic Speed Controllers (20 amps)
- Controller (Atmega328)
- ZigBee modules (XBee S2)
- Accelerometer (3 axes)
- Power Supply (Li-Po Battery 7.4 V)

3.1 Micro Controller

The controller to be selected should have the capability to generate 4 PWM waves simultaneously. Each PWM wave is required tocontrol the speed of the BLDC motors through the ESCs. Atmega328 is used because of the availability of 6 PWM digital outputs in the frequency of 50 Hz.

The PWM waves act as a control signal to the ESC. The speed of the BLDC motors are controlled by varying the duty cycle of the

Fig 3.1 Arduino UNO development board

output PWM wave. Lesser the duty cycle, lesser the speed.

3.2 XBee-Wireless Communication Protocol

The XBee is used to transmit instead of RF because, the XBee has a longer range and analog data can be transmitted. The XBee is used in two different modes: API mode and AT mode. In either of the two modes, the XBee can act as one of the three configurations. They are, Coordinator, router and end point. For this project, the XBees need to be used in coordinator mode and router mode.

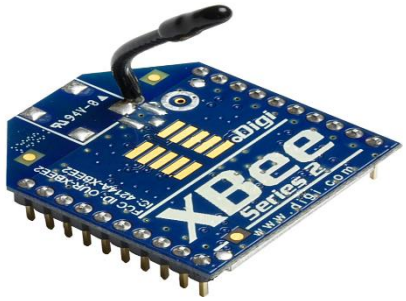

Fig 3.2 XBEE module

The coordinator XBee should be in API mode and router XBee should be in AT mode. The router XBee collects the analog data from the 3 axis accelerometer and broadcasts it to the coordinator XBee. The serial data received in the coordinator XBee is decoded by the Atmega328. Based on the analog voltages of the accelerometer, the respective commands are given to the four ESCs to control the speed of the BLDC motors.

3.3 System Design

The whole system is divided into two parts. The transmitter side and the receiver side. The transmitter side is the part where the control accelerometer and the router XBee is present. This side is mounted on a glove, worn by the user. Based on the hand gestures, the accelerometer varies the output voltage. This voltage is transmitted via the router XBee. The schematic and the PCB layout are shown in the figures below.

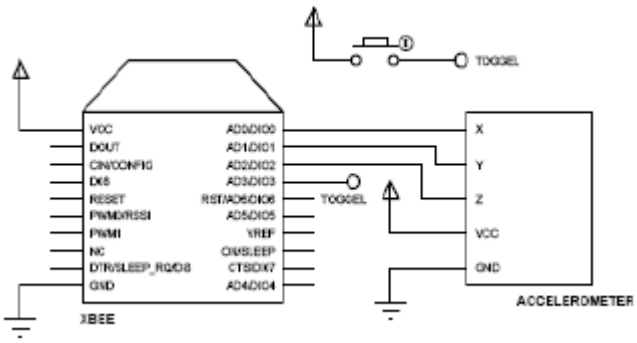

Fig 3.3 Circuit to be placed on the User's Hand

The 3 axes 'x','y','z' of the accelerometer are connected to the 3 analog pins of the XBee module. The toggle switch is used to change themode of operation of the accelerometer.

Since we need a total of 7different hand movements. It is difficult to use the accelerometer in one single combination. So, a toggle switch is used to multiply the hand gesture combinations by 2in order to utilize the accelerometer more efficiently. The receiver part of the system is the Quadcopter on which the microcontroller and the coordinator is mounted.The router XBee connected to the coordinator XBee, wirelessly transfers the analog and digital data. The coordinator XBee connected to the microcontroller, feeds the controller with the pin status of the router XBee. This information is used by the controller to vary the duty cycle of the PWM waves and thus controlling the 4 ESCs.

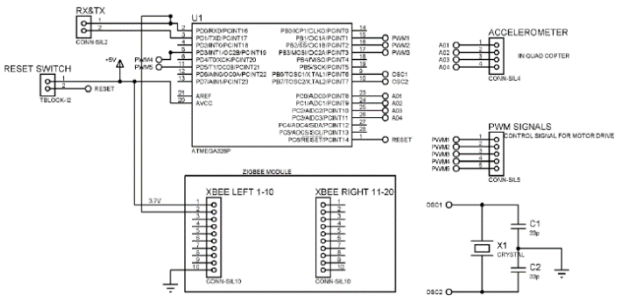

Fig 3.4 Circuit to Be Mounted On the Quadcopter

The schematic and the PCB layout of the circuit on the quadcopter is shown below. The on board circuit consists of a microcontroller, accelerometer, XBee module. The onboard accelerometer is used to maintain the stability of the quadcopter.

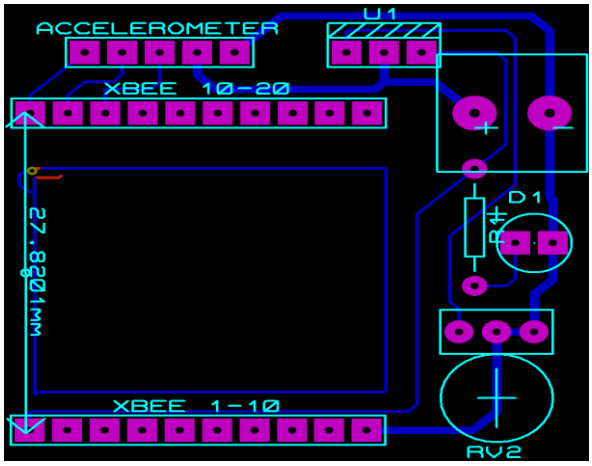

Fig 3.5 PCB Layout of the Circuit in Hand

The 3 axes of the accelerometer are connected to the analog pins of the controller. This accelerometer continuously senses the motion of the quadcopter and generates respective voltages. Based on the calibrated

voltages, the controller senses any disturbances in the quadcopter's flight and generates necessary signals to bring back the quadcopter to stable state.

```
sensorValueX = analogRead(sensorPinX);
sensorValueX = map(sensorValueX,
sensorMinX, sensorMaxX, 0, 255);
sensorValueX = constrain(sensorValueX, 0,
255); if(sensorValueX<140) {
pwm_dutyX++; if(pwm_dutyX>254) {
pwm_dutyX=254; } pwm_dutyY++;
if(pwm_dutyY<254) { pwm_dutyY=254; } }
```

Fig. 3.6 Part of the main program

IV. Experimental Result

By using the gesture control method, the quadcopter can be controlled about 60 % more efficiently. This control can be employed not only in quadcopters but any kind of copters such as, Xcopters, tricopters, hexacopters, etc. This can be achieved by varying a few parameters in the program. Also by using the Atmel processors, it becomes easier for any further changes to be done.

V. Conclusion

Human mind is works efficient in controlling objects if the nature of control is something which one does in daily life. We use hand gestures to communicate and signal others. This, if employed in controlling a quadcopter, or any machine for that sake, gives us more control over the quadcopter. It would be easier for our mind to process the gestures and easy for us to control compared with other control methods. It also increases the accuracy of control. This way of control is easy to understand and it doesn't require any special study to operate the quadcopter. It reduces the cost of the system and advances the user interface with the system.

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