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Study the Attitude of a Seesaw to Develop Flying Robots

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ABSTRACT

Design, manufacture and attitude control of a seesaw are described in this paper. At the beginning, mechanical design of the system is completed in SolidWorks. Then the system is made. To control the system several dynamic equations and parameters are studied. Further more, a number of electric components such as motor, electronic speed controller, micro controller board are studied and selected for the experimental setup. Finally, proportional integral derivative controller algorithm is used to control the seesaw. Gain values of the proportional integral derivative controller are estimated on the basis of trial and error method. Ultimate values of the proportional, integral and derivative gains are 3.05, 0.005 and 0.75 respectively. During experiment, it is found that, system takes only ten seconds to reach the same position as the input command. Therefore, this technique can be used to control the roll and pitch attitude of the quad rotor as well as other unmanned aerial vehicle.

Keywords: Attitude Control, ESC, IMU, Seesaw.

1. Introduction

A seesaw is a single point pivoted board which can rotate small angle about the pivot axis depending on applied force. It includes one degree of freedom rotational dynamics which can be compared with the roll of an airplane or any floating object in fluid.

Development and use of unmanned aerial vehicle (UAV) is increasing day by day. Nowadays, this is one of the most popular fields of research. Various types of unmanned airplane and helicopter are using in different applications. Dynamics and avionics of UAV are not easy. Furthermore, it is very costly to develop UAV. If made any mistake then it may crash and cost a lot to develop again. Therefore, it is essential to study the dynamics and control of the system before flying it. In the present study, a seesaw is made for preliminary study the attitude of UAV. It helped to develop control algorithm for roll and pitch of UAV.

There are few researchers studied the behavior of the seesaw. Jae-Nam Kim et al. [1] developed a single axis seesaw as a preliminary study of a quad-rotor aerial vehicle. They initially studied the roll attitude of seesaw to control the quad rotor UAV. Erol Uyar et al. [2] developed the real model as well as a MATLAB model of seesaw and estimated different parameters through experiment and simulation. They found a very little discrepancy between experiment and simulation results. Huafeng Liu et al [3] describe design, fabrication, and characterization of a seesaw-lever force-balancing suspension for a gravity gradiometer that is capable of operation from 0 to 1 g gravity.

The main objective of this research was to develop a seesaw mechanism and study the controller. Fig. 1 shows the 3 D model of the seesaw.

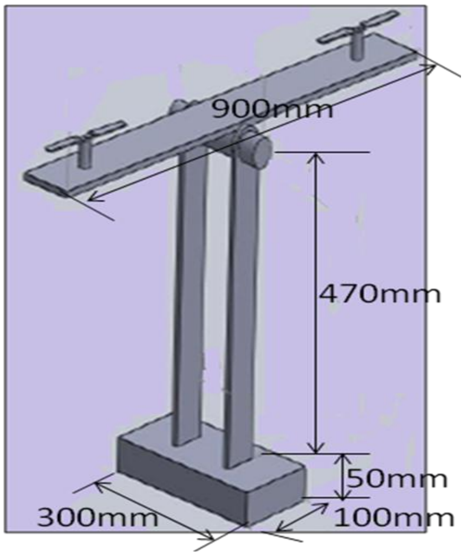

Fig. 1 3D model of the Seesaw

2. Dynamics of Seesaw

Angular displacement (θ) and moment (M) of the seesaw and thrust (T) produce by two rotors are presented in Fig. 2. To estimate the rotor thrust blade element theory, blade

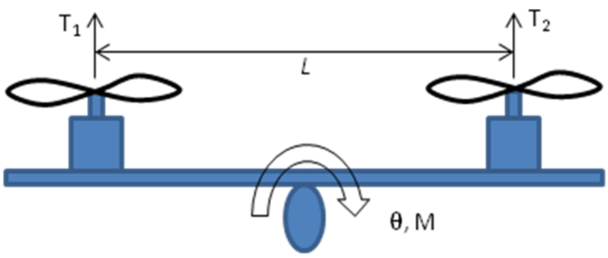

Fig. 2 Dynamics model of Seesaw

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element momentum theory can be used. But in the present study, very simple experimental method is applied to find out thrust of two motors. Thrusts of two rotors are calculated by eq. (1) and eq. (2).

$$T_1 = C_T * \omega_1 \quad (1)$$

$$T_2 = C_T * \omega_2 \quad (2)$$

Here, C_T is the propeller thrust constant and ω is the angular velocity. On the other hand, moment of the seesaw is calculated by eq. (3).

$$M = 0.5*L*(T_1-T_2) - D*\dot{\theta} \quad (3)$$

Here, L is the distance between two rotors and D is the viscous damping coefficient.

3. Different Components of Seesaw

The main components of seesaw are brushless DC motor, propeller, electronic speed controller (ESC), inertial measurement unit (IMU), board, stand, micro controller board, transmitter and receiver. Fig. 3 shows the constructed model of the seesaw.

A motor converts electrical energy into mechanical energy. In this research, BLDC motor is used because it has high efficiency, less heat generation and nice controllability. Here, EMAX XA 2212 Brushless DC motor of 1400 KV is used. A BLDC motor is presented in Fig. 4.

A propeller is a type of fan that converts rotational motion from motor or any other power source into thrust. Here, two propellers are directly connected with motor shaft. The diameter and slope of the 8045R propeller is 8 inches and 4.5 inches respectively. Propeller is made of Carbon Nylon. On the other hand, weight of each propeller is 10 gram. Fig. 5 shows a 8045R propeller.

In the present study, a six axis IMU (MPU-6050) is used. IMU is a single unit electronic module. It generally contains accelerometer, gyroscope and

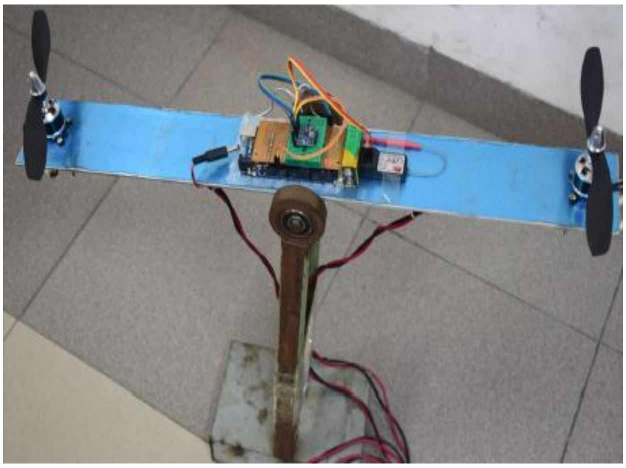

Fig. 3 Seesaw (Experimental setup)

Fig. 4 Brushless DC motor

Fig. 5 Propeller

Fig. 6 IMU (MPU-6050)

magnetometer. Accelerometer, gyroscope and magnetometer are used to detect the linear acceleration, angular velocity and heading reference respectively. MPU-6050 module does not contain magnetometer. In this research, magnetometer is not necessary. In MPU-6050 module gyroscope of micro electro mechanical systems (MEMS) is added. Digital outputs of X, Y and Z axis gyroscopes can be programmed by an user at different ranges like ±250, ±500, ±1000, and ±2000°/sec. Conversely, Digital outputs of X, Y and Z axis accelerometers can be programmed at different ranges such as ±2g, ±4g, ±8g and ±16g. IMU accumulates linear acceleration as well as angular velocity data and sent to the micro controller board. An IMU is shown in Fig. 6.

An Arduino mega 2560 is used for the seesaw as the main control board. It has a physical programmable circuit board called micro controller and several input and output pins in it. It uses special software called integrated development environment (IDE) to write code and upload to the Arduino. An Arduino mega board is presented in Fig. 7.

Fig. 7 Arduino mega board

Fig. 8 Electronic speed controller

Fig. 9 (a) Transmitter (b) Receiver

Electronic speed controller is a circuit that is used for controlling the speed of the motor. It is vastly used in field and aerial robotics industries. Here, motor power is supplied from the battery through the ESC. On the other hand, motor control signal generated by the transmitter goes through the micro controller board and ESC to the motor. An electric speed controller is presented in Fig. 8. It's a 30 ampere and 25 gram ESC.

A CT6B FlySky 2.4 GHz 6 channel transmitter and a receiver [Fig. 9 (a), (b)] are used. Transmitter is powered by 12V battery. It can be configured by connecting to the computer. Important features of transmitter and receiver are: very low power consumption, high receiving sensitivity and stability.

Fig 10 shows the circuit diagram of the electrical setup. In this study, two batteries are used. A 9V and 12V battery is used to power supply to the arduino board and motor respectively. Besides an IMU and a receiver is directly connected to the board. A Receiver collects the command of the transmitter and sends to the board.

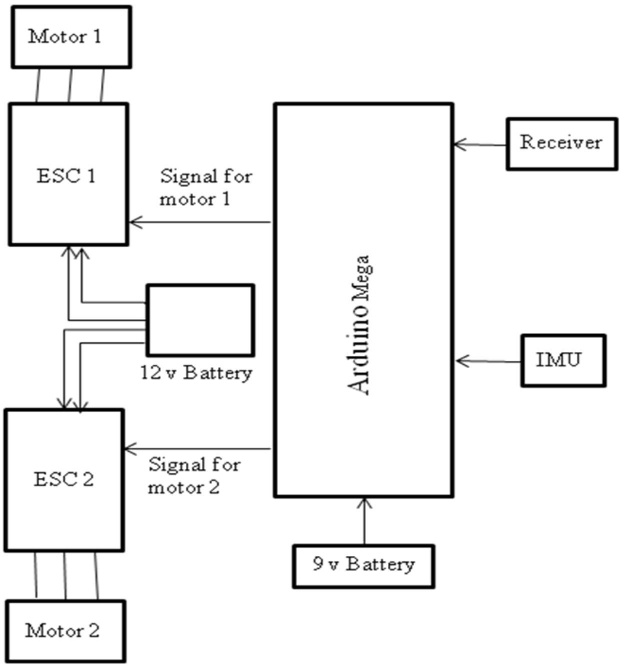

Fig. 10 Block diagram of the electric circuit

4. PID controller

PID controller is a part of closed loop system which is used to control any dynamic object or plant. The Input of the PID controller is the error signal (Error signal: The difference between the reference input and the output of the plant) and output of the PID controller is a weighted sum of the error signal as well as integral and derivative of the error signal. The output of the PID controller is presented in eq. (1).

$$u(t) = K_p e(t) + K_i \int_0^t e(\tau) d\tau + K_d \frac{de(t)}{dt} \qquad (1)$$

Here, K_p, K_i, K_d are the proportional, integral and derivative gain respectively. These gain values can be estimated manually or by using software. *e(t)* is the error signal and τ is the variable of integration (consider values form time 0 to *t*). Fig. 11 shows the block diagram of the control system with a PID controller.

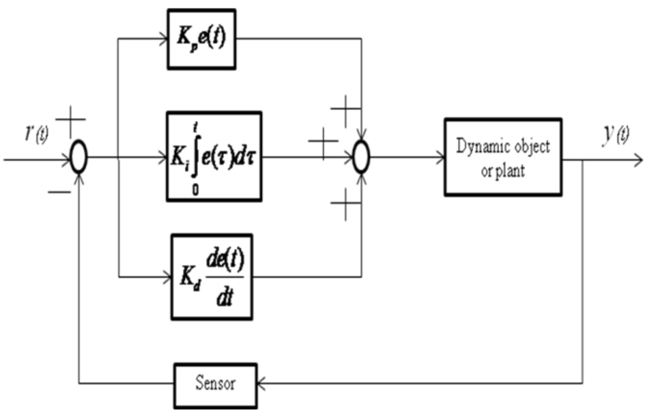

Fig. 11 Block diagram of the control system

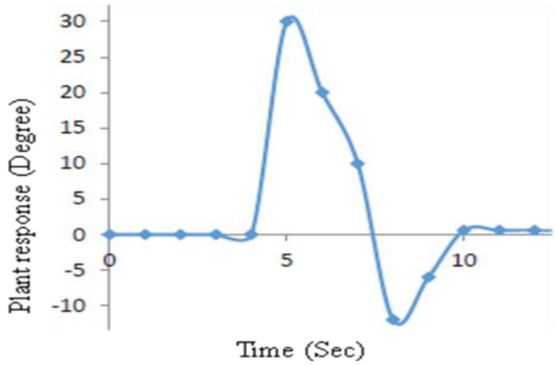

Fig. 12 Response of the seesaw with respect to time

5. Result and Discussion

Finally, a seesaw is made and experiment is carried out. Initial throttle value is 1300 revolution per minute. All the gain values are estimated through trial and error method. The values of K_p, K_i, K_d are 3.05, 0.005 and 0.75 respectively. Fig. 12 shows the stabilization result of the seesaw. In the present research, a disturbance is introduced by using hand after four second of the propeller start running. Force is applied by hand in one side of the seesaw. Therefore, seesaw starts to oscillate about the pivot point after four second (Fig. 12). From the graph, it is clear that it takes only five seconds to stabilize the seesaw by the controller.

6. Conclusion

This paper describes about the development and control mechanism of a seesaw. The seesaw is successfully controlled by the PID controller. Desired input command was zero degree and the seesaw reached to this angle within five seconds after disturbance is applied. Therefore, this technique can be used to control the roll and pitch attitude of the flying robot.

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NOMENCLATURE

r (t) : reference input, degree
y : plant response, degree

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