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FLYING DYNAMICS WITH QUADCOPTER IN INDOOR AND OUTDOOR FLYING CAPABILITIES

[1]Naveen Kumar.K, [2]Shiva.B, [3]S.S.Ganesh Kumar, [4]M.Sudhakaran
[1,2]Dept of EEE, GTEC, Vellore, India
[3]Asst. Prof, Dept of EEE, GTEC, Vellore, India
[4]Associate Prof, Dept of EEE, GTEC, Vellore, India

Abstract:
Angular maneuvering scheme along with standard flight operations such as taking-off, landing and hovering is proposed for a quadcopter with indoor or outdoor flying capabilities. This is achieved by simultaneously controlling the speed of the four rotors in order for the quadcopter to attain the correct orientation. The total thrust is determined using the inputs of altitude, pitch and roll angles. Then the thrust that the rotors must generate independently is obtained from the ratio of the angles and the calculated thrust for maintaining the input altitude. Voltage supply that is needed to spin the rotors at a certain RPM (Rotations per minute) is obtained to produce the thrust computed in the previous step. Moreover, the procedure on varying the thrust direction of rotors is also illustrated to perform the standard flight operations.

Key words: Altitude, Quadcopter, Hover, Land, UAV, Orientation, Pitch, Roll, Rotor, RPM, Takeoff, Thrust, Velocity.

1. INTRODUCTION

A quadcopter is a popular form of UAV (Unmanned aerial vehicle). It is operated by varying the spin RPM of its four rotors to control lift and torque. The thrust from the rotors plays a key role in maneuvering and keeping the copter airborne. Its small size and swift maneuverability enables the user to perform flying routines that include complex aerial maneuvers. But for conducting such maneuvers, precise angle handling of the copter is required. The precise handling is fundamental to flying by following a user-defined complex trajectory-based path and also while performing any type of missions.

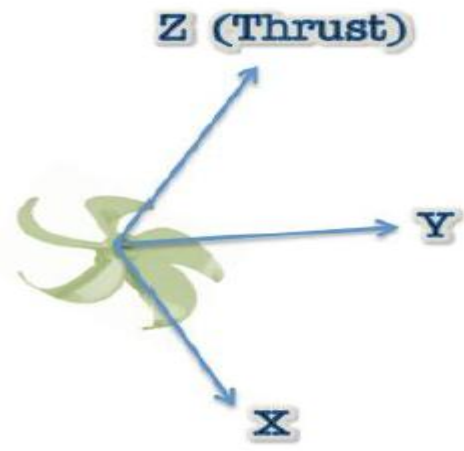

Fig. 1. Body frame

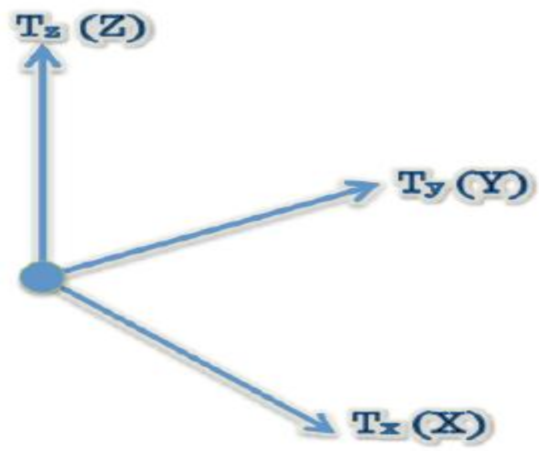

Fig. 2. Inertial frame

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This paper serves as a solution to handling the quadcopter with angular precision by illustrating how the spin of the four rotors should be varied simultaneously to achieve correct angular orientation along with standard flight operations such as taking-off, landing and hovering at an altitude. The particular interest of the research community in the quadrotor design can be linked to two main ad- vantages over comparable vertical take off and landing (VTOL) UAVs, such as helicopters. First, quadrotors 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. This simplifies both the design and maintenance of the vehicle. Second, 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, mitigating the risk posed by the rotors should they entrain any objects. Furthermore, by enclosing the rotors within a frame, the rotors can be protected from breaking during colli- sions, permitting flights indoors and in obstacle-dense environments, with low risk of damaging the vehicle, its operators, or its surroundings. These added safety benefits greatly accelerate the design and test flight process by allowing testing to take place indoors, by inexperienced pilots, with a short turnaround time for recovery from incidents.

2. PROCEDURE EVALUATION

A particular controller in the joystick is used to adjust the altitude. When the controller is moved up or down, This feature is used for taking-off/landing or fixing altitude while airborne. [2] Another controller is used to control the pitch/roll or angle of the quadcopter enabling it to move forward/back and left/right. Moving the controller to a certain direction increases the speed of the propellers in opposite relation to the direction the controller is pushed. [2] For instance, if the controller is pushed right, the left side propellers will speed up to tilt the quadcopter and cause it to move to the rightThe inertial frame is defined with respect to the ground, with gravity pointing in the negative Z-axis.

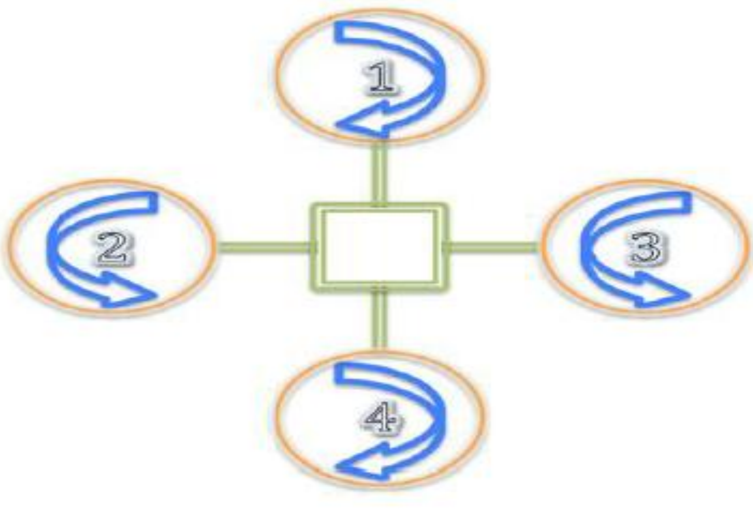

Fig. 3. Hovering

The body frame is defined by the orientation of the quadcopter, with the rotor pointing in the positive Z-axis and the arm- extensions pointing in the positive/negative X and Y axes. As a result, the velocity of rotors required for the quadcopter to climb up or down, or hover a fixed altitude is also variable at external conditions. So, a constant air-density reading would dramatically compromise the performance of the rotors and therefore, the overall total thrust of the quadcopter. For the latter parameter, the crosssectional areas of all the propellers are constant during anystate of the flight. However, the area of the propellers could also contribute to the amount of total thrust generated. This work focuses on three aerodynamic effects experienced by quadrotors, one that impacts altitude control and two that impact attitude control. First, for altitude control, total thrust is affected by the vehicle velocity and by the angle of attack, with respect to the free stream. This nonlinear function consists of three nonlinear flight regimes, one of which results in a stochastic thrust profile. Second, for attitude control, advancing and retreating blades experience differing inflow velocities, resulting in a phenomenon called blade flapping. This induces roll and pitch moments at the blade root, and tips the thrust vector away from the horizontal plane.

3. AERODYNAMIC EFFECTS

Although quadrotor vehicle dynamics are often assumed to be accurately modeled as linear for attitude and altitude control, this assumption is only reasonable at slow velocities. Even at moderate velocities, the impact of the aerodynamic effects resulting from variation in air speed is significant. This section focuses on four main effects, three of which are quantifiable and are incorporated into the nonlinear dynamics model of the vehicle for estimation and control, and one which results in unsteady airflow and can therefore be mitigated through structural redesign. The three quantifiable aerodynamic effects relate to motion of the vehicle relative to the free stream. The first effect is that the total thrust varies not only with the power input, but with the free stream velocity, and the angle of attack with respect to the free stream. This is further complicated by a flight regime, called vortex ring state, in which there is no analytical solution for thrust, and experimental data shows that the thrust is extremely stochastic. The second effect results from differing inflow velocities experienced by the advancing and retreating blades. This leads to "blade flapping" which induces roll and pitch moments on the rotor hub as well as a deflection of the thrust vector. The third effect is the interference caused by the vehicle body in the slip stream of the rotor. It results in unsteady thrust behavior, rendering attitude tracking difficult. This effect was demonstrated to be significantly reduced by airframe modifications. The derivation of the nonlinear dynamics is performed in North-East-Down (NED) inertial and body fixed coordinates. Let {eN,eE,eD} denote unit vectors along the respective inertial axes, and {xB,yB,zB} denote unit vectors along the respective body axes, as defined in Figure 4. Euler angles of the body axes are {φ,θ,ψ} with respect to the eN, eE and eD axes, respectively, and are referred to as roll, pitch and yaw. The current velocity direction unit vector is ev, in inertial coordinates, and defines coordinates relative to the c.g. referred to as longitudinal, lateral and vertical. The rotor plane does not necessarily align with the xB, yB plane, so for the ith rotor let {xR,i,yR,i,zR,i} denote unit vectors aligned with the plane of the rotor and oriented with respect to the lateral, longitudinal, and vertical directions as shown in Figure 5. Let r be defined as the position vector from the inertial origin to the vehicle center of gravity (c.g.), and let ωB be defined as the angular velocity of the aircraft in the body frame.

4. RESULT ANALYSIS

We saw that the total thrust is subject to change depending on ! is the graph of ! and ! vs. T. The graph illustrates that as the angles ! and ! increase the total thrust also increases. This is because more thrust {Z-axis body frame} is needed to keep the copter airborne. For the purposes of further evaluation we take samples of thrust for angles 30, 45, 60 and 75 (! and !) from is the graph of the mentioned angles vs. magnitude of Tx, Ty, and Tz. We observe that magnitude for the X and Y components increase as the angles increase. However, as expected the magnitude of the Z component of thrust is the same throughout. Brushless motors are often used in quadcopter due to their higher efficiency, reliability and lesser maintenance costs. These motors are rated in Kv (RPM/volt), also known as motor constant. Quadrotor helicopters are popular as testbeds for small UAV development, but their aerodynamics are complex and need to be accurately modeled in order to enable precise trajectory control. Although many good control

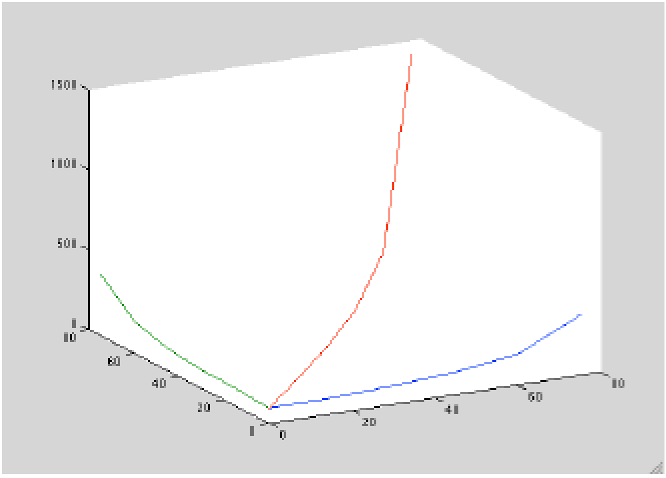

Fig.4.Output Graph

results have been reported in previous work, these have focused primarily on simple trajectories at low velocities, in controlled indoor environments. In this paper, we have addressed a number of issues observed in quadrotor aircraft operating at higher speeds and in the presence of wind disturbances. We have explored the resulting forces and moments applied to the vehicle through these aerodynamic effects and investigated their impact on attitude and altitude control.

CONCLUSION

This paper presents a way to adjust thrust of the rotors via voltage supply to perform standard flight operations and to position the quadcopter into certain angular orientation depending on the circumstances of a particular flight routine. Moreover, it also illustrates the different behaviors of the copter mathematically that might be observed within a rangeset of angles. Total thrust is determined by the user-defined altitude and angles ! and !. Then the ratio of total thrust depending on the angle ratio is used to find the thrust for each independent rotor that is needed to calculate the voltage supply for the required RPM. The solution lays the foundation for further use in control scheme to develop a way to autonomously control the copter for flight stability and precision maneuvering when following a flight path.

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