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APPLICATION OF PI CONTROL STRATEGY ON UNDERACTUATED QUADROTOR

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Abstract— A quad rotor, is also called a quad rotor helicopter or quad rotor, is an aerial vehicle that generates lift with four rotors, which are gaining prominence as Unmanned Aerial Vehicles (UAVs) owing to their simplicity in construction and ease of maintenance. They are being widely developed for applications relating to reconnaissance, security, mapping of terrains and buildings, etc. The control of the quad rotor is a complex problem. It is an unstable system in open loop. The motion in X-Y direction is coupled with pitch and roll. Thus, by developing a closed loop control for maintaining the stability of quad-rotor is essential. As a precursor to developing a model based design, the simulation of the mathematical model of the quad rotor is implemented. This will facilitate easier implementation of the model based design using Matlab Simulink

Index Terms—quad rotor, unmanned aerial vehicle.

I. INTRODUCTION

A quad rotor, is also called a quad rotor helicopter or quad rotor, is an aerial vehicle that generates lift with four rotors. Quad copters are classified as rotorcraft, as opposed to fixed-wing aircraft, because their lift is generated by a set of rotors(vertically oriented propellers).

Quad-rotor helicopters have been an increasingly popular research platform in recent years. Their simple design and relatively low cost make them attractive candidates for swarm operations, a field of ongoing research in the UAV community

Quad copters use two pairs of identical fixed pitched propellers; two clockwise (CW) and two counterclockwise (CCW). By changing the speed of each rotor it is possible to specifically generate a desired total thrust; to locate for the centre of thrust both laterally and longitudinally; and to create a desired total torque, or turning force.

At a small size, quad copters are cheaper and more durable than conventional helicopters due to their mechanical simplicity. Their smaller blades are also advantageous because they possess less kinetic energy, reducing their ability to cause damage. For small-scale quad copters, the vehicles safer for close interaction. It is also possible to fit quad copters with guards that enclose the rotors, further reducing the potential for damage.

However, as size increases, fixed propeller quad copters develop disadvantages over conventional helicopters. Increasing blade size increases their momentum. This means that changes in blade speed take longer, which negatively impacts control.

At the same time, increasing blade size improves efficiency as it takes less energy to generate thrust by moving a large mass of air at a slow speed than by moving a small mass of air at high speed. Therefore, increasing efficiency comes at the cost of control. Helicopters do not experience this problem as increasing the size of the rotor disk does not significantly impact the ability to control blade pitch.

It is an inherently unstable system in the open loop. The motion in x and y directions is coupled with pitch and roll. Thus, developing a closed loop control for maintaining the stability of the quad rotor is essential. The modeling of the system is a precursor to implementing the control strategy.

II. LITERATURE SURVEY

A. Robust Environment for Simulation and Testing of Adaptive Control for Mini-UAV

The overall control architecture consists of an simple onboard controller, a fixed-gain baseline controller, as well as an augmented adaptive controller. This approach primarily addresses the problem of actuator uncertainty, but is also robust with respect to other types of uncertainties.

B. Back stepping and Sliding-mode Techniques Applied to an Indoor Micro Quad rotor

The Sliding-mode controller has to stabilize the system and maintain the roll, pitch and yaw angles to zero. The controller stabilizes well the system for the roll and pitch angles while the shattering effect is present. The big negative overshot in the pitch angle is due to the huge initial condition for the yaw angle. The controller introduced using the sliding-mode approach provides average results. This is partly due to switching nature of the controller which introduces high frequency, low amplitude vibrations causing the sensor to drift. On the other hand, the back stepping controller proves the ability to control the orientation angles in the presence of a relatively high perturbations confirming by the way some previous studies on under actuated systems.

C. MPC with Nonlinear H_∞ Control for Path Tracking of a Quad-Rotor Helicopter

The control structure is performed through a model-based predictive controller (MPC) to track the reference trajectory and a nonlinear H¥ controller to stabilize the rotational movement

III. CONTROLLER

1 PROPORTIONAL CONTROLLER

A proportional control system is a type of linear feedback control system. In the proportional control algorithm, the controller output is proportional to the error signal, which is the difference between the set point and the process variable. In other words, the output of a proportional controller is the multiplication product of the error signal and the proportional gain.

This can be mathematically expressed as

$$P_{out} = k_p e(t) + P_o \qquad (1)$$

Where

P_{out}: Controller with zero error

P_o : Output of proportional controller

K_p : Proportional gain

2. PI CONTROLLER

PI controller will eliminate forced oscillations and steady state error resulting in operation of on-off controller and P controller respectively. However, introducing integral mode has a negative effect on speed of the response and overall stability of the system

Thus, PI controller will not increase the speed of response. It can be expected since PI controller does not have means to predict what will happen with the error in near future. This problem can be solved by introducing derivative mode which has ability to predict what will happen with the error in near future and thus to decrease a reaction time of the controller. PI controllers are very often used in industry, especially when speed of the response is not an issue. A control without D mode is used when:

a) Fast response of the system is not required

b) Large disturbances and noise are present during operation of the process

c) There is only one energy storage in process (capacitive or inductive)

d) There are large transport delays in the system

Parameter	Speed of response	Stability	Accuracy
Increasing K	Increases	deteriorate	Improves
Increasing K_p	Decreases	deteriorate	Improves

IV. QUAD ROTOR MODELING

The quad rotor motion is controlled by varying the rpm of the motors and not by using any mechanical actuators. The craft requires active control of six degrees of freedom to fly.

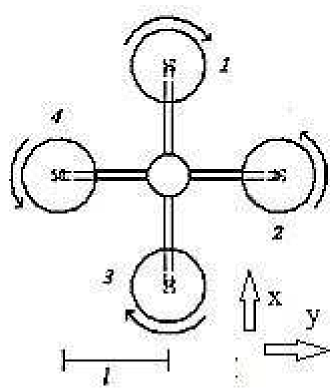

Fig 1: Quad rotor layout topview

It consists of two arms with motors connected to each ends by means of a mechanical shaft. Motor 1 and 3 rotates in clock wise direction and rotors 2 and 4 rotates in counter clock wise direction the motion of these four together cause lift. This type of rotation is provided inorder to prevent torque imbalance.

V. MATHEMATICAL MODEL

The mathematical model of the quad rotor is given by,

$$\dot{x}_2 = (\cos x7 \sin x9 \cos x11 + \sin x7 \sin x11)\frac{U1}{m}$$
$$\dot{x}_4 = (\cos x7 \sin x9 \sin x11 - \sin x7 \cos x11)\frac{U1}{m}$$
$$\dot{x}_6 = -g + (\cos x7 \cos x9)\frac{U1}{m}$$
$$\dot{x}_8 = x_{10}x_{12}\left(\frac{I_{yy} - I_{zz}}{I_{xx}}\right) + \frac{J_r}{I_{xx}}\Omega_d x_{10} + \frac{1}{I_{xx}}U_2$$
$$\dot{x}_{10} = x_8 x_{12}\left(\frac{I_{zz} - I_{xx}}{I_{yy}}\right) - \frac{J_r}{I_{yy}}\Omega_d x_8 + \frac{1}{I_{yy}}U_3$$
$$\dot{x}_{12} = x_{10}x_8\left(\frac{I_{xx} - I_{yy}}{I_{zz}}\right) + \frac{1}{I_{zz}}U_4$$

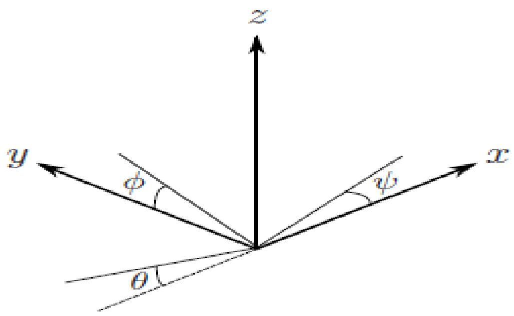

Fig 2: The inertial of a quadcopter

VI. CONTROLLER BLOCK

This block is used to compare the reference values of the rotational parameters - roll, pitch and yaw - and the translational parameter, z, with the actual values obtained as feedback from the quad rotor's mathematical model. The error obtained from the comparison is given to a PID control block which performs the control action and the necessary control signals are generated. Four PID controllers control the parameters of the system. The outputs from this block are

$$\frac{U_1(s)}{e_{alt}} = K_{p_{alt}} + K_{i_{alt}}\frac{1}{s}$$
$$\frac{U_2(s)}{e_{roll}} = K_{p_{roll}} + K_{i_{roll}}\frac{1}{s}$$
$$\frac{U_3(s)}{e_{pitch}} = K_{p_{pitch}} + K_{i_{pitch}}\frac{1}{s}$$
$$\frac{U_4(s)}{e_{yaw}} = K_{p_{yaw}} + K_{i_{yaw}}\frac{1}{s}$$

u1=actuation signal from altitude controller
u2=actuation signal from roll controller
u3=actuation signal from pitch controller
u4=actuation signal from yaw controller

V.SIMULATION RESULTS

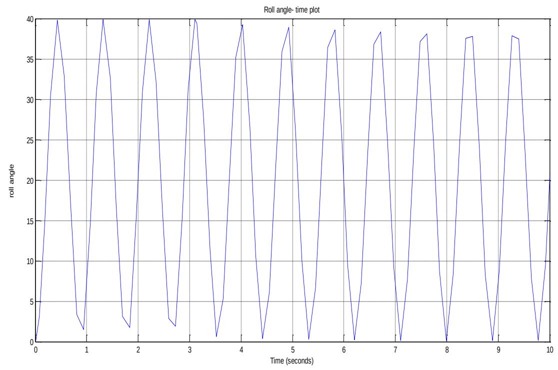

Fig 3: Variation of roll angle with time without controller

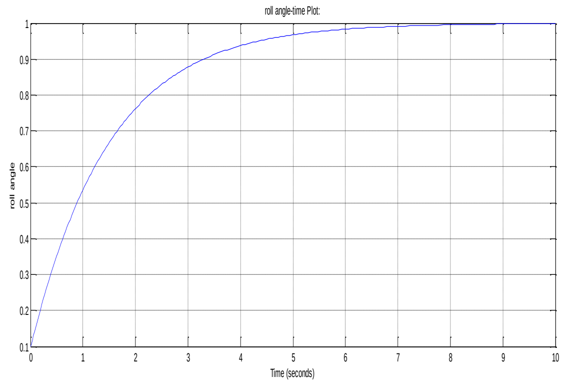

Fig 4: Variation of roll angle with time with controller

VII. CONCLUSIONS

Here we considers the modelling and simulation of underactuated quad-rotor using PIcontroller. The simulation results prove the ability of the control system to stabilize the quad-rotor,. Future works involves the comparison of various control algorithms for quad rotor control and conversion of the simulation to a control system to be used on the actual flying quad rotor.

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