QUADROTOR TRAJECTORY TRACKING USING NONLINEAR MODEL PREDICTIVE CONTROLLER WITH OBSTACLE AVOIDANCE

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College ***:*** *Manipal Institute of Technology, Manipal*
Branch ***:*** *Aerospace Engineering*
Guide(s) ***:*** *Dr. Shreesha Chokkadi*
Dr. Thirunavukkarasu Indiran
Student(s) ***:*** *Ms. Sonu N*

Keywords:

Hexsoon Edu 450 Quadrotor, Trajectory tracking, Moment of Inertia, Particle swarm optimization, Nonlinear Model Predictive Controller, Active Disturbance Rejection Controller, Obstacle avoidance.

Introduction:

The Quadrotors are being used widely for past few years for various applications such as surveying, Mapping, Agriculture, Surveillance etc. It is also grabbing an attention of most of the researchers when compared to any other type of aerial vehicles. Among all the applications mentioned above one of the major issues is the trajectory tracking. In order to overcome the trajectory tracking problem a Nonlinear model predictive controller is developed. Along with this it is important that the quadrotor should follow the path with any collision with the external structure, so to obtain the collision free trajectory tracking the obstacle avoidance algorithm is developed. In most of the researches carried out earlier the NMPC algorithm is generated using the Robot operating system or any automatic code generation toolkits available in the MATLAB. Then the performance of the developed algorithm is mostly analysed by conducting only the simulation experiments whereas in our work the developed NMPC algorithm is analysed using both the simulation and real time experiments. Also, for the collision free trajectory tracking we are implementing the RPLiDAR A1M8 360 Degree Laser Range Finder sensor along with Raspberry Pi 3/4 camera to detect and avoid the obstacle while moving in the particular trajectory. Since the NMPC possess highly computational load Jatson nano computational unit is used along with the Pixhawk flight controller to obtain the good and the faster response for the real time performance of the quadrotor which very rarely is previous research works. To obtain the fast and better response under the effect of wind disturbance an Active disturbance rejection controller is combined along with Nonlinear model predictive controller to reject the disturbance and give the better performance. The developed controller is analysed using both simulation and real time experiment.

Objectives:

First objective of this project work is to estimate the parameters of Hexsoon Edu450 quadrotor using first principle method. Second objective is to develop the Nonlinear model predictive controller (NMPC) for trajectory tracking of Hexsoon Edu450 quadrotor. Then simulation is carried to check the effectiveness of the developed controller using the rectangular trajectory as reference. Third objective is to develop the obstacle avoidance algorithm along with NMPC to obtain the collision free path while tracking the trajectory, then simulation is conducted by considering the point and solid obstacles. Finally, the real time experiment is conducted by implementing the developed algorithm into Pixhawk flight controller by interfacing the RPLiDAR A1M8 360 Degree Laser Range Finder sensor along Raspberry Pi 3/4 camera with Hexsoon Edu450 quadrotor to detect and avoid the obstacle while following the trajectory.

Methodology:

Initially, the mathematical model for Hexsoon Edu450 quadrotor is derived using Newton-Euler formulas. Then parameters of the quadrotor are estimated using first principle method. Since of the parameters like moment of inertia, coefficients of thrust and drag cannot found directly, therefore these parameters are estimated using some of the techniques or test beds. The Fig 1a, Fig 1b and Fig 1c shows the images captured at lab of chemical department of Manipal institute of technology while weighing the quadrotor and its components.

Fig 1a: Weighing quadrotor

Fig 1b: Weighing motor

Fig 1c: Weighing landing gear

To find the coefficients of thrust and drag the subsonic wind tunnel test is conducted at NITK, Surathkal which are shown in Fig 2a and Fig 2b.

Fig 2a: Subsonic wind tunnel

Fig 2b: Hexsoon Edu450 quadrotor in wind tunnel

To estimate the moment of inertia of quadrotor the pendulum model method is used and procedure carried out for the same are shown in Fig 3a and Fig 3b.

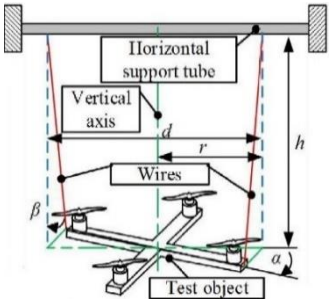

Fig 3a: Pendulum model

Fig 3b: Estimating Moment of

To validate the obtained parameters an open loop flight test is conducted, then using the I/O data obtained from flight test is used to estimate the parameters of quadrotor using data driven method. Using the mathematical model and parameters of Hexsoon Edu450 quadrotor NMPC algorithm is developed for trajectory tracking along with obstacle avoidance algorithm to obtain collision free path and Active disturbance rejection controller (ADRC) to reject the disturbance and give the better response. Simulation is conducted to validate the effectiveness developed algorithm. Then to validate the real time performance the developed controller algorithm is dumped into Pixhawk flight controller, since the NMPC possess highly computational load therefore Jetson nano computational unit is used along with Pixhawk to obtain the faster response. To detect the obstacle and avoid collision RPLiDAR A1M8 360 Degree Laser Range Finder sensor along Raspberry Pi 3/4 camera is interfaced with Hexsoon Edu450 quadrotor.

Components purchased from KSCST fund are shown in Fig 5a and Fig 5b

Fig 5a: RPLIDAR A1M8 360degree laser finder

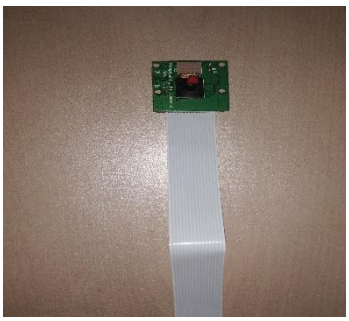

Fig 5b: IR-Cut Camera for Raspberry Pi

Results and Conclusion:

Simulation experiment is conducted to validate the effectiveness of the developed Nonlinear Model predictive controller with obstacle avoidance algorithm along with Active disturbance rejection controller. Experiment is carried out by considering the rectangular trajectory as the reference. Results of NMPC algorithm for trajectory tracking is shown in Fig 6a and Fig 6b.

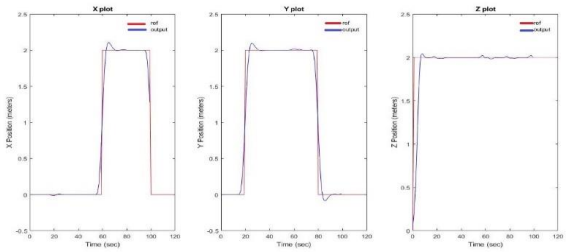

Fig 6a: x, y and z plot of Rectangular trajectory tracking using NMPC

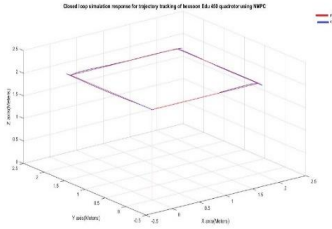

Fig 6b: 3D view of Rectangular trajectory tracking using NMPC

Then to avoid the disturbance and obtain better response ADRC is developed along with NMPC. Simulation results for same are shown in Fig 7a and Fig 7b.

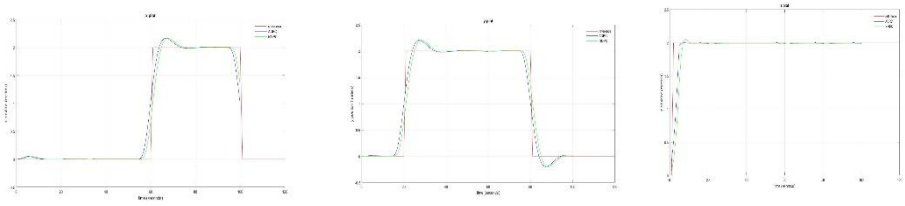

Fig 7a: x, y and z plot of Rectangular trajectory tracking using ADRC

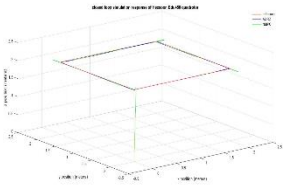

Fig 7b: 3D view of Rectangular trajectory tracking using ADRC

Error between NMPC and ADRC is analysed using mean square error and root mean square error plot and same are shown in Fig 8a and Fig 8b.

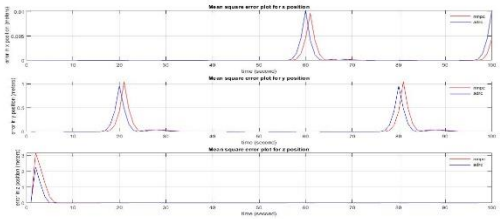

Fig 8a: Mean Square error plot

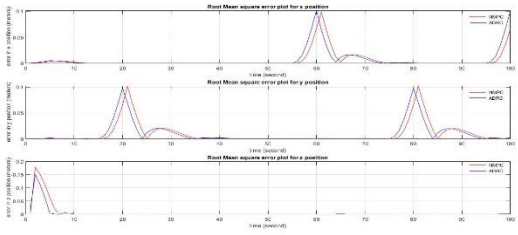

Fig 8b: Root Mean Square error plot

The obstacle avoidance algorithm is validated by creating single, multiple point and cylindrical obstacle in the reference trajectory. Results for same are from Fig 9a to Fig 9c.

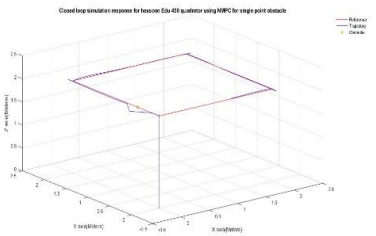

Fig 9a: Trajectory tracking with obstacle avoidance for single point obstacle

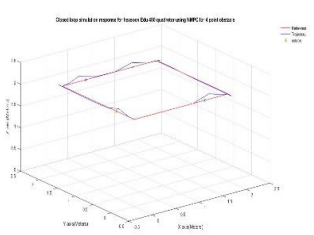

Fig 9a: Trajectory tracking with obstacle avoidance for multiple points obstacle

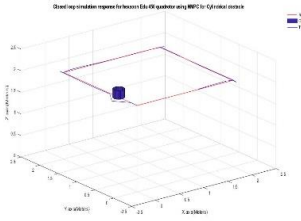

Fig 9a: Trajectory tracking with obstacle avoidance for cylindrical obstacle

From above results it can be concluded that the developed NMPC controller with obstacle avoidance algorithm and ADRC method accurately tracks the given rectangular trajectory by successfully avoiding the obstacles along the trajectory by rejecting the wind disturbance effect on the quadrotor and gives better and faster response.

Scope for future work:

Implementing the developed controller algorithm into the pixhawk flight controller of Hexsoon Edu450 quadrotor so that it can be used for various applications such as medical, agriculture, mapping, surveying etc. Different applications require some different technologies to be incorporated like trajectory tracking, obstacle avoidance, disturbance rejection etc. Trajectory tracking with obstacle avoidance algorithm is one of the most important objectives for the quadrotors used in the medical applications, surveying/inspection, agriculture. It is important that the quadrotor should follow the trajectory without collision or causing damage to the system or any surfaces, therefore it is important to incorporate obstacle avoidance algorithm in quadrotor. Quadrotors can be used to deliver the medicines to the hill stations or to any isolated places, along it can also deliver medicines faster to areas with high traffics when compared to any kind of road transport. While performing these operations it is important that the quadrotor does not colloid with birds, buildings or to any surfaces, therefore it is important to have the obstacle avoidance technology with trajectory tracking for quadrotors. Also, quadrotors are used for inspection of pipes used in the oil refiners in such cases obstacle avoidance plays very important role to avoid collision. Nowadays quadrotors are also used for photography which also requires obstacle avoidance technology for proper path following. Trajectory tracking with obstacle avoidance technology can be used for any other kind of unmanned vehicle to perform the various operations.