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Flight Simulation and Control of a Quadrotor based on MATLAB/Simulink

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Abstract

Nowadays anyone can fly Unmanned Aerial Vehicle (UAV) and land it according to the specified instructions drafted by the manufacturer. However, the controlling phase is growing day by day as one of the crucial roles of UAV. Obtaining control for autonomous landing is the crucial and critical step. So based on various literature surveys and centering into Industry 4.0, this proposed work deals with image flight simulation and control of Quadrotor, which is an important field of Industry 4.0 in future production and business power. This research is eyed on Quadrotor, a type of flying vehicle with four rotor blades wherein the opposite pairs rotate in alternate direction, which is very useful for vertical take-off and landing. The Quadrotor is created by using CATIA software which is best suited for modelling and developing real time application. The model is extracted in MATLAB/SIMULINK in which a variety of blocks are available under the set of control and aerospace blocks. Then, a suitable simulation environment and controller are made. The advantage of making this proposed work in MATLAB is that it has the features of testing, controlling, and maintaining various operations without equipping any mechanical components, and there is no risk for property or lives.

Keywords: Quad, Quadrotor, Control, Model, MATLAB, SIMULINK

1. Introduction

Drone industry is booming in recent century and this will continue. The advantages and applications of drones are numerous and some of them are surveillance, weaponry, delivery of goods and armaments, etc. Nowadays anything can be developed in prototype before the model is developed and analyzed with suitable software, especially those that are

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designed open and using high cost software. The drones are designed in software like AutoCAD, SOLIDWORKS, CATIA, etc. This developing and analyzing cost is much more lesser than the rapid prototype generation and building it with appropriate and ideal instruments for better controllability and switchability of drones with AI interface, and if needed, autonomous comes into action.

Drones are also called as Unmanned Aerial Vehicle (UAV). Drones are pilotless; hence, these unmanned vehicles are capable of producing a variety of opportunities in defense sectors, for any personalized location. A Quadrotor also called a quadrotor helicopter or quadcopter, is a multicopter which is lifted and propelled by four rotors. When physically developed, these Quads are more reliable, highly compact with low maintenance, etc. Therefore in this proposed work, Quadrotor is developed in design software CATIA and is imported in MATLAB/SIMULINK, and various performance parameters are analysed.

The quadrotor consists of Frame, Motors, Electronic speed controller, Transmitter, Propeller, Battery, Receiver, Flight controller, etc. This proposed work concentrates on the controls, which is the very crucial part in the entire flight operation. Various types of controls used for the quadrotor type are Proportional controller, Proportional Integral controller, Backstepping controller, Fuzzy controller, etc. The Backstepping and Fuzzy controller are the combination of one or more controllers used for stabilization. The main of objective of this proposed work is to develop a mathematical model and flight simulation of a Quadrotor in MATLAB / Simulink, to implement Quadrotor non-linear dynamics and kinematics using MATLAB functions, and to design controllers (PD, PID, etc.) to control the attitude of Quadrotor. In future, it can be developed as a prototype from the results obtained, and be used for various applications like in agriculture, construction, defense, etc.

2. Related Work

In the paper of modelling and simulation of quadrotor, Kose O et al., [1] created a 4 rotor Unmanned Aerial Vehicle's (UAV's) mathematical model of wind disturbances affecting UAV during flight, and added simulation to the space model. A control system was designed and evaluations were done. PID control algorithm was used for the control aspects. Then, UAV modelling was done in Solidworks, simulations in Simulink and achieved successful control of dynamic model in both noise and noiseless environment. Designing of UAV yaw angle using fuzzy controller was proposed by Ning W et al., [2], which focused in Reconnaissance application, and established non-linear dynamic model of Quadrotor UAV. A

variable domain Fuzzy PID controller was used for controlling the vehicle. The result produced was advantageous over traditional PID, based on the dynamic property, steady state errors index, and improved quality of adjustment of yaw angle. Therefore the work was very useful in shortening the yaw angle adjustment time by 64% in UAV reconnaissance mission, and future enhancements can be made far more better by making their work as reference.

In quadrotor modelling and control proposed by Naidoo Y et al., [3] investigation of modelling and control of a Quadrotor helicopter were done. It consists of 2 pairs of counter rotating rotors situated at the ends, which are symmetric about center of gravity. Then modelling was done by momentum theory and blade element theory to determine extended payload capacity and lift performance of rotorcraft. The control strategy was developed using linear PID controller and Numerical simulation was performed in MATLAB/Simulink. The investigation mainly focussed on the behavior of rotorcraft and in determining effectiveness of implemented control system.

A Design and simulation of quadrotor using hybrid control system was proposed by Shen X et al., [4] where hybrid control system was enabled with backstepping and PID controller. The switching controller type was opted based on the respected angles of altitude and attitude. By establishing the various test like reliability, stability, etc. via the hybrid control system, the result obtained was much satisfied. The stabilized control of eight rotor UAV in complex environment was improved by verifying the result.

The modelling and simulation of quadrotor was done in [5], in which dynamic model, controllers and trajectory planners were implemented in MATLAB / Simulink. VR Simulation model of Quadcopter was created using 3D World editor in MATLB. Mathematical model of quadcopter was done with reference to earth inertial frame and body fixed frame. Optimal controllers used for attitude stabilization were Feedback Linearization controller and Linear Quadratic Regulator control. Then, trajectory planning was done using image processing.

The simulation and controller's actual performance was analysed by Sattar M et al., [6]. The adaptive fuzzy controller was developed, analyzed and compared with PID and fuzzy PID. The detailed simulation model of quadrotor was also studied. In order to avoid the physical damage, mathematical model of Quadrotor was made, and various strategies of control parameters namely roll, pitch, and yaw were studied. The proposed adaptive fuzzy controller was found to be best suited. Trajectory planning using sliding mode control was

proposed by Xiao J [7], where the trajectory planning of under-actuated quadcopter UAV was designed. Two control models, the inner model and outer model were made, so as to get rid of complex tasking of quick manoeuvre ability. This control was presented with high results of robustness and better performance than traditional controllers.

Feedback control of Quadrotor by Armah S et al., [8] signified that precise regulation of position and control is one of the most vulnerable tasks when designing any UAV. The quad simulation was processed using PD feedback control for achieving stabilization. The models were used to design and analyze the simulation results using various dedicated control algorithms. The simulation results were presented graphically for more visualization results. The MATLAB GUI interface was more easy to implement the different control algorithms using various parameters and conditions.

3. Proposed Work

MATLAB is a modern programming language environment, that has sophisticated data structures, contains built-in editing and debugging tools, and supports object-oriented programming. These factors make MATLAB an excellent tool for teaching and research. Therefore, MATLAB/SIMULINK is used for controlling and getting satisfactory results.

Firstly, the model of Quad is designed in designing software (CATIA). Every parts of the Quad such as rotor, motor, telemetry, propeller, battery, etc. are modelled using CATIA software. CATIA is the world's one of the best engineering and design software for product 3D design excellence. It is used to design the manufacture product in a variety of industries including aerospace, automotive, consumer goods and industrial machinery. Some of the design of Quad parts are Slide Entry case, Rotor case, Propeller etc.

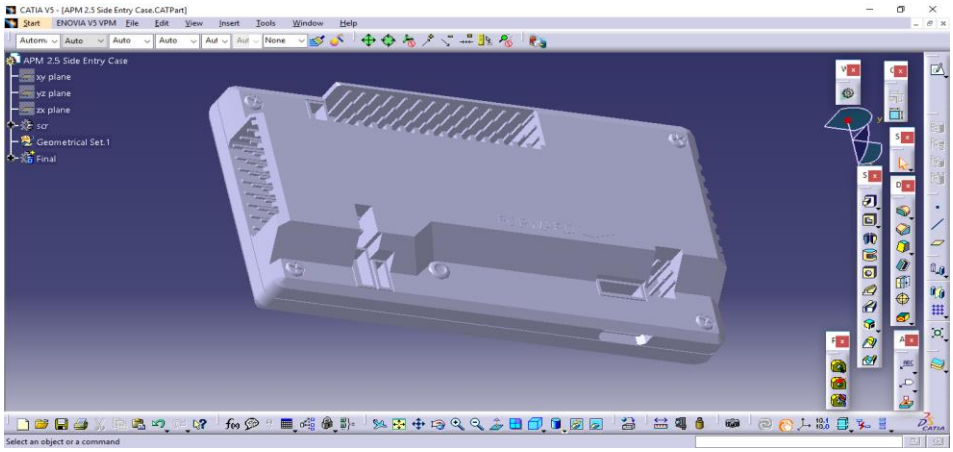

Figure 1. Slide Entry case

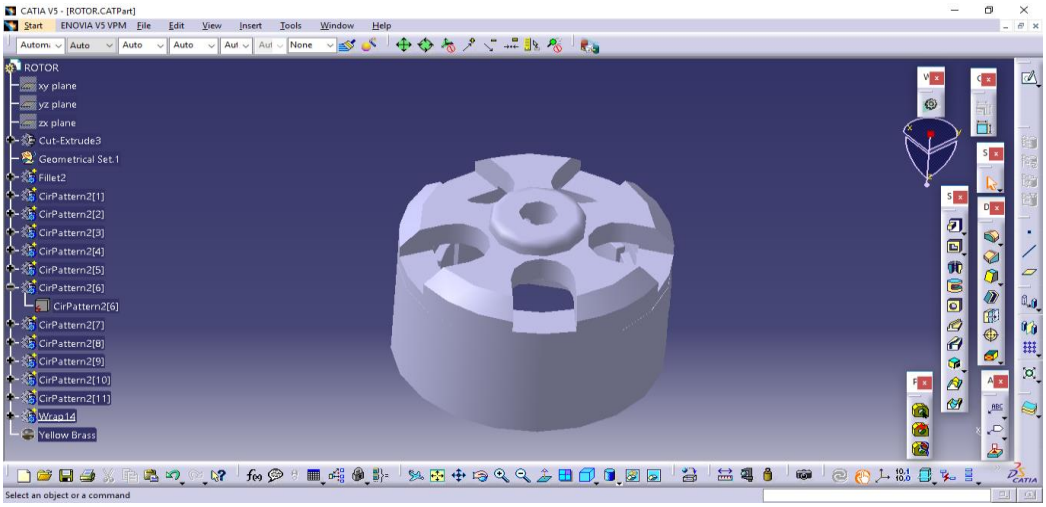

Figure 2. Rotor casing

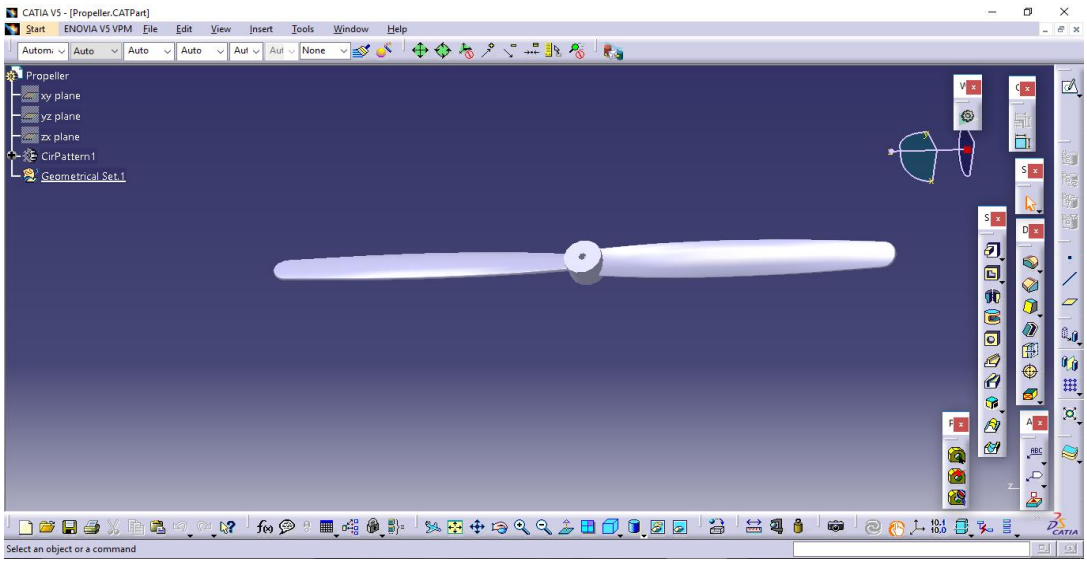

Figure 3. Propeller

The above figures show some of the parts necessary for the quad modelling in CATIA software. The parts are designed and assembled as a whole Quad which is shown in results section. Figure 1 is the slide entry case which is used to mount the Quadrotor on frame. Figure 2 shows the rotor casing in which the rotor is placed inside the casing to avoid damage when there is a collision. Figure 3 shows the propeller which is very useful for the propelling of the Quad in the sky.

A simulation is the imitation of the operation of a real-world process or system over time. Simulations require the use of models; the model represents the key characteristics or behaviors of the selected system or process, whereas the simulation represents the evolution of the model over time. The simulation in this study is used for the following:

- Evaluate a new design.
- Diagnose problems with existing problems.
- Helps in predicting the behavior.
- Test a system under conditions that are hard to reproduce.
- Easy to use.
- Easy to implement.

For simulations the MATLAB / SIMULINK is used for the import of CATIA model and control for better simulation environment. After creating Simulink blocks in SIMULINK, the simulation environment is created.

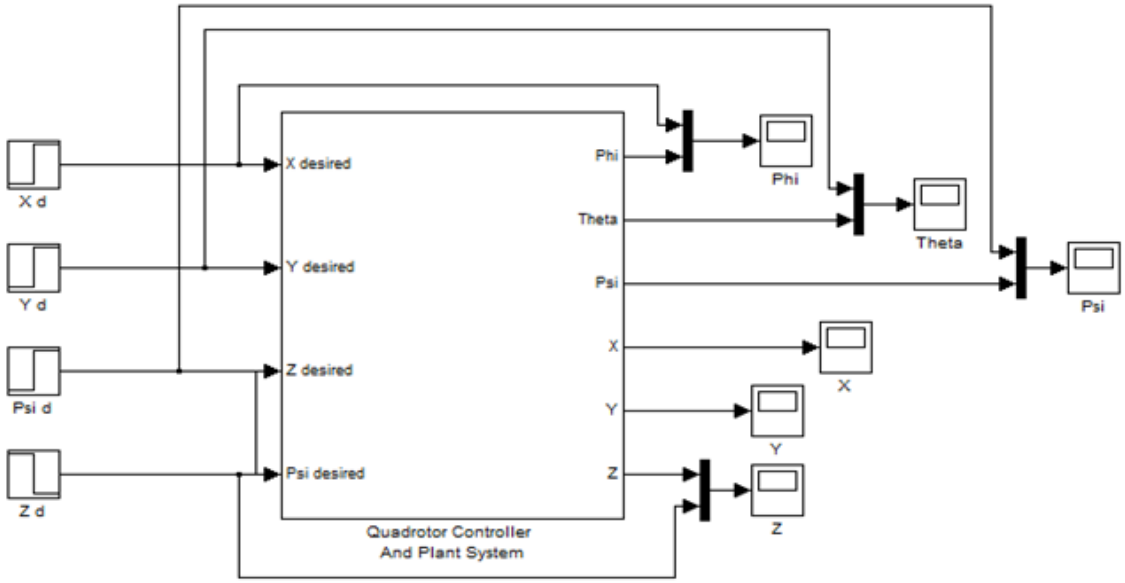

Figure 4. Simulation block

Figure 5. Simulation environment

Figure 4 shows the simulation block for the environment by which the simulated environment is created. The blocks are available in SIMULINK for creating such

environment. Figure 5 shows the simulation environment which is the result of the simulation block created previously. After making the model and simulation, the control part is designed so as to understand which control system is best suited for this proposed Quad design and model.

4. Results and Discussion

As previously discussed, the model is designed using the designing software (i.e., CATIA) and then the simulation environment is created in MATLAB. Later suitable control system is designed for the proposed quad model. The final product of CATIA model and Simulink environment is shown below:

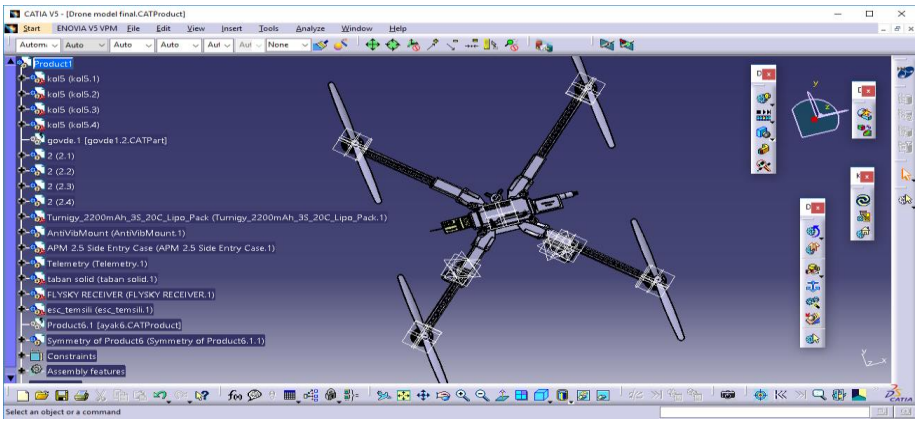

Figure 6. Final quadrotor model (a)

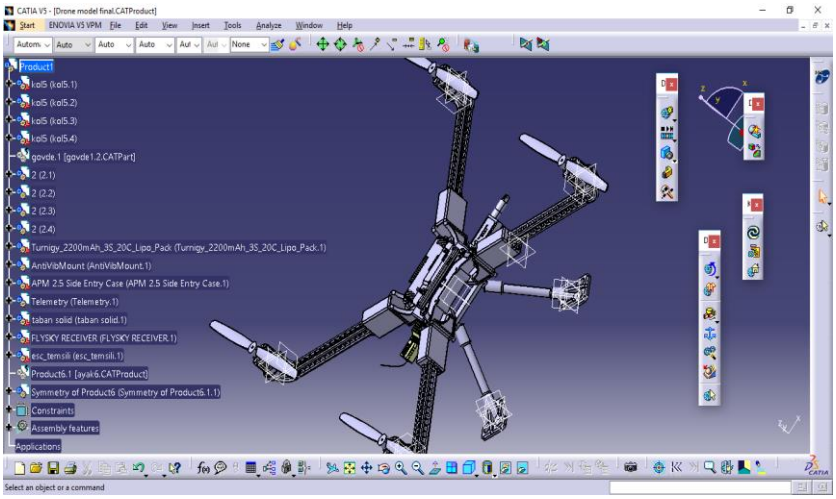

Figure 7. Final quadrotor model (b)

Figure 6 and Figure 7 show the Quadrotor which is created and assembled in the CATIA designing software. Then the model is exported to MATLAB and the control is made in the given simulated environment.

Figure 8. Simulation environment with Quad

Figure 8 shows the Quadrotor in the simulated environment. The simulation result is much satisfiable for which the fusion controller would be developed in future so that highly stabilized control of Quadrotor is achieved.

5. Conclusion

The simulation environment and CATIA designed models for stabilized quad controlling have been illustrated in this research. This paper includes various literature reviews, and by keeping those as references, the proposed work has been modelled. This study fills the gap between the Solidworks and CATIA drawings that can be imported in MATLAB/SIMULINK for various analysis. The work involves the importing of the CATIA designed Quad model in MATLAB and simulating it with the created simulation environment and designed control for better results of controlling aspects. The PID controller used in this project is found to be best suited and has produced more satisfiable result. In future, it would be equipped with advanced smart controller for the easy controlling of Quadrotor and would be analysed with traditional controllers. The future work will be equipping the real time model of quadrotors and the testing will be done for various aspects of control. It will also utilize the PID and PID hybrid controller, so that in real time it would serve with better results in every aspects of defense industry.

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