Design of Controller for UAV

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A B S T R A C T

An efficient method for velocity control of a one after the other excited DC motor (SEDC) via the usage of fuzzy good judgment controller (FLC) in a MATLAB environment and has proved to be a fruitful over conventional strategies. The controller design is fully based on the expert understanding of the device taken below the attention. For the proposed SEDC motor case, nine fuzzy regulations are designed for a fuzzy logiccontroller with inputs i.e. pace errors and change in pace error between the reference and real speeds. The motor is being modelled and taken to a subsystem in SIMULINK. The PID parameters are being tested withMATLAB/SIMULINK and are directly been applied to the transfer feature of the motor. The performance of the SEDC motor is being judged with the aid of the extraordinary varieties of controllers (PID and FUZZY logic) and it's been determined that the FLC plays the first-rate in overshoot, settling time and steady country error.

Keywords: controller, SIMULINK, PID

1. Introduction

A quad-rotor or quad-copter may be described as a "multi-rotor copter with four hands, every of which have a motor and apropeller at their ends".
UAVs are categorized relying upon kind of wings.
UAV Classifications
Quad-rotor lies inside the class of Rotary wing class of UAVsthey're generally used within thepackages that requiredhovering flights along with seek and rescue operations, security,journalism, emergency response and in military packages.
Quad-rotors have many blessings over traditional helicopters together with

a) Quad-rotors have Small sizes

b) They're secure to use for civilians because of small rotor.

c) Less complicated mechanical shape

d) They're very easy to preserve

e) Because of their manoeuvrability, they're more secure hazardous situations.

1.1 Applications Of Quadrotor

Quad-rotors are widely used in variety of applications some of the uses includes are

- Images: Quad-rotors are utilized in covering wedding occasions as well as they've brilliantfunction in real property pictures.
- Seek/Rescue: As quad-rotors can effectively fly low, are able to getentry to tough regions andcan easily provide aerial perspectives they're getting used for search/rescue missions.
- Exploring Lava Lakes: Temperature may be very high near lavalakes so for the cause ofhigher predictions of eruptions in volcanoes and also testing the fabric present in andout of the lava lakes drones are used by researchers to get the desired statistics.

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- Surveillance: Quad-rotors are small and pretty that's why are these days utilized in anti-poaching efforts, building protection, borderpatrolling, jail surveillance, trackingcrowded protests, sitemonitoring, and for police and personal investigations
- Creation: In recent years many agencies are the use of quad-rotorto seize the aerialview of production web sites and utilising that inside the 3-d demonstrating achieved.
- Sports activities/information: As quad-rotors are much cheaper to perform, enormously manoeuvrable and ableto get in the direction of themotion they've extensive use in sports activities and news....
- Mining: In mining industries, engineers in shape quad-rotors with special gadget to be able tolook for minerals. they're extensively utilized to check out power lines and after blast areas.
- Agriculture: Quad-rotors also are used in agriculture majority for the purpose ofspraying.
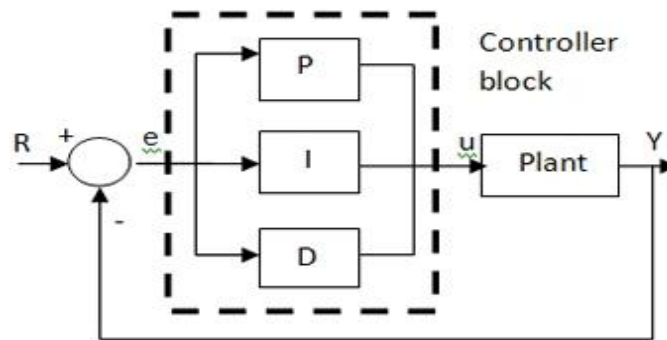
1.2 Controllers
For the QUADROTOR model presented above for each input separate controller is designed.This presents controller design techniques.
1.2.1 Basics of PID CONTROLLER
A PID controller has three terms a proportional, Integral and Derivative. PID is used in automatic control. Now a days electrical devices are using PID control either in the form of stand alone or in functional blocks.
1.2.2 PI CONTROLLER
PI controller combines both the characteristics of both proportional and integral controller. Main advantage of using a PI controller is to eliminate the

steady state error completely. PI controller is only used in the systems where the speed is not only an issue. Implementation of PI controller is shown below.
Figure-1.1 PI controller model
1.2.3 PD CONTROLLER
PD controller is the combination ofProportional and Derivative controller. The maximum distinguishcharacteristic of PD controller is balance as it may predict the errors. Introducing the derivate part withproportional can lessen overshoots and settling time because the result of that gadget is a lot quicker.
1.2.4 PID CONTROLLER
PID controller is used widely in all the applications. Advantages of using PID controller are that it eliminates steady state error, settling time and improves stability. Mathematically equation of PID can be shown.
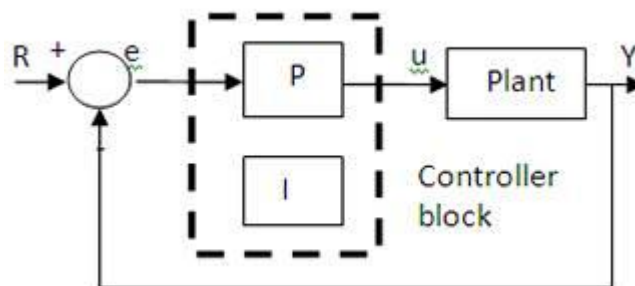

FIGURE 1.2 PID CONTROLLER MODEL

1.2.5 FUZZY LOGIC CONTROLLER
I.   FUZZY LOGIC BASISCS
In 1965 Lotfi Zadeh evolved fuzzy logic mathematical device to address uncertainty.
Fuzzy common sense is based totally on if then linguist regulations which might be clean to define as an instance variable t isrepresented as temperature in fan based totally cooling system the fan should begin operating on the t>25C.

So a linguist value of hot is assigned to t>25. Fuzzy based totally systems helps to explain thetroubles which can be sick described in lots simpler way are The reasons of using fuzzy logic are as follows

a) When you have right information of the machine underneath attention Fuzzy Controllers area lot simpler to implement in comparison to the conventional controller.

b) Fuzzy common sense based controller are more study.

c) For the nonlinear structures which includes a Quad-rotor fuzzy logic can offer more appropriatecontrol

Fuzzy good judgment has kind of applications that are stated below.

a) In Aerospace industry it is used for altitude and mind-set manipulate of aircrafts and satellites.

b) Washing machines, Air conditioners and different electronic home equipment.

c) In chemical enterprise it has vide software for PH manipulate and chemical distillationmanner.

d) Fuzzy good judgment is likewise utilized for digital photograph processing and photo stabilization.

e) Synthetic intelligence in modern video games is also the use of Fuzzy logic Controller.

f) In enterprise individual use fuzzy common sense for the help of decision making and privateassessment.

g) Some other major application of fuzzy common sense is the estimation of minerals.

II. KEY COMPONENTS OF A FLC

Fuzzy Logic Controller is divided into five main components

1. Defining inputs.
2. Fuzzification.
3. Fuzzy rules.
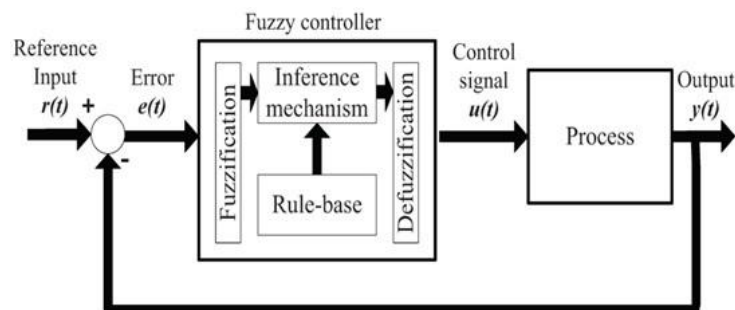4. Defuzzification.
5. Defining output.

Figure-1.3 Fuzzy system base model

III. INPUT VARIABLES

In most of the systems enter variable is the favoured value we need to get from the device beneathattention. Fuzzy good judgment controller worked as a human expert.

In maximum of the structures twoinput variable are described which might be error and exchange in error.Error input usually tells us aboutthe mistake we have become from our device whereas change in Errors is the difference among thefavoured cost and the value of the system.

All of this calls for a deep information of the machineif a few records is missing one ought to put in force every other sensor or method to get theinformation.

IV. FUZZIFICATION

FUZZIFICATION is divided into two parts

A) Membership functions derivation for both inputs and outputs.

B) Linguistic variable representation

V. FUZZY RULES

The most of the critical and most important part of fuzzy logic based control system is to define IF THEN rules. IF part usually represents an event and THEN part is the action against that event.

The overall efficiency of the system depends upon the how well the rules are defined.

Table-1.1 Fuzzy rules comparisontable

| INPUTS	LOW	MEDIUM	HIGH
LOW	FAST	MEDIUM	MEDIUM
MEDIUM	FAST	SLOW	SLOW
HIGH	MEDIUM	SLOW	SLOW

VI.   DEFUZZIFICATION

The results of fuzzy cannot be used to for the system application so in order to process the fuzzy data must be converted to data. There are many methods for DEFUZZIFICATION the most used method is known as CENTROID METHOD.

VII.   ADVANTAGES OF FUZZY LOGIC

- Fuzzy common sense offers smooth computation.
- FLC is considered to be most bendy controller.

Fuzzy based systems are can learn without problems so can be utilized in adaptive packages.

- FLC provides the maximum simplest and handy consumer interface.
- Due to FLC flexibility any quantity of inputs and outputs can be processed and generated.
- Due to its robustness it's far constantly noise unfastened.
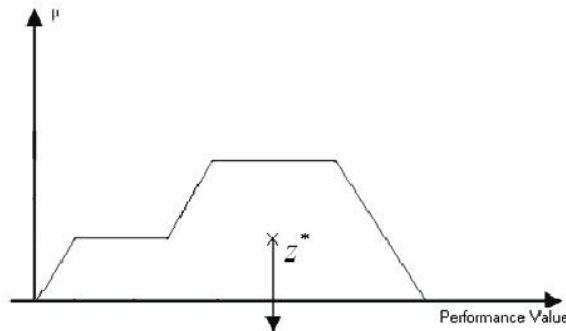
1.1   MATLAB

Is a proprietary multi-paradigm programing language and numeric computing environment developed byMathWorks. Matlaballows matrix manipulations, plotting of functions and data, implementation of algorithms, creation of user interfaces, and interfacing with programs written in other languages. Although MATLAB is intended primarily for numeric computing, an optional toolbox uses the Mu PAD symbolic engine allowing access to symbolic computing abilities. An additional package, Simulink, adds graphical multi-domain simulation and model-based design for dynamic and embedded systems.

The first early version of MATLAB was completed in the last 1970s. The software was disclosed to the public for the first time in February 1979 at the Naval Postgraduate School in California. Early versions of MATLAB were simple matrix calculators with 71 pre-built functions. At the time, MATLAB was distributed for free to universities. Matlab would leave copies at universities he visited and the software developed a strong following in the math departments of university campuses. In the 1980s, Cleve Moler met John N. Little. They decided to reprogram MATLAB in C and market it for the IBM desktops that were replacing mainframe computers at the time. John Little and the programmer Steve Bangert re-programmed MATLAB in C, created the MATLAB programming language, and developed features for toolboxes. Some especially large changes to the software were made with version in 2008. The user interface was reworked and Simulink's functionality was expanded. By 2016, MATLAB had introduced several technical and user interface improvements; including the MATLAB live edition notebook, and other features.

SYNTAX - The MATLAB application is built around the MATLAB programming language. Common usage of the MATLAB application involves using the "Common Window" as an interactive mathematical shell or executing text files containing MATLAB code.

VARIABLES - Variables are defined using the assignments operator, =.

MATLAB is a weakly typed programming language because types are implicitly converted. It is an inferred typed language because variables can be assigned without declaring their types, except if they are to be treated as symbolic objects, and that their type can change. Values can come from constants, from computation involving values of other variables, or from the output of a function.

1.2   MATLAB/SIMULINK

Simulink is a Matlab-based graphical programming environment for modeling, simulating and analyzing multi domain dynamical system. Its primary interface is a graphical block diagraming tool and a customizable set of block libraries. It offers tight integration with the rest of the Matlab environment and can either drive Matlab or be scripted from it. Simulink is widely used in automatic control and digital signal processing for multi domain simulation and model-based design. MathWorks and other third-party hardware and software products can be used with Simulink. For example, state flow extends Simulink for design environment for developing state machines and flowcharts. MathWorks claims that, coupled with another of their products, Simulink can automatically generate C source code for real-time implementations of systems. As the efficiency and flexibility of the code improves, this is becoming more widely adopted for production system, in addition to being a tool for embedded system design work because of its flexibility and capacity for quick iteration. Embedded coder creates code efficient enough for use in embedded systems.

Simulink's real-time (formally known as xPC target), together with x86-based real-time systems, is an environment for simulating and testing Simulink and State flow models in real-time on the physical system. Another MathWorks product also supports specific embedded targets. When used with other generic products, Simulink and state flow can automatically generate synthesized VHDL and Verilog.

Simulink verification and validation enables systematic verification and validation of models through modeling style checking, requirements traceability and model coverage analysis. Simulink Design verifier uses formal methods to identify design errors like integer over flow, division by zero and dead logic, and generates test case scenarios for model checking within the Simulink environment.

Sim Events is used to add library of graphical buildings blocks for modeling queuing systems to the Simulink environment, and to add an event-based simulation engine to the time-based simulation engine in Simulink. Therefore, in Simulink any type of simulation can be done and the model can be simulated at any point in this environment.

Different type of blocks can be accessed using the Simulink library browser. And therefore, the benefit could be taken out from this environment efficiently.

1.5 OBJECTIVE

- Design and analysis of Fuzzy Logic Controller for UAV QUADROTOR.
- Development of longitudinal control using PID control and FUZZY inference system.

1.6 METHODOLOGY

- Design of longitudinal fuzzy controller using MATLAB/SIMULINK.

2. Literature Review

Rekhakushwah, (IJETT-2013) demonstrates the importance of a fuzzy logic controller over conventional method .There is 9 fuzzy rules designed for fuzzy logic controller. The output response of the system is obtained by using two types of controllers, namely, PID and fuzzy logic controller. The result shows that the fuzzy logic approach has minimum overshoot, minimum transient and steady state parameters, which shows more effectiveness and efficiency of FLC than conventional PID controller.

Atheer L.201 it describes the developments of a PID(proportional-integral-derivative) control method to obtain stability in flying the Quad-rotor flying object.It presents the design of a PID controller algorithm to control the quad-rotor system.The modelling of a four rotor vertical take-off andlanding (VTOL) unmanned airvehicle known as thequad rotor aircraft.

Matheus Hentschke 2016it describes the development of a control and navigation system for a small scale un-manned Aerial vehicle (UAV) using as strategy a combination of classical control and Fuzzy Inference Systems (FIS).The navigation control system is designed using a FIS to control the roll of the aircraft and the yaw control system to control the aircraft's heading.

Nguyen Xuan-Mung 2019 it present an altitude control algorithm for quad-copters that consists of a combination of nonlinear and linear controllerIn this algorithm is simple to design and implement, and can be applied to a large range of position control applications for unmanned vehicles. The smooth transitions between the nonlinear and linear modes areguaranteed through controller gains that are obtained based on mathematical analysis.

Zhihui He 2019 In order to restrain the influence of structural parameters change and internal and external disturbances on attitude control performance and improve the adaptability.The experimental results show that the proposed method can effectively realize the attitude control of plant protection UAV, and has good static and dynamic control performance and good adaptability.

Dizhou zhang 2016 it reveal that the controller not only improves the dynamic performance and control precision of the system, but also has Strong adaptive ability to the changes of system error and flight status.According to the simulation and flight experiments, the designed controller has strong adaptive ability to the changes of flight status, and improves the dynamic response performance of the system.

Amr Sarhan, 2016. The online fuzzy inference is used as self-adaptive mechanism for tuning the PID parameters. The proposed
Adaptive PID flight controller is comparedwith two other controllers.The autopilot controlled by adaptive PID achieves an excellent performance when dealing with external wind disturbances and UAV parametric uncertainty

Ravi jaiswal 2016 As the effectiveness of the baseline controller depends on the knowledge of aircraft dynamic model and aerodynamic coefficients, which is difficult to be found accurately for the whole flight regime,Use of flaps in the Longitudinal control in UAVs result in better control authority, and hence, can be used for applications like autonomous landing, formation flight, etc.

3. Modelling and Design

3.1 MODELLING

    I. **STEP BLOCK:**

The Step Block provides us the step between two definable levels at a specified time. If the simulation time is less than Step time parameter value, the block's output is the initial value parameter value. Otherwise, the block outputs a signal of the same dimensionality and dimensions as parameters.

II.   SIGNAL GENERATOR BLOCK:

It can produce one of three different waveforms: sine wave, square wave, and sawtooth wave. The signal parameters can be expressed in Hertz or radians per second. This figure shows each signal displayed on a scope using default parameter values.

III.   6DOF BLOCK:

The 6DOF Block implements quaternion representation of six degrees of freedom equation of motion with respect to body axes. The more information on integration on the rate of change of the quaternion vector.

IV.   SUM BLOCK:

The sum block performs addition or subtraction on its inputs. Add, subtract, sum of elements, and sum blocks are identical blocks. This block can add or subtract scalar, vector or Matrix input. It can also collapse the elements of a single and perform a summation.

V.   GAIN BLOCK:

The gain block multiplies the input by a constant value. The input and the gain can each be a scalar, vector, or Matrix. The input and gain are then multiplied, and the result is converted to the output data type using a specified rounding and overflow modes

VI.   PID CONTROLLER BLOCK:

In one common implementation, the PID controller block operates in the feed forward part of the feedback loop. The input of the block is typically an error single, which is the difference between a reference signal and system output. For a two-input block that permits setpoint weightage, seePID controller.

VII.   RAMP BLOCK:

The Ramp block generates a signal that starts at a specified time and value and changes by a specified rate. The block's slope, start time, and initial output parameters determine the characteristics of the output signal. All must have the same dimensions after scalar expansion

VIII.   SCOPE:

The scope allows you to adjust the amount of time and the range of input values displayed. You can move and resize the Scope window and you can modify the scope's parameter values during the simulation. When you start a simulation, Simulink does not open Scope windows, although it does write data to connected scopes.

IX.   STATE SPACE

In control engineering, a state-space representation is a mathematical model of a physical system as a set of input, output and state variables related by first-order differential equations or difference equations. State variables are variables whose values evolve over time in a way that depends on the values they have at any given time and on the externally imposed values of input variables. Output variables' values depend on the values of the state variables.The matrix and the variable input parameters are taken from the reference paper directly.

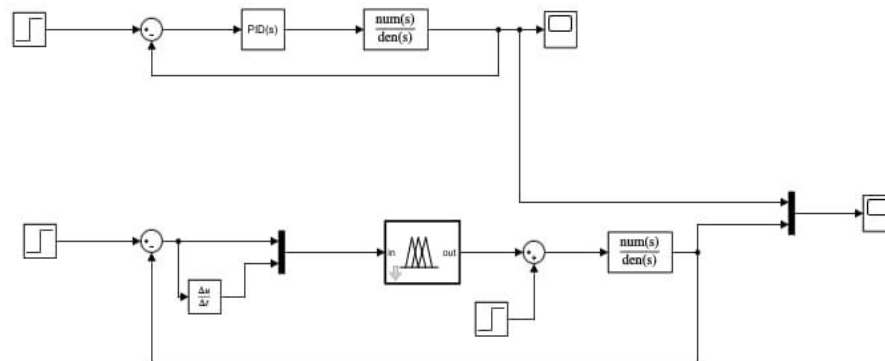**3.2   PID and FUZZY LOGIC CONTROLLER**

Figure-3.1Fuzzy-PID design in simulink-longitudinal speed control

- The transfer function of the model is obtained from the reference paper is followed below

- The overall transfer function is given as

$$\frac{0.5}{0.02s^2+0.50s+0.625}$$

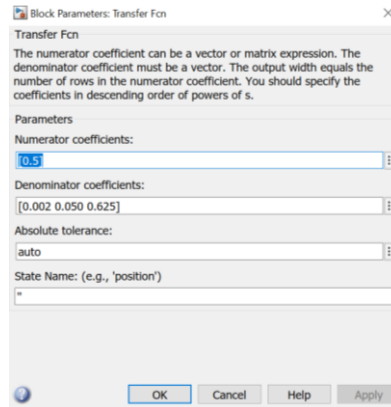In the above the transfer function is defined below

Figure-3.2 Transfer functions block parameters

CONSTRUCTION OF RULES AND RULE VIEWER FOR FLC

If figure fuzzy if – then rules are shown and output are shown. There are total 9 rules output variable.
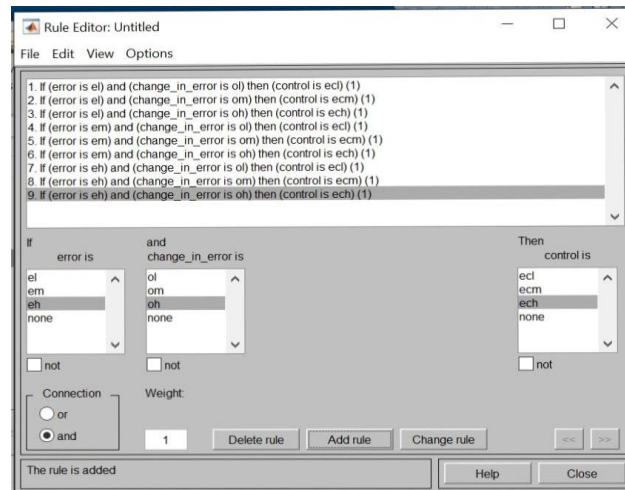

Figure-3.3   fuzzy if – then rules

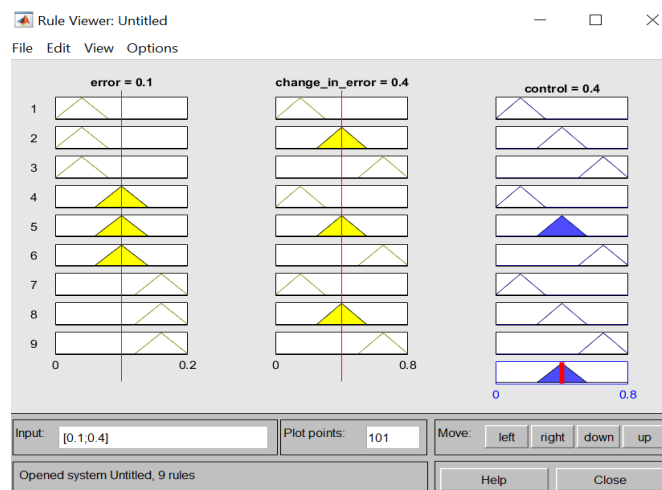In the below figure analysis of both inputs and outputs are shown

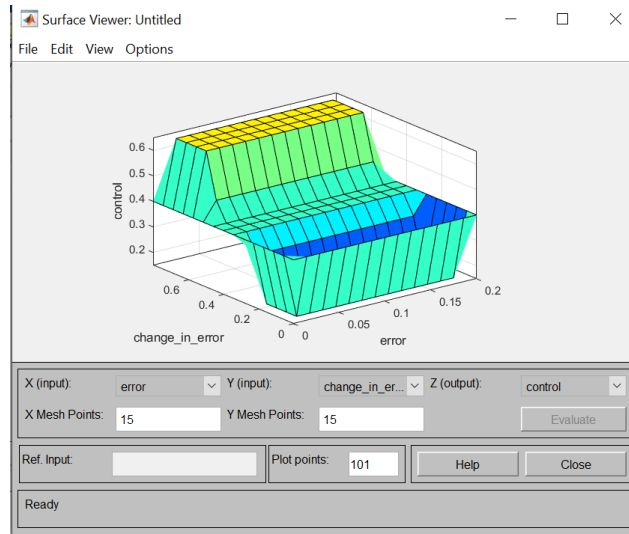**Figure-3.4   Analysis of both the inputs and outputs**

Figure-3.5 Combined rule surface viewer
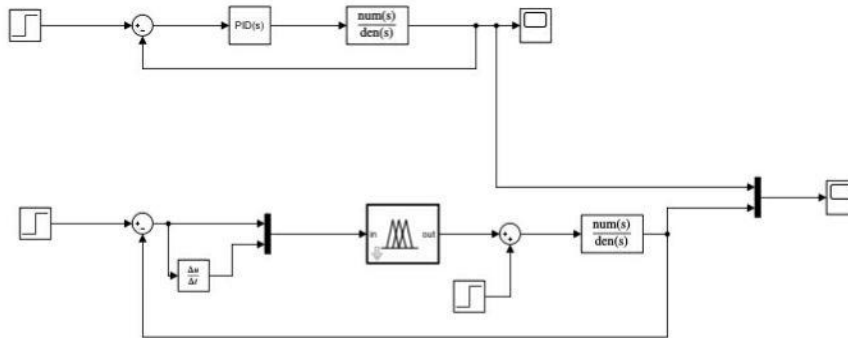
In order to investigate the phenomenon lets add disturbance to the model

Figure-3.6Addition of disturbance to the Simulink design

3.2 CONSTRUCTION OF MODEL WITH STATE SPACE
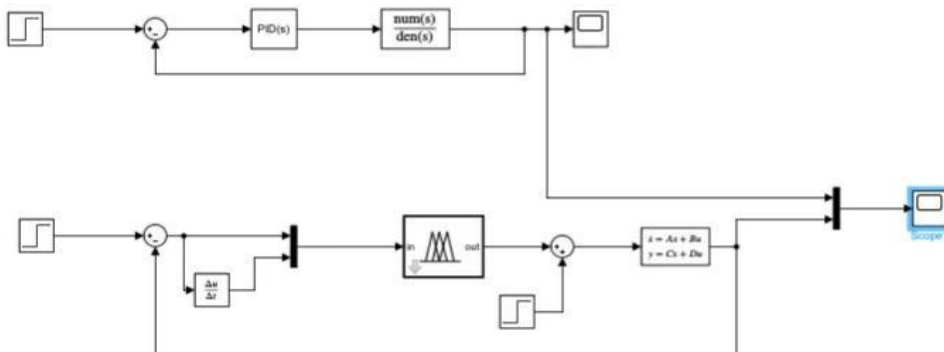
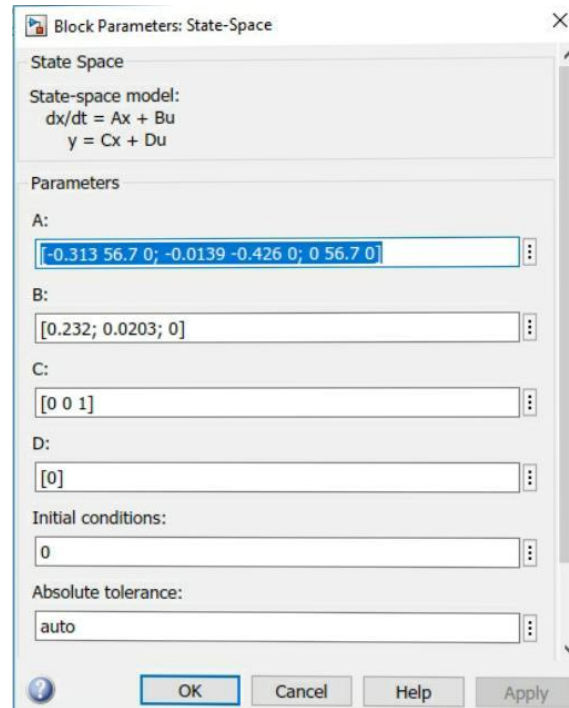**Figure-3.7 MATLAB/Simulink model of system with state space**

Figure-3.8State space parameters input block

For the speed of motor with parameters giventhe appendix, the overall State space function of the system.

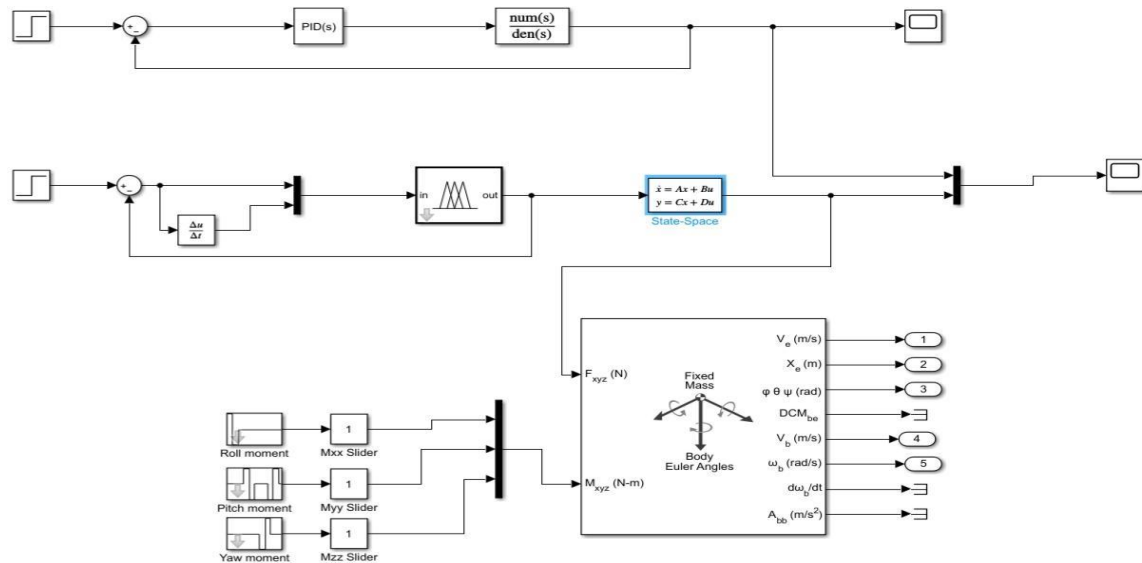For the following model, 6dof is added to the state space

Figure-3.9 MATLAB/Simulink model of fuzzy PID to the 6dof

The model is connected through the force vector of 6dof and fuzzy PID.
- The model having constant inputs for the rolling, pitching and yawing respectively.
- For the fixed mass of euler angles are taken directly from the reference
- The inputs and outputs of the system will be shown in the following figures.

The input parameters of the 6dof while construction to the fuzzy PID MATLAB/Simulink model
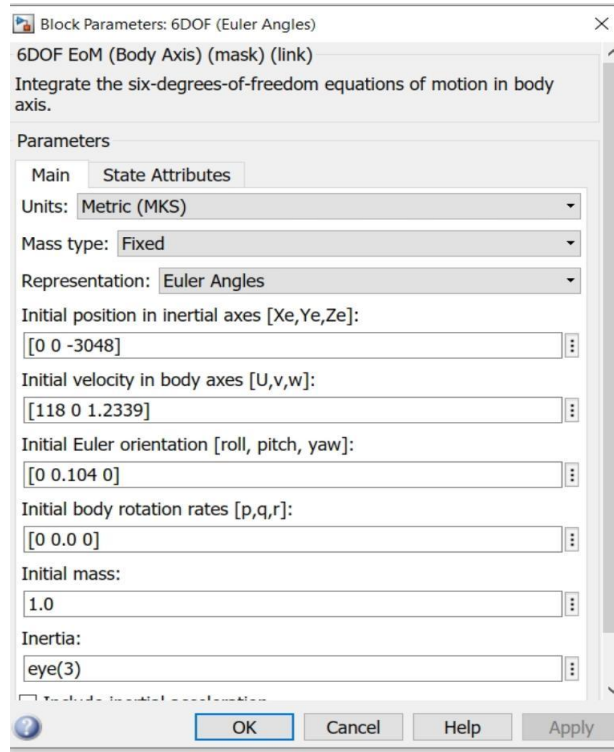
Figure-3.10 Block parameters of 6dof

From the above the initial mass of the system should be constant and the rotational axes rates also are zero. Flight gear preconfigured animation is added to the following
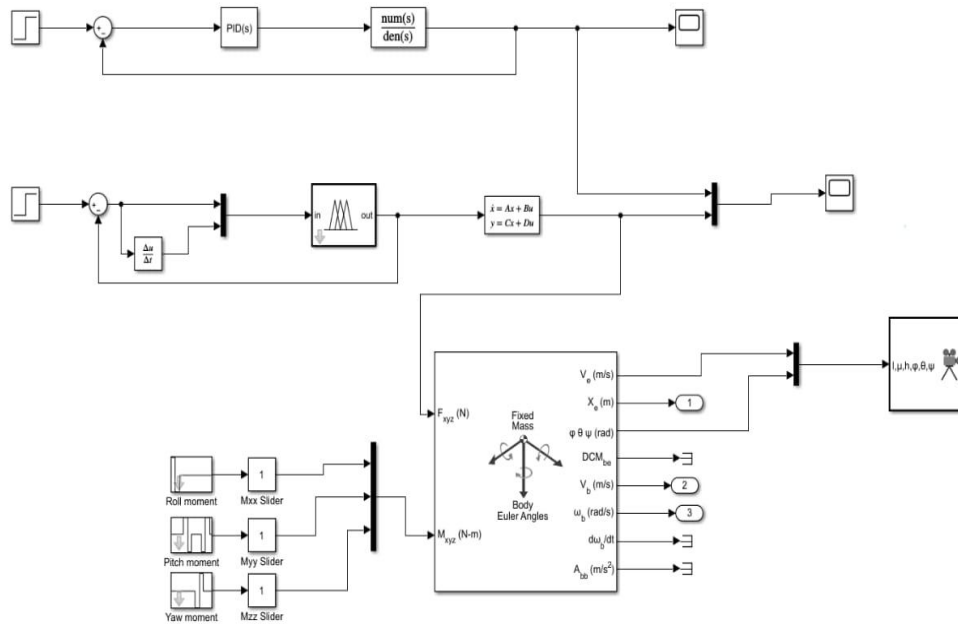

Figure-3.11FlightGear preconfigured model

Block Parameters: FlightGear Preconfigured 6DoF Animation

Figure-3.12 Parameters of Flight gear preconfigured model

4. Results and Discussion
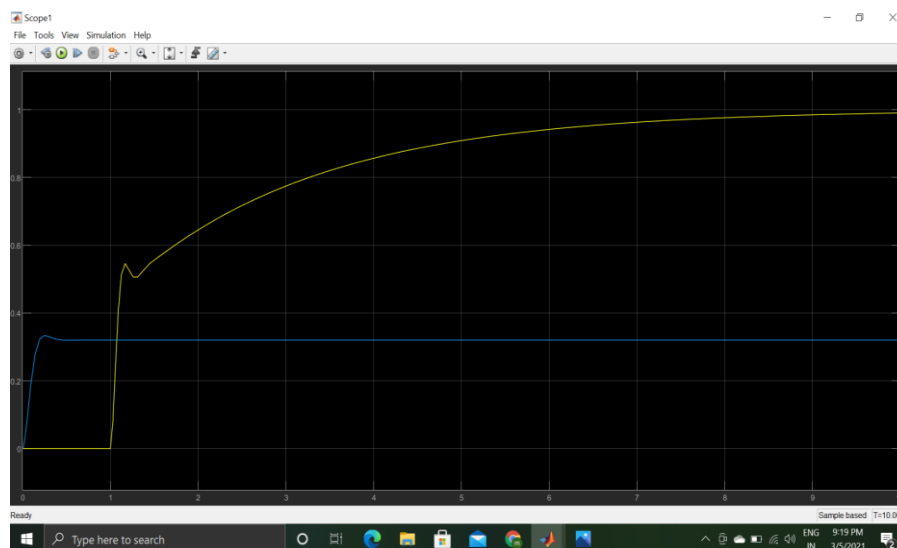
Scope Of Pid And Flc

Figure – 4.1 step response of system using PID and Fuzzy logic controller

X-axis – time(s)

Y-axis – amplitude

The above figure shows that the response of the system has greatly improved on application of fuzzy logic controller(FLC).

The overshoot of the system using FLC has been reduced, settling time; peak time of the system also shows appreciable reduction.
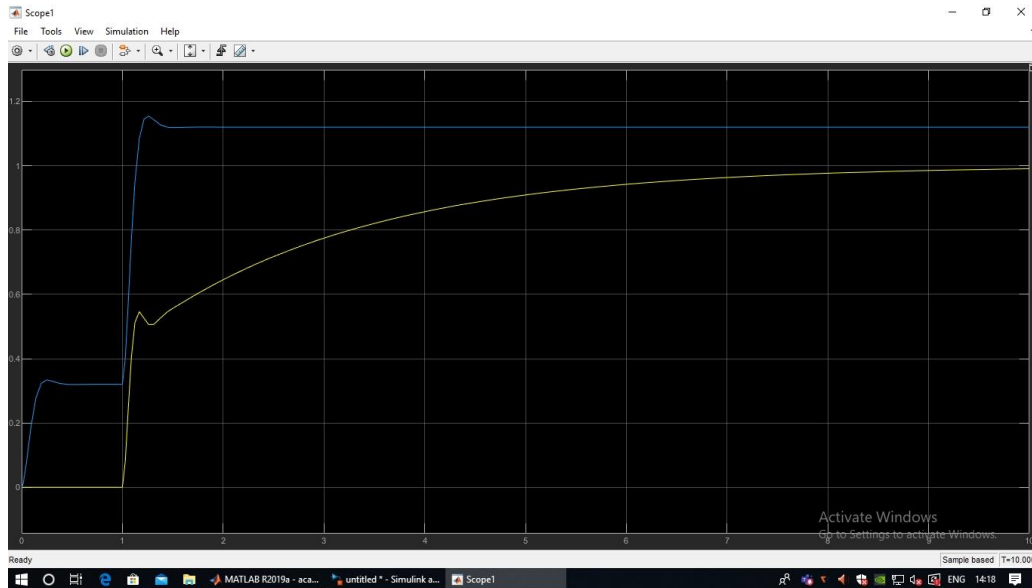
SCOPE OF FLC WITH DISTURBANCE

Figure-4.2 Step responses of the system using PID and fuzzy with disturbance

X-axis – time (sec)

Y-axis – amplitude

The above figure shows that the response of the system has greatly improved on application of fuzzy logic controller (FLC).

The overshoot of the system using FLC has been reduced, settling time; peak time of the system also shows appreciable reduction.
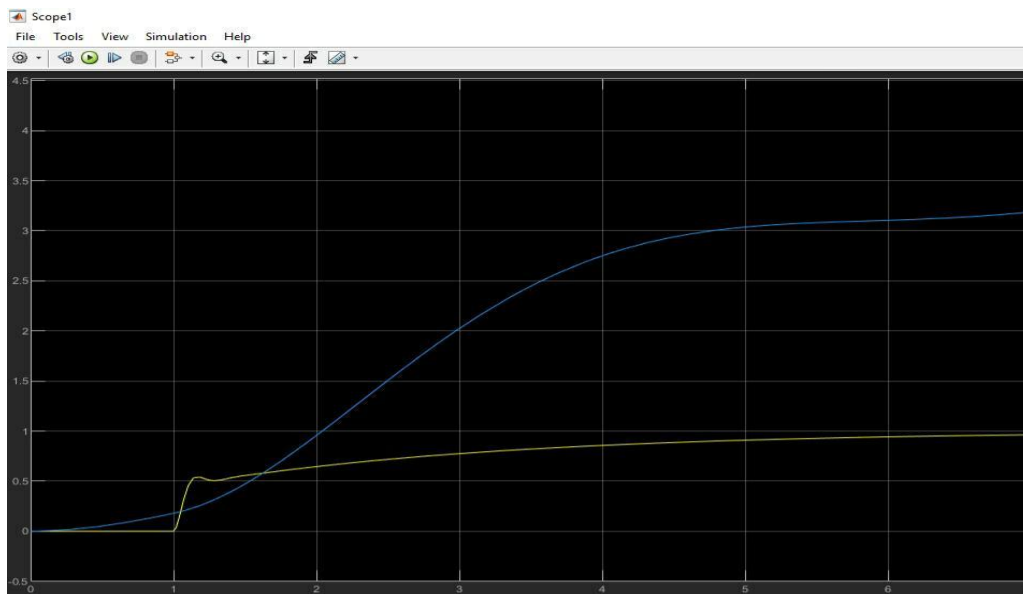
SCOPE OF PID AND FUZZY WITH STATE SPACE

Figure-4.3 Step responses of the Simulink model with states space

X–axis – time (sec)

Y–axis – amplitude

In the above response compared to the PID, FLC is increasing quickly in linear motion.
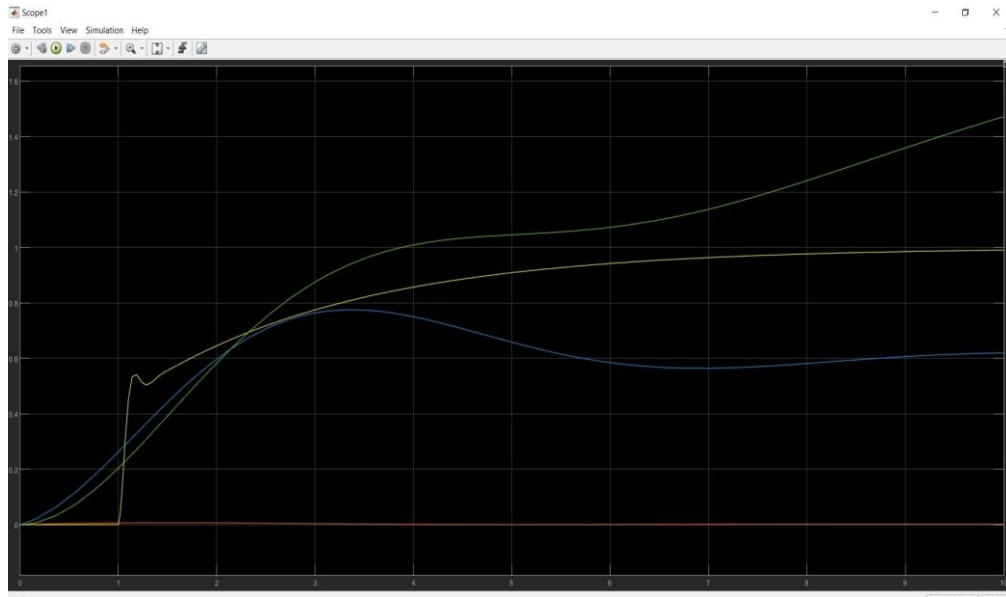
4.1. COPE OF 6DOF CONNECTED TO THE STATE SPACE

Figure-4.4 Step responses of the MATLAB/SIMULINK 6D0F

X-axis – time(sec)

Y-axis – amplitude

5. Conclusion

In this project, a basic general control system for quad-copter has been designed based on fuzzy-PID controller. In order to test the performance of the designed controller, the longitudinal speed control used to compare the output of the designed controller with a PID controller and FLC using MATLAB/Simulink. According to the comparison results, the designed controller FLC has close results. By calculating the simulation results of each controller, the designed controller shows that it has the best performance among the two controllersand it can be used in practical test.

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