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Design of Controller for Aircraft

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A B S T R A C T

The project is about the design of controllers of aircraft. The main objective is analysis and design of robust adaptive control for aircraft lateral movement in landing mode. Adaptive control, it varies when used by a controller to modify control system with different parameters. While varying with different parameters it will have non- parametric perturbations like time delay, unstructured dynamics. To remove these perturbations the robust will, play the key role and adding the robust to adaptive control it will remove non parametric perturbations and it will give the good ability for controllers. And this results the problem of adaptive control and the control system with a reference model on the modified algorithm of high order tuner is proposed.

Keywords: controller, aircraft, Matlab

1. Introduction

1.1 Aircraft Controllers

There are three basic control movements of Aircraft i.e.; Pitch, Roll and Yaw. One of the important parameters out of these is pitch control moment. In the present work we have considered this problem as variable approach and carried out work by applying intelligent control techniques for controlling the longitudinal motion of aircraft. Aircraft pitch control moment is a critical phase during takeoff phase as well as during study flight.
This parameter is of a concern as aircraft can go into a stall condition if pitch control of aircraft is not calibrated property. This is an important stage during which aircraft changes its transition from one state to another. The pitch moment of aircraft is categorized under longitudinal stability whereas roll and yaw are categorized under lateral stability.

A set of control surfaces known as elevator are used for controlling aircraft pitch moment. Elevators are movable control surfaces located at the back of fixed wing aircraft and hinged to the trailing edge of horizontal stabilizer, running parallel to the main wings that cause this rotation of aircraft. The elevators cause the aircraft climb and descend and also to obtain sufficient lift from the wings to keep the aircraft in level flight at various speed. The elevators are movable control surfaces which can be moved up or down. If the elevator is rotated up, it decreases the lift force on the tail causing it to raise and the nose to rise and the nose to lower. Lowering the aircraft's nose increases forward speed, and raising the nose decreases the forward speed.

Mechanical or manually operated flight control systems are the most basic methods of controlling an aircraft. They were used in early aircraft and are currently used in small aircraft where the aerodynamic forces are not excessive. Very early the aircraft used a system of wing warping where no conventionally hinged control surfaces were used on the wing, and sometimes not even for pitch control as on the Wright Flyer 1, which only had a hinged/pivoting rudder in addition to the wrapping-operated pitch and roll controls. A manual flight control system uses a collection mechanical parts such as pushrods, tension cables, pulleys, counterweights, and sometimes chains to transmit the forces applied to the cockpit controls and directly to the control surfaces. Increases in the control surface area required by large aircraft or higher loads caused by high airspeeds in small aircraft lead to a large increase in the forces needed to move them, consequently complicated mechanical gearing arrangement were developed to extract maximum mechanical advantages in order to reduce the forces required from the pilots.

1.2 Primary Flight Controls

Basically, we have 3 primary control surfaces namely Ailerons, Elevator, and Rudder. Primary control surfaces change the angle of attack and therefore the lift on an aircraft.

1.2.1 AILERONS

Ailerons are basically used to roll an aircraft using yoke or stick. Their differential movement alters angle of attack and lift causing the plane to roll. They are located at trailing edge, near the tip of the wing. Consider if you want to roll in the left direction.

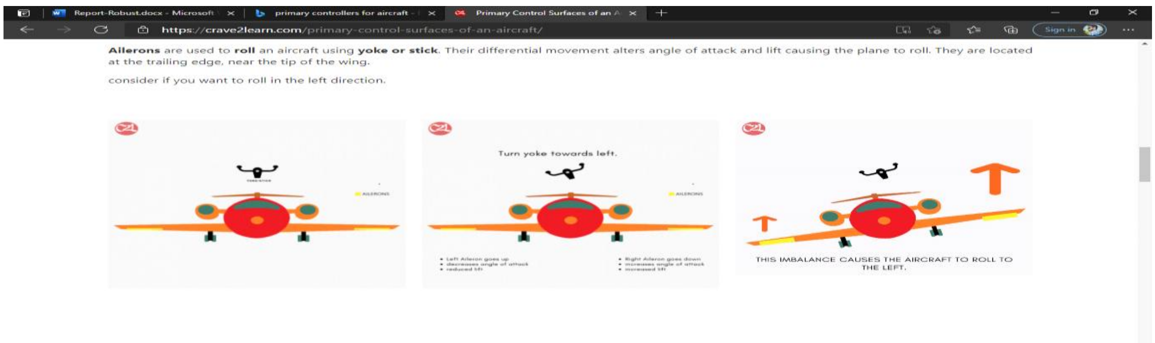

Figure 1.2.1-Aileron

1.2.2 Elevators

Elevators are basically used to pitch an aircraft using forward/backward motion of yoke or stick. Their movement changes the angle of attack and lift causing the plane to pitch up/down. Elevators are located at horizontal stabilizer.

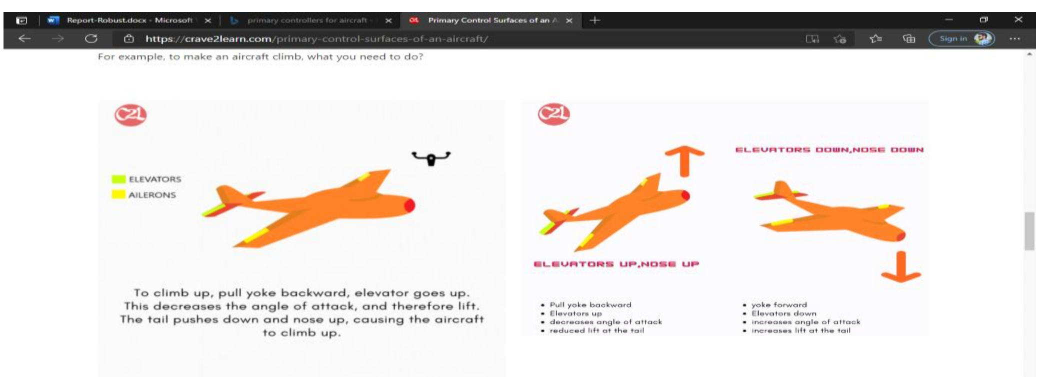

Figure 1.2.2-Elevator

1.2.3 RUDDER

Rudders used to yaw an aircraft using the rudder pedals or ruddles.

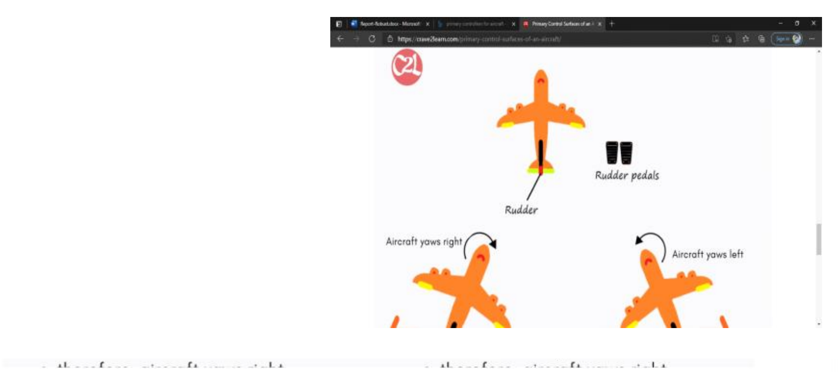

Figure 1.2.3-Rudder

1.3 ADAPTIVE CONTROL

Adaptive control is the control method used by a controller which must adapt to a controlled system with parameters which vary, or are initially uncertain. For example, as an aircraft flies, its mass will slowly decrease as a result of fuel consumption; a control law is needed that adapts itself to such changing conditions. Adaptive control is different from robust control in that it does not need a priori information about the bounds on these uncertain or time-varying parameters; robust control guarantees that if the changes are within given bounds the control law need not be changed, while adaptive control is concerned with control law changing itself.

1.4 Robust Control

In control theory, robust control is an approach to controller design that explicitly deals with uncertainty. Robust control methods are designed to function properly provided that uncertain parameters or disturbances are found within some (typically compact) set. Robust methods aim to achieve robust performance and stability in the presence of bounded modelling errors.

The early methods of bode and others were fairly robust; the state-space methods invented in the 1960's and 1970's was sometimes found to lack robustness, prompting research to improve them. This was the start of the theory of robust control, which took shape in the 1980's and 1990's and is still active today. In contrast with an adaptive control policy, robust control policy is static, rather than adapting to measurements of variations, the controller is designed to work assuming that certain variables will be unknown but bounded.

1.5 Matlab

Is a proprietary multi-paradigm programing language and numeric computing environment developed by MathWorks. Matlab allows 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. Moler 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.

1.6 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 modelling 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.

1.8 OBJECTIVE OF THE WORK

Analysis of robust adaptive control aircraft lateral movement in landing mode.

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2. Literature Review

Binbin Yan, Pei Dai, Ruifan Liu, Shuangxi Liu 2019 [1] in a paper, a novel and more explicit longitudinal model of wing sweep morphing aircraft is proposed, accounting for variations in aerodynamics, mass and inertial properties.

Zongxia jiao, Dong sun, Yaoxing shang, Xiaochao liu, Shuai wu 2019 [2] proposed an anti-skid brake algorithm to identify the maximum friction force by analysing the runway/tire friction characteristics that can only base on the aircraft wheel speed signal.

Yaqi Dai, Jian sang, Liangyao yu, Zhenghong lu, Sheng zheng, Fei li 2019 [3] discussed the lateral control during aircraft on ground deceleration which is one of the most important issues in aircraft on ground manoeuvres.

Junjie liu, Mingwei sun, Zengqiang chen, Qinglin sun 2019 [4] presented a novel fixed-time extended time observer based fixed time output feedback control scheme for aircraft with thrust vector at high AOA in a paper.

Jie liu, Wei han, Haijun peng, Xinwei Wang 2018 [5] proposed a towed carrier aircraft system without bar is transformed into tractor trailer system and nonlinear motion constraint.

Qing wang, Ligang gong, Chaoyang dong, kewei zong 2019 [6] investigated the control problem of a morphing aircraft with variable sweep wings based on switched nonlinear systems and ADP.

Peixin Gao, Tao yu, Yuanlin Zhang, Jiao wang, Jingyu zhai 2020 [7] provided a detailed review on the current vibration control technologies in hydraulic pipeline system.

Xiang ai, Yang-Yang chen, Ya zhang 2020 [8] addressed the anti-flow cooperative control problem of a fleet of non-holonomic aircraft like vehicles to achieve formation flying around their desired circles on a target sphere in 3D space.

Lixin wang, Ning zhang, Ting Yue, Hailiang liu, Jianghui zhu, Xiaopeng jio 2020 [9] proposed a flight control law design method that couples the longitudinal axis with the lateral directional axes.

Xinwei wang, Jie liu, Xichao su, Haijun peng, Xudong zhao, CHen lu 2020 [10] proposed a comprehensive investigation of techniques and research progress for the aircraft dispatch path planning on the deck.

Batuhan eroglu, M.Cagatay sahin, Nazim kemal ure 2020 [11] proposed a data driven fault estimation method for estimating actuator faults from aircraft state trajectories.

Jie wang, Ping wang, Xiao ma 2020 [12] investigated the trajectory problem of a quadrotor with six degrees of freedom in the case of time varying and asymmetric output constraints.

Boris Adrievsky, Elena V.Kudryashova, Nikolay V.Kuznetsov, Olga A.Kuznetsova 2020 [13] proposed an application of the simple adaptive control approach with the implicit reference model (IRM) and numerically studied.

Liguo sun, Lewen shi, Wenqian tan, Xiaoyu liu 2020 [14] proposed an aper which was focused on the parameter tuning problem for the design of nonlinear flight controllers.

Dmitry I.Ignatyev, Hyo sang shin, Antonios tsourdos 2020 [15] presented two layered adaptive augmentation for incremental backstepping (TLA-IBKS) control algorithm designed for a large transport aircraft.

Zongxia jiao, Ning bai, Dong sun, Xiaochao liu, Yaoxing Shang, Shuai wu 2020 [16] proposed an article which generalised different types of disturbances based on the respond of the control.

Shiqi gao jinkun liu 2019 [17] studied a boundary vibration control problem for a flexible aircraft wing system with input signal quantization and unknown input disturbance.

R.Priem, N.Bartoli, Y.Diouane, A.Sgueglia 2020 [18] proposed a paper in which they adapted the so called super-efficient global optimization algorithm TP solve more accurately mixed constrained problems.

Xiao zheng jin, Tao he, Xiao ming wu, Hai wang, Jing chi 2020 [19] addressed the position and attitude trajectory tracking problems of a class of quadrotor aircrafts with bounded external disturbances and state dependent internal uncertainties.

Yang zhou, Guoping huang, chen xia 2020 [20] presented a new concept of vertical take-off and landing propulsion system based on gas driven fan. This system has simple mechanical actuation mechanism and enables high cruising efficiency.

Xin wei wang, Hai jun peng, Jie liu, Xian zhou dong, Xu dong zhao, chen lu 2020 [21] proposed a paper in which they coordinated taxiing path planning problem is transformed into a centralized optimal control problem where collision free conditions and mechanical conditions are considered.

Xiao ming wang, Wenya zhou, Ruinan mu, Zhigang wu 2020 [22] proposed an MMC strategy for roll control of low-speed flexible hale aircraft.

Zongxia jiao, Hao zhang, Yaoxing shang, Xiaochao liu, Shuai wu 2020 [23] proposed to improve the safety and maintenance of aircraft a novel concept of power by wire aircraft brake system.

Weilai jiang, Kangsheng wu, Zhaolei wang, Yaoanan wang 2020 [24] addressed the gain scheduled output feedback control for morphing aircraft in full envelope using switching polytopic linear parameter varying theory.

Majeed mohamed, Madhavan G 2020 [25] designed an optimal flight cintrol law from a reduced order model and realized with a flexible aircraft representation by a full order model.

Zhiru cao, Tinggang jia, Yugang niu 2020 [26] designed a mode independent self-triggered scheme based on the proposed triggered condition to determine the triggering instants.

Qingrui zhang, Hugh H.T.Liu 2018 [27] presented an aerodynamic model based robust adaptive control algorithm for closed formation flight.

Zhongjiao shi, Liangyu zhao 2017 [28] proposed a novel method to improve the transient performance, and to restrain high frequency oscillation of the control signal, without modifying the selected reference model.

Mousa rezaee, Reza jahangiri, Rasoul Shabani 2019 [29] derived the governing coupled partial differential equations by using the airy stress function and applying the Hamilton's principle.

Andres Marcos, Jean marc biannic, Matthiu Jeanneau, Declan G. Bates, Ian Postlethwaite 2006 [30] proposed a paper in which an application exact nonlinear symbolic LFT modelling approach to an on-ground airbus aircraft is shown.

2.1 SCOPE OF THE RESEARCH

Reverse framing normalizing is used to analysis the robustness of lateral control system. Analysising the adaptive control system with robust.

3. Methodology

3.1.1 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.

3.1.2 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.

3.1.3 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.

3.1.4 SINE WAVE BLOCK

Sine Wave block provides a sinusoid. The block can operate in either time based or sample-based mode. time based mode has two submodes:continuous Mode or discrete mode

3.1.5 SUM BLOCK

The sum block performs addition or subtraction on its inputs. The 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.

3.1.6 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

3.1.7 PID CONTROLLER BLOCK

In one common implementation, the PID controller block operate 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.

3.1.8 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.

3.1.9 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.

Aircraft Pitch: Simulink Controller Design

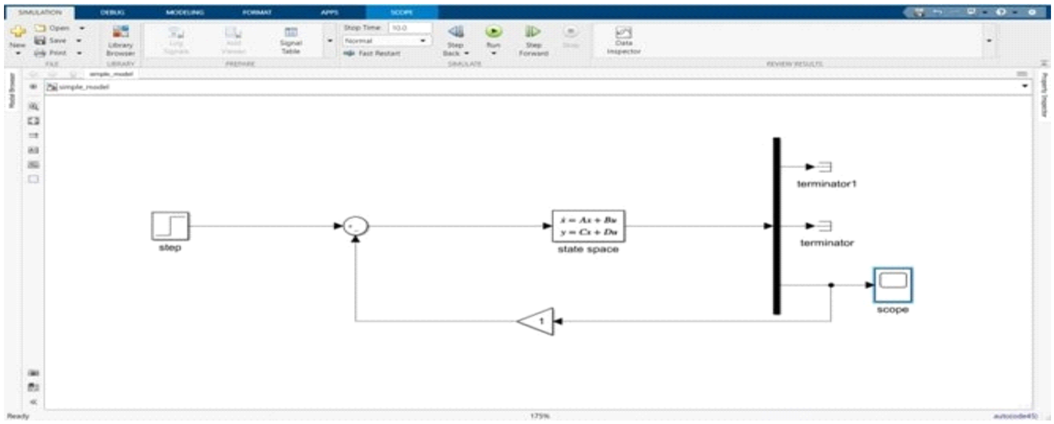

Figure 3.1 - Aircraft pitch Simulink

Here considering basic design for aircraft pitch with step signal, sum block, state space, gain block, terminators and scope. Connecting all this blocks will give the results in scope. Graph of time vs amplitude.

Giving parameters for state space with different matrices will show the results in scope.

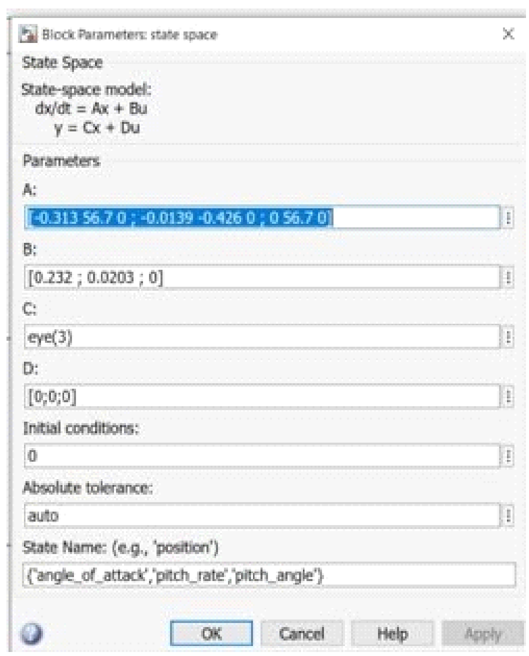

Figure 3.2-State space parameters

In order to investigate this phenomenon, let's add a disturbance to our model as shown in the figure below. Adding the disturbance to the sum block will show different results when compared with without disturbance.

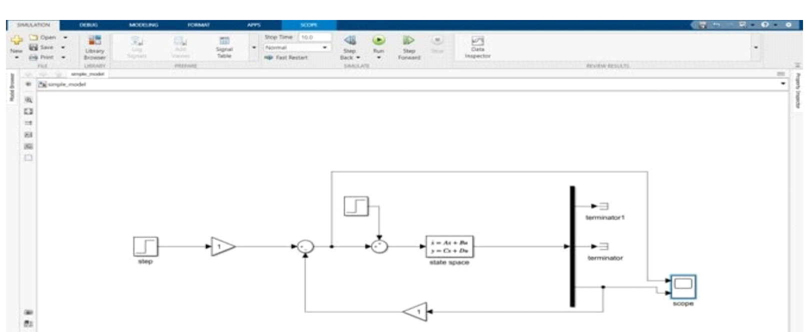

Figure 3.3-Aircraft pitch with disturbance

Robustness analysis in Simulink

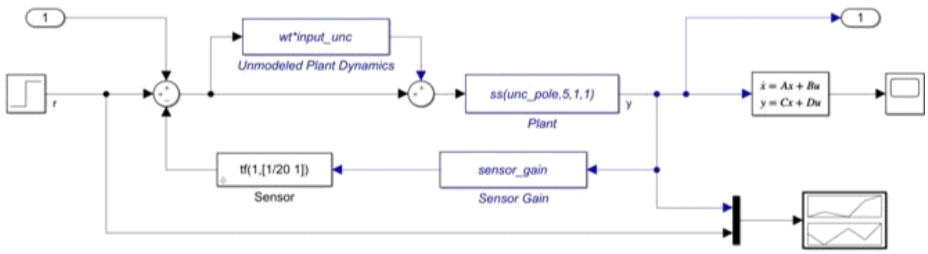

Figure 3.4-Robustness analysis in Simulink

In the robustness analysis in Simulink, considering various blocks like input, output, multigraph, state space, sensors and scope will shows the results.

1.The "Uncertain system variable" parameter specifies the uncertain plant model.

2.The "Uncertain Value" parameter specifies values for the block's uncertain variables.

3.State space parameters is defined as given below.

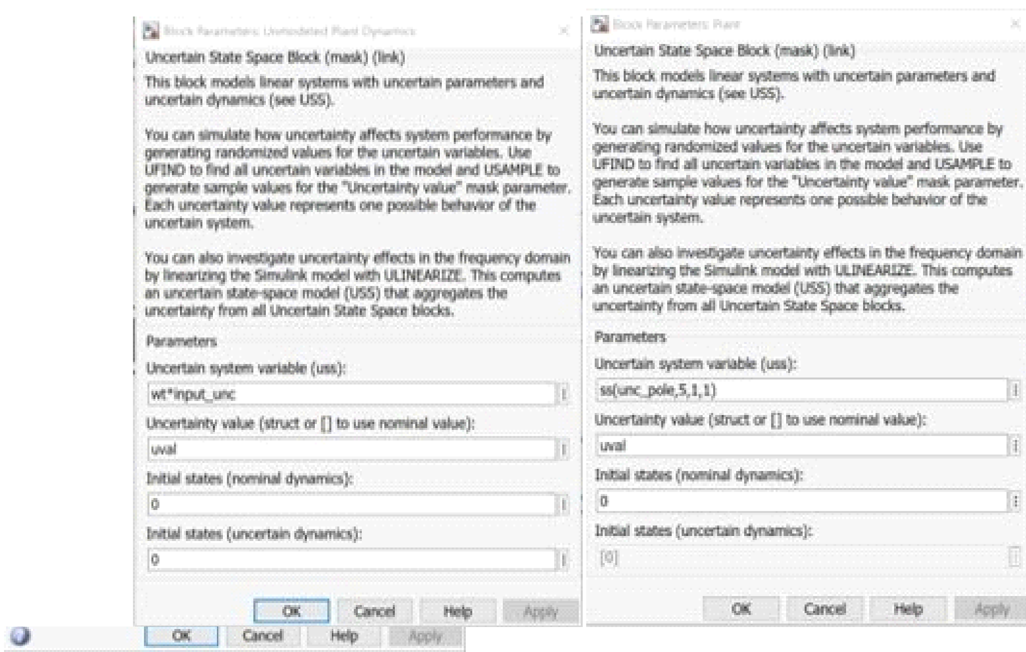

Figure 3.5-Parameters of state space for robust analysis in Simulink

Six degrees of freedom – Pitch, Roll, Yaw;

Left and right;

Forward and backward;

Up and down.

For the following Robustness, 6DOF is added to state space

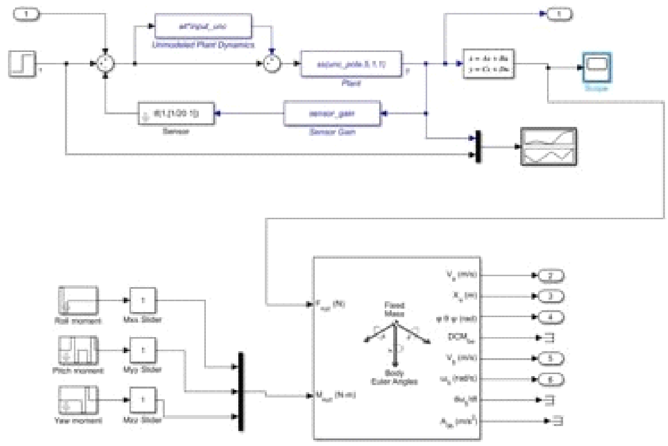

Figure3.6-Robust analysis of Simulink with 6dof

In the below, the 6DOF Eular axis parameters are given

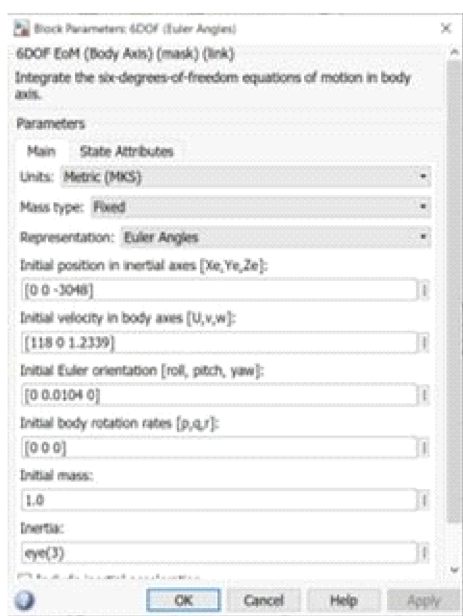

Figure 3.7-Parameters of state space for robust analysis of Simulink with 6dof

 International Journal of Research Publication and Reviews Vol (2) Issue (4) (2021) Page 474-488

FlightGear Preconfigured 6DoF Animation is added to the following

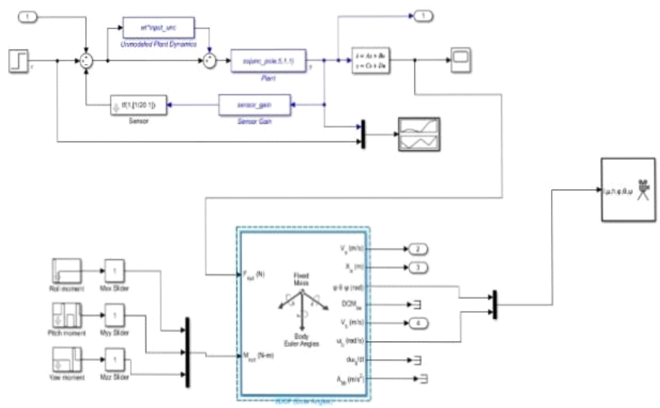

Figure 3.8-Flight gear preconfigured 6dof

Here we are considering the 6dof with robustness gives the exact result with different inputs. And the 6dof with roll moment, pitch moment and yaw moment and also with silders,inputs and Terminators. And also adding the animation part for the robustness analysis in Simulink.

Block Parameters: FlightGear Preconfigured 6DoF Animation

Figure 3.9-Parameters of flight preconfigured 6dof animation

4. Results And Discussion

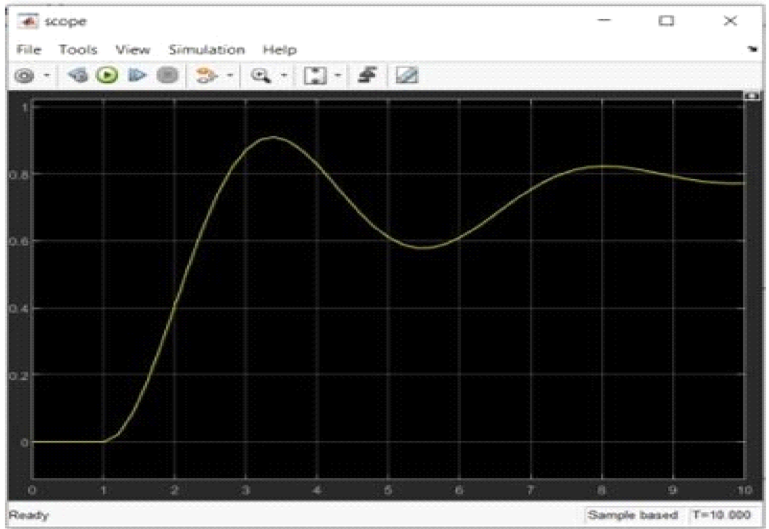

Figure 4.1 - Scope of aircraft pitch, Simulink control design

In the aircraft pitching, Simulink control design it demonstrates that the rise time, settle time and overshoot requirements are all met.

Running the simulation will generate a response like the one shown below.

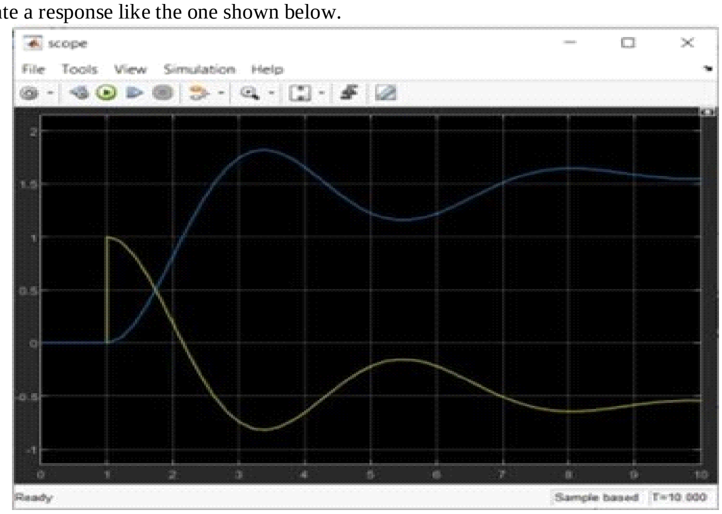

Figure 4.2 - scope of aircraft pitch with disturbance

In the aircraft pitch, in order to investigate the phenomenon adding the disturbance to the model then the running simulation will generate a response

For the input step signal, step time is 1 the following multigraph is shown below

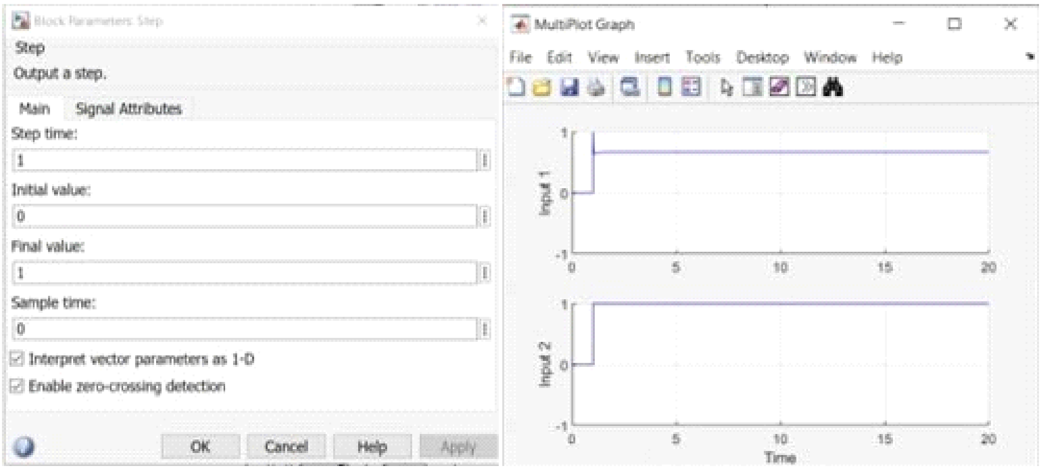

Figure 4.3-Parameters and multigraph for input step signal

In the robust analysis in Simulink, considering different parameters with including 6dof. Considering the input step signal, step time is 1

For the input step signal, step time is 1 the following scope is shown below

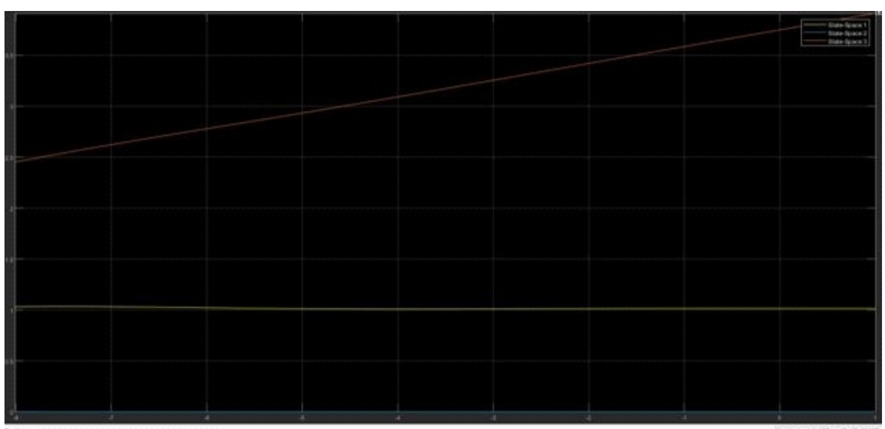

Figure 4.4-scope for input step signal

While considering the input step signal with step time 1 with different state space parameters. The input and the output are firstly constant and further drastically increasing

For the input signal generator, amplitude and frequency is 1 the following multigraph is shown below

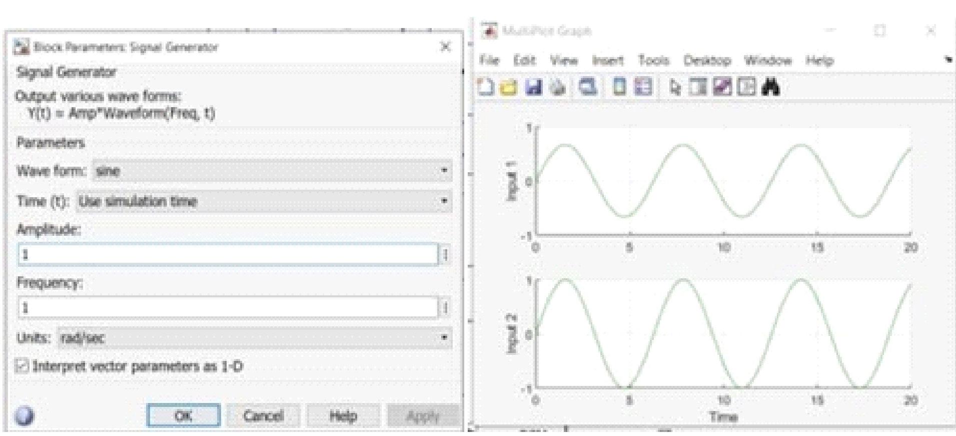

Figure 4.5-Parameters and multigraph for input signal generator

When considering the input signal generator with amplitude and frequency 1 it will also be having the same as like step signal which is firstly constant and further drastically increasing.

For the input chirp signal, initial frequency is 0.1 the following multigraph is shown below

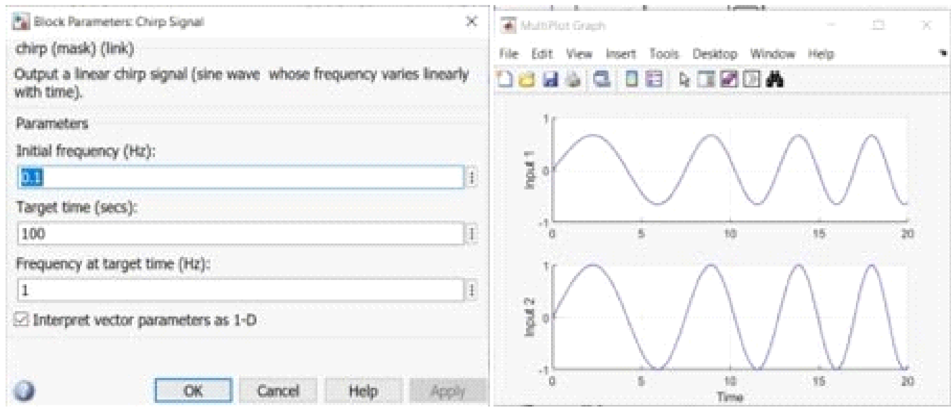

Figure 4.6 - Parameters and multigraph for input signal generator

For the input chirp signal, initial frequency is 0.1 the following scope is shown below

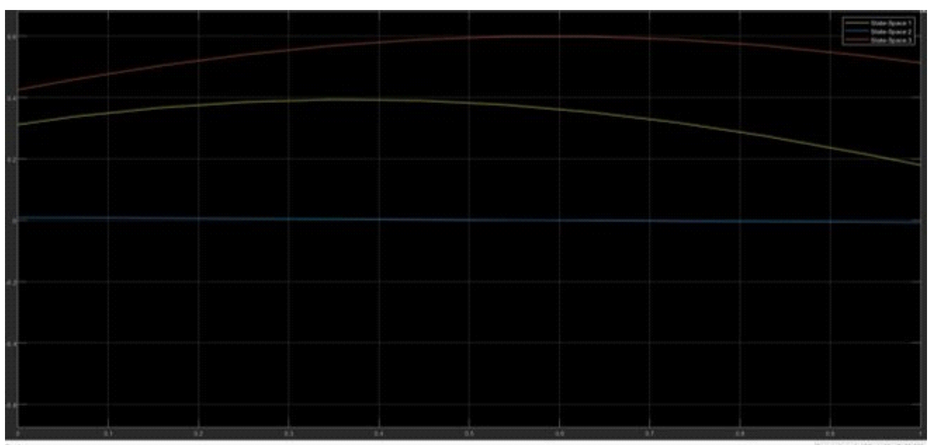

Figure 4.7-Scope for input chirp signal

For the following inputs considering the input chirp signal with initial frequency 0.1 and the multigraph and scope with the parameters of state space shows that the input and output firstly constant and further also remains constant.

For the input sine wave, amplitude and frequency is 1 the following multigraph is shown below

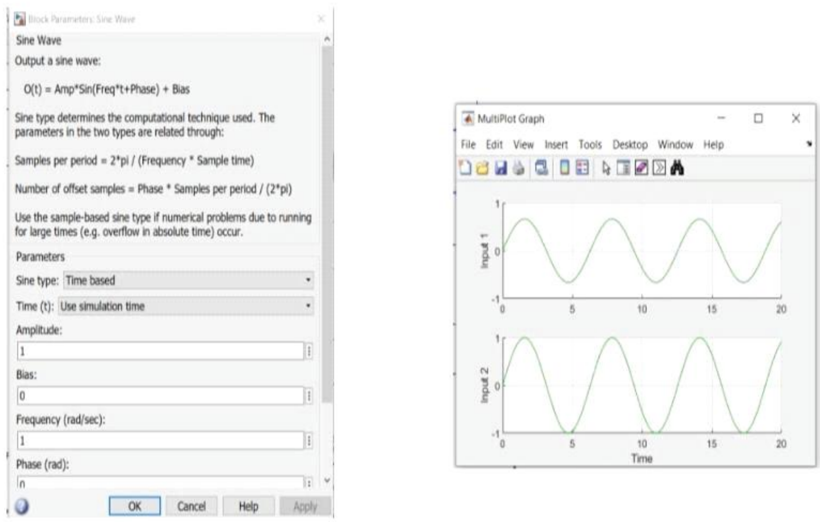

Figure 4.8-Parameters and multigraph for input sine wave

For the input sine wave, amplitude and frequency is 1 the following scope is shown below

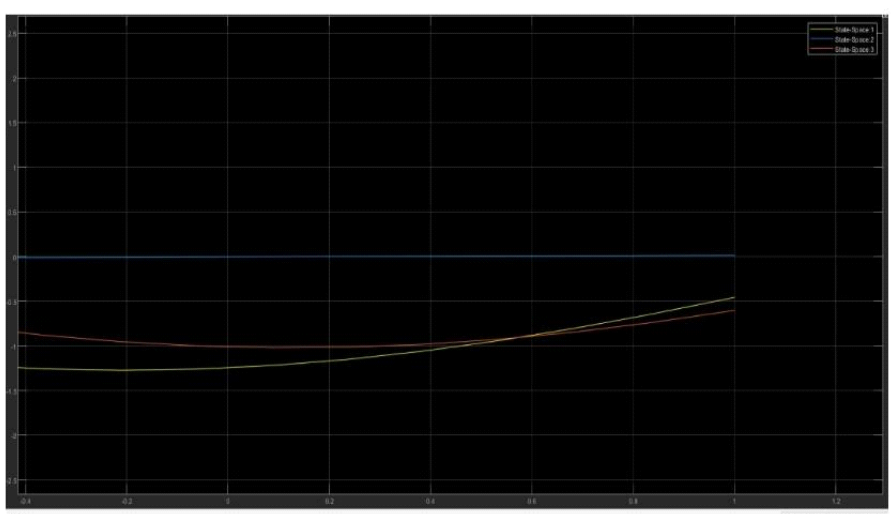

Figure 4.9-Scope for input sine wave of robust analysis in Simulink

While considering the input sine wave with amplitude and frequency 1 the multigraph and scope for the state space parameters is same as the chirp signal. That the input and output firstly remain constant and increases slightly.

5. Conclusion

Analysing the robust adaptive control aircraft lateral movement in landing mode with different parameters and different inputs like step signal, signal generator, chirp signal, sine wave and 6 degrees of freedom.

Considering the aircraft pitch and robust analysis in Simulink firstly for the aircraft pitching, the rise time, settle time and overshoot requirements are meet at same point and remains same and even while running the simulation.

In the robust analysis in Simulink considering the following inputs with 6dof are step signal, signal generator, chirp signal and sine wave. For the step signal the input and the output are firstly constant and further drastically increasing. For the signal generator, it is also same as the step signal which is firstly constant and further drastically increasing. For the chirp signal for given parameters of state space the input and output firstly constant and further also remains constant and for the sine wave also acts same as the chirp signal.

By this analysis for the robust adaptive control aircraft lateral movement in landing mode, we can say that chirp signal input with 6dof acts well when compared with other inputs and controllers.

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