Scilab case study project on

Pitch simulation of an aircraft employing Xcos

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Abstract

Air vehicle orientation and movement control is a not a linear process. It involves three critical parameters (the angles of rotation in three dimensions about the vehicle's centre of gravity), called pitch, roll and yaw. In this project, simulation of the pitch of an aeroplane is carried out. It is determined by the axis perpendicular to the longitudinal plane of symmetry. The study is accomplished using a PID (Proportional – Integral – Derivative) controller system on Xcos. Xcos is an open-source application of Scilab that supports modelling and simulating dynamic systems.

Pitch is controlled by adjustment of the elevator, present at the rear side of the plane. These are Flight Control Surfaces (FCS) which redirect the air flow and the action of pressure on the wings. Further, longitudinal dynamic stability is also a crucial feature. It denotes the damping of stabilizing moments, which prevents persistent or rising oscillations in pitch. A decent pitch control ensures safe descend and ascend of the aircraft.

1. Introduction

Pitch can be referred to as the "up and down" or "nodding" motion of an aircraft. Control of pitch is what most evidently distinguishes operating an aircraft in the sky from any vehicle that runs on the land. This incorporates the act of managing an airplane on the runway. The pitch axis makes a right angle to the centre of the aircraft. This is also called the transverse axis or the lateral axis. Pilots control the pitch through the elevator, which creates lift for the aircraft. It sits on the aircraft's horizontal stabilizer. Understanding pitch took place early in aviation. The first successful staffed aircraft, the Wright Brother's 1903 Wright Flyer, held an elevator. However, as the aircrafts have evolved over time, it has become crucial to revise its features for better operation.

The elevator can be controlled using the servo motor control signal. These control signals are generated by the PID controller. PID stands for the Proportional+ Integral+ Derivative control and was invented by Christiaan Huygens in the 17th century. It is widely used in most of the 'process control' industries because of its feasibility, simple design and low cost. The purpose of the PID controller in the industry is to provide a control mechanism for the error signal. The error signal is the variation between the controlled output and a desired set point. Based on that error signal, the necessary actions taken by the controller are fed to the process station. This enables it to produce the anticipated output.

2. Problem Statement

To achieve the desired control over pitch of an aircraft, a well-defined mathematical model is essential. For this purpose, system identification is a favourable numerical process. It is required that the output of the controller varies smoothly in reaction to the error or rate of change of error. When the system is a combination of different continuous controller modes this aim can be easily accomplished. Therefore, this project utilises the PID controller, simulated over Xcos.

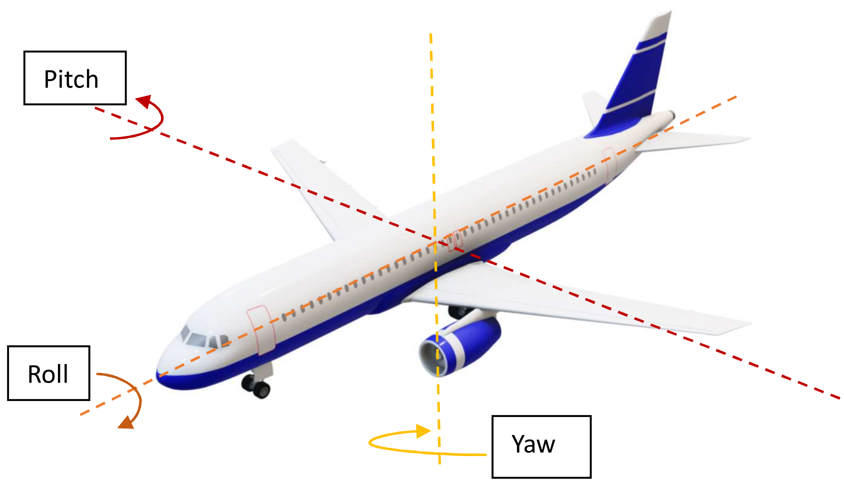
3. Basic concepts related to the topic

The movement [stability] of the airplane can be controlled by three different techniques:

• Pitch (rotation around the front-to-back axis)

• Yaw (rotation around the vertical axis) and

• Roll (rotation around the side-to-side axis).



Altering any one of the three influences the other two. These methods are necessary for safe flight, landing, and take off.

❖ To regulate the movement of an aircraft along these three axes, the following three control systems are installed in the aircraft:

- Ailerons [to control the roll]

  On each wing, the ailerons are placed at the rear edge. It moves in contradictory directions so as to decline lift on one wing while enhancing it on the other. Due to this, the plane rolls left or right. To turn the airplane in a particular direction, the pilot uses these ailerons to lean the wings.

- The Elevator [to control the pitch]

  When the elevators of an airplane are tilted skyward, there is more lift on the wings and less lift on the tail. Therefore, the airplane rises. The reverse happens when the pilot wishes to direct the nose of the airplane towards the ground. We shall focus on this aspect in this case study.

- Rudder [to control the yaw]

  It helps the pilot to change the direction towards left or right.

- To determine the pitch of an aircraft, the derivation of the mathematical modelling using mass and energy balance equation is crucial. Longitudinal dynamics are used to command the pitch of the aircraft. Here, we explore an autopilot control system.

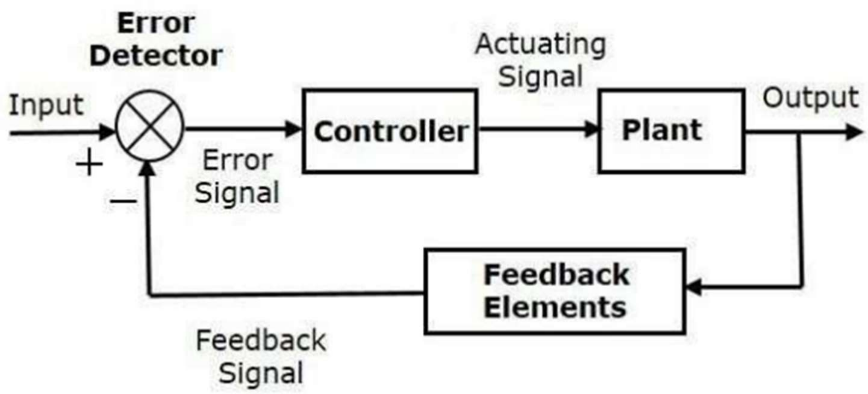


Figure- The Block diagram of a closed loop system

- PID controller is used to generate a control action for the error signal. An error signal is the deviation between the controlled output and an applied set point. That signal is fed to the controller in order to reduce it. This routine is continued till the controller output becomes equal to that of an applied set point.

$$u(t) = k_p e(t) + k_i \int e(t)dt + k_d \frac{de}{dt}$$

The longitudinal dynamic transfer function is obtained from the above equation is as follows:

$$P(s) = \frac{\theta(s)}{\Delta(s)} = \frac{1.151s+0.1774}{s^3+0.739\,s^2+0.921s}$$

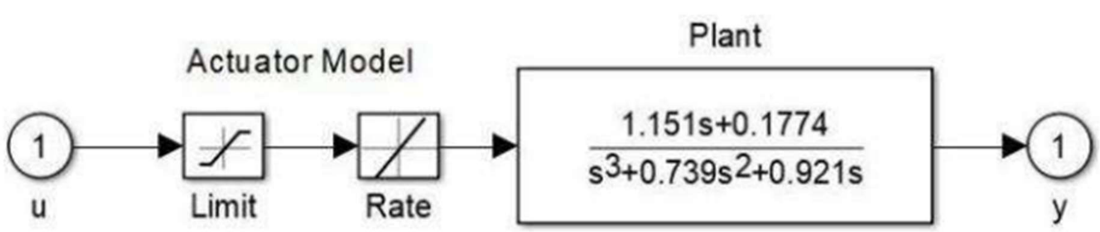
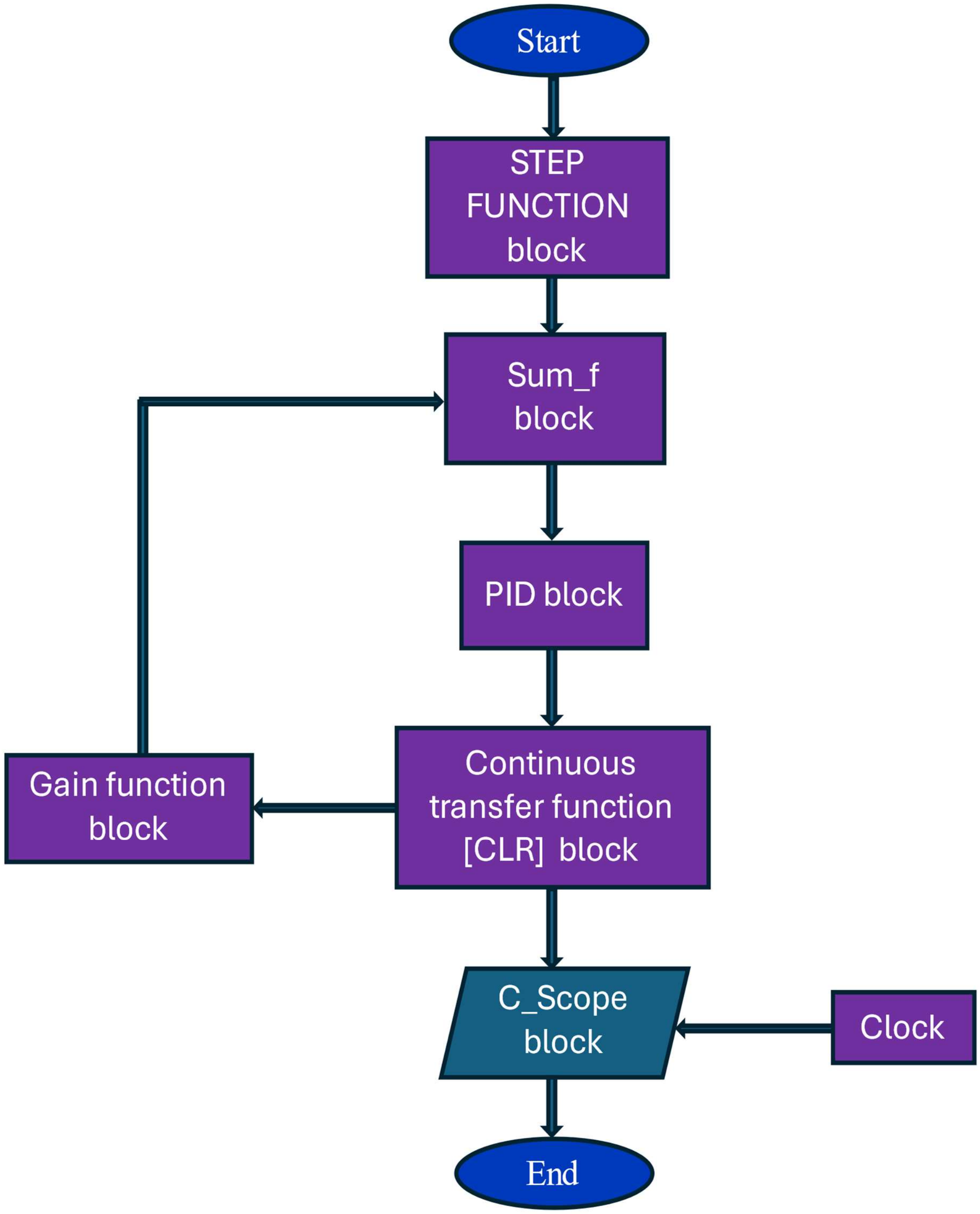


Figure- The Block diagram of the Plant – Actuator system

4. Flowchart


Start
STEP FUNCTION block
Sum_f block
PID block
Continuous transfer function [CLR] block
Gain function block
C_Scope block
Clock
End

5. Software/Hardware used

Operating System: Windows 11

Toolbox: None

Hardware: Personal Computer with 12th Gen Intel Core Processor, 16GB RAM

Software: Xcos, Scilab Version: 2024.0.0 and Microsoft Office 2021

6. Procedure of execution

I. Launch the Scilab Desktop on the computer.

II. Open the Xcos file " PID_aircraft_Xcos.zcos".

III. Run the model by selecting the triangular icon of "Run" in the ribbon.

IV. Observe the plot obtained on graphic window.

V. Repeat the simulation multiple times for different values of gain to obtain most suitable plot.

7. Result

The PID controller setup is opened in Xcos and the model is run with different gain magnitudes. The diverse plots thus obtained, were analysed for examining effect of error signals over the pitch.

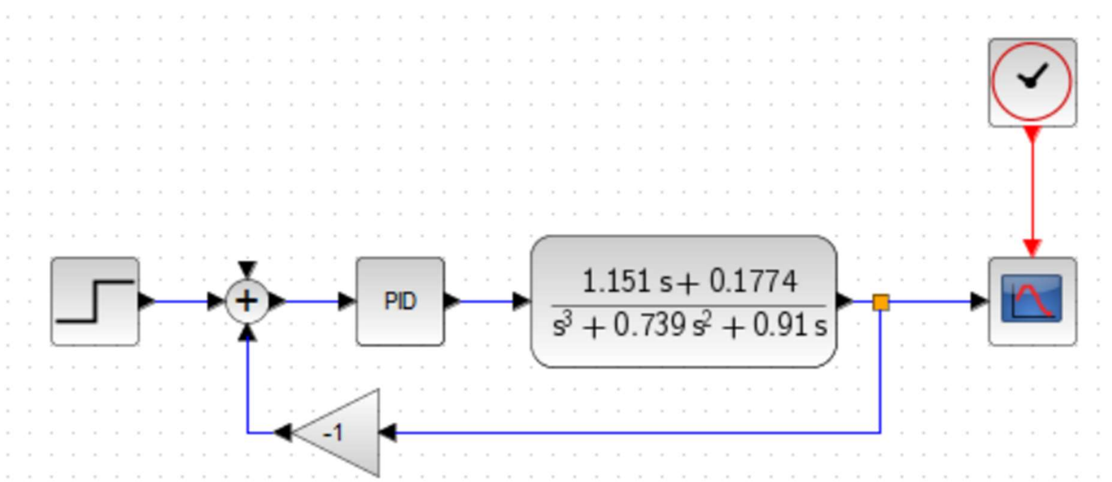


Figure- Xcos PID Controller system

Initially, the value of negative gain is maintained as less as possible. Nevertheless, the error signal keeps rising. This is not good for the aircraft pitch as drastic oscillations can interrupt in landing of the aircraft or even harm the system.

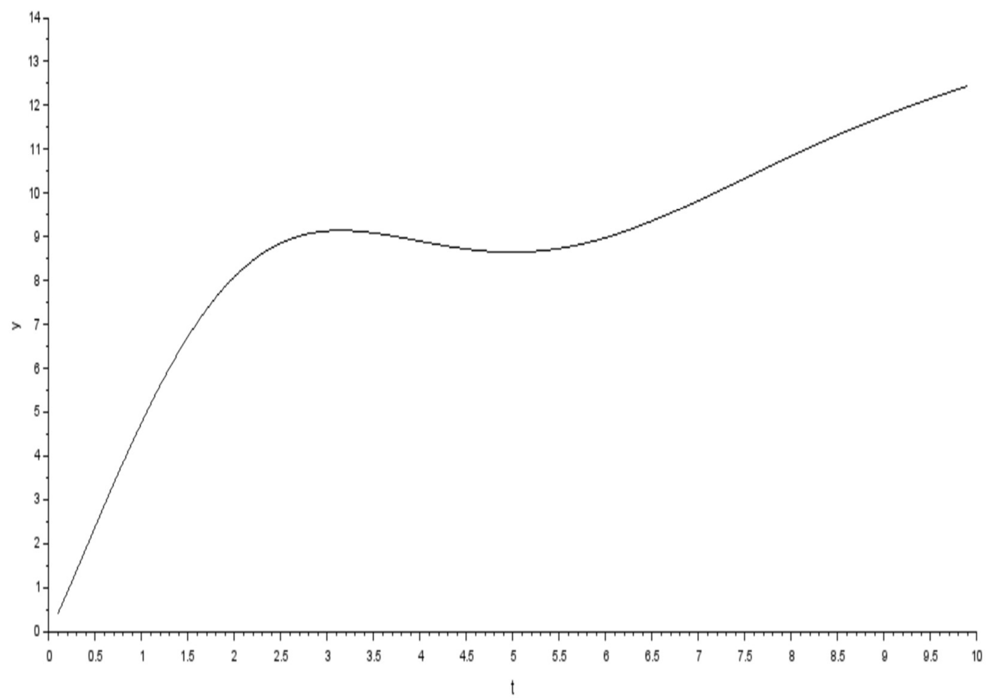


Figure- Retaliation of Aircraft pitch control with a gain of -0.005

As compared to the above scenario, some improvement is observed with the gain -1. In this case the oscillations first rise, but halt after some time. But this is not sufficient for reliable pitch control. Hence, further simulations are proceeded.

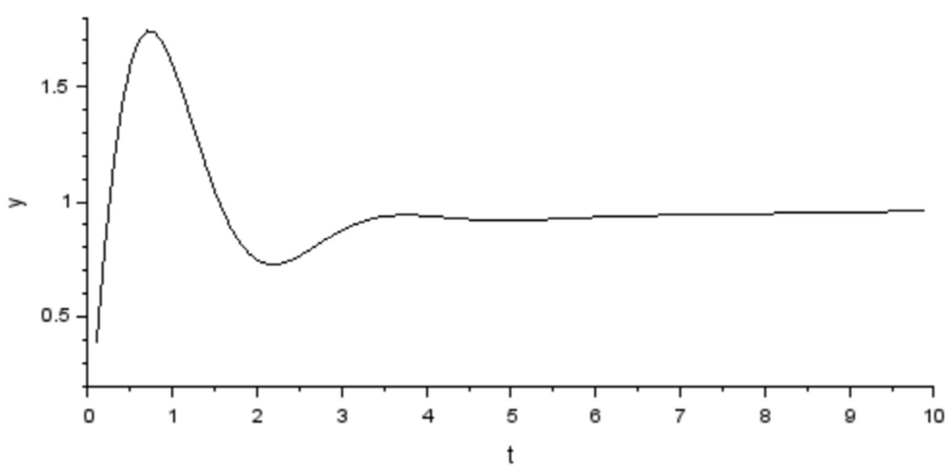


Figure- Retaliation of Aircraft pitch control with a gain of -1

Finally, it is found that the most favourable oscillations are obtained when the gain is -2. This is because maximum value of the function becomes 1.1 here. Less than this gain maxima are not easy to achieve realistically. Furthermore, it is more convenient than the previous gain as the constancy is attained even below 1.

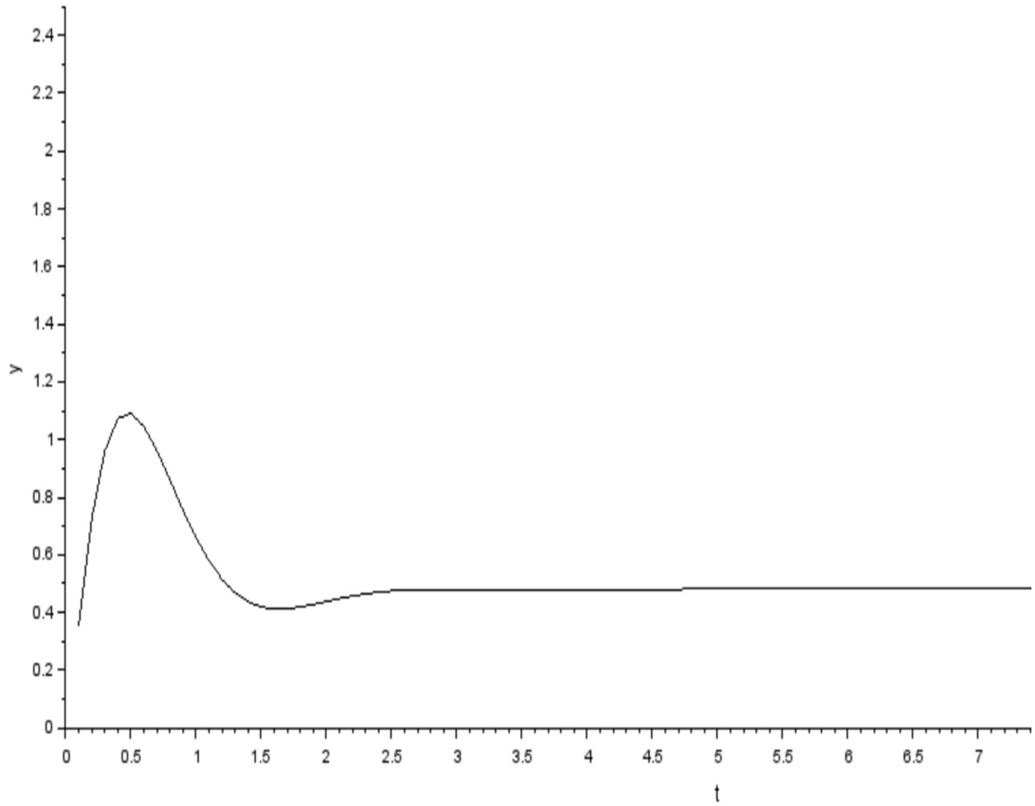


Figure- Retaliation of Aircraft pitch control with a gain of -2

In conclusion, the simulation proved to enhance the stabilization of aircraft pitch-motion control successfully. It not just ensures safe operation of the airplane, but also reduces time and cost for doing practical experiments over the elevator.

8. References

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