ELE2038: Design of an aircraft pitch controller **QUB, 2024/25**

Group Assignment

Important: Before you start, read the instructions

1 Problem statement

You need to design a control system for the pitch of an aircraft. The system is illustrated in Figure 1. The manipulated input is the *elevator deflection angle*, δ; changing the deflection rate affects the pitch of the aircraft. In Figure 1, α denotes the *angle of attack*, which is the angle between the longitudinal axis of the aircraft and its velocity vector. The *pitch angle* of the aircraft is denoted by θ. The *pitch rate* is denoted by r.

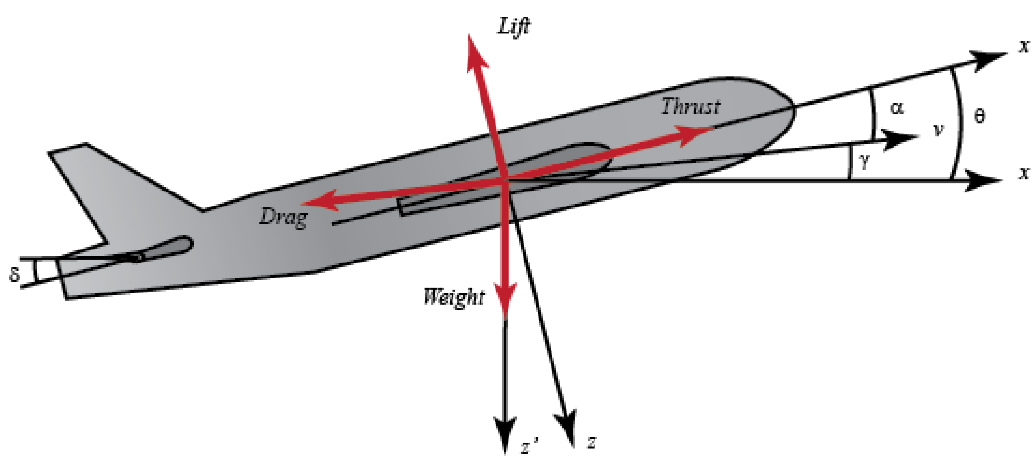

Figure 1: Illustration of an aircraft with its pitch angle, θ, the angle of attack, α, and the deflection angle of the elevators, δ. The angle $\gamma = \theta - \alpha$ is known as the *slope*.

The system dynamics is described by the following system of differential equations

$$\dot{\alpha} = -0.31\alpha + 57.4r + 0.232\delta, \tag{1a}$$
$$\dot{r} = -0.016\alpha - 0.425r + 0.0203\delta, \tag{1b}$$
$$\dot{\theta} = 56.7r, \tag{1c}$$

where all quantities are in SI units[1]. In addition, the deflection angle of the elevators is controlled by an actuator whose dynamics has been found to be of the first order with unit static gain and a time constant of 14.5 ms. The sensor has the transfer function

$$G_m(s) = \frac{\exp(-0.0063s)}{0.0021s + 1}. \tag{2}$$

[1] In Equation (1), α, θ and, δ are measured in radians — not degrees — and q is measured in radians per second.

The task of your team is to:

1. **Present a complete analysis of the given dynamics**: Your report should include a detailed study of the properties of the open-loop dynamics and your results should be accompanied by appropriate plots. Your report must also include a block digram of the control system.

2. **Design an appropriate controller for the system**: Your controller needs to satisfy the standard requirements for a closed-loop control system. You need to make sure that the controlled system is BIBO-stable and that there is zero offset. Additionally, you may want to check how your closed-loop system will behave in presence of *disturbances*. You need to consider what sort of possible disturbances may be present. You should tune your controller to achieve reasonable *stability margins* and of course to exhibit a desirable (not highly oscillatory, not overly slow, not too aggressive) closed-loop behaviour.

2 Assessment procedure

You will need to upload a **two-page technical report** to Canvas summarising your methodology and your results. Your report needs to include a link to your code (preferably on GitHub). On the 28th of March I will meet with each team separately for 10 minutes and I will ask you a few questions on your proposed design. The attendance is compulsory for all team members. The meetings will take place in my office in room 07.013 on the 7th floor of the Ashby building. The exact time will be announced on Canvas in the next few days.