Control of Autonomous Systems – Autumn 2025

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Exercise Session 3

1. Consider the pitch dynamics of a Dakota Piper plane represented by the following transfer function

$$P(s) = \frac{\theta(s)}{\delta_e(s)} = \frac{160(s+2.5)(s+0.7)}{(s^2+5s+40)(s^2+0.03s+0.06)} \tag{1}$$

where θ is the pitch angle of the plane and δ_e is the elevator angle, both angles being expressed in degrees. Use the command `tf` to setup this system in Matlab. Verify whether this system is stable or not. Then, display the Bode plot (command `bode`).

2. Implement system (1) in Simulink using a Transfer Fcn block and apply a sine wave to its input. See what you obtain at the output. Then, apply a sine wave at the frequency where the system is most resonant.

3. Apply now a step input to system (1). Comment?

4. What is the zero-frequency gain of the system?

5. Implement and tune your own PID controller (ie not the one directly available as a block) so that the pitch angle follows a desired reference (for tuning, do **not** use the Ziegler-Nichols rule).

6. Compute the transfer function of the system in closed-loop with your PID controller (the computation can either be done manually or by using the command `feedback`). Is this new system stable? Compare this with system (1) by itself.

7. Display the Bode plot of your system in closed-loop, and compare with the Bode plot you obtained in question 1 (resonance, zero-frequency gain).

8. In this question, we assume that the model of the plane is not known to the control engineer. Hence we need to estimate this model. To do so, first use a Matlab function block (if you want) and create a small program to construct an input signal made of a sum of 27 sine waves (from 0.1 to 0.9, from 1 to 9, from 10 to 90), with different and possibly randomly generated phases. Apply this input signal to system (1) in open-loop, ie without PID controller. Then, use two “To Workspace” blocks to save the input and the corresponding output. In the workspace, use the command `tfest` to identify the “unknown” transfer function of the Dakota Piper. Finally, display the corresponding Bode plot and compare it again with the original one obtained in question 1.