Project 5 - Altitude control of Cessna Citation 500 aircraft

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Abstract

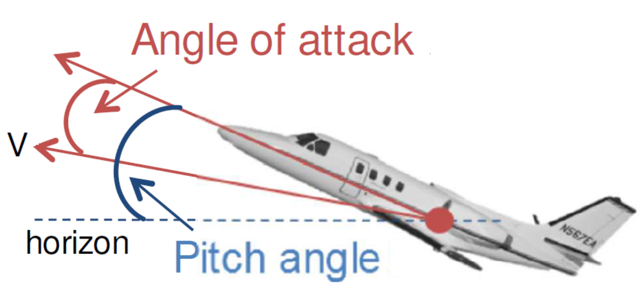
The aim of this practice is to design a stabilizing controller for Cessna Citation 500 aircraft. The model taken from [1] is linearized at an altitude of 5000 m and a speed of 128.2 m/sec:

$$\begin{cases} \dot{x}(t) = Ax(t) + Bu(t) \\ y(t) = Cx(t) + Du(t) \end{cases}$$

$$A = \begin{bmatrix} -1.2822 & 0 & 0.98 & 0 \\ 0 & 0 & 1 & 0 \\ -5.4293 & 0 & -1.8366 & 0 \\ -128.2 & 128.2 & 0 & 0 \end{bmatrix} \quad B = \begin{bmatrix} -0.3 \\ 0 \\ -17 \\ 0 \end{bmatrix}$$

$$C = \begin{bmatrix} 0 & 1 & 0 & 0 \\ 0 & 0 & 0 & 1 \\ -128.2 & 128.2 & 0 & 0 \end{bmatrix} \quad D = \begin{bmatrix} 0 \\ 0 \\ 0 \end{bmatrix}$$

where the states are: x_1 the angle of attack, x_2 the pitch angle, x_3 the pitch rate, x_4 the altitude as shown in the figure below.
The input u corresponds to the elevator angle, which is limited to $\pm 15^o$ (± 0.262 rad), and the elevator slew rate is limited to $\pm 30^o$/sec (± 0.524 rad/sec). These are limits imposed by the equipment design, and cannot be exceeded. For passenger comfort the pitch angle is limited to $\pm 20^o$ (± 0.349 rad).
Warning: to avoid a recently found bug in **quadprog**, you have to use the following option **optimset('LargeScale','off')**. Check the help in **quadprog** to see how you pass options.
Once you have the MPC code running, you can set the option '**display**' to '**off**'. This will make the simulation a bit faster.



Exercises

1. Design a stabilizing LQ controller for arbitrary initial conditions chosen by the user (Hint: **dlqr** and **c2d** may be helpful MATLAB commands).

2. Use the closed loop simulations with the LQ controller to come up with reasonable value for the sampling time **Ts**.

3. Create an MPC controller without any active constraints. Make sure that it is consistent with the control law from LQR (they should coincide if the prediction horizon **N** is sufficiently long).

4. Add control constraints. Is it still working? Does it better than the LQR? How does it behave when you try to make it more aggressive?

5. Add the constraint on the pitch angle (state *x2*).

6. Add over-shot constraint on altitude (state *x4*, might require addition of back-up plan if problem is infeasible).

7. Add control rate saturation constraints. To add rate constraints, you need the previous control input.

8. Suppose that the state is not measurable, then study the effect of the introduction of a Kalman filter in the schema with the MPC on the overall performances.

References

[1] J. M. Maciejowski: *Predictive Control with Constraints*, Pearson Education Limited, 2002