ASEN 5519 Small UAS Guidance and Control

Exam 1 Assignment

Assigned: Tuesday, March 14, 2023

Due: 11:59 PM, Thursday, March 23, 2023

The following take-home midterm exam must be completed individually by each student. Students may use their notes, the textbook, and other resources they have. Students are NOT allowed to consult with one another or provide each other with assistance. I will be available via email to answer any questions regarding the exam and will do my best to email any necessary clarification to the entire class in a timely manner. DO NOT USE the course Slack channel to ask questions about the exam.

The exam is to be submitted via Gradescope no later than **11:59 pm on Thursday, March 23, 2023**. If needed you may submit a scanned copy of work done by hand, however I prefer an electronic copy (i.e. a pdf from Word, LaTex, etc). You may submit code as well, however, you will be judged on the written submission.

Problem 1 (18 pts)

An aircraft has state vector

$$\mathbf{x} = [100\text{m}, 200\text{m}, -1655\text{m}, -12^\circ, 9^\circ, 140^\circ, 15\text{m/s}, -3\text{m/s}, 1\text{m/s}, .08^\circ/\text{s}, -0.2^\circ/\text{s}, 0^\circ/\text{s}]^T$$

1. (6 pts) What is the time rate of change of the pitch angle?
2. (6 pts) Let the inertial wind velocity in inertial coordinates be $\mathbf{w}_E^E = [0 \quad 1 \quad -2]^T$ m/s. What is the angle of attack of the aircraft?
3. (6 pts) Let $\dot{u}^E = 0.04$ m/s^2, $\dot{v}^E = 0.02$ m/s^2, and $\dot{w}^E = 0.05$ m/s^2. Assume the motor thrust is applied in the body-x direction. What is the component of the aerodynamic force in the body-z direction?

Problem 2 (12 pts)

Justify your answers to all problems.

1. (6 pts) TRUE or FALSE: If a total energy control system (TECS) is implemented on an aircraft and the throttle is used to keep the total energy constant, feedback control on the elevator will change the airspeed of the aircraft while keeping the height constant.
2. (6 pts) TRUE or FALSE: The linear design models can only be derived for an aircraft with stable modes.

Problem 3 (10 pts)

Consider the control approach for altitude hold using commanded pitch presented in Lecture 8. What is the equation that describes the overall control law for the elevator angle for this approach?

Problem 4 (24 pts)

The files on the course web site titled `AerosondeLinearModel.mat` and `AerosondeLinearModel.ascii` contain the linear model for the Aerosonde UAS corresponding to the trim definition $V_a = 25$ m/s, $\gamma = 0$ deg, and $h = 200$ m. The files also contain the trim state (`aircraft_state0`) and trim control surfaces (`control_surfaces0`) for the aircraft. For the matrices the state and input vectors correspond to:

$$\mathbf{x}_{lon} = \begin{bmatrix} \overline{u} & \overline{\alpha} & \overline{q} & \overline{\theta} & \overline{h} \end{bmatrix}^T \qquad \mathbf{u}_{lon} = \begin{bmatrix} \overline{\delta}_e & \overline{\delta}_t \end{bmatrix}^T \tag{1}$$

$$\mathbf{x}_{lat} = \begin{bmatrix} \overline{\beta} & \overline{p} & \overline{r} & \overline{\phi} & \overline{\psi} \end{bmatrix}^T \qquad \mathbf{u}_{lat} = \begin{bmatrix} \overline{\delta}_a & \overline{\delta}_r \end{bmatrix}^T. \tag{2}$$

1. (4 pts) Determine the natural frequency and damping ratio of the short period and phugoid modes of the aircraft.

2. (4 pts) Calculate the mode shapes (eigenvectors) for the short period and phugoid modes using the 5-state longitudinal state space model.

3. (4 pts) Simulate the initial condition response of the linear (5 state) longitudinal model (e.g. using `initial.m`) using the real components of the phugoid eigenvector scaled such that the initial pitch angle perturbation is 3 degrees.

4. (6 pts) Simulate the initial condition response of the full nonlinear system such that the initial perturbations from the trim condition are the same as those used in Part 3. Plot the results of Part 3 and Part 4 on the same figure. How do the results compare to one another? Is the linear model a good approximation of the nonlinear behavior? (Note: the control surfaces are fixed at their trim values for this simulation.)

5. (6 pts) Repeat Part 3 and Part 4 while scaling the initial condition such that the initial pitch angle perturbation is 20 degrees. Is the linear model still a good approximation of the nonlinear behavior?