ASEN 5519 Small UAS Guidance and Control

Exam 2 Assignment

Assigned: Friday, April 28, 2023

Due: 7:00 PM, Wednesday, May 10, 2023

The following take-home 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 **7:00 pm on Wednesday May 10, 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)

Justify your answers to all problems.

1. (6 pts) TRUE or FALSE: A pitot-static system is used to measure the airspeed of an aircraft. The system uses the density of air at sea level in its computations. The airspeed reading output from the sensor system will be greater than the true value.

2. (6 pts) TRUE or FALSE: If an aircraft has no sideslip ($\beta = 0$), then the yaw angle and course angle must be equal.

3. (6 pts) TRUE or FALSE: In order to stabilize an aircraft to a straight, level trim condition, an autopilot must have an estimate of the full aircraft state.

Problem 2 (20 pts)

You are part of the team responsible for validating several sensors on the Tempest UAS prior to deploying on a storm chasing mission. After looking at some flight test results, the project leader is concerned that two sensors are not performing correctly. In order to check these sensors, you take the aircraft to the field and obtain independent measurements of the aircraft state:

$$\begin{aligned}\mathbf{x} = \; & [500\text{m} \quad 300\text{m} \quad -1655\text{m}, \cdots \\ & 6^\circ \quad 9^\circ \quad -75^\circ, \cdots \\ & 21\text{m/s} \quad -1\text{m/s} \quad 4\text{m/s}, \cdots \\ & 0.2^\circ/\text{s} \quad -1.4^\circ/\text{s} \quad 4.8^\circ/\text{s}]^T.\end{aligned}$$

1. (10 pts) **Accelerometer:** There is a 3-axis inertial measurement unit (IMU) mounted in the Tempest aircraft. A student believes they aligned the acclerometer and rate gyros such that the sensor axes correspond to the body axes of the aircraft. Another sensor is used to measure $\dot{u}^E = 0.1$, $\dot{v}^E = -0.06$, and $\dot{w}^E = -0.4$. The accelerometer returns the measurement $\mathbf{y}_{accel} = [9.75 \quad 1.62 \quad 0.67]^T$. Is the accelerometer mounted correctly? Justify your answer.

2. (10 pts) **Wind Angles:** A wind sensing system measures the airspeed, sideslip angle, and angle of attack and then derives the wind velocity using these wind angles and the aircraft state. When in the state given above, the sensing system measures the wind in body coordinates to be $\mathbf{w}_B^E = [12.2 \quad -0.2 \quad 2.3]^T$ m/s. In order to validate the sensor system, you obtain a second measurement of the wind in inertial coordinates that you know is highly accurate, $\mathbf{w}_E^E = [0 \quad 6 \quad 0]^T$. Based on this measurement, which sensors (airspeed, sideslip angle, angle of attack) in the wind sensing system on the Tempest are not functioning properly, i.e. have errors. Justify your answer.

Problem 3 (32 pts)

Students may use any autopilot function (written by you or provided by me) to complete this problem.

1. (8 pts) Create a nonlinear guidance model of the behavior of the TTwistor aircraft using the autopilot you chose for this problem. Use Kinematic Guidance Algorithm 1A from Lecture 11 to describe the response of the combined aircraft and control system to course angle, height, and speed commands. In particular, determine the parameters $b_{\dot{\chi}}$, b_{χ}, $a_{\dot{h}}$, $b_{\dot{h}}$, b_h, and b_{V_a} such that the guidance model gives a similar response to the full system response to a command. Provide plots of the response of each variable (height, course angle, and speed) that compares the guidance model response to the full model response. Hint: Determine the parameters for each equation separately. Start from a trim condition (not on the ground) and command step changes for each variable separately. For the height and course angle equations the commanded rates will be zero.

2. (6 pts) Implement a guidance algorithm of your choosing for following a straight line at a constant speed. Demonstrate that your implementation works by simulating the system using a first-order inner loop guidance model such that the input to the model is the velocity vector, i.e. $\dot{\mathbf{p}}_E^E = \mathbf{u}$.

3. (6 pts) Demonstrate that your algorithm from Part 2 works, and tune it if needed, by simulating the system using the kinematic guidance model developed for Part 1 of this question. You may have to convert the output of the guidance algorithm into the appropriate commands for this kinematic guidance model.

4. (6 pts) Demonstrate that your implementation works by simulating the response of the complete system, i.e. with autopilot and controller.

5. (6 pts) Compare the responses of all three simulations (Parts 2-4) on the same plots. For this comparison you only need to plot the airspeed, course angle, and height.

Provide sufficient discussion and plots of your simulations to demonstrate that your implementation works. Be sure to use enough different initial conditions.