Final Project

**MAE 521 Multivariable Control and Design**

# Spring 2017

**Due Date : April 26 , 2017, Wednesday at Noon**

**Aircraft Pitch Pointing and Vertical Translation Control**

Suppose an aircraft model as:

+ **d** (1)

 (2)

where **x** is the state vector, **u** is the control vector, and **y** is the output vector as:

, , and  (3)

where *nzp* is normal acceleration at the pilot’s station. **d** is disturbance input.

In addition, A and B are described as follows:

 and  (4)

Also, the relation for the normal acceleration, *nzp* in the output vector is set by

 (5)

which define the output matrix, **C**.

Your job is to design a set of feedback systems that will be stable and will exhibit a “satisfactory” performance. (I will leave it up to each individual to define what it means to have a “satisfactory” performance, but traditional four areas of performance need to be discussed: Command Following, Disturbance Rejection, Insensitivity to Noise, and Robustness to parameter changes.)

Part 1 – Examine the controllability and observability for the MIMO system and each of the four SISO systems (all combinations of inputs and outputs). Observable and controllable

Part 2 – Examine the open-loop system response to an impulse disturbance on angle of attack and step input change on both elevator and flaperon deflections, separately.

Part 3 – Design a full-state feedback system , where the feedback matrix *F* is 2x5 feedback gain matrix. Make sure to minimize the steady-state error and pay close attention to the cost of control. Also, when assigning feedback gains, try to shape the eigenvector directions for the first and the third states as follows:

, where *X* denotes “don’t care” entries.

Part 4 – Examine the Singular Values and Decomposition of your feedback system in Part 3 and comment on its min-max behavior. Pay particular attention to the normal acceleration output and make sure that it does not go beyond 3.0 g, which becomes uncomfortable for the pilot.

Part 5 – Suppose that the flaperon control failed during the pitch motion. With only the pitch control, design a feedback control system that will sacrifice the least from the performance of the MIMO system in Part 3. Discuss in detail the limits of this approach, if any, compared to the system in Part 3.

Part 6 – Design an observer for the system (either full-state or reduced order) using output measurements of pitch rate and pitch attitude. Make sure that your observer dynamics is at least five times faster than your system dynamics.

Part 7 – Using the feedback of the observed states in Part 6, design a MIMO feedback system much like in Part 3 and compare the performances of the two systems. Examine the ‘cost’ involved in each of the approaches and make recommendation on which is ultimately the better design to use.

**Project Report**

The project report should, in general, include four parts: **1.** **Problem Definition, 2. Modeling, 3. Solutions and Approaches, and 4. Evaluation**.

In the evaluation section, provide the best critique of your designs and the assessment as to how you could have done it differently to further improve the results.

**Requirements:**

* **MatLab plots and codes are to be used whenever performances are discussed**. All MatLab codes have to be provided in the appendix section. Each figure has to be appropriately **titled and numbered**, and there has to be corresponding comments and/or discussion as to its result IN THE MAIN TEXT. No figure **without discussion** of the result will be considered.
* **No hand-written report** is allowed in the main body of the project report. Hand-written derivation and calculation are allowed but should be put in the appendix section.
* For comparison of performances, a **use of tables** is recommended.
* The report has to be **bounded and neatly covered** front and back. (DE students may submit a scanned version of the final report to EOL.)

Reference:

K. M. Sobel and E. Y. Shapiro, “Eigenstructure Assignment for Design of Multimode Flight Control Systems,” IEEE Control Systems Magazine, 5(2), May 1985, pp 9-15.