SD 352 – Project 2

March 6, 2009
Due date: April 3, 2009.

The System:

Pilots flying at night or in weather where they cannot see the horizon rely on information from instruments to help them fly the airplane. A representative model of this kind of activity is shown below

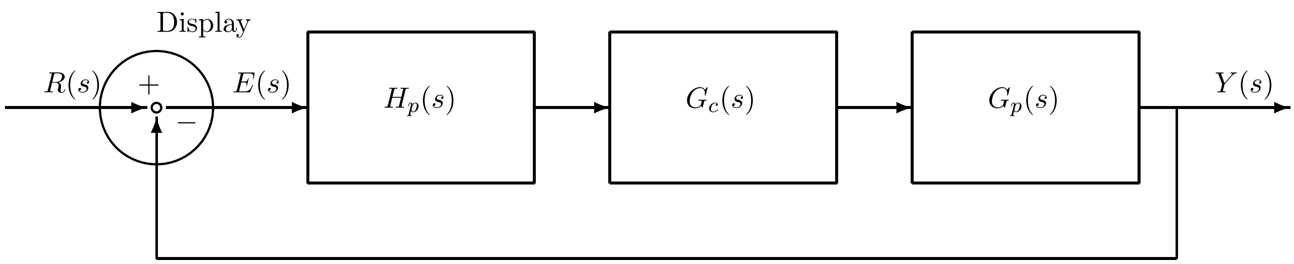

Figure 1: System block diagram.

where

1. $R(s)$ represents an unknown input signal which the pilot attempts to track.
2. $E(s)$ represents the output error for the tracking task.
3. $Y(s)$ represents the appropriate aircraft attitude variable; it might be pitch angle, yaw angle, bank angle, altitude or heading direction. Specifically which it is does not matter for this project.
4. The transfer function that describes the appropriate part of the aircraft motion is given by:

$$G_p(s) = \frac{-10.45(s + 0.9871)}{(s + 1.204 + j1.492)(s + 1.204 - j1.492)}$$

5. The transfer function that describes the pilot is:

$$H_p(s) = \frac{K_p \exp(-sT)}{T_N s + 1}.$$

The parameter T is a pure time delay that represents the muscle control functions of the cerebellum and the neuromuscular delay. We will assume a delay time of $T = 0.2$ s. (Realistic values for T are usually such that $0.12 \leq T \leq 0.30$.)
The time constant of the pole (T_N) relates to physiological, largely muscular, characteristics

of the pilot and is often on the range $0.1 \leq T_N \leq 0.2$. We will assume a value of $T_N = 0.1$. The pilot gain K_p varies with task and display parameters but is most often on the range $1 \leq K_p \leq 100$. We will assume that $K_p = 20$.

6. A control element that will yield satisfactory closed loop system performance is needed between the aircraft dynamics and the pilot; the transfer function of that control element is $G_c(s)$.

7. The pilot gets input from the Display as illustrated below;

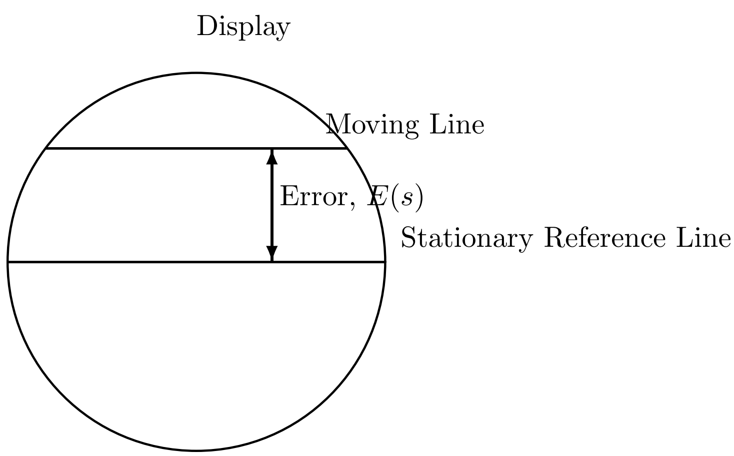

Figure 2: Display.

The Task:

Design a lead controller, a lag controller, a lead-lag controller, a pure gain controller or some combination of them for the aircraft so that the following objectives are met.

- The system is closed loop stable; with
  1. a gain margin of 10 dB $\pm$ 3 dB.
  2. a phase margin of $45° \pm 5°$.
- The tracking error is minimized for all input signals that have frequencies less than the cross over frequency.
- Minimize the sensitivity of the dominant closed loop poles to variations in T_N.

Completely specify the control parameter values and fully explain why you chose the design that you did. You may use *MAPLE*, *MATLAB*, etc. as computational aids.

There is no single correct answer. The grade will be based on the correctness and thoroughness of the design and analysis presented in the report. Part of the grade will also be assigned for the engineering quality of the report. Reports may be neatly handwritten.

The Project Grading: *or* What I'm Looking for in the Report

- Title page with the date and the group members names and ID numbers on it.
- Derivation and justification of your time domain performance specifications.
- A concise rendering of those objectives.
- A brief discussion of the scope of the design; what limitations are there and what assumptions have you made and why.
- A clear and thorough discussion of the design and analysis process complete with comments and observations on the design decisions and trade-offs that you made in order to reach your final design.
- A concise description of your final design (ie what is the controller configuration and what are the gain values?)
- A thorough presentation of the performance of your chosen design with respect to the stated control objectives.
- Appropriate figures where necessary.
- Thoroughly cited references.

You are being graded on your understanding of time domain and frequency domain design concepts and your ability to relate them together. There should be evidence of a thoughtful analytical design and analysis process that has an understood goal. Each item listed above does not have to be very long. Be complete, be concise.