University of Glasgow

James Watt School of Engineering

Simulation of Engineering Systems 3

Assignment: Instrument Landing System Lateral Beam Guidance System

Part 2: Model & Simulation Based Design

Aim

Part 2 of the Simulation of Engineering Systems 3 Assignment involves the model based design of the control system for the Instrument Landing System (ILS) Lateral Beam Guidance System simulation that you developed in Part 1 of the assignment. This part of the assignment involves improving the controller design for this system used in the Matlab version of your simulation. Once your control system is making your simulated system perform better, you should study the effects of changing a key system parameter through the interpolation of data. For the ILS Lateral Beam Guidance System the key parameter is the range to the airfield, R. This document provides an overview of the control system used in this simulation followed by the Assignment Specifications for this final part of the assignment.

Introduction

The initial design of the ILS Lateral Beam Guidance System, which was developed in Part 1 of this assignment, was not very good i.e. very oscillatory. The reason for this was that the design of the controller (called the coupler in this case) was not suitable for this system. Therefore, the first stage of Part 2 of the assignment involves the redesign of the control system so that the performance of the overall system is much improved.

The second stage of Part 2 of the assignment is to test the redesigned control system by varying a key parameter that has been constant in the earlier stages of this assignment. In the case of the ILS Lateral Beam Guidance System the key parameter is the range to the airfield R. This range represents the longitudinal displacement of the aircraft and the variation of this value represents approximate changes in the longitudinal dynamics. In this assignment the variation in values is achieved by interpolating data points that represent the range at specific time points.

Problem Specification

The Assignment Specification Document for Part 1 indicated that the Lateral Beam Guidance System produces the required aileron commands to generate a coordinated banking manoeuvre that positions the aircraft within the localiser beams. It achieves this by combining the roll control system with the heading control for the aircraft. The total system is shown in Figure 1.

From Figure 1 it can be seen that the Lateral Beam Guidance System takes a value for the reference angular error between the aircraft and the centre line, λ_{ref}, and compares it with the actual error, λ. In this case the values for λ_{ref} is taken to be zero. The comparison of these values is performed by the *coupler* which is a control system. The first control system design, used in Part 1 and at the beginning

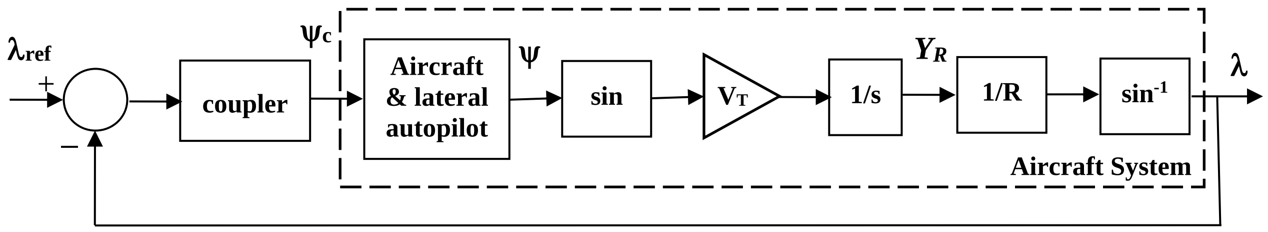

Figure 1: Lateral Beam Guidance System

of Part 2 is a proportional control system i.e.

$$\psi_c = G_c\left(\lambda_{ref} - \lambda\right) \tag{1}$$

Here G_C is the controller's proportional gain. The performance of this control system can be improved by changing the gain value for G_C. Another way to improve performance is to add an integral term into the control system i.e. it then becomes a PI controller of the following form:

$$\psi_c = G_c\left(1 + \frac{K_I}{s}\right)\left(\lambda_{ref} - \lambda\right) \tag{2}$$

Here K_I is the integral gain, and s is the Laplace operator. The resulting commanded heading angle ψ_c is then fed into the lateral autopilot to generate an appropriate heading for the aircraft to follow (ψ).

Assignment Specifications

The main purpose of this second and final part of the assignment for this course is to redesign and test the control system so that the ILS Guidance System performs better. This involves completing the following steps:

Control System Design & Implementation

1. Using your MATLAB script-based simulation and the parameter values in Appendix A, investigate the effect of varying the coupler gain G_c on the performance of the Lateral Beam Guidance System.
2. In order to improve the performance of the coupler further it is normal practice to include an integral term within the coupler of such a Lateral Beam Guidance System. Use your MATLAB simulation and the best value for G_c (found in step 1 above) to investigate the effect of introducing the integral term into your coupler and varying the associated gain K_I. Is the performance of this system improved further?

Interpolation

3. So far the longitudinal dynamics of the aircraft have not been considered. One way to incorporate these dynamics is to vary the range of the aircraft, *R*. Within your MATLAB simulation use the data presented in Table 1 (Appendix B) to represent the change in the range of the aircraft as time progresses by using Newton's Divided Difference interpolation method. Firstly, use this method to calculate by hand the interpolating polynomial that represents the range values that connect the data points in Table 1.
4. Implement the resulting interpolating polynomial within your MATLAB simulation code and analyse the effect of forward motion on the Lateral Beam Guidance System. **Do not** use the in-built Matlab interpolation functions i.e. write your own code.

Report Part 2 Specifications

Once you have finished this part of the assignment, complete the report form for the second part of the assignment. This report form should outline the redesign of your control system for your model, the interpolation of the range in your simulation and your analysis of this system in each case. The part 2 report form template can be found on the Moodle page for this course. Your completed report for this final part of the assignment must not exceed 5 pages in length and it should be submitted through the Moodle submission portal for part 2 of the assignment before 4:30pm on **6th December 2024**.

Appendix A: Parameter Values

The following parameters are typical for the Lateral Beam Guidance System:

$B_{SM} = 0.7$
$g = 9.81$ m/s^2
$G_c = 45.5$
$J_M = 0.006$
$K_A = 1.2$
$K_D = 0.9$
$K_E = 0.9$
$K_P = 52.5$
$K_R = 1.2$
$K_T = 1.7$
$K_V = 1.3$
L_A= 0.2H
R_A= 10 Ω
T_A = 2.0 seconds

Typical initial conditions are:

$\psi_o = -20°$
$\phi_o = 0°$
R_o = 6000m
Y_{Ro} = 150m
V_T = 55 m/s

Appendix B: Range Variation

The following table contains data points that describe how the range of an aircraft on ILS approach changes with time:

Table 1: Range Data

Time (s)	0	24	30	56	88	100
Range (m)	6500	5200	4000	3100	1900	430

Dr Euan McGookin
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