

University of Glasgow
James Watt School of Engineering
Simulation of Engineering Systems 3

Assignment: Position Control System of a Robotic Arm for Wind Turbine Blade Test

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 a Robotic Arm Position Control 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 Robotic Arm Position Control System the key parameter is the upper arm deflection angle, θ_U . 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 Robotic Arm Position Control 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 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 Robotic Arm Position Control System the key parameter is the upper arm deflection angle, θ_U . This deflection represents the motion of the upper arm and the variation in this value represents approximate changes in the dynamics of the upper arm. In this assignment the variation in values is achieved by interpolating data points that represent the upper angle deflection at specific time points.

Problem Specification

The Assignment Specification Document for Part 1 indicated that the elbow control system produces the required actuator rotation to move the forearm to a reference angle. It achieves this by comparing the actuator deflection angle, θ_M (radians), with the reference angle, θ_{Fref} (radians). This provides indirect control of the Forearm's deflection angle, θ_F (radians). A diagram of the total system is shown in Figure 1.

From Figure 1 it can be seen that the Elbow Control System uses the error difference between the reference deflection angle and the actuator's deflection angle. In this case the value for θ_{Fref} (the reference angle) is taken to be 55° . The reference deflection passes through the Reference Amp which is represented by a simple gain K_R . Also, the motor deflection is measured by the Actuator Sensor,

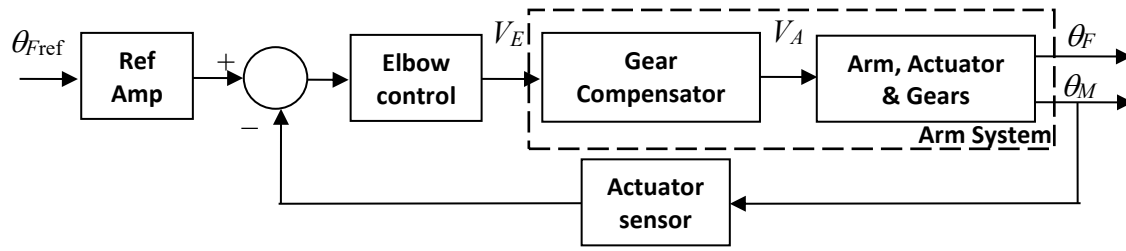


Figure 1: Elbow Control System

which is represented by a simple gain K_S . The comparison of these signals is performed by the elbow control system. The first control system design, used in Part 1 and at the beginning of Part 2, is a proportional control system i.e.

$$V_E = G_c \Delta\theta \quad (1)$$

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:

$$V_E = G_c \left(1 + \frac{K_I}{s} \right) \Delta\theta \quad (2)$$

Here K_I is the integral gain, and s is the Laplace operator. The resulting commanded voltage V_E is then fed into the gear compensator and the arm, actuator and gears configuration to generate an appropriate actuator deflection angle (θ_M).

Assignment Specification

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 Robotic Arm Control 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 Robot Arm System.
2. In order to improve the performance of the Elbow Control System further it is normal practice to include an integral term within the controller for such a Robot Arm 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 control system and varying the associated gain K_I . Is the performance of this system improved further?

Interpolation

3. So far the motion of the Upper Arm has been considered to be constant. One way to incorporate these dynamics is to vary the Upper Arm deflection, θ_U . Within your Matlab simulation use the data presented in Table 1 (Appendix B) to represent the change in the deflection of the Upper Arm 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 deflection values that connect the data points in Table 1.
4. Implement the resulting interpolation polynomial within your Matlab simulation code and analyse the effect of changing Upper Arm deflection values on the Robot Arm System you have designed. **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 5th December 2025**.

Appendix A: Parameter Values

The following parameters are typical for the Robot Arm and its Elbow Control System:

$$B_{SM} = 0.03 \text{ Nm/rad/s}$$

$$B_{SF} = 1.5 \text{ Nm/rad/s}$$

$$J_M = 0.003 \text{ kgm}^2$$

$$J_{GI} = 0.001 \text{ kgm}^2$$

$$J_F = 0.0204 \text{ kgm}^2$$

$$g = 9.81 \text{ m/s}^2$$

$$G_c = 3.5$$

$$GR = 1.5$$

$$K_E = 0.35 \text{ V/rad/s}$$

$$K_F = 0.5$$

$$K_G = 3$$

$$K_R = 1.2;$$

$$K_S = 1.3;$$

$$K_T = 0.35 \text{ Nm/A}$$

$$L = 0.12 \text{ H}$$

$$l_F = 0.35 \text{ m}$$

$$m_F = 0.5 \text{ kg}$$

$$R = 4 \Omega$$

Typical initial conditions are:

$$\theta_{Fo} = 7^\circ$$

$$\theta_U = 7^\circ$$

Appendix B: Angle Variation

The following table contains data points that describe how the Upper Arm deflection changes with time:

Table 1: Upper Arm Deflection Data

Time (s)	0	1.5	5.5	15	21	29
θ_U (°)	3.0	10.5	25.5	33	45	50