Mechatronics 5CCE2MCT Individual Coursework Project

Design & Analysis of a Two-axis Camera Gantry System

Module Instructors

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You are a mechatronics design engineer working for a firm that specialises in developing custom components for cinematic production. Your manager has sent you a parametric model of a two-axis gantry mechanism that was developed on a previous project. The gantry can move a camera both horizontally and vertically by rotating lead screw mechanisms attached to runners.

Brief

Your manager has asked you to design a new electromechanical actuation system composed of two geared DC motors that drive the leadscrew runners of the two-axis gantry system shown in Figure 1. She provided CAD components and Simulink starter models for the assembly, n.b. these files can be downloaded from the KEATS module page in the MATLAB project archive, `camera_gantry.mlproj`. She has also sent you a list of requirements that she has discussed with the customer appended to the end of this document. She encourages you to use the model as a starting point and welcomes further input on how to improve the mechanical design.

You are responsible for:

- specifying DC motor, power supply, and gearbox characteristics
- design a digital motor controller
- demonstrate the effectiveness of your design.

You are highly encouraged to brainstorm additional information about the context in which this mechanical system is to be used.

Deliverables

- a 3-minute video recording in which you present the motor and mechanism design to an engineering design team. The video should contain an animation of the mechanism and an overview of the Simulink model and results.
- a 1-page written report presenting the results of your design analysis with a maximum of 2 page of supporting figures in appendix
- a GitHub repository (https://github.kcl.ac.uk) where the project model and data can be shared with assessors.

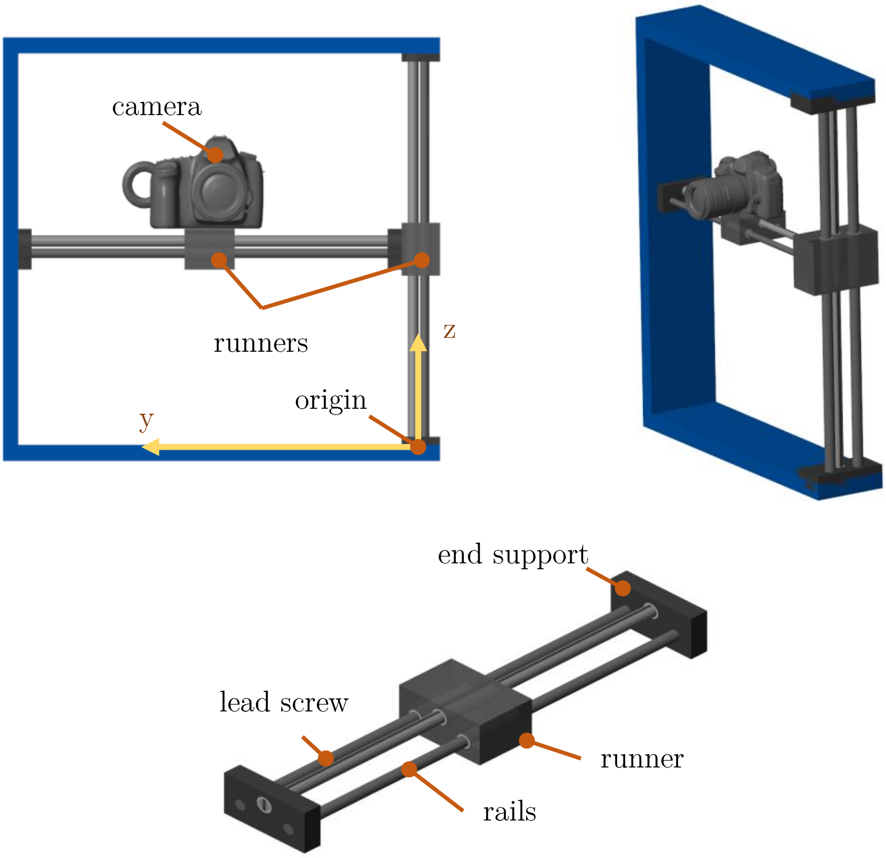

Figure 1: Camera Gantry System
`twoaxis_camera_gantry_start.slx`

Learning objectives

- Model the electromechanical system that actuates the gantry using a combination of mathematical, physical and data-driven methods and critique the choice of your modelling approach
- Specify component parameters based on a design analysis of system requirements
- Implement and tune a feedback controller to control position and speed of the mechanism
- Test the controller design against multiple loading scenarios
- Conduct a design space study to optimise system-level performance
- Report and justify recommended design implementation

Additional resources

You are encouraged to complete laboratory exercises of weeks 22-26 to develop skills in modelling and control of mechatronics systems.

Marking Criteria

Individual coursework submission accounts for 30% of module grade.

Your submission will be scored with regards to its merits in six core areas:

Area	Actions
Science & Mathematics (20 marks)	Justify modelling and control design approach Interpret design performance using mathematical and statistical techniques Critique choice for actuator and sensor characteristics and technology
Engineering Analysis (20 marks)	Apply engineering tools to solve the design task Conduct critical analysis to identify, classify and describe system performance compared to benchmark Adopt systems approach to improve on design Extract and evaluate pertinent data to solve unfamiliar problems
Engineering Design (20 marks)	Evaluate user needs and requirements Identify and work with design constraints and unknowns Communicate to a technical audience Deliver efficient, effective and robust design
Engineering Context (10 marks)	Identify and mitigate areas of risk
Engineering Practice (20 marks)	Demonstrate design effectiveness in the context in which the system is applied
Additional General skills (10 marks)	Demonstrate effectiveness, clarity and originality of communication

Requirements

Your manager discussed these requirements with the customer. You are welcome to add you own requirements to this initial draft.

Battery / Power Supply Requirements

week 1: quadcopter_start > scopes

Battery Voltage: 5-12V

Battery Capacity: 2-5 Ah

Battery Resistance: 1-10 Ω

Battery Lifespan: 15-20 minutes

DC Motor Requirements

Stall current: 0.2A-1A

Stall torque: 500 g.cm

No-load speed: 7000-21000 rpm

Motor Sensor Requirements

Hall Sensor Encoder with 24 counts per revolution

Gantry Lift Requirements

Lift a camera payload weight of 1-2 kg

Camera Safety Requirements

No collisions with frame

Fail safe mechanisms for operation and calibration

Maximum acceleration of 30 m/s^2

Camera Manipulation Requirements

Cover an area of 0.75 by 0.4 m^2

Maximum jerk of 10 m/s^3

System Response Requirements

week 1 part 2: robot_arm_notes

Rise time < 3-5 s per 100 mm travel **(time it takes to get from 10mm to 90mm)**

Settling time < 5-7 s per 100 mm travel **(time it takes for e to stay below 2mm)**

Overshoot < 2%

Undershoot < 2%

Steady-state error < 2% **measured y - target y = 2mm**

Tracking Response Requirements

Relative error < 3%

Absolute error < 3%

Detailed Mark scheme

Area	Actions	Marks
Science & Mathematics (20 marks)	Justify modelling and control design approach Interpret design performance using mathematical and statistical techniques Critique choice for actuator and sensor characteristics and technology	• Model a DC motor using a method of choice **(3 marks)** • Justify method choice **(3 marks)** • Deduce DC motor model parameters from requirements **(3 marks)** • Implement an appropriate controller for each axis **(3 marks)** • Attempt to improve controller architecture **(1 mark)** • Model an incremental rotational encoder **(3 marks)** • Comment on DC motor technology choice **(1 marks)** • Develop state estimation to convert rotational encoder readings to linear motion **(3 marks)**
Engineering Analysis (20 marks)	Apply engineering tools to solve the design task Conduct critical analysis to identify, classify and describe system performance compared to benchmark Adopt systems approach to improve on design Extract and evaluate pertinent data to solve unfamiliar problems	• Reference data to justify model parameters **(2 marks)** • Consider input saturation **(1 mark)** • Define a benchmark or target performance **(1 mark)** • Demonstrate improvement through a tuning method compared to the benchmark or target **(2 marks)** • Comment on model uncertainty and/or runs a sensitivity analysis **(2 mark)** • Demonstrate attempts at optimising system performance using formal methods, *e.g.* parameter sweep, response optimization or equivalent **(2 mark)**
Engineering Design (20 marks)	Evaluate user needs and requirements Identify and work with design constraints and unknowns Communicate to a technical audience Deliver efficient, effective and robust design	• Identify and evaluate trade-offs of using a reducing gearbox **(9 marks)** • Use appropriate technical language and engineering schematics to communicate design **(3 marks)** • Demonstrate attempts at optimising system performance using physical intuition **(2 mark)** • Attempts to improve mechanical parameters for design **(2 marks)**
Engineering Context (10 marks)	Identify and mitigate areas of risk	• Implement a strategy for calibration **(2 marks)** • Implement a control strategy to avoid collision with frame **(2 marks)** • Recognise increased cost of high-performance components and attempt to minimise cost **(2 marks)**

		• Identify sources of noise or disturbance in system **(2 marks)** • Model noise or disturbance in system **(2 marks)**
Engineering Practice (20 marks)	Demonstrate design effectiveness in the context in which the system is applied	• Address requirements provided **(10 marks)** • Identify additional requirements **(2 marks)** • Report on system response test(s) **(7 marks)** • List key design parameters using a table or engineering drawing **(1 mark)**
Additional General skills (10 marks)	Demonstrate effectiveness, clarity and originality of communication	• Report within single page and with less than 10 **grammatical errors (5 marks)** • Provide high quality schematics (diagrams, plots, or equivalent) to support your argument **(5 marks)**