ENG2006

UNIVERSITY OF EXETER
FACULTY OF ENVIRONMENT, SCIENCE AND ECONOMY

ENGINEERING

2022/ 2023

Industry 4.0
Coursework 2 - Robotics: design challenge - group project

Module Convenor: Dr Halim Alwi

Date set: 4th October 2022
Submission date: 31 March 2023 @ 1200
Return date: 3 May 2023 (TBC)
Method of submission and file type: eBART (zip)
s
This coursework comprises **45%** of the overall module assessment.
This is a **group** exercise, and your attention is drawn to the guidelines on collaboration and plagiarism in the College guidelines.
(See http://intranet.exeter.ac.uk/emps/studentinfo/studentservicesandprocedures/studentresponsibilities/ and http://intranet.exeter.ac.uk/emps/studentinfo/subjects/engineering/assessment/academicmisconduct/ for further detail).

This coursework contains multiple parts and the allocated marks for each part are specified as follows:

Part	Tasks	Group/ Individual	marks (%)
1	Design challenge	Group	65
2	Robotics practical lab	Group	20
3	Peer assessment	Individual	15
		Total	100

Part 1: Robotics design challenge using MATLAB/SIMULINK

The main brief

Imagine that you and your team run a company that design a robotic arm.

The customer requires a robot for an application in a car manufacturing industry. The main task is to develop a robot that can weld, by following a specific trace or shape.

Your team need to convince the customer (through a report) why they should invest in your design in comparison to other competitions in the market (your cohort).

Your report needs to consider at least the following (or any other relevant design considerations):

- The capability and the accuracy of the robot. (This can be through the overall design and the design of the controller),
- realistic conditions (such as gravity, the mass and moment of inertia of each of the robot arms)
- how good and convincing the model and the simulation of the robot arm is.

The report is meant to be read by a very busy Chief Technical Officer (CTO) of the customer's company. Note that the CTO has vast experience in robot design, modelling, simulation and control. Therefore, the report needs to be brief and straight to the point, but contain all the important technical information for the CTO to make an informed decision whether to invest and purchase your product.

Remark:

- Think about how you present your data and how you analyse the results in order to convince the customer to invest in your product.

The challenge

The challenge is for you and your team to design your own robot that uses the end effector to trace a specific shape. This mimics a welding action (for example the welding robot in Figure 1).

Figure 1: An example of a welding robot

The shape to be traced is a *rectangle* and has the following waypoints (in cartesian coordinate (x, y, z), with units in metres):

(0.5,-0.5,0.1), (1.0,-0.5,0.5), (1.0,0.5,0.5), (0.5,0.5,0.1), (0.5,-0.5,0.1).

Figure 2 shows the waypoints and the trace shape in 3 dimensions.

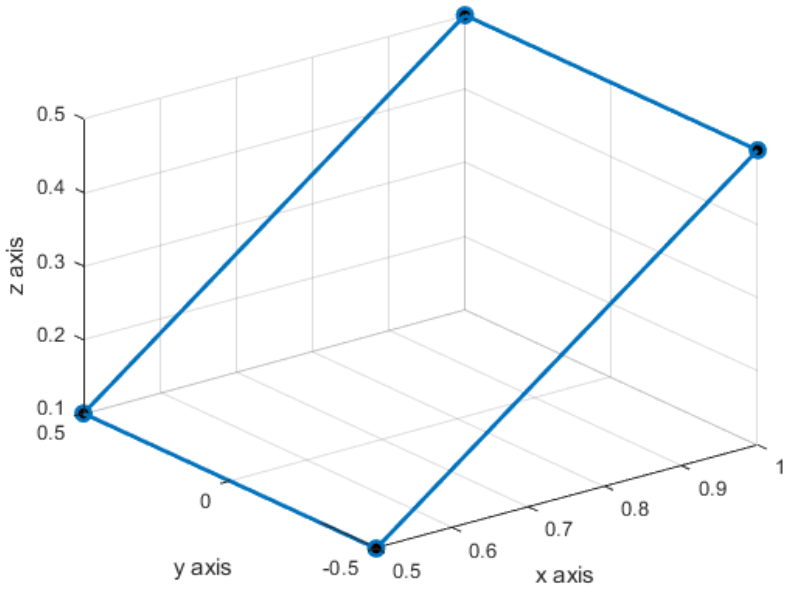

Figure 2: Waypoints and trace shape

These waypoints should not be changed and must remain fixed. These waypoints provide the specific location the welding tip (end effector) should be located since the components to be welded has to be at this location. The base of your robot should be at (0, 0, 0).

The tasks

Based on your design, complete the following tasks for your robot.

Task 1 (25 marks)
Sketch the overall design of your robot. Clearly label and specify

- all the joints (e.g., revolute or prismatic),
- all the arms (and length).
- Clearly indicate the limits of each joint (e.g., to avoid clash)
- Also specify the mass and moment of inertia of each arm.

Task 2 (5 marks)
Draw the reachable workspace for the robot designed in Task 1.

Task 3 (5 marks)
Draw the kinematic diagram using the Denevit-Hartenberg frame rules for the robot designed in task 1.

Task 4 (60 marks)
Using MATLAB/SIMULINK, create the robot simulation and animation to trace the required shape. Ensure that the robot passes through all the waypoints with no or minimal distortion to the desired trace.

You need to design all the controllers needed (feedforward and feedback) to enable the end effector position control.

Notes:

- *Use workshops 5 and 6 as a starting point, but marks will be given based on the originality of your robot design. See especially the example in week 6 (WS5 - EXTRA EXAMPLE - Desired End Effector Trajectory)*
- *Do not change any of the "to workspace" blocks. This is to preserve the data saved to the workspace and to ensure the simulation of the robot (through the file "TwoLinkRobot_animate_3d.m".*
- Save the simulation results (i.e., save all variables in the workspace as a mat file) and submit this together with the m and the slx files.
    - Note that to save all the variables in the workspace, you can select all variables (e.g., using ctrl+A), right-click, and then use "save as".
    - Make sure the variables are saved as a ".mat" file.

Presentation (5 marks)
Marks are given for:

- clarity of writing and overall readability of the report,
- report that satisfies the formatting requirements,
- the report has page numbers, all sections are numbered, all figures have figure numbers and captioned,
- all tasks and results have been discussed in the report with clear discussions and clarifications for design decision made.
- See also the marking criteria.

Part 1 Marking criteria

This part of the report should be brief, concise and to the point. Please also refer to the main brief of the report.

Task	Criteria	Marks (%)
1	• How original and unique is the designed robot? • Do the arms, joints and their limits been specified properly? • Is there a possibility that any of the joints might clash with its arms? • Have the mass and moment of inertia of each joint been specified properly? • Are these design choices are discussed in the main report?	25
2	• Does the reachable workspace have been drawn properly and represent the designed robot from task 1 and its limits? • Does the drawing/figure have been discussed in the main report?	5
3	• Does the kinematic diagram have been drawn properly and represents the design in task 1? • Does the diagram satisfy the Denevit-Hartenberg frame rules? • Do the diagrams/figures been discussed in the main report?	5
4	• Has the Simulink model and animation been implemented correctly and represent the design in task 1? • How tidy is simulation model? • Does the end-effector position trace the rectangle and the waypoints with no (or small) distortion? • Have the feed-forward and feed-back (PID) controllers been designed, implemented and tuned correctly? • Does the results and plots included in the report and been discussed (example of plots required are the joint angle tracking and end-effector position tracking). Comment on the accuracy of the actual joint angle/end-effector position as compared to the desired values. • Have the ".m", ".slx" and ".mat" files been saved correctly and submitted together with the main report? *Remark:* - *Think about how you can present your results and data.* - *How can the accuracy of the trace can be verified? (Error between desired and actual end effector position?)* - *Does it include the accuracy of the controller (the joint angles control for example).*	60
5	*Presentation* • Clarity of writing and overall readability of the report • Does the report abide by the formatting requirements? • Does the report within the page limit, use the correct font type and size and have correct page margins • does every page have a page number? • does all sections are numbered • does all figures have figure numbers and captions? - does all tasks and results have been discussed in the report?	5
	Total	**100**

Part 2: Robotics Laboratory – Braccio manipulator using Arduino

For part 2, attached the completed assessment form.
An example of the form is given below. This form will be filled by one of the teaching staff once you have completed all the tasks in the lab.
Please see the robotics lab sheet on ELE for details.

ENG2006: BRACCIO ROBOT ARM PRACTICAL

Assessment form

Date: _____

Name 1: _____

Name 2: _____

Name 3: _____

Name 4: _____

Group number: _____

Marker: _____

Task no	Evaluation Criteria	Full Marks	Given Marks
1	Perfect vertical alignment. Robot upright position.	15	
2	Grabber jaw open	10	
3	Turn the base clockwise by 10 degrees	10	
4	Set the joint angles such that the angles X, Y and Z of the robot arm has the following values :-		
	X = 160 degrees (measured angles:)	5	
	Y = 110 degrees (measured angles:)	5	
	Z = 90 degrees (measured angles:)	5	
5	Programming the Robot arm to perform the given loop program. How well the robot performs the action? Record a video of the robot movement.	50	
	Totals	100	

Remarks on marking criteria:
Part 4:

- Angles within ± 15 deg of the desired angle: 5 marks (full)
- Angles within ± 30 deg of the desired angle: 3 marks
- Angles within ± 45 deg of the desired angle: 1 mark
- Angles > 45 deg of the desired angle : 0 mark.

Part 5:

- Start & end positions are within ± 5 cm of the desired position : 50 marks
- Start & end positions are within ± 10 cm of the desired position: 25 marks
- Start & end positions are > 10 cm of the desired position : 0 marks

Instructions:

- Once you have completed the tasks, call a supervisor for marks to be awarded.
- Using your mobile phone, record a video of the robot's movement for task 5.
- Take a picture of this form so you can attach it in Part 3 of your Coursework 1 main report.
- **Leave the hard copy of this form with a supervisor.**

Page **1** of **1**

Figure 3: Example of robotics laboratory assessment form

Part 3: Peer assessments

This part of the coursework is set up to encourage collaborations, teamwork and contributions from all the team members for the group work. The form is available at the end of this coursework sheet as well on ELE page on assessments (docx file).

Each member of the group will have to submit the common report and the individual peer assessment form (at the end of the report) to eBart.

An example of the form is given below:

ENG2006: peer assessment form for the Robotics: design challenge - group project

Your name: _____
Group number: _____

- Write the name of each of your group members (***yourself included***) in a separate column.
- For each member, indicate the extent to which you agree with the statement on the left, using a scale of 1-4:
  (1=strongly disagree; 2=disagree; 3=agree; 4=strongly agree).
- Total the numbers in each column.
- These evaluations are *completely confidential* and will never be shown to your team members. Please respond as honestly as possible.

Evaluation Criteria	Your name	member 2 name	member 3 name	member 4 name
Names				
Attends group meetings regularly and arrives on time.				
Contributes meaningfully to group discussions.				
Completes group assignments on time.				
Prepares work in a quality manner.				
Demonstrates a cooperative and supportive attitude.				
Contributes significantly to the success of the project.				
Totals				

Feedback on team dynamics (optional):

1) List down your and your team members areas of responsibility. How does this was agreed within the team?

2) How effectively did your group work?

3) Were the behaviours of any of your team members particularly valuable or detrimental to the team? Explain.

4) What did you learn about working in a group from this module/project that you will carry into your next group experience?

Page **1** of **1**

Figure 4: Example of peer assessment form

eBart Submission Instructions:

- This coursework submission files have two components:
  a) A report in PDF that contains answers for tasks in part 1 task 1 to task 3
  b) Simulation files that implement the simulation model for part 1 task 4*.
     The simulation files should contain:
     i. One m file and
     ii. one Simulink (slx) file
     iii. one mat file (simulation results)

- ZIP all four files (PDF, m, slx and mat files) before submitting to eBart**.
  Name your zip file CWeBartCandidateNumber.zip

- File naming convention***:
  - CWeBartCandidateNumber.pdf
  - CWeBartCandidateNumber_init.m
  - CWeBartCandidateNumber.slx
  - CWeBartCandidateNumber.mat

  For example:
  - CW123456.pdf
  - CW123456_init.m ****
  - CW123456.slx ****
  - CW123456.mat
  - CW123456.zip

REMARK:
* The submitted simulation files should run task 4 for part 1.
** Make sure that files submitted are the correct file type. Incorrect file type may fail to open and thus preventing it from being marked.
*** If you are not sure what your eBart candidate is, check the eBart submission page.
**** Note that Matlab and Simulink does not allow filenames to start with numbers. Therefore start with the letters CW followed by your eBart candidate number.

The ZIP file for this coursework must be submitted to **e-BART** (https://bart.exeter.ac.uk - Faculty: ESE, location: Harrison) by 12:00 noon on the date indicated on the front page of this document.

In the report, you should address all questions in all parts presented above, which should be **brief and to the point**. Furthermore, you should include the important MATLAB commands or SIMULINK diagrams you used, and the text or image of outputs produced. Finally, you should include the reasoning and motivation behind the choices made.

eBart Submission Instructions (continued) …

Matlab Version requirement:

The official version to be used for this coursework is Matlab R2022a

If you are using Matlab later than R2022a, please save your Simulink file to R2022a version – In Simulink, Menu>File>Export Model to>previous version>select R2022a models.

If you are using a Mac, make sure the file can be open in a windows PC

REMARK:

Marking will be done on a windows PC running Matlab 2022a.
It is your responsibility to check that the file you submitted can be executed on a windows PC running Matlab 2022a.
Marks will be deducted if the files are not executable on windows PC running Matlab 2022a.

Report (PDF) formatting requirement:

- The report should **not exceed ten A4 pages** (or approximately 4000 words - when excluding plots/figures/codes).
- Only **Arial or Calibri Light** font styles may be used and text should be **justified left**.
- You should use a **minimum font size of 11.**
- Margins must be at least 2cm in all directions.
- The document size should be standard **A4 size**, single column.
- All **pages must be numbered**.
- All figures must be labelled

In the main report:

- you should address all questions in all parts, which should be *brief and to the point*.
- You should only include/discuss the important MATLAB commands (m file) or SIMULINK diagrams you used.
- You should include plots in the report and discuss the plots (examples of plots required are the joint angle tracking and end-effector position tracking). Comment on the accuracy of the actual joint angle/end-effector position as compared to the desired values.
- You should include the reasoning and motivation behind the choices made (especially for Part 1).

ENG2006: peer assessment form for the Robotics: design challenge - group project

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Group number: _____

- Write the name of each of your group members (***yourself included***) in a separate column.

- For each member, indicate the extent to which you agree with the statement on the left, using a scale of 1-4:
  (1=strongly disagree; 2=disagree; 3=agree; 4=strongly agree).

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4) What did you learn about working in a group from this module/project that you will carry into your next group experience?