ROBOTICS AND MACHINE INTELLIGENCE

MECH3465

COURSEWORK
ASSIGNMENT 2

2025

Assignment Brief: Robot Librarian!

Group Allocation

You will complete the coursework working in groups of 2. This is designed to provide you with a balance of skills in your group and to ensure that you have the opportunity to collaborate and learn together in completing the assignment.

Task Description

You have been given the schematics for a **4DOF Robot Arm**, the arm consists of:.

- Fixed Base
- Revolute Waist Joint
- Revolute Shoulder Joint
- Revolute Elbow Joint
- Revolute End-Effector Joint
- *Revolute* End-Effector (TCP) (*It's technically a revolute servo drive mechanism if you look at the drawings, but we model end-effectors as a **fixed joint in MATLAB**!)

You must develop a control system for the serial manipulator to follow a desired path and manipulate objects within the scenario.

Scenario

Help! The library is a complete mess! I couldn't possibly clean this up myself, I need a robot arm to automate this process!

You are to design a librarian robot, it will pick and place books from their initial "messy" positions, and eventually it will sort, pick, and place them onto the "shelf". See below the attached figure for an example of the final outcome!

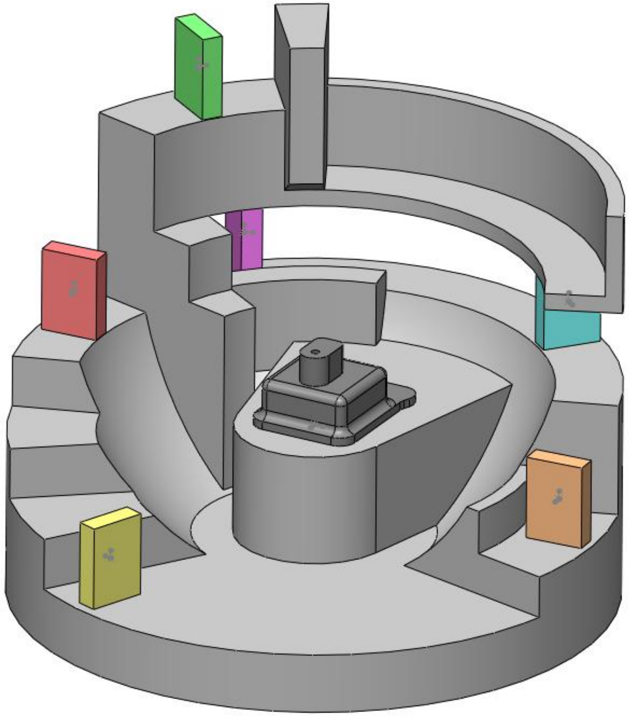
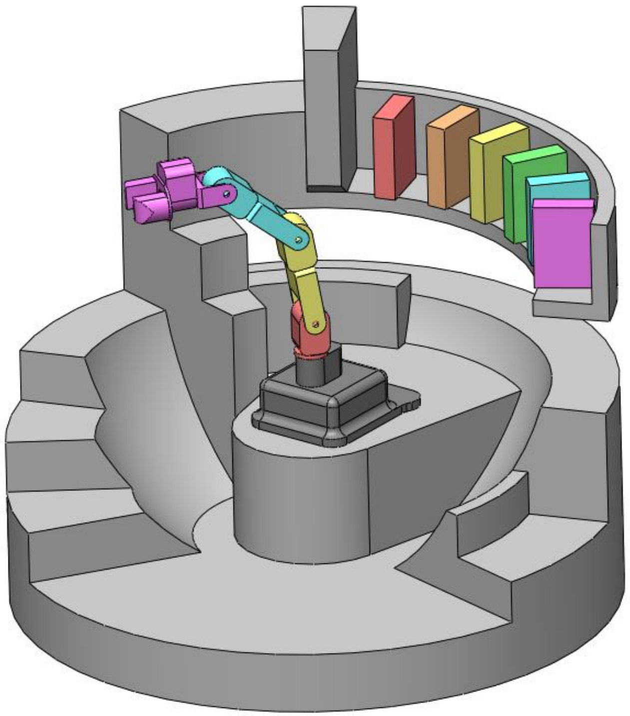

Figure: MATLAB Figure showing the imported view of the state-of-the-art librarian robot. Your beginning scenario incomplete (left), a complete librarian robot with books in the correct positions (right)

- Base of the robot is included in the URDF, also including the first actuator, the total height of the base is 55mm + 35mm = 90mm. You will use this to build your robot from the given datasheet.
- Do not collide with other books or the library or the robot arm itself whilst travelling on the way to collect the next button or placing one on the shelf. This will result in “damage” to the library and the customer will not be happy!

- You will build your robot on top of the given scenario URDF (on the same rigidBodyTree)
- You can edit the home configuration of your robot after generation, just specify your home configuration in the script and any changes you have made. You must start your final submission for the video/animation from the home configuration.
- You should write your report in a **MATLAB Live Script**, incorporating your code, calculations, and explanations into different sub-sections. You will be given a basic template with some basic sub-sections.
- You are marked on the clarity of your explanation not your word count (don’t make your explanations extremely long

unless you feel it's necessary)

- Use headings for main tasks, sub-headings for subtasks, and a table of contents to organise the report.
- You should comment any code you write throughout the document so that it is understandable.
- Within your MATLAB Live Script you should complete the following tasks given below, each of the 5 main tasks is worth 20% and contains a breakdown of marks for sub-tasks within each main task.

Tasks (1-5) and Sub-Tasks

1. **Forward Kinematics**
   a. Using the provided drawings of the robot, produce a labeled diagram of the model with attached frames and insert this figure into your live script
      i. The diagram can be Hand-drawn, CorelDRAW, SolidWorks, etc… are all viable options for the diagram, as long as it is readable!
      ii. Produce a Complete Denavit-Hartenberg Parameter Table for your manipulator.
      iii. Show the table in your Live Script output.
   b. Explain your approach and any choices made during D-H frame assignment
      i. **Note:** Code comments, code-section text, figures, and presentation are all counted towards explanation marks.

2. **Build Robot in MATLAB Robotics Toolbox**
   a. Import the Scenario URDF from the handout folder on Minerva
   b. Use the Denavit-Hartenberg Table to build your robot from into a rigidBodyTree
      i. Build your robot on the same model
      ii. Hint: There is an example of this in RP04!
   c. Add Visual Geometry to the robot links
      i. There are many shapes you can use to build your robot, you can also add multiple shapes to one link to create different looks.
   d. Add a collision sphere to your robot at the TCP of the end-effector of size 0.005m
      i. This sphere will be used to detect book collisions, you all need to have the same size sphere.
   e. Show your fully built robot in a figure in its home configuration
      i. You can edit your home configuration just make sure you state this in the script.
   f. Explain your approach to building the robot and any problems you encountered.
      i. **Note:** Code comments, code-section text, figures, and presentation are all counted towards explanation marks.

3. **Analytical Inverse Kinematics**
    a. Solve inverse kinematics analytically to move the robot from its home configuration to the frame of book_1, documenting each step.
    b. Explain your approach to solving the inverse kinematics problem and any assumptions or simplifications you have made. (Max 200 words).
        i. **Note:** Code comments, code-section text, figures, and presentation are all counted towards explanation marks.
    c. Explain any considerations you have made to either simplify the problem, or examples where you may have changed your algorithm to obtain a specific book orientation.

4. **Trajectory Generation**
    a. Plan a trajectory for the end effector to follow such that the robots Tool Centre Point grabs each of the books and places them on the bookshelf in your specified order. (Orders to be released after team confirmations)
    b. Using your analytical solution from section 3, solve the inverse kinematics of each point required by your trajectory plan and generate a matrix of theta values containing your robots joint angle data.
        i. Hint: Check out RP06
    c. Explain your approach to trajectory generation between each waypoint/via.
        i. Joint-space or task-space solutions are worth equal marks, just justify your choice.
        ii. Note: Code comments, code-section text, figures, and presentation are all counted towards explanation marks.

5. **Final Animation**

Create an animation showing your robot pressing each button in your teams pre-defined order
    a. Use your pre-built matrix of joint angle data:
        i. Plot the path that the robots end-effector follows, plotting a mark at each point the TCP touches during a single book path.
        ii. Once a book has been detached from the end effector and placed in the correct position, hide/delete the old path and start a new path/plot.
        iii. The deletion of old paths should help in the clarity of the final animation, if too many paths are on screen it will become difficult to follow what is happening.
        iv. Hint: We have plotted paths before in the Inverse Kinematics practical, RP05.
    b. Once you have reached a book, verify this by checking collisions, then attach the book to the end effector (example will be given on how to do this)
        i. Once the book is attached to the end effector, move it to the bookshelf in the correct position.
        ii. Neither the book nor robot arm should collide with the scenario or it’s own body. This will be judged by

sight.

iii. Your robot arms movements should be realistic e.g. no “teleporting” between positions such as lefty/righty solutions.
iv. Once in the correct position and your are happy with your work, detach the book. It should remain there for the rest of the simulation.
v. Repeat steps for the next book.
vi. Books must be placed in the correct position, but they can be placed in any order. e.g. you can start with book_1 or book_2 or book_3 as long as the go in the right place.

c. Attach and detach the books in a realistic manner, there is no physics in the simulation but I will judge whether the book is “stable”, you will lose marks for unrealistic attachments and placements where a book will clearly fall off the shelf.
d. Use the gif creation/screen capture tool to export your animation – **NOTE we may need to use screen capture this year due to the new simulation environment in MATLAB, I will update with answer!**
e. Attach and detach the books in a realistic manner, there is no physics in the simulation but I will judge whether the book is “stable”, you will lose marks for unrealistic attachments and placements where a book will clearly fall off the shelf.
f. Explain your approach to generating your animation
    i. Note: Code comments, code-section text, figures, and presentation are all counted towards explanation marks.

A Marking Rubric Overview will be handed out later.

Deadline: Week 23 – Thursday 1st May - @15:00 – 01/05/2025

<u>You will submit:</u>

1. The complete code of your solution as a MATLAB Live Script
   Please also include outputs (e.g. do not clear the outputs after processing)
2. Please, export your MATLAB Live Script as a PDF with the same file name.
3. Please export your animated gif with your team name included.
4. Do not compress any files into zip format.
5. Files should be uploaded one by one into Minerva by one of your teammates.
6. Please make sure you included you Team name, Names of the members of the Team, and SID’s for both members at the top of the LiveScript.

Appendix A: Marking Scheme:

Grade Range		0% - 29%	30% - 39%	40% - 59%	60% - 69%	70% - 79%	80% - 89%	90% - 100%
Weight (%)	**Contents/Sections**	Very Poor	Weak	Average	Satisfactory	Good	Very Good	Excellent
30%	**Forward Kinematics** **Robot Building** **Analytical Inverse Kinematics**	*No Attempt made or code sections are not running successfully, no diagrams.* *Robot visuals and collisions are not present.*	*MATLAB code with few bugs and kinematics described or justified with limited information. Poor quality diagrams.* *Robot visuals and collisions are not complete.*	*MATLAB Code with few bugs and kinematics not well described and justified. Diagrams included.* *Robot visuals and collisions are not representative of the specs.*	*MATLAB Code with minor bugs and kinematics described or justified with limited information. Readable diagrams. Robot visuals and collisions are almost representative of the specs.*	*MATLAB Code with limited bugs and kinematics described or justified with detailed information. Good diagrams. Robot visuals and collisions are representative of the specs.*	*MATLAB Code without bugs, kinematics described and justified in detail with a few exceptions with detailed diagrams. Robot visuals and collisions are representative of the specs and look good.*	*MATALB Code without bugs and kinematics described and justified in a high level of detail. Diagrams are extremely well produced and explained. Robot visuals and collisions are representative of the specs and look very good.*
10%	**Waypoint Planning** **Trajectory Generation** **Collison Checking**	*No attempt made. No thought to trajectory plan. Attempt not described.*	*Very little evidence of waypoint planning or trajectory generation. One book attempt.*	*Only limited waypoint planning or trajectory generation. Not much description of the plan. Some attempt to avoid collisions and reach multiple books.*	*Waypoint planning and trajectory generation has been thought out and described. Some attempt to avoid collisions and all books attempted.*	*Waypoint planning and trajectory generation has been thought out and described. Some attempt to avoid collisions and all books attempted and placed on the shelf. Minor collisions detected during path.*	*Waypoint planning and trajectory generation has been thought out and described. Avoided all collisions and all books attempted and placed on the shelf parallel to the shelf and in stable configuration.*	*Waypoint planning and trajectory generation has been very well thought out and described. Avoided all collisions and all books attempted and placed on the shelf parallel to the shelf and in stable configuration in the correct order.*
20%	**Final Animation of the Robot Simulation**	*No attempt or only minor movement of the arm shown.*	*The arm moves and attempts to touch/attach a book, but does not place it on the shelf.*	*The arm moves and places books on the shelf. The movement is jerky and some movements are skipped/missing. Arm collisions are clearly visible. There is attempt to plot trajectory/path of the end effector. There is attempt to plot trajectory/path of the end effector. Attempted to attach books in a realistic manners.*	*The arm moves and places almost all books on the shelf. The movement is mostly smooth and only minor movements are skipped. Minor collisions. The trajectory/path of the end effector is present for each book. Books are mostly attached realistically.*	*The arm moves smoothly and places all books on the shelf. No movements are skipped. Minor collisions. The trajectory/path of the end effector is present for each book and the simulation is well labelled. All books are attached realistically.*	*The arm moves very smoothly and places all books on the shelf, books are parallel to the shelf.. No movements are skipped. No collisions. The trajectory/path of the end effector is present for each book, shown one at a time, and the simulation is well labelled. The arm shows an attempt at acceleration and deceleration. All books are attached realistically.*	*The arm moves extremely smoothly and places all books on the shelf, books are parallel to the shelf.. No movements are skipped. No collisions. The trajectory/path of the end effector is present for each book, shown one at a time, and the simulation is well labelled. The arm shows very good acceleration and deceleration between key positions. All books are attached realistically.*
20%	**Report Writing with critical discussion.**	*Unintelligible. Impossible to read due to exceptionally poor use of English. Not explanation of choice of MATLAB approach/function*	*The volume and nature of the grammatical errors, combined with poor writing makes this report difficult to read. Superficial way of explanation of MATLAB approach/function choice.*	*Hard to understand much of the text. Significant spelling errors and grammatical flaws.* *Some of MATLAB approach/function choice but no motivation mentioned.*	*The text can be understood, but some elements are not entirely clear. A sizeable volume of errors is noticeable. Marginally information provided for MATLAB approach/function choice.*	*Most of the text is clear and easily understood. There are some issues with grammar and spelling. Detailed MATLAB approach/function choice provided.*	*Clear and well written, easy to understand, and mostly free of errors. MATLAB approach/function choice and motivation provided in detail.*	*Exceptionally clear, precise and concise English. Excellent spelling & grammar, few typos. MATLAB approach/function choice and motivation provided in detail and well explained.*

10%	**Report Presentation** **Figures** **Code Comments**	*No evidence of any effective effort on the quality of the presentation. Report is hard to follow due to unclear figures.*	*Unacceptable presentation: untidy and inconsistent use of styles. Figures are messy and unclear.*	*Significant flaws in the presentation detracting from the overall impression of the report. Flawed figures, e.g. badly drawn and untidy.*	*A number of basic errors present – inconsistent use of styles, margins etc. Figures are satisfactory.*	*There are some minor flaws in the presentation and the clarity of the figures.*	*A clear and consistent presentation style making it easy to read. Most of the figures are clear and well presented.*	*Professional standard of presentation. All illustrations are well formatted and presented.*
10%	**Report Organisation & Structure**	*No discernable structure. Illogical placement of sections. Impossible to follow argument.*	*Serious flaws in structure which makes it difficult to read and understand the report.*	*There are flaws in the way the report is structured which damages the overall quality of the report.*	*There may be some issues with the structure, but these do not detract from overall quality.*	*A report which is sufficiently well organised, making the reading easy.*	*A well organised report with all sections logically placed enhancing understanding of work.*	*Structure is entirely correct with all sections correctly placed. Reading contents gives clear overview.*