THE HUMANOID PROJECT

Instructions:

1. This assignment contains 5 questions.
2. Sophies are required to attempt at least one of the starred/highlighted questions
3. Make a pdf of your answer script and upload it in the google form.
4. In your pdf submission, please write your name, roll no. and the email address which you have mentioned in the form.
5. If you choose to submit hand written assignments, paste the pictures into a doc and then submit it as a pdf. But please ensure that it is readable.
6. In your pdf submission, name it as Name_RollNumber_Subsystem. For example, **Ayushman_200020039_Controls.pdf**
7. Wherever you may want to attach a link to files, github repos, videos or photos please do so. **Make sure the access permissions is public**
8. Mention all the references you have used at the end of the pdf.
9. Lastly, this assignment is expected to be technically challenging. Solve as much as you can and put in adequate effort, and even if you haven't finished attempting or solved completely, submit whatever you have done. Remember, we are looking for people who are ready to put in effort.
10. For any queries, feel free to reach out.

CONTROLS SUBSYSTEM

(Sophies should at least attempt 1 starred/blue highlighted question, i.e. one out of ****1, *4, or *5(c)****)*

***1.** Robotic arms, often referred to as manipulators, are essential tools in automation, as they manipulate the surrounding environment. Composed of joints and links, each joint enables either rotation or translation. While operating manipulators, expressing coordinates of various objects in the ground reference frame can be challenging. This is where Transformation matrices, denoted as ${}^{A}_{C}T$, play a crucial role. These matrices facilitate the transformation or expression of coordinates from one reference frame to another. Read about these matrices and find out what will be the 'Transformation matrix' between the coordinate frame C and coordinate frame A in the figure-1. **Justify** your answer clearly.

- 70 marks

(The figure is a corner of a wedge; Note that Transformation matrix should be a 4x4 matrix)

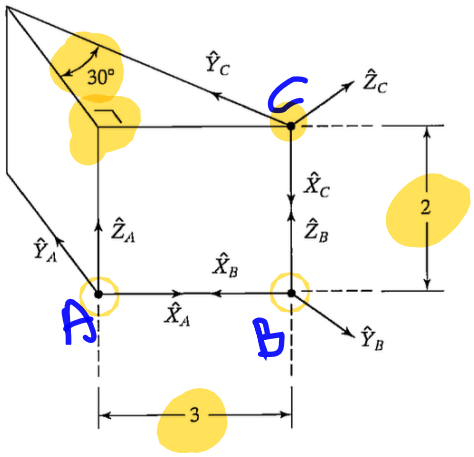
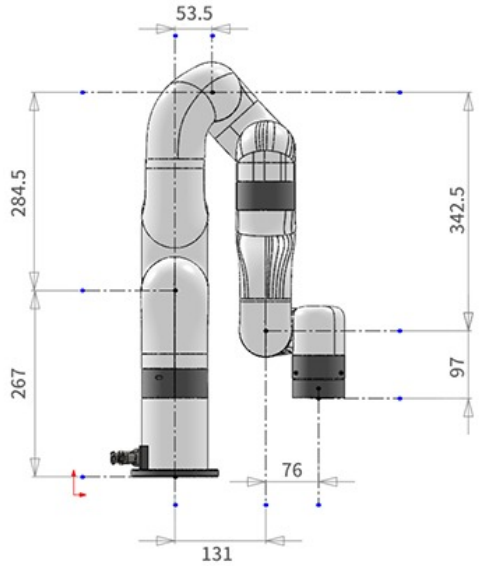


Figure-1

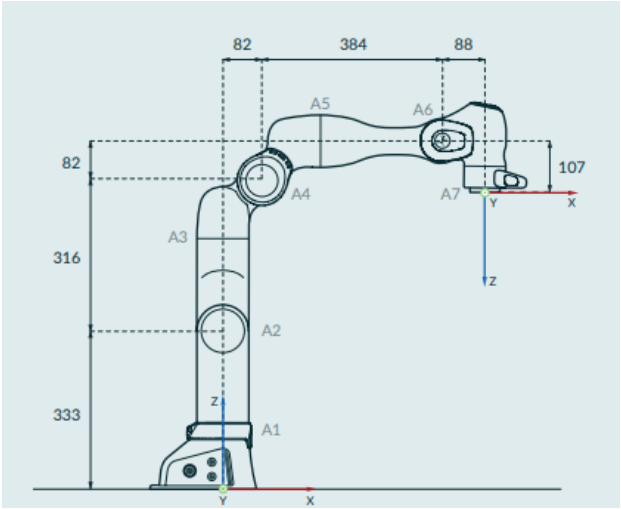
2. What do you think is involved in controlling a humanoid with the same purpose as the team is currently aiming to build? List any and all parts or situations that involve the robot requiring **autonomous** control.

- 50 marks

3. Suppose you are working as an engineer in a packaging industry. You need a robotic arm for pick and drop packages from one conveyor belt to another. You come across two robotic arms that can do the task. Given below are the two robotic arms with their link dimensions (in mm):



(1)



(2)

As you embark on analysing and comparing both robotic arms, consider various aspects of their designs. This involves determining the Degree of Freedom (degree of freedom) and creating a stick/kinematic diagram. Additionally, to simulate the robotic arms effectively, you'll need to provide the DH (Denavit–Hartenberg) parameters, crucial for describing the system's links.

(a) Determine the Degree of Freedom for each robotic arm. Explain how the number of DOFs impacts the arm's flexibility and range of motion
(b) Investigate and provide the DH parameter table for each arm. Outline the significance of DH parameters in describing the geometric and kinematic properties of robotic systems.
(c) Discuss any variations or unique characteristics in the DH parameter tables between the two arms.

***4.** Familiarise yourself with robotics-toolbox-python by Peter Corke. Implement Inverse Kinematics for Puma560 robotic arm (see, Models in roboticstoolbox).
Calculate q values for

```
[[1,    0,    0,    0.5],
 [0,    1,    0,   -0.1],
 [0,    0,    1,    0.5],
 [0,    0,    0,    1 ]]
```

i.e, end-effector on coordinates (0.5,-0.1,0.5) with orientation

```
[[1,    0,    0],
 [0,    1,    0],
 [0,    0,    1]]
```

- 80 marks

***5.** Assume the below diagram is a map of a library-like room, where the green bars are the shelves, the two squares are tables, and the two triangles are entry and exit points(the entry point being the bottom triangle and exit point being the upper triangle). Let's say our humanoid wants to go along each shelf and scan for books, but also avoid obstacles.
(a) Explain the concept of waypoints and why they are essential for path planning in this scenario. How would you strategically place waypoints around the shelves to guide the robot effectively? *(you can include diagrams to show your work)*

-20 marks

(b) Mention and explain which path planning algorithms you will use to solve the problem. What advantage does your chosen algorithm have over others?

-25 marks

***(c)** Explore this library: Path Planning — PythonRobotics documentation. Try to write a python script which uses the above library and solve the challenge. You can assume any dimensions of your own convenience, the objective is to get the logic right. You can have a look at the examples in the library to know how you represent a map and obstacles, before applying an appropriate algorithm.
If you are not able to come up with a working python script, or if you are not familiar with Python, then please write a pseudo code instead.

- 40 marks

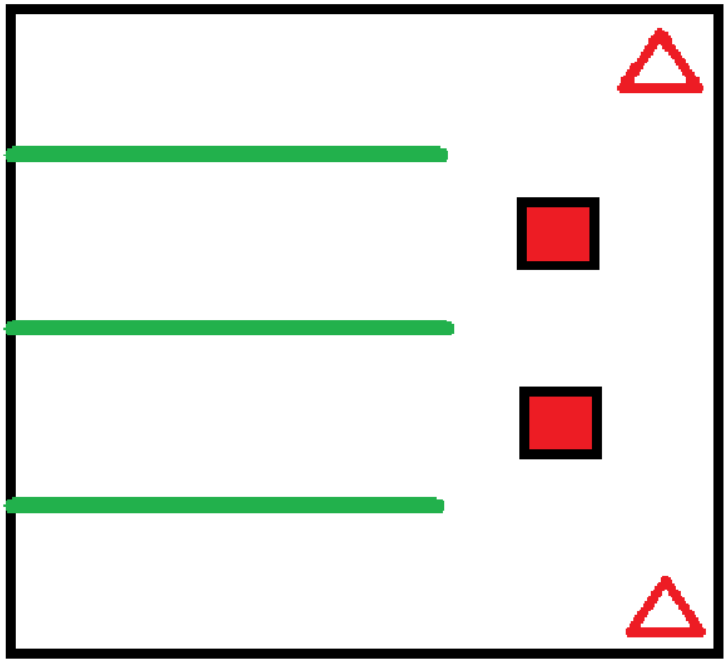


Figure: A map of a sample library