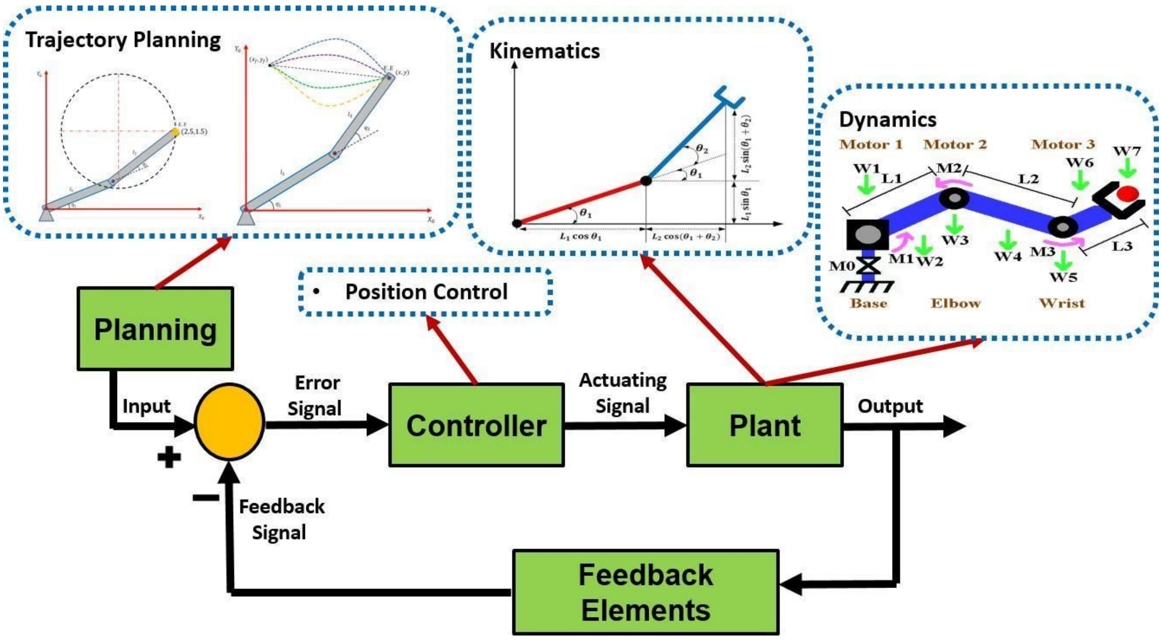
Project Description

List of Contents:

Project Description

Overview:

The main objective of the Robotics Programming (MCTR911) course is to go through the robotic systems challenges. One of these challenges is to derive the robotic systems equations of motion through modeling of the robotic manipulators using both kinematic and dynamic approaches. Another challenge is to obtain the desired trajectory for either the manipulator's end effector or its joints to be followed by the manipulator to reach its destination. And finally, to control the robot's motion to follow the designated trajectory to close the loop of the whole system.



All these challenges are going to be highlighted and tackled in the course project, as students will learn how to model a robotic system and how to control its motion to perform the desired task successfully and efficiently. Students will also have the chance to visualize the motion of your created robot and build an **interactive GUI** with a full environment for the robot in an **industrial application** through the use of **ROS2** and **MuJoCo** connecting coded by **Python** or other simulator of your choice (teams that choose to use other simulators are expected to be able to debug its problems themselves). This document is to introduce the Robotics course project objectives highlighting the project's regulations and draft milestones plan including a brief description for each milestone, the milestone weight and expected deadline.

Project Description

Objectives:

The robot which is of interest in this year's project is **Industrial Robotics (Several designs are present online as Open Source XML models)**. The objectives of the project are mainly to be able to model and analyze **the robotic arm** (obtain the kinematics, trajectory and control the arm to perform the desirable industrial motion) using **ROS2** and **Python** to be used **in Industrial Robotics Applications**. In addition, build a simulation environment of the visualization of the limb's motion through **MuJoCo**. Furthermore, build **a GUI** of the selected robotic arm in an industrial application environment performing the desirable movements.

Project Description

Project Regulations:

- The project team consists of **4-6 members cross tutorials**.
- Each team is required to **simulate and analyze** a **robotic arm (4-7 DoF)** to perform an **industrial robotics application** which should be **chosen based on literature review**.
- Each team will work on a single robotic arm to **simulate its motion in the GUI** and for the **industrial robotic application chosen**.
- **Students that are not assigned** to teams are going to be **randomly** clustered and get assigned to a random project.
- Registration of **less than 4 members or more than 6 members** will NOT be considered and the project selection will be canceled.
- Once the team is formed, NEITHER changes in the team's members NOR in the assigned project will be acceptable.
- The evaluation process of each milestone will follow the following procedures based on the milestone requirements:
  - **Online Submissions:** Each team will be requested to submit the requirements of the milestone through **GitHub**. These requirements may include: reports, narrated presentations, codes, videos and others. Each team will have a **repository on GitHub** to share folders with **team members and course instructors**.
  - **Evaluations:** Two evaluations will be conducted throughout the project, the evaluations timings are presented below. Evaluation method will be announced soon.

Project Description

Project Milestones Overview:

- The project weight is **30%.**
- The project is divided into **5 milestones** covering all the course content.
- Each milestone is weighted based on the complexity of the requirements.
- All milestones will include a simulation platform for coding. The simulation platforms required for the course are **MuJoCo** utilizing **ROS2** and **Python** (you are free to choose whatever simulator you like, but you will have to **ensure** it work)
- Visualization of the robot's motion is required
- You will be asked to search for available **models** for a **robotic arm.** The **course team** will choose **2-3 robots** for each team to select **one** and start **simulating the robot's motion** and **building the GUI.**
- Each team will construct a suitable **full simulation environment** based on the selected industrial application, ex.: robot assembling Legos, the robot and a worker are moving objects in an industrial sector which should be shown through a simulator of your choice (the course team should approve using this simulator).

Project Description

Project Milestones Requirements:

Milestone #	Deliverables	Expected Deadline	%
Registration	**Requirements:** ● **Project registration:** each team required to register through a Google form: https://docs.google.com/forms/d/e/1FAIpQLSd3azhk2VRIligOnh2P6hSKF6fP_kPhRG5vTkl7cOomQTAb3w/viewform?usp=dialog ● The team members are required to fill their names, IDs, the priorities, a contact person's email to contact in case of any problems	**Friday 3rd of October, 2025**	**0%**
Milestone 01	**Requirements:** ● State the selected application and propose a draft project flow to serve your **selected industrial robotic application**. ● Search for **available** models having **4-7 degrees of freedom** (number of motors). ● Download **ROS2** and **MuJoCo** (you can choose a simulator other than MuJoCo). **Documentation** is on the CMS. ● If you would like to use **another simulator**, mention the simulator and provide us with a **video you have done previously** with it. ● Each team member should have an account on **GitHub** and create one repository for each team (documentation will be available on CMS). **To be submitted:** ● **Github Repository Link** containing a folder named **"Milestone 01"** including all the following: -One/Two page **literature review**. -Robotic manipulator **CAD models**. -Video of the software **(ROS2, simulator)**.	**Wednesday 8th of October, 2025**	**5%**

Project Description

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<tr>
<td>Milestone 02</td>
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<u>Requirements:</u>

Assign the frames on the robotic arm (on paper or by the help of the frames present in the simulator used).
Develop the DH convention of the robot.
Obtain the robotic arm Forward and Inverse Position Kinematics using Python.
Place the model in MuJoCo or the chosen simulator through the linking between ROS2 and the simulator by integrating it with Python. Links will be provided.
Analyze and visualize the motion of the limb by actuating the joints using constants, signal builders and sliders as inputs to the simulation environment
Start building the GUI of the environment

<u>To be submitted:</u>

Create another folder in the previously created GitHub repository named “Milestone 02” including the following:

A Report (Word or Latex format) having the performed DH convention, forward kinematics
Codes of the forward kinematics analysis and the visualization of the robot’s motion.
Video for the simulations performed on the simulator including the building process of the environment’s GUI.

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<td>Wednesday 22th of October, 2025</td>
<td>7%</td>
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Project Description

Milestone 03	<u>**Requirements:**</u> • Derive the **Forward and Inverse Velocity Kinematics** of the robotic arm using **Python**. • Derive the **Forward and Inverse Acceleration Kinematics** of the robotic arm on **Python**. • Test the equations of the **Forward** and **Inverse Position and Velocity Kinematics** obtained on the **chosen simulator** by inputting joint angles/angular velocities/angular accelerations and sensing the position/velocities/accelerations of the end effector and the inverse process to be the same as that obtained by the kinematic equations with simple tolerance. • Continue building the **GUI process** which includes all the environment components; chairs, conveyors, people, tools, etc. <u>**To be submitted:**</u> • Create another folder in the **previously created GitHub** repository named **“Milestone 03”** including the following: – **Video** of the kinematics validation in a simulation commenting on the results. – **Report** having the steps of the performed analysis of the **velocity kinematics and acceleration kinematics** – **Codes** of the forward and inverse velocity kinematics and the robot’s motion visualization – **Videos** for the created GUI. – **Videos** for testing the kinematics equations obtained on the model by inputting joint angles and sensing the end effector’s position to be the same as that obtained by the kinematic equations with simple tolerance.	**Wednesday 12th of November, 2025 + Evaluation**	**7%**

Project Description

Milestone 04	**<u>Requirements:</u>** • Derive Task-Space trajectories for the arm's end effector to follow using **Python.** • Derive Joint-Space trajectory for the robot's joints to follow using **Python**. • Validate the simulated **Task-Space trajectories** for the arm's end effector to follow on **ROS2** and **the simulator** • Validate the simulated **Joint-Space trajectories** for the robot's joints to follow on **ROS2** and **the simulator** • **Send the joint angles** required to perform the task-space trajectory and the joint-space trajectory to the simulator to perform the desirable motion in the created **GUI**. **<u>To be submitted:</u>** • Create another folder in the **previously created GitHub** repository named **"Milestone 04"** including the following: – **Videos** of the trajectory validation in a simulation commenting on the results. – **Codes** of the and trajectory tracking analysis using joint-space and task-space and the visualization of the robot's motion	**Wednesday 26th of November, 2025**	**6%**
Milestone 05	**<u>Requirements:</u>** • Derive position control algorithms for the motor level control • Test the **closed loop** system taking into consideration the robot's visualization tool • Perform the desired industrial application. **<u>To be submitted:</u>** • Create another folder in the **previously created GitHub** repository named **"Milestone 05"** including the following: – **Narrated presentation** having ALL the steps conducted in the project – **Report** having ALL steps performed with screenshots and analysis.	**Wednesday 10th of December, 2025** **+** **Final Evaluation**	**5%**

Project Description

	– **Codes** of the control equations of the arm and the visualization – **Videos** for the fully functioning simulation		

Project Description

Project Remarks and Resources:

** Registration is open starting from Thursday 29th of September, 2025 till Friday 3rd of October, 2025. Link of the registration process can be found below: https://docs.google.com/forms/d/e/1FAIpQLSd3azhk2VRIligOnh2P6hSKF6fP_kPhRG5vTkl7cOomQTAb3w/viewform?usp=dialog

** Each team will Search for a model of a robotic manipulator having **4-7 degrees of freedom**.

** A **literature review** on the most recent **Industrial Robotic Applications** will be conducted by each team to propose an application for his arm.

** A detailed description for each milestone will be provided with all the required deliverables and the submission details (links for submissions will be provided in each announcement).

** Teams will visualize the motion of the robot using **MuJoCo or others (if approved)**.

** Full analysis of the robot using **ROS2 and Python**.

** **Evaluations** will take place within the semester for monitoring the progress of each team and for grading purposes.

Best Wishes and Happy Semester,
Robotics Programming Team ☺