Manchester Robotics / Tecnológico de Monterrey

MR3001C Cyber-physical Systems I

Final challenge

Introduction

This challenge, developed by Manchester Robotics (MCR2) in conjunction with Tecnológico de Monterrey, aims to provide the student with a real-world problem to be solved using collaborative robotics in ROS.

The challenge consists of solving a day-to-day task in industry, by controlling a wheeled mobile robot in collaboration with a robotic arm, in a coordinated and sequential manner.

Challenge Description

Sorting and moving goods from one place to another is a daily task in factories. This challenge is focused on such a task, allowing students to experience the problems involved firsthand.

The challenge consists of moving three pieces from an initial place (g_0) and delivering them to a destination (g_f) following a path (P_1 *or* P_2), using a mobile robot in conjunction with a robotic arm, as shown in Figure 1 and Figure 2.

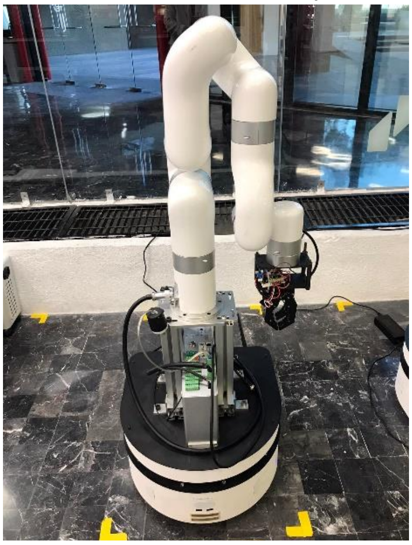

Figure 1 Mobile robot (B1) and Robotic Arm (xArm)

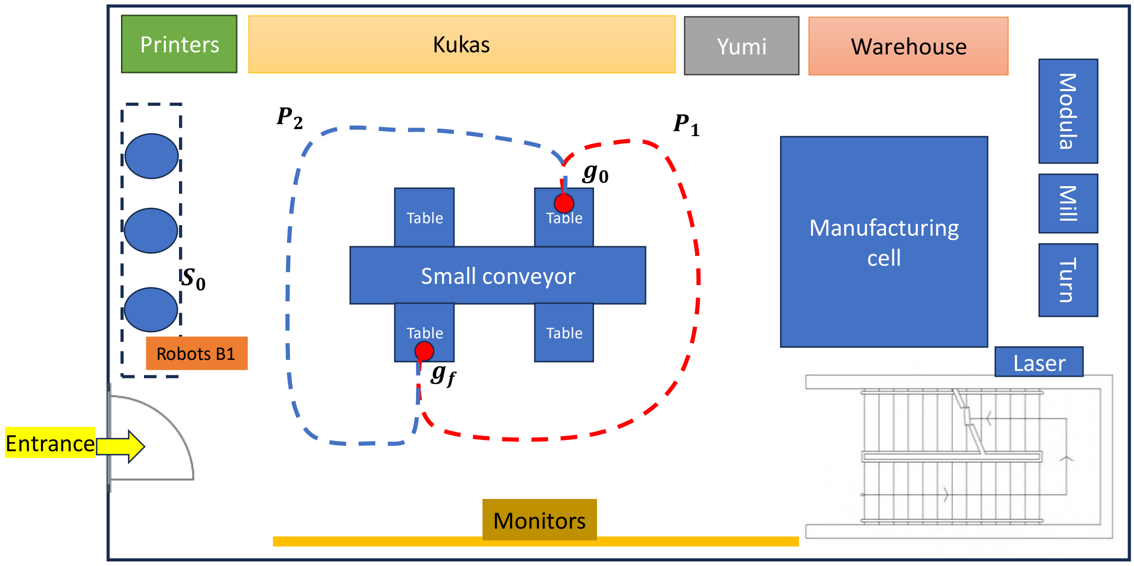

Figure 2 Paths and goals of the task at the Smart Factory facilities

The challenge can be separated into several different tasks.

1. Design of the fixtures and pieces to move.
2. Moving the mobile to follow the designated paths by the user.
3. Moving the robotic arm for a pick-and-place task. The pieces must be picked up following a given order and placed at the destination in a different sequence.

Task 1: Design of the fixtures and pieces

Pieces design and manufacturing.

The student must design the pieces to be picked up and placed by the robot.

- The pieces must be different, as shown in Figure 3.
- They must be simple to be easily handled by the robotic arm; considering the gripper attached to the xArm's flange.
- The student is allowed to choose the colour of each piece if required.
- They must be manufactured according to the specifications of the students; pieces can be manufactured using 3D printing, milling, laser cutting, etc.
- Some example pieces are shown in Figure 3. The student is allowed to change them if required.

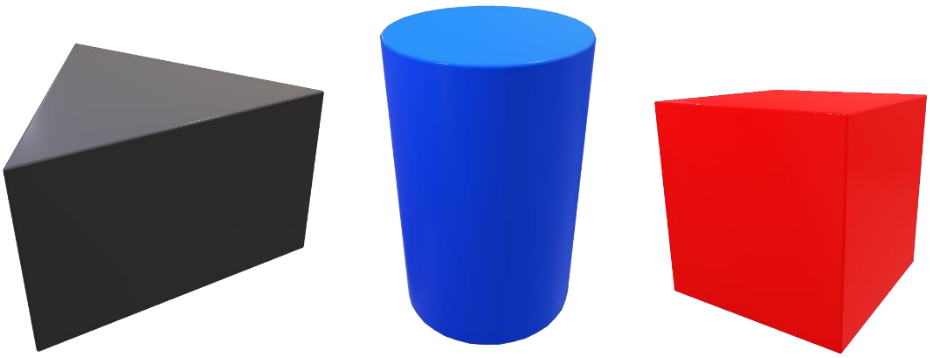

Figure 3 Example pieces to be manufactured.

Fixtures design and manufacturing

The student must design and manufacture the fixtures required for this task. Some examples can be seen in Figure 4

- Three different fixtures must be designed:
  - The "pick-up storage fixture": where the pieces will be stored, positioned and ready to be picked up by the robot.
  - The "robot storage fixture": Fixture to load, store, and transport the pieces on the robot.
  - The "final storage fixture": Where the pieces will be delivered, sorted, and positioned to be picked up by a technician.
- The fixtures must contain and hold the 3 different parts in a designated order, as shown in Figure 4.
- The fixture design and manufacture must be defined by the student according to the task specifications and constraints.
  - The position of the piece inside each fixture is not required to be precise.

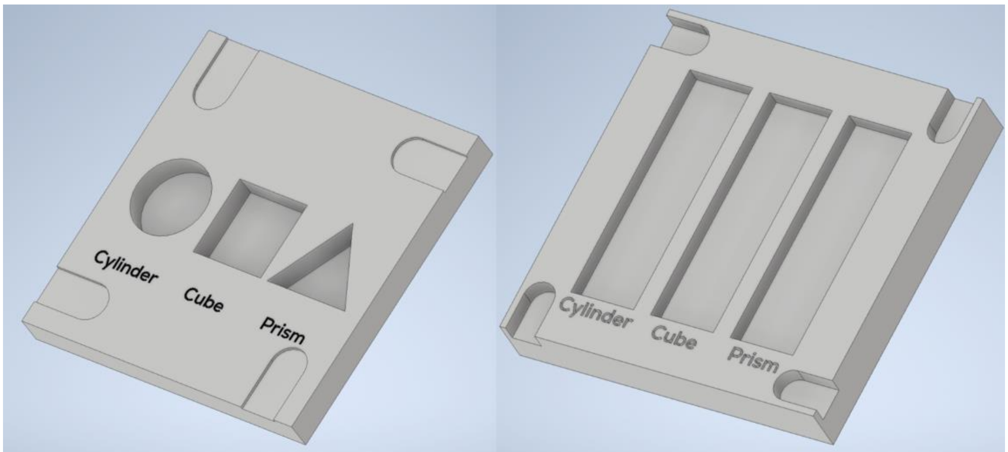

Figure 4 Fixture Examples

Task 2: Mobile robot trajectory

This task involves moving a mobile robot to follow a path and transport the pieces from one place to another.

- The student must define the four positions and paths required for this challenge, depicted in Figure 5 (Example).
  1. The positions $\boldsymbol{s_0}, \boldsymbol{g_1}, \boldsymbol{g_f}$ must be defined by the student.
     - The positions $\boldsymbol{g_1}$ and $\boldsymbol{g_f}$ must be on opposite ends (corners) of the "small conveyor" as depicted in Figure 5.
     - The positions $\boldsymbol{s_0}$ and $\boldsymbol{g_1}$ must be at least 1 m apart.
     - The final position $\boldsymbol{s_0} = \boldsymbol{s_f}$.
  2. Path ($\boldsymbol{P_0}$): Move the robot from an initial position ($\boldsymbol{s_0}$) to the first goal ($\boldsymbol{g_1}$) to pick up the pieces.
  3. Path ($\boldsymbol{P_{1/2}}$): Move the robot alongside $\boldsymbol{P_1}$ or $\boldsymbol{P_2}$ to reach the second goal $\boldsymbol{g_f}$ and deliver the pieces.
  4. Path ($\boldsymbol{P_3}$): Move the robot back to its initial position $\boldsymbol{s_0}$.
- Use a closed-loop control technique such as PID (P, PI or PID) or any other type of controller to move the robot to the required positions to fulfil the challenge.
- The path must be designed taking into consideration the size of the robot and the arm to avoid collisions and, at the same time, be able to reach the pieces with the arm.
- The xArm robot must be positioned properly before moving to avoid the unbalancing of a robot and fall to one side.

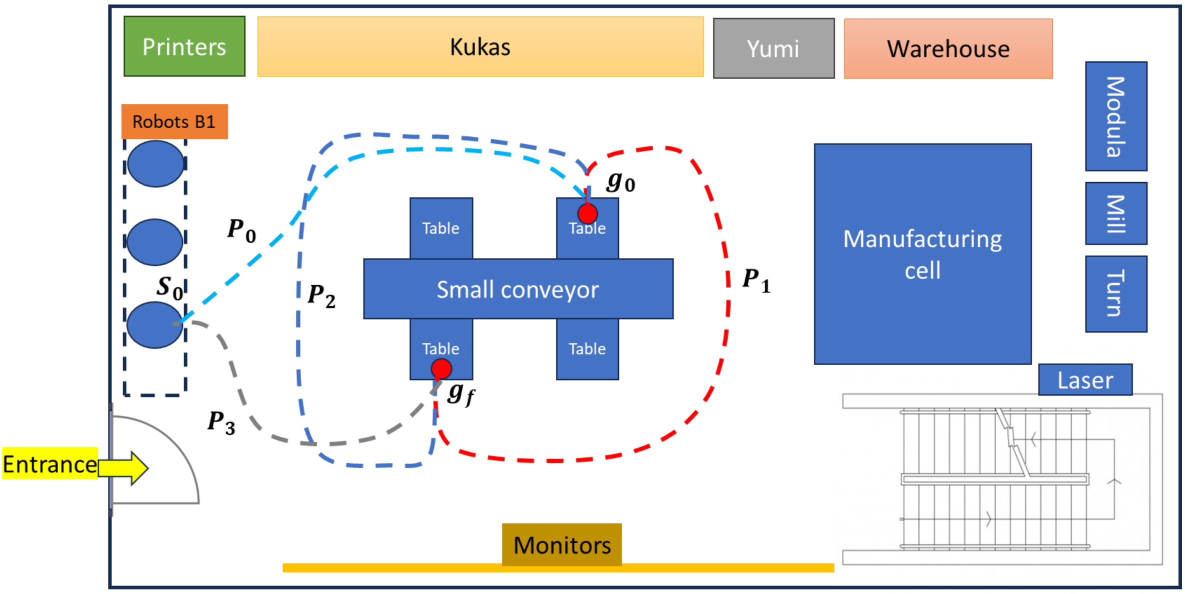

Figure 5 Challenge paths and goals.

Task 3: Robotic Arm

The student must move the arm's end effector to reach, move and sort the target pieces.

- The student must define a trajectory for the end effector to reach, move and deliver the pieces.
- The trajectories must consider obstacles to avoid collisions with them and avoid singularities.
- When delivered at the destination, the pieces must be sorted according to the name written in the fixture.
- The trajectories must be flexible to consider localisation problems with the robot.
- The position of the pieces can be hardcoded.

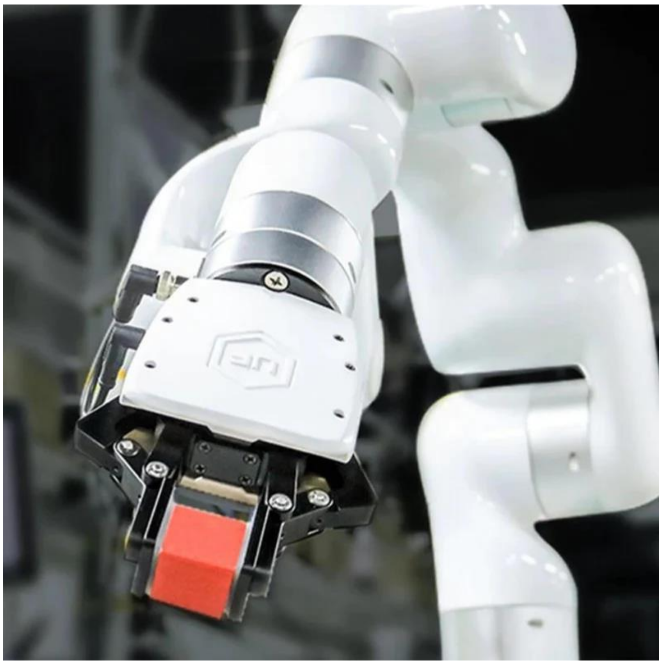

Figure 6 X-Arm end effector.

Considerations

- The student must take into consideration the obstacles presented in the laboratory and avoid at all costs any collision.
- The student must consider the localisation problem present in the mobile robot and the arm.
- The algorithms must be robust to deal with all the problems of this task.
- The student must be aware of the environment when using the robot.
- They student is required to make a complete analysis of each problem presented in each task, propose solutions, develop them, and finally implement their solutions.

Extra marks (Optional tasks)

Obstacle avoidance

Design a simple obstacle avoidance technique based on the Bug algorithms (Bug0, Bug1, Bug2) to avoid some obstacles present in the trajectories, as depicted in Figure 7.

- The obstacles can be cardboard boxes provided by the professors.
- Minimum of two obstacles required.
- The algorithm must be reactive (no hardcoding obstacle positions).
- The student must present that the obstacles can be moved (to avoid hardcoded obstacles).
- The student must show in at least 2 min. extra of the video and 1 page extra in the report, how the code works and how was implemented.

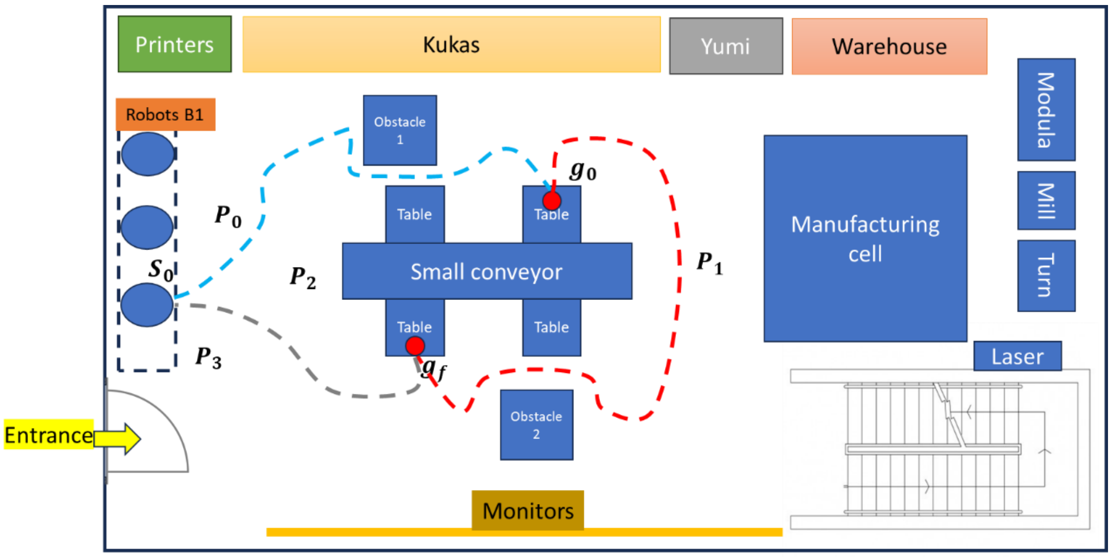

Figure 7 Obstacle avoidance

Camera-based piece localisation (Optional Task)

The student must implement a camera-based colour/QR code localisation to make more robust the robotic arm task of picking, sorting and delivering the pieces. The use of a stereo camera can also be used as another option.

- The student can use any algorithm or library to estimate the position and sort the pieces with more precision.
- The student must show in 2 min. extra of the video and 1 page extra in the report, how the code works and how was implemented.

Figure 8 X-Arm Camera

TE3001B MR3001C Cyber-physical Systems

Final Challenge Report Rubric

The grade consists of two parts:

- Video = 20%
- Individual Written Report = 80%

Deadline: **TBD**.

This is a team challenge, with an individual report.

Teams:

- The students must form teams for this challenge.
- The teams will be the same as in other classes of this concentration.
- The teams must be multidisciplinary.
- The students must respectfully help each other to understand all the topics.
- The team must manage the project, using a project management methodology, and present it in the report.
- The methodology selected can be simple, e.g., Waterfall, Agile, Kanban, etc.

Video (20%)

- Duration: Under 5 min. (If longer, increase speed)
- Show the team, names. Only one team member can speak at a time (not necessary for the whole team to speak in the video).
- Video on YouTube (Unlisted)
- Include the video link on the first page of the report.
- Video in English

Task
Brief introduction (problem to be solved, solution strategy, team tasks, etc.)
Explain how the program works (launch files, libraries made, the structure of the project, etc.)
Show the results of the root being controlled, and the methodology followed to solve it.
Explain briefly the Blockling programming for the xArm and the implementation of ROS to have the xArm integrated to the B1 robot.
Analysis of the behaviour of each robot and comparison of both behaviours. What is expected? Is the behaviour good? Why? Advantages/disadvantages of this type of control? Problems with this type of control?
A brief set of conclusions from the task.

Report (80%)

- Language: English
- Maximum Pages: 5 (not including front page and references)
- Min Font size: 11 pt. and Min. Line spacing: 1
- Front page: Your name, team names and id's
- Appendix: No
- Report design: Single-column or double-column
- Format: PDF
- Details:
  - Each exercise and task in a different section
  - Results in diagrams, figures, tables, etc.
  - Include discussion, reflections, conclusions, and recommendations for each result.
  - Include references to books or publications in peer-reviewed journals (IEEE format)
- Results, tables, figures, etc., without detailed explanation/information, will be penalised.

Task
Introduction • Problem statement and its importance in a real-world scenario
Project management strategy • The student must show diagrams explaining how the project management strategy was implemented (planning, objectives, development, task assignment, etc.). • The student must describe concretely, why this strategy was selected and how were the task divided.
Control strategy • The student must show a pseudocode/ flowchart explaining how the control strategy was implemented (the grade will depend on how detailed the diagram is. • The student must describe in a concrete manner the behaviour of the code. • The student must describe the structure of the code for the xArm and the methodology to insert the Python code to be run inside the framework of ROS.
Tuning methodology • The student is required to explain the tuning methodology of the parameters (e.g. if done by trial and error, the student must show the different trials, constraints and conditions to select the parameters), Which tests were used to tune the parameters? Plots used? Constraints? Acceptance conditions?
Reflections and proposals • The student must provide a small reflection on the behaviour of the robot (is it as expected? Good? Bad?) • What problems occur with their control algorithm in the simulated and real robot (friction due to points too close, proportional controller saturation because of points too far away, etc.) • The student must propose some solutions on how to solve these issues for the real and simulated robots. • The student is expected to present solutions to the localisation problem (mechanical: such as better friction on the wheels, less noise encoders, electronics: filtering or software: better localisation algorithms if possible)
References • IEEE Conference Format
Presentation and clarity • The report must be clear for the reader, well organised and with a good presentation.

Rules

- This is a challenge, not a class. The students are encouraged to research, improve, tune, and explain their algorithms, designs, and manufacturing processes.
- MCR2(Manchester Robotics) Reserves the right to answer a question if it is deemed to contain partially or totally an answer.
- The students are welcome to ask only about the theoretical aspects challenge.
- For the autonomous part of the challenge, no remote control, or any other form of human interaction with the manufacturing process is allowed (except at the start).
- All the students must respect each other and abide by the previously defined rules.
- Manchester Robotics Ltd. reserves the right to provide any form of grading. Grading and grading methodology are done by the professor in charge of the unit.
- Further questions about the challenge can be asked to the professor in charge of the unit.
- Modifications to this challenge must be in accordance with the professor in charge of the unit and MCR2.
- The students are free to use any software or hardware available (within the scope of the unit) to perform the tasks previously mentioned.
- The students must act in a safe and respectful manner towards each other when using the equipment.
- The students MUST comply with the safety regulations of the laboratory and all the equipment used.

- Manchester Robotics Ltd. gives no warranty and accepts no responsibility or liability for the accuracy or completeness of the challenge presented.
- Students must care of all the equipment used in the Smart Factory laboratory, and leave the equipment as it was initially set.
- Under no circumstances will Manchester Robotics Ltd. be held responsible or liable in any way for any claims, damages, losses, expenses, costs, or liabilities whatsoever (including, without limitation, any direct or indirect damages for loss of profits, teaching interruption or loss of information) resulting or arising directly or indirectly from your use of or inability the information and material on this presented, even if the client (Tec de Monterrey) has been advised of the possibility of such damages in advance.