# Manchester Robotics / Tecnológico de Monterrey

# MC3001C: Cyber-Physical Systems I

## Introduction

The objective of this course, created by Manchester Robotics Ltd. (MCR2), is to equip students with the skills needed to operate mobile robots and solve challenges in cyber-physical systems.

This course is divided into two sections, carefully designed for the user to learn about the different aspects of ROS, from topics and messages to control and simulation of a real robot.

The first part of this course introduces the basic concepts and general knowledge of the ROS environment to the user.

The second part of the course is dedicated to the analysis, control, and simulation of mobile robots in different environments.

This course will be based on challenges to make the student aware of the problems faced while implementing advanced intelligent algorithms in robotics.

## General Information

* MCR2 Person in Charge: Dr. Alexandru Stancu and Dr. Mario Martinez
* Tecnológico de Monterrey Person in Charge: Dr. Consuelo Rodríguez Padilla
* Duration 10 Weeks.
* Student counseling: Via appointment.
* Weekly Briefings: TBD.
* Classes: 10 sessions, 2 groups.
  + Group 1: Monday, 9- 11 AM (Central Mexico Time)
  + Group 2: Monday, 3 - 6 PM (Central Mexico Time)
* Starting: Monday, 7 August 2023
* Ends: Monday, 16 October 2023
* No Class: 11 September (UR Certification)

## Requirements:

* Computer with access to Zoom (online classes).
* Computer with Ubuntu 20.04 and ROS Noetic or MCR2 Virtual Machine.
* Knowledge of Windows.
* Knowledge of ROS.
* Knowledge of Ubuntu.
* Understanding of robotics.
* Access to a SMART Robot
* DC Motor (6V with Encoder), Arduino Mega, Wires, and an H-Bridge (Suitable for the Motor L298).

## Course Information

* Student Demographic: TBD
* Number of Professors: 2
* Grading: Rubric at the End.
* Deliverables: Two Reports, mid-term challenge, and final challenge report.
* Final Challenge Deliverable: TBD.
* ZOOM Link Classes:
  + Group 401: <https://itesm.zoom.us/j/8207925594>
  + Group 402: <https://itesm.zoom.us/j/2108335799>
* ZOOM Link Briefings: TBD
* Student GitHub Link: https://github.com/ManchesterRoboticsLtd/MR3001C\_Cyber-Physical\_Systems\_I

## Week 1: ROS – Fundamentals

This session will introduce the teaching team and the basics of ROS.

## Session:

* Who are we?
* Introduction to robotics.
* Introduction to VM/Ubuntu
* Introduction to ROS
* Overview of ROS Environment
  + Topics, Messages
  + Launch Files

### Activity 1: Talker and Listener

* Generate a node that sends a message to another node to listen to it.

### Activity 2: Launch Files

* Create a launch file for the previously created nodes

### Mini- Challenge

* Generate a node that sends a signal to another node to process it.

### Requirements

* Computer with access to Zoom
* Ubuntu 18.04 or 20
* ROS Melodic /Noetic Installed (Full installation).
* If Ubuntu 18.04 or 20 cannot be installed, MCR2 offers a Virtual Machine with ROS preinstalled (installation instructions in Week 1 Folder).

## Week 2: ROS Practicalities

This week will introduce some helpful ROS practicalities.

### Session:

* ROS Namespaces
* ROS Parameter Server
* ROS Custom Messages

### Activity 3: Linearisation

* Parametrise previous nodes.

### Activity 4: Confidence ellipsoid

* Create a custom message for the previous nodes.

#### Mini-Challenges

* P/PI Controller from scratch to a 1st order simulated system.

**Requirements**

* Requirements of Session 1.

### Week 3: ROS-Hardware Communication

This week will introduce hardware communication between ROS and the Hackerboard/Arduino using ROS Serial.

### Session:

* ROS Serial
* Arduino
* ROS Serial/Arduino Communication.

### Activity 5: Linearisation

* Rosserial communication with Arduino/ESP32.

#### Mini-Challenges

* Motor Speed regulation using ROS.

**Requirements**

* Requirements of Session 1.
* Installation of the Arduino IDE and the Rosserial package in the VM or Ubuntu (See instructions on Session2 MCR2\_Arduino\_IDE\_Confirguration),
* Access to Hackerboard and an MCR2 DC motor.
  + \* In case you have no access to the Hackeboard, the hardware can be replaced with an Arduino Mega, an L298n Motor Driver, and a DC motor brushed with encoder (More information MCR2\_General\_Information\_Prerequisites).

Diagram

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### Week 4: ROS-Hardware Communication (Data Acquisition)

This week we will present how to acquire data using a microcontroller and ROS.

### Session:

* Encoder Basic Theory.
* Acquiring data from a source.
* Mid-Term Challenge Presentation.

### Activity 6: Data Acquisition

* Acquiring data from hardware.

#### Mini-Challenges

* **Acquire data from the encoders using Arduino.**

**Requirements**

* Requirements of Session 1.
* Installation of the Arduino IDE and the Ros Serial package in the VM or Ubuntu (See instructions on Session2 MCR2\_Arduino\_IDE\_Confirguration),
* Access to Hackerboard and an MCR2 DC motor.
  + \* In case you have no access to the Hackeboard, the hardware can be replaced with an Arduino Mega, an L298n Motor Driver, and a DC motor brushed with encoder (More information MCR2\_General\_Information\_Prerequisites).

Diagram

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### Week 5: Mid-Term Challenge Presentation

This week each team will present its Mid-Term Challenge.

### Session:

* Presentations.

### Week 6: Mobile Robots Introduction. \*

This week, the basics of mobile robots will be introduced.

### Session:

* Modelling Basics.
* Differential Drive Basics.
* ROS Visualisation / Simulation Tools.

### Activity 7: Teleoperation of a mobile robot

* Teleoperation of a Mobile robot.

#### Mini-Challenges

* **Simple Teleoperation of a real Mobile Robot.**

**Requirements**

* Requirements of Session 1.
* TBD.

### Week 7: Open Loop Control. \*

This week will introduce some basics of open-loop control for mobile robotics.

### Session:

* Open loop control theory.
* Differential Drive Robot Open Loop Control.

### Activity 8: Teleoperation of a mobile robot

* Simple DDR control.

#### Mini-Challenges

* **Open Loop Path following of a real Mobile Robot.**

**Requirements**

* Requirements of Session 1.
* TBD.

### Week 8: Closed Loop Control. \*

This week will introduce some basics of closed-loop control for mobile robotics.

### Session:

* Closed loop control theory.
* Differential Drive Robot Closed-Loop Control.
* Presentation of the Final Challenge

### Activity 9: Teleoperation of a mobile robot

* Simple closed-loop control.

#### Mini-Challenges

* **Closed Loop Path following a real Mobile Robot.**

**Requirements**

* Requirements of Session 1.
* TBD.

### Week 9: Robot Simulation. \*

This week will introduce some basics on simulating the robot in Gazebo and RVIZ.

### Session:

* Robot Visualisation/Simulation Tools.

#### Mini-Challenges

* **Final Challenge.**

**Requirements**

* Requirements of Session 1.
* TBD.

### Week 9: Final Challenge Presentation. \*

Presentation of the final challenge.

### Session:

* Presentations.

*\* Weeks may change due to material and laboratory sessions.*