# Manchester Robotics / Tecnológico de Monterrey

# TE3003B: Integration of Robotics and Intelligent Systems

## Introduction

This course, developed by Manchester Robotics ltd. (MCR2), aims to provide students with understanding of modern autonomous systems.

This course is divided into ten sessions, carefully designed for the user to learn about the problems of localisation and provide students with an overview on main topics encountered in autonomous systems field such as localization techniques, navigation, and intelligent path-planning.

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

## General Information

* MCR2 Person in Charge: Dr. Alexandru Stancu, Dr. Mario Martínez Guerrero
* Tecnológico de Monterrey Person in Charge: TBD
* Duration 10 Weeks.
* Student counselling: 2 hours session.
* Weekly Briefings: TBD.
* Classes: TBD.
* Starting: TBD
* Ends: TBD
* Requirements:
  + Computer with access to Zoom (online classes).
  + Computer with Ubuntu 18.04 and ROS Melodic.
  + Knowledge of Windows.
  + Knowledge of ROS.
  + Knowledge of Ubuntu.
  + Understanding of robotics.
  + Access to a MCR2 Puzzlebot Lidar/Jetson Edition.
* Student Demographic: TBD
* Number of Professors: TBD
* Grading: TBD.
* Deliverables: Each professor determines.
* Final Challenge Deliverable: TBD.
* Rubric: TBD.
* ZOOM Link Classes: Alejandro TBD
* ZOOM Link Briefings: Alejandro TBD
* Student GitHub Link: TBD

## Week 1: Dynamical Systems

## Session:

* Course Introduction.
* Dynamical Systems.
* State space representations.
* Linear and Nonlinear systems.
* Discrete-Time Systems.

### Activity: Dynamical System Modelling

* Model a Nonlinear system in SS using ROS and visualise it using RVIZ.

## Week 2: Mobile Robots Fundamentals

## Session:

* Introduction to mobile robotics.
* Kinematics for a differential drive mobile robot.
* Proprioceptive and exteroceptive sensors.
* Dead Reckoning (Encoder-based localisation)
* Point-to-point navigation.

### Activity: Robot Modelling

* Model the Puzzlebot in ROS and Visualise it in RVIZ.
* Move the robot using a point-to-point navigation strategy.

## Week 3: Probabilities in Robotics

### Session:

* Introduction to probabilities
  + Preliminaries (Basics).
  + Discrete random variables.
  + Continuous random variables.
  + Distributions (Uniform, Gaussian)
* Linearisation – Fundamentals

### Activity: Linearisation

* Linearise a dynamical system and compare its behaviour with the original nonlinear real system.
* Mobile robot linearisation.

## Week 4: Uncertainty in mobile robotics

### Session:

* Ellipsoid of confidence.
* Mobile robot localisation (dead reckoning) in the presence of uncertainties

### Activity 1: Localisation Problems

* Move the Puzzlebot in a straight line (open loop) from point A to point B, for a specified time. Repeat the experiment 15 to 20 times and record the position data.
* Turn the robot from an initial angle (open loop), for a specific time to a final angle, and record the position data. Repeat the experiment 15 to 20 times.
* The experiment must be run with the real robot, Gazebo and kinematic simulation.

### Activity 2: Localisation Problems

* Multiple point navigation for the different paths designed. Repeat the experiment multiple times.

### Activity 3: Confidence ellipsoid

* Plot the confidence ellipsoid of a mobile robot. Use the multiple-point navigation.

## Week 5: Reactive navigation

### Session:

* Exteroceptive sensors.
* Obstacle avoidance
* Obstacle avoidance algorithms:
  + Bug 0, Bug 1, Bug 2.

### Activity: Reactive navigation

* Implementation of obstacle avoidance algorithms Bug 0 and Bug 2 in simulation (Gazebo) and with the real robot.

## Week 6: Sources of information

### Session:

* Bayes Filter.
* Kalman Filter
* Kalman Filter for map-based localisation (2D).

### Activity: Reactive navigation (Week 5)

* Implementation of obstacle avoidance algorithms Bug 0 and Bug 2 in simulation (Gazebo) and with the real robot.

## Week 7: Final Challenge

### Session:

* Kalman Filter for map-based localisation (2D).
* Camera-based localisation for mobile robots.
  + Aruco markers
  + Visual localisation of mobile robots using Aruco markers
  + Kalman filter for map-based localisation in 3D. Kalman filter estimation by combining visual localization with encoder information.

### Final Challenge: Kalman Filter Localisation

* Mobile robots’ navigation
* Camera based Kalman filter localisation for the Puzzlebot. (Steps)
  1. Multiple-point navigation with obstacle avoidance. Use Dead reckoning localisation.
  2. Multiple point navigation no obstacles, using visual based localisation.
  3. Multiple point navigation no obstacles, using Kalman filter estimation.
  4. Multiple point navigation with obstacles, using Kalman filter estimation.

## Week 8: Final challenge Q&A

### Session 1:

* Q&A

## Week 9: Grading

### Session:

* Grading