MCT443: Design of Autonomous Systems

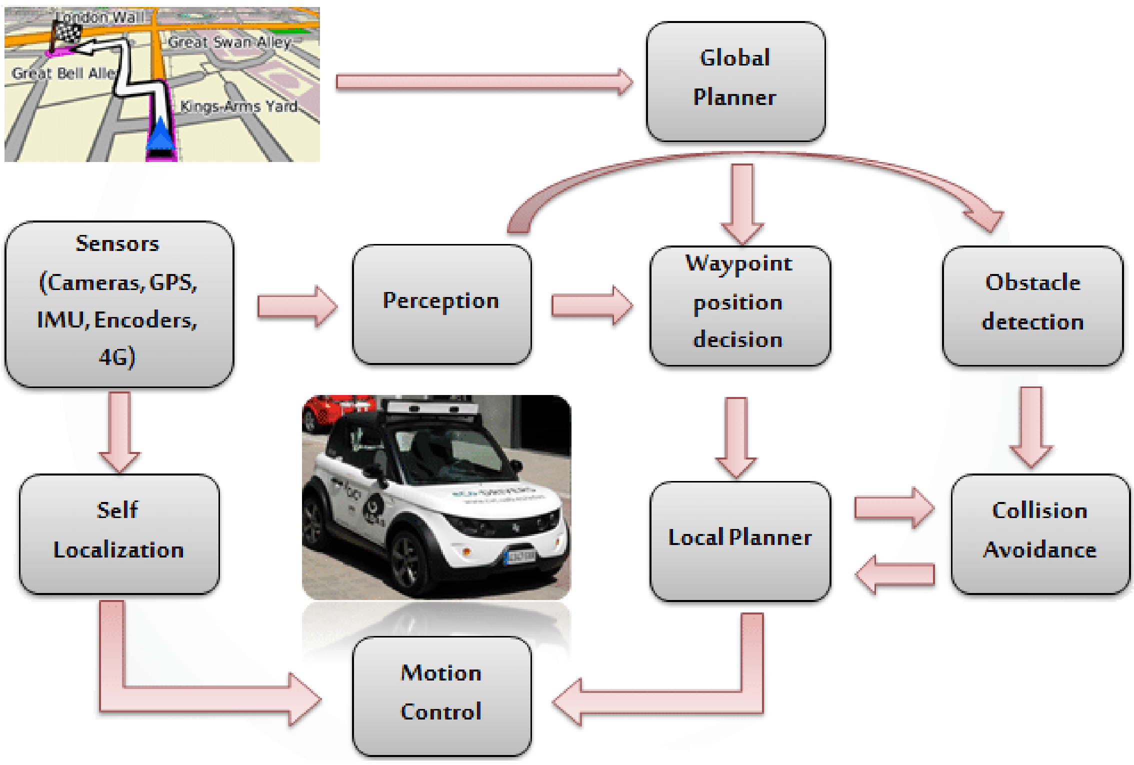
Fall 2025

Project Description

Wheeled Mobile Robot with Lane-Keeping and Obstacle Avoidance

Project Objectives

The objective of this project is to equip students with the ability to design and implement a fully functional autonomous vehicle system in both simulation and (optionally) hardware environments. This includes integrating control systems for lane-keeping and obstacle avoidance using a differential drive robot. Students will develop and validate their control algorithms in simulation tools like ROS2 and Gazebo, while incorporating safety and efficiency considerations. Additionally, students will enhance their skills in mechatronic system design, testing, and documentation, with an optional hardware implementation offering practical insights into real-world applications.



Project Details

Students will design and simulate an autonomous differential drive robot capable of performing two distinct tasks:

1. **Phase 1 - Lane-Keeping:**
   The robot must maintain a straight-line trajectory while staying within a single lane for a total distance of 10 meters. This phase emphasizes stability and accuracy in lane-keeping using feedback control.
2. **Phase 2 - Obstacle Avoidance and Lane Transitions:**
   Once lane-keeping is achieved, the robot must detect obstacles and change lanes. In this phase, the robot encounters two obstacles:
   - The first obstacle is located 4 meters into the lane. The robot must detect this obstacle, transition to the adjacent lane, and continue for another 4 meters.
   - A second obstacle will be encountered in the new lane. The robot must detect it, transition back to the original lane, and stop at a designated checkpoint 10 meters from the starting point.

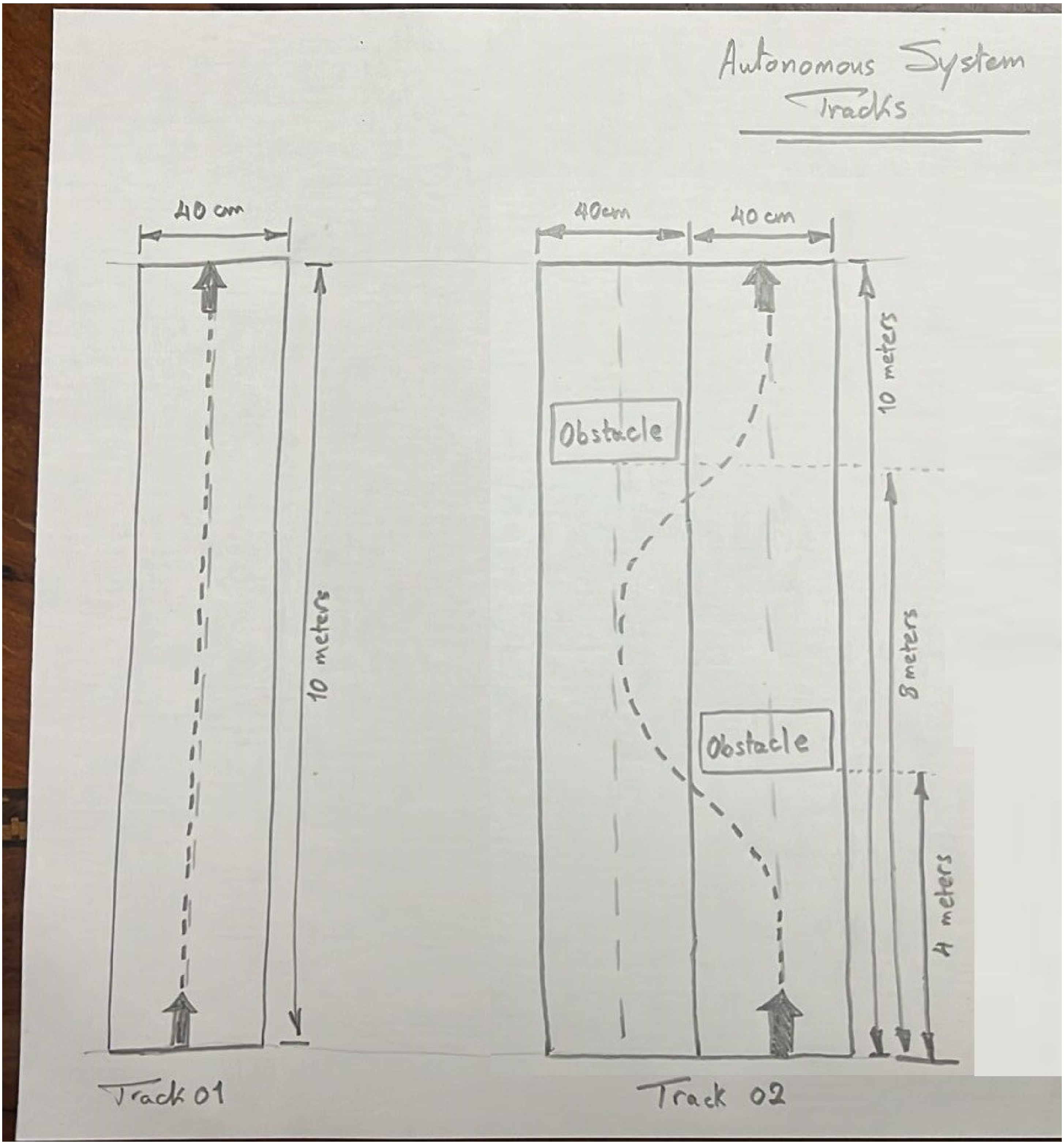
Simulation Tools:

The project **must** be implemented using the Robot Operating System 2 **(ROS2 Jazzy)** and Gazebo simulation environment. Students may use **ready-made CAD models** from open-source platforms like **GrabCAD** or **build their own.**

You must read directly from the chosen sensors, reading from Gazebo topics is **NOT** allowed.

Hardware Implementation Bonus:

An optional 5 marks bonus will be granted to teams that develop and demonstrate a physical prototype of the autonomous differential robot, applying the same control strategies in the real world.



You **must** design your robot to fit within the shown tracks.

Milestones and Submissions

To guide the progress, there will be **two** major submissions spread throughout the semester, with the final implementation due in **Week 14.** The earlier submission focuses on planning, design, and control strategies, which are directly related to the final project output.

Formative Submission (Week 12 Saturday 6-Dec):

1. **System Architecture & Overview:**
   - Develop a high-level block diagram showing the system’s architecture, including sensors for lane-keeping and obstacle detection, controllers for propulsion, and actuators.
2. **Control Strategy**
   a. Define and develop the control strategy for lane-keeping, focusing on feedback control using sensors (e.g., PID controllers).
   b. Develop the strategy for obstacle detection and avoidance, specifying how the robot will execute lane transitions.
3. **Simulation Setup:**
   - Set up the Gazebo simulation environment, using predefined models (e.g., TurtleBot) or ready-made CAD designs.
   - Integrate the control strategies into the Gazebo simulation environment and demonstrate partial progress on lane-keeping or obstacle avoidance.

Deliverables: System architecture block diagram, Control strategy documentation, partially integrated simulation with control strategies.

Final Submission (Week 14 Saturday 20-Dec): Final Simulation for Both Phases

1. **Phase 1 Implementation - Lane-Keeping**:
    - Demonstrate the robot traveling in a straight line for 10 meters while maintaining its lane.
2. **Phase 2 Implementation - Obstacle Avoidance and Lane Transitions:**
    - Implement the obstacle detection and lane transition systems, showing the robot’s ability to avoid obstacles and return to its original lane.

Assessment Criteria

- **Formative Submission (0%)**: Detailed control strategy development and progress on lane-keeping or obstacle avoidance in simulation.
- **Final Submission (85%)**: Final simulation covering both lane-keeping and obstacle avoidance, demonstrating full functionality.
- **Final Report (15%)**: Completeness, clarity, and depth of analysis.