Wheeled Robots

1. **Course number and name**: 020RBMES4 Wheeled Robots

2. **Credits and contact hours**: 4 ECTS credits, 2x1:15 contact hours per week

3. **Instructor's or course coordinator's name**: Danielle S. Nasrallah

4. **Instructional materials:** Textbook, Lecture notes, Journal and Conference papers, Chapters in books.

5. **Specific course information**
   a. **Catalog description:**
   This course provides in-depth coverage of wheeled mobile robots. The material covers (i) nonholonomy and integrability of kinematics constraints; (ii) modelling: kinematics, dynamics, and state-space representation; (iii) nonlinear control strategies (open-loop and closed-loop), and (iv) simulation using the virtual wheeled mobile robots' laboratory. Four architectures are covered: differential-drive robot, Ackermann-based steering robot, Articulated-based steering robot, and mobile wheeled pendulum.

   b. **Prerequisite:** None

   c. **Selected Elective** for ME and EE students.

6. **Educational objectives for the course:**
   a. **Specific outcomes of instruction:**
      - Build the kinematics model of a three-wheeled robot composed of a rear differential-axle and front caster wheel.
      - Understand nonholonomic constraints, write the system in Pfaffian form, and define vector of independent speeds.
      - Derive kinematics model. Use Gazebo as dynamics engine. Identify navigation coordinates.
      - Control the robot using Lyapunov function for navigation and sliding mode control.
      - Build the kinematics model of the robot with Ackermann-steering based mechanism.
      - Apply the non-linear change of coordinates to put the robot in a one-chain system form.
      - Generate a trajectory for point-to-point motion using polynomial inputs.
      - Apply those inputs to the dynamics model and observe the drift due to dynamics, which was not considered.
      - Re-inject those inputs in the kinematics model to generate the references for navigation coordinates.
      - Apply closed-loop control strategy to track the gamma-shape trajectory.

- Notice that MWP is a subclass of DDR, where the caster wheel has been removed rendering the platform oscillating and introducing unstable zero-dynamics.
- Build the dynamics using Natural Orthogonal Complement
- Apply the non-linear change of coordinates to achieve global input-output linearization.
- Control the platform oscillation via heading speed and its orientation via steering rate.
- Implement upper layer of control for robot navigation as done in DDR.

b. PIs addressed by the course

PI	1.1	1.2	1.3	7.1	7.2
Covered	x	x	x	x	x
Assessed	x	x	x	x	x

7. Brief list of topics to be covered and approximate lecture hours:

a. Differential-drive robot
- Kinematics model and nonholonomy.
- Nonlinear control: sliding mode with Lyapunov function for navigation.
- Virtual lab: validation of modelling and control.

b. Ackermann-based steering robot
- Kinematics model and nonholonomy.
- Nonlinear control: chained form and polynomial inputs.
- Virtual lab: validation of modelling and control.

c. Articulated-based steering robot
- Kinematics model, Nonholonomy, and Gamma-shape trajectory following.
- Virtual lab: validation of modelling and control.

d. Mobile wheeled pendulum: inverted and non-inverted
- Kinematics model, nonholonomy, and open-loop motion control of non-inverted pendulum.
- Dynamics model using Natural Orthogonal Complement.
- Nonlinear control: input-output linearization.
- Virtual lab: validation of modelling and control.