COMP0244: Legged Robotics
Coursework 2: Real-Robot Foot Contact Estimation & Path Tracking

Demo:
31/03/2025 at 12:00-16:00 (UK time), with a mandatory in-person demo that day in the Robotics Lab (One Poole Street).

Code:

31/03/2025 at 16:00 via Moodle

Total Weight: 60% of your final grade (for this module).

Introduction

In this second coursework, you will extend your legged-robot control and perception skills from simulation into reality. You will deploy your solutions on a real Unitree Go2 quadruped robot and demonstrate your system live in the Robotics Lab. Although you are encouraged to develop and iterate on your solution within Gazebo simulation for speed and convenience, the final assessment will be performed on the real robot.

Your overarching goal is to (1) estimate foot contacts using on-board sensing (excluding direct foot contact force measurement), and (2) develop a path-tracking controller with suitable localization and control methods. You can use any approaches or sensor modalities you like so long as they can run on the robot in real time.

Coursework Overview

Environment & Setup

- **Hardware**: Unitree Go2 quadruped robot.
- **Software**: ROS2-based system in Python (recommended).
- **Evaluation**: Real-robot tests conducted on 31/03/2025.
- **Simulation**: Students should use the Gazebo simulation resources provided for development and preliminary testing.

You will deliver two main **Tasks** described below.

Task 1: Foot Contact Estimation (40% of CW2 Grade)

Objective

Develop a method to estimate whether each of the four feet is in contact with the ground. You *cannot* use the built-in foot contact force sensor data directly for your estimation; instead, you must rely on any other available on-board sensors (e.g., IMU, joint states, joint torques, etc.). You can use the foot contact sensor when developing to assess the accuracy of your system.

Requirements

1. Your algorithm must publish a **contact state** for each of the four feet as a ROS node in real time.
2. You can use any data-processing techniques or machine learning methods of your choice, as long as they run reliably in real time on the real robot.
3. You must handle normal walking gaits on the robot. The Teaching Assistants (TAs) will pilot the robot for approximately one minute, traversing an arbitrary path in the lab.

Evaluation

- We will record both (a) your estimated foot contacts and (b) the robot's built-in foot contact force signals (considered ground truth) during the demo.
- Your grade for Task 1 will be based on the **accuracy** of your contact estimates (e.g., the fraction of frames in which your estimate matches the ground-truth force sensor readings).
- The ranking for accuracy will determine your mark.

Grading Criteria

- **ROSBag Provision**:
  - TA will Provide two standard ROSBags:
    - One for **training** (with ground truth included).
    - One for **testing** (without ground truth).
  - The robot's movement in both ROSBags should include:
    - Going straight, stopping, and turning, lasting approximately **20 seconds**.
  - Students can use the training ROSBag to verify the correctness of their algorithms.
  - For grading, students must submit their estimation results for the testing ROSBag.
- **Result File Submission**:
  - Students must provide a result file (following the provided template) for the training ROSBag, containing the true state of foot contacts.

    - The same template must be used to submit the estimation results for the testing ROSBag.
- **Evaluation and Grading**:
    - Students' results will be evaluated based on the accuracy of their foot contact estimates.
    - Results will be sorted in **descending order** of accuracy to determine the final grades.

Task 2: Path Tracking on the Real Robot (60% of CW2 Grade)

Objective

Implement a path-tracking controller that drives the quadruped to follow a given trajectory in the lab. This involves:

1. Localizing the robot's position and orientation (using any sensor fusion or state estimation method of your choice).
2. Commanding velocity inputs (high-level control) to achieve minimal cross-track error.

Requirements

1. **Unknown Path**: The path will be provided on demo day. You must be prepared to handle a variety of curve or polygonal patterns on the floor.
2. **Outer Loop Control**: Your solution should produce velocity commands (e.g., linear and angular velocities) for the robot's locomotion system.
3. **Localisation**: May rely on onboard sensors such as IMU, joint encoders, or external sensors (e.g., camera), as long as you can integrate them on the robot in real time.

Evaluation

- We will measure how **accurately** your robot follows the path (cross-track error) and how quickly it completes the path.
- Teams will be ranked according to a combined metric of path-tracking error and completion time (speed).
- Higher accuracy and lower time to finish result in higher scores.

Evaluation Criteria

- **Pose Tracking**:

    - Accumulated error: The total distance between the robot's current odometry and the planned waypoints along the trajectory.
- **Completion Time**:
    - The total time taken by the robot to complete the entire trajectory.

Submission Details

1. **Code Submission**:
    - Create a folder named cw2_team_<team_number> containing all your source code and launch files.
    - Ensure that your code runs on the real robot *and* in Gazebo simulation (though final marking is on hardware).
    - You can adapt or extend the starter packages from the course labs, but any changes must be contained or documented clearly in your own package.
2. **README File**:
    - Summarize your approach for each task (up to 1 page per task).
    - Specify how to build and run your package on the real robot as well as in simulation.
    - Include a brief description of each team member's contributions and approximate work hours.
3. **On the Day**:
    - Arrive prepared to run your code on the real quadruped.
    - You will have a short time slot to demonstrate each task. The TAs will measure the performance metrics (contact estimation accuracy for Task 1, path-tracking performance for Task 2).
4. **Deadline**:
    - You must upload your code to Moodle by **31/03/2025 at 16:00 (UK time)**. The in-lab demo will happen on the same day.
    - If your code fails to build or run, we will follow your README instructions. If it still does not function, you may receive zero for the relevant tasks.

Marking Criteria

Your overall mark (out of 100% for this coursework) will be split between:

- **Task 1 (Foot Contact Estimation)**: 40%
    - **Accuracy** (e.g., correct detection vs. ground truth)
- **Task 2 (Path Tracking)**: 60%
    - **Cross-Track Error** and **Completion Time**

In addition, for both tasks, we will also consider:

- **Clarity and Readability of Code**
- **Quality of Documentation** (your README)
- **Code Structure and Efficiency**

Good Luck!

Use this coursework to develop and demonstrate your skills in perception and control on real legged systems. We look forward to seeing your robots in action!