ME639 : Introduction To Robotics
[Fall 2025]

Assignment 1 : ROS 2 & MuJoCo Simulation

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1 Environmental Validation

The original instructions referred to the **official `mujoco_ros` interface**, which is now deprecated. As an alternative, open-source options were explored, including the **MuJoCo ROS 2 controls interface** from the MoveIt GitHub repository (Link), which was successfully installed and tested with sample demonstrations such as the differential drive launch file.

For this assignment, simulations were conducted directly in the **MuJoCo Viewer** to ensure smooth testing of the required robotic models without compatibility issues.

2 Serial Chain Manipulator - Franka Research 3

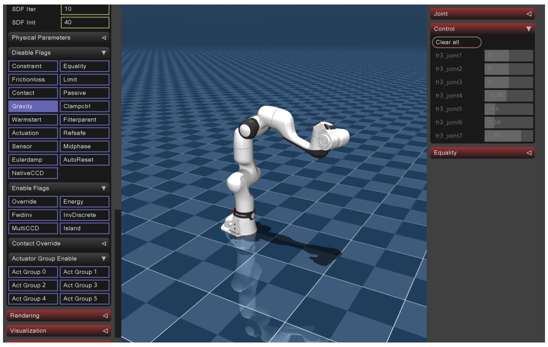
In the `MuJoCo` viewer, the control joints and joint angles can be interactively modified, allowing observation of the manipulator's behavior under different configurations.

In simulation, three main cases were observed:

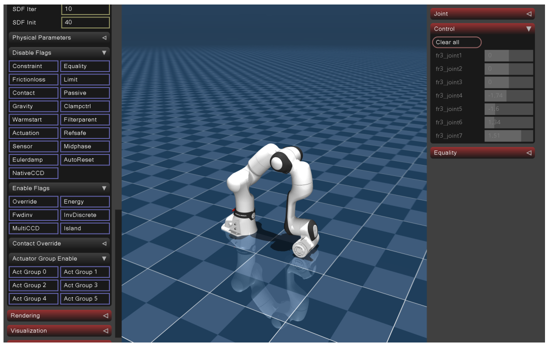
1. **Actuators disabled, gravity enabled:** The manipulator's joints offered no resistance to motion, allowing the links to fall freely under gravity. The arm collapsed to the ground, with each link responding realistically to contact forces and joint constraints.

2. **Actuators disabled, gravity disabled:** Without gravity acting on the system, the manipulator remained suspended in its initial configuration despite the absence of actuator control. The links exhibited no drift, confirming the absence of gravitational torque in the simulation.

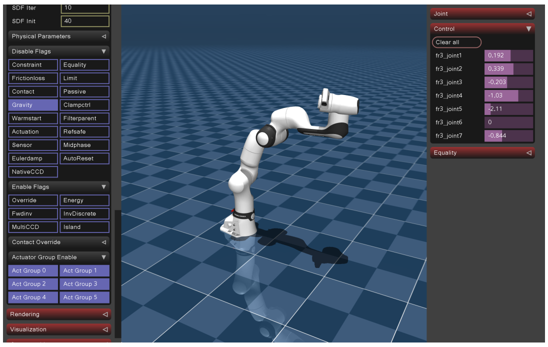
3. **Actuators enabled, gravity enabled:** With joint actuation active, the manipulator maintained its commanded positions regardless of gravity. The arm did not sag or deviate from the set configuration, and joint controls responded as expected, demonstrating the ability of actuators to counteract gravitational forces.



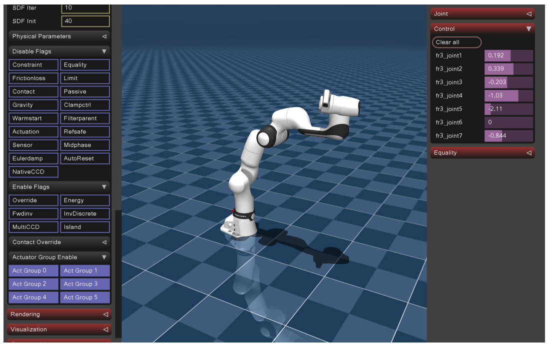
(a) Actuators disabled, gravity disabled



(b) Actuators disabled, gravity enabled



(c) Actuators enabled, gravity disabled



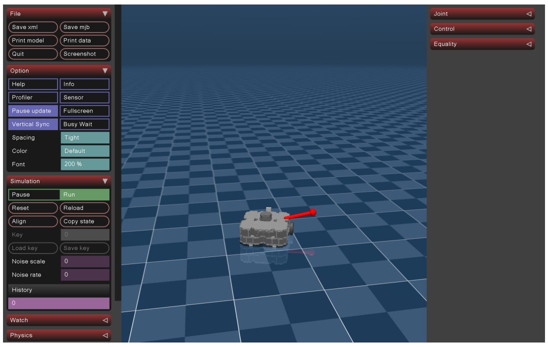
(d) Actuators enabled, gravity enabled

Figure 1: Simulation of FR3 manipulator

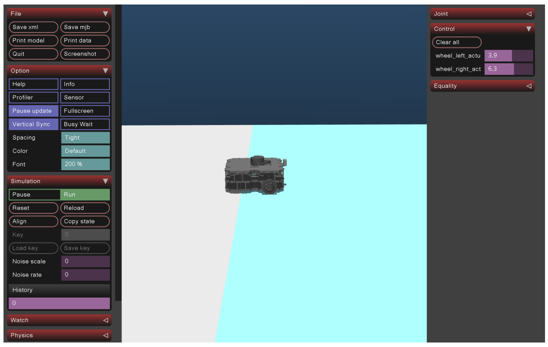
3 Wheeled Mobile Robot – TurtleBot Waffle Pi

The **TurtleBot Waffle Pi** differential-drive mobile robot was simulated in the `MuJoCo` viewer to study its physical behavior under various interaction scenarios.

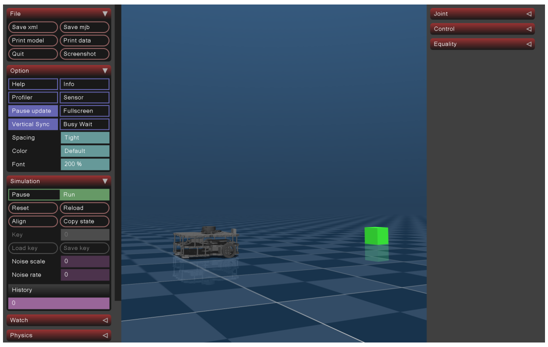
- **Pushing and Toppling:** The robot was pushed and dragged using applied forces, and in certain cases was toppled over to observe stability limits.
- **Wheel Slip:** When one wheel was driven while the other remained stationary, noticeable slip was observed. A custom floor scene was created where half the surface had regular friction and the other half (cyan-colored) was assigned minimal friction. On the slippery half, only minor slip occurred under normal motion. By reducing the wheel friction parameters in the robot's configuration file, significant slip could be induced for more pronounced results.
- **Drift:** Drift behavior was examined by setting the robot to a high velocity and then disabling the actuators. The robot coasted forward slightly due to momentum before coming to a stop.
- **Collision:** Two obstacles were created: an immovable wall and a lightweight block. At lower collision speeds with the block, the TurtleBot moved together with it. At higher speeds, the robot pushed the block away upon impact. In the case of the immovable wall, the wheels began slipping at the point of contact, causing the robot to remain stuck without forward progress.



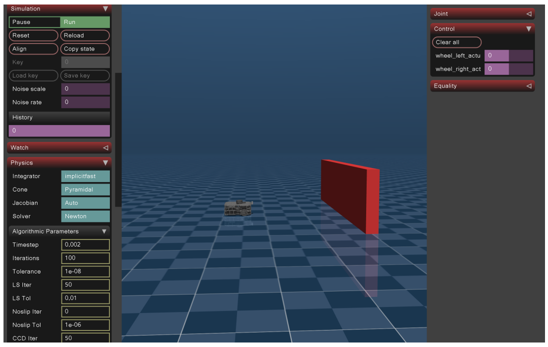
(a) Applying different forces



(b) Slipping on frictionless (slippery) floor



(c) Collision with block



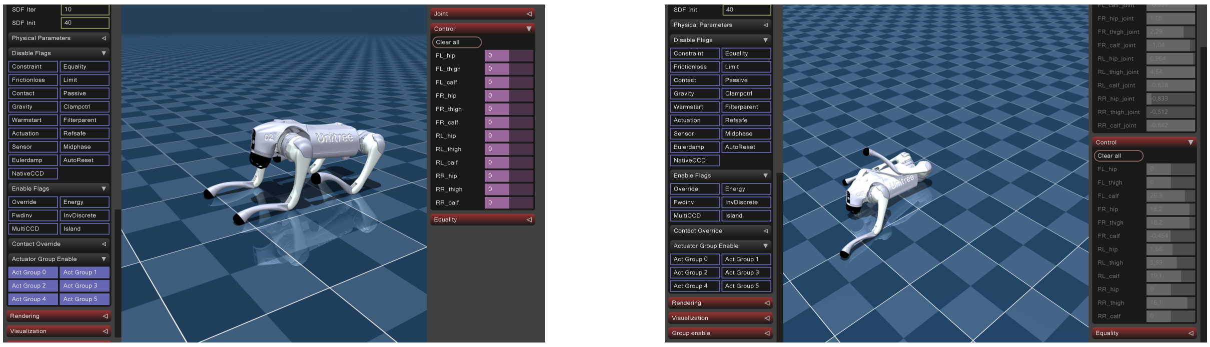
(d) Collision with wall

Figure 2: Simulation of Turtlebot Waffle Pi

4 Quadruped Robot – Unitree Go 2 EDU

The **Unitree Go 2 EDU** quadruped robot model was simulated to observe its stability, joint limits, and interactions with the ground under gravity.

- With actuators disabled, the robot crumpled under its own weight, collapsing into a low, resting position on the ground. The fall was consistent with expected rigid-body dynamics and joint constraints.
- The model featured a large number of control joints for the legs. Coordinating these joints to produce realistic locomotion required moving multiple controls in a precise, rhythmic pattern. Random or uncoordinated adjustments often resulted in unstable or jerky motion.
- Under normal actuation, the quadruped maintained balance when stationary. Joint limits prevented overextension of the legs, and ground contact behaved realistically, showing appropriate reaction forces and friction effects.



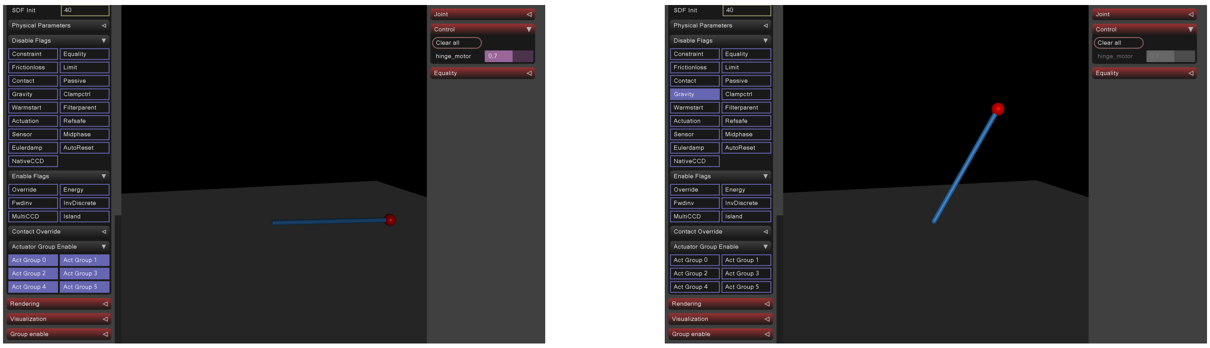
(a) Initial spawning with gravity enabled (b) Actuators & gravity disabled

Figure 3: Simulation of Unitree Go 2

5 Inverted Pendulum

A simple inverted pendulum model was simulated to study its behavior under different gravitational conditions, observe actuator response, and note general stability characteristics.

- Under gravity, the pendulum quickly fell from its initial position and struck the ground, unable to maintain an upright position without active control. With gravity disabled, it stayed fixed at the set angle, and actuator control felt smoother as there was no constant torque required to oppose gravity.
- In the absence of gravity, fine adjustments to the pendulum's angle were easier to achieve. Under gravity, the actuators had to work continuously to counteract the pendulum's weight.
- The pendulum exhibited realistic rotational inertia, joint friction, and damping effects. When given an initial push in gravity-enabled mode, it oscillated briefly before settling on the ground due to energy loss from friction and damping.



(a) Gravity enabled (b) Gravity disabled

Figure 4: Simulation of Inverted Pendulum

6 Challenges Faced

1. Faced compatibility and dependency issues while setting up the MuJoCo–ROS bridge, so I used MuJoCo Viewer directly as an alternative while continuing to learn the bridge setup.

2. MJCF/XML files were new to me; it took time to understand the structure and the significance of elements like `geoms` and `links`, which can drastically affect the simulation behaviour.

3. Robots like the Unitree Go 2 EDU had many control joints, making coordinated movement difficult, so I experimented with individual joints to see their effects.