Project: Furuta Pendulum

Robotics (B-KUL-H02A4A)

2025

1 Introduction

The goal of this project is to control a Furuta pendulum so that it can swing up and balance in the upright position, as shown in Figure 1. For this task, you will implement and compare two different approaches: (1) an optimization-based motion planning approach and (2) a reinforcement learning (RL) approach.

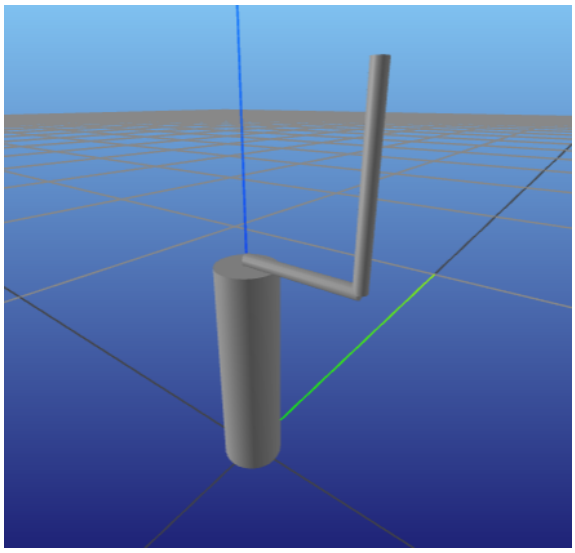

Figure 1

2 What is provided?

The following is provided to help you complete the project:

1. A basic simulation environment for the Furuta pendulum, as seen in Figure 1.
2. A URDF file defining the dynamics and kinematics of the pendulum, called `furuta_pendulum.urdf`.
3. A Python notebook `furuta_pendulum.ipynb` that demonstrates how to interact with the simulation environment and provides a starting point for the project.

4. An RL policy that can stabilize the pendulum in the upright position when starting from a nearly upright position. The policy is implemented using the cleanRL library and is trained using the proximal policy optimization (PPO) algorithm.

3 Task

The projects consists of the following tasks:

1. **Model-based control**
   (a) Design and implement an optimization-based motion planner that can swing the pendulum from the downward position to the upright position.
   (b) Combine the motion planner with the provided RL policy to create a complete control system for the pendulum, that can swing up and balance the pendulum in the upright position.
2. **Reinforcement learning**
   (a) Implement a reinforcement learning algorithm (e.g., DDPG, PPO, etc.) to learn a policy that can swing the pendulum from the downward position to the upright position. The policy should be able to handle disturbances and noise in the system. You can use the provided RL policy as a starting point.
   (b) Use domain randomization to improve the performance of the RL algorithm. This can be done by randomly changing the parameters of the pendulum (e.g., mass, length, etc.) during training.
3. Compare the performance of the model-based approach with the RL approach. Discuss the advantages and disadvantages of each approach.
4. Add another unactuated link to the pendulum, and modify the model-based and RL approaches to handle the additional link.