UNIVERSITÀ DI BOLOGNA

School of Engineering

Master Degree in Automation Engineering

Optimal Control and Reinforcement Learning

OPTIMAL CONTROL OF A GYMNAST ROBOT

Professor: **Giuseppe Notarstefano**

Students:

Rubén Gil Martínez

Guillermo López Pérez

Academic year 2025/2026

Abstract

This project focuses on the optimal control of a planar gymnast robot, modeled as a double pendulum with torque applied only at the hip (Acrobot). We implement trajectory generation using Newton-like algorithms and tracking via LQR and MPC techniques[cite: 37, 51, 61].

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Introduction

The goal of this project is to design an optimal trajectory for a planar gymnast robot[cite: 3]. The system consists of two links where actuation is provided only at the second joint (the hip)[cite: 3, 12]. The dynamics involve nonlinear interactions described by mass, Coriolis, and gravity matrices[cite: 13, 16].

Contributions

Chapter 1

Problem Setup and Discretization

In this section, we present the continuous-time dynamics of the Acrobot and the discretization scheme used (e.g., Runge-Kutta 4th order) to transform the system into discrete-time state-space equations[cite: 24, 26].

Chapter 2

Trajectory Generation

This chapter covers the computation of system equilibria and the generation of an optimal transition trajectory using a closed-loop Newton-like algorithm[cite: 36, 37]. We also explore trajectory generation for smooth state-input curves[cite: 49].

Chapter 3

Trajectory Tracking via LQR

We linearize the robot dynamics around the reference trajectory and implement an Infinite or Finite Horizon LQR controller to ensure robust tracking under perturbed initial conditions[cite: 51, 54].

Chapter 4

Trajectory Tracking via MPC

This chapter discusses the implementation of Model Predictive Control (MPC) to track the optimal reference, accounting for system constraints and performance[cite: 61].

Chapter 5

Results and Animation

We present the simulation results, including the required semi-logarithmic plots for cost and descent directions[cite: 70, 71]. A link to the Python animation of the gymnast robot is also provided[cite: 64].

Conclusions