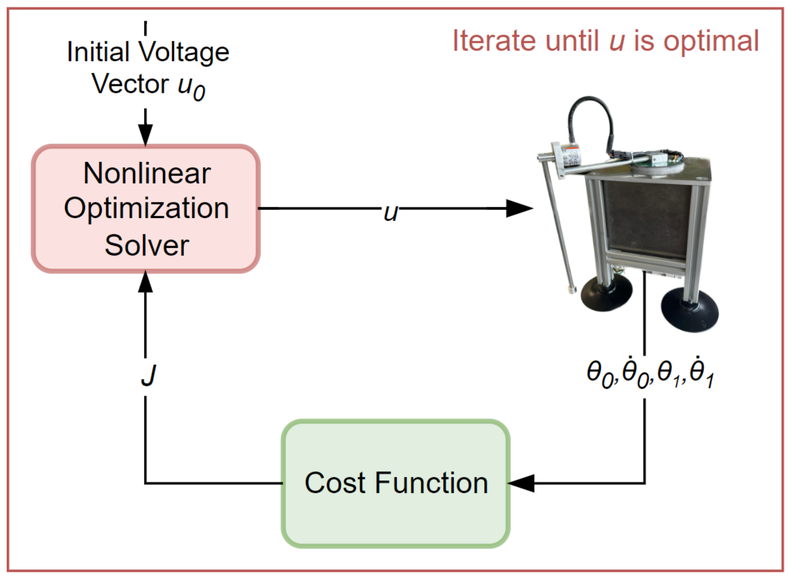
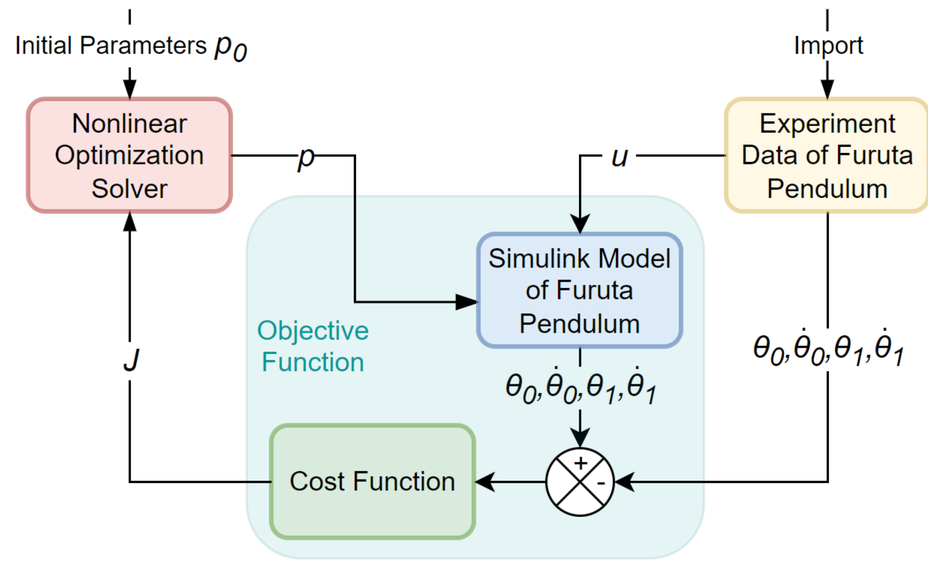
HSLU Hochschule Luzern

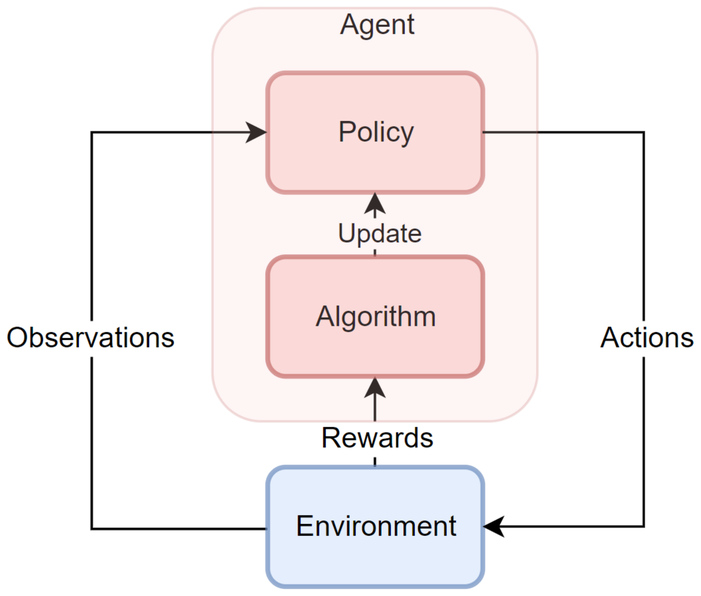
Technik & Architektur

Control of a Furuta Pendulum with Optimization and Reinforcement Learning

Modelling, optimization and reinforcement learning control on a rotary inverted pendulum







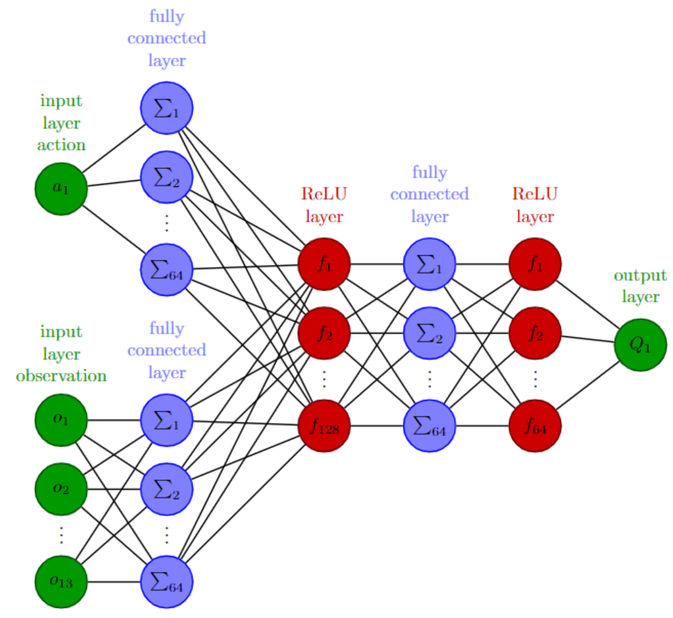


Figure 9.4: Critic Network

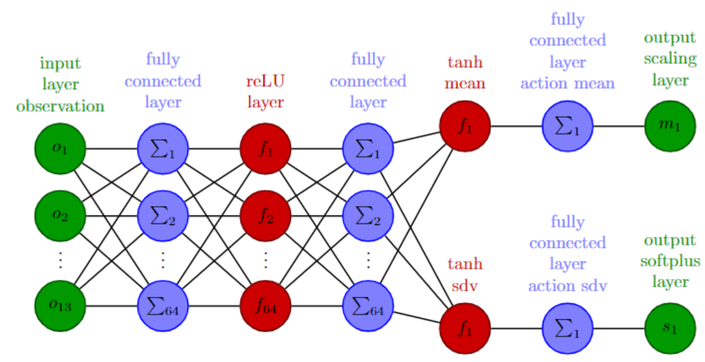


Figure 9.5: Actor Network SAC

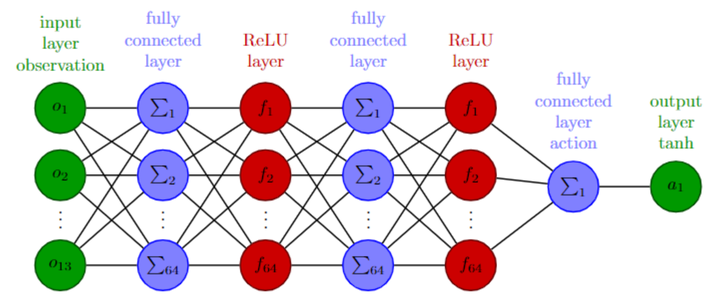


Figure 9.6: Actor Network TD3

Problem statement

A mathematical model of the system is established using Lagrange equations extended with the Rayleigh dissipation function to incorporate the non-conservative torques into the energy equations. Rapid simulation models are built, and friction parameters are identified through experiment design and optimization to increase the model's accuracy. Swing-up control of the Furuta pendulum is accomplished by optimizing a voltage sequence first in simulation and then validating it in the real setup. MATLAB software is integrated into the real setup to test the control algorithms through real-time data transfer. Moreover, reinforcement learning control is explored with different tasks. The performances of two reinforcement learning agents, SAC and TD3, with actor-critic structure, are compared with several reward functions. The velocity control and pendulum stabilization tasks are achieved in simulations.

Key Concept

Nonlinear systems pose extra control challenges. The Furuta pendulum, an underactuated mechanical system, is an experimental platform for developing nonlinear control methods. This project presents advanced control approaches for the Furuta pendulum, highlighting the efficiency of optimization and reinforcement learning with complex system dynamics

Results

Optimization techniques are explored to identify the physical parameters of the experimental setup for a robust simulation. After successfully replicating the setup, a swing-up control sequence for the Furuta pendulum is also obtained using optimization. Designing cost functions for optimization to avoid local minimums was challenging, leading to in-depth research on gradient-based methods for effectively implementing optimization algorithms. The voltage sequence optimized for swing-up is then validated in the actual setup.

Two reinforcement learning agents with different policy gradient methods are brought into desired structures and tested with various reward functions and parameters. Experiments were conducted to explore learning methods for the swing-up and stabilization of the Furuta pendulum. While the swing-up control was not reached, pendulum stabilization was successfully achieved in the simulation.

Student: Kaan Uzel
Advisor: Prof. Thierry Prud'homme
Expert: Martin Scharf