Karlsruher Institut für Technologie

Institut für Industrielle Informationstechnik
Hertzstraße 16, Geb. 06.35
76187 Karlsruhe
www.iiit.kit.edu

Masterarbeit

Safe Reinforcement Learning for Autonomous Quantum Calibration

Description

Design safe, learning-based controllers to stabilize squeezed-light generation in optical parametric oscillators using simulation only. You will model realistic OPO dynamics and noise (including 1/f spectra), incorporate actuator limits and latencies, and develop RL agents with explicit safety constraints as well as hybrid controllers (LSTM predictor + PID or MPC). The project balances algorithmic novelty (safe RL, reward shaping, curriculum learning) with practical deployment concerns (sim-to-real strategies, conservative pilot policies), producing methods that could later be tested in a lab under supervision.

Tasks:

1. Build an OPO dynamics model in QuTiP including pump parameters, damping, decoherence and noise spectra.
2. Create a simulation environment with actuator limits, measurement latency and safety checks.
3. Implement and train RL agents (PPO/TD3) with safety mechanisms (action clipping, constraint penalties) and hybrid controllers (LSTM+PID, MPC).
4. Compare against tuned PID and MPC baselines using Time-to-Loss-of-Lock, control energy and failure rates.
5. Apply curriculum learning and domain randomization to improve robustness and prepare a sim-to-real transfer plan.

The work can be done in German or English.

Prior knowledge

- Control Theory and System Dynamics
- Python and RL frameworks (e.g., StableBaselines3)
- Understanding of constraints and safety in automation
- Experience with QuTiP is advantageous
- Basics of LSTM/Recurrent Networks

Research area

- Safe Reinforcement Learning
- Quantum Control (OPO Stabilization)
- Sim-to-Real Transfer strategies
- Hybrid Control Systems
- Robotics and Autonomous Calibration

Studiengang

- [x] Elektro- und Informationstechnik
- [x] Informatik
- [x] Mathematik
- [x] Physik

Alignment

- [x] Research
- [x] Implementation
- [x] Analysis and evaluation
- [x] Method development
- [x] Simulation

Start

At any time

Links

Mitarbeiterseite

Ansprechpartner

Dr. Hamza Gardi
Westhochschule, Hertzstr. 16
Geb. 06.35, Zimmer 115
hamza.gardi@kit.edu
Tel.: (0721) 608 - 4451759