

Master's Thesis

Task description for the Master's Thesis on the topic of

Imitation Learning for Optimal Thrust Control of Rocket Engines

Background

Traditionally, rocket engines were designed to deliver constant thrust at a fixed oxidizer–fuel ratio, with only minor variations around the nominal operating point. However, with the rise of *New Space*, operational demands have shifted significantly. Modern engines must be capable of rapidly adjusting thrust across a wide envelope – for example, during propulsive landing manoeuvres.

Conventional decoupled PI control loops are no longer sufficient: their effectiveness is limited to narrow operating regimes, and the inherent time-wise decoupling leads to slow dynamic responses.

To address these challenges, the Chair of Space Mobility and Propulsion employs modern control techniques such as Model Predictive Control (MPC). MPC offers two key advantages:

1. It is inherently nonlinear (NMPC), which renders thrust control over a wide operational range feasible, and
2. It can explicitly handle constraints, which are essential for rocket engines.

While NMPC provides excellent control performance, its computational demand remains the major drawback, particularly for real-time deployment.

Task Description

This thesis aims to overcome the real-time limitations of NMPC by **mapping the NMPC control policy onto a Deep Neural Network (DNN)** using **Imitation Learning** (also known as *behavioral cloning* or *learning from demonstrations*).

The core idea is to train a neural network to **mimic the optimal control behavior of the NMPC**. Once trained, the DNN can execute the NMPC control commands in real time.

Note: The NMPC implementation will be provided by the chair. Developing the NMPC is not part of this thesis.

The tasks break down into

- Conduct a literature review on imitation learning strategies
- Define research question and control policy requirements (together with supervisor)
- Implement an imitation learning setup
- Train a deep neural network to reproduce the NMPC policy
- Evaluate and improve performance
- Document and present results

The thesis is designed as a Master's project with the goal of publishing the results in a scientific conference or journal.

Candidate Profile

We are looking for a highly motivated student who combines a passion for space exploration with strong analytical and programming skills.

Requirements:

- Strong interest in control and deep learning
- Proficiency in Python programming
- Prior experience with deep learning (through coursework or projects)

Our Offer

The Chair of Space Mobility and Propulsion is located at the new TUM Campus in Ottobrunn (south of Munich), surrounded by leading aerospace industry partners. The campus offers a dynamic, interdisciplinary environment – an excellent place to help shape the future of space technology.

We offer:

- A cutting-edge thesis at the intersection of control and machine learning research
- Freedom to guide the project direction within the scope defined (e.g., cascaded imitation + reinforcement learning, feature reduction and NN compression, NN architecture comparison, or constraint satisfaction within the imitation learning framework, etc.)
- The opportunity to publish results in top-tier conferences or journals
- And, of course – delicious coffee ☺️

Contact

Supervisor

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