Chair of Spacecraft Systems
TUM School of Engineering and Design
Technical University of Munich

Semester Thesis

Start date: 01/10/2024

Topic: *Collaborative Earth Observation: Enhancing Satellite Operations Through Deep Reinforcement Learning and Coordinated Task Planning*

The proliferation of Earth observation satellites with diverse capabilities and ownership has created a need for coordinated operations to maximize efficiency and data quality. Collaborative spacecraft operations, where satellites communicate and coordinate to optimize their activities, are essential in leveraging the unique properties of each satellite in a federation. This thesis proposes a Deep Reinforcement Learning (DRL) framework that facilitates collaboration among satellites with different properties for efficient task planning and execution.

The main objectives are:

- Adapt an existing DRL-based approach that enables satellites to work collaboratively on object detection to an Earth observation use case, by sharing information and coordinating task schedules, for object detection. The framework will consider the unique capabilities and limitations of each satellite, such as sensor type, resolution, and coverage area.

- Design algorithms that enable satellites to autonomously coordinate tasks such as image acquisition, data processing, and transmission.

Research questions:

1) How can an existing DRL-based framework be adapted to enable efficient and effective collaboration among Earth observation satellites with diverse capabilities, such as sensor type, resolution, and coverage area?
2) What algorithms can be designed to facilitate autonomous coordination of tasks like image acquisition, data processing, and transmission among a federation of Earth observation satellites?
3) How do the proposed collaborative operations techniques using DRL framework improve task completion rate, data accuracy, and network resource utilization compared to traditional satellite management approaches?

Tasks:

- Literature review on collaborative spacecraft operations and DRL
- Adapt an existing simulation environment, that includes modules such as satellite orbit propagation, power and data handling, communication constraints, etc., used in the Chair for object detection operations, to Earth observation use cases.
- Use the mention environment to train and test the DRL algorithms.
- The algorithms will be designed to optimize the overall performance of the satellite federation by maximizing rewards for successful task coordination and data delivery.
- Evaluate the performance of the collaborative DRL framework using metrics such as task completion rate, data accuracy, and network resource utilization. Comparisons will be made with traditional satellite management approaches.
- Validation of the results

Timeline:

1st month: Analysis of the problem, literature review, preliminary trade off of possible choices

2nd month: Adaptation of the existing simulation environment and algorithm to the Earth observation use case

3rd month: Training and test of the algorithm

4th and 5th months: Test of the algorithm with different scenarios, analysing the results and validating the results

6th month: Final validation of the results, writing of the reports.

Prerequisites:

- A degree in aerospace engineering, computer science, or a related field, with foundational knowledge of satellite systems.
- Proficiency in programming (Mainly Python, or C++), and a strong understanding of machine learning, particularly reinforcement learning and DRL.

Supervisor

Vincenzo Messina
Phone: +49 89 289 – 55752
E-mail: vincenzo.messina@tum.de