Autonomous Satellite Attitude Control Using Reinforcement Learning

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Introduction

Spacecraft attitude control is essential, but actuator failures can cause mission failure without adaptive control mechanism which is crucial to ensure mission reliability [1].

Recent advancements shows that the optimal attitude control remains challenging due to the balancing complexity with limited on-board computational resources [2].

Reinforcement Learning allow us to model sequential actions and uncertainties, in order to achieve adaptive strategies and efficient resource management in space [3].

Challenges

Complex Systems

- Spacecraft consist of thousands of intricate components.
- Many components are designed for specific mission requirements.

Interrelated Components

- Autonomous control systems must comprehend the complex interactions between various parts.

Monitoring Constraints

- Continuous monitoring of every component is impractical and requires extensive resources.

Processor Limitations

Spacecraft processors are relatively weak with limited RAM and processing capabilities.

Computing Power Allocation

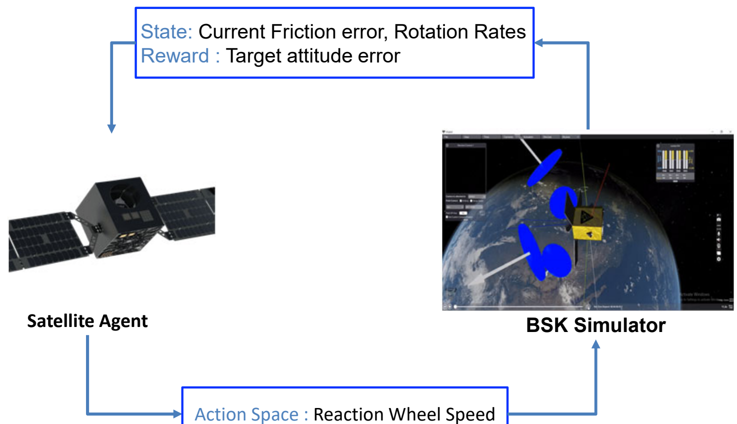
A significant portion of computing resources is dedicated to essential operations, leaving less available for autonomous functions.

Aims

- Enhance intelligent decision-making for dynamic adjustment of satellite operations in response to failures or degradations.
- Minimize disruption to mission objectives in unpredictable and resource-constrained space environments.
- Ensure robust performance on resource-constrained spacecraft platforms.

Formulated Problem

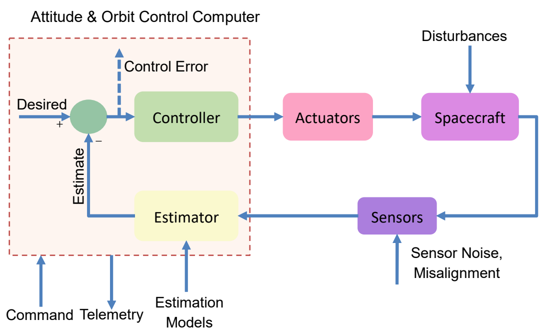
Reinforcement learning involves an agent learning by interacting with its environment, modelled as a Markov Decision Process (MDP) with states, actions, transitions, and rewards. The goal is to find an optimal policy that maximizes rewards. For attitude control, the satellite (agent) uses observations from the Basilisk simulator to predict reaction wheel speeds for target attitude and stability.



Overview of Attitude Control System using Reinforcement Learning

Methods

- **PID Controller:** Best for simple, linear systems. Effective and easy to implement but limited in handling nonlinearities and complex dynamics.
- **PD Controller:** A simpler version of PID, effective where integral action is unnecessary. Easier to tune and implement.
- **DNN Controller:** Suitable for complex, nonlinear systems. Requires extensive training and computational resources.
- **MPR Controller:** Optimizes control actions by predicting future system behaviour, suitable for multi-variable and constrained systems but computationally intensive.



Block Diagram for an Attitude and Orbit Control System

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3) Chagas, Ronan Arraes Jardim. "INTELLIGENT ATTITUDE CONTROL OF SATELLITES VIA DEEP REINFORCEMENT LEARNING." CEP 12: 010.

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