Aerospace Europe Conference 2023
Joint 10th EUCASS – 9th CEAS Conference

Abstract #XXX *(to be filled by the organizers)*
Preferred Topics: FLIGHT DYNAMICS/GNC and AVIONICS
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Type: Oral
Status of corresponding author: Regular

Title

Artificial Intelligence in Planetary Exploration: Enabling Autonomous Decision-Making for Spacecraft

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Abstract

Artificial Intelligence and Machine Learning (AI/ML) technologies have the potential to revolutionize the field of planetary exploration by enabling spacecraft to make autonomous decisions in real-time. With the increasing complexity of space missions, such as landing on a asteroid or very fast fly-by of unknown objects, intelligent decision-making may significantly improve science return from these missions. In this paper, we explore the role of AI/ML in planetary exploration and focus on some of the challenges of this approach.
Many in the field have realized that AI/ML approach may lead to non-deterministic results, which limit potential applications. Another challenge is that missions, especially beyond the Low Earth Orbits, have to rely on radiation hardened hardware to operate in outer space environments. Typically, this hardware lags in performance, compared to cutting edge technology available for typical use. Additionally, the development of AI algorithms for spacecraft requires a significant amount of expertise and resources, making it a challenging task for many organizations.

One of the most promising applications of AI in planetary exploration is in the field of autonomy for landing and navigation. In addition to landing and navigation, AI can also be used for scientific data analysis, anomaly detection, and fault diagnosis. Another promising application of AI in planetary exploration is in the area of teaming, where multiple spacecraft work together to achieve a common objective. AI algorithms can enable spacecraft to collaborate and communicate with each other, adapting to changing conditions and coordinating their actions to achieve mission objectives.

Our work will concentrate on creating an autonomous system for planetary navigation. The most advanced planetary rover, Mars Perseverance, is using the classical approach to path planning and still relies significantly on the information received from mission control. The Mars helicopter Ingenuity on the other hand, features a very efficient and capable architecture for autonomous flying. As the next step, NASA Researchers proposed machine-learning capabilities for future NASA's Mars Sample Fetch Rover via the NASA HPSC program, which delivers 100x compute power. We are preparing a demonstration rover platform for planetary navigation. Experimental

architectures will be based around a specialized RISC-V processor with additional computational modules to enable fast AI processing. The platform will be equipped with a simple stereo camera setup with an IMU and a sun-sensor. The goal of the research is to identify the most effective combination of sensor, algorithms, and computing platform to enable autonomous traverse. The objectives will be to minimize the power consumption, enable operations during minimal light conditions and achieve faster traverse speeds, compared to today’s rovers.

AI has the potential to revolutionize the field of planetary exploration by enabling spacecraft to operate autonomously in challenging and unpredictable environments. In this work, we identified experimental architectures to enable autonomous traverses. The next step will be to understand robustness of the algorithms through modeling and testing in the desert. Another effort will be concentrated on a layered structure to handle fault tolerance due to radiation and autonomous requirements.