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ARTIFICIAL INTELLIGENCE FOR AUTONOMOUS LUNAR EXPLORATION: A STUDY ON FEDERATED LEARNING IN A LUNAR ARCHITECTURE

Abstract

As lunar commerce takes seed and grows this decade following initial technology demonstration and scientific missions delivered commercially, there will be a growing demand for enabling autonomy for surface operations based on self-reliant mission architectures. With novel technology to deploy and maintain the use of Artificial Intelligence in spaceflight, Mission Control is pioneering how lunar missions can embed AI in their systems.

In this paper, we begin with an overview of how lunar systems can increasingly leverage AI to enable intelligent data analysis and decision-making processes and how mission teams on Earth can use these capabilities in operations. For example, AI-based perception of the lunar environment can support autonomous navigation for lunar rovers and other ground vehicles, as well as autonomous targeting for onboard scientific payloads and actuation such as scooping, drilling, and robotic arm operations. Other applications such as anomaly or fault detection, or intelligent data prioritization for downlink to Earth, have potential to greatly improve the efficiency of missions.

Following this overview, we will provide results from a recent study that explored how Federated Learning, a decentralized machine learning approach, can be implemented in a lunar architecture to enable efficient training of AI models on-site rather than on Earth. While for the near future, computationally intensive training processes for AI will be conducted on Earth, in the future we will also see the rise of lunar data centers, and resources to facilitate training on-site or even at the edge, i.e. close to the point

of operations. In addition to concept analysis performed in this study, an experimental test campaign was conducted using our high-fidelity lunar operations testbed and multiple robots, to simulate scenarios of multi-agent learning in a lunar architecture.

Last, we will highlight progress on a lunar surface demonstration presented previously. On December 11th 2022, Mission Control's MoonNet AI payload launched onboard the first ispace mission M1. Slated to begin operations in Q2 2023, MoonNet will be the world's first demonstration of Deep Learning on the lunar surface, a historic milestone for space exploration. It will classify lunar surface features visible in images from the Rashid rover in the Emirates Lunar Mission (ELM) led by the Mohammed Bin Rashid Space Centre (MBRSC). Following this critical demonstration of AI-based autonomy, Mission Control looks forward to deploying this technology for future lunar surface missions. For our lunar surface demonstration, we acknowledge support of the Canadian Space Agency (CSA) [3CAPDEMO21].