A Deep Learning Framework for Planetary Exploration Data and Model Management

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Deep learning techniques are the leading standard in terrestrial computer vision applications [1]. In the space sector, earth observation government and commercial entities rely on deep learning to analyze satellite imagery [2] and in earth orbit ESA has demonstrated deep learning as part of the flight segment of Φ-sat-1 [3]. In deep space planetary exploration missions, adopting deep learning is challenging due to the risk tolerance of mission critical applications, the difficulties of risk quantification for statistical techniques, and the extreme environmental requirements imposed on flight hardware. However, with the multitude of forthcoming government and commercial lunar and deep space missions humanity will be conducting more complex operations in space that will require more robots, more autonomy, and better operations [4, 5]. Deep learning techniques stand to be a key enabler of both robotic mission autonomy in the flight segment and intelligent decision support in the ground segment as we begin this next phase of planetary exploration.

To successfully overcome the challenges to deep learning techniques in deep space planetary exploration we must consider the integrity and robustness of the entire data pipeline, from raw data sources to production models. At Mission Control we have developed a deep learning data framework, illustrated in Figure 1, that provides quality controls on both data and models, inspired by best practices established in terrestrial applications. This framework translates user needs into data needs and creates data and model documentation that meets the needs of existing mission program lifecycles, such as critical design reviews. We use this pipeline in the development and testing of specific models, such as terrain and novelty classifiers, but also in developing software that reduces barriers to entry for development, testing, and integration of algorithms for flight software, such as our Deep Learning Accelerator and Payload Data Management System.

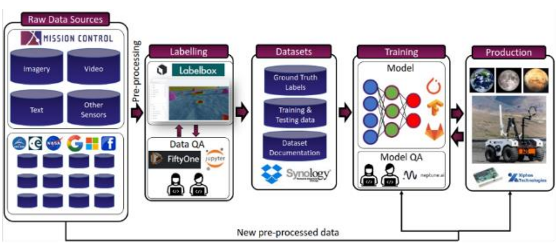

Figure 1: Mission Control's deep learning data pipeline and methodology.

Modern deep learning has the potential to help deep space robots better perceive their environment, adapt to unexpected changes, synthesize data for human analysis, and maximize productivity during idle time. In 2022, Mission Control will demonstrate this potential in two missions. Our deep learning terrain classifier will be deployed onboard the ispace lunar lander mission M1 and will directly support the Emirate Lunar Mission (ELM) micro-rover. This classification model has been trained and validated with data from analogue deployments, Mission Control's Moonyard testbed, and lunar imagery. We have developed a deep learning accelerator that optimizes the model for use in deep space hardware. This accelerator will also be used to benchmark the performance of models as part of ESA's OPS-SAT mission. By performing the first commercial use of deep learning in deep space during the ELM and gaining experience in optimizing deep learning run-times for use in orbit these missions will inform better data practices and provide insights into new validation techniques in an iterative cycle to continually improve mission performance.

References:

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