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LUNAR REGOLITH PARTICLE CLASSIFICATION USING A DEEP LEARNING APPROACH

Abstract

The Moon is a significant resource due to its proximity to Earth. It can be used for advancing human space exploration, in-situ resource utilization, and uncovering the history of the solar system. Over billions of years, the Moon has been continuously bombarded by impacts resulting in a thick layer of soil on the surface called regolith. Lunar regolith is composed of various particles including glass, mineral, rock and breccia fragments, and clumps of these fragments called agglutinates. Understanding the ratios of these particles in different regions of the lunar surface may provide insight into the geologic history of the Moon. Regolith grain types have distinguishable features detectable from visual inspection which is generally done manually by a geologist evaluating individual particles via microscopy. For example, glass fragments have sharp edges, and agglutinates have a combination of sharp and rounded fragments. A significant challenge for in-situ particle classification is the limited supply of regolith returned to Earth from the Apollo missions. With upcoming missions to the Moon which may include sensors such as micro-imaging instruments, optical images may be analyzed using deep learning techniques to identify and quantify the particles present on the lunar surface.

This paper outlines the development of a Convolutional Neural Network (CNN) based algorithm for the autonomous classification of regolith particles. A labeled dataset was first prepared using images of lunar simulants and limited images of Apollo regolith. The images were taken with an optical microscope at 30 microns resolution. However, deep learning requires a large dataset of labeled data, which was a considerable challenge to generate. To reduce the amount of data required for training, transfer learning – a concept in which a network pre-trained on a broad dataset is fine-tuned for a specific application – was explored. Next, a CNN-based classifier was trained to classify particles into three distinct categories: 1) rock/mineral/breccia; 2) glass; and 3) agglutinates. Cross-validation was used during training of the classification model, while testing was conducted on an unseen test-set where the main performance metric measured was model accuracy.

The initial results are promising for detecting and classifying regolith particles from microscopic images. Further work will include testing on additional images, hyper-parameter tuning, and algorithm revision to improve performance.

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