Deep Ensemble MERNet: Recent Advances for the Content-Based Classification of MER Pancam Images

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Introduction: Automated machine learning classification of planetary science image data enables the content-based search of large archives held by the NASA Planetary Data System (PDS). The PDS Image Atlas III uses machine learning classifications to help users quickly find images of interest [1]. The initial version of the MER Pancam image classifier (MERNet v1) was deployed to the Atlas III in March 2021 [2]. In this abstract, we present recent advances that improve the performance of the MERNet classifier.

Deep Ensemble MERNet (DE-MERNet): DE-MERNet classifier was built to improve the performance of the MERNet v1 classifier. For the creation of the DE-MERNet classifier, we employed similar image augmentation, transfer learning, and classifier calibration techniques as the MERNet v1 classifier. The improvements we made to the DE-MERNet classifier are described below:

1) Data Set: The MERNet v1 classifier was built using a labeled subset of MER Pancam image data [3]. During a post analysis, we discovered that the Spherules class contains two distinct views of spherule objects and decided to split the Spherules class into Close-up and Distant Spherules classes. As a result, the DE-MERNet classifier consists of the 26 classes shown in Figure 1.

2) Ensemble Classifier Chains: The DE-MERNet classifier is an ensemble model consisting of five individual CNN classifiers. Each CNN classifier is trained using a classifier chain approach [4] to explicitly model the dependencies between classes. Among the five individual classifiers, four classifiers utilized a single classifier chain approach, and the other one utilized a multiple classifier chains approach in which the class list was divided into 10 sub-groups (see dashed line in Figure 1) using a hierarchical clustering algorithm. A classifier chain requires the specification of the order in which classes are processed. We experimented with a general-to-specific order for three classifiers using different loss functions and dropout operations and a specific-to-general class order for one classifier.

The DE-MERNet ensemble classifier combines the outputs of the five individual classifiers. We explored four different strategies for combining outputs from individual classifiers and decided to use the "weight by F1 score" strategy for the DE-MERNet ensemble classifier because of its superior performance. The "weight by F1 score" strategy refers to a weighting schema in which the per-class logits vectors of the individual classifiers are weighted by the F1 scores computed as the harmonic mean of the precision and recall scores.

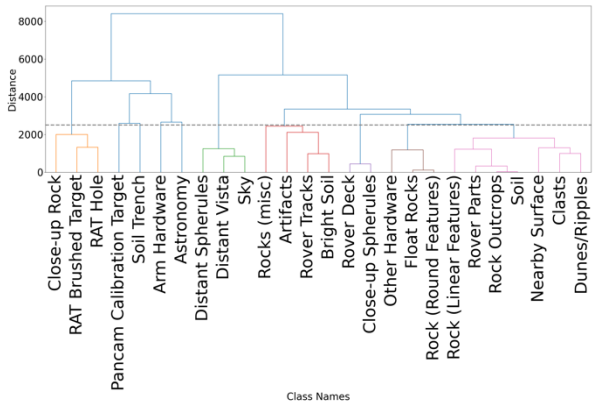

Figure 1: Dendrogram of 10 sub-groups

3) Results: The DE-MERNet classifier is an improvement of the MERNet v1 classifier. The average F1 score (i.e., averaged over all classes) of the DE-MERNet classifier is 61.7% and the average F1 score of the MERNet classifier is 52%. In addition, the MERNet v1 classifier reports zero F1 score for seven classes due to the limited training examples, and the DE-MERNet classifier reduces the number of zero F1 score classes to only three.

PDS Deployment: The results of the DE-MERNet classifier have been deployed to the PDS Image Atlas III (https://pds-imaging.jpl.nasa.gov/search/).

Conclusion: In this abstract, we demonstrated a machine learning approach to create a multi-label ensemble CNN classifier for the content-based search of the MER Pancam images on the PDS Image Atlas III. In addition, by utilizing the ensemble classifier chain approach, we also showed improvements of the DE-MERNet classifier over the MERNet v1 classifier.

References: [1] Wagstaff et al., (2021) *Mars Image Content Classification: Three Years of NASA Deployment and Recent Advances*, *IAAI.* [2] Lu et al., (2021) *Content-Based Classification of Mars Exploration Rover Pancam Images*, *LPSC* [3] Zhao et al., (2020) *Zenodo,* http://doi.org/10.5281/zenodo.4302760. [4] Read et al., (2009) *Classifier Chains for Multi-label Classification, Machine Learning 85, 333.*

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