# A TWO-STAGE APPROACH FOR PREDICTING COMPOSITION FROM MICROSCOPIC IMAGES: EXAMPLES FROM THE MARS EXPLORATION ROVERS SPIRIT AND OPPORTUNITY.

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**Introduction:** Rovers employed in planetary exploration missions are typically equipped with multiple measurement and observational instruments, e.g., an alpha particle X-ray spectrometer (APXS) for determining the chemical composition of target sites, and cameras for capturing target images at the geologist's hand-lens scale. Measurement via an APXS is a time-consuming process (the complete analysis of one sample has typically required at least three hours during MER operations). Conversely, cameras can capture images at much faster rates. Since there is a relationship between the area of chemical analysis and a complementary (coincident) image, a triage system can be designed that facilitates the use of images to limit the need to perform compositional analysis. Here we describe how such a system has been constructed and tested.

**Procedure:** The system consists of three building blocks: (1) an image segmentation block, (2) the first artificial neural network (ANN1), and (3) the second artificial neural network (ANN2). The image segmentation block groups similar pixels into meaningful regions. ANN1 mimics the ability of a geologist to classify the image regions into predefined rock or surface types, e.g., blueberries, basalts, dark soils, bright dusts. Finally, ANN2 predicts the chemical composition of the captured image from the areas of these surface types. ANN1 thus performs a classification task, and ANN2 performs a prediction task.

**Results:** Initially, our primary triage system employed pixel-based segmentation in the first building block. A low classification accuracy of the ANN1 was observed. However, with a low accuracy ANN1, the prediction error of ANN2, which is considered a system error, was bounded and the predicted values of chemical compositions were fairly close to the target values. To improve the system accuracy, a state-of-the-art multi-resolution segmentation approach was deployed in the first building block, derived from commercially available eCognition software (a technique usually used for analyzing remotely sensed images and medical images). It was in-house implemented and used in the developed triage system. Additionally, to comply with the increasing use of multi-core processors, a parallel version of the algorithm was developed and tested.

**Conclusions:** Approximately 30 compositional analyses and matching images are required to facilitate image-only compositional estimations given a common family of materials (e.g., blueberries set in sedimentary host). Ultimately, the goal is to enable the rover to perform autonomous decisions in real time. Currently, due to limitations in processor performance, the aim is to assist mission operations geologists in analyzing images of target sites, for which chemical compositions are not available.