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Semi-automated surface mapping via unsupervised classification

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Abstract

Due to the increasing volume of the returned data from space mission, the human search for correlation and identification of interesting features becomes more and more unfeasible. Statistical extraction of features via machine learning methods will increase the scientific output of remote sensing missions and aid the discovery of yet unknown feature hidden in dataset. Those methods exploit algorithm trained on features from multiple instrument, returning classification maps that explore intra-dataset correlation, allowing for the discovery of unknown features. We present two applications, one for Mercury and one for Vesta.

1. Introduction

Machine learning is a fast-growing subfield of computer science in which computers are programmed to learn complex concepts and behaviours using generalized optimization procedures without being explicitly programmed. In recent years, machine-learning methods have achieved unprecedented results in image processing and other high-dimensional data processing tasks with wide applications from medical imaging and diagnosis to autonomous and assisted driving. ML is employed in a range of computing tasks where designing and programming explicit algorithms with good performance is difficult or unfeasible. Due to the growing number of complex nonlinear systems that have to be investigated in various fields of science and the bare raw size of data nowadays available, ML offers the unique ability to extract knowledge in an intelligible and innovate way regardless the specific application field. Examples are image segmentation, supervised/unsupervised/ semi-supervised classification, feature extraction, data dimensionality analysis/reduction.

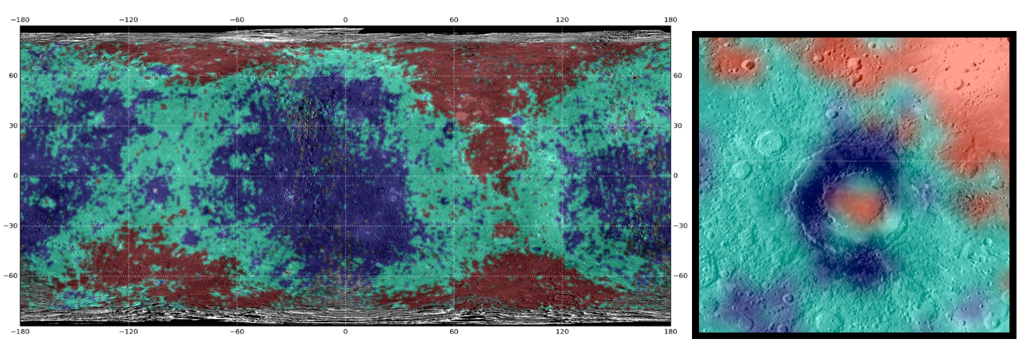

Figure 1: Classification on Mercury spectral data (left panel) in 3 classes. Zoom on Rachmaninoff with clear distinction inner and outer ring material from background material out of the crater.

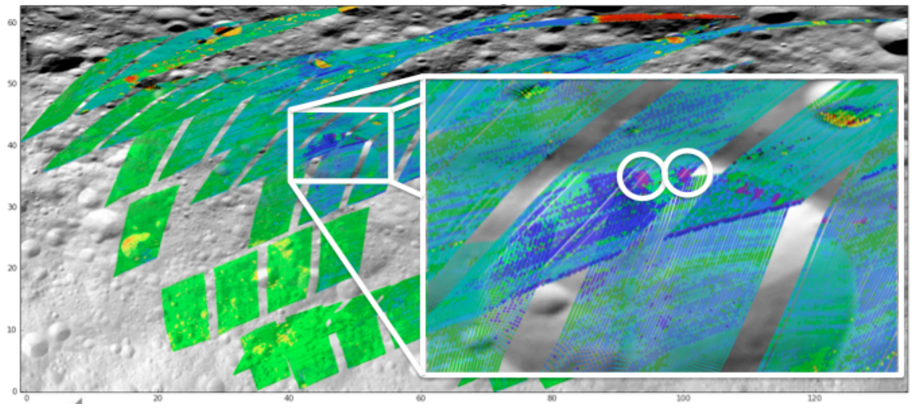

Figure 2: Automatic classification of DAWN/VIR spectral data. The two purple outcrops marked by circle on the crater wall correspond to the Olivine finding from [1].

2. Mercury Dataset

The Mercury Atmospheric and Surface Composition Spectrometer (MASCS) instrument has mapped Mercury surface in the 400–1145 nm wavelength range during orbital observations by the MESSENGER spacecraft. We have conducted k-means unsupervised hierarchical clustering to identify and characterize spectral units from MASCS observations. The results (Figure 1.) display a dichotomy, with two spectrally distinct groups: polar and equatorial units, possibly linked to compositional differences or weathering due to irradiation. To explore possible relations between composition and spectral behavior, we have compared the spectral provinces with elemental abundance maps derived from MESSENGER's X-Ray Spectrometer (XRS). Nonetheless, by comparing the VIS/near-infrared MASCS and XRS datasets and investigating the links between them, we can provide further clues to the formation and evolution of Mercury's crust.

3. Vesta Dataset

For the Vesta application, we explored several Machine Learning techniques: multi-step clustering method is developed, using an image segmentation method, a stream algorithm, and hierarchical clustering. The DAWN Visible and infrared spectrometer (VIR) data from Vesta is are test-beds for our algorithm. The algorithm successfully separates the Olivine outcrops around two craters on Vesta's surface [1]. New maps summarizing the spectral and chemical signature of the surface could be automatically produced.

4. Conclusion

The techniques applied belong to the vast file of ML and allow drastically reducing human time for the long data analysis work on bigger and bigger dataset. Instead of digging in single data-unit searching for novelties, scientist could choose a subset of algorithms with well known feature (i.e. efficacy on the particular problem, speed, accuracy) and focus their effort in understanding what important characteristic of the groups found in the data mean, their morphology on the surface and correlation with other datasets.

References

[1] E Ammannito et al. "Olivine in an unexpected location on Vesta's surface". In: Nature 504.7478 (2013), pp. 122–125.