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Applying new spectral unmixing technique to Martian hyperspectral data

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Hyperspectral datasets are now a common feature in planetary data, as recent missions have mapped planetary surfaces thanks to spectro-imagers with improved spatial and spectral resolutions. For those instruments the spatial extent of a pixel is usually large enough to have a mixture of various constituents contributing to the spectrum of a single pixel, involving both linear and non-linear mixing effects (which in the case of atmospheric contributions, for example, have to be corrected). The aim of spectral unmixing is to identify the materials present in each pixel of a hyperspectral image, and to evaluate the proportion of each of those materials in the pixels. This can yield important clues about the surface composition of planetary bodies and their geological history.

In this context, Bayesian source separation with positivity constraint (BPSS) is a useful unsupervised approach, under linearity constraints [1]. Its main interest is to ensure the non-negativity of both the unmixed component spectra and the abundances of those components and, through a recent extension of the algorithm, to impose the sum-to-one constraint to the estimated abundances, also called 'full aditivity' condition [2]. These constraints greatly help the physical interpretation of the results. However, when dealing with complete hyperspectral images with a size typically encountered in planetary science, large requirements in terms of computation times and memory have been limiting the use of those algorithms, since the estimation is performed using Markov Chain Monte Carlo (MCMC) methods. Thus, we investigated implementation strategies in order to be able to process a whole hyperspectral image within a reasonable computation time. For the first time, thanks to an optimization of the BPSS algorithm, it was possible to run it on a complete hyperspectral image [3].

A selection of pixels has also been performed as a pre-processing step, aiming at extracting a few (typically several hundreds) especially relevant pixels among typically several hundreds of thousands. The algorithm was then launched on this selection [3], with a significantly lower computation time. In order to evaluate the impact of this pixel selection, we used two kinds of datasets. Firstly we tested synthetic datasets generated by linear mixing of a known number of mineral endmembers, in order to test the influence of various parameters (number of endmembers, limits in terms of pixel purity, addition of noise, etc.). Then we used a real planetary dataset, an OMEGA (Observatoire pour la Minéralogie, l'Eau, les Glaces et l'Activité) [4] hyperspectral image of the South polar cap of Mars, results gathered through other approaches being considered as a reference in terms of mineralogical surface composition. These tests helped to better understand the behaviour of the method, and to identify in which situations the pixel selection could be used without a significant loss of quality, as regards the estimation of the spectral sources in the hyperspectral image.

References: [1] Moussaoui et al. (2006), IEEE Trans. on Signal Processing, vol. 54, no. 11. [2] Dobigeon et al. (2009), Signal Processing, vol. 89, no. 12. [3] Schmidt et al. (2010), submitted to IEEE Trans. on Geoscience & Remote Sensing, available on http://arxiv.org/abs/1001.0499. [4] Bibring et al. (2004), ESA SP-1240.