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Material identification on hyperspectral images using Bayesian source separation

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Abstract

Identification of materials in a scene observed by an imaging spectrometer is a common problem in Planetology. Usually the pixel size is larger than the typical size of material change over planet surfaces, leading to both linear and non-linear spatial mixing models. We propose here an unsupervised approach based on linear source separation to estimate the pure spectra of the components present in the observed scene and their abundances in each pixel. Previous application of this approach to Martian ices[1] have shown its relevance when the positivity of both the pure spectra and the abundances is taken into account. We propose here to apply this approach to detect Martian minerals and we show that adding the sum-to-one constraint (or additivity constraint) on the abundance vectors leads to an improvement of the estimation performances.

Dataset

The analysis is performed on a particular Martian terrain in the polar Northern plains observed during the local summer, where sulphates (mainly gypsum) has been recently detected [2]. This mineral type could sign the presence of liquid water that melt from the polar layered deposits [3]. In order to test our algorithm, we propose to consider the map based on a supervised detection method using band ratio [2] as a reference map of surface proportion. The gypsum spectral reference recorded in the Laboratoire de Planétologie de Grenoble (Fig. 1) have been also used [4]. We produce a mosaic made of 8 OMEGA images georeferenced in stereographic north polar projection: 972-2, 973-2, 975-2, 976-2, 979-2, 980-2, 989-2, 1004-2. We choose 107 spectral bands with reduced noise level, reduced atmosphere residue in the spectral domain from 1 to 2.5 microns (C detector of OMEGA instrument). Water ice, with strong absorption bands compared to gypsum, is present in this season on the polar cap. In order to focus on minerals detection, we propose to filter all ice spectra on the scene using the WAVANGLET method [5].

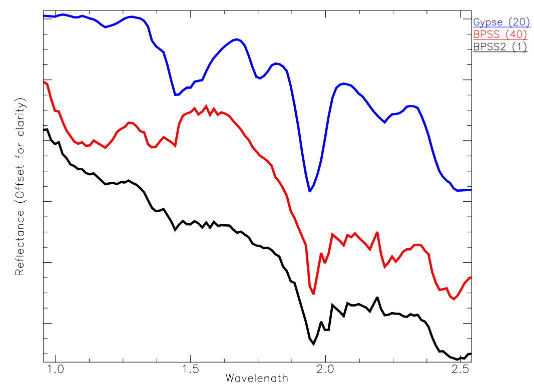

Figure 1: Results vs reference: laboratory spectrum of gypsum [4] (blue), spectrum estimated by the BPSS1 method (red, correlation coef.: 0.87) and by BPSS2 (black, cor. coef.: 0.93). For clarity, all spectra are scaled by the factors indicated on the legend.

Methods

By considering P pixels of an hyperspectral image acquired at L frequency bands, the observed spectra are gathered in a $P \times L$ data matrix $\mathbf{Y}$. Each row of this matrix contains the measured spectrum at each pixel with spatial index $p = 1, \ldots, P$. According to the linear mixing model, the pth spectrum can be expressed as a linear combination of the R pure spectra of the surface components. Using matrix notations, this model can be written as

$$\mathbf{Y} \approx \mathbf{AS}. \quad (1)$$

The rows of matrix $\mathbf{S}$ contain the pure spectra of the R components and each element A_{pr} of matrix $\mathbf{A}$ corresponds to the abundance of the rth component in pixel with spatial index p. For a qualitative and quantitative description of the observed scene composition, we propose to estimate matrices $\mathbf{A}$ and $\mathbf{S}$ allowing to explain the data matrix and having a physical interpretation : A hard constraint is the positivity of the elements of both matrices $\mathbf{S}$ and $\mathbf{A}$ since they correspond to spectrum amplitudes and component abundances, respectively. A second constraint that may be imposed is the additivity constraint. Indeed the abundances cor-

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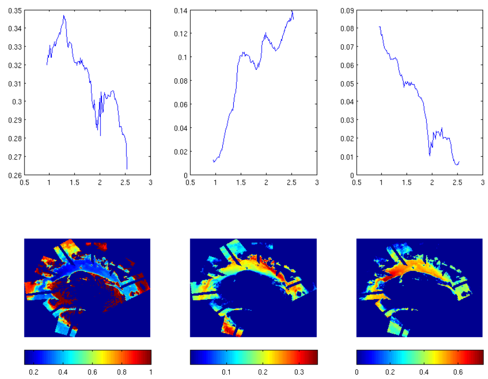

Figure 2: Results of the separation under additivity and positivity constraints: estimated material spectra (top) and corresponding abundance maps (bottom).

respond to proportions and therefore should sum to unity. This constrained estimation task can be viewed as a source separation problem and can be addressed in a Bayesian framework. We recently proposed two algorithms to perform an unsupervised joint estimation under positivity constraints (BPSS1) [6] and also to include the additivity constraint (BPSS2) [7]. These algorithms are based on hierarchical Bayesian models to encode prior information regarding the parameters of interest ; additivity and sum-to-one constraints. The complexity of the estimation from the resulting posterior distribution is overcome by using Markov Chain Monte Carlo methods.

However, since these algorithms use MCMC methods, the computation time increases with the image size. We thus proposed in [1] a method that allows to combine independent component analysis (ICA) and Bayesian positive source separation (BPSS) to select a few representative mixture spectra.

Results

The selection of pixels has been performed on 10 independent components (without noise filtering) with 10 spectra selected for each component. The first two sources are not directly interpretable and should be attributed to the effect of water ice trace with strong absorption bands (see fig. 2). Interestingly, the last source is compatible with the reference dataset for the spectra and the map. Characteristic absorption bands at 1.5 microns and 1.95 microns are well estimated and the spatial pattern is compatible with the supervised method [2].

The figure 1 exhibits the two spectra estimated by BPSS1 and BPSS2 and the gypsum measured in laboratory. There is a bad match between the BPSS1 and the reference spectra at 1.1 microns and 1.75 microns. Those two spectral region are significantly better estimated with the BPSS2 method.

In conclusion, we showed that the detection of minerals present at the surface of Mars using hyperspectral imaging and source separation is a relevant approach. In previous work, we have shown that the positivity constraint is required to interpret the result in physical term [1]. In the present work, focused on mineralogy in the Northern plain of Mars, we show that the sum-to-one constraint significantly improves the detection of surface minerals. We infer that the relative weak absorption bands of minerals compared to ice is the main reason to this behaviour. In future works, we will propose to apply the separation algorithm with positivity and additivity constraints on other hyperspectral datasets.

References

[1] S. Moussaoui, H. Hauksdóttir, F. Schmidt, C. Jutten, J. Chanussot, D. Brie, S. Douté, and J.A. Benediktsson, (2008), *Neurocomputing*, 71, 2194–2208

[2] Y. Langevin, F. Poulet, J.-P. Bibring, and B. Gondet, (2005), *Science*, 307, 1584–1586

[3] K. Fishbaugh, F. Poulet, V. Chevrier, Y. Langevin, and J.-P. Bibring, (2007), *JGR*, 112

[4] A. Pommerol and B. Schmitt, (2008), *JGR*, 113, 10009–+

[5] F. Schmidt, S. Douté, and B. Schmitt, (2007), *IEEE Trans. Geo. Rem. Sens.*, 45, 1374–1385

[6] S. Moussaoui, D. Brie, A. Mohammad-Djafari, and C. Carteret, (2006), *IEEE Trans. Signal Processing*, 54, 4133-4145

[7] N. Dobigeon, S. Moussaoui, and J.-Y. Tourneret, (2007), *Proc. IEEE Stat. Signal Proc. Workshop*, 79–83.

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