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# On the unmixing of MEx/OMEGA hyperspectral data

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## Abstract

This article presents a comparative study of three different types of estimators used for supervised linear unmixing of a MEx/OMEGA hyperspectral cube. The algorithms take into account the constraints of the abundance fractions, so as to get physically interpretable results. Abundance and spatial reconstruction error maps show that using a Bayesian MAP estimator, a satisfying compromise between complexity and performance can be achieved.

## 1. Introduction

The surface of Mars is currently being imaged with a combination of high spectral and spatial resolution. This gives the ability to detect and map chemical components on the Martian surface and atmosphere more accurately than before. Spectral unmixing (SP) is one of the techniques used for this purpose, [4]-[5]. SP is the procedure by which the measured spectrum of a mixed pixel is decomposed into a number of constituent spectra, called endmembers, and the corresponding fractions, or abundances, that indicate the proportion of each endmember present in the pixel. Linear SP, which considers that the spectrum of a mixed pixel is a linear combination of its endmembers' spectra, is more commonly used in practice. Based on the physical interpretation, two hard constraints are imposed on the abundance fractions of the materials in a pixel; they should be nonnegative and sum to one.
In this paper, we focus on the problem of supervised SP, where prior knowledge of the image endmembers is available. Our intent is to estimate the vector of abundances of each pixel in the image, subject to the constraints already mentioned. In the following, three different linear unmixing algorithms are applied and compared on MEx/OMEGA data, through their corresponding abundance and spatial reconstruction error maps.

## 2. Methodology

### 2.1 Data set description

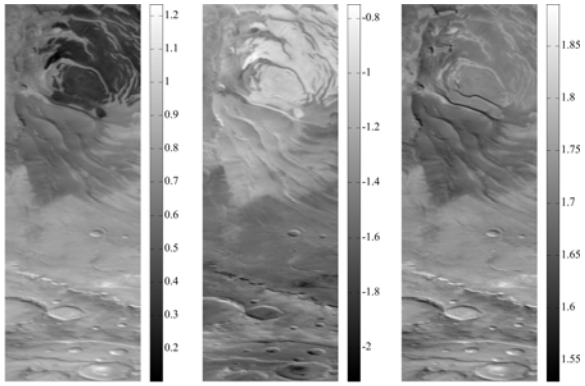
The data set consists of a single hyperspectral data cube obtained by looking to the South Polar Cap of Mars in the local summer (Jan. 2004). The data cube is made up with two channels: 128 spectral planes from 0.93 to 2.73 μm with a resolution of 0.013 μm and 128 spectral planes from 2.55 to 5.11 μm with a resolution of 0.020 μm. Noisy bands were excluded, 186 bands out of the 250 initial were finally utilized. $CO_2$ ice (synthetic data with grain size = 100mm), $H_2O$ ice (synthetic data with grain size = 10μm) and dust were previously detected using a Bayesian Positive Source Separation method [4]. The linear model mixing matrix consists of these three reference spectra.

### 2.2 Unmixing techniques

Three different unmixing approaches were applied to the dataset: i) a singular value decomposition method (ENVI-SVD), [2], available in the ENVI image processing software ii) a quadratic programming (QP) technique [3] and iii) a recently proposed MAPs estimator [6], [1]. These algorithms belong to different classes of estimators. Specifically, ENVI-SVD is a deterministic algorithm, MAPs is a stochastic algorithm and QP is an iterative algorithm. It is interesting to note that the main difference of the examined methods relies on the way the constraints are imposed. ENVI-SVD enforces only the sum-to-one constraint, while QP and MAPs impose both nonnegativity and additivity.

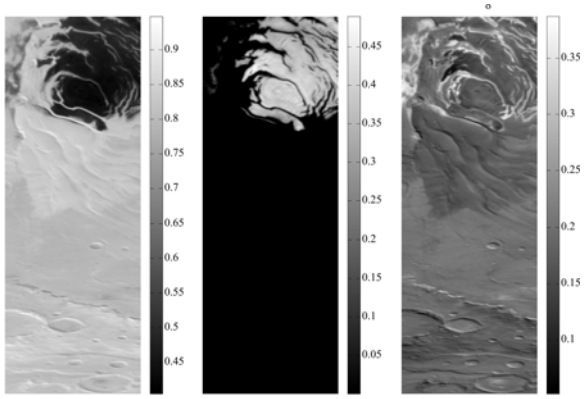
## 3. Results and Conclusion

Resulting abundance maps are displayed in figures 1-3. As shown, the ENVI-SVD abundances for $CO_2$ ice have negative values and thus, they have no physical meaning. Moreover, abundance values calculated by QP and MAPs are in agreement, and significantly different from those of ENVI-SVD.



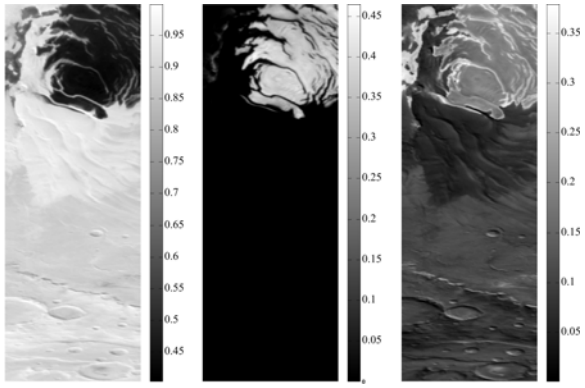
(a) (b) (c)

Figure 1: Abundance maps using ENVI-SVD corresponding to (a) dust (b) $CO_2$ ice (c) $H_2O$ ice.



(a) (b) (c)

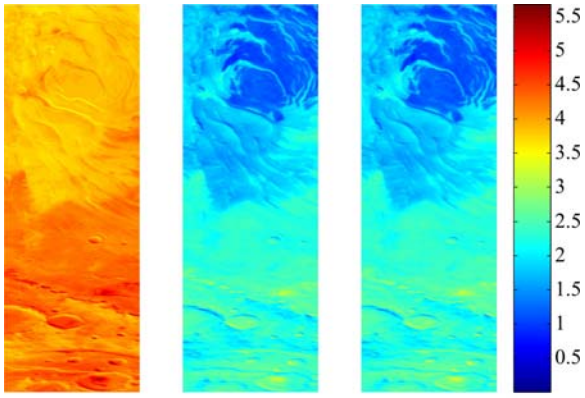
Figure 2: Abundance maps using QP corresponding to (a) dust (b) $CO_2$ ice (c) $H_2O$ ice.



(a) (b) (c)

Figure 3: Abundance maps using MAPs corresponding to (a) dust (b) $CO_2$ ice (c) $H_2O$ ice.

Moreover, the spatial reconstruction error, (figure 4), shows relatively low and comparable pixel to pixel error values for MAPs and QP, while ENVI-SVD presents systematically higher error values. Although MAPs and QP present comparable results in terms of reconstruction error, MAPs can be used in real time application due to its lower computational complexity (MAPs results in a closed form solution). Therefore, among the three algorithms, the MAPs estimator seems to offer the best compromise between estimation performance and complexity.



(a) (b) (c)

Figure 4: Spatial reconstruction error maps of (a) ENVI-SVD (b) QP (c) MAPs.

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