Sequential Minimum Noise Fraction Use:
An Approach to Noise Elimination

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1 INTRODUCTION

Noise is very common on hyperspectral images. Because it causes interference with the identification of materials and with the calculation of their abundance, it is necessary to eliminate it in order to make it possible to acquire good spectra. For this purpose, the most commonly used processing technique is Minimum Noise Fraction (MNF).

The MNF procedure is derived from, and similar to, the PCA (Principal Component Analysis). The main difference between them is that MNF considers the noise and PCA the data variation. MNF is considered a method of ordering components according to image quality (Green *et al.*, 1988.)

A noise sample set is required as a reference to process the MNF technique. Because of the different kinds of noise, there is a question to be answered: W*hat kind of noise is to be eliminated?* A noise's definition provides for the establishment of a methodology for its correction. The noise sample reference set can be from external or internal images.

2 EXTERNAL NOISE REFERENCE (INSTRUMENTAL NOISE)

Behavior of instrumental noise during a flight can be obtained from de the dark reference measurement. Some instruments of imaged spectrometry register dark references per each scanned line during a flight. Those data can be used with MNF to evaluate the noise of the instrument (Lee *et al.*, 1990).

3 INTERNAL NOISE REFERENCE

Noise references can also come from its image. The employment of statistical techniques enables the distinction of the noise fraction from the sign. Considering the multi-variance data from an image with "p" bands and "x" samples, we have:

$$\mathbf{Zi\ (x),\ i= 1,....,\ p} \qquad \text{Equation 1}$$

Considering that the set data are constituted of sign and noise, we have:

$$\mathbf{Z(x) = S(x) + R(x)} \qquad \text{Equation 2}$$

Where:
S (x=) sign component, and
R (x=) noise component.

Filter (Green *et al.*, 1988) and PCA (Kruse and Boardman, 1994) are the most commonly used methods to obtain the sample of the noise component required for the MNF employment. The application of a PCA in the MNF is the most commonly used method that is implemented the ENVI program. Better results for noise elimination using MNF with APC are obtained when the evaluation of variance's characteristics and the correlation of noise types are considered. Three types of noises can be defined by variance:

a) Uncorrelated Noises with Equal Variance in All Bands – This noise presents a spherical distribution around the data mean (Fig.1). The PCA provides an optimal ordering of this type of noise (Lee *et al*., 1990). The sign is retained in initial bands because of the variance's disposition toward axes with the highest correlation while the noise tends to stay in last bands because of the axes with low correlation.

The MNF using APC is used to eliminate this kind of noise. The determination of the inherent dimensionality of data is obtained through the combined examination of the final auto-values and their respective images (Figs. 2 and 3). Data reduction generally occurs and they acquire a size that is 10% from initial bands introduced. So, a signal concentration occurs with the first components being the noises the rest of the other components.

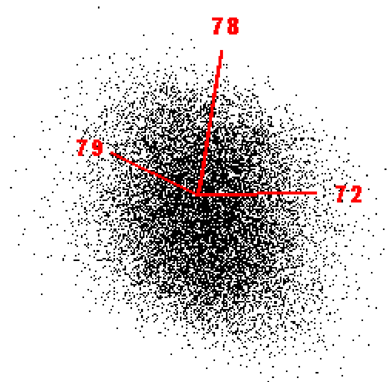

Figure 1. Behavior of spherical distribution of noise not correlationed and of equal variance on a space n-dimensional.

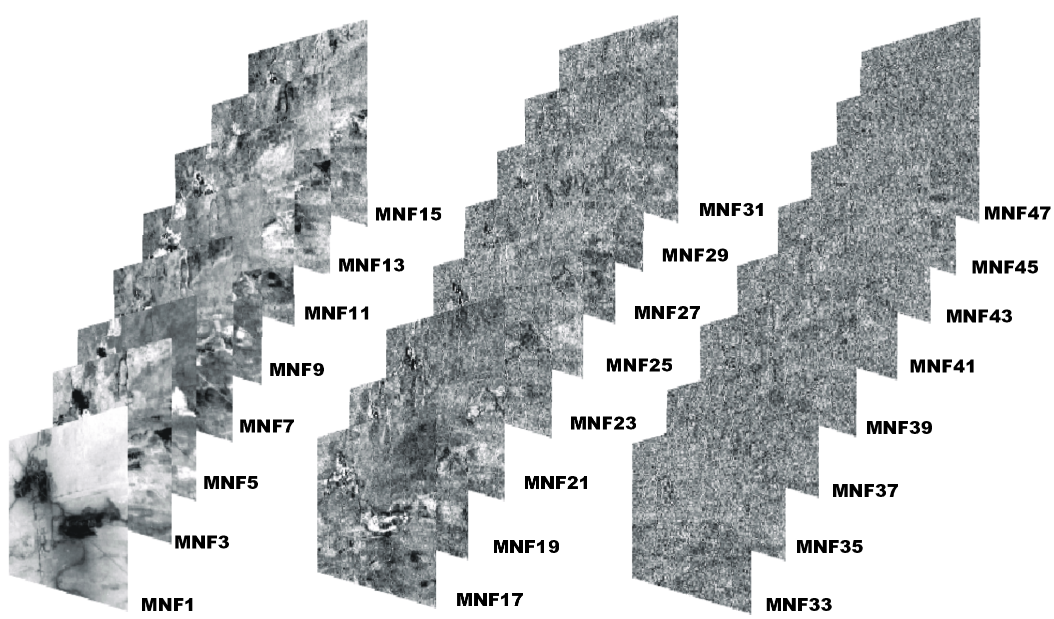

Figure 2. Degradation of the signal all along the MNF components.

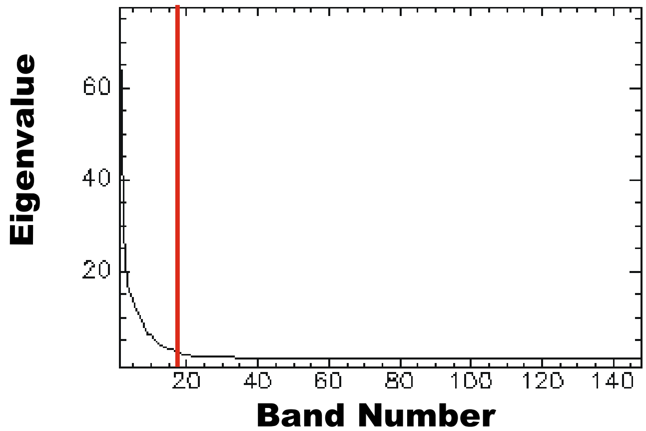

Figure 3. MNF plot used to determine bands that contain data and that contain predominantely noise. In this case, the selected point was above the eigenvalue 3, witch corresponds to the 15 first MNF bands.

b) Highly Correlated Noises – The existence of high correlation noise as a Yi (x) function allows its concentration in a single APC or MNF component. The presence of a linear combination enables the minimization of the noise in a single band -- leaving other bands free of noise. The high noise correlation component joins itself with the sign components because of its high variance and correlation. A differentiated brightness on an image can produce this kind of feature.

Hyperspectral images of Niquelandia present this kind of noise in the 2ª MFR component characterized by a lateral modification of tonality (Fig. 4). The horizontal profile of the 2ª MFR component exhibits value variation intensity (Fig. 5).

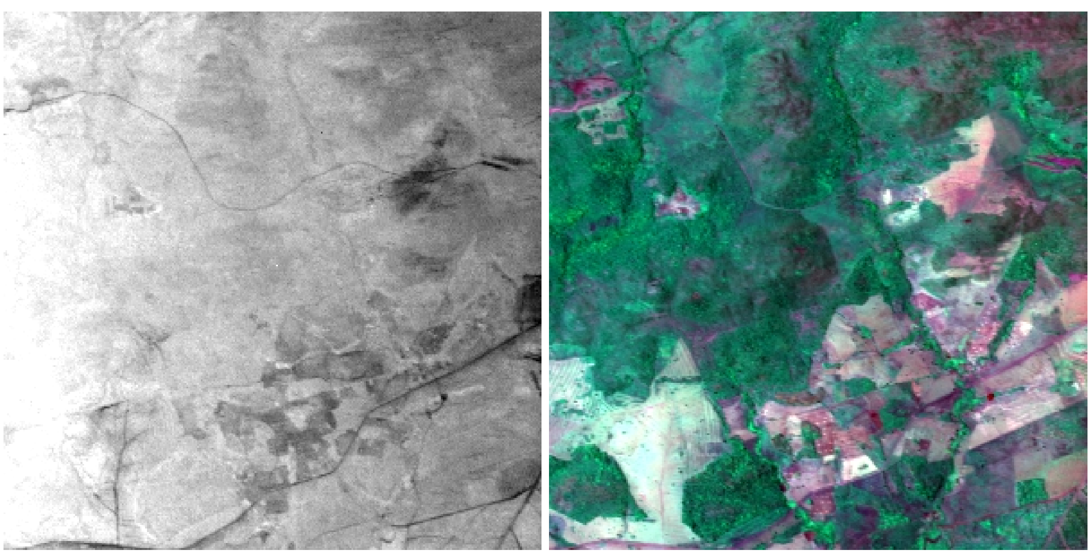

Figure 4. a) concentration of noise on the 2ª component MNF for hyperspectral image of Niquelândia; b) colored composition of the same area with bands 30, 60 and 90 of AVIRIS.

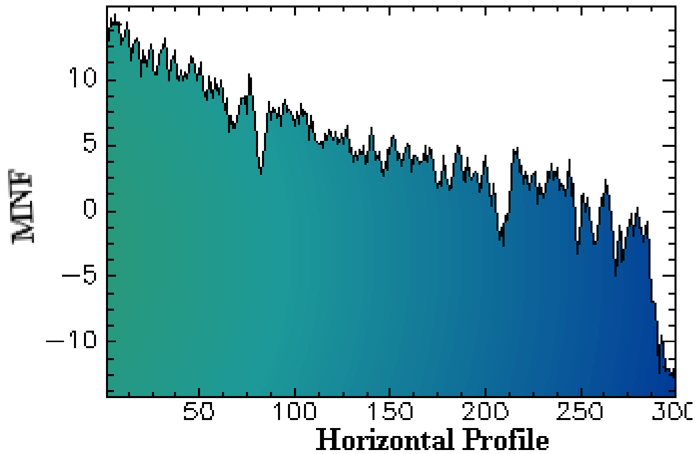

Figure 5. Horizontal profile of north part on the 2[a] component on MNF shadow area with vegetal covering.

c) Noises with Structure of Unknown Covariance – These are sign degradation noises such as: salt-and-pepper noise and striping. The AVIRIS sensor presents a kind of electrostatic arcing noise originated during a flight (Hoffman & Johnson, 1994). This noise is called ES and appears as an isolated peak on the data. This peak is confined to a single line, although it can be extended for two or three channels and adjacent samples.

Noises of sign degradation stay in the MNF space with the more noisy components. The use of scatterplot on the noise bands presents pixels with sign degradation and isolated distant from the spherical cloud. This behavior is due to its variance characteristics that is consistent neither with the spectral behavior of the imaged targets nor with the uncorrelated noises. The scatterplot between MNF bands 34 and 32 presents a pixel positioned with noise in the upper left corner illustrating this point (Fig. 6) The spectral curve of this point shows the absence of a spectrum strip that differentiates it from the others, except for water absorption strips.

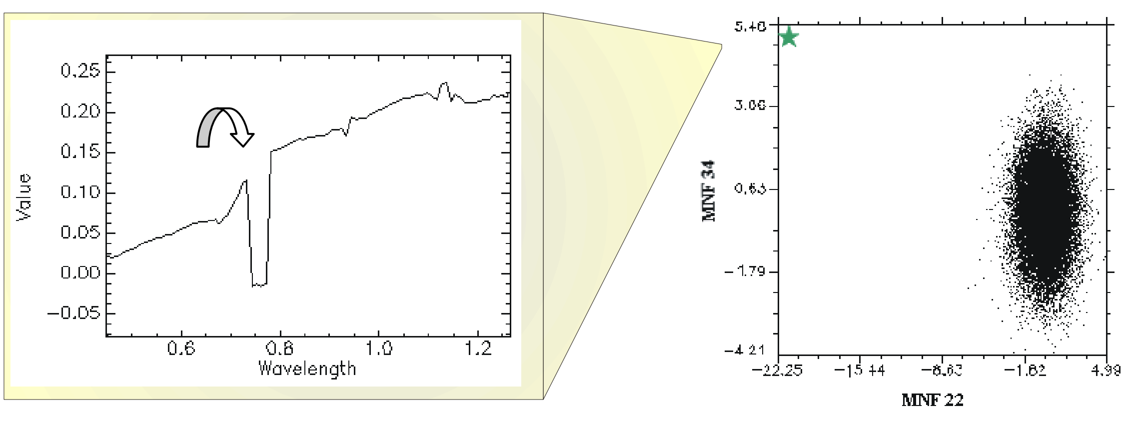

Figure 6. Demonstration of noise type salt and pepper beginning from a dispersion graphic between MNF components relative to the noise of band.

4 SEQUENTIAL METHOD TO ELIMINATE DIFFERENT KINDS OF NOISES BY MNF

The sequential procedure of the MNF enables the elimination of different kinds of noises from the image. The MNF must be always accomplished on the interested bands, neglecting those bands with strong atmospheric interference. A sequential procedure of three MNF stages can be employed on AVIRIS images (Fig.7)

The first stage of the MNF is performed to group noises according to their variances. After the MNF transformation, salt-and-pepper noises must be identified together with the noisiest components, as previously described. From this selection, a mask must be generated for those points to be used in the second MNF. The inversion of the MNF is performed without considering components related to non-correlated noises (analysis of the auto-values along bands) and the high correlation noise contained on the first bands.

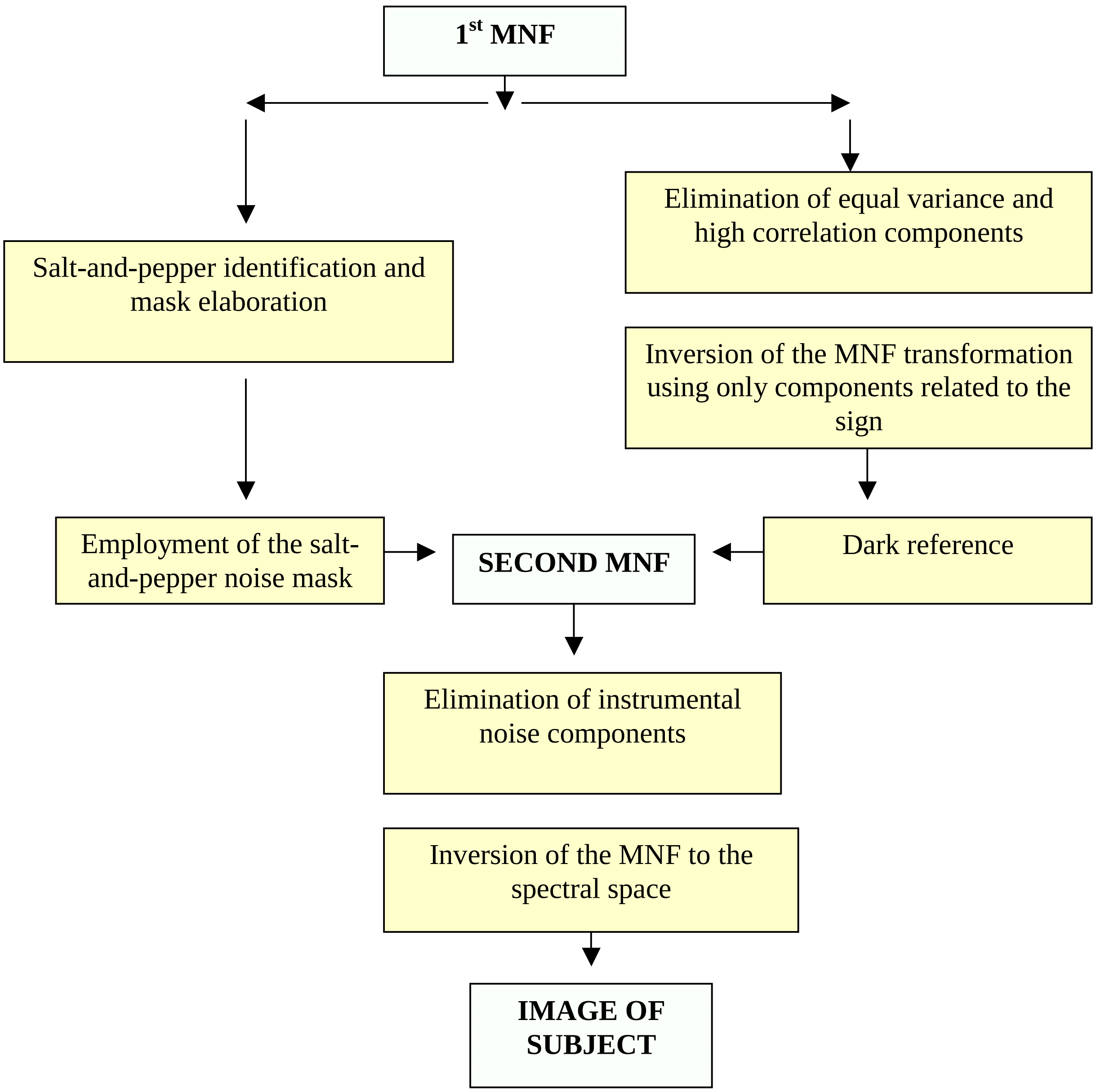

Figure 7. Sequential procedure for elimination of noises using Sequential MNF.

From the inverted images of the first MNF, a second stage of MNF is performed to segregate instrumental noises (using the dark reference) and salt-and-pepper noise (using the salt-and-pepper noise mask). The inversion of the second MNF is performed removing instrumental noise components that are retained on last components.

Figure 8 shows spectral curves before and after the sequential MFR treatment for the same point. Notice, in detail, that the spectrum suffers an accentuated smoothing out with the noise removal treatment. Noise removal is very important because secondary features originated from them can disturb the classification procedures.

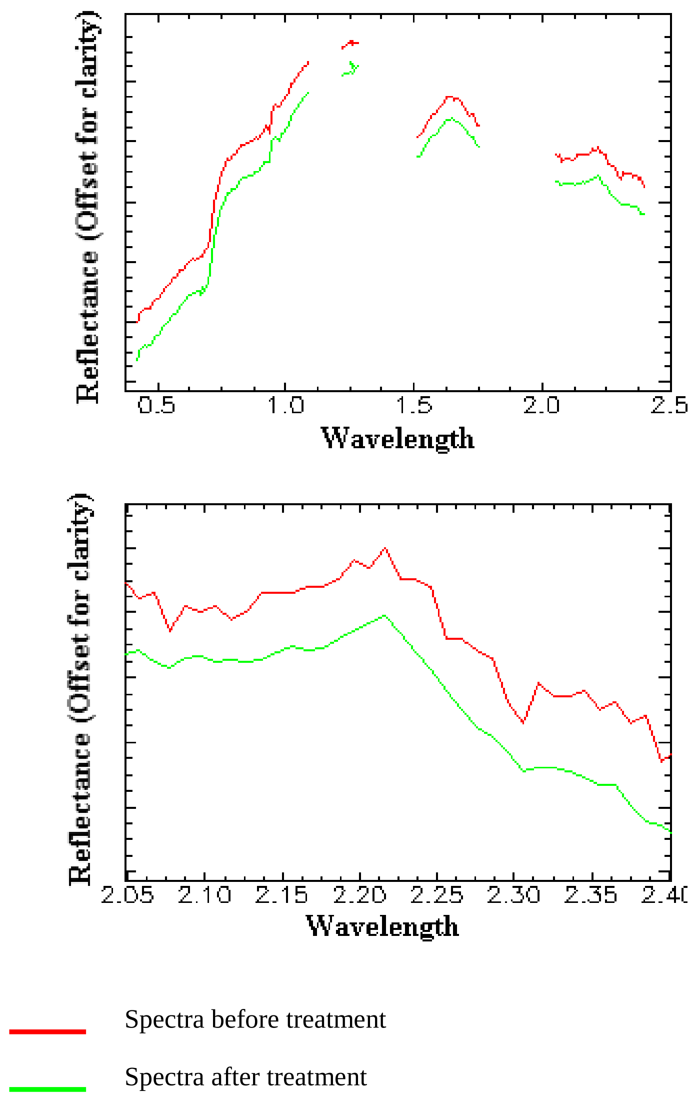

Figure 8. Spectra before and after the use of sequential MNF.

5 CONCLUSION

The employment of sequential MNF presented in this paper used the elimination of different types of noises to obtain better spectra.

This procedure enabled instrumental noise removal through the dark reference and the elimination of noises discriminated by the variance: a) Uncorrelated noises with equal variance in all bands, b) highly correlated noises and c) noises with structure of unknown covariance. For the first and second types, noise components were removed from the MNF space with a posterior return to the spectral space, and for the third a mask was used to eliminate it.

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