

A NOVEL TECHNIQUE FOR HYPERSPECTRAL SIGNAL SUBSPACE ESTIMATION IN TARGET DETECTION APPLICATIONS

N. Acito, G. Corsini, M. Diani, S. Matteoli, S. Resta

Department of "Ingegneria dell'Informazione"

University of Pisa

Pisa – ITALY

E-mail: {n.acito, g.corsini, m.diani, stefania.matteoli}@iet.unipi.it

A hyperspectral sensor (HS) measures the energy reflected or emitted by an observed surface over hundreds of narrow and contiguous spectral bands. A HS produces an image cube made up of many images that are spatially co-registered. Each hyperspectral image pixel can be modeled as the combination of the signal and noise components and can be represented as a point in an L -dimensional space, L being the number of sensor channels. The signal component generally addresses a lower dimensional subspace than the noise signal. A very important step in hyperspectral signal processing is dimensionality reduction aimed at reducing the redundancy in the spectral data by preserving the features needed for classification and detection applications. Dimensionality reduction decreases both the computational complexity of hyperspectral image processing algorithms and the number of image pixels needed to obtain accurate statistical estimates of unknown data parameters. A possible way to reduce hyperspectral data redundancy is to project the image pixels onto the low dimensional signal subspace.

Generally the dimension (rank) and the basis of the signal subspace are not known *a-priori* and must be estimated from the data themselves. The two problems can be solved by resorting to two distinct steps. Several techniques have been proposed in the past years for both rank estimation and basis selection. Most of the rank estimation algorithms such as the ones based on the Akaike Information Criterion (AIC), the Generalised Information Criterion (GIC), the Bayesian Information Criterion (BIC) and the Minimum Description Length (MDL) rely on information theory. Recently, new techniques to estimate the rank of hyperspectral data have been proposed based on the Virtual Dimensionality (VD). It is defined as the minimum number of spectrally distinct signal sources that characterize the hyperspectral data in target detection and classification applications.

Concerning the signal subspace basis selection different methods have been proposed exploiting global or local properties of the observed data. Dimensionality reduction algorithms strongly depend on the data information content to be preserved with regard to the application of interest. Principal Component Analysis (PCA), Singular Value Decomposition (SVD) and Maximum Noise Fraction (MNF) based techniques are largely used to reduce multispectral and hyperspectral data dimensionality in classification applications. Several endmembers estimation methods such as the NFINDR algorithm and the Automated Endmember Extraction Algorithm (AEEA) are used for dimensionality reduction in unmixing problems. The above mentioned techniques are not suitable for dimensionality reduction in target detection applications. In particular, they do not preserve the spectral features contained in rare pixels that could represent targets of interest.

In this paper we present a new technique to jointly estimate the rank and the basis of the signal subspace in hyperspectral image. The proposed technique is specifically designed for target detection applications and is derived by assuming the Linear Mixing Model (LMM). The generic hyperspectral pixel is modeled as a noisy signal and the noise component is assumed to be Gaussian distributed. The algorithm has been derived solving a specific optimization problem where both the rank and the basis of the signal subspace are obtained by minimizing the maximum energy of the residuals, i.e.: the components of each pixel on the subspace orthogonal to the signal one. Since the exhaustive search of the optimum solution is unfeasible a suboptimum algorithm is defined based

on a typical forward selection strategy. The algorithm is implemented through an iterative procedure: at the k -th step the rank is assumed to be known and equal to k . The signal subspace basis is obtained by upgrading the ones derived at the previous step. The new basis vector is the image pixel having the maximum residual energy. In order to determine the true signal subspace dimension a specific decision rule is applied to the maximum residual energy at each step. The decision strategy is derived by exploiting the statistical properties of the noise signal and by resorting to the Neyman-Pearson theory. The derivation of the adopted decision rule is one of the original contributions of this work.

In the final paper results obtained by applying the new algorithm will be discussed. In particular, both simulated and real hyperspectral data will be considered in order to test the efficiency of the proposed technique.