ROBUST ENDMEMBER EXTRACTION IN THE PRESENCE OF ANOMALIES

O Duran and M Petrou

Imperial College London, Dept. of Electrical and Electronic Engineering,
Exhibition Road, South Kensington, London, SW7 2AZ
United Kingdom
email: maria.petrou@imperial.ac.uk

ABSTRACT

Mixed pixels can occur when the resolution of the sensor is low, for instance for remote platforms performing wide-area surveillance. Spectral unmixing consists of decomposing the measured spectrum of a mixed pixel into a set of pure class spectra, or *endmembers*, and computing their corresponding fractions, or *abundances*. Pure cover classes correspond to the usual components in the scene, such as water, soil, or metal. Pure substances might be considered rare events in an image where most of the background pixels correspond to mixtures of pure materials.

Most available methods for endmember extraction use the convexity of the data structure and assign the vertices of the data as the purest pixels [1]. However, the major objection to such methods is that they simply treat the spectra as mathematical vectors, and they do not consider the applicability of the linear model once the endmembers have been extracted. It has to be taken into account that anomalies as well as the purest pixels present in an image might be the extremes of the spread of spectral signatures [2]. In other words, pixels that constitute the vertices of the convex hull of the cloud of data points might be either anomalies or purest pixels, and in order to distinguish between those, the applicability of the linear model has to be considered. On the other hand, methods that search for anomalies might wrongly return endmembers as anomalies, since both populations are relatively small [1].

A robust endmember extraction algorithm for hyperspectral data is presented in this paper. The algorithm extends the work presented in [3] and shows its applicability for the robust identification of the endmembers in a scene. The method is based on the assumptions that the linear mixing model is valid and that due to the resolution of the image, most pixels are mixtures of relatively rare pure substances. Thus, if we represent all pixels as linear combinations of the background classes, pixels corresponding to each pure class are expected to show extreme abundance values with respect to one of the background classes. Moreover they are also expected to show small values of residual error after having applied the linear unmixing model allowing negative and superunity abundances. On the contrary, anomalies are identified as pixels with spectra that cannot be explained as linear combinations of the spectra of the background classes.

The proposed endmember extraction allowing negative and superunity weights (EENSU) method consits of three steps. In a first stage of the algorithm, the classes associated with the background, which are the dominant classes in the image, are identified by clustering the image pixels [3]. The resulting clusters may be considered as representatives of the background classes in the image. In a second stage, all pixels in the image are unmixed using the unconstrained least square error approach (negative and superunity abundances are allowed) and the extracted background classes. Finally, we search for pixels with

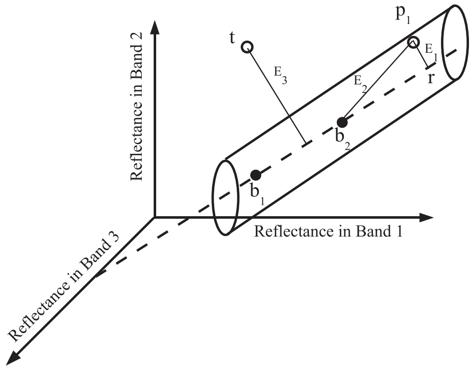

Fig. 1. Residual error in spectral unmixing. The background classes are represented by b_i. E_1 represents the residual error of pure class pixel p_1 allowing negative and superunity mixing proportions. E_2 represents the residual error of pure class pixel p_1 using non-negative mixing proportions only. E_3 represents the residual error of anomaly t.

extreme values of abundance fractions and low residual error, when expressed as linear combinations of the background class spectra. The pixels within the convex hull formed by the background classes will have positive fractions that are smaller than 1. The pure substances, however, will be outside such a convex hull, and will show extreme negative or superunity fractions. Pixels with such mixing proportions may be explained as linear combinations of the background classes, and, therefore, as not true anomalies. Pixels corresponding to anomalies, however, when expressed as linear combinations of the background classes, will show high residual error, even with negative and superunity mixing proportions. It is this last step of the algorithm that allows us to characterise the algorithm as robust as opposed to just using an algorithm that identifies the extreme points of the simplex of data in the spectral space.

Figure 1 represents a simple example of a 3D feature space, where linear combinations of the two background classes b_1 and b_2 occupy the dashed line. Pixels that satisfy the positivity constraint (positive fractions that are smaller than 1) lie on the b_1b_2 segment. When performing spectral unmixing of a pixel p_1, in order to find the optimal solution, point r is shifted along line b_1b_2 until its distance from point p_1 is minimal. In the general case, the identified background classes define a low dimensionality manifold embedded in the high dimensionality spectral space. We "thicken" that manifold by allowing pixels to belong to it, as long as their distance from it is below a certain threshold, and we consider all other pixels anomalies.

We tested the proposed algorithm with real and synthetic data and compared it with the VCA, SGA and NFINDR algorithm, showing better and more robust endmember extraction.

1. REFERENCES

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