

Research and development of the classification algorithm based on the method of reference planes

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Abstract. In this paper a classification algorithm for hyperspectral images based on the reference planes using the values of the contingency table is developed and researched. We propose a new procedure for generating the reference planes. The training vectors are formed with the use of vectors from other classes. The results of experiments on the test image are given.

Keywords: hyperspectral images, method of reference planes, classification, conjugacy indices

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1. Introduction

Thematic classification of hyperspectral images is gaining popularity. Studies in remote sensing are useful in many fields such as agriculture, mineralogy, physics, surveillance, forensics etc. Remote sensing of the Earth surface allows us to survey the productivity of the lands, forest fires, construction of roads and various objects.

The most widely used algorithms of thematic classification for solving the above problems are based on methods of spectral angle and support vector machine (SVM). This paper presents a classification algorithm based on the method of reference planes using the values of the conjugacy indices.

2. Statement of the problem

The source data is a hyperspectral image obtained by remote sensing [1]. It is a data structure in which intensity values are stored with the coordinates X , Y , Z , which includes spatial coordinates (X , Y) and spectral coordinates (Z). The objective is to find the given object in this hyperspectral image.

It is assumed that each of spatial coordinates of the hyperspectral image belongs to one of K classes. Each class represents some object (for example, field of corn, field of wheat, roads, etc.).

3. Description of the classification algorithm

To describe the algorithm, consider the k^{th} class. In this class we will choose the reference plane X_k [2] consisting of a pair of hypervectors. For selected reference plane k class index of conjugacy [3] with the vectors from other classes can be calculated with the following expression:

$$R_k(j) = \frac{\mathbf{x}_j^T \mathbf{Q}_k \mathbf{x}_j}{\mathbf{x}_j^T \mathbf{x}_j}$$

where $\mathbf{Q}_k = \mathbf{X}_k [\mathbf{X}_k^T \mathbf{X}_k]^{-1} \mathbf{X}_k^T$, \mathbf{x}_j is vector j from the class $n \neq k$, $j = 1, \dots, N_n$. Thus, we have N_n values of conjugacy indices R_k . For these indices the root-mean-square (RMS) value can be calculated as following

$$\mathbf{R}_{mean}(n) = \sqrt{\frac{(R_j)^2}{N_n}}$$

where $n = (1, \dots, K) \setminus k$. Next, we do the same with the remaining classes. For all remaining $K - 1$ values \mathbf{R}_{mean} , we calculate RMS value

$$\mathbf{R}(i) = \sqrt{\frac{(\mathbf{R}_{mean}(n))^2}{K - 1}}$$

where $n = (1, \dots, K) \setminus k$, $i = 1, \dots, C_{N_n}^2$.

Further, we similarly define conjugacy indices for all planes X_k of k^{th} class and calculate $C_{N_n}^2$ values of $\mathbf{R}(i)$, where $i = 1, \dots, C_{N_n}^2$. Then the minimum value $\mathbf{R}(i)$ is sought among them

$$R = \min_{i=1, C_{N_n}^2} \mathbf{R}(i).$$

The hyperplane which corresponds to the received minimum value \mathbf{R} is stored. Let us denote it as \mathbf{Y}_k . Thus, we get the reference plane with the highest value of the conjugacy index with its class. This plane allows us to effectively recognize the chosen class. At the same time, it will be less responsive to vectors of other classes. This allows us to enhance the effectivity of the hyperspectral images classification.

On recognition stage [4] it is necessary to choose the minimum threshold of conjugacy. It is performed by calculating the conjugacy indices with the reference plane \mathbf{Y}_k

$$R_Y(m) = \frac{\mathbf{x}_m^T \mathbf{Q}_Y \mathbf{x}_m}{\mathbf{x}_m^T \mathbf{x}_m},$$

where $\mathbf{Q}_Y = \mathbf{Y}_k [\mathbf{Y}_k^T \mathbf{Y}_k]^{-1} \mathbf{Y}_k^T$, \mathbf{x}_m is vector m from class k , $m=1, \dots, N_k$, and N_k is the number of vectors in class k . The N_k values obtained from this procedure are sorted in ascending order. Then first (lowest) or N^{th} value from ordered sequence of R_Y is chosen.

4. The results of the experiment

The algorithm was tested on a Salinas test image from open dataset of hyperspectral image MultiSpec. This image was obtained within AVIRIS program (Airborne Visible/ Infrared Imaging Spectrometer). The image size is 512×217 hyperpixels. Each hyperpixel has 224 spectral bands. A sample of hyperspectral layer and classified test image are shown in figures 1a), 1b), respectively.

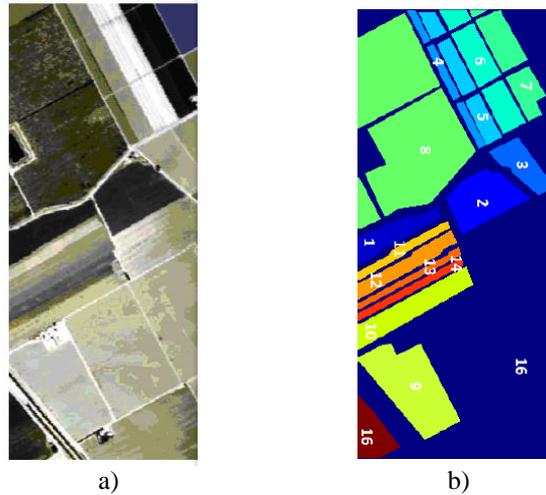


Fig. 1. – Salinas test image: a) hyperspectral layer with the use of artificial coloring; b) classified image

The algorithm was applied to detect the 4th, 5th, and 11th classes (the area with roughly plowed fields, smooth ground, four-week lettuce, respectively). The figure shows the location of the fifth and eleventh class vectors with skipping the 20% lowest conjugacy indices. The figure shows a few falsely recognized hyperpixels from other classes.



Fig. 2. –Location of 5 and 11 classes vectors respectively

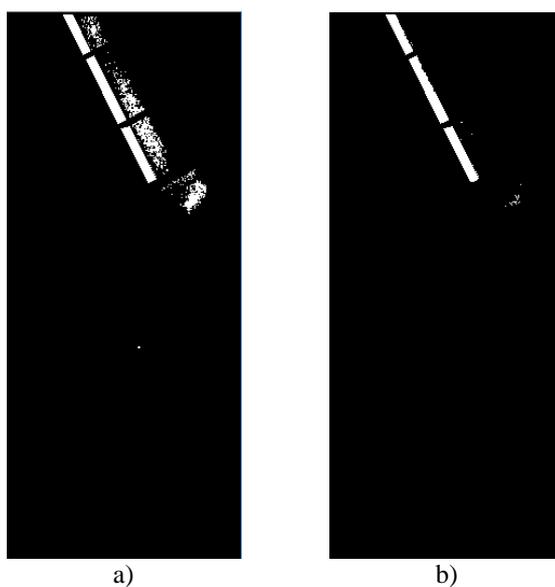


Fig. 3. – Location of the fourth class vectors: a) the 0% threshold; b) the 2% threshold

Figures 3a), 3b) shows an example of the recognition of the fourth class vectors with a different minimum conjugacy threshold. The figures show that the choice of the threshold strongly influences the number of recognition errors in other classes. The increase in the threshold enhances recognition quality in its class.

5. Conclusion

The choice of an appropriate reference plane in the proposed algorithm has a high computational complexity. Recognition quality depends on the choice of the minimum conjugacy threshold. A small value of the threshold increases the number of recognition errors associated with “wrong detection” from other classes. The increase in the threshold leads to the points loss in a recognized class.

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