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Unmixing method for hyperspectral data based on sub-space method with learning process

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Abstract

An unmixing method for hyperspectral Earth observation satellite imagery data is proposed. It is based on a sub-space method with learning process. The proposed method utilizes a sub-space for feature space during unmixing. It is used to be done in a feature space which consists of spectral bands of observation vectors. As the results from the experiments with airborne based hyperspectral imagery data, AVIRIS, it is found that the proposed unmixing is superior to the other existing method in terms of decomposition accuracy and the process time required for the decompositions.

Keywords: Unmixing; Category decomposition; Hyperspectral data; Sub-space method; Learning process; AVIRIS

1. Introduction

Remote sensing is the practice of deriving information about the earth land and water surfaces using images acquired from an overhead perspective, using electromagnetic radiation in one or more regions of the electromagnetic spectrum, reflected or emitted from the earth surface. In particular, hyperspectral sensor (for instance, Lilles Kiefer 1994) which covers from visible to short wave infrared wavelength region has many continuation spectrum bands (Vane et al., 1993; Adams Smith 1986). Not only one single ground cover target but also two or more targets (category) are contained in the instantaneous field of view of the sensor. It is generally called as mixed pixel (Mixel) (Arai, 1991). Unmixing is the technique of presuming the category kind which constitutes the mixel, and its mixing ratio (Keshava Mustard 2002). There are two models for the mixel, a linear and a nonlinear model (Liangrocapart Petrou 1998; Arai Terayama 1992). The spectrum feature of the pixel which consists of one category is called a pure pixel (also it is called an end-member). Unmixing is performed based on the linear or the nonlinear models (Borel Gerstl 1994). It is as which a linear model disregards the interaction between end-members, and a nonlinear model considers the multiple reflection and scattering which depends on the geometric relations among the sun, a ground cover target, and a sensor (Arai and Inagaki, 2002). There are linear model based unmixing methods that based on (1) a maximum likelihood method (Settle, 1996; Matsumoto et al., 1991), (2) a least square method with constraints (Chang, 2003; Arai Terayama 1995), (3) a spectrum feature matching (Mazer, 1988), (4) a partial space projective technique (Chang et al., 1998; Arai and Chen, 2002), (5) a rectangular partial space method (Harsanyi Chang 1994), etc. The least square method with a constraint presumes a mixing ratio vector based on an end-member's spectrum feature vector by the generalized inverse matrix or the least-squares method which makes convex combination conditions a constraint. The spectrum feature matching searches and selects two or more spectrum features out of a plenty of spectrum features in a spectral database. It is the spectral feature matching method in consideration of those mixing ratios, and the spectrum feature of the mixel in concern.

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Further studies are required for appropriate end-member determination, improvement of accuracy, reduction of processing time, etc. for unmixing methods. This paper mainly focuses on improvement of unmixing accuracy, estimation accuracy of mixing ratio. The methods based on a partial space projective technique (Chang et al., 1998; Arai and Seto, 2005), and a rectangular partial space method (Harsanyi Chang 1994) may make the spectrum feature of a desirable category conspicuous, they map and combine the spectrum feature of the mixel with sub-space which is made to intersect perpendicularly with the other spectrum feature. It also can perform dimensionality reduction. Moreover, the unmixing technique based on an orthogonal sub-space method has comparatively good unmixing accuracy, and is used abundantly. Furthermore, it is equivalent to the unmixing based on a maximum likelihood method, and this is also equivalent to the method of least square. An independent component analysis method (ICA) decomposes given

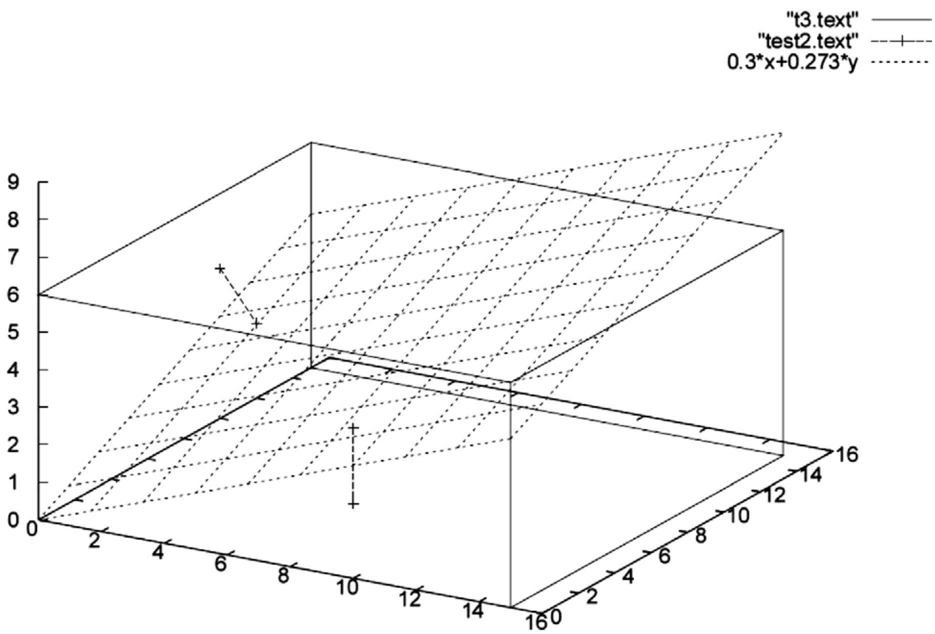

Fig. 1. An example of the existing sub-space method (SSM). x and + shows the data for categories A and B, respectively. The category A is situated at (10, 0, 4) and (10, 0, 2) while the category B is situated at (0, 10, 4) and (0, 12, 4), respectively. The sub-space for category A is situated at (10, 0, 3) while that for category B is situated at (0, 11, 3), respectively.

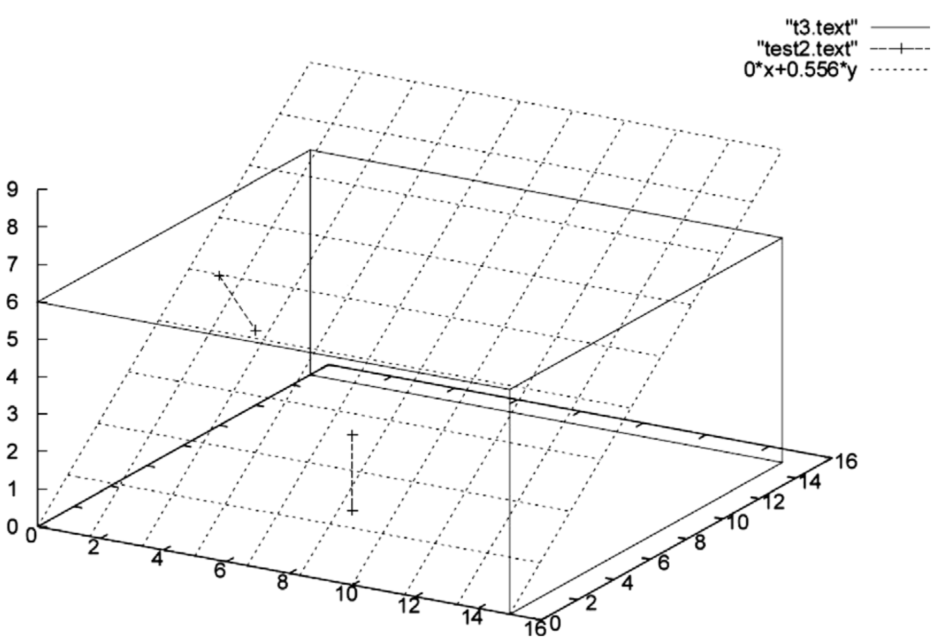

Fig. 2. An example of the proposed sub-space method with learning process. The sub-space of the category A is situated at (10, 0, 0) while that of category B is situated at (0, 9, 5), respectively.