

VEGETATION ENDMEMBER EXTRACTION IN HYPERION IMAGES

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ABSTRACT:

Hyperspectral imaging sensors on environmental applications have high spectral resolution and low spatial resolution so that numerous disparate substances can contribute to the spectrum measured from a single pixel or in the field of view of the sensor. An important problem in Hyperspectral imaging processing is to decompose the mixed pixels into the materials that contribute to the pixel, endmember, and a set of corresponding fractions of the spectral signature in the pixel, abundances, and this problem is known as the unmixing problem. According to the definition, an endmember is an idealized pure signature of a class. Endmember extraction is one of the fundamental and crucial tasks in hyperspectral data exploitation. It has received considerable interest in recent years, with many researchers devoting their effort to develop algorithms for endmember extraction from hyperspectral data. An ultimate goal of an Endmember Extraction Algorithm (EEA) is to find the purest form of each spectrally distinct material on a scene. Endmember extraction tendency to the type of endmembers being derived, and the number of endmembers, estimated by an algorithm, with respect to the number of spectral bands, and the number of pixels being processed, also the required input data, and the kind of noise, if any, in the signal model surveying done. Identifying endmembers that satisfy both physical and mathematical imperatives is a considerable challenge, making autonomous endmember determination the hardest part of the unmixing problem. Of three stages that comprise unmixing, endmember determination is the most closely aligned with the material identification capabilities of unmixing. Non-statistical algorithms or Geometrical approach essentially assume the endmembers are deterministic quantities, whereas statistical approaches view endmembers as either deterministic, with an associated degree of uncertainty, or as fully stochastic, with random variables having probability density functions. In addition, specific features concerning the outputs, inputs, and noise models used by these algorithms are included according to the model specifically distinguishing the properties of endmember-determination algorithms.

In this paper, Endmember Extraction Algorithms (EEAs) applied on a Hyperion image of southern of Tehran, IRAN. A large number of endmembers were suggested to enhance the classification accuracy while the seasonal variation in the spectral response should be taken into account in vegetation classification. We compare results of Geometrical approach in vegetation endmember extraction assistance with vegetation indices.

1. INTRODUCTION

1.1. OVERVIEW

Hyperspectral imaging sensors on environmental applications have high spectral resolution and low spatial resolution so that numerous disparate substances can contribute to the spectrum measured from a single pixel or in the field of view of the sensor. An important problem in Hyperspectral imaging processing is to decompose the mixed pixels into the materials that contribute to the pixel, endmember, and a set of corresponding fractions of the spectral signature in the pixel, abundances, and this problem is known as the unmixing problem.

Availability of new generation of hyperspectral sensors such as the Hyperion has lead to the new challenges in the area of crop type mapping and agricultural management. The sensor's 242 Spectral band between 400 and 2500 nm (level 1B1) and spatial resolution of 30m bear high potentials for agricultural crop discrimination and detailed land use classification[1]. Advantages of this technology include both the qualitative benefits derived from a visual overview, and more importantly,

the quantitative abilities for systematic assessment and monitoring. In every remotely sensed image, a considerable number of mixed pixels is present. A mixed pixel is a picture element representing an area occupied by more than one ground cover type. Several research objectives were accomplished:

- (1) Select optimal bands in hyperspectral images those are most useful in vegetation classification,
- (2) Identify optimal endmember, signature spectrum that represents a certain class, for vegetation classification, and
- (3) Test effective Endmember Extraction Algorithms for classification of vegetation type.

First pre-processing step which include radiometric correction and removing atmospheric effect involves calibration and atmospheric correction. We used Fast Line-of-sight Atmospheric Analysis of Spectral Hypercube (FLAASH) in ENVI software for atmospheric correction. In this research, capabilities of Hyperion hyperspectral imagery acquired from an agricultural area located in southern parts of Tehran, Iran,

has been evaluated for discrimination of vegetation area from others. Atmospheric correction and other pre-processing operations on the hyperspectral imagery have been performed by using routine procedures.

Spectral unmixing algorithms use a variety of different mathematical procedures to endmember extraction and estimate abundances. Unmixing problem comprises three sequential steps: dimension reduction, endmember determination, and inversion. Because hyperspectral scenes can include extremely large amount of data, some algorithms for spectral unmixing first use image itself to estimate endmembers present in the scene. The dimension-reduction stage reduces the dimension of the original data in the scene. This step is optional and is invoked only by some algorithms to reduce the computational cost of subsequent processing; it also selects bands with higher signal to noise ratio (SNR) to separate endmembers spectra without any data loss. We use the MNF method to achieve this goal. In this paper, we introduce that the site study and EEA that applied on image then emphasize on the second step of unmixing problem. Finally represent the result of this research.

1.2. THE SITE STUDY

An agricultural area located in southern parts of Tehran, known as Ahmadabad has been selected as the study site. Wheat and barley are the main agricultural crops in the area. More than 30 fields of detailed ground-truth dataset have been visited in the field and their records have been used as a ground truth data for training and verifying the results of the classification.

1.3. OPTIMAL BANDS IN HYPERION IMAGES

Hyperion data were acquired over the Ahmadabad village on May 21, 2002 at 06:57:56 GMT. The EO-1 satellite is a sun-synchronous orbit at 705 km altitude. Hyperion data includes 256 pixels with a nominal size of 30 m on the ground over a 7.65 km swath. Well-calibrated data (Level 1B1) is normally available. Post-Level 1B1 processing of the dataset, as performed in this study, included correction for bad lines, striping pixels and smile, atmospheric correction and co-alignment. Hyperion data is acquired in pushbroom mode with two spectrometers. One operates in the VNIR range (including 70 bands between 356-1058 nm with an average FWHM of 10.90 nm) and the other in the SWIR range (including 172 bands between 852- 2577nm, with an average FWHM of 10.14 nm). 44 of 242 bands including bands 1-7, 58-76 and 225-242 are set to zero by TRW software during Level 1B1 processing [2][3]. Post-level 1B1 data processing operations for preparation of the Hyperion data for classification including band selection, correction for bad lines, striping pixels and smile, a pixel-based atmospheric correction using FLAASH [2] and a co-alignment were performed.

2. IDENTIFY OPTIMAL ENDMEMBER

An important problem in Hyperspectral image processing is to decompose the mixed pixels into the materials that contribute to the pixel, endmember and a set of corresponding fractions of the spectral signature in the pixel, abundances, and this problem is known as the unmixing problem.

According to the definition, an endmember is an idealized pure signature of a class. Endmember extraction is one of the fundamental and crucial tasks in hyperspectral data exploitation. It has received considerable interest in recent years, with many researchers devoting their effort to develop algorithms for endmember extraction from hyperspectral data.

Hyperspectral imaging sensors on environmental applications have high spectral resolution and low spatial resolution so that numerous disparate substances can contribute to the spectrum measured from a single pixel or in the field of view of the sensor. A mixed pixel occurs due to high spectral resolution or low spatial resolution when more than one material substance present in a pixel, in this case these substances are considered to be mixed linearly or nonlinearly in the pixel.

Recent researches aim to identify the individual constituent materials existing in the mixture pixel, as well as the proportions in which they appear. Spectral unmixing is the procedure by which the measured spectrum of a mixed pixel is decomposed into a collection of constituent object spectra that present in scene. In estimating the constituent members and abundances in pixel spectra, unmixing algorithms incorporate philosophical assumptions regarding the physical mechanisms and mathematical structure by which the reflectance properties from disparate substances combine to yield the mixed pixel spectra. Detection algorithms make similar assumptions when testing for the existence of a specific substance in a mixed pixel. Not surprisingly, the hyperspectral detection and unmixing problems are closely related.

2.1. PPI

The Pixel Purity Index (PPI) has been widely used in hyperspectral image analysis for endmember extraction due to its publicity and availability in the Environment for Visualizing Images (ENVI) software.[4] In this experiment, the PPI was implemented to find endmembers for the image scene in Fig 1, using the same set of randomly generated initial skewers. Fig 2 shows the endmember pixels extracted by the PPI, respectively.



Fig 1

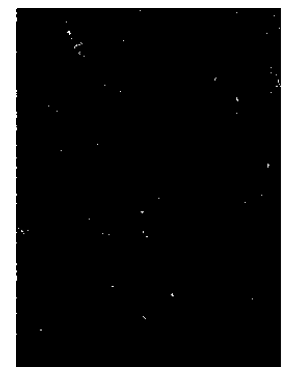


Fig 2

Fig 1 :Hyperio image scene subset
(R=650.67,G=569.27,B=477.69)

Fig 2 :Hyperion PPI

2.2. SMACC¹

A new endmember extraction method has been developed that is based on a convex cone model for representing vector data. The endmembers are selected directly from the data set. The algorithm for finding the endmembers is sequential: the convex cone model starts with a single endmember and increases incrementally in dimension. Abundance maps are simultaneously generated and updated at each step. A new endmember is identified based on the angle that it makes with the existing cone. The data vector which is making the maximum angle with the existing cone is chosen as the next

¹ - Sequential Maximum Angle Convex Cone

endmember to add to enlarge the endmember set. The algorithm updates the abundances of previous endmembers and ensures that the abundances of previous and current endmembers remain positive or zero. The algorithm terminates when all of the data vectors are within the convex cone, to some tolerance. The method offers advantages for hyperspectral data sets where high correlation among channels and pixels can impair un-mixing by standard techniques.[5]. The SMACC has been contrived in hyperspectral image analysis for endmember extraction due to its publicity and availability in the Environment for Visualizing Images (ENVI) software. In Endmember Extraction Algorithm finding the number of endmember is very important. For example Virtual Dimensionality (VD) and hyperspectral signal identification by minimum error (Hysime) are two methods to estimate number of endmember but computational complexities are high. [6]



Fig 3:Hyperion SMACC Abundance image

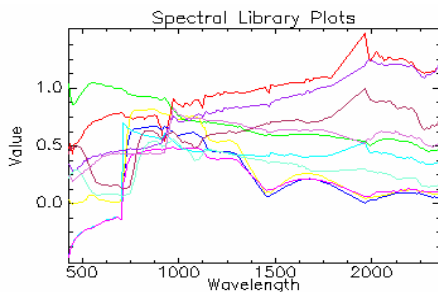


Fig 4: Hyperion SMACC Spectral Library for 10 endmember

3. TEST EFFECTIVE ENDMEMBER EXTRACTION ALGORITHMS FOR CLASSIFICATION OF VEGETATION TYPE

The Modified Red Edge Normalized Difference Vegetation Index (mNDVI 705) is a modification of the Red Edge NDVI. It differs from the Red Edge NDVI by incorporating a correction for leaf specular reflection. The mNDVI 705 capitalizes on the sensitivity of the vegetation red edge to small changes in canopy foliage content, gap fraction, and senescence. Applications include precision agriculture, forest monitoring, and vegetation stress detection. The mNDVI 705 index is defined by the following equation:[7],[8]

$$mNDVI_{705} = \frac{\rho_{750} - \rho_{705}}{\rho_{750} + \rho_{705} - 2\rho_{445}} \quad (1)$$

Where : ρ_{750} =reflectance at 750 nm
 ρ_{705} =reflectance at 705 nm
 ρ_{445} =reflectance at 445 nm

In this experiment, the mNDVI 705 was implemented to find vegetative area on the image scene (Fig 5).

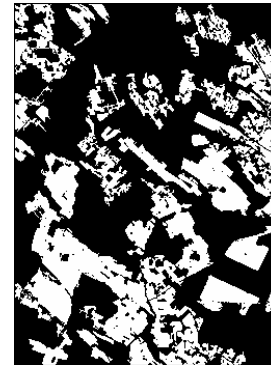


Fig 5: Hyperion image of area that mNDVI 705 > 0.3

Then mask vegetation area from original hyperion image. We applied SMACC to find endmember for the alternative endmember number $p = 7, 10, 20, 30$. In this experiment we knew how the number of endmember will help us to find pure pixels and mixed one. If the number of endmember is over the real, the algorithm found mixed pixels such as pure. For accurate image classification using of vegetation index was suitable. With this approach we can estimate the number of vegetative endmember are less than 11 and other endmember related to mixed pixels. This result is depicted in figure (6-9).

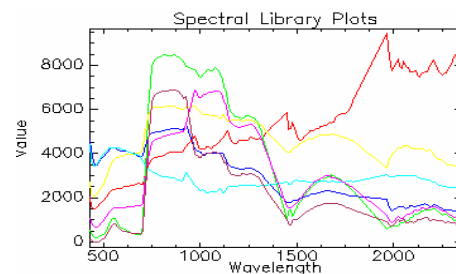


Fig 6: Hyperion SMACC Spectral Library P=7

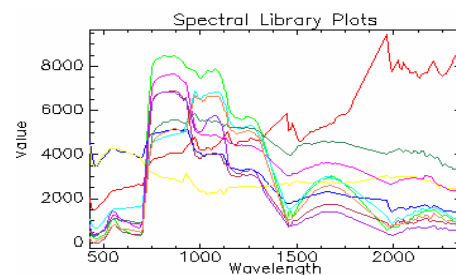


Fig 7: Hyperion SMACC Spectral Library P=1

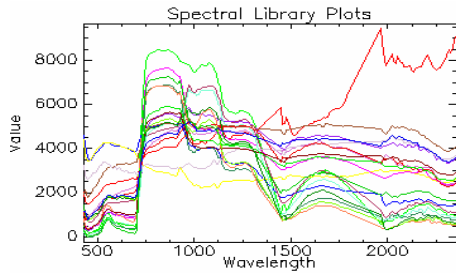


Fig 8: Hyperion SMACC Spectral Library P=20

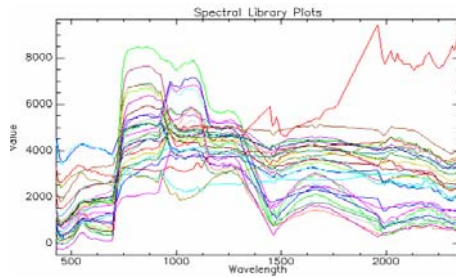


Fig 9: Hyperion SMACC Spectral Library P=30

4. CONCLUSIONS

Endmember extraction provides a powerful tool for analysis of the highly redundant, pixel spectra and channel images of hyperspectral data sets. An ultimate goal of an Endmember Extraction Algorithm (EEA) is to find the number of each spectrally distinct material on a scene. Endmember extraction tendency to the type of endmembers being derived, and the number of endmembers, estimated by an algorithm, with respect to the numbers of spectral bands and the number of pixels being processed. Also the required input data, and the kind of noise, if any, in the signal model surveying was done. Identifying endmembers that satisfy both physical and mathematical imperatives is a considerable challenge, making autonomous endmember determination the hardest part of the unmixing problem. SMACC approach with constraints requiring positive abundances and constraints on the maximum number of endmembers for a pixel model provides a detailed physical description of the spatial and spectral features of hyperspectral imagery. The approach can extract spectra that account for environmental and illumination variations in the spectral data and model the variations in the non-extreme spectra. The convex factorization approach finds small subsets of end-spectra to model the material types and variations autonomously. End-spectra that describe localized features are candidate anomalous spectra for processing with detection algorithms. Convex factorization applied to channel images determines the spectral bands in the data where images are highly correlated. Sets of images within these bands are nearly scaled copies of each other. Images within these bands could be co-added to increase the signal-to-noise ratio. Images from separate bands can be selected to enhance visualization of spatial spectral boundaries in the data. When applying vegetation indices and incorporation by SMACC vegetative endmember extraction done accurately.

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