FEATURE EXTRACTION AND CLASSIFICATION OF HYPERSPECTRAL IMAGES

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Abstract: As it is known, unlike the traditional multispectral remote sensing (RS) data taken in the optical range of an electro-magnetic spectrum, the hyperspectral data sets deal with an enormous amount of image bands and offer the greater potential for more accurate and detailed information extraction. This paper aims to compare two different approaches in feature extraction for a hyperspectral image classification. For the actual feature extraction, principal components analysis and spectral knowledge are used. The output of each of the feature extraction method is classified using a maximum likelihood classification and spectral angle mapper methods. The results are analyzed and compared.

1. INTRODUCTION

In recent years, the processing and analysis of hyperspectral images have become the main tasks of many researchers dealing with RS image processing. Unlike the traditional multispectral datasets taken in the optical range of electro-magnetic spectrum, the hyperspectral data deals with an enormous amount of bands and the data are formed as collections of hundreds of images of the same scene with each image corresponding to a narrow interval of the electro-magnetic wavelength. It is clear that such datasets offer the superior potential for more accurate and detailed information extraction than is possible with other types of RS data. This means that hyperspectral data sets provide a wealth of information and are used for many different applications such as geological investigation, forest change analysis, environmental mapping, global change study, wetlands mapping, crop analysis, traffic ability assessment, plant identification, mineral recognition, and many others (Plaza *et al.* 2012, Amarsaikhan *et al.* 2011).

As the hyperspectral images consist of a large number of bands, their unique characteristics pose different processing problems, which could be necessarily tackled under specific mathematical formalisms, such as segmentation and classification as well as spectral mixture analysis (Smith *et al.* 1990 and Jia *et al.* 1999). In order to reduce the data volume, the techniques for reducing the image dimensionality are often applied. Usually, it is reduced by applying different transformation techniques by retaining only the significant components for further processing. Information extraction is generally done through classification of the images and identifies which pixels contain a variety of spectrally distinct labels. Many attempts are being made to reduce the data dimensionality and extract reliable information needed for different decision-making (Amarsaikhan and Ganzorig 1999, Keshava and Mustard 2002, Richards 2005, Tsai *et al.* 2009, Yang *et al.* 2009, Vega *et al.* 2012).

The aim of this paper is to compare two different methods for a feature extraction and use the selected features in a classification of hyperspectral images. For this purpose, 242 band HYPERION image of Ulaanbaatar, the capital city of Mongolia has been used. For the actual feature extraction, principal components transformation and spectral knowledge were used. The output of each of the feature extraction method was classified using a maximum likelihood classification and spectral angle mapper methods. The results indicated that hyperspectral images could be used for an efficient land cover mapping and differentiation of the classes having similar spectral characteristics.

2. TEST SITE AND DATA SOURCES

As a test site, Ulaanbaatar city of Mongolia has been selected. Although, Ulaanbaatar is extended from the west to the east about 30km and from the north to the south about 20km, the study area chosen for the present study covers more southern part of the capital city and extends from the west to the east about 6.5km and from the north to the south about 4.8km.

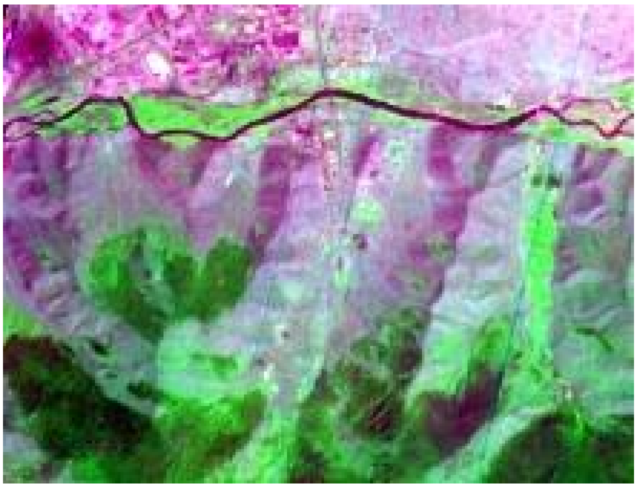

Figure 1: HYPERION image of the test site

In the current study, 242 band HYPERION image taken on 18 August 2002, has been used. Hyperion is a hyperspectral sensor launched by NASA in November 2000 and it marked the establishment of spaceborne hyperspectral mapping capabilities. It covers 355nm to 2577nm spectral range with 242 spectral bands at approximately 10nm spectral resolution and the data has 30m spatial resolution. The instrument captures 256 spectra over a 7.5km-wide swath perpendicular to the satellite motion (Kruse 2002). Figure 1 shows a HYPERION image of the test site, and its land cover.

3. FEATURE EXTRACTION

Initially, the multi-channel HYPERION image has been analyzed in terms of radiometric quality. It was found out that the water absorption bands and some other bands of the image had zero values. When these bands have been excluded, the original HYPERION dataset was reduced from 242 bands to 155 bands.

Then, for the feature extraction the following approaches have been used:

- Feature extraction using principal component transformation (PCT). The PCT is a statistical technique that transforms a multivariate data set of intercorrelated variables into a set of new uncorrelated linear combinations of the original variables, thus generating a new set of orthogonal axes (Richards and Xia, 1999). It is also a data compression technique used to reduce the dimensionality of the multidimensional datasets and helpful for image encoding, enhancement and multitemporal dimensionality (Pohl and Van Genderen 1998). PCT has been performed using all available bands and the result showed that the first three principal component (PC)s contained 98.48% of the overall variance (81.85%, 13.57%, 3.06% for the PC1, PC2 and PC3, respectively). The visual inspection of a PC4 that contained only 0.4% of the overall variance, indicated that it contained noise. Likewise, the other PCs contained noise from the total data set. A colour image created by the use of the first three PCs is shown in Figure 2a.
- Application of spectral knowledge of the classes of interest. Nowadays, application of a knowledge-based approach has more and more usage in spectral classification of RS images. The knowledge in image classification can be represented in different forms depending on the type of knowledge and necessary of its usage. In our case, spectral knowledge of the classes of objects was used for selection of the features and it is defined on the basis of the general spectral characteristics of the classes of objects and the available spectral knowledge. Initially, the pixels representing the selected classes have been chosen from different parts of the image. Then, the statistics of

these pixels was defined and plotted in a feature space and the bands which demonstrated the maximum separabilities were chosen for a further analysis (i.e., bands 38, 82, 100). A colour image created by the use of this method is shown in Figure 2b.

a) b)

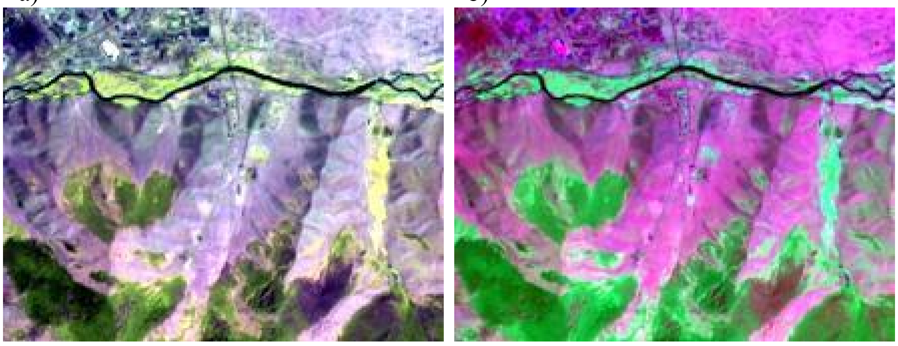

Figure 2: a) Image created by the use of bands 38, 82 and 100,
b) Image created by the PCA method

4. CLASSIFICATION OF THE FEATURES

Initially, to define the sites for the training signature selection, areas of interest (AOI) representing the available six classes (built-up area, soil, grass, deciduous forest, coniferous forest and water) have been selected from the hyperspectral image. The separability of the training signatures was firstly checked in feature space and then evaluated using Jeffries–Matusita distance. The values of Jeffries–Matusita distance range from 0 to 2.0 and indicate how well the selected pairs are statistically separate. The values greater than 1.9 indicate that the pairs have good separability (Amarsaikhan *et al.* 2010). After the investigation, the samples that demonstrated the greatest separability were chosen to form the final signatures. The final signatures included about 368–474 pixels.

a) b) c) d)

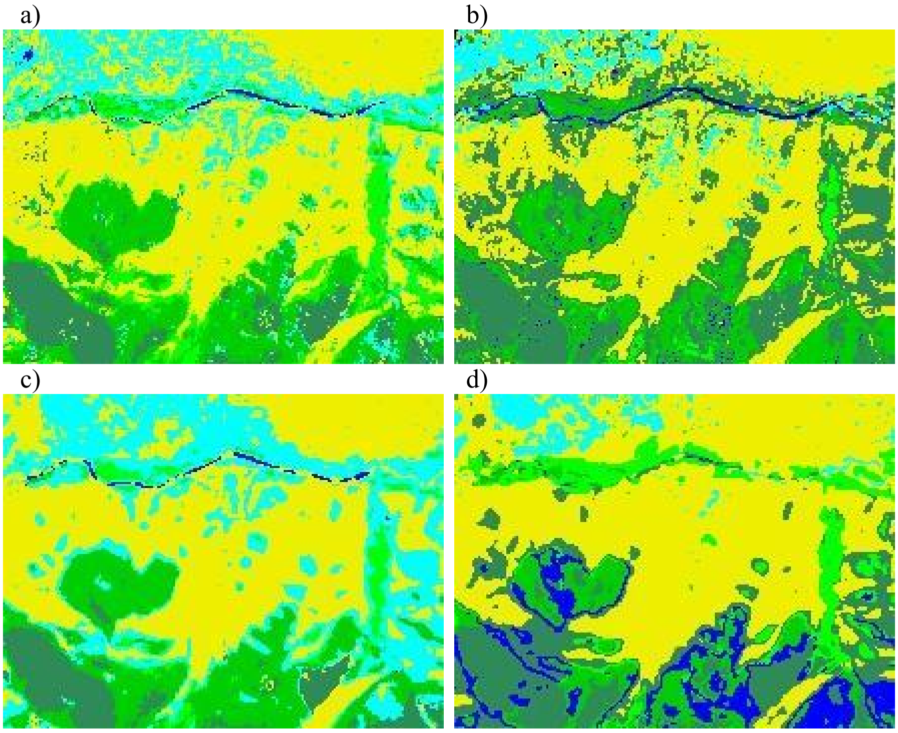

Figure 3: Comparison of the classification results (cyan-urban, yellow-soil, light green-grass, green-deciduous forest, dark green-coniferous forest, blue-water). Classified images using maximum likelihood classification and spectral angle mapper (a,b) bands defined by spectral knowledge, (c,d) PC bands

For the actual classification, a maximum likelihood classification and spectral angle mapper methods have been used. The maximum likelihood classification is the most widely used statistical classification technique, because a pixel classified by this method has the maximum probability of correct assignment. The spectral angle mapper is one of the most widely used hyperspectral classification techniques and it uses an *n*-dimensional angle to match pixels to reference spectra. The method determines the spectral similarity between two spectra by calculating the angle between the spectra, treating them as vectors in a space with dimensionality equal to the number of bands (Amarsaikhan *et al.* 2011). The final classified images are shown in figure 3. As could be seen from figure 3, the classification results of the PC image give the worst results, because there are high overlaps among classes: built-up area, soil and other classes. However, these overlaps decrease on other images classified using the bands defined by the spectral knowledge. Comparing 2 classification results obtained by the use of the spectral knowledge (figure 3a,b), one can see that, the performance of the maximum likelihood classification was better than the other method.

For the accuracy assessment of the classification results, the overall performance has been used. This approach creates a confusion matrix in which reference pixels are compared with the classified pixels and as a result an accuracy report is generated indicating the percentages of the overall accuracy (Amarsaikhan *et al.* 2011). As ground truth information, different AOIs containing 2,268 purest pixels have been selected. AOIs were selected on a principle that more pixels to be selected for the evaluation of the larger classes such as built-up area and open area than the smaller classes such as central squire and snow-ice. The overall classification accuracies for the selected classes were 89.85% and 85.43%, for the results of the spectral knowledge using maximum likelihood classification and spectral angle mapper, and 79,62% and 70.16% for the results of the PC bands using maximum likelihood classification and spectral angle mapper.

5. CONCLUSIONS

The overall idea of the research was to test and compare two different approaches for feature extraction in a hyperspectral image classification. For this aim, initially, the hyperspectral HYPERION image was analyzed in terms of radiometric quality and the water absorption bands and some other bands with zero values were excluded. For the actual feature extraction, principal components analysis and spectral knowledge were used and for each case, 3 spectrally separable bands were defined. Then, these outputs were classified using a maximum likelihood classification and spectral angle mapper methods. As could be seen from the results of the classifications, the maximum likelihood classification in combination with the spectral knowledge method produced a superior result in comparison with other methods. Also, thorough analysis of the HYPERION image indicated that hyperspectral images could be used for an improved land cover mapping and differentiation of the classes having similar spectral characteristics.

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