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ScienceDirect

Advances in Space Research 53 (2014) 1720–1734

Advances in Space Research
(a COSPAR publication)

www.elsevier.com/locate/asr

Assessment of the impact of dimensionality reduction methods on information classes and classifiers for hyperspectral image classification by multiple classifier system

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Available online 25 November 2013

Abstract

Identification of the appropriate combination of classifier and dimensionality reduction method has been a recurring task for various hyperspectral image classification scenarios. Image classification by multiple classifier system has been evolving as a promising method for enhancing accuracy and reliability of image classification. Because of the diversity in generalization capabilities of various dimensionality reduction methods, the classifier optimal to the problem and hence the accuracy of image classification varies considerably. The impact of including multiple dimensionality reduction methods in the MCS architecture for the supervised classification of a hyperspectral image for land cover classification has been assessed in this study. Multi-source airborne hyperspectral images acquired over five different sites covering a range of land cover categories have been classified by a multiple classifier system and compared against the classification results obtained from support vector machines (SVM). The MCS offers acceptable classification results across the images or sites when there are multiple dimensionality reduction methods in addition to different classifiers. Apart from offering acceptable classification results, the MCS indicates about 5% increase in the overall accuracy when compared to the SVM classifier across the hyperspectral images and sites. Results indicate the presence of dimensionality reduction method specific empirical preferences by land cover categories for certain classifiers thereby demanding the design of MCS to support adaptive selection of classifiers and dimensionality reduction methods for hyperspectral image classification.

Keywords: Hyperspectral image; Multiple classifier system; Land cover classification; Remote sensing; Dimensionality reduction; Supervised classification

1. Introduction

Hyperspectral image provides detailed spectral information about objects in hundreds of spectral bands in the electromagnetic spectrum. The information content in a hyperspectral image is highly correlated with neighboring bands and suffers from the curse of dimensionality (Jimenez and Landgrebe, 1998). Dimensionality reduction is a common pre-processing step in the supervised classification of hyperspectral images for various applications such as land cover mapping. Data generalization schema of various dimensionality reduction methods differs by their ability to retain spectral integrity and residual spectral information required for discrimination of materials. Often, critical information needed for class separation in the hyperspectral image is lost as noise by the application of dimensionality reduction methods. Thus, the use of dimensionality reduction methods without knowledge on the types of land covers available in image may lead to poor results. It has been established that there is no single best classifier which can be applied across different images and land cover categories (Giacinto et al., 1997). Identification of the classifier which is optimal to the application and

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http://dx.doi.org/10.1016/j.asr.2013.11.027

data at hand is thus a recurring task in every image classification task. Numerous studies are available in the literature dealing with selection and comparison of classifiers for various applications (Joshi et al., 2006; Lu et al., 2008, 2011; Al-Ahmadi and Hames, 2009; Szuster et al., 2011; Srivastava et al., 2012). Similarly, a number of studies have reported on the selection of dimension reduction methods for various land cover classification scenario (Lu and Weng, 2007; Lu et al., 2007; Chen and Qian, 2008; Clemmensen et al., 2010). For suggesting optimal classifiers and dimensionality reduction methods for land cover classification, however, most of the studies have used a single classifier for comparing the performance of various dimensionality reduction methods or a single dimensionality reduction method for comparing the performance of various classifiers.

Having the theoretical framework to combine the differential performances of various dimensionality reduction methods and classifiers enhances the robustness and reliability of hyperspectral image classification. Multiple classifier system (MCS) provides the conceptual framework to incorporate various input data sources and classifiers in the classification process (Ceamanos et al., 2010; Yang et al., 2010a,b). The apparent one-to-one relationship between classifier and dimensionality reduction method found in multispectral image classification is seldom evident in hyperspectral image classification. Our extensive literature survey reveals the lack of understanding on the suitability of classifiers and dimension reduction methods for hyperspectral image classification by MCS for a range of land cover categories. The objective of this research is to assess the impact of the relationship between information class, classifier, and dimensionality reduction method on the hyperspectral image classification for land cover classification by MCS. The understanding gained from this research is valuable for (a) identification of adaptable classifiers for a given dimensionality reduction method, and (b) identification of the information class dependent sets of classifiers and dimensionality reduction methods for hyperspectral image classification by MCS. Airborne hyperspectral images acquired from four different sensors and five sites are classified by the MCS designed with five dimensionality reduction methods and seven classifiers.

2. Materials and methods

2.1. Hyperspectral images

We used five different sources of airborne hyperspectral images (one image each from HyMAP, ProSpecTIR, HYDICE and two images from ROSIS airborne hyperspectral imaging system) covering several land cover categories and sites. As there are two images acquired by the ROSIS sensor for two different sites, we appended name of the location to the ROSIS image for its readily identification. False color composites of the images are shown in Fig. 1.

HyMAP image: The HyMAP hyperspectral image was acquired over the Dedelow research station of the Leibnitz-Centre for Agricultural Landscape Research (ZALF), Germany (Nidamanuri and Zbell, 2011) on 9 May, 1999. The predominant land use categories in the study site were agricultural crops namely winter barley, winter rape, winter wheat and winter rye, built up, and grass. The image has a spatial resolution of 5 m and 128 spectral bands in the spectral range 0.40–2.48 μm. A subset of the image acquired was used in this study.

ROSIS-University image: The next hyperspectral image used in our experiment was acquired on 8 July, 2002 over the University of Pavia, Italy, by ROSIS airborne hyperspectral sensor in the framework of the HySens Project managed by DLR (German Aerospace Agency) (Fauvel et al., 2009). The image has 103 spectral bands in the spectral range 0.43–0.86 μm with spatial resolution of 1.3 m. This image consists of ten land cover classes namely, trees, asphalt, meadow, gravel, metal sheet, bare soil, bitumen, bricks, shadows and built up.

ProSpecTIR image: The ProSpecTIR airborne hyperspectral image was acquired over the City of Reno, USA on 13 September, 2006. This image consists of 356 spectral bands in the spectral range 0.39–2.45 μm with spatial resolution of 1 m. The dominant land use categories in the image are trees, water, bare soil, asphalt, built up, shadows, and vehicles.

ROSIS-City of Pavia image: ROSIS airborne hyperspectral sensor was acquired on 8 July, 2002 over the City of Pavia, Italy in the framework of the HySens Project managed by DLR (German Aerospace Agency) (Fauvel et al., 2009). The image has 102 spectral bands in the spectral range 0.43–0.86 μm with spatial resolution of 1.3 m. This image consists of ten land cover classes namely, water, trees, asphalt, meadow, self building blocks, tiles, bare soil, bitumen, shadows and built up.

HYDICE image: This airborne hyperspectral image was acquired over a mall in Washington DC by the HYDICE hyperspectral image sensor on 23 August, 1995. A total of 191 bands were collected in the spectral range 0.4–2.4 μm. The spatial resolution of the image is 2 m. This image consists of seven land cover classes namely, water, road, grass, trees, roof, path, and shadow.

The water absorption bands were removed in all the hyperspectral images and the number of bands mentioned above are the total number of bands available after removal of water the absorption bands.

2.2. Selection of dimensionality reduction methods

In order to assess the information class–classifier–dimensionality reduction method relationship in the framework of MCS, we selected five widely used dimensionality reduction methods: principal component analysis (PCA), independent component analysis (ICA) (Wang and Chang, 2006), minimum noise fraction (MNF) (Green et al., 1988),