ICA AND KERNEL ICA FOR CHANGE DETECTION IN MULTISPECTRAL REMOTE SENSING IMAGES

Silvia Marchesi and Lorenzo Bruzzone

Department of Information Engineering and Computer Science, University of Trento,
Via Sommarive, 14 I-38050, Povo, Trento, Italy, Fax: +39-0461-882093
E-mail: lorenzo.bruzzone@ing.unitn.it

Preference: Oral presentation

1. INTRODUCTION

Change detection aims at classifying multitemporal images into two different classes, one related to changed areas and the other to unchanged ones. Usually change-detection algorithms compare two multitemporal images acquired at different times by assuming that they are similar to each other except for the presence of true changes. However, this assumption is seldom completely satisfied due to differences in atmospheric and sunlight conditions of acquired images, as well as in the sensor acquisition geometry (especially with very high geometrical resolution images). In order to overcome these problems, change-detection techniques generally implement pre-processing steps, which include image co-registration, radiometric and geometric corrections, and noise reduction. Depending on the kind of sensors considered for image acquisition and on the related geometrical resolution, these steps can result in different complexity. Nonetheless, in real problems pre-processing is not sufficient to guarantee the ideal condition in which radiometric changes in corresponding pixels on the multitemporal images are associated with true changes on the ground. Usually, residual components of noise (e.g. due to residual radiometric differences, residual misregistration, etc.) result in false alarms in the change-detection maps, which cannot be easily identified in the phase of post-processing.

In this paper, we address the aforementioned problem by exploiting image transformation techniques for separating the different sources of noise from real changes in different components to be selectively exploited in the change-detection phase. In particular, we study from a theoretical and an experimental viewpoint, the effectiveness of Independent Components Analysis (ICA) as a preliminary step to change detection, and investigate the use of the kernelized version of ICA (which is called Kernel Independent Component Analysis (KICA)) for separating the information and noise sources in the change detection process. These techniques are integrated in standard change-detection methods and their performances are analyzed on different data sets deriving general conclusions on their effectiveness in change-detection applications.

2. METHODOLOGY

Let us consider a couple of images acquired over the same geographical area at different times. The present work aims at identifying changes occurred on the ground between the two dates, by separating them from sources of noise. In addition, we investigate the possibility to distinguish in the multitemporal images different kinds of changes. The proposed approach exploits a simple change-detection scheme based on multitemporal images comparison and thresholding, after a preliminary phase based on image transformation. The main idea of the proposed approach is that through the transformation of the images it is possible to identify and separate changes from other sources of information (noise, unchanged areas, etc.). Then, through a simple analysis of the components that contain information on changes, it is possible to extract real changed areas.

A standard transformation approach to isolate changed areas from unchanged areas is that based on the Principal Component Analysis (PCA) technique [1]. The PCA is a linear transformation which uses image data second order statistics to extract orthogonal components ordered according to decreasing variances. The transformation can be based on eigenvector analysis of the correlation or of the co-variance matrix. The transformed components are globally uncorrelated. PCA can be used in change detection either by applying the transformation separately to single date images, or by applying the transformation jointly to the multitemporal images. In many applications, a subset of the resulting transformed components proved to exhibit a more focused representation of the changed areas than the original spectral channels [1]. However, PCA is not suitable for separating information sources from sources of noise that are associated with the complexity of many change-detection problems. A better methodological tool for trying to separate sources of noise form true changes (and potentially to distinguish different kind of changes) is the Independent Component Analysis (ICA), which is intrinsically designed for modeling in different components the information sources present in a complex problem. Nonetheless, marginal attention has been devoted to the use of ICA in change detection, without a proper analysis of its potentialities [2], [3]. The objective of ICA is to extract components with higher-order statistical independence, through a non-linear transformation function. The obtained components are statistically as independent as possible. It is worth noting that the goal of independence is stronger than uncorrelatedness which can be obtained on the global data distribution with the PCA technique. It follows, that ICA can provide more effective decomposition than PCA, especially for non-Gaussian signals.

Kernel ICA is an approach recently introduced in the literature, in which the ICA problem is not solved on the basis of a single nonlinear function, but on an entire reproducing kernel Hilbert space of candidate nonlinear functions [4]. The use of a function space makes it possible to be adapted to a variety of sources and thus makes this algorithm more robust to varying source distributions. However, this is obtained at the cost of a significantly increased computational load.

In both cases (ICA and KICA), two different transformation strategies were investigated: i) all the spectral channels of the two multitemporal images were jointly transformed; and ii) the multispectral difference image (obtained by a simple subtraction of corresponding pixels of the same bands at the two dates) was transformed.

In order to extract changed areas from the components obtained with the ICA and the KICA transformations we applied two different procedures: i) identification of relevant single components and thresholding [5]; and ii) application of the Change Vector Analysis (CVA) technique in the polar domain combining pairs of components [6]. In the first case the difference image was computed and then the threshold was retrieved according to the expectation-maximization algorithms and the Bayes rule for minimum error. In the second case, both the magnitude and the direction components of the difference vectors were evaluated for defining the change-detection map according to a semi-automatic procedure. For space constraints, additional details on the adopted procedures will be reported in the full paper.

3. EXPERIMENTAL RESULTS

In order to assess the reliability of the proposed methods and to understand which transformation technique is the most suitable for change-detection applications, several experiments were carried out on both medium and very high geometrical resolution multispectral and multitemporal images. In the first case, images acquired by the Landsat 5 sensor on the Sardinia Island (Italy) in September 1995 and July 1996 were considered. Concerning very high resolution images, data acquired by the Quickbird sensor on the Trentino area (Italy) in October 2005 and July 2006 were studied.

Results obtained on these data sets confirmed the effectiveness of the presented methodology, and in particular the capabilities of ICA and KICA techniques to properly separating the different sources intrinsic in the change-detection problem. In greater detail, comparing the results obtained by all the investigated techniques with the results yielded by both the standard PCA and the standard CVA technique applied to the original spectral channels, we observed a sharp increase of the overall change-detection accuracy, especially when dealing with very high resolution data. This is mainly due to a considerable reduction of false alarms, depending on the capabilities of the decomposition methods to separate true changes from noise in a correct way. Results yielded through the ICA allowed us to obtain the best tradeoff between complexity and change-detection accuracy, while the PCA obtained the poorest change detection results. Kernel ICA achieved results only slightly better that the ICA, thus leading to the conclusions that the increased computational complexity required from this approach does not seem justified for the considered change-detection problems. For space constraints, greater details on the proposed methodology, the experimental results and the performances of the different transformation methods and change-detection strategies will be reported in the full paper.

4. REFERENCES

[1] T. Fung and E. LeDrew, “Application of principal component analysis to Change detection,” *Photogrammetric Engineering and Remote Sensing*, Vol. 53, No. 12, pp. 1649-1658, Dec. 1987.

[2] J. Zhong and R. Wang, “Multi-temporal remote sensing change detection based on independent component analysis,” *International Journal of Remote Sensing*, Vol. 27, No. 10, pp. 2055-2061, May 2006.

[3] M. Ceccarelli and A. Petrosino, “Unsupervised Change Detection in Multispectral Images based on Independent Component Analysis,” *Proceedings of the 2006 International Workshop on Imagining Systems and Techniques*, pp. 54-59, April 2006.

[4] F.R. Bach and M.I. Jordan, “Kernel independent component analysis,” *The Journal of Machine Learning Research*, Vol. 3, pp. 1-48, March 2003.

[5] L. Bruzzone and D.F.Prieto, “Automatic analysis of the difference image for unsupervised change detection,” *IEEE Transaction on Geoscience and Remote Sensing*, Vol. 38, No. 3, pp. 1171-1182, May 2000.

[6] F. Bovolo and L. Bruzzone, “A theoretical framework for unsupervised change detection based on change vector analysis in polar domain,” *IEEE Transaction on Geoscience and Remote Sensing*, Vol. 45, No. 1, pp. 218-236, 2007.