A probabilistic generative model for unsupervised invariant change detection in remote sensing images

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ABSTRACT

Automatic change detection from images of the same scene acquired at different times is a problem of widespread interest due to a large number of applications in diverse disciplines. Such applications include video surveillance, medical diagnosis treatment or remote sensing.

Usually change detection in remote sensing involves the analysis of two registered, aerial or satellite multispectral images from the same geographical area obtained at two different times. Such an analysis aims at identifying changes that have occurred in the same geographical area between the two times considered.

Two main approaches have been proposed to solve the change detection problem: the supervised approach and the unsupervised approach. The former is based on supervised classification methods, which require a learning set with multitemporal ground truth while the latter perform change detection without relying on any additional information. As the generation of a learning set is usually a difficult and expensive task, the use of unsupervised methods is of great interest in many applications in which a learning set is not available.

In this paper we solve the unsupervised change detection problem between two images by a generative probabilistic model that is based on the image formation process and is invariant to affine changes in pixel intensities. Generative models represent homogeneously all the relevant variables in a domain by a joint probability distribution. In our case the variables of interest are the corresponding intensity values for each pixel in the two images and the pixel classes (‘Change’ or ‘No Change’).

There are several benefits from such theoretical formulation. We can easily compare the change detection problem with other computer vision problems and with other approaches to the change detection problem. Also, since the joint distribution factorizes as the conditional distribution of the images given the classes times the prior distribution of the classes, the first factor forces us to explicitly model the image formation process (including as unknown parameters possible brightness transforms between images or small registration errors) and the second factor forces us to model the spatial coherence of the class assignment for all pixels. Finally, all the unknown parameters in the model and the unknown class values are computed using sound and well known established statistical techniques: The optimal classification is obtained maximizing the conditional distribution of the classes given the pixel values. This is the Maximum a Posteriori (MAP) criterion that can be exactly and efficiently calculated using graph cut techniques. The determination of the parameters of the model is solved

by the Expectation Maximization (EM) algorithm. Note that since any intensity transform between the images is estimated the whole process is invariant to global changes in intensity between the two images.

In order to asses the effectiveness of the proposed techniques for change detection, we have performed a set of experiments using four sets of images of different types (monospectral and multispectral) at different spatial resolutions (from 1 meter per pixel to 28.5 meters per pixel) and taken by different sensors (airborne and satellite). The proposed method is compared with two other commonly used change detection techniques. The experimental results obtained on the four sets of multispectral remote sensing images confirm the validity of the proposed approach.