Change Detection in Optical Aerial Images by a Multi-Layer Conditional Mixed Markov Model

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Abstract

In this paper we propose a probabilistic model for detecting relevant changes in registered aerial image pairs taken with significant time differences. The introduced approach, called the Conditional Mixed Markov model (CXM), is a combination of a mixed Markov model and a conditionally independent random field of signals. The model integrates global intensity statistics with local correlation and contrast features. A global energy optimization process ensures simultaneously optimal local feature selection and smooth, observation-consistent segmentation. Validation is given on real aerial image sets provided by the Hungarian Institute of Geodesy, Cartography and Remote Sensing and Google Earth.

Index Terms

Change detection, aerial images, mixed Markov models

DOCUMENT AVAILABILITY

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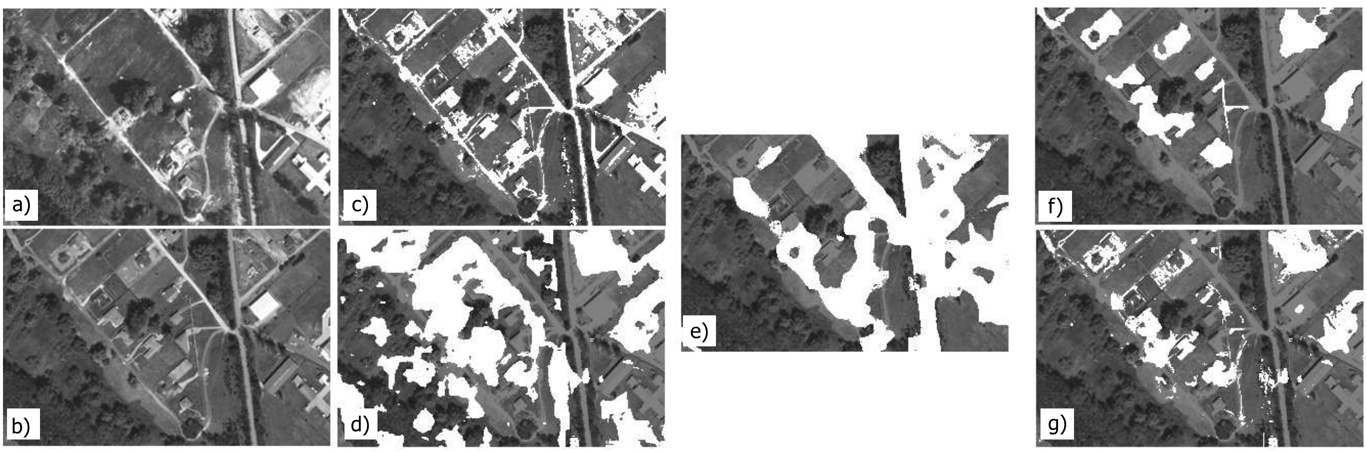


Fig. 1. Feature selection: a) image 1 (G_1), b) image 2 (G_2), c) intensity based change detection ($\phi_g(.)$, changes are marked with white), d) correlation based change detection ($\phi_c(.)$) , e) local variance based segmentation, white if $\phi_\nu(s) = c$, f) ground truth, g) change detection results obtained by per pixel integration of $\phi_g(.)$, $\phi_c(.)$ and $\phi_\nu(.)$ maps

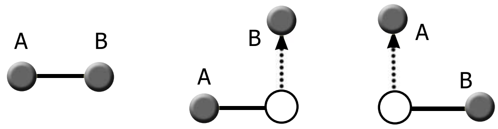


Fig. 2. Three different configurations, where A and B regular nodes may directly interact in mixed Markov models. Empty circles mark address nodes, continuous lines are edges, dotted arrows denote address pointers.

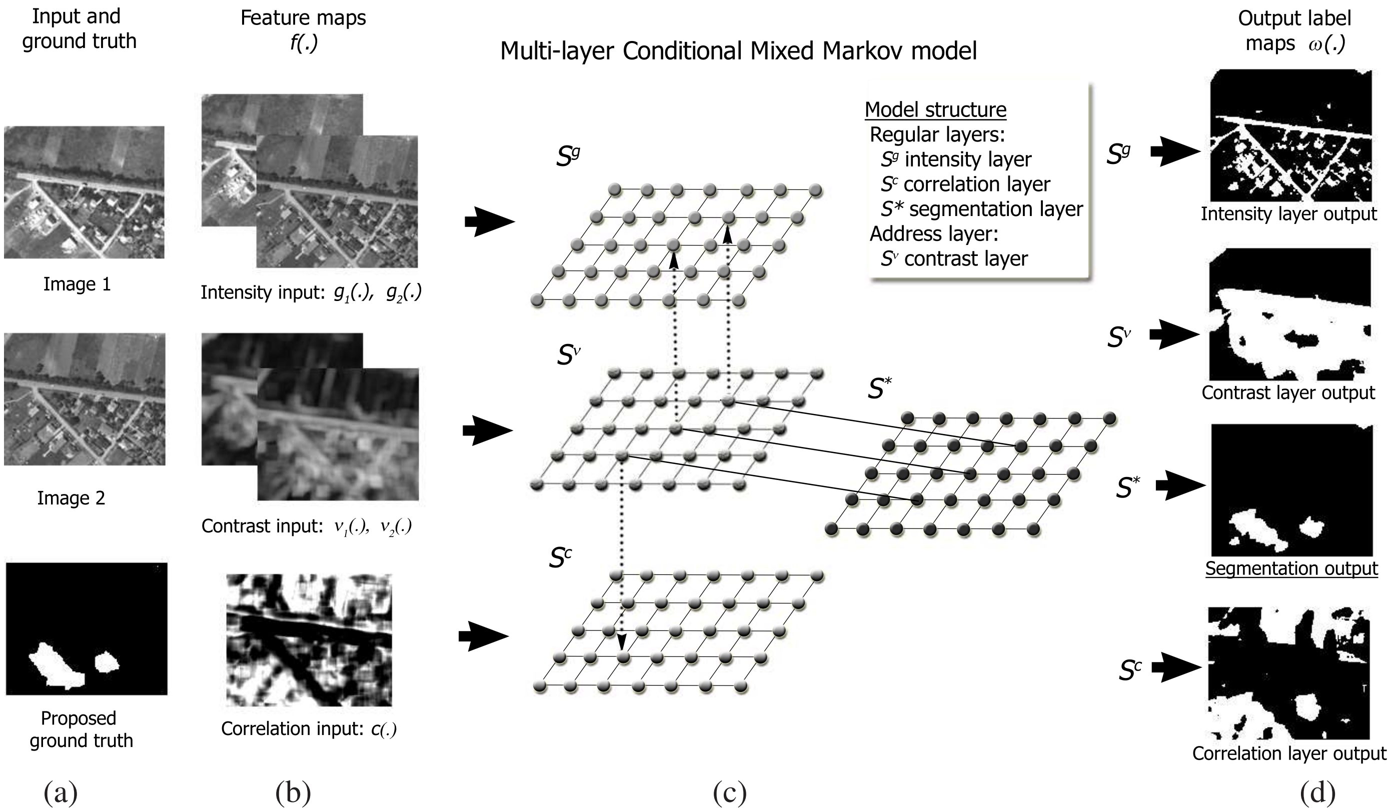


Fig. 3. Structure of the proposed model and overview of the segmentation process. (a) registered input photos and ground truth change mask for validation (b) $\overline{g}(.)$, $\overline{\nu}(.)$ and $c(.)$ feature maps extracted from the input image pair. (c) Structure diagram of the CXM model. (note: the inter-layer connections are only shown regarding three selected pixels) (d) Output label maps of the four layers after MMD optimization. The segmentation result is obtained as the labeling of the S^* layer.

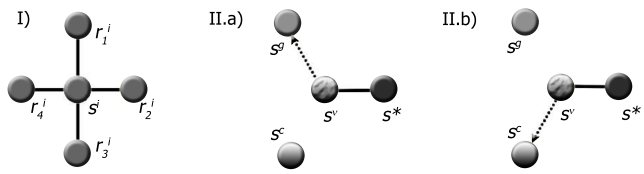


Fig. 4. Demonstration of (I) intra- and (II.a,II.b) inter-layer connections regarding nodes associated to pixel s. Continuous line is an edge of $\mathcal{G}$, dotted arrows denote the two possible a destinations of the address node s^ν. (in I: $i \in \{g, c, \nu, *\}$)

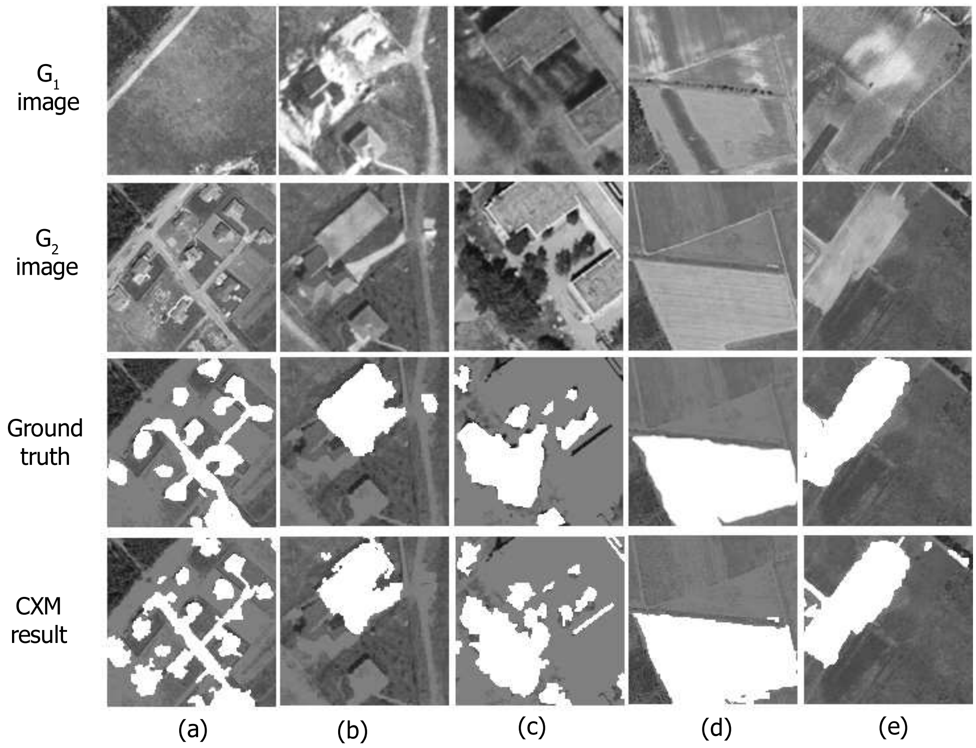


Fig. 5. Change prototypes considered for ground truth generation (a) new built-up regions (b) building operations (c) planting of trees (d) fresh plough-land (e) groundwork before building over

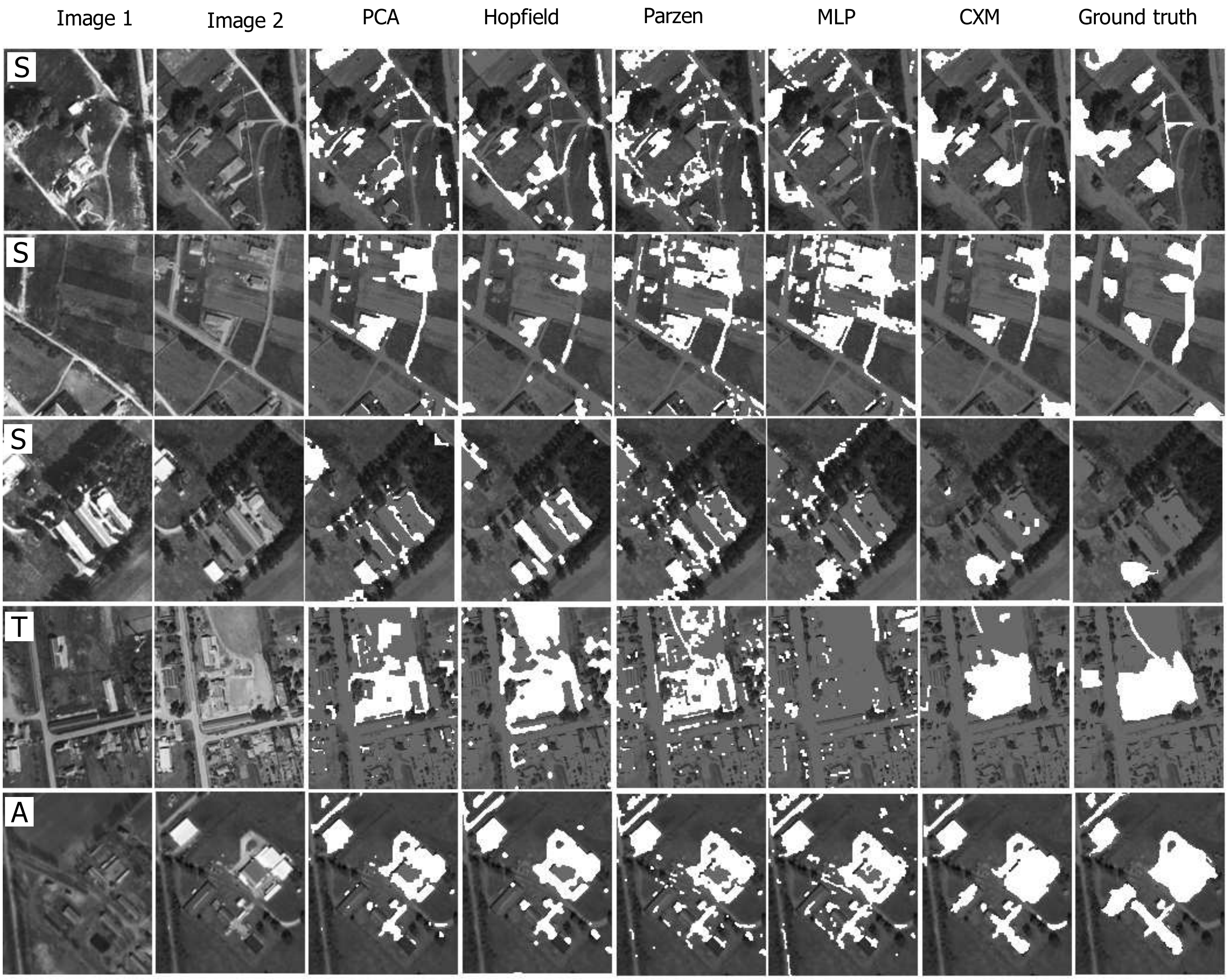


Fig. 6. Qualitative comparison of the change detection results with the different test methods and the proposed CXM model. White regions mark the detected/ground truth changes. Each image part covers a $45\mathrm{m}^2$ sized area (128×156 pixels at 1.5 resolution). Capital letters at the beginning of the rows refer to the corresponding datasets: SZADA (S), TISZADOB (T) and ARCHIVE (A).

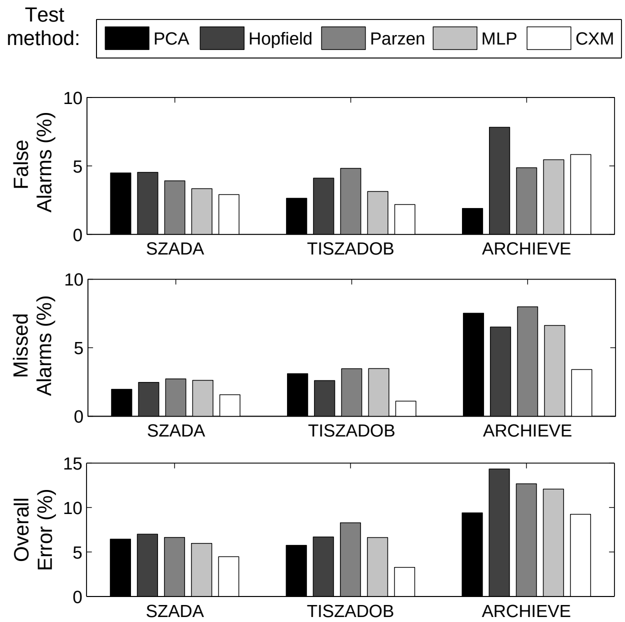
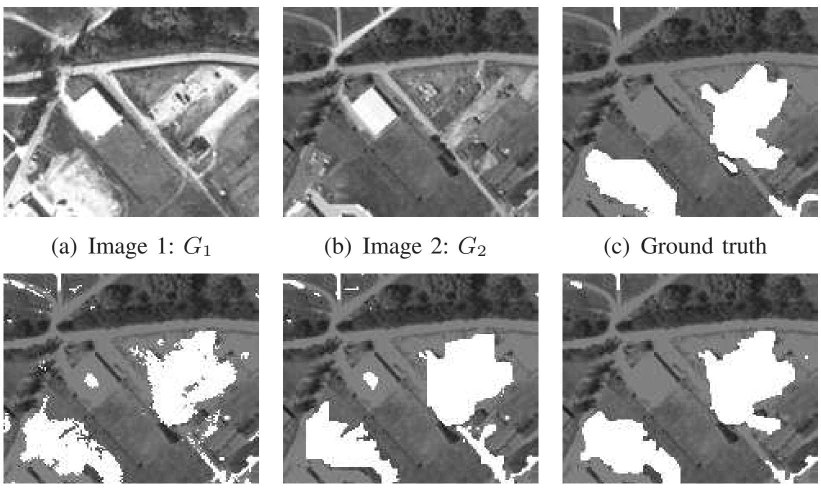


Fig. 7. Quantitative comparison of the different test methods regarding the three test sets: SZADA, TISZADOB and ARCHIVE. False alarm, missed alarm and overall error rates are given in percent of the checked pixels.



(a) Image 1: G_1 (b) Image 2: G_2 (c) Ground truth

(d) Pixel by pixel labeling (e) Ensemble of MRFs (f) Proposed CXM

Fig. 8. Impacts of the multi-layer CXM structure for the quality of the change mask. We compare the results of (d) the pixel by pixel classification without spatial smoothing, (e) the ensemble of three independent, single-layer MRFs and (f) the proposed multi-layer model