A Mixed Markov Model for Change Detection in Aerial Photos with Large Time Differences

DEVA Group

Csaba Benedek[1,2] and Tamás Szirányi[1]
[1]Distributed Events Analysis Research Group, Computer and Automation Research Institute,
H-1111, Budapest, Kende utca 13-17, Hungary, http://web.eee.sztaki.hu/ , e-mail: {bcsaba, sziranyi}@sztaki.hu
[2]Ariana Project-Team INRIA/CNRS/UNSA, B.P. 93, 06902 Sophia Antipolis, France

1. Introduction and Research Goals

- Change detection in optical aerial image pairs
  - new built-up regions, building operations
  - planting of trees, fresh plough-lands
  - groundwork before building-over etc
- Large time differences (many years) → different seasons, illumination conditions, vegetations etc.
- Input - preliminary registered orthophotos:

Image from 2000 (G_1)

Image from 2005 (G_2)

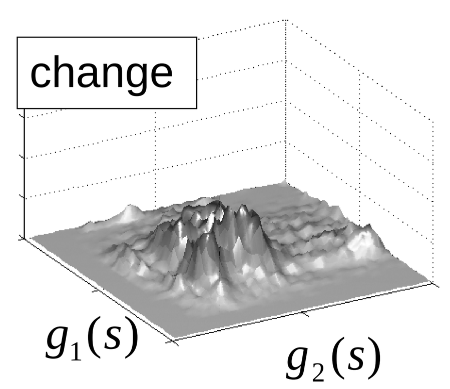
2.Global Statistics of Intensity Co-occurrences

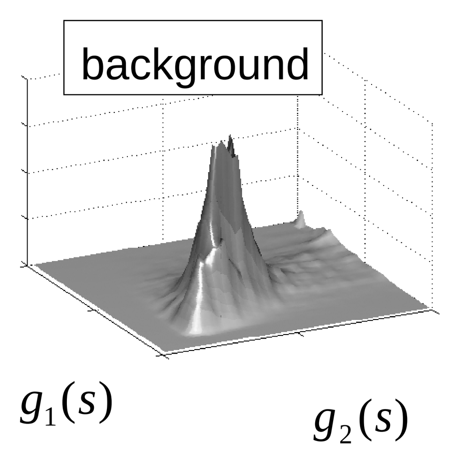
- Feature vector of pixel *s:* pair of intensity values of *s* in the two images: $\bar{g}(s) = [g_1(s), g_2(s)]^T$

$g_1(.)$

$g_2(.)$

Intensity maps





2D histograms of co-occurring gray levels

- Multi-Gaussian Intensity-based (MGI) change detection: 'change' class is modeled by a 2D uniform *pdf*, while 'background' with a mixture of Gaussians in the $\bar{g}(s)$ feature space

$$P(\bar{g}(s)\,|\,ch) \equiv u$$

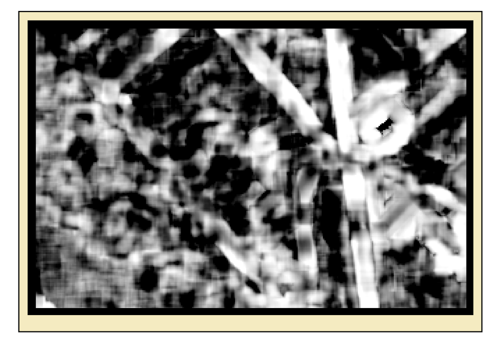
$$P(\bar{g}(s)\,|\,bg) = \sum_{i=1\dots K} \kappa_i \cdot N(\bar{g}(s), \mu_i, \Sigma_i)$$

ML change map

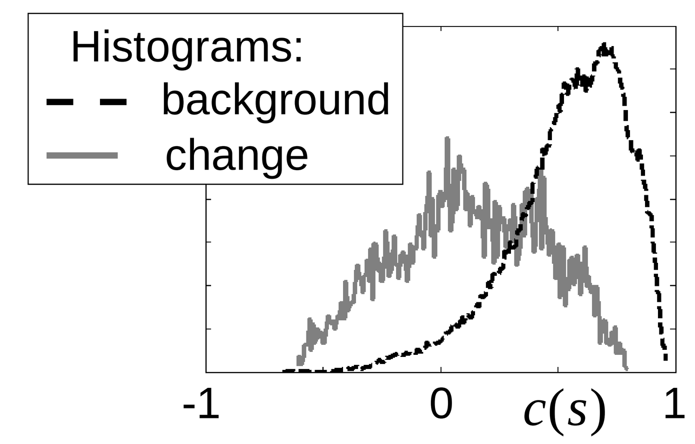
Weak point of MGI: false changes in <u>textured</u> regions

3. Local Block Correlation

- $c(s)$: correlation of the v×v neighborhoods of pixel *s* in G_1 resp. G_2



Correlation map



- 'change' and 'background' classes are modeled by different Gaussian densities in the $c(s)$ feature space.

$$P(c(s)\,|\,ch) = N(c(s), \mu_{ch}, \sigma_{ch})$$

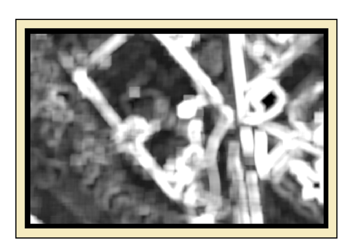
$$P(c(s)\,|\,bg) = N(c(s), \mu_{bg}, \sigma_{bg})$$

ML change map

Weak point of correlation-based classification: false changes in <u>homogenous</u> regions

4. Feature Selection

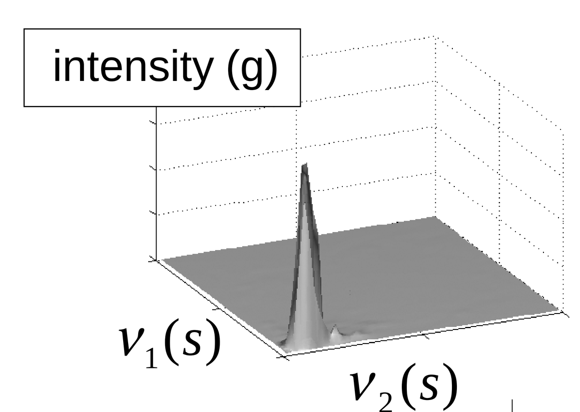
- Evidence: intensity feature should be used in low contrasted, while correlation feature in high contrasted image regions.
  - Indicator feature: local intensity variances $\bar{v}(s) = [v_1(s), v_2(s)]^T$

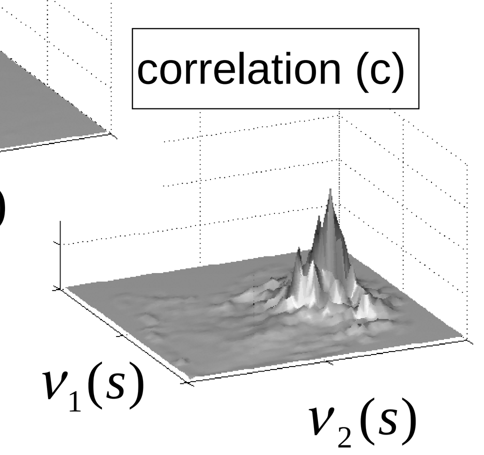


$v_1(.)$

$v_2(.)$

Contrast (variance) maps





Reliability histograms of the intensity respectively correlation features as a function of local contrast

$$P(\bar{v}(s)\,|\,'g') = N(\bar{v}(s), \mu_g, \Sigma_g)$$

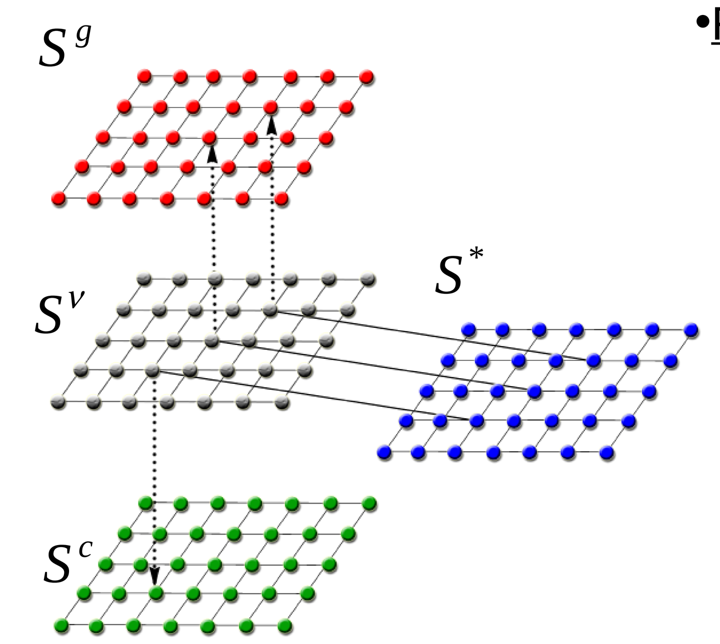
$$P(\bar{v}(s)\,|\,'c') = N(\bar{v}(s), \mu_c, \Sigma_c)$$

ML feature selection

Contrast-based feature selection-map (red regions: correlation feature preferred)

5. Four-Layer Mixed Markovian Segmentation Model

- Robust MRF-like segmentation model for the feature integration schema
- Multi-layer approach to jointly handle the 3 feature-maps and the final change map
- Feature selection requires dynamically changing links in the graph



- <u>Regular layers:</u>
  - S^g, S^c: change masks based on the $\bar{g}(s)$ resp. $c(s)$ features
  - S^*: combined layer – output change mask
- <u>Address layer:</u>
  - S^v: switch layer: providing configurable, data-driven inter-layer connections
- <u>Node labels:</u> $\omega(s^i)$
- <u>Interactions and clique potentials</u>
  - Singletons: data-label consistency
  - Intra-layer cliques V_{C_2}: smooth label maps
  - Inter-layer cliques V_{C_3}: label fusion

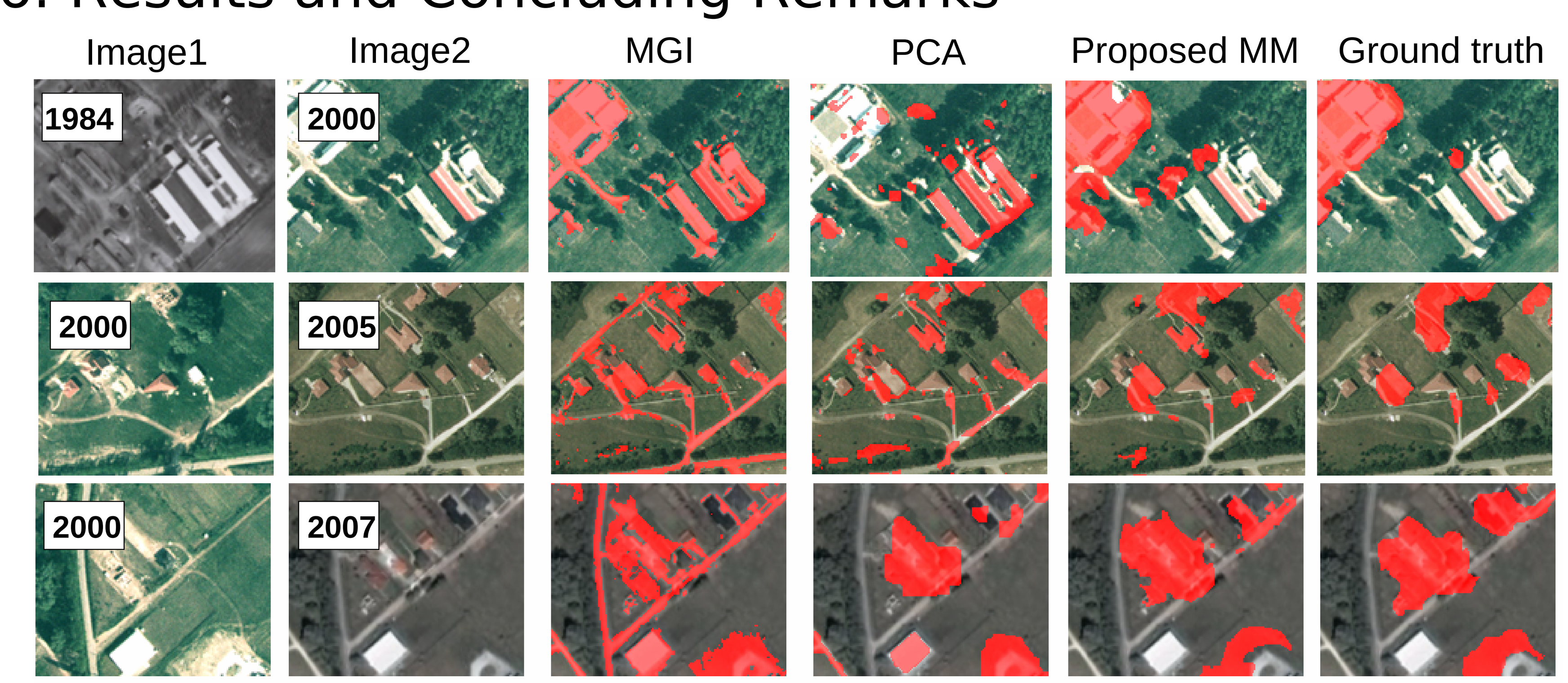
- Output label-map by global energy optimization:

$$\hat{\underline{\omega}} = \arg\min\Big\{ \sum_{s\in S} -\log P\big(\bar{g}(s)\,|\,\omega(s^g)\big) + \sum_{s\in S} -\log P\big(\bar{v}(s)\,|\,\omega(s^v)\big) + \sum_{s\in S} -\log P\big(c(s)\,|\,\omega(s^c)\big) + \sum_{i;\{s,r\}\in C_2} V_{C_2}\big(\omega(s^i), \omega(r^i)\big) + \sum_{s\in S} V_{C_3}\big(\omega(s^*), \tilde{\omega}(s^v)\big) \Big\}$$

Output change mask →

Ground truth changes →

6. Results and Concluding Remarks



- Fast, not object-specific, robust regarding image quality ☺
- Less efficient at high resolution and in the presence of high parallax ☹
- Acknowledgement: MUSCLE Shape Modeling E-Team and Josiane Zerubia (INRIA)