A Novel Video-Based Smoke Detection Method Based on Color Invariants

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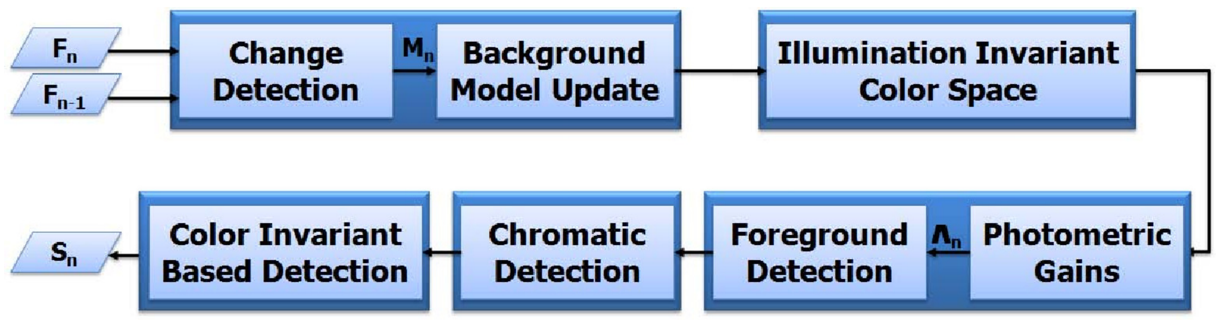
Motivation

- Robust video-based smoke detection in challenging outdoor environments.
- Exploiting photometric invariants to achieve robustness against both local and global illumination changes.
- Resorting to color invariant descriptors as salient smoke features.

Proposed Method



Block diagram of the proposed method.

- A novel color invariant-based smoke detection method, relying on the following steps:
  1. Adaptive estimation of the background model.
  2. Conversion of both current frame and background image towards an illumination invariant color space.
  3. Block-based background subtraction by means of photometric gains.
  4. Filtering non-smoke pixels by exploiting the color characteristics of smoke.
  5. Identification of smoke regions based on two invariant color descriptors.
- Robustness to illumination changes and noise very often encountered in outdoor video-surveillance environments.

References

[1] K. E. A. van de Sande, T. Gevers and C. G. M. Snoek. Evaluating Color Descriptors for Object and Scene Recognition. *IEEE Trans. PAMI, vol. 32, no. 9, pp. 1582-1596, 2010.*

[2] J. V. Weijer and C. Schmid. Coloring Local Feature Extraction. *ECCV, 2006, pp. 334-348.*

[3] P. Dollar, Z. Tu, P. Perona and S. Belongie. Integral Channel Features. *BMVC, 2009, pp. 1-11*

[4] P. Barmpoutis, K. Dimitropoulos and N. Grammalidis. Smoke detection using spatio-temporal analysis, motion modeling and dynamic texture recognition. *EUSIPCO, 2014, pp. 1078-1082.*

Background Estimation

- We adopt an adaptive background model to deal with the local illumination variations:

$$B_{n+1} = \begin{cases} \alpha B_n + (1-\alpha) F_n & \text{if } M_n = 0 \\ B_n & \text{otherwise} \end{cases}$$

- The change detection mask M_n is computed by thresholding the block differences between two RGB consecutive frames.

Invariant Color Space

- In order to discard the influence of global illumination changes, both the frame F_n and its corresponding background B_n are converted towards an invariant color space:

$$\begin{bmatrix} R' \\ G' \\ B' \end{bmatrix} = \begin{bmatrix} \frac{R-\mu_R}{\sigma_R} \\ \frac{G-\mu_G}{\sigma_G} \\ \frac{B-\mu_B}{\sigma_B} \end{bmatrix}$$

- This *transformed* RGB color space ensures invariance to light color changes and shifts according to the diagonal-offset model [1].

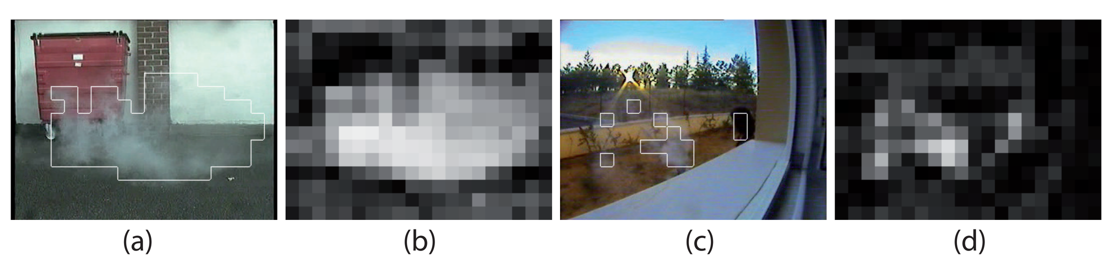
RGB images (a,c) and their invariant color representations (b,d).

Moving Region Detection

- Effective background subtraction computed based on photometric gains Λ_n^c:

$$\Lambda_n^c = 1 - \frac{\min\left(F_n^c, B_n^c\right)}{\max\left(F_n^c, B_n^c\right) \times |F_n - B_n|}, \; c \in \{R', G', B'\}$$

- Blockwise decision to further robustness against noise and local illumination changes.
- Moving regions reliably extracted even in color similarity situations, e.g. smoke regions in front of white background.



Detected moving regions (a,c) based on the photometric gains (b,d).

Chrominance Detection

- Smoke color: black, grayish or white ⇒ smoke colored pixels can be detected by thresholding chroma C, intensity I and saturation S:

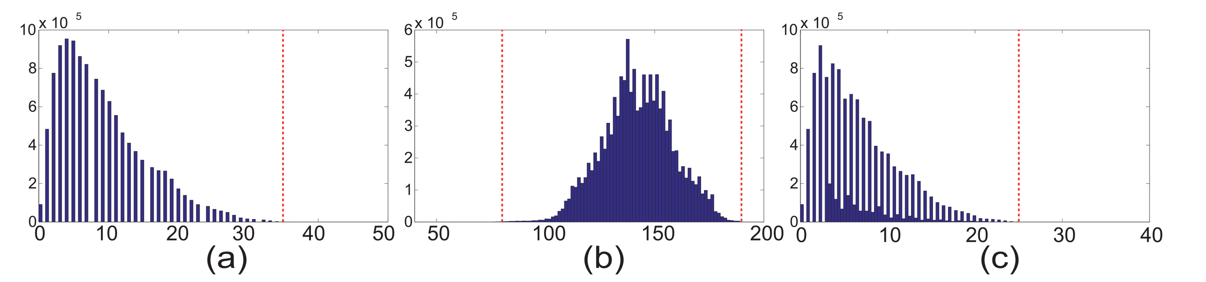
$$C = \max(R', G', B') - \min(R', G', B')$$

$$I = \frac{R' + G' + B'}{3}$$

$$S = \sqrt{\frac{1}{2}(R'-G')^2 + \frac{1}{6}(R'+G'-2B')^2}$$

Rule : $(C < T_1)$ and $(T_2 < I < T_3)$ and $(S < T_4)$

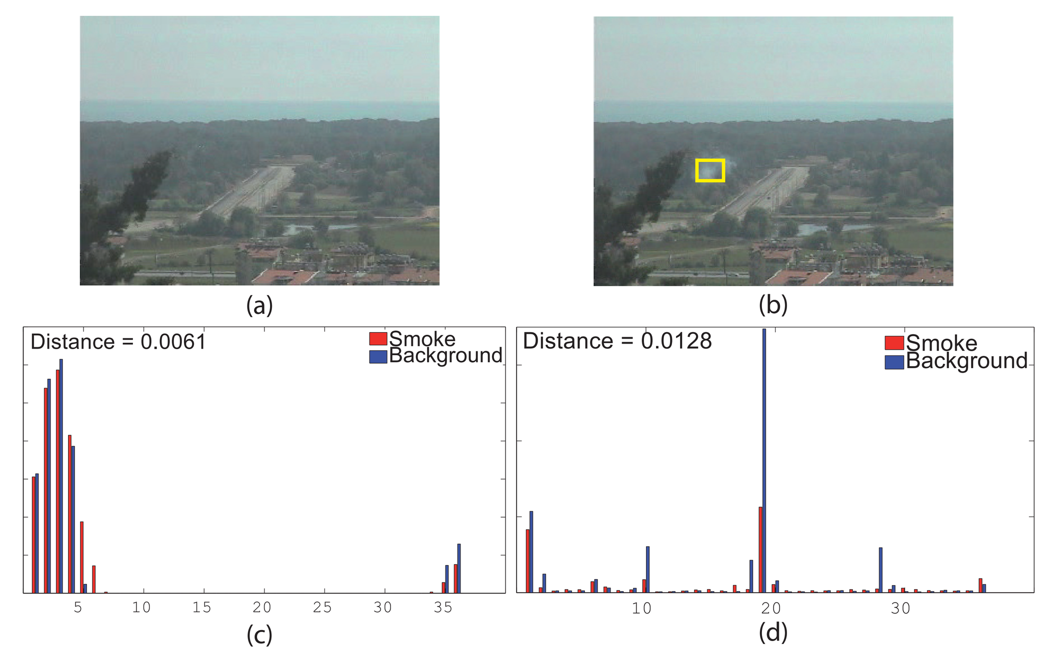
- Thresholds empirically adjusted.



Color characteristics of smoke according to (a) chroma C, (b) intensity I and (c) saturation S.

Invariant Color Descriptors

- Two invariant color descriptors to local illumination changes exploited:
  - Robust hue descriptor $\mathcal{H}^h$ [2], since smoke lowers the saturation S of the background but preserves its hue H.
  - Hue oriented gradient histogram $\mathcal{H}^g$ [3], since smoke decreases the gradient magnitude of the background but maintains its gradient orientation.
- A candidate block classified as smoke if it is similar to the background reference in both chromaticity and texture by means of respectively $\mathcal{H}^h$ and $\mathcal{H}^g$.



Invariant color descriptors $\mathcal{H}^h$ (c) and $\mathcal{H}^g$ (d) of background and smoke regions.

Experimental Results

Experimental results of the proposed method.

- The proposed method outperforms the method [4], with a true positive rate average of 94.55%.
- A true negative rate average of 98.94% due to considerable decrease of false alarms.

Smoke Detection performance in Bilkent videos.

Smoke videos	TNR	TPR	TPR of [4]
sBehindtheFence	100	94.72	94.44
sBtFence2	100	99.08	98.71
sEmptyR1	100	98.08	73.08
sEmptyR2	100	89.55	88.60
sMoky	100	86.23	99.78
sWasteBasket	92.60	99.89	99.29
sWindow	100	94.30	88.52
Average total	**98.94**	**94.55**	**91.77**

Conclusion

- Robust smoke detection to both global and local illumination changes.
- Background subtraction based on photometric gains.
- Smoke discrimination by means of chrominance detection and invariant color descriptors.
- In future works, integration of additional discriminant features such as texture, shape and motion.