Watermark detection for video bookmarking using mobile phone camera

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Outline

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- Watermark Embedding and Detection
- Image Registration Problem
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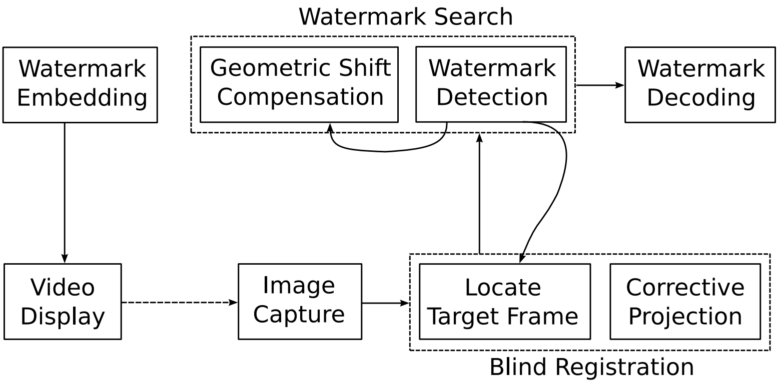
Application Scenario

1. Embed content identifier (32 bit) and time-stamp (24 bit) in individual video frames as invisible watermark
2. Capture image of a video frame using mobile phone camera
3. Detect and decode watermark information
4. Profit!

see also: Related Service Introduction System [5, 6]

Application Overview



Watermark Embedding

Embedding of $B = 56$ bit payload **b** in luminance DWT detail subbands (HL_2, LH_2, HH_2) denoted **x** of individual video frames

- Permute **x** and split into non-overlapping coefficient blocks $\mathbf{x}_i$
- Embed one payload bit $b[i]$ in block $\mathbf{x}_i$ of length S using pseudo-random spreading sequence $w_i[k] \in \{-1, 1\}$

$$x\prime_i[k] = x_i[k] + \alpha \cdot b[i] \cdot w_i[k]$$

- Embedding strength α fixed to obtain 43 dB PSNR

Watermark Detection (1)

Blind detection using Cauchy distribution model of the received DWT detail subband coefficients $\mathbf{y}$ of length L

- Compare detection statistic ρ of Rao-Cauchy [3] detector against threshold T

$$\rho = \frac{8\hat{\gamma}^2}{L}\left[\sum_{k=1}^{L}\frac{y[k]\cdot w[k]}{\hat{\gamma}^2 + y[k]^2}\right]^2 \gtrless_{\mathcal{H}_0}^{\mathcal{H}_1} T$$

- γ is estimate of the Cauchy scale parameter
- $\rho \sim \chi_1^2$ under $\mathcal{H}_0$ and $p \sim \chi_{1,\lambda}^2$ under $\mathcal{H}_1$ [2]
- Set T for desired probability of false-alarm (Neyman-Pearson)

$$P_f = \mathbb{P}\{\rho > T|\mathcal{H}_0\} = \mathrm{Q}_{\chi_1^2}(T) \Longrightarrow T = \left[\mathrm{Q}^{-1}(\frac{P_f}{2})\right]^2$$

Watermark Detection and Decoding (2)

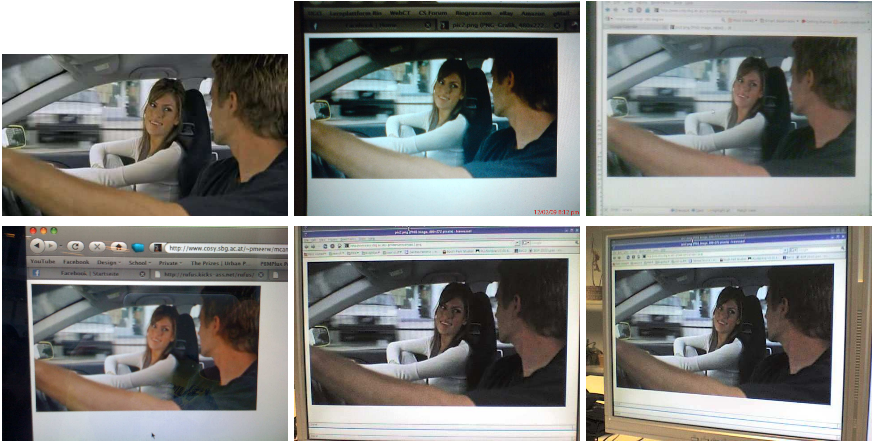
Detector over B blocks with known $\mathbf{w}_i$ but unknown $b[i]$

- Detection statistic ρ_i for received block $\mathbf{y}_i$ does not depend on $b[i]$
- Sum of B χ^2 random variables is again χ^2 with B degrees of freedom, $\sum_{i=1}^{B} \rho_i \sim \chi_B^2$

Bit-by-bit hard decoding

$$b[i] = \text{sgn}\left(\sum_{k=1}^{S} \frac{y_i[k] \cdot w_i[k]}{\hat{\gamma}_i^2 + y_i[k]^2}\right)$$

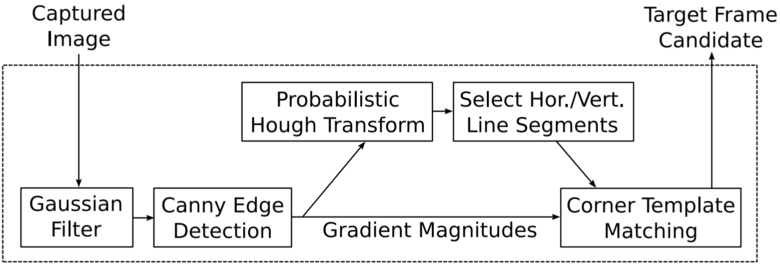
Image Registration Problem



Blind Image Registration (1)

For correlation based detector, the received signal and watermark must be aligned (synchonized), e.g. via

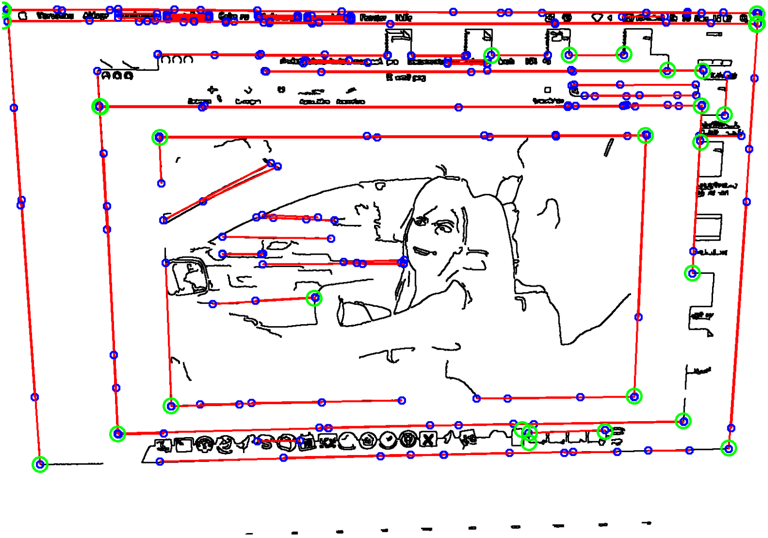
- Template (pilot) watermark [1]
- Auto-correlation function [4]
- This work: Corner detection and corrective projection



Blind Image Registration (2)

- Target frame localization
  - Canny Edge detection
  - Hough transform to detect approximately horizontal and vertical line segments
  - Template matching on gradient magnitude image to validate endpoints of line segments
- Corrective projection using candidate corner points
- Shift compensation
- Watermark detection
- Watermark decoding

Blind Image Registration (3)



Experimental Results

Watermark embedded in two 480 × 272 frames, 43 dB PSNR

56 bit payload in each frame

Detection threshold $T = 144.30$ for $P_f = 10^{-9}$

Phone / Camera Model and Resolution	Frame #1		Frame #2	
	ρ	BER	ρ	BER
Apple iPhone 3GS (1600 × 1200)	349.25	0.00%	901.07	0.00%
Motorola Razr v3 (640 × 480)	202.37	3.57%	204.10	5.36%
Nokia 6300i (1600 × 1200)	710.80	0.00%	1211.41	0.00%
Nokia 6303 (2048 × 1536)	*361.94	*1.79%	*213.96	*5.36%
Nokia E51 (640 × 480)	431.71	0.00%	1524.15	0.00%
Nokia N97 (2592 × 1944)	909.52	0.00%	1972.83	0.00%
Qtek 2020i (640 × 480)	320.28	0.00%	524.51	0.00%
Samsung SGH-X550 (640 × 480)	*204.77	*1.79%	220.37	1.56%
Samsung SGH-F480 (2560 × 1920)	452.11	0.00%	2483.59	0.00%
Sony Ericsson W200 (640 × 480)	482.55	0.00%	505.30	0.00%
Sony Ericsson W302 (1600 × 1200)	*162.27	*5.36%	667.95	0.00%
Sony Ericsson K550i (1632 × 1224)	*312.67	*0.00%	395.61	0.00%
Canon IXUS 70 (3072 × 2304)	586.16	0.00%	972.85	0.00%

Conclusion

- No pilot used for synchronisation, simple blind registration approach
- Cauchy host signal model improves detection performance over linear correlator [4]
- Source code available: `http://www.wavelab.at/sources`
  - Python using PIL, numpy, OpenCV
  - ImageMagick for corrective projection
  - Detection takes ~ 1 sec per image

References

D. Delannay, J.-F. Delaigle, B. M. Macq, and M. Barlaud.
Compensation of geometrical deformations for watermark extraction in the digital cinema applications.
In *Proceedings of SPIE, Security and Watermarking of Multimedia Contents III*, volume 4314, pages 149–157, San Jose, CA, USA, Jan. 2001.

S. Kay.
Fundamentals of Statistical Signal Processing: Detection Theory, volume 2.
Prentice-Hall, 1998.

R. Kwitt, P. Meerwald, and A. Uhl.
A lightweight Rao-Cauchy detector for additive watermarking in the DWT-domain.
In *Proceedings of the ACM Multimedia and Security Workshop (MMSEC '08)*, pages 33–41, Oxford, UK, Sept. 2008. ACM.

M.-J. Lee, K.-S. Kim, Y.-H. Suh, and H.-K. Lee.
Improved watermark detection robust to camcorder capture based on quadrangle estimation.
In *Proceedings of the IEEE Internationel Conference on Image Processing, ICIP '09*, pages 101–104, Cairo, Egypt, Nov. 2009. IEEE.

T. Nakamura, A. Katayama, M. Yamamuro, and N. Sonehara.
Fast watermark detection scheme for camera-equipped cellular phone.
In *Proceedings of the 3rd International Conference on Mobile and ubiquitous Multimedia*, pages 101–108, College Park, MD, USA, Oct. 2004. ACM.

T. Nakamura, S. Yamamoto, R. Kitahara, A. Katayama, T. Yasuno, and N. Sonehara.
A fast, robust watermark detection scheme for videos captured on camera phones.
In *Proceedings of the IEEE International Conference on Multimedia and Expo, ICME '07*, pages 316–319, July 2007.