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メタデータ	言語: 出版者: 琉球大学工学部 公開日: 2008-09-02 キーワード (Ja): キーワード (En): Multimedia protection, Video watermarking, PCA, Color channels 作成者: 仲尾, 善勝 メールアドレス: 所属:
URL	http://hdl.handle.net/20.500.12000/7087

Multi-color channel video watermarking*

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Abstract

Embedding a digital watermark in an electronic document is proving to be a feasible solution for multimedia copyright protection and authentication purposes. In the present paper we propose a new digital video watermarking scheme based on Principal Component Analysis. We detect the video shots based on informational content, and color similarities; we extract the key frames of each shot and each key frame is composed of three color channels, and our proposed algorithm allows us to embed a watermark in the three color channels RGB of an input video file. The preliminary results show a high robustness against most common video attacks, especially frame dropping, cropping and recalling for a good perceptual quality. Keywords: Multimedia protection, Video watermarking, PCA, Color channels.

1. Introduction

A picture is worth a thousand words. And yet, there are many phenomena which are not adequately captured by a single static photo. The obvious alterative to static photography is video. The video becomes an important tool for the entertainment and educational industry. However the entertainment industry is losing billions of dollars every year due to the new information marketplace where the digital data can be duplicated and re-distributed at virtually no cost. One possible solution to this problem is video watermarking. This involves the addition of an imperceptible and statistically undetectable signature to video file content. The embedded watermark should be resistant to common methods of signal processing, and, at the same time, it should not change the quality of the original video file.

Most of the proposed video watermarking schemes are based on the techniques of image watermarking. But video watermarking introduces some issues not present in image watermarking. Among the various video watermarking proposed schemes, Dittmann et al.[2] have embedded in the extracted feature of a video stream, while P.W Chan *et al. [1]* have used the Discrete Wavelet Transform by embedding in frequency coefficients of video frames. On the other hand Hien D Thai *et al [4]* were the first to introduce the PCA domain to gray-scale image watermarking.
In a previous work [5] we embedded the watermark in the three color channels of a color fixed image. In the present paper we tried to take advantage of the texture of video units to extract the key frames of the input video [6][7]; frames can be considered as color images. In this paper we propose to embed an imperceptible watermark separately, into the three different RGB channels of the video frame. We used the PCA transform to embed the watermark in each color channel of each frame. The main advantage of this new approach is that the same or multi-watermark can be embedded into the three color channels of the image in order to increase the robustness of the watermark. Furthermore, using PCA transform allows to choose the suitable significant components into which to embed the watermark.

2. Proposed algorithm

2.1. Video texture

Most of the existing effort has been devoted to the shot-based video analysis. However, in this work we will focus on the frame-based video analysis.
Video: An unstructured data stream, consisting of a sequence of video shots.
Scenes: Semantically related shots are merged in scenes.
Shots: Video units produced by one camera, and the shots boundary detection is made using the key frames. Shot boundary detection is important with respect to the trade-off between the accuracy and the speed in the reconstruction phase.
Frames: It is one complete scanned image from a series of video images; it is a static image.

* Part of the work was presented at the Second International Conference on Innovative Computing, Information and Control, Kumamoto, Japan, September 2007.

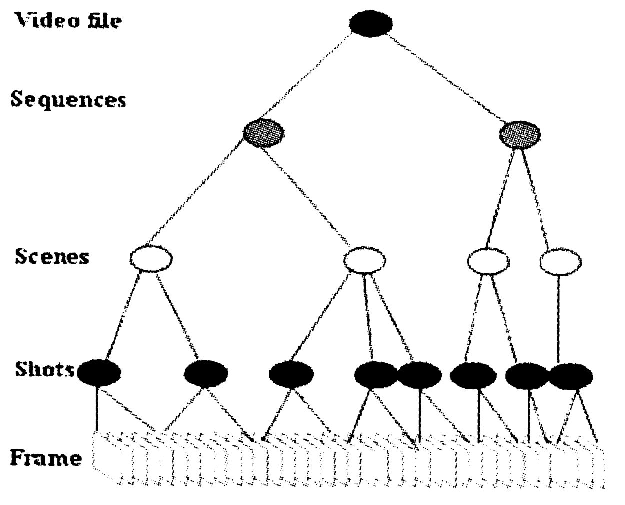

Figure 1. A hierarchical video representation

In the present paper we decompose the video[Fig.1] stream to sequences, then to scenes then to shots and then we extract each frame in each shot, using key frame extraction technique in [8] based on spatio-temporal features of the shots; we embed the watermark in each key-frame for robustness reasons.

2.2. Principal Component Analysis

In digital image processing field, the PCA or also called the KL transform, is considered as a linear transform technique to convey most information about the image to principal components. In the present algorithm, we first separate each frame to three color RGB channels, and we separately apply the PCA transform to each of the sub-frames before we proceed to the proper watermarking process. In fact we need to extract the principal component of sub pixels of each sub-frame by finding the PCA transformation matrix.

Each sub pixel is transformed by the PCA transformation matrix $[\varphi]$. It is then of primary importance to find the transformation matrix $[\varphi]$, going through the following process:

Task 1: For numerical implementation and convenience we divide the frame F to a certain number of sub-frames. We consider each sub-frame an independent vector (vector of pixels). Thus, the frame data vector can be written as:$F = (f_1, f_2, f_3..., f_m))^T$where the vector f_i is the f^{th} sub image, T denotes the transpose matrix, each sub-frame has n^2 pixels, and each vector f_i has n^2 components.

Task 2: Calculate the covariance matrix C_x of sub-frame, eigenvectors, and eigenvalues of the covariance matrix.

$$C_x = E(F - m_i)(F - m_i)^T \quad (1)$$

where $m_i = E(F)$ are the mean vector of each sub-vector f_i , each sub-picture may now be transformed into uncorrelated coefficients by first finding the eigenvectors (basic functions of transformation) and the corresponding eigenvalues of the covariance matrix:

$$C_x\Phi = \lambda_x\Phi \quad (2)$$

The basis function $[\varphi]$ is formed by the eigenvectors $\Phi = (e_1, e_2, e_3...e_{n^2})$. Eigenvalues $\lambda(\lambda_1 \geq \lambda_2 \geq \lambda_3 \geq ..... \geq \lambda_{n^2})$ and eignvector $[\varphi]$ are sorted in descending order. The matrix $[\varphi]$ is an orthogonal matrix called basis function of PCA.

Task 3: Transform sub-frame into PCA component. The PCA transform of sub-frame can be done by the inner product of the sub-frame with the basis functions. The original frame F can be de-correlated by the basis function frame $[\varphi]$, and we obtain Y by the following equation:

$$Y = \Phi^T F = (y_1, y_2, ...y_m)^T$$

The corresponding values are the principal components of each sub-frame. Corresponding to each sub-frame, we can embed the watermark into selected components of sub-frame.

Task 4: To retrieve the watermarked frame, we perform the inverse process using the following formula:

$$F = (\Phi^T)^{-1}Y = \Phi Y \quad (3)$$

2.3. Embedding process

In this work our encoding process consists of the following steps :

First step: An input video is split into audio and video stream [Fig.2] and the video stream is represented by the key-frame [Fig1]. Each frame is considered as a color image separately.

Second step: In order to embed a watermark into a given original color frame of size F(N, N), using the proposed technique, we have to separate the frame F(N, N) to three RGB color channels: Red, Green and Blue. We get, respectively, the three sub-frames:$F_R(N, N)$, $F_G(N, N)$ and $F_B(N, N)$.[Fig 3]

Third step: For each of the three sub-frames we apply PCA transform. Each of the three color-banded frames F_R , F_G and F_B is separately subdivided to a certain number n of sub-frames[Fig.3]. We can get PCA basis function for each of the sub-frames respectively: $[\Phi]_R$, $[\Phi]_G$, and $[\Phi]_B$. The principal components of each of F_R, F_G and F_B are computed by the process discussed above through task 1 to task

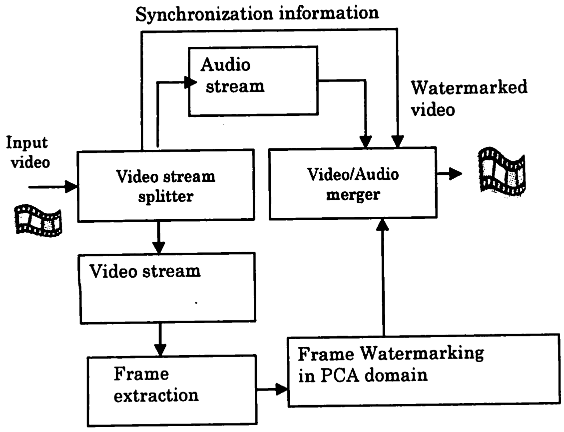

Figure 2. Video watermarking algorithm

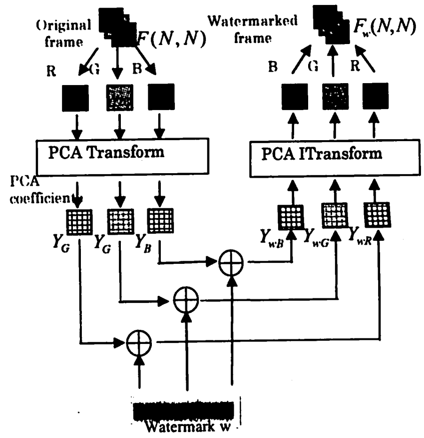

Figure 3. Key Frame watermarking process in PCA domain

3. We then have the three PCA coefficients : Y_R, Y_G, Y_B.
Fourth step: Select the perceptually significant components of each of the three coefficients, into which the watermark will be inserted. In this algorithm, the watermark is a random signal that consists of a pseudo-random sequence of length M, the values of w is a random real number with a normal distribution, $W = w_1, w_2 ... w_M$. We need then to embed the watermark into the predefined components of each PCA sub-block uncorrelated coefficients. The embedded coefficients were modified, for each sub-frame, by the following equation:

$$(y_i)_w = y_i + \alpha \mid y_i \mid w_i \quad (4)$$

where α is a strength parameter. Then we obtain y_{wR}, y_{wG}, y_{wB}.

Fifth step: The three RGB watermarked color channels are separately recovered by the inverse PCA process. (Task 4.)

$$F_w = (\Phi^T)^{-1} Y_w = \Phi Y_w \quad (5)$$

And by superposing the three resulting color channels F_{wR}, F_{wG} and F_{wB} we retrieve the watermarked frame $F_w(N, N)$.
Sixth step: We proceed to video reconstruction, by retrieving first the video shots [7], we reintegrate the watermarked key frames in the order they originally were, and by using the Video/ audio merger tool, we reproduce the watermarked video file.

2.4. Decoding process

For recognition of the authenticity of the embedded watermark, a watermark is detected through the process described in [Fig.4]. The tested video stream is subjected to frames extraction process [Fig.1], and for each frame we applied the correlation based detection. Three extracted watermarks are compared to other 1000 watermarks. Suppose we received an image, and we need to confirm the positive or negative presence of the original watermark in the watermarked image $F^*(N, N)$. For $F^*(N, N)$ we apply step 1 and step 2 (as detailed in the encoding process). In consequence we get the PCA coefficient for each of $F_R^*(N, N)$, $F_G^*(N, N)$, $F_B^*(N, N)$, namely; Y_R^*, Y_G^*, Y_B^*. The correlation formula used, for each sub-frame separately is:

$$(CV) = \frac{WY^*}{M} = \frac{1}{M} \sum_{i=1}^{M} w_i y_i^* \quad (6)$$

3. Computer simulation

For an MPEG video of 15 minutes extract of the movie "rush hour 2", of rate 30 frame/ second, and resolution 640x480, we extract 98 color key frames. We randomly generate an M=65536 length watermark . After extracting all the 98 color frames, we proceed to watermarking process as described in sub-section (2.3) with strength parameter $\alpha = 0.7$, the watermarked frames were uploaded to a video editor (Honestec Video Editor) for reintegration of the key frames, Figure.5 shows an original and watermarked frame number 19 as examples, more results to come in the complete paperversion.

After applying the proposed watermark to the video stream, the obtained watermarked and reconstructed video shows that there is no noticeable difference between the watermarked and the original video, which confirm the invis-

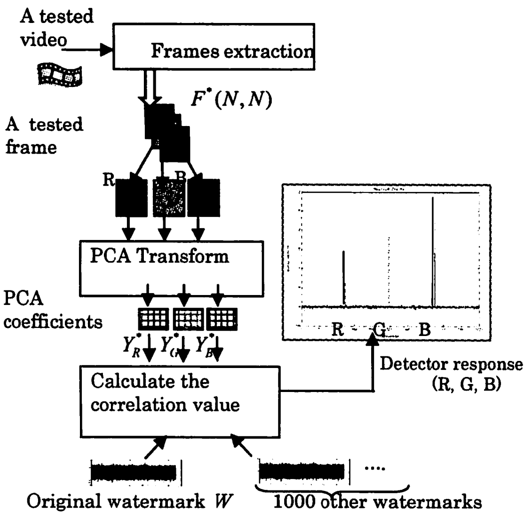

Figure 4. Watermark detection process

Detection rate	$R_w = 0.67, G_w = 0.70, B_w = 0.80$
Frame PSNR(average)	83.2dB

Table 1. Average PSNR and detection rate for watermarked frames

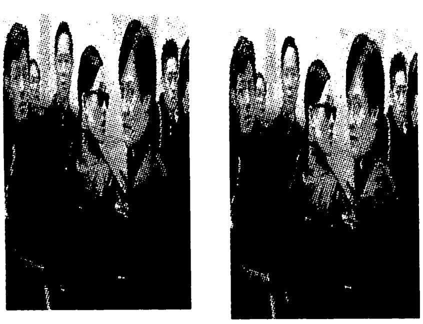

Figure 5. Original(left) and watermarked (right) key frame N^o19

Attack/class	a	b	c	d
PSNR	83.2	72.0	76.0	83.0
Cropping	0.73	0.68	0.66	0.78
Rescaling	0.65	0.63	0.62	0.75
Frame dropping	0.91	-	-	-
Rotation	0.71	0.60	0.61	0.73
Median Filter	0.63	0.54	0.54	0.74

Table 2. Attacks and comparison with previously developed schemes

ibility requirement in our watermarking method. (An average PSNR value is shown in Table 1). In order to test the the robustness of our algorithm, a number of signal processing attacks were applied to the watermarked video stream as described in section 2.4, and the system shows good results for watermark detection. From Table 2 we can see that for cropping, frame dropping and rotation attacks we could easily detect the presence of the three watermarks in the three color layers, and an overall watermark was calculated for comparison. As for both median filtering and rescaling attacks, at least one of the three watermarks was detected which demonstrates the effectiveness of the system. The overall watermark detection after attacks, using StirMark, are shown in Table 2 along with a comparison with the video watermarking schemes previously proposed, where:

(a)The proposed method: Color channels video watermarking based on PCA

(b)DWT- based watermarking scheme[1].

(c)Scene-based watermarking scheme.

(d)Visual-audio hybrid approach.

4. Conclusions

A new digital video watermarking technique is proposed in this paper. The idea of embedding the watermark in the three color channels of each key frame, was checked for robustness by inserting it in each color channel while the PCA based watermarking scheme allowed to select the appropriate PCA coefficients for embedding, and in fact we could demonstrate that it is always possible to watermark a color video file without affecting its perceptual quality.

ACKNOWLEDGMENTS

This research was supported in part by Ministry of Internal Affairs and Communications (Japan) under Grant: SCOPE 072311002, for which the authors are grateful.

References

[1] P.W. Chan and M. R. Lyu, "A DWT-based Digital Video Watermarking Scheme with Error Correcting Code," *Proceedings Fifth International Conference on Information and Communications Security*, pp. 202-213, 2003.

[2] Dittmann and Steinebach, "Joint Watermarking of Audio-Visual Processing," *2001 IEEE Fourth Workshop on Multimedia Signal Processing*, France October 2001.

[3] Jeffrey A.Bloom, Ingemar J. Cox, Copy Protection for DVD Video, *Proceedings of the IEEE*, USA, 1999.

[4] Thai D.Hien, Yen-Wei Chen, and Z.Nakao, A robust digital watermarking technique based on principal component analysis, *International Journal of Computational Intelligence and Applications*, Vol4, No.2, pp138-192, 2004.

[5] Kazuyoshi Miyara, Thai D. Hien, Hanane Harrak, Zensho Nakao, and Yasunori Nagata, Multichannel color image watermarking using PCA eigenimages, *Advances in Soft computing*, Springer, vol. 5, pp. 287-296, 2006.

[6] Arno Sch dl, Richard Szeliski, David H. Salesin, and Irfan Essa, Video textures, *Proceedings of SIGGRAPH 2000*, pp. 489-498, 2000.

[7] Yong Rui, T. Huang and S. Mehrota, Exploring Video structure beyond the shots, Proceedings of IEEE International Conference on Multimedia Computing and Systems, USA, 1998.

[8] J.Bruno, E. Bruno and T. Pun, *Information-theoritic temporal segmentation of video and applications: Multiscale keyframe selection and shot boundaries detection*, Kluwer Academic Publishers, Neitherland, 2005.