Robust Watermarking for Compressed Video Using Fingerprints and Its Applications

Sooyeun Jung, Dongeun Lee, Seongwon Lee, and Joonki Paik*

Abstract: This paper presents a user identification method at H.264 streaming using watermarking with fingerprints. The watermark can efficiently reduce the potential danger of forgery or alteration. Especially a biometric watermark has convenient, economical advantages. The fingerprint watermark can also improve reliability of verification using automated fingerprint identification systems. These algorithms, however, are not robust against common video compression. To overcome this problem, we analyze H.264 compression pattern and extract watermark after restoring damaged watermark using various filters. The proposed algorithm consists of enhancement of a fingerprint image, watermark insertion using discrete wavelet transform and extraction after restoring. The proposed algorithm can achieve robust watermark extraction against H.264 compressed videos.

Keywords: Fingerprint, IIR filter, watermarking, wavelet.

1. INTRODUCTION

The widespread distribution of multimedia contents over communication networks draws increasing attention on the property-right issue of digital production because the reproduced digital contents can be unlimitedly distributed without quality difference from the original version [1]. Such illegal duplications result in serious monetary damage to content providers. Thus there is an urgent need for copyright protection techniques to secure owner's right. To prevent the piracy of valuable digital data, data access control techniques based on encryption and fire-wall have been developed [2]. With such techniques the unauthorized plays of the encrypted contents only show unrecognizably scrambled data. After decryption, however, the data are no longer protected. Watermarking, which directly embeds owner identification into the digital contents, plays a representative role in content protection and securing owner's right.

Since the embedded watermark remains in the contents after the decryption of received data it should be reliable, invisible, unambiguous and difficult to be removed without significantly degrading the perceived quality of video. The embedded watermark should also survive both intentional and unintentional attacks such as image filtering. In particular, digital video is distributed in the compressed format such as MPEG or H.264. Therefore an embedded watermark must be robust to video coding processes [3].

In order to meet the demand of personalized watermarking, biometric security systems have been studied [4]. The biometric security system utilizes biometric characteristics such as face, voiceprint, and iris, to name a few. Among them, a fingerprint image has been proved to be the most reliable feature for personal authentication [5]. It can be automatically identified in the fingerprint identification system instead of the human eyes to verify. The fingerprint watermarking technique also has the advantages of the uniqueness, immutability, and portability. A few recently published papers have discussed fingerprint-based watermarking systems [6]. Hsieh's authentication method use human fingerprint images as watermarks. The scheme includes the feature extraction of the fingerprint image and the generation of the share image used to retrieve the fingerprint image. The previous work has dealt with fingerprint watermarking using wavelet transform [7]. However, these algorithms are suitable for only static images such as medical images, satellite images and can barely reflect compression effects on the watermark.

In this paper, we present a novel fingerprint watermarking technique for the H.264 video coding

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system using two-dimensional (2D) wavelet-based watermarking. To improve the robustness of biometric based watermarking we analyze the noise pattern mode by H.264 compression and its effects on the watermarking. We then find a suitable filter to remove the noise. The proposed algorithm enhances fingerprint image for the compression process, and then inserts it as a watermark in the wavelet domain. After removing noise, we finally extract watermark. Experimental results show that the proposed algorithm can effectively reconstruct watermark from the highly compressed video contents.

This paper is organized as follows. Section 2 presents fingerprint image enhancement. Section 3 describes a series of steps for the proposed watermark insertion, and Section 4 explains extraction schemes in detail. The experimental results and conclusions are respectively provided in Sections 5 and 6.

2. BACKGROUND INFORMATION

The proposed work uses a fingerprint image as a watermark. In the late 19th century, immutability and individuality of a fingerprint was found by F. Galton, and at sunrise of the 20th century modern fingerprint classification was established by E. R. Henry. Although fingerprint verification is mostly associated with criminal identification, it has now become more popular in civilian applications such as access control, financial security, verification of firearm purchasers and driver license applicants.

A human fingerprint is made of the patterns that convey individual characteristics that are known as minutiae. Minutiae are the points of interest in a fingerprint, such as bifurcations (a ridge splitting into two) and ridge endings. The overall pattern of ridges and minutiae points determined the uniqueness of each people's fingerprint.

Fingerprint recognition techniques include fingerprint acquisition, enhancement, and classification. Previous works on fingerprint enhancement mainly focused on feature extraction for automated fingerprint identification systems (AFIS) [8]. On the other hand we enhance the fingerprint image to make it more robust to the video compression process. Noise filtering in the fingerprint image, smoothing, binarization, thinning, and normalization techniques have been proposed for fingerprint image processing in [9]. Gabor filter, directional filter bank, and directional Fourier filtering are also proposed to improve directional features [10].

3. WATERMARK EMBEDDING ALGORITHM

The proposed algorithm inserts fingerprint watermark into every intra (I) prediction frame in the given order of the GOP. As a fixed image watermark to each frame in the video exhibits the problem of maintaining statistical and perceptual invisibility, scene change-based insertion scheme is proposed. As applying a fixed image watermark to every I picture, the propose algorithm is robust to frame cutting, and statistical analysis. Since the embedded picture-selection algorithm is controlled by a user, the attacker does not know the actual location of watermarked picture.

The proposed wavelet-domain watermark insertion algorithm is performed in the LL2 band of a two-level DWT. Although the low frequency band is strong against various attacks, strong watermarks at the LL2 band can be visible. In the proposed algorithm, however, it will not cause much change in the video fidelity because the watermark is carefully embedded at the LSBs. Fig. 1 shows the block diagram of the watermark insertion process in the proposed algorithm.

In order to make the fingerprint watermark robust to video compression, we first enhance the fingerprint image. A series of Gaussian filtering, contrast enhancement, binarization, and thinning processes in the proposed watermarking scheme are conducted as shown in Fig. 2.

Smoothing by a Gaussian filter is the first step of the enhancement process, and contrast enhancement and thinning follows. After binarization a 2-bit fingerprint watermark image of size 72x88 is obtained. We then decompose the Y (352×288×8bits) signal into 2-levels DWT using Daubechies D4 wavelet filters. The proposed schemes use only Y signal because most of the embedded information is mainly concentrated in the luminance channel. As a result, six sub-bands of high frequency (LHi, HLi, HHi, i=1~2) and one low-frequency sub-band (LL2) are generated. The watermark embedding process is then performed as

$$I^{(r,s)*}(x,y) = \begin{cases} I^{(r,s)}(x,y) = I^{(r,s)\prime}(x,y) \\ \qquad + LSB(I^{(r,s)}(x,y)), \\ I^{(r,s)}(x,y) = I^{(r,s)\prime}(x,y) \\ \qquad + \alpha \cdot W(x,y), \ \ \textit{If Intra frame} \\ I^{(r,s)}(x,y) = I^{(r,s)\prime}(x,y), \ \textit{otherwise} \end{cases} \tag{1}$$

where $I^{(r,s)}(x,y)$ represents the coefficient value of the decomposition at level r, orientation s, and position (x, y) within the subband coefficients. W is a binary watermark image and α is additive embedding

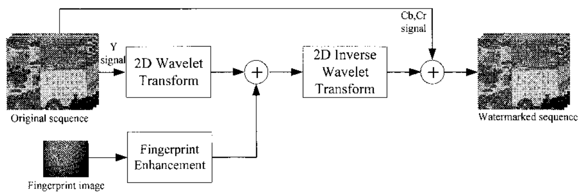


Fig. 1. The block diagram of the proposed watermark embedding procedure.

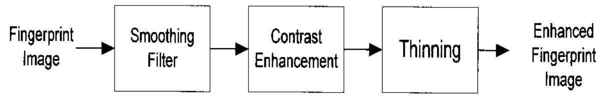


Fig. 2. The block diagram of the proposed watermark enhancement procedure.

strength which is adaptively determined for the host image. We use $\alpha = 2^3$ for the experiment.

If the type of the picture is the intra (I) frame, the least significant four bits of the LL2 band coefficients are replaced by the enhanced binary fingerprint image. Finally, we obtain the watermarked video by performing the inverse DWT.

4. WATERMARK EXTRACTION ALGORITHM

The proposed watermark detection algorithm is the inverse process of the watermark embedding procedure. Fig. 3 shows the proposed watermark extraction and the reconstruction algorithm with noise removing filter procedures.

Given the decoded watermarked video, we first apply the two-level DWT. The embedded watermark value is obtained from four LSBs of the LL2 band coefficients. To improve filtering performance we analyze noise pattern by H.264 and rearrange output values. Noise due to quantization error in the extracted watermark can be removed by the following filtering step. Then binarization is conducted.

4.1. Noise analysis

The watermark could be damaged by lossy video compression. In the case of the watermark being corrupted by additive noise, the n-th sample of the extracted watermark x[n] is modeled as $x[n] = s[n] + d[n]$, where s[n] and d[n] denote the n-th samples of the watermark and the noise, respectively. On the assumption that the noise is white Gaussian, if multiple measurements of the same set of watermark samples are available a reasonably good estimate of the uncorrupted watermark vector can be found by evaluating the ensemble average. Embedded watermark is binary bit (1, 0) and scale factor is equal to 2^3. And extracted watermark is values between 0 and 15 from four LSBs. As a result, error could be a data between -8 and 15. We analyze error distribution, average error tendency, and the correlation between

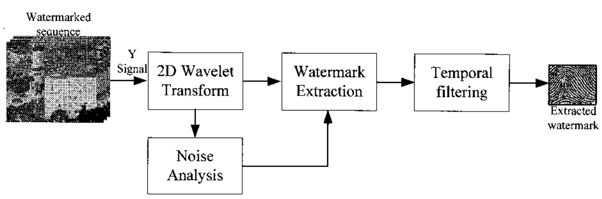


Fig. 3. The block diagram of the proposed watermark extraction procedure.

Table 1. The average error analysis under QP24 compression.

Input watermark	0, 8
Output watermark	0~15 (possible value from 4bit)
Error range	-8 ~ 15
Average error (in case of input value of 8)	-1
Average error (in case of input value of 0)	7

Table 2. The correlation between the upper bits value (A, B) and errors (C). A and B are 5th and 6th bit plane of LL2 coefficient of original video respectively. C is 4th bit plane of LL2 coefficient of QP 24 compressed video. (input watermark is all 0).

	OR (A||B)	NOR (!(A||B)	XOR ((!A) || B) && (A || (!B))	XNOR (!((!A) || B) && (A || (!B)))
C	0.45	0.54	0.5	0.49

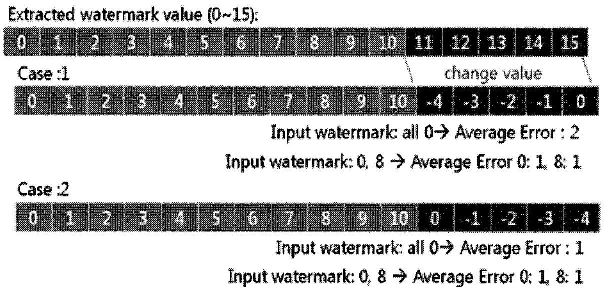


Fig. 4. The range of output value controlled to decrease average of error.

the upper bits value and errors as shown Tables 1 and 2. Table 1 shows that average error does not converge to 0 in case of zero input. Table 2 represents existing correlation between original upper bits and neighboring error bits of watermark when input watermark is all zero. The correlation between original 5th bit and extracted 4th watermark bit is 0.57.

To reduce average error, we shift the output values above 10 so that it receives the effect of high position bit at four LSBs to below zero as sketched in Fig. 4. So it reduced an average error consequently below 2 under the same condition with Table 1.

4.2. Temporal filtering

The tradeoff between an infinite-impulse response (IIR) filter and a finite-impulse response (FIR) one is that the former requires much lower orders for a given desired specification [11]. This means that IIR filters require much fewer multipliers and adders for digital implementation and are very efficient because the

Table 3. The filter coefficients.

	Butterworth	
	a	b
1	1.0	0.059795780370020/1000.0
2	-3.984543119612337	0.298978901850100/1000.0
3	6.434867090275871	0.597957803700200/1000.0
4	-5.253615170352271	0.597957803700200/1000.0
5	2.165132909724134	0.298978901850100/1000.0
6	-0.359928245063556	0.059795780370020/1000.0
	Chebyshev	
	a	b
1	1.0	0.030096060246065/1000.0
2	-4.339893617026483	0.150480301230327/1000.0
3	7.666032896567668	0.300960602460654/1000.0
4	-6.878835360045532	0.300960602460654/1000.0
5	3.132212054251763	0.150480301230327/1000.0
6	-0.578552899819542	0.030096060246065/1000.0

output feedback is immediately apparent in the equations defining the output. The commonly used IIR filters are the Chebyshev, Butterworth and Elliptic filters derived from the corresponding digital filters.

The proposed scheme insert watermark at the same position into every fifteen frame. And extracted watermarks have a fixed position. So each pixel of extracted watermark can represent time-based DC. In this case temporal low pass digital filter is effective to remove additive noise. We experiment on filtering performance with increasing order and decreasing cutoff frequency IIR filter. Considering the complexity and performance efficiency we use the same low-pass 5-order IIR Butterworth and Chebyshev filter $H_0(z)$ as in (2).

$$H(x)=\frac{B(z)}{A(z)}=\frac{b(1)+b(2)z^{-1}+\ldots+b(n+1)z^{-n}}{1+a(2)z^{-1}+\ldots+a(n+1)z^{-n}} \cdot (2)$$

Table 3 shows the filter coefficients in length 6(n+1) row vectors. a and b are coefficients in descending powers of z. cutoff frequency is 0.1.

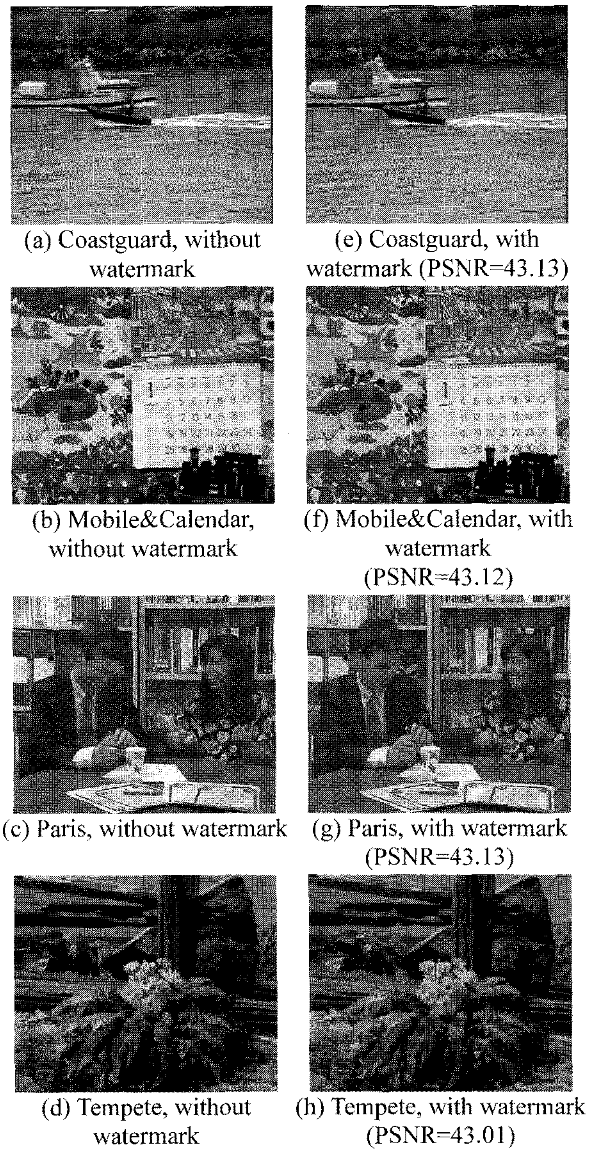
5. EXPERIMENTAL RESULTS

The performance of the proposed algorithm has been tested on various video sequences, including Mobile and Calendar, Paris, Tempete, and Coastguard. Only the luminance component of size 352×288 is used in the experiment. The watermark is an 88×72, binary fingerprint image. We assume that the GOP structure has enough number of I pictures to evaluate filter performance. Daubechies D4 filter coefficients are used for the two-level wavelet decomposition. To evaluate robustness against a lossy compression, we experimented with various bitrates, and perceptual degradation of video quality caused by the embedded watermark is evaluated by both subjective and objective quality measurement. Peak signal-to-noise ratio (PSNR) is used to analyze the objective quality of the watermarked video.

The number of mismatched data between the original and the extracted watermarks is used to represent the integrity of watermarks. In order to measure the integrity, normalized correlation (NC) for valid watermarks, which represents the characteristics of the extracted watermark, is defined as

$$NC=\frac{\sum_{x,y} w_{x,y}w'_{x,y}}{\sum_{x,y} w_{x,y}^{2}}, \qquad (3)$$

where w represents the inserted watermark, w′ the extracted watermark. The obtained NC values are rounded to the fourth decimal place. The NC for



(a) Coastguard, without watermark
(e) Coastguard, with watermark (PSNR=43.13)
(b) Mobile&Calendar, without watermark
(f) Mobile&Calendar, with watermark (PSNR=43.12)
(c) Paris, without watermark
(g) Paris, with watermark (PSNR=43.13)
(d) Tempete, without watermark
(h) Tempete, with watermark (PSNR=43.01)

Fig. 5. Four different pairs of original and watermark embed sequence.

Fig. 6. (a) Original fingerprint image, (b) Enhanced image, (c) Extracted watermark image.

random noise is approximately equal to 0.5, and probability of distinctively extracted image is over 0.7~0.8 NC.

Fig. 5 shows representative frames for the evaluation of subjective quality of four different videos. The PSNR of the attacked images shows objective quality. The subjective and objective quality of watermarked frames shows no degradation with watermark insertion. Fig. 6 shows an example of the embedded watermark image. Fig. 6(a) shows the original image, Fig. 6(b) a enhanced image, Fig. 6(c) a extracted fingerprint image from the watermarked sequence.

Watermarked sequences are tested for H.264 compression under various birates. We evaluate enhancement by spatio-temporal filtering by comparison between the original fingerprint image and the enhanced fingerprint image. Table 4 presents the NC values between the original watermark image and its enhanced version according to H.264 quantization step sizes. Table. 5 shows NC values over various filters.

Table 4. NC of original image and it's enhanced version for different quantization step size.

QP	Coastguard		Mobile&Calendar	
	Original Image	Enhanced Image	Original Image	Enhanced Image
20	0.87	0.9	0.86	0.88
24	0.72	0.74	0.71	0.74
28	0.53	0.56	0.54	0.55
QP	paris		tempete	
	Original Image	Enhanced Image	Original Image	Enhanced Image
20	0.84	0.86	0.86	0.87
24	0.66	0.71	0.69	0.73
28	0.52	0.55	0.52	0.56

Table 5. NC after filtering under QP24 compression.

filter	frame	coast guard	mobile	paris	tem pete
Moving -average	10	0.87	0.85	0.79	0.82
	20	0.86	0.85	0.79	0.82
	30	0.87	0.84	0.78	0.82
Butterworth	10	0.73	0.73	0.70	0.71
	20	0.91	0.89	0.82	0.87
	30	0.91	0.88	0.81	0.85
Chebyshev	10	0.73	0.73	0.70	0.71
	20	0.92	0.89	0.82	0.87
	30	0.90	0.87	0.81	0.84

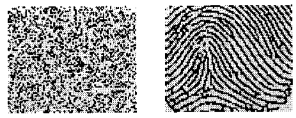


Fig. 7. (a) Extracted watermark under QP24 compression and, (b) it's filtering version using Butterworth.

Table 6. Verifications using VeriFinger Algorithm Demo. "O" and "X" are denoted the success and the failure, respectively.

QP	Coastguard		Mobile&Calendar	
	Without filtering	With filtering	Without filtering	With filtering
20	O	O	O	O
24	X	O	X	O
28	X	O	X	O
QP	paris		Tempete	
	Without filtering	With filtering	Without filtering	With filtering
20	O	O	O	O
24	X	O	X	O
28	X	X	X	O

The NC is 0.73 without filtering. In case the 5-point moving average filtering, we get the 10% improved result. And the cases of the 5th-order butterworth filter of 0.1 cut-off frequency shows similar results with the 5th-order chebyshev filter.

Fig. 7(b) shows an enhanced fingerprint under H.264 compression while a damaged fingerprint is shown in Fig 7(a). Table 6 lists the result of fingerprint identification with and without filtering using VeriFinger Algorithm [12] fingerprint image identification system. Up to QP 24 we use 5-order Buttterworh filter and at QP 28 use Moving average filter because it is easy to extend point needed more at high compression. The result shows that the number of acceptance with the filtering version is higher than that without the filtering.

6. CONCLUSION

In this paper, we present fingerprint watermarking for H.264 streaming using two-level DWT. In the proposed system, we obtain the fingerprint image using a device, enhance the fingerprint watermark through pre-processing and insert the watermark on the low frequency band in the DWT domain. We also demonstrate the potential of use over the H.264 compression using effective noise removal filter. The results of computer simulation on various video sequences (352×288×8bit) show that the proposed technique has the improved performance over 15% of extracting valid watermark by spatio-temporal filtering. On the other hand the embedded watermark results in slightly reduced PSNR. Further research will include a study on correlation-based watermark extraction.

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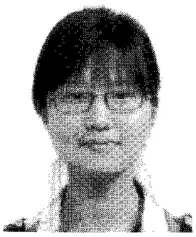

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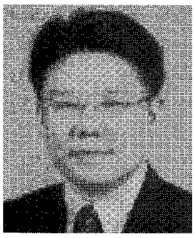

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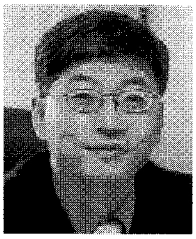

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