Robust Video Watermarking Scheme Based on Temporal Modulation

Sang-Woo Lee, Byung-Gil Lee, Dae-Hee Seo

Information Security Research Division,
Electronics and Telecommunications Research Institute
138 Gajeongno, Yuseong-gu, Daejeon, South Korea
{ttomlee, bglee, dhseo}@etri.re.kr

Abstract. This paper presents a robust video watermarking algorithm which is suitable for consumer devices such as IP TV set-top boxes. A watermark pattern is generated based on an analysis of the histogram of the host video. Then, a watermarked video is generated by temporally modulating the mean chrominance value of each chrominance channel in relation with the watermark pattern, depending on the watermark message that is encoded using error correction codes to improve robustness. Experimental results show that the proposed algorithm is robust against geometrical distortions and signal processing attacks including compression format conversion.

Keywords: Video watermarking, robust watermarking, multimedia security.

1 Introduction

Due to the rapid development of the Internet, a lot of multimedia content has become available through several services such as IP TV. Since digital media is easily reproduced and manipulated, the demand for protecting copyright ownership has increased in IP TV services [1]. In particular, the unauthorized copying and illegal distribution of copyrighted content have greatly increased in the area of digital video.

Digital watermarking refers to the process of embedding secret information, called a watermark, into digital content [2],[3]. The main requirements of digital watermarking include imperceptibility, capacity, and robustness. Imperceptibility means that embedding a watermark should not have noticeable artifacts in the watermarked video. Capacity refers to the amount of information that is embedded by a watermarking algorithm in a host video. The robustness of a watermarking scheme refers to the detectability of watermarked information from watermarked content that has been modified by various attacks such as geometrical distortions and signal processing attacks. It is important to note that these requirements are usually in conflict with one another. Therefore, we should take this trade-off into consideration in designing a watermarking system on targeted applications.

This paper presents a robust video watermarking algorithm based on temporal modulation with an error correction code. This paper is organized as follows. The proposed watermarking algorithm is described in section II, where we explain the embedding procedures of the proposed algorithm in detail. In section III, the experimental results and an analysis are discussed. Finally, we end with a brief conclusion in section IV.

2 Proposed Watermarking Algorithm

The proposed watermark embedding algorithm is composed of three steps: watermarking pattern generation, temporal modulation, and watermark message encoding. To generate the watermark patterns, we measure the mean luminance value of each frame. In our watermarking algorithm, each frame of size $M \times N$ is considered. $R(x, y)$, $G(x, y)$, and $B(x, y)$ indicate three primary color values of the RGB color model. Here, (x, y) denotes the pixel position, where $0 \le x < M$, $0 \le y < N$. The watermark pattern generation is performed as follows:

1. All $R(x, y)$, $G(x, y)$, and $B(x, y)$ are transformed into $Y(x, y)$, $Cb(x, y)$, and $Cr(x, y)$ in the YCbCr color model.
2. Calculate the average values of $Y(x, y)$ such as

$$Y_{mean}(x, y) = \frac{1}{M \times N} \sum_{x=0}^{M-1} \sum_{y=0}^{N-1} Y(x, y) \quad (1)$$

3. The generated watermark pattern $W(x, y)$ is given by

$$W(x, y) = \begin{cases} +\alpha & \text{if } Y(x, y) \ge Y_{mean}(x, y) + (Y_{mean}(x, y) \times \beta) \\ -\alpha & \text{if } Y(x, y) < Y_{mean}(x, y) - (Y_{mean}(x, y) \times \beta) \\ 0 & \text{else.} \end{cases} \quad (2)$$

Here, α is the gain constant. We divide the watermark pattern into two parts based on the mean luminance value. One part of the watermark pattern is marked with positive value, $+\alpha$, and the other part is marked with the negative value, $-\alpha$. β is the parameter used to choose the number of pixels that will be modified in one entire frame. The remaining part of the watermark pattern is set to zero. The watermark information is embedded in each frame of the original video by temporally modulating the mean pixel values. To improve robustness, we encode a watermark message prior to embedding it into the original video through temporal modulation. In addition, we consider the BCH and repetition codes. Binary BCH codes can be constructed using parameters (n, k, t), where n represents the length of the code word, k is the length of the message size, and t represents the number of bit errors the code can correct.

Table 1. Test videos

No.	Test video	Size	FPS	Frame
1	Highway	352x288	29.97	2000
2	Paris	352x288	29.97	1065
3	Drama	640x352	29.97	1000
4	Music show 1	640x352	29.97	1000
5	Music show 2	640x352	29.97	1000

Table 2. Bit error rates of test videos.

	Video 1 2 3	Video 4		Video 5	
	Without ECC	Without ECC	With ECC	Without ECC	With ECC
Rotation 15°	0	11.42	0	8.56	0
Cropping 10%	0	11.42	0	11.42	0
Scaling x 0.5	0	11.72	0	8.57	0
Projective	0	17.13	0	11.42	0
FRC (20fps)	0	2.85	0	5.71	0
FRC (40fps)	0	11.42	0	5.71	0
Smoother	0	14.27	0	8.57	0
Sharpening	0	11.42	0	5.71	0
H.264/AVC	0	17.13	0	8.57	0

3 Experimental Results and Analysis

In this section, we explain the performance of the proposed watermarking algorithm. The length of the message was set as 36 bits. This is a reasonable length of watermark information as we consider that the watermarking data payload is required to be a minimum of 35 bits in digital cinema specifications [4]. We adopt BCH (63, 36, 5) codes and set the repetition number as 3. The proposed watermarking algorithm was tested on five test videos, as shown in Table 1. Videos 1 and 2 are frequently used as video watermarking tests. Video 3 is a drama. Videos 4 and 5 are music shows. We choose different video genres because video characteristics, which include frequent scene changes, are different according to their genre. The robustness of each test video is summarized in Table 2. First, we evaluated the robustness to geometric distortions. A rotation attack was performed by rotating the watermarked video clockwise and anti-clockwise by 15 degrees. For a cropping attack, we cut 10 percent of the upper, lower, left, and right sections of the watermarked video. We also scaled the watermarked video to half of its original size to test the resistance of scaling modification. A projective transform is the modeling of video distortion by a camcorder recording. The experimental results show that the proposed watermarking algorithm is robust to geometric distortions such as rotation, scaling, cropping, and projective transform. In addition, we evaluated the robustness to temporal modification and signal processing attack. We changed the original frame rates to 20 fps and 40 fps. After restoring the frame rate of the attacked video to its original rate, we performed the watermarking detection algorithm. The proposed watermarking algorithm was robust to frame rate conversion and low-pass / high-pass filtering attack.

In the watermark embedding procedure, we assume that the mean value of each frame in consecutive frames is approximately constant. However, some videos such as Videos 4 and 5 have high variations in luminance and chrominance channel. This causes high bit error rates in the watermark detection procedure of the attacked video. To compensate for this drawback, we employed the BCH and repetition codes. The experimental results of Videos 4 and 5 with and without ECC are shown in Table 2. For the tests on Videos 4 and 5 without ECC, we investigated high bit error rates in the watermark detection procedure against many kinds of attacks. However, we were unable to find bit errors in the tests with ECC.

The PSNR values of the watermarked videos are above 48 dB. In general, it is well known that human eyes have difficulty in recognizing visual artifacts of modified videos that have PSNR values of higher than 37 dB. Therefore, we can say that the watermarked videos have sufficient visual quality in terms of PSNR.

4 Conclusion

This article presents a robust video watermarking algorithm which is suitable for consumer devices such as IP TV. To improve the robustness, we employed the error correcting codes. The experimental results showed that the proposed watermarking algorithm is resistant to geometrical distortions and temporal attacks. It is well known that there are trade-offs between the several requirements in video watermarking technology. From this viewpoint, it is important to note that the proposed algorithm satisfies the requirements of invisibility and and it supports high robustness against not only a specific attack but also many kinds of attacks.

Acknowledgments: This work was supported by the IT R&D program of MKE/KEIT. [10041686, Cooperative Control Communication/Security Technology and SoC Development for Autonomous and Safe Driving System]

References

1. Shiguo Lian and Zhongxuan Liu: Secure Media Content Distribution Based on the Improved Set-Top Box in IP TV. IEEE Transactions on Consumer Electronics, vol. 54, no. 2 (2008)
2. G. Doërr and J. Dugelay: A Guide Tour of Video Watermarking. Signal Processing: Image Communication, vol. 18, no. 4, pp. 263–282 (2003)
3. C. Chen et al.: Temporal Statistic Based Video Watermarking Scheme Robust against Geometric Attacks and Frame Dropping. Proceedings of IWDW 2009, LNCS 5703, pp. 81-95 (2009)
4. Digital Cinema Initiatives, LLC, Digital Cinema System Specification Version 1.2 (2008)