



Transcoding resilient video watermarking scheme based on spatio-temporal HVS and DCT[☆]

Antonio Cedillo-Hernandez^a, Manuel Cedillo-Hernandez^b,
Mireya Garcia-Vazquez^c, Mariko Nakano-Miyatake^{a,*},
Hector Perez-Meana^a, Alejandro Ramirez-Acosta^d

^a Postgraduate Section, Mechanical Electrical Engineering School, National Polytechnic Institute of Mexico, Santa Ana Av. 1000, D.F. 04430, Mexico

^b Electric Engineering Division, Engineering Faculty, National Autonomous University of Mexico, Universidad Av. 3000, D.F. 04510, Mexico

^c Research and Development of Digital Technology Center (CITEDI), National Polytechnic Institute of Mexico, Park Av. 1310, Tijuana, B.C. 22510, México

^d MIRAL R&D, 1047 Palm Garden, Imperial Beach 91932, USA

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ABSTRACT

Video transcoding is a legitimate operation widely used to modify video format in order to access the video content in the end-user's devices, which may have some limitations in the spatial and temporal resolutions, bit-rate and video coding standards. In many previous watermarking algorithms the embedded watermark is not able to survive video transcoding, because this operation is a combination of some aggressive attacks, especially when lower bit-rate coding is required in the target device. As a consequence of the transcoding operation, the embedded watermark may be lost. This paper proposes a robust video watermarking scheme against video transcoding performed on base-band domain. In order to obtain the watermark robustness against video transcoding, four criteria based on Human Visual System (HVS) are employed to embed a sufficiently robust watermark while preserving its imperceptibility. The quantization index modulation (QIM) algorithm is used to embed and detect the watermark in 2D-Discrete Cosine Transform (2D-DCT) domain. The watermark imperceptibility is evaluated by conventional peak signal to noise ratio (PSNR) and structural similarity index (SSIM), obtaining sufficiently good visual quality. Computer simulation results show the watermark robustness against video transcoding as well as common signal processing operations and intentional attacks for video sequences.

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* Corresponding author. Tel./fax: +52 55 5656 2058.

E-mail addresses: antoniochz@hotmail.com (A. Cedillo-Hernandez), mcedillohdz@hotmail.com (M. Cedillo-Hernandez), freemgraciav@gmail.com (M. Garcia-Vazquez), mnakano@ipn.mx, mariko@infinitum.com.mx (M. Nakano-Miyatake), hmpm@prodigy.net.mx (H. Perez-Meana), ramacos10@hotmail.com (A. Ramirez-Acosta).

1. Introduction

With the rapid advance of multimedia and networking technologies, multimedia services such as teleconferencing, video on demand and distance learning have become more popular in our daily life. In these applications the video format is often required to be converted in order to adapt to several channel capacities (e.g., network bandwidth) as well as end-user's terminal capabilities (e.g., computing and display capacity) [1]. The transcoding is one of the key technologies to fulfill this challenging task. Using a transcoder we can convert

a previously compressed video bit-stream into another bit-stream with different bit-rates, different spatial resolutions and/or different compression standards, etc. In the copyright protection issue, the transcoding poses new challenges on video watermarking technologies since it performs complex conversion operations that generate problems regarding the preservation of embedded copyright information. Then malicious users can perform the transcoding to obtain copyright-free video sequence with similar quality as the original ones and they can distribute them illegally [2]. Considering the above mentioned situation, watermark robustness against video transcoding must be considered to design an efficient video watermarking algorithm, however in almost all video watermarking techniques proposed in literature, the embedded watermark is not robust against transcoding and therefore the copyright protection is not sufficiently done.

Recently several robust watermarking schemes have been proposed in the literature [3–6], in which the resilience to transcoding is also considered. Lee et al. [3] propose a real-time video watermarking robust against transcoding, in which notable results against spatial reduction are shown, obtaining robustness against conversion of spatial resolution from High-Definition Television (HDTV) to Quarter Video Graphics Array (QVGA). This scheme is performed on MPEG-2 video bit-stream directly in order to satisfy the real-time requirements, however it generates vulnerability against the conversion of other video compression standards with low bit rates. Chen et al. [4] propose a robust video watermarking algorithm using the singular value decomposition (SVD) and slope-based embedding technique, in which synchronization information, together with the watermark sequence, is embedded to combat frame attacks, however re-synchronization mechanism of this scheme is not sufficient for the frame rate reduction caused by some aggressive transcoding. In [5], the Human Visual System (HVS) is used to adapt the watermarking energy of the quantization based video watermarking scheme in DWT domain. This scheme shows watermark robustness to some signal processing attacks; however combined attacks caused by common transcoding tasks remove the embedded watermark sequence. Ling et al. [6] propose a video watermarking algorithm robust mainly to geometrical distortions using Harris-Affine interest point detector. The watermark robustness of this scheme strongly depends on an accurate detection of interest points and generally an aggressive transcoding causes an inaccurate detection of many interest points, reducing the performance of this scheme.

The watermark embedding domain is an important aspect to design a video watermarking scheme robust against video transcoding. Video watermarking algorithms proposed in the literature can be classified into three main categories from embedding domains points of view: base-band domain algorithms [7,8], watermarking during video coding process [9,10] and watermark embedding directly on the encoded video sequence [11,12]. We consider that the base-band domain technique is more suitable for a watermarking scheme robust against aggressive video transcoding, because it is not focused on any video compression standard and also in this domain the watermark embedding energy can be adjusted easily according to its robustness and imperceptibility requirements, since the whole spatial information is available.

In this paper we propose a video watermarking scheme robust against video transcoding which performs in base-band domain using Quantization Index Modulation (QIM) algorithm [13]. To design a video watermarking scheme robust against an aggressive video transcoding task, first the key aspects of video transcoding, such as quality degradation caused by low bit-rate coding, similarities and difference among video compression standards, and effects of the temporal/spatial resolution change, are analyzed in detail. To embed a watermark sequence as robust as possible keeping the watermark imperceptibility, in the proposed scheme the quantization step size of the QIM algorithm is adaptively calculated using spatial and temporal HVS criteria. In the image watermarking techniques, QIM algorithms with adaptive quantization step size based on the spatial HVS properties have been proposed in order to obtain watermark imperceptibility and robustness simultaneously [14,15]. The proposed scheme also considers and exploits temporal information in order to get advantage on deficiency of the HVS to follow regions with high motion speed, using the spatio-temporal contrast sensitivity function and influence of eye movement. Additionally in the proposed scheme, the visual attention region is segmented in each video frame using Information Maximization to obtain more adequate quantification step size. So the watermark embedding process is performed combining four HVS criteria; texture and luminance sensitivity, a motion distortion threshold and visual attention region. The performance of the proposed scheme is compared with four recently reported robust video watermarking schemes [3–6], showing a better performance of the proposed scheme, especially in robustness against video transcoding. We consider that the main contribution of the proposed scheme is robustness to transcoding which is obtained by a detailed analysis of transcoding task and exploiting the spatio-temporal HVS properties in order to obtain adaptively the quantization step size of the QIM algorithm. In our best knowledge there is no another video watermarking scheme that exploits the spatio-temporal HVS criteria and visual attention region estimation to improve watermark robustness against aggressive attacks.

The rest of the paper is organized as follows: In Section 2, we analyze key aspects of video transcoding process to design an efficient watermarking scheme. Section 3 provides a detailed explanation of the watermark energy adaptation based on spatio-temporal HVS-based criteria and the visual attention region segmentation. In Section 4 the proposed scheme is described in detail. The evaluation results of the proposed scheme are compared with four recently reported video watermarking schemes in Section 5 and finally Section 6 provides the conclusions of this research.

2. Video transcoding

Digital video can be dynamically adapted according to the available resources of the end-user's devices, such as computing power and display capability, as well as the channel capacity for transmission of the video sequence, such as channel bandwidth. One common example is the delivery of a high-quality multimedia source, such as a Digital Versatile Disc (DVD) or High Definition TV (HDTV), to a receiver with lower resources, such as Smart Phone, Tablets and Personal

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