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A Survey on Original Video-based Watermarking

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***Abstract*—With the quick development of communication technology, digital video has become an indispensable media content for people's daily life and entertainment, and its copyright protection has also turned into a vital research topic. The digital video watermarking is expected to become a technology that can solve the problem of digital video network infringement. Based on various embedding positions, the digital video watermarking algorithm includes two major categories: the compressed video-based and original video-based watermarking algorithm. The latter has stronger versatility than the former, hence, in this paper, we mainly focus on the survey of the original video-based watermarking algorithm.**

***Keywords*—copyright protection; original video-based watermarking; survey**

I. Introduction

The rapid development of communication technology makes the forthputting and spreading of the digital video more and more convenient, but it has also caused serious network infringement problems. Hence, the copyright protection of network video content is imminent. By using the video watermarking technology, a mark (watermark) containing copyright information is embedded imperceptibly into the video content. If there are some copyright disputes occurring, we can extract the watermark to prove the creator's ownership of his work. Video watermarking technology provides a solution for the copyright tracking and verification of digital video content, and it is very important to study reasonable and effective video watermarking algorithms.

Based on the various embedding positions, we can divide the video watermarking algorithms into two categories: compressed and original video-based watermarking [1]. Compressed video-based watermarking algorithm embeds and extracts the watermark in partially decoded compressed video or compressed video stream. This type of algorithm has low computational complexity and can meet the real-time performance of video watermarking. However, due to the limitation of the compression bit rate, the watermark capacity of this type of algorithm is small. In addition, the embedding and extraction strategy is limited by the video codec standard and compression algorithm, so its versatility is very poor. The original video-based watermarking is also called the uncompressed video-based watermarking, embedding and extracting the watermark based on some specific uncompressed frames. Most of these algorithms refer to the design ideas of image watermarking algorithms, and they have a large watermark embedding capacity, with good robustness and versatility. However, if you want to embed a watermark in a video that has been encoded and compressed, you must decode and encode the video totally, so the efficiency will be reduced, which may not be able to meet the real-time requirement.

The original video-based watermarking algorithm is more versatile and has more practical value, so this paper is mainly a survey of it. It mainly includes two aspects of research content: the selection of video frames during embedding and extraction, and the design of the watermarking algorithm scheme. The former is a unique problem of video watermarking compared to other digital media watermarking, while the latter can take the design design philosophy and method of image watermarking as reference. This paper will then elaborate on these two parts in detail.

II. The selection of video frames during embedding and extraction

Different original video-based watermarking algorithms use different strategies to select video frames for watermark embedding and extraction. Specifically, it is divided into selecting all and partial frames.

The algorithms of selecting all frames [2]–[7] have low execution efficiency and poor invisibility. Some algorithms select part of the frames in the video instead of all frames for watermark embedding, such as I frames [8], [9], keyframes [10], [11], scene change frames [12], [13], and so on, to improve the efficiency and invisibility.

There are problems to be solved whether all or partial frames are selected: Some algorithms need to use the original watermark information to detect whether the video frame contains the watermark or not when extracting, and they are non-blind; Other algorithms need to extract watermarks

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from all video frames that may contain watermarks, and then statistically analyze the extracted information of each frame to get the final watermark information. However, the final result may be interfered by the error information extracted from video frames that do not contain watermarks, thus affecting the accuracy of the extraction results.

III. The design of the watermarking algorithm scheme

The design of the original video-based watermarking algorithm scheme can draw lessons from the philosophy of the image watermarking, which needs to perform three processes as well: the selection of the embedding region, the selection of the embedding domain, and the design of the watermark embedding and extraction scheme.

A. The selection of the embedding region

The embedding regions are divided into global and local regions.

The algorithm that uses the whole content of an image or a frame as the watermark embedding region is named as the global watermarking algorithm [5], [6], [11], [12]. Its execution efficiency is higher, but it processes the whole information of the image or the frame during execution, which makes it difficult to resist cropping attacks.

The algorithm that only embeds watermarks in multiple specific regions in an image or video frame is a local watermarking algorithm [14]–[20]. Local watermarking algorithms usually locate the embedding regions by extracting the feature points. This type of algorithm will extract some translation, rotation, or scale-invariant feature points from the host image or frame as reference, then the watermark is embedded in the non-overlapping regions located by these reference points repeatedly. Bas et al. [15] use Harris corner detector to locate several feature points, and triangulate the host image according to these points, and the watermark is embedded and detected in the triangle region. Gao et al. [14] construct underlapping regions centered on scale-invariant feature transform (SIFT) points according to the minimum span tree clustering algorithm, and then the watermark is embedded into these regions, using the scale and rotation invariance of SIFT feature points to resist geometric attacks. Deng et al. [16] apply the Harris-Laplace detector to determine the embedding regions, and then directly modified the gray histogram of the regions for watermark embedding. Tang et al. [17] extract some specific feature points through the Mexican-Hat wavelet-scale interaction method, and the watermark is embedded into normalized circular regions centered on these corresponding points. Nasir et al. [18] use an end-stopped wavelet-based feature extraction method to extract important feature points, then take them as synchronization reference between embedding and detection. They embed the watermark in the underlapping normalized circular regions centered on these points repeatedly, and obtain the rotation invariance through image normalization. Jen-Sheng and Tsai et al. [19], [20] put forward some novel methods for selecting non-overlapping embedding regions, such as simulating attacks, tracing, and pruning programs, mapping to multidimensional knapsack problems and solving them by genetic algorithm, and so on. The purpose is to make these selected embedding regions still be recognized when the watermark is extracted.

B. The selection of the embedding domain

The embedding domain consists of the spatial and transform domain. The spatial domain algorithms modify the pixels of an image or a frame for watermark embedding, which has high execution efficiency. While the transform domain watermarking algorithms modify the coefficients through Discrete Fourier Transform (DFT) [21], Discrete Cosine Transform (DCT) [7]–[9], [22]–[26], Discrete Wavelet Transform (DWT) [6], [10]–[12], [23], [27], [28], Singular Value Decomposition (SVD) [5], [10], [23], [24], [27], [29], Discrete Multiwavelet Transformation (DMT) [2], Contourlet Transform [5], Dual-Tree Complex Wavelet Transform (DT CWT) [4], [30] and other transformations, to embed the watermark, they have better invisibility and robustness, but their computational complexity is high.

C. The design of the watermark embedding and extraction scheme

Spread spectrum and quantization are two common watermark embedding and extraction schemes.

Cox et al. [31] first introduced the spread spectrum principle to the field of watermarking. The method transforms each bit of the information to an independent code vector and then superimposes it into the transform domain coefficients of the host image. During extraction, the embedded watermark is obtained by correlating the corresponding transform domain coefficients with the code vector. The watermark extraction process of the spread spectrum scheme does not need the participation of the host image, so that it belongs to blind watermarking technology and is suitable for practical applications such as copyright protection. Moreover, the watermark embedding ability and robustness to noise of the spread spectrum scheme have attracted much attention in the field of digital watermarking. However, this scheme has host signal interference (HSI), that is, the information of the image itself will affect the accuracy of watermark extraction, which leads to the degradation of extraction performance. At present, many kinds of research are devoted to solving this problem. TDSS [32] combines the advantages of the spread spectrum scheme with the steadiness of AC coefficients in the two-level discrete cosine transform domain, so that it can stand up to typical image processing attacks as well as some geometric attacks. Zarmehi et al. [33] modulate the image signal with spread spectrum watermark and noise, so that the signal can obey Laplacian distribution, using the maximum likelihood decoding for watermark extraction. The invisibility and robustness of the watermark have been improved. Kim et al. [21] propose a novel selective correlation detector, which can perform correlation detection on part of the carrier signal instead of the whole. The power ratio between the carrier signal and watermark and the correlation's estimated variance are used to determine the part of the carrier signal used for detection, which effectively reduces the correlation between the code vector and the carrier signal. Bhinder et al. [34] selects some low-frequency wavelet coefficients from the image block with high information entropy to form the feature vector, and revises the embedding strength to make the feature vector scale in the upward or downward direction, so that the maximum likelihood decoding can be used to extract the watermark during extraction. Maity et al. [35] use genetic algorithms to determine the threshold used to construct the feature vector and the embedding strength of the spread spectrum watermark. Selecting transform domain coefficients with stable characteristics to form feature vectors improves the robustness of the algorithm and adaptively determining the appropriate embedding strength can achieve better invisibility. Malvar et al. [36] proposed a modulation technique to compensate HSI, by regulating the energy of the embedded information. Valizadeh et al. [37] use the correlation between transform domain coefficients and code vectors for watermark embedding, enhancing the effect of the spread spectrum method. Although these methods have shown good robustness, they have not completely eliminated the influence of HSI.

The quantization scheme is similar to the index method, and there is no host signal interference. Quantization index modulation (QIM) [38] is the first quantization method proposed in the field of watermarking. This method generates two different quantizers based on the quantization step when embedding the watermark, and then uses the quantizer to quantize different coefficients into disjoint index intervals according to different watermark information. When extracting, the same quantizer as that used for embedding is used to quantize the coefficients possessing the information. Finally the relevant information is achieved according to the index interval where the quantized coefficient is located. Since the same quantization step is applied during the embedding and extraction, the corresponding coefficients containing the watermark may fall into different intervals after the scaling attack, so that the watermark information cannot be extracted correctly. Many watermarking algorithms [6]–[9] use QIM to embed and extract watermarks in different transform domains. They adjust the quantization step adaptively based on the features and coefficients of the selected embedding domain to balance invisibility and robustness. These algorithms have the same quantization step size in the embedding and extraction processes, so their ability to resist scaling attacks is usually weak. For balancing the robustness and invisibility of watermarking, Liu et al. [39] used entropy masking model and distortion compensation for improving quantization method. Munib et al. [40] combine Zernike moments with the feature points, then use these points to locate non-overlapping triangular regions. The Zernike moments of each triangular region is calculate, and the watermark is embedded into these momemnts using a quantization method. This method can effectively resist some geometry attacks. Liu et al. [41] calculate the quantization step size through the ordering strategy of wavelet coefficients, and use an appropriate quantization parameter to control the modification amount of each wavelet coefficient to reduce the distortion of the image. Fazlali et al. [42] use the edge density and information entropy of the image block to adaptively change the quantization step to achieve high robustness and acceptable invisibility. An adaptive dither quantization modulation model [25] can effectively resist scaling attacks by modifying the Waston model so that the quantization step size can keep the size synchronization before and after scaling. This model can't resist aspect ratio change attacks, because it can keep the synchronization of quantization step only for equal scale scaling attacks. Furthermore, the computational complexity of this model is very high. The differential quantization scheme with adaptive quantization threshold (DQAQT) [26] is a quantization method based on two-level discrete cosine transform watermarking [32], and it takes advantage of the stability of difference between adjacent components of feature vectors in the two-level discrete cosine transform domain and embeds the watermark by quantizing the difference. Due to the limitation of embedding location, this method has weak resistance to some large-scale scaling attacks. At the same time, due to the implementation of two-level discrete cosine transform, binary search, and other operations, the operation efficiency of this method is low.

IV. Conclusion

In this paper, we mainly focus on the survey of the original video-based watermarking algorithms. Firstly, the selection of video frames during embedding and extracting is introduced, specifically including two strategies for selecting partial and all frames; Then, the design of the watermarking algorithm scheme is described, which mainly includes three parts: the selection of the embedding region, the selection of the embedding domain, and the design of the watermark embedding and extraction scheme. There are more or fewer problems to be solved in every aspect, and the research of the original video-based watermarking has a long way to go.

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