Efficient Watermarking in Color Video Using DWT-DFT and SVD Technique

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Abstract. With the advancement in Internet technology, a digital video can be easily modified, copied, and distributed among a large audience. Copyright protection and security become very essential aspects because of the extensive use of digital multimedia applications. Digital watermarking is being used for copyright protection, data authenticity for multimedia contents such as image, audio, and video. In this paper, a DWT-DFT-SVD-based method is opted to improve robustness and overall computational requirements. The computed PSNR between original video signal and watermarked signal is improved up to 60 db. The normalized correlation value of the original and the extracted watermark image have a high level of imperceptibility. The proposed scheme shows strong robustness against several geometric and non-geometric attacks.

Keywords: Discrete Fourier transform (DFT) · Discrete wavelet transform (DWT) · Singular value decomposition (SVD) · Digital video watermarking

1 Introduction

The security and unauthorized redistribution of digital contents are getting essential in the digital world. Recent advances in internet technology resulted in an increase in the utilization of the digital video. Hence, the digital data (video) can be shared, copied, distributed, and modified very easily [1, 2]. For the security of digital media in opposition to illegal distributions and manipulations, digital watermarking is being used [3, 4].

The uniqueness of digital media is obtained by extracting the embedded information. Watermarking can be used for many reasons, such as proof of ownership, copy control, broadcast monitoring, and authentication. [5, 6]. Visible watermark and an invisible watermark are two types of watermark. The invisible watermark gives more security to the multimedia like video, image, and document because human eye scan analyzes visible watermark so that attackers can attack without any difficulty on this by different attacks that may be geometric or non-geometric [7].

The watermark embedding, attack, and watermark detection are the essential components of robust watermarking [8]. Goal of watermark is to be robust enough to resist

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attacks, but not at the expense of altering the value of the multimedia data being protected. Digital video watermarking is achieved by inserting secret data in a video sequence to protect the video from unauthorized copying. Video string is still undisturbed with evenly time spaced images. Image data hiding methods can be applied for video watermarking as well, but video watermarking schemes require to face many challenges. Watermarked video is much sensible to plagiarize attacks, namely digital–analog conversion, frame interchanging, averaging of the frame, lossy compression, etc.

The rest of the paper is organized as follows. In Sect. 2, we explained related work done in digital video watermarking. Our proposed algorithm, with its block diagram, is explained in Sect. 3. The experimental results demonstrated in Sect. 4 followed by conclusion of the proposed work in the last section.

2 Related Work

Digital watermarking can be done using discrete cosine transform based on binary watermark technique [9] and QIM technique. Sridha and Arun [10] proposed a discrete wavelet transform (DWT) for security enhancement in video watermarking. Dual SVD and DWT based on selective pixel [11] give high robustness against multiple watermarking attacks. To achieve strong robustness against various signal processing operations, DWT- and PCA-based scheme is proposed [12]. DWT and PCA are used to hide the data in the digital video [13].

A digital watermarking system for video authentication using DMT is discovered by Monika et al. [14]. It presents multi-wavelet-based invisible watermarking. A hybrid DMT-SVD method is determined to be more reliable than the DWT method [15]. In [16], DWT-DCT-SVD is implemented on intravascular ultrasound (IVUS) video. Replacing biomedical signals among hospitals necessitates reliable and efficient communication. In this, binary watermark images embedded into intravascular ultrasound video. The whole video is divided into frames and application of DWT, DCT followed by SVD composes the watermark hiding technique.

Different existing video watermarking technologies based on DWT [17–21] and SVD [22–24] and their properties were studied to make it easier to select an appropriate technique which provides quantitative results. To increase the security and robustness of the watermark, some cases used combined or hybrid two frequency domains [25]. Based on DWT and DCT, for example, a watermark was embedded in a selected sub-band of the Y-component. The required perceptual quality of the video can be achieved by combining DWT with SVD [26]. The study proposed in [27] presented DWT- and DCT-based digital video watermarking using an invisible watermarking algorithm based on the spatial frequency domain. This paper presents a video watermarking technique using DWT-DFT-SVD, and watermark is embedded in YCbCr color space.

3 Proposed Algorithm

The robustness of the proposed model is improved by utilizing the features of DWT, DFT, and SVD technique. DFT is robust to Gaussian noise, shift invariance, JPEG compression, image sharpening and helps in noise removal. Inserting watermark using

DWT enhances the robustness against attacks, and it retains the image quality. Any change in singular values does not affect the video quality, and singular values remain unchanged to attacks. The presented method consists of two sections, namely the watermark embedding process and extraction process.

3.1 Watermark Embedding Process

The process of embedding watermark in the video is depicted in Fig. 1, and steps are described as follows:

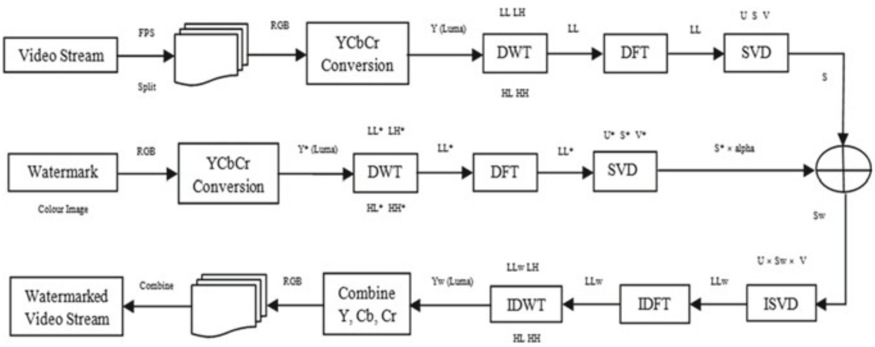


Fig. 1. Watermark embedding process

S1 The input video is divided into frames, and it is converted from RGB to YCbCr color space. The Y-component is used for watermark embedding process.

S2 2D-DWT (Haar wavelet) of single level is applied to the Y luma component. Four sub-bands, namely LL, LH, HL, and HH, are obtained. Out of which LL component is selected from total sub-bands.

S3 DFT is applied to LL component.

S4 To get an array of U, S, and V matrices of the video frame, SVD is performed on the output of DFT transformed LL component.

$$A = \mathrm{USV}^T \tag{1}$$

S5 The watermark video is converted from RGB to YCbCr color space. Here, again the Y luma component is used.

S6 The LL* component is selected after applying DWT on the Y-component.

S7 Complex valued Fourier transformed LL* component is achieved by applying DFT to LL* sub-band.

S8 To get U*, S*, and V* matrices, SVD is applied on the output component.

$$A = \mathrm{U} * \mathrm{S} * \mathrm{V}*^T \tag{2}$$

S9 Singular values of watermark embedded with singular values of every frame. The number of singular values to be embedded in each frame is equal to α scaling factor which concludes the power of watermark.

$$S_W = S + \alpha S* \tag{3}$$

S10 Inverse SVD is applied on U, Sw, and V matrices to get the LLw component.
S11 Untransformed LLw is obtained by applying IDFT using magnitude and phase components.
S12 Watermarked Yw luma component is achieved by performing IDWT to LLw, LH, HL, and HH.
S13 RGB format conversion is done after combining Cb and Cr components to Yw component.
S14 Non-selected frames are combined with the watermarked frames to obtain the complete watermarked video sequence.

3.2 Watermark Extraction Process

The process of extraction watermark is depicted in Fig. 2, and steps are described as follows:

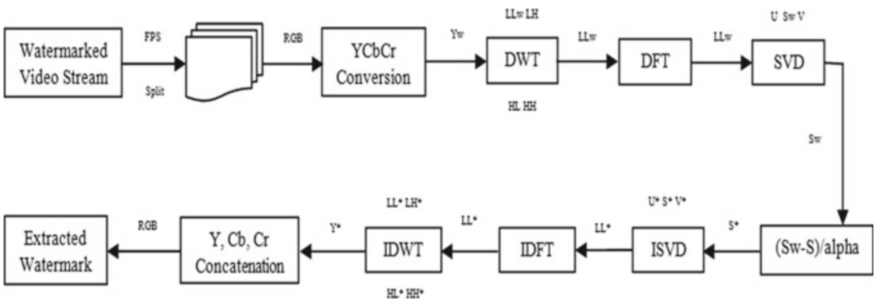


Fig. 2. Watermark extraction process

S15 Initially, watermarked video is split into frames and it is converted from RGB YCbCr color space. For the watermark extraction process, Yw component is selected.
S16 2D-DWT (Haar wavelet) of single level is used to the Yw component which is nothing but the luma component. Four sub-bands, namely LLw, LH, HL, and HH, are obtained. Out of which LLw component is selected from total sub-bands.
S17 DFT is applied to LLw component.
S18 To get an array of U, Sw and V matrices of the selected video frame, SVD is performed on the output of DFT transformed LLw part.

$$A_W = U\, S_W V^T. \tag{4}$$

S19 Singular matrix (S*) of watermark can be achieved by the given equation,

$$S^* = S_W - S/\alpha. \tag{5}$$

S20 To get the LL* component, ISVD is performed after combining S* matrix with U* and V* matrices.

S21 Untransformed LL* component is obtained by applying IDFT using magnitude and phase components.

S22 Unwatermarked Y*luma component is achieved by performing IDWT to LL*, LH*, HL* and HH*.

S23 RGB format conversion is done after combining Cb* and Cr* components to Y* component to obtain the original watermark.

4 Experimental Results

The experimentation of the presented approach is carried out using MATLAB 10. Six video samples were used having various resolutions with distinct format (.avi, .mov, .mp4, .mpg, .wmv). Color watermark with size 384 × 512 in.png format has been selected. Frame selection and embedding have done according to the proposed scheme.

Table 1 shows the original and watermarked video frames of different video samples. It describes that the watermarked and original frames are indistinguishable subjectively. Peak-signal-to-noise ratio (PSNR) is calculated to assure the security of the video. PSNR values are dependent on MSE.

Table 2 illustrates the extracted watermark images for all video samples without attack and after applying different attacks. From this, it is observed that the maximum correlation is obtained between the original and extracted watermark.

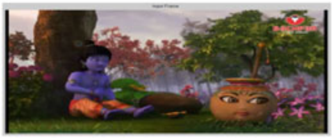
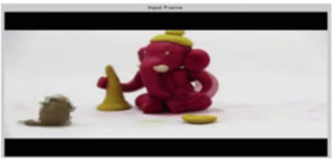
Normalized correlation for all video samples is compared and shown in Table 3. NC is used to measure the similarity between the original watermark image and extracted watermark image. The average normalized correlation (NC) of all videos is equal to 0.99, and it gets somewhat degrade for salt and pepper attack as well as for rotation attack. Vid.avi (720 × 1280) and Vid.mpg (480 × 640) give a very low value of NC, which is equal to 0.37 for cropping attack.

The robustness of the proposed algorithm is analyzed by applying different attacks on the video. Figure 3 demonstrates the PSNR with and without attacks for six different video samples, where I1—PSNR without attack, I2—Gaussian noise, I3—salt and pepper noise, I4—rotation attack, I5—cropping attack, I6—median filtering attack, I7—histogram equalization, I8—image sharpening.

The investigational outcomes have validated the proposed model in terms of improved NC and PSNR results by applying different attacks on videos.

Table 4 depicts the comparison analysis of the proposed work with the existing video watermarking techniques. It gives better results than the other methods. In present work, various videos of high-definition resolution are used with color watermark, and several attacks are applied to check the robustness. The given method achieved great PSNR in the range of 63–73 dB with NC value 0.99.

Table 1. Original and watermarked frames of six different videos

	Original video frame	Watermarked video frame
Bus.avi (288 × 352)		
Vid.avi (720 × 1280)		
Vid.mov (720 × 1280)		
Vid.mp4 (720 × 1280)		
Vid.mpg (480 × 640)		
Vid.wmv (720 × 1280)		

5 Conclusion

The primary purpose of the work recognized so far is to give accurate and precise video watermarking. The algorithm is implemented DWT in conjunction with DFT transform and SVD, which is vital for achieving better security. A color watermark has

Table 2. Extracted watermark for six video samples

	Bus.avi (288 × 352)	Vid.avi (720 × 1280)	Vid.mov (720 × 1280)	Vid.mp4 (720 × 1280)	Vid.mpg (480 × 640)	Vid.wmv (720 × 1280)
Original watermark						
Without attack						
Gaussian noise						
Salt and pepper						
Cropping attack						
Rotation attack						
Median filter						
Histogram equalization						
Image sharpening						

been embedded into the original video. Without much loss of data and features of the host video, inserting color watermark in the low-frequency sub-band helps to improve the robustness of embedding procedure. The proposed algorithm is imperceptible and robust against several attacks, and the value of PSNR (more than 60 dB) and NC (0.99) is measured high. There are some ways to be discovered for future work. An alternate watermark can be used, such as audio or video for embedding process to check the robustness of video watermarking. The implementation of this algorithm can be done using VHDL to address the hardware efficiency of this work.

Table 3. Normalized correlation against attacks for different video frames

Normalized correlation (NC)						
	Bus.avi (288 × 352)	Vid.avi (720 × 1280)	Vid.mov (720 × 1280)	Vid.mp4 (720 × 1280)	Vid.mpg (480 × 640)	Vid.wmv (720 × 1280)
W/O attack	0.9798	0.9985	0.9986	0.9925	0.9991	0.9976
Gaussian noise	0.9665	0.9665	0.9628	0.9417	0.9726	0.9698
Salt and pepper	0.9413	0.8892	0.8420	0.8491	0.8434	0.8338
Cropping (50 × 50)	0.9160	0.3741	0.9979	0.3679	0.3703	0.9967
Rotation (2°)	0.8850	0.8708	0.9541	0.7706	0.5258	0.8024
Median	0.6496	0.9937	0.9951	0.9877	0.9965	0.9830
Histogram equalization	0.9593	0.9835	0.8117	0.9633	0.7898	0.6726
Image sharpening	0.6481	0.9106	0.9268	0.8999	0.9147	0.8863

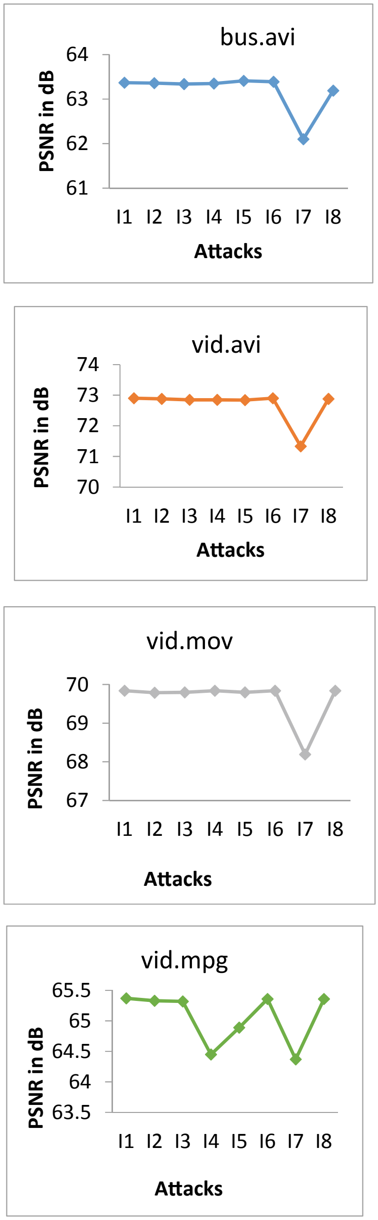


Fig. 3. PSNR with and without attacks for different videos

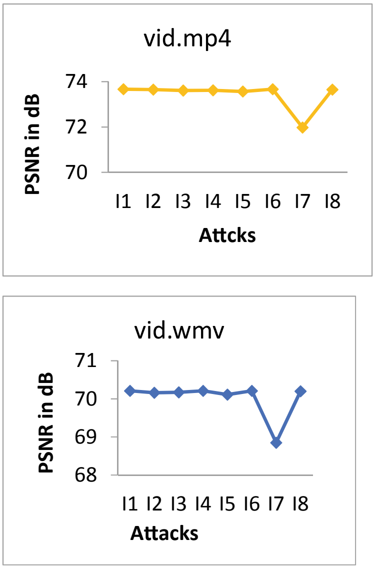


Fig. 3. (*continued*)

Table 4. Comparative analysis

Method	Host video size	Watermark	Attacks	PSNR(dB)
DCT [9]	256 × 256	Binary wm 32 × 32	Gaussian, salt and pepper noise, median filter, histogram equalization	45.98
5-level DWT [11]	256 × 256	Image	Gaussian noise adding, salt and pepper noise adding, frame dropping	45
DWT, PCA–QIM [14]	256 × 256	Image 32 × 32	Gaussian noise addition, hist. equalization, gamma correction, contrast adjustment	45.41
DWT and PCA [15]	Not given	Binary image	Gaussian and salt pepper noise, cropping, rotation, median filtering, contrast adj., hist. equalization.	46.23
MPEG [18]	320 × 240	Not given	Frame dropping and averaging, cropping	31.5–38.5
DWT, DFT, and SVD [Proposed]	(.avi, .mpg, .mp4, .wmv) 720 × 1280	Color watermark 384 × 512	Salt and pepper, rotation, cropping, image sharpening, hist. equalization, filtering	63–73

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