DWT/DCT-based Invisible Digital Watermarking Scheme for Video Stream

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Abstract—**Digital watermarking is a technique of hiding information for copyright protection and authentication. In this paper, an invisible digital watermarking algorithm on Discrete Wavelet Transform (DWT) and Discrete Cosine Transform (DCT) domains is presented. Herein, a binary watermark image was embedded in the middle sub-band coefficients of a video stream. The experimental results of proposed algorithm indicates that the PSNR values of the watermarked videos were as high as almost up to 37 dB with the optimal watermarking strength. The proposed algorithm was proven robust against HEVC stream compression. It is hence anticipated that it could be effectively applied for copyright protection and authentication.**

Keywords- Watermarking; DWT; DCT; Video Stream

I. Introduction

Watermarking technology has been widely applied in various multimedia archiving and communication, including but not limiting to protection of data and their authentication. The major advantages of this technology are security, readability, imperceptibility and robustness [1]. However, some concerns remain an area of investigations, which is resilience against various attacks and thus not seriously compromising quality and value of embedded data. The watermarking technique can be categorized based on its operating domain into 2 groups: spatial and frequency watermarking.

Most recent works in the literature have put the emphasis on watermarking video streaming data. They generally adopted frequency domain approaches, such as those based on Discrete Cosine Transform (DCT) [2-6]. In [2], for example, a logistic chaotic map was combined with error correction coding for creating watermarked data, in order to improve its robustness and security. The resultant watermark was embedded in low frequency band of selected DCT blocks. The watermarking scheme proposed in [3] first detected moving and then selected the moving regions as the embedding sites. Embedding was similarly performed on DCT domain. Video watermarking carried out on a DCT domain but in three dimension (3D-DCT) [4] was also proposed by quantization based embedding techniques. Another study proposed in [5], used even-odd quantization algorithm to embed an image in all bit planes, which were decomposed into selected DCT coefficients of 8×8 blocks, extracted from an original video. Another study [6] proposed an algorithm based on pattern recognition and embedded digital data into AC coefficients of DCT responses.

Some more recent watermarking techniques were performed on DWT domain [7-9]. In [7], watermark was embedded in HL3 sub-band of 3-Level DWT. Their experiments was carried out on video clip in .avi format. Similarly, as presented in [8], watermarking was performed on a video in QCIF. Unlike [7], they embedded a watermark into two sub-bands of DWT and used a chaotic map, for improving robustness and security. In [9], a watermark scheme was integrated with the HEVC technique. In order to examine overall performance, a watermark was embedded in one or more of the resultant DWT.

Emphasizing on improving robustness and security of watermark, some studies used hybrid or combined two frequency domains [10-12]. In those cases, for example, a watermark was embedded in a selected sub-band of Y component based on DWT and DCT [10]. The study proposed in [11] presented a hybrid DWT and DCT based digital video watermarking of color watermark logo using index mapping technique. In [12], DWT are combined with Singular Value Decomposition (SVD) to achieve required perceptual quality of the video. The key frame was selected by using chaotic map.

This paper proposed a novel video watermarking scheme based on hybrid DWT/DCT domains. Once the spatio-frequency components were extracted, their middle frequency sub-bands coefficients of a video steam were selected and used as the embedding site.

The rest of this paper is organized as follows. Background on DWT, DCT and HEVC are presented in Section 2. Section 3 describes the proposed method. Then, section 4 discusses the results. Finally, the last section states the concluding remark.

II. Background

A. Discrete Wavelet Transform (DWT)

DWT [2] is a linear transformation that operates on a vector value whose each dimension is an integer power of two. The vector is transformed numerically onto another space with an identical dimensions. DWT is normally employed to

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separate vector signal into different frequency and spatial (or temporal) components, at varying scales so they may be independently studied at respective resolution. Generic DWT is computed with a cascade of filtering (Figure 1).

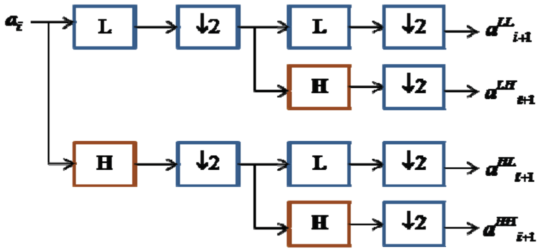


Figure 1. Wavelet Decomposition for two-dimensional [2]

B. Discrete Cosine Transform (DCT)

DCT is closely related to the discrete Fourier transform. It transforms a multi-dimensional signal (such as image) from its spatial domain to the frequency one. It is considered as a separable linear transformation. Accordingly, DCT linearly separate an image into spectral sub-bands, whose importance is determined by spectral energies and thus visual quality.

C. High Efficiency Video Coding

The ITU-T Video Coding Experts Group in collaboration with ISO/IEC Moving Picture Experts Group have developed a novel encoding standard that is promised to outperform the earlier MPEG-4, H.263 and H.264 ones, effectively offering better compression of a video stream. This new standard is named High Efficiency Video Coding or HEVC. Its first version (also known as H.265) was released in 2013 [13] with a reference software called HM (HEVC Test Model). The main merit of HEVC was its ability to increase data compression rate by 50 percentage over its precedent H.264, while ensuring the same high image quality.

III. DWT/DCT-BASED WATERMRKING SCHEME

A. Embedding Watermark

A watermark is defined as a binary image, whose pixel intensities were either 1 or –1 and was blended with pseudo-random sequence, whose value was also either 1 or –1. The block diagram of embedding process is showed in Figure 2. Listing 1 illustrates pseudocode of the proposed watermark embedding scheme. The Y component of video sequence is transformed by one-level two-dimensional DWT and the middle sub-band (LH and HL) were then selected (as seen in Line 4-8 of Listing 1). After that, these selected sub-bands (in alternated frame) were transformed by two-dimensional DCT and then reordered by zigzag scan. A watermark was then embedded in the middle frequency coefficient (25 percentages) (Line 11). Line 12 is an equation of watermark image. The magnitude factor (α) determined the watermark strength. Finally as shown in Line 13-14, DCT and DWT were inverted.

Listing 1: Pseudocode of Watermark Embedding Scheme

```
1:  Initialize: key, pseudo random, alpha, binary image, Video
2:  For  frame number = 1: length (Video)
3:         LL, LH, HL, HH  ← DWT2(video)
4:  If  frame number  is even number Then
5:            x  ← DCT2(HL)
6:  Else If frame number  is odd  number Then
7:            x  ← DCT2(LH)
8:  End If
9:    x*  ← zigzag scan of (x)
10:  L = Length of x*
11: choose middle frequency
             C  ← x* ((L*0.375)+1:(L*0.625))
12:  CC = C + ( α * pseudo random*binary image)
13:  inverse 2DCT
14:  inverse 2DWT
15:  End For
16:  watermarked video
17:  calculate PSNR
```

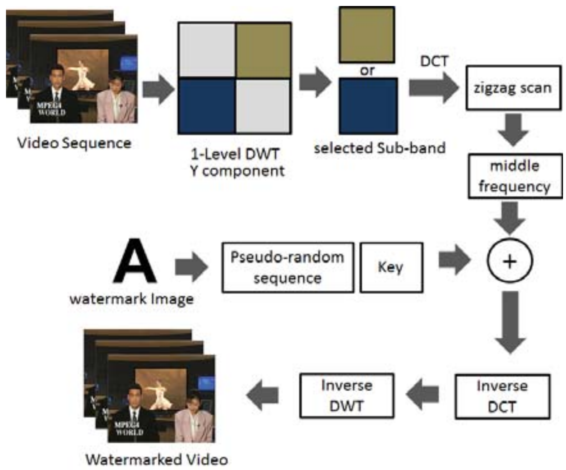


Figure 2. Block Diagram of Embedding Watermark

B. Extracting Watermark

Listing 2: Pseudocode of Watermark Extracting Scheme

```
1:  Initialize: key, pseudo random, alpha, binary image,
               watermarked video
2:  For  frame number = 1: length (watermarked video)
3:   LL, LH, HL, HH ← DWT2(watermarked video)
4:  If  frame number  is even number Then
5:            x+← DCT2(HL)
6:  Else If frame number  is odd  number Then
7:            x+← DCT2(LH)
8:  End If
9:    x**← zigzag scan of (x+)
10:  L = Length of x*
11: choose middle frequency
             C+ ← x** ((L*0.375)+1:(L*0.625))
12:  set value of  C+ to 0 and 1
13:  If  C+ =  0 Then
14:      C+ = -1;
15:  End If
16:  predicted video using averaging filter (3×3 mask)
17:   D+ ← repeat step 3  to 11
18:  estimate of the watermark  Delta ← D+- C+
19:  watermark ← sign(Delta)
20:  use median filler for reduce noise
21:  End For
22:  calculate NC
```

Listing 2 shows pseudocode of the proposed watermark extraction scheme. It is worth emphasizing that this process did not need the original video sequence. A prediction of the original pixel values was instead performed online. In this paper, we used a 3×3 mask for image prediction. As stated in Line 18, the estimate of the watermark was indicated by the difference between D^+ and C^+. Therefore, the sign of error of the prediction from actual value was embedded in a single bit (Line 19). The watermark could be estimated by multiplying pseudo random number with this embedded bit. Note that, if a wrong pseudo random sequence were used, the extraction would not produce the correct image, thus resilient against forgery.

IV. Results and Discussions

Table I depicted a set of YUV video samples used in the experiment. In the proposed work, a watermark is embedded in all frames of Y component. The scheme was validated by using the following parameters: the magnitude factor (α) was varied from 12 – 20 and the key was set to 150.

The optimal magnitude factors (α) were 14 – 16. In Table II, the PSNR of the Basketballpass sequence equaled to 39.1008 and 37.9538 dB with α = 14 and 16, respectively. The NC was up to 0.97. The PSNR of the Mobile sequence equaled to 39.1245 and 37.9680 dB (for optimal magnitude factor) and the NC was up to 0.92 following Table III. Table IV reports the PSNR value and NC of the News sequence. Moreover, the comparison of NC are showed in Figure 3-4. The results in Table II–IV and Figure 3-4 indicate that the robustness of the proposed method compared with [10] has been significantly improved.

A watermarked video with α =16 are shown in Table VI. Table V shows extracted watermark of 35[th] frame of the BassketBallPass, 184[th] frame of Mobile and 100[th] frame of News sequence, with α = 16. It can be noticed that there were some noises in all extracted watermarks in the Y component. This is because extraction process did not rely on the availability of the original video sequence. Without loss of generalization ability a trivial median filter was adopted to remove the noises.

TABLE I. SIZE OF VIDEO SEQUENCE

Video File	Width	Height
Basketballpass.yuv	416	240
Mobile.yuv	352	288
News.yuv	352	288

TABLE II. PSNR AND NC OF BASKETBALLPASS

	α	12	14	16	18	20
[10] MIDDLE SUBBAND	PSNR	40.4439	39.1076	37.9502	36.9393	36.0186
	NC (NO ORIGINAL)	0.6020	0.6653	0.7182	0.7619	0.7989
PROPOSED METHOD	PSNR	40.4370	39.1008	37.9538	36.9352	36.0270
	NC	0.8421	0.8805	0.9074	0.9273	0.9415
	NC (FILTER)	0.9666	0.9724	0.9759	0.9787	0.9806

TABLE III. PSNR AND NC OF MOBILE

	α	12	14	16	18	20
[10] MIDDLE SUB-BAND	PSNR	40.4605	39.1224	37.9690	36.9535	36.0388
	NC (NO ORIGINAL)	0.2113	0.2456	0.2786	0.3113	0.3433
PROPOSED METHOD	PSNR	40.4454	39.1245	37.9680	36.9523	36.0413
	NC	0.5559	0.6002	0.6391	0.6728	0.7026
	NC (FILTER)	0.8802	0.9043	0.9209	0.9327	0.9413

TABLE IV. PSNR AND NC OF NEWS

	α	12	14	16	18	20
[10] MIDDLE SUB-BAND	PSNR	40.4564	39.1184	37.9653	36.9502	36.0353
	NC (NO ORIGINAL)	0.5154	0.5840	0.6411	0.6945	0.7397
PROPOSED METHOD	PSNR	40.4436	39.1224	37.9659	36.9502	36.0391
	NC	0.7660	0.8004	0.8287	0.8526	0.8727
	NC (FILTER)	0.9527	0.9607	0.9655	0.9698	0.9728

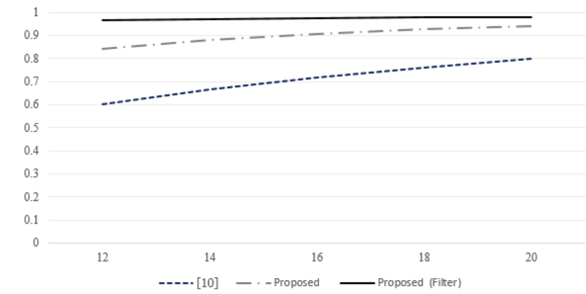


Figure 3. NC of basketballPass video sequence

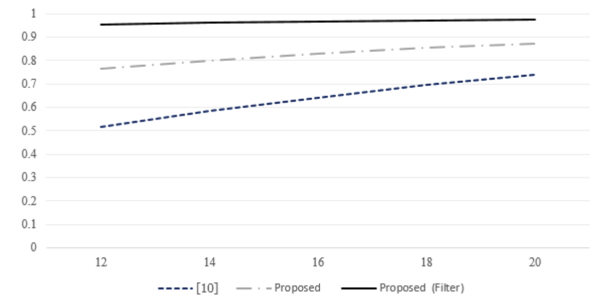


Figure 4. NC of News video sequence

TABLE V. EXTRACTED WATERMARK OF VIDEO SEQUENCE

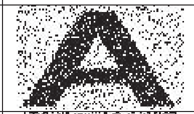
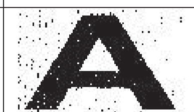
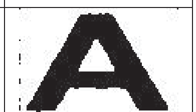
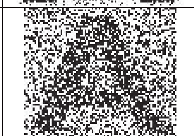
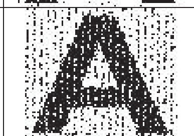
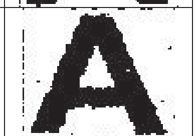
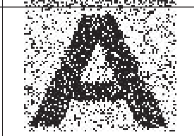
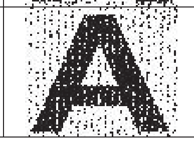
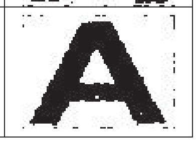
	α = 16		
	[10]	**No filter**	**Median filter**
Basket ball			
Mobile			
News			

TABLE VI. VIDEO AFTER EMBEDDED WATERMARK

Video	α = 16
	Proposed Method
Basketball	
Mobile	
News	

Since noise could adultery the video during transmission, we then tested the robustness of the proposed scheme with the compression noise, refereeing to the block diagram shown in Figure 5. To this end, the HEVC reference software, i.e., HM (HEVC Test Model), whose download link could be found in the website [13], was employed. The corresponding extracted watermarks with α = 16 and NC are 0.0914 and NC = 0.1966, respectively. It can be interpret from Figure 6 that the proposed algorithm has been proven to be effective in compressed HEVC streams.

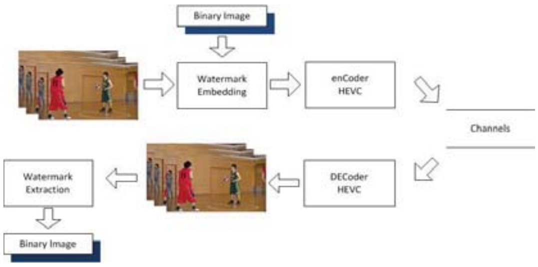
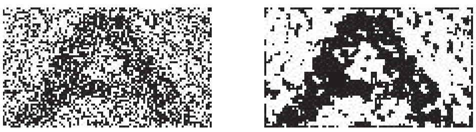


Figure 5. Experimental Design for HEVC encoder



(a) (b)

Figure 6. Watermark of Bassketballpass Sequence after Encoded by HEVC (a) no filter (b) with filter

V. CONCLUSIONS

This paper presents a novel invisible watermarking scheme based on spatio-frequency domain. The scheme was carried out by applying a watermarking on the Y component sub-band of a video sequence. The binary watermark image was embedded in the middle frequency coefficients of DWT and DCT. Herein, experimental results indicated that the proposed algorithm was able to extract the embedded watermark with visually acceptable quality, without the need of the original sequence. Based on the video samples, the optimal magnitude factor was 16, yielding the PSNR (in Bassketballpass stream, for example) of up to 37.9538 and normalized correlation (NC) of up to 0.9757. Attacked with an HEVC compression, the watermark could be also successfully extracted.

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