Reversible color video watermarking scheme based on hybrid of integer-to-integer wavelet transform and Arnold transform

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ABSTRACT

Unauthorised redistribution and illegal copying of digital contents are serious issues which have affected numerous types of digital contents such as digital video. One of the methods which have been suggested to support copyright protectionis to hide digital watermark within the digital video. This paper introduces a new video watermarking system which based on a combination of Arnold transform and integer wavelet transforms (IWT). IWT is employed to decompose the cover video frames whereby Arnold transform is used to scramble the watermark which is a grey scale image. Scrambling the watermark before the concealment makes the transmission more secure by disordering the information. The system performance was benchmarked against related video watermarking schemes, in which the evaluation processes consist of testing against several video operations and attacks. Consequently, the scheme has been demonstrated to be perfectly robust.

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1. INTRODUCTION

Recently, digital watermark systems have been demonstrated to be the efficient technique to protect the copyright of digital information contents such as text, image and video. The first introduction of digital watermarking was at the beginning of the 1990's, as the next generation of practical security protection [1]. The embedded watermark is employed as a proof to demonstrate the ownership of any conflict manner. Any digital watermarking schemes must have some characteriscs such as a transparency of the hidden watermark and the robustness against various attacks. Robustness relies on the employed embedding technique, the watermark payload and the strength of the retrieved watermark after applying attacks and processing, whereas the transparency is defined as the hidden watermark that should be kept invisible [2]. Watermarking techniques are branched into two groups according to the embedding domain: firstly, spatial domain techniques and secondly frequency domain techniques. The earliest and important spatial domain scheme is the least significant bit (LSB) technique [3]. The simplicty and low calculations are deemed the main advantages of this technique, nevertheless, optimization is hard to be implemented by means of the only spatial domain analysis methods as they are susceptible to most image transformation techniques and attacks [2]. On the other hand, the frequency domain analysis methods embed the watermark into the frequency components of the cover image, resulting in more robustness against various kinds of attacks and more embedded information. Recent common transforms include discrete Fourier transform (DFT), discrete cosine transform (DCT) and discrete wavelet transform (DWT) [4].

Image watermarking systems could be applied easily to video watermark [5]. For video watermarking schemes, many attributes of the watermark embedding procedure are required as below:

- Imperceptibility: the embedded watermark in the video sequences must be imperceptible to the observer.
- Robustness: the embedded watermark should resist various types of intentional and unintentional attacks, simultaneously the significant degrading of the quality of the video sequences there by lowering its commercial rate. Such processes are, for example, lossy compression, cropping, frame averaging, signals addition and frame collusion and dropping.
- Capacity: the quantity of data that can be added to the watermarked video is termed data payload. Any watermarking scheme should tolerate a convenient amount of data to serve the intended application [6].

Video watermarking has some issues that are not existing in digital image watermarking. For instance, adding a specific image watermark to each video frame produces the issue of perceptual invisibility and maintaining statistical [7]. In general, digital video watermarking systems are categorized into two classes. In the first class, the watermark is added to a video after compressing while in the second class, the watermark is added to a video without uncompressing.

Hsu and Wu [8] embedded a pseudo-random number sequences into inter and intra frames of MPEG-1 by means of DCT with several residual masks. Wang et. al [9] proposed video watermarking scheme of low computation complexity in the spatial domain. A nonblind watermarking algorithm was presented by [10] based on wavelet transform. They implemented the embedding process in the four subbands of the intra frame of the compressed MPEG video. The authors in [11] extended the process to include the embedding in the compressed MPEG-2 and uncompressed domains. The algorithm proposed by [12] was implemented in the discrete cosine transform (DCT) of each frame in the compressed MPEG-2 domain. The shortage of the present algorithms; neverthless, contains: (i) The embedded watermark is not robust against attacks which are particularly targeted at video frames. (ii) The watermark bit rate is low. Some schemes employ one bit of information as a watermark [13]. (iii) The high computational complexity as the majority of them implement the embedding in the transform domain. Most the existing schemes do not handle with these issues efficiently, in this regard, a new video watermarking algorithm is proposed in this paper to hide the watermark into the corresponding frequency components of integer to integer wavelet transform in video intra frames. Integer to integer wavelet transform algorithms provide low computational complexity because this transform has almost half the amount of calcuations as compared to tradational wavelet transform. Because of this decreasing in the computatinal complexity, integer wavelet schemes appear to be more appropriate for high performance applications and for the real time perormance. Moreover, perfect retreiving of the hidden watermark is provided by integer wavelet transform because their coefficients are integer. As a result, the perceptuality of the watermarked image is perserved and the hidden watermark can be successively extracted even when the watermarked images have been subjected to critical attacks. Additionally, the improved algorithm exhibits superior robustness against several video processing operations as compared to the existing schemes of copyright protection.

The arrangement of this paper is as follows: Section 2 and section 3 present the integral definition about Arnold transformand integer wavelet transform, respectively. In Section 4, the proposed algorithm is described, while in Section 5 explains the detailes of the experimental results. The conclusion is elaborated in Section 6.

2.   ARNOLD TRANSFORM

An efficient and famous method for image encryption is Arnold transform. In this method, each image is denoted by a two-dimensional matrix wherein both the number of rows and columns perform the pixel number for the image height and width, respectively [14]. For an image of a size N×N, the given Arnold process of the pixel trajectories (*x, y*) is:
where: n is the time repeated or iterative transformation and A is the Arnold transform matrix. Figure 1 shows the resulting Arnold transform when applied to the watermark Lena image.

$$\begin{bmatrix} x' \\ y' \end{bmatrix} = \begin{bmatrix} 1 & 1 \\ 1 & 2 \end{bmatrix} \begin{bmatrix} x \\ y \end{bmatrix} mod N, \quad x, y \in \{0, 1, \dots, N-1\} \tag{1}$$

The Arnold transform iterative expression is explained as follows:

$$P_{xy}^{n+1} = A P_{xy}^n \ mod \ N, P_{xy}^n = (x, y)^T \ n = 0, 1, \dots \tag{2}$$

To retrieve the original image, inverse Arnold transform is applied to the transformed image [15].

(a)   (b)

Figure 1. (a) Lena image (b) the scrambled Lena image

3.   INTEGER WAVELET TRANSFORM (IWT)

Despite the numerous advantages of the discrete wavelet transform in image processing applications, it is not appropriate to the invertible watermarking schemes as the reversibility is not assured [16]. Now, suppose a block of an image has integer-valuedpixels is converted into discrete wavelet transform using a floating point wavelet transform. If changing is done to the wavelet coefficients while the watermark is embedded, the corresponding image block with the watermark is no longer guaranteed to hold integer components. The truncation of floating point values of the pixels can lead to loss of information, and consequently, the reconstruction of the original watermark from the watermarked image is failed. In addition, the traditional wavelet transform is employed as a floating point decomposition followed by a rounding as it cannot represent the transform coefficients in their full precision: information can theoretically be changed during forward with inverse processes [15]. An invertible integer-to-integer wavelet transform, which is based on lifting, is employed in this work to overcome this problem. In this transform, there is no loss of information since the coefficients are mapped from integer to integerduring the forward and inverse processes [17].

According to the theoretical conception of the integer wavelet transform presented by [18], every one-dimension wavelet transform can be decomposed into one or multi lifting stages. Split, predict and merge are the main three operations for any IWT stage. Split and merge operations are used instead of up and down sampling processes present in DWT, so it can be considered as nonlinear wavelet transform. In addition, because of the split and merge processes, the computational cost is decreased to about a half as compared to the conventional wavelet transform.

3.1. A Image decomposition using an integer wavelet transform

The spatial-frequency domain of the integer wavelet transform has three stages: split, predict and update:
- Split stage: an image is split into two groups of pixel coefficients: odd and even [19]. This pair of coefficients is termed the poly phase matrix array. Let $I\ (m,n)$ is the matrix of a given image, then:

$$\begin{cases} Xe(m,n) = X(m,2n) \\ Xo(m,n) = X(m.2n+1) \end{cases} \tag{3}$$

$Xe(m,n)$: Even sample set;
$Xo(m,n)$: Odd sample set.
- Predict stage (dual lifting operation): in this phase, the odd coefficients set: $Xo(m,n)$ is predicted by the neighboring even coefficients. The resulting error from predicting the odd coefficients can be computed using the following prediction operator P:

$$h(m,n) = Xo(m,n) - P\lfloor Xe(m,n)\rfloor \tag{4}$$

where $h(m,n)$ is the prediction error which represents the high pass coefficients. The odd coefficients set can be canceled from (2) as depicted by (3).
- Update stage (optimal lifting operation): in this phase, the even sample is updated by the updating value: $Uh(m,n)$ to produce the low-pass coefficients: $l(m,n)$ as shown in the following equation:

$$l(m,n) = Xe(m,n) + Uh(m,n) \tag{5}$$

4.   THE ALGORITHM OF THE PROPOSED VIDEO WATERMARKING

4.1. Videopreprocessing

For an MPEG stream, there are three kinds of coded image as follows I-type, intra frame-type, and type of compressed employing intra frame coding, P, predicted frame, codded bymotion compression employing former I frames or P- frames and B, Bidirectional frame, codded with motion compensation usingpast Iframe or future P frame. In this work, only the I – frames are employed to embed the watermark to increase the robustness and decrease the complexityof the system [4, 20].

To obtain Iframes prior to the embedding step, the video stream is initially divided into I, Band P frames as depicted in Figure 2. As the embedding will be performed only in theRGBIframes, they are changed to YUVcolorelement: Y performs the luminance element for example the brightness while U and V perform the chrominance elementsi.e. color. To increase the imperceptibility of the proposed system, only the luminance component is employed to embed the watermark while the chrominance components are untouched [4].
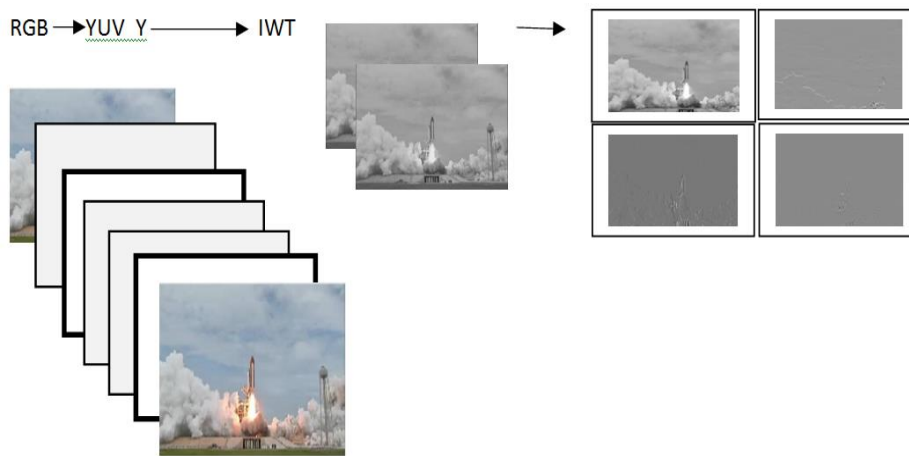

Figure 2. Splitting video stream and employing IWT on I- frames

4.2. The procedure of watermark embedding

Once the video stream is divided into frames, the operation watermark embedding is performed as the following steps:

- Applying the level one of integer wavelet transform with spline 5/3 to each frame of size *MxN*. The 5/3 integer wavelet transform is selected because it is quite easy to implement and permits exact reconstruction of the embedded watermark by avoiding the round off errors.
- After applying the integer wavelet transform, the main frame is divided into 4 sub-images, namely *LL*, approximate parameter; *HL*, horizontal detail parameter: *LH*, vertical detail parameter; *HH*, diagonal detail parameter.
- The robust watermark is a grey scale image of the same size of the cover frames, is scrambled by Arnold transform.
- The scrambled watermark is then transformed into four sub bands; *LLw*, *HLw*, *LHw* and *HHw* using discrete wavelet transform.
- Taking into consideration the imperceptibility and robustness of the watermarked image, the vertical detail sub band; *HHw* is chosen to be embedded inthe lowersub band of the decomposed frames; *LL* according to the following equation:

$$LL_{new} = \begin{cases} LL + \propto \times HHw, & LL < T \\ LL, & others \end{cases} \tag{6}$$

where: LL_{new} is the lower sub band of the cover frame after the modification,
$\propto$: is the embedding strengh used to adjust the invisibliy of the watermarked frame,
T : is the embedding and detection threshold.

- Performing inverse integer wavelet transform on LL_{new}, *LH*, *HL* and *HH* yields the watermarked frames.
- Finally, the watermarked video streams are converted back to RGB format.

To evaluate the imperceptibility of the watermarked frames, the peak-signal-to noise ratio (*PSNR*) [21] is considered between the watermarked frame; *F'* and the original frame; *F* as stated in the following:

$$PSNR = 10\, log_{10}\left[\frac{M \times N \times max(I)^2}{\sum_{i=1}^{M}\sum_{j=1}^{N}(I-I')^2}\right] \tag{7}$$

where *M*, *N*: represent frame dimensions.

4.3. Theprocedureof watermark detection

To perform the copyright protection, the watermark is extracted by applying the inverse process of the embedding side as follows:

- First, the RGB *I* frames of both the original video and the watermarked video are converted to YUV color componentand applying the first level of integer wavelet on them.
- The vertical sub band of the embedded watermark is obtained by applying the following equation:

$$HH_w = \begin{cases} \frac{LL_{new}-LL}{\propto} & LL < T \\ HH_w & otherwise \end{cases} \tag{8}$$

This equation performs the inverse operation of (6)

- The obtained vertical subband is added to the remaining subbands to get the grey scale watermark image by applying IDWT.

To compare between the original watermark: *W* and the retrieved watermark: *W'*, thenormalised cross-correlation is computed as follows:

$$NCC = \frac{\sum_{i=1}^{L} w(i) \times w\prime(i)}{\sqrt{\sum_{i=1}^{L} w^2(i)}\sqrt{\sum_{i=1}^{L} w\prime^2(i)}} \tag{9}$$

5.   EXPERIMENTAL RESULT

In order to perform the testing of the proposed watermarking system, it is carried out on two standard colored video clips. The first video is shuttle.ave compounds of 121 frames and rate of 30 fbs. The second video is Wild-life.ave compounds of 750 frames while the employed watermark is a grey scale image and the equal size of the video frame as depicted in Figure 3. The threshold: *T* is set to 330, also the watermark strength *k* is 0.03. The grey scale watermark is scrambled by Arnold transformprior the embedding stage as depicted in Figure 1.

As mentioned in section 4, the *PSNR* is employed for the imperceptibility evaluation and normalised cross correlation (*NCC*) between the original watermark and the retrieved watermark has been employed to evaluate the robustness of the presented system as depicted in (6) and (8), respectively. To prove the effectiveness of the proposed scheme in terms of achieved imperceptibility, the original and watermarked video frames are compared as depicted in Table 1.
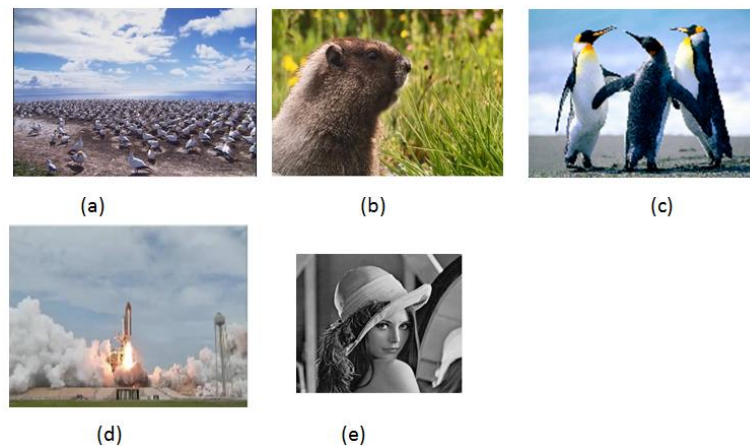

Figure 3. (a-d) Cover video frames (e) watermark image

Table 1. Imperceptibility evaluation of the proposed scheme

Original frame	Watermarkedframe/ *PSNR*	Extracted watermark/*NCC*
	PSNR=47.49	*NCC*=1
	PSNR= 49.62	*NCC*=1
	PSNR= 51.32	*NCC*=1
	PSNR= 47.82	*NCC*=1

The obtained *PSNR* varies from 47 to 51 dB and the watermarked frames look visibly similar to the original ones. In addition, the obtained values of *NCC*afterretrieving the watermark, in the case of no attack, is equal to one which means that the watermark is completely retrieved. In general, to ensure that the embedded watermark is invisible, the *PSNR*value of the watermarked image must be greater than 35 dB and the value of *NCC* should be one in case of no attack [22] and the acceptable value of *NCC* should be equal to or above 0.75 [23]. Consequently, the achieved value of *PSNR* is considered as reasonable and high.

To evaluate the rigidity of the system fairly, several geometrical and nongeometricalattacks are performed. The attacks are performed on each frame of the watermarked video and the watermark is extracted from each video frame. The obtained watermark is then compared with the original watermark and *NCC* has been calculated as detailed in Table 2. None geometric attacks are treated as removal attacks that attempt to totally remove or deteriorate the watermark from the linked content. This type contains filtering, JPEG and noise attacks. Gamma correction is listed under denoising attacks.

It is clear from the above table that the proposed method has high resistance against the mentioned attacksas it has the ability to detect the existence of the embedded watermark even after the severe attacks. In order to demonstrate the performance of the system over the other existing techniques, the results of two other schemes are compared with the proposed algorithm. The first algorithm is a DWT based video watermarking [24] while the second algorithm is integer wavelet transform based [25]. The chosen attacks for benchmarking these three schemes are median filter and noise addition as depicted in Table 3. The achieved values of *NCC* for [24, 25] are between 0.50 and 0.97, respectively whereas the comparable value of *NCC* for the proposed technique is more than 0.89. The achieved values show that the proposed technique displays more robustness against the mentioned attacks as the achieved *NCC* exceed the acceptable limit 0.75 [23].

Table 2. *PSNR* and *NCC* results of the prosed scheme under various attacks

Attacks	Watermarked image/*PSNR*	Extracted Watermark/*NCC*
Median filter [3 3]	*PSNR*=22.54	*NCC*=0.955
Gamma Correction (.6)	*PSNR*=15.67	*NCC*=0.987
Salt and Pepper (0.01)	*PSNR*=16.84	*NCC*=0.954
Gaussian filter [3 3]	*PSNR*=11.68	*NCC*=0.998
Speckle noise 0.3	*PSNR*=8.852	*NCC*=0.821
JPEG compression = 20	*PSNR*=11.54	*NCC*=0.977
blurring	*PSNR*=4.955	*NCC*=0.814

Table 3. Benchmarking the prosed scheme with others

Attacks	DWT[24]	LWT[25]	Proposed algorithm
Salt and Pepper	0.79	0.87	0.99
Gaussian filter	0.88	0.51	0.99
Median filter	0.80	0.86	0.97
Gaussian	0.73	0.83	0.96
Contrast	0.50	0.97	0.98
Poisson	0.62	-	0.89

6.   CONCLUSION

Imperceptibility and robustness are typically a trade off in video watermarking algorithms. Nevertheless, to satisfy both parameters, this paper presented a significant video watermarking scheme which based on combination of Arnold transform and integer wavelet transforms. This choice permits to obtain high robustness to several attacks. In addition, to increase the imperceptibility of the system, a layer of luminance has been selected for the embedding operation. Afterward, the watermark embedding is implemented to its corresponding coefficients of lifting wavelet transform in video I-frames. This scheme preserves high imperceptibility of video frames,as well as, results in high resistance to several attacks such as noise addition, filtering blurring and compression. In addition, the proposed system has outperformed the existing algorithms in terms of Imperceptibility and robustness.

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