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# A High Capacity Digital Watermarking Scheme for Copyright Protection of Video Data based on YCbCr Color Channels Invariant to Geometric and Non-Geometric Attacks

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## ABSTRACT
Digital video is becoming popular more than ever due to the widespread of video-based applications. However, a byproduct of such popularity is the worldwide unauthorized copying and distribution of digital video. Digital watermarking has been proposed in the last decade as a solution to prevent unlawful and malicious copying and distribution of digital media by embedding unnoticeable information (called watermark) into the media content. In this study, a robust and heuristic algorithm based on DWT for video watermarking is presented. With the aim of providing the security of the proposed method, the watermark is encrypted first, then the color video is partitioned into units of fixed length. Embedding process is followed by detecting the key-frames in each shot. In order to make the watermark imperceptible, RGB video stream is converted into YCbCr color space. The luminance layers are chosen to embed the watermark and the chrominance layers are left unchanged. Eventually, by using a multiplicative hiding method, watermark image is embedded into frequency components of frames. Using this method a large amount of data can be hidden in a video. Furthermore, the presented method maintains a good transparency of video stream meanwhile resists the watermark against a variety of attacks including geometric attacks such as rescaling, rotation, and non-geometric attacks like Gaussian noise, salt & pepper noise, speckle noise, median & low-pass filtering, blurring, JPEG and MJPEG compression.

## General Terms
Information Security, Digital Rights Management, Multimedia, Encryption.

## Keywords
Image Scrambling, YCbCr Color Channel, Copyright Protection, Capacity.

## 1. INTRODUCTION
The rapid progress of the Internet and the potential problem of illegal distribution of multimedia have made the copyright protection an important practical problem in the area of multimedia security. Principal actors involved in copyright protection are the content generators (e.g. cinema industry), the Information Technology industry, the licensing agency, the Consumer Electronics industry and the consumers. Classical approach for multimedia security is to employ encryption technologies. However, once the multimedia content is decrypted, there is nothing to protect it. For this purpose, the digital watermarking has received considerable attention in the last years, since it has been revealed as an efficient way to the protection of intellectual property rights such as copyright protection, data authentication and fingerprinting and so on [1].

The main concept of digital watermarking is to insert a watermark or a metadata containing information relative to the multimedia host data. This information could be the copyright, logo, signature or any other useful information. The detection of watermark from the watermarked data can then prove the ownership or the copyright of the host data [1].

The watermarking techniques are grouped as text-based watermarking [2,3], image watermarking [3], video watermarking [4], audio watermarking [5] and 3D watermarking [6]. As almost 90% of the contents are being transmitted in image and video [7,8], a number of techniques have been developed for these two groups.

Most of the proposed video watermarking schemes are based on the techniques of image watermarking. But video watermarking introduces some issues which are not presented in image watermarking such as the large volume of inherently redundant data between frames. Numerous inventive watermarking approaches have been proposed in these few years. These techniques can be categorized into two main groups: the spatial domain methods and the transform domain methods. The spatial domain methods are the earliest and simplest watermarking techniques but they have a low information hiding capacity, and the watermark can be easily erased by lossy compression. On the other hand, the transform domain approaches insert the watermark into the transform coefficients of the original image, yielding more information embedding and more robustness against watermarking attacks.

Recent popular transforms contain the Discrete Cosine Transform (DCT) [9], the Discrete Wavelet Transform (DWT) [10], and the Discrete Fourier transform (DFT). Image watermarking techniques can be easily extended to video watermarking [1,11,12,13]. For digital watermarking of video, different characteristics of the watermarking process as well as the watermark are desirable. These requirements are imperceptibility, robustness and capacity. Also in order to enhance the safety of algorithm another feature, i.e. security, can be added to the main necessities of video watermarking.

***Imperceptibility*:** A degree that an embedded watermark remains unnoticeable when a user observes the watermarked digital media. The information should embed the watermark in the regions of the video frame in which imperceptibility is least affected [14].

***Robustness***: It should be impossible to manipulate the watermark by intentional or unintentional operations on the uncompressed or compressed video, at the same time, degrading the perceived quality of the digital video significantly thereby reducing its commercial value. Such operations are, for example, addition of noise, cropping, lossy compression, filtering, and collusion [15].

***Capacity***: A watermarking system must allow for a useful amount of information to be inserted into a video. The amount of information that can be embedded in a watermarked video is called data payload. The data payload in video watermarking means the number of bits encoded with the video. The payload of the embedded watermark information must be sufficient to enable the envisioned application [16].

***Security***: The ability of the watermark to resist attempts by a sophisticated attacker to remove it or destroy it via cryptanalysis, without modifying the video itself [17].

Several image/video watermarking schemes have been developed in the past few years, for watermark embedding in wavelet domain. A wavelet-based watermarking scheme was delivered in Ref. [18] which uses two trees for embedding each watermark bit. One of the two trees is quantized with respect to a quantization index, and both trees exhibit a large statistical difference between the quantized tree and the unquantized tree; the difference can later be used for watermark extraction. Also a wavelet tree based watermarking method using distance vector of binary cluster was suggested in Ref. [19]. In this method wavelet trees are classified into two clusters using the distance vector and insignificant wavelet coefficients of wavelet trees are used to embed the watermark. In Ref. [20] another watermarking method based on the DWT using maximum wavelet coefficient quantization was proposed. They used variable block sizes and embed a watermark bit using different sub-bands which are selected randomly from two sub-bands. On the other hand, in the domain of embedding the watermark into key-frames, a digital video watermarking scheme based on Principal Component Analysis (PCA) was proposed in [12]. This scheme extracts the key-frames of video, and then using PCA transform embeds the watermark in all three color channels of RGB video frame. In this method each key-frame is considered as a separate image. Also in [13] a novel approach for embedding the watermark in video key-frames was presented. This scheme extracts a certain number of key-frames (i.e. the first, the middle, and last key-frame) and then modifies blocks of these key-frames by exploiting the average color of the homogeneity regions of the cover image. However, the aforementioned methods have not enough robustness against geometric attacks. Also they contain a low capacity for embedding the watermark. Furthermore they did not guarantee the security of their proposed algorithms (e.g. applying encryption techniques for implemented algorithms).

Inspired by the aforementioned methods and using the multi-resolution features of DWT, a novel watermarking technique for embedding the watermark into key-frame of video which is robust against both geometric and non-geometric attacks is proposed. The simulation results depict that the proposed scheme is robust against a variety of attacks including Gaussian noise, salt & pepper noise, speckle noise, median filtering, low-pass filtering, rotation, rescaling, motion blurring, JPEG and MJPEG compression.

The rest of paper is organized as follows: Section 2 expresses an integral definition about discrete wavelet transform. Section 3 explains the preprocessing of watermark before embedding. Section 4 presents the proposed watermarking algorithm. In section 5, the simulation results are illustrated. Finally, section 6 concludes the paper.

## 2. DISCRETE WAVELET TRANSFORM

The wavelet transform is a valuable tool for multi-resolution analysis that has been broadly used in image/video processing applications. The wavelet transform has a number of benefits over other transforms as it presents a multi-resolution description, it allows superior modeling of the human visual system (HVS), the high resolution sub-bands allow easy detection of features such as edges or textured areas in transform domain.

The DWT (Discrete Wavelet Transform) separates an image into a lower resolution approximation image (LL) as well as horizontal (HL), vertical (LH) and diagonal (HH) detail components. For each successive level of decomposition, the LL sub-band of the previous level is utilized as the input.

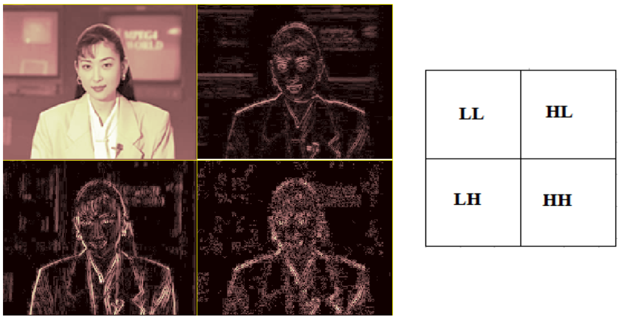
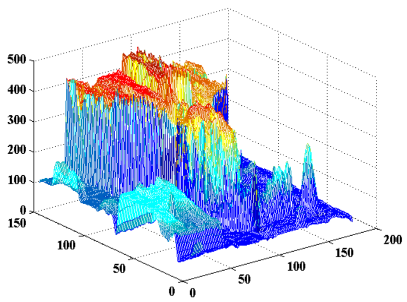



**Fig 1: One level of DWT decomposition for Akiyo video sequence**

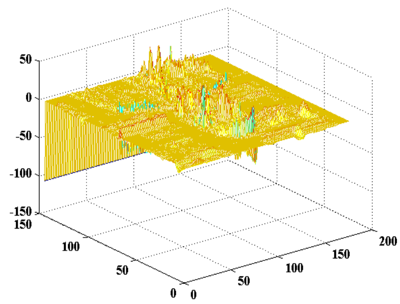
Performing one-level of decomposition over an image results in 4 sub-bands per component. HH contains the highest frequency bands present in the image tile, while LL contains the lowest frequency band [21]. Fig. 1 depicts an example of one-level DWT over one frame of the Akiyo video sequence.

### 2.1 DWT AND IMAGE MULTI-RESOLUTION ANALYSIS

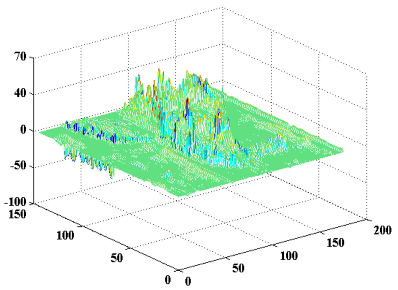
From human visual point of view, it is generally believed that the watermark information should be embedded into the component which has the greatest impact on human vision. As the important components in vision are usually the main components of images, they include most of the energies in the image signal. If the image is so disturbed by noise that a certain degree of distortion is produced, generally it will not lead to a greater visual impact. It indicates that the image retains its major components, and also shows that the main



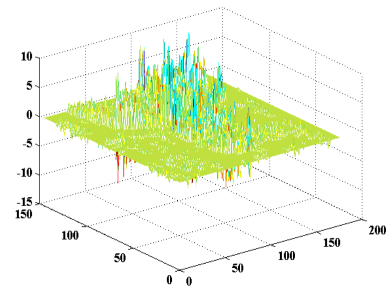

**LL**




**HL**




**LH**




**HH**

**Fig.2 Energy sub-bands of Akiyo video sequence which is depicted in Fig.1**

components of the image have a strong anti-interference ability. Therefore, by embedding the watermark in this part, a better robustness can be achieved [22].

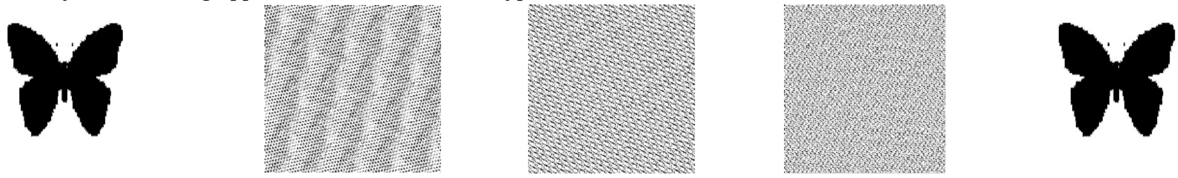
In Ref. [23], the authors experimentally showed that embedding the watermark in the low and high frequency components of an image increases the robustness against attacks. Moreover, inserting the watermark in low-frequency components increases the robustness against attacks that have low frequency characteristics such as filtering and geometric distortions; furthermore, embedding the watermark in the middle and high frequency components is typically less robust against low-pass filtering and small geometric deformations of the image. According to Fig. 2 the main energy of image is concentrated in LL sub-band of wavelet, so it has the main effect on HVS and can be a good candidate for embedding the watermark, as inserting the watermark image in this part can guarantee the robustness of system against attack which has low frequency characteristics like filtering and geometric distortions.

## 3. WATERMARK PREPROCESSING

Usually scrambling transform is used in the pretreatment stage of the watermark as a way of encryption. Generally, a meaningful watermark image becomes meaningless and disordered after scrambling. For improving the security and confidentiality, a scrambling approach [24] is used to encrypt the binary watermark image. After scrambling, human eyes cannot distinguish the shape of the original watermark. Without the scrambling algorithm and the key(s), the attacker will not recover the watermark at all even if it has been extracted from the watermarked video. So shuffling the image gives a secondary security for the digital products. This method is defined as follows:

$$\begin{bmatrix} x_{n+1} \\ y_{n+1} \end{bmatrix} = \begin{bmatrix} 1 & a \\ b & ab+1 \end{bmatrix} \begin{bmatrix} x_n \\ y_n \end{bmatrix} \text{mod}(N) \quad (1)$$

Where $(x_n, y_n)$ is the pixels position in an $N \times N$ image; $(x_{n+1}, y_{n+1})$ is the transformed position after cat map; *a* and *b* are the system parameters and must be the positive integers. The determinant value is 1, so cat map is a map which keeping area (no attractor). At the same time, the cat map is one-to-one mapping; each point in matrix can be transformed to another point uniquely. Cat map has two typical factors, which bring chaotic movement: tension (multiply matrix in order to enlarge *x*, *y*) and fold (taking mod in order to bring *x*, *y* in unit matrix). In fact, cat map is a chaotic map. Image position can be scrambled via the iteration of cat map. By considering (a=10,b=15), consequently the encrypted image will be achieved. After a period of iteration the original watermark image will be attained.



**(a)** **(b)** **(c)** **(d)** **(e)**

**Fig.3 (a) Watermark image; (b) Encrypted image(iteration=30); (c) Encrypted image(iteration =75); (d) Encrypted image(iteration =142); (e) Recovered watermark image (iteration =192)**

So iteration times and system parameters (a,b) can be used as the encryption keys. By using these three keys the security of our scheme will be enhanced. This process is shown in Fig.3.

# 4. THE PROPOSED VIDEO WATERMARKING SCHEME

## 4.1 Video Preprocessing

It is not a reasonable video watermarking scheme of directly extension of image watermarking by taking each frame as an individual still image. Since this method has two disadvantages. First, the pirate can easily extract the watermark by statistical comparing or averaging of the successive video frames. Second, it is impossible to embed watermark into each frame in real time for a large amount of data and high computational complexity. On the other side, RGB color space is highly correlated and is not suitable for watermarking applications.

So at the first step, video is partitioned into units of fixed length and then RGB video is converted to YCbCr color component (Y represents the luminance component; Cb and Cr represent the chrominance components). In order to make the watermark imperceptible, the luminance layers of key-frames are used to embed the watermark and the chrominance layers are left unchanged. Equation 2 shows conversion from RGB color space to YCbCr and Equation 3 shows the conversion of YCbCr color space to RGB [25].

$$\begin{bmatrix} Y \\ Cb \\ Cr \end{bmatrix} = \begin{bmatrix} 16 \\ 128 \\ 128 \end{bmatrix} + \begin{bmatrix} 0.257 & 0.504 & 0.098 \\ -0.148 & -0.291 & 0.439 \\ 0.439 & -0.368 & -0.071 \end{bmatrix} . \begin{bmatrix} R \\ G \\ B \end{bmatrix} \quad (2)$$

$$\begin{bmatrix} R \\ G \\ B \end{bmatrix} = \begin{bmatrix} 1.164 & 0.000 & 1.596 \\ 1.164 & -0.392 & -0.813 \\ 1.164 & 2.017 & 0.000 \end{bmatrix} . \begin{bmatrix} (Y-16) \\ (Cb-128) \\ (Cr-128) \end{bmatrix} \quad (3)$$

## 4.2 Watermark Embedding Procedure

**Step 1**: Performing first level of Haar wavelet transform over key-frames which are M×N in size. Haar wavelet is the simplest compactly supported orthogonal wavelet function which has features like uncomplicated computation and easy to use and so on. Different levels of wavelet decomposition are applied in our method and we found that more than one level wavelet i.e. two, three,…, levels wavelet will decrease the robustness of watermark. Also, as the watermark is planned to be extracted from the low-frequency sub-band of wavelet, so by performing more levels of wavelet, the capacity of watermark will be decreased, this matter is visually shown in Fig. 5. Furthermore performing more levels of wavelet reduces the quality of video with increasing in computational complexity; therefore it is appropriate to carry out only one level wavelet decomposition. So, key-frames are decomposed into four sub-images which any of them have the same size, namely LL, approximate wavelet coefficient; HL , horizontal detail coefficient; LH , vertical detail coefficient; HH , diagonal detail coefficient. These coefficients are depicted in Fig. 1.

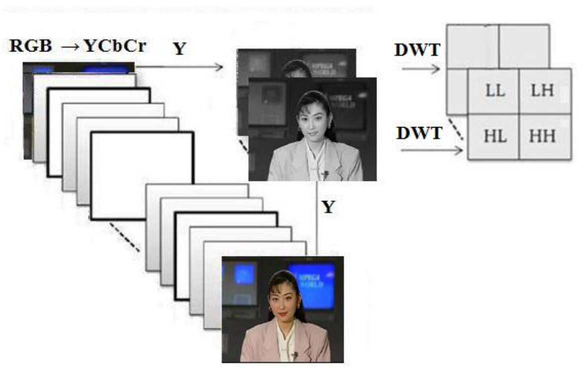



**Fig4. Splitting video stream into frames and performing 2D-DWT on key-frames**

**Step 2:** the first level of Haar wavelet decomposition is performed on the watermark image, too. Therefore, four sub-images, can be gotten, namely, $LL_W$ , $HL_W$ , $LH_W$ and $HH_W$ , respectively.

**Step 3:** Taking into account the transparency of the embedded watermark, $LL_W$ is embedded into LL; also, taking into account the robustness $HL_W$, $LH_W$, $HH_W$ are embedded into detail coefficients of HL, LH, HH, respectively. Watermark embedding algorithm adopts multiplicative hiding method [26]:

$$\begin{cases} C_a = (1+\alpha_1.LL_W).LL \\ C_h = (1+\alpha_2.HL_W).HL \\ C_v = (1+\alpha_3.LH_W).LH \\ C_d = (1+\alpha_4.HH_W).HH \end{cases}$$

Where $\alpha_1$, $\alpha_2$, $\alpha_3$, $\alpha_4$ are the power factors which are used to control the features of the embedded watermark. If they get larger values, the watermark will have good robustness ability, but its transparency will be poor; if they get smaller values, the watermark will have poor robustness ability, and its transparency will be good.

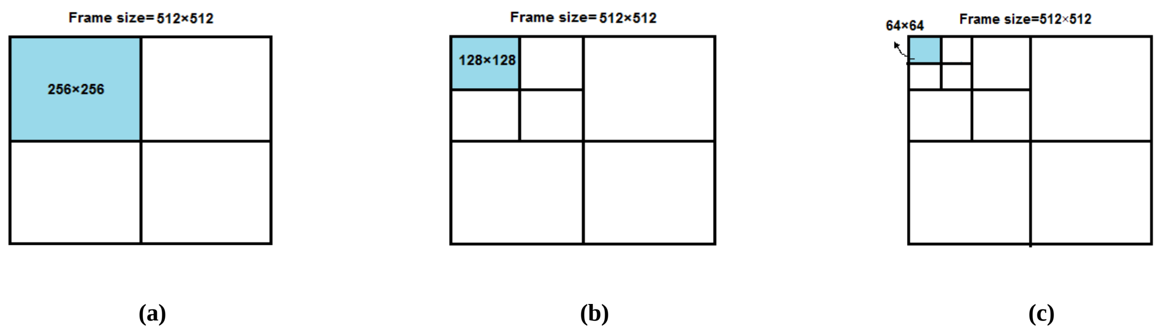



**Fig. 5 The capacity of the proposed watermarking scheme for different levels of wavelet decomposition; (a) one level (b) two levels (c) three levels.**

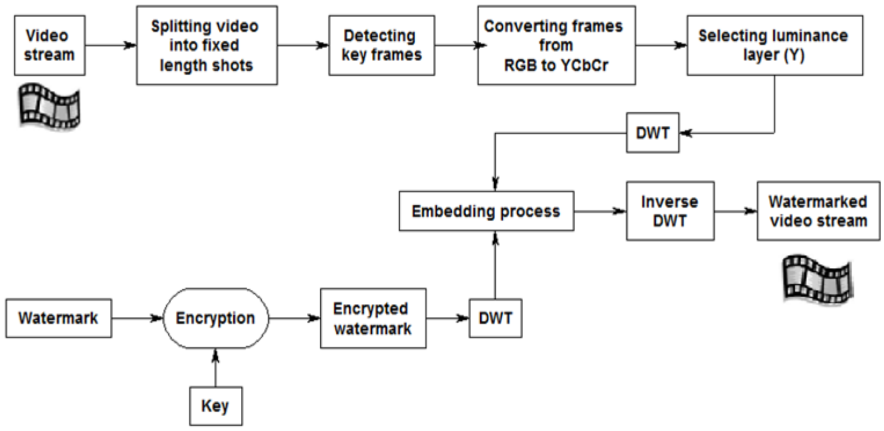



**Fig.6 Block diagram of the proposed watermarking scheme**

Obviously, robustness and transparency should be taken into account in the watermark embedding process. In addition, experiments show that the power factor values vary in different videos. Experimentally we found that the above power factors should be within the range of 0.01 and 0.09.

The new coefficients of $C_a$, $C_h$, $C_v$, $C_d$ are the decomposed sub-images of the watermarked frame. Among these sub-images, the main influence on watermark is related to $C_a$, because it has the most energy respect to other sub-images.

**Step 4:** Applying IDWT on the earned new coefficients i.e. $C_a$, $C_h$, $C_v$, $C_d$ gives the watermarked frames. The process of embedding is shown in Fig. 6.

## 4.3 Watermark Extraction Procedure

The extraction process is non-blind, consequently the original video is needed. This section is followed like embedding process:

**Step 1**: Decomposing both watermark video stream and original video stream into shots and then detecting key-frames.

**Step 2**: Conducting first level of Haar wavelet transform on original key-frames and watermarked key-frames, respectively. Detail sub-images and two low-frequency approximation sub-images i.e. $C_a$ and $C_{aw}$ are achieved.

**Step 3**: By performing the inverse operation of the embedding process using the low-frequency approximation sub-images i.e. $C_a$ (original low-frequency approximation) and $C_{aw}$ (watermarked low-frequency approximation) and finally by defining a threshold the watermark image can be clearly detected .It means:

If Obtained watermark $\leq$ Th
Then watermark is *detectable*
End

# 5. Simulation Results and Discussions

The proposed watermarking scheme is performed on two different color video sequences (i.e. Akiyo and Bus sequences) which are shown in Fig. 7(a). Both of them are the same size of 256×256. These sequences are 30 fps and in a period of 10 seconds. Also a binary image (butterfly) with the same size of video sequences is considered as the watermark (Fig. 3(a)).

## 5.1 Imperceptibility

Generally, the accurate measurement of the invisibility as perceived by a human observer is a great challenge in image/video processing. The reason is that the amount and visibility of distortions introduced by the watermarking attacks strongly depend on the actual image/video content [27]. To measure the perceptual quality, we calculate the peak to signal-to-noise ratio (PSNR) that is used to estimate the quality of the watermarked frames in comparison with the original ones. The PSNR [28] is defined as follows:

$$PSNR = 20\log_{10}\left(\frac{\max_i}{\sqrt{MSE}}\right) \quad (4)$$

Where $\max_i = \max\left\{\hat{F}_{ij}, 1 \leq i, j \leq m\right\}$ and the MSE is the mean squared error between the cover frame $F$ and the watermarked frame $\hat{F}$:

$$MSE = \frac{1}{m^2}\sum_{i=1}^{m}\sum_{j=1}^{m}\left\|F_{ij} - \hat{F}_{ij}\right\|^2 \quad (5)$$

Where *m* defines the number of frames. As mentioned before the value of $\alpha_i$ can vary in different video sequences. It should be noted that $\alpha_2$, $\alpha_3$ and $\alpha_4$ have very insignificant influence on the transparency of video sequences meanwhile $\alpha_1$ has the main effect on the transparency. So for implementing a good trade-off between the robustness and imperceptibility $\alpha_1$ is considered as 0.01565 in our method. Also in order to detect the watermark after facing all attacks Th (threshold) is considered as 0.9.

A comparison between the original and watermarked video sequences shows that the watermark invisibility achieved by this method is very effective. Fig. 7 testifies the transparency of the watermarked videos.

**PSNR=38.52** **PSNR=40.08**

**Fig.7 The First row shows the original video sequences and the second row shows the watermarked video sequences.**

## 5.2 Robustness

After extracting and refining the watermark, a similarity measurement between the extracted and reference watermark is used for objective judgment of the extraction fidelity which defined as:

$$NC = \frac{\sum_i \sum_j W(i,j)\hat{W}(i,j)}{\sum_i \sum_j [W(i,j)]^2} \qquad (6)$$

Which is the cross-correlation normalized by the reference watermark energy to give unity as the peak correlation [29]. In this experiment this measurement is used to evaluate the robustness of proposed scheme. Extracted watermarks are shown in Fig. 8.

**(a) NC=0.9954** **(b) NC=0.9846**

**Fig.8 The extracted watermark (a) from Akiyo sequence (b) from Bus sequence**

The extraction process shows that the size of obtained watermark is changed, because the watermark image is extracted from the low-frequency part of key-frames, so the size of extracted information is 1/2 of the original watermark size (i.e. 128×128). By comparing the capacity of the proposed watermarking algorithm with other literatures, it can be easily found that, our scheme provides a high payload for insertion of watermark. This significance is illustrated in section 5.4.

## 5.3 Assessment of robustness

Several experiments have been carried out to evaluate the robustness of the proposed watermarking algorithm. For this purpose, different attacks are performed on the watermarked video. The embedded watermark is retrieved using the proposed algorithm and the NC value of the recovered watermark is recorded for different attacks. These selected attacks are Gaussian noise, salt and pepper noise, speckle noise, rotation, rescaling, median filtering, low-pass filtering, blurring, MJPEG compression and JPEG compression which any of them have a particular effect on the watermarked video.

From the literature, we know that the wavelet transform is not rotational invariant. The potential point of the presented algorithm is its capability for extracting the watermark for acceptable values of rotation. Some of these attacks are explained as follows:

### *5.3.1 Filtering*

One of the most common manipulations in digital videos is filtering. The extracted watermark, after applying 3×3 median filtering and low-pass filtering is achieved. By applying these filters, videos are significantly degraded and lots of data are lost but the extracted watermark image is still recognizable with high NC value.

### *5.3.2 Addition of Noise*

Addition of noise is another method to estimate the robustness of the watermark. Generally, addition of noise is responsible for the degradation and distortion of the video. The watermark information is also degraded by noise addition and results in difficulty in watermark extraction. So, in order to test the robustness of the proposed system 0.01% Gaussian noise with zero mean, 4.5% salt & pepper noise, and 0.4% speckle noise are added to video stream, respectively.

**Median filtering** **Salt & pepper noise**

**Fig.9 An example of filtering and noise attack over one frame of watermarked Akiyo video sequence**

### *5.3.3 Rescaling and rotation*

To fit the video into the desired size, enlargement or reduction is generally performed and results in information loss of the video including embedded watermark. For this attack, first the size of the watermarked video is reduced to 128×128 and again brought to its original size 256×256. Also, from the literature, we know that the wavelet transform is not rotational invariant. The proposed method can extract the watermark for an acceptable rotation values. We extracted the watermark from 5° rotated watermarked image. The effect of rotation and motion blurring are shown in Fig. 10.

**Rotation(5°)** **Motion blurring**

**Fig.10 An example of rotation and motion blurring over one frame of watermarked Akiyo video sequence**

### *5.3.4 JPEG & MJPEG compression*

A popular manipulation in digital image is image compression. To check the robustness of the proposed method against image compression, the watermarked frames are tested with JPEG compression attacks. The watermarked frames are compressed with a quality factor of 80% and then the watermark image is extracted. Also MJPEG is one of the common video compressors which reduce the volume of video significantly. But the extracted watermark is still clearly detectable. This compression is also done with a quality factor of 80%.

The considered attacks are executed on the watermarked video and their results are depicted in Table 1. This table shows the satisfactory robustness of the proposed method for different kinds of attacks.

**Table 1. Effect of various attacks on the proposed video watermarking algorithm based on NC**

| Attacks | Akiyo | Bus |
|---|---|---|
| No attack | 0.9954 | 0.9846 |
| Motion blurring | 0.9290 | 0.7326 |
| Median filtering ( windows size= [3 3]) | 0.9496 | 0.6768 |
| Low-pass filtering ( windows size= [3 3]) | 0.9170 | 0.6983 |
| Salt & pepper noise (density=2.5% ) | 0.9157 | 0.9165 |
| Gaussian noise (mean=0,variance=0.01%) | 0.8620 | 0.8266 |
| Speckle noise (variance=0.4%) | 0.7225 | 0.7215 |
| JPEG compression ( quality factor=80 ) | 0.9318 | 0.8079 |
| MJPEG compression (quality factor=80) | 0.8183 | 0.7119 |
| MJPEG compression (quality factor=100) | 0.9151 | 0.8628 |
| Rotation (5°) | 0.8763 | 0.6691 |
| Rescaling (50%) | 0.9118 | 0.6810 |

## 5.4 Comparison with other existent methods:

In order to show the preference of the proposed scheme in comparison with existent algorithms, the robustness of the proposed scheme is compared with the results of other two recently delivered algorithms.

Method [19] is a wavelet tree based watermarking method which uses distance vector of binary cluster. In this method wavelet trees are classified into two clusters using the distance vector and insignificant wavelet coefficients of wavelet trees are used to embed the watermark. Also, in method [20], the maximum wavelet coefficient quantization is used for watermarking process. The authors used variable block sizes and embed a watermark bit using different sub-bands which are selected randomly from two sub-bands. However, the aforementioned methods have not enough robustness against geometric attacks. Also they contain a low capacity for embedding the watermark. Furthermore they did not guarantee the security of their proposed algorithms (e.g. applying encryption techniques for implemented algorithms).

By extending these image watermarking scheme [19,20] over key-frames of video, and considering the same size of 512×512 for all methods of Table 2, there will be a fair comparison among the methods. The selected attacks for this purpose are median filtering, JPEG compression, rotation, and rescaling. As it can be observed from table 2, the presented method has better robustness compared to other two algorithms.

**Table.2 Comparison of the proposed algorithm with other two algorithms based on NC**

| Attacks | Ref. [19] | Ref.[20] | Proposed |
|---|---|---|---|
| Median filtering (3×3) | 0.92 | 0.90 | 0.95 |
| Median filtering (4×4) | 0.75 | 0.76 | 0.81 |
| Median filtering (7×7) | NA | 0.53 | 0.83 |
| JPEG(QF=90) | 1 | 0.99 | 0.94 |
| Rotation (0.25°) | 0.61 | 0.59 | 0.95 |
| Rotation (0.75°) | 0.34 | NA | 0.90 |
| Rotation (-0.25°) | 0.65 | 0.60 | 0.95 |
| Rescaling (50%) | 0.86 | 0.88 | 0.91 |

As Table 2 depicts, the presented method has improved the robustness of watermarking for attacks such as filtering, rotation and rescaling in contrast with other two algorithms. Furthermore our method is resistant to another group of attacks like motion blurring, salt & pepper noise, speckle noise, low-pass filtering and MJPEG compression.

Concerning the preference of the proposed method because of including the security compared to other algorithms (because of using encryption in watermark preprocess), it has higher capacity for embedding the watermark. As Fig. 11 shows, in [19,20], the achievable embedding capacity were limited to 0.002 bpp (bits per pixel) i.e. 512 bits for a frame size of 512×512, whereas our approach delivers a higher embedding capacity of 0.25 bpp for a frame size of 512×512.

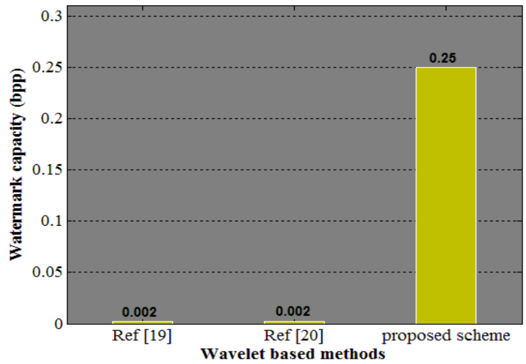



**Fig.11 Comparison of watermark capacity among wavelet based methods**

Then, by applying DWT, watermark is embedded into the luminance layer of YCbCr video frames. The method is easy to implement and has low computational complexity, furthermore the experimentally determined robustness shows that the proposed method can be used without fear of being detected or changed. So the delivered algorithm provides a new approach for digital video watermarking research and practice.

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