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A Double Embedding of an Anti-Removable Visible Logo Using Discrete Wavelet Transform and Chaotic Map

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Abstract

The aims of visible watermarking are to prevent the illegal copying of videos and images and to avoid the theft and unauthorized advertisement of the legitimate owners' content. The visible watermark is distinguishable with the naked eye. This makes it easily removed by an attacker. This paper proposes an anti-removable visible logo by double embedding using the discrete wavelet transform (DWT) and a chaotic map. The main purpose of this method is to prevent the removal attack and restore the original video without information loss after the logo is legally removed. DWT is used for both the cover area and the logo to embed sub-bands of information from the cover area into sub-bands of the logo. The main idea of using a chaotic map is to make it difficult to recover the original video when the logo is removed by illegal means. The experiment results show that the proposed method is robust against illegal watermark removal. In addition, video frames were recovered without loss after the legal extraction process.

Keywords: Discrete Wavelet Transform (DWT), Chaotic Map, Visible Watermark

تضمين مزدوج لشعار مرئي غير قابل للإزالة باستعمال التحويل المويجي المنفصل والخريطة الفوضوية

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الخلاصة

تهدف العلامة المائية المرئية الى منع النسخ غير القانوني لمقاطع الفديو والصور وتجنب السرقة والإعلان غير المصرح به لمحتوى المالكين الشرعيين. من الممكن تمييز العلامة المائية المرئية بالعين المجردة وهذا يجعل من السهل إزالة العلامة المائية من قبل المهاجمين. حيث تقترح هذه الورقة شعارًا مرئيًا من الصعب ازالته وهذا يتم عن طريق عملية التضمين المزدوج باستعمال التحويل المويجي المنفصل وخريطة فوضوية. حيث ان الغرض الرئيسي من هذا النظام هو منع ازالة العلامة المائية بطريقة غير قانونية, واستعادة الفديو الأصلي دون فقد المعلومات بعد إزالة الشعار بطريقة قانونية. يستعمل التحويل المويجي المنفصل لكل من منطقة الغلاف (منطقة العلامة المائية) والعلامة المائية لتضمين النطاقات الفرعية لمعلومات من منطقة العلامة المائية في النطاقات

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الفرعية للعلامة المائية. والفكرة الرئيسية من استعمال خريطة فوضوية هي جعل من الصعب استعادة الفديو الأصلي عند إزالة الشعار بوسائل غير قانونية. أظهرت نتائج التجربة أن الطريقة المقترحة قوية ضد الإزالة غير القانونية للعلامة المائية. بالإضافة الى استرجاع اطارات الفديو بدون فقدان عند ازالة العلامة المائية بطريقة قانونية .

1. Introduction

In these days of quick advancements in computer and Internet technology, there is an enormous amount of digital data available online. This data may be accessed, collected, or modified by anybody utilizing processing tools. The aforementioned factors make it clear that data authentication and copyright are major roadblocks for legal owners. Watermarking, both visible and invisible, is one of several solutions to this problem [1]. Visible watermarking is a type of watermarking that is used to mark and protect the copyright of digital images or videos for certain reasons. This is meant to deter illegal usage of the image. However, because the watermark is visible, the owner of the video is concerned about preventing an unauthorized user from removing the watermark [2]. There are two techniques for watermarking: spatial and frequency domain techniques [3]. However, techniques used in the frequency domain, sometimes referred to as the transform domain, are more reliable than those used in the spatial domain [4]. Some characteristics should be met by visible watermarking approaches, such as transparency, perceptibility, distinguishability, and robustness [5].

The work described in this paper aims to develop a video copyright protection system that is very effective in recovering the original video without any loss after the watermark has been removed and is also resistant to removal assault. Specifically, we propose a visible watermark method based on DWT and the chaotic map. Arnold's modification initially confuses the cover area data. Then, both the confused cover area and the watermark are transformed by the DWT transform. Finally, two embedding processes will accrue: embedding the confused cover area into the watermark image and embedding the modified watermark into the frame.

This paper is organized as follows: Section 2 addresses related work. Some theoretical backgrounds are listed in Section 3, including DWT and Arnold's Map. The proposed work is shown in Section 4. Section 5 discusses the proposed work and the results, and Section 6 wraps up the conclusions.

2. Related work

The visible watermarking schemes were developed to resist some types of attack and solve the problem of lossy recovered information [6]. Some of the published works related to the visible watermarking are given in the following paragraphs.

- [2] proposed a method for creating a lossless visible watermark utilizing modified DCT coefficients of an image. The host image's DCT coefficients become covered to embed the watermark's DCT coefficients. Consequently, the 2-dimensional DCT is carried out via integer mapping. The suggested method, which adheres more strictly to Kerckhoff's concept, provides greater protection against attempts to erase watermarks, and reversibility is provided by keeping the watermarked image's lossless format.

- [7] proposed visible watermarking for video based on the Haar Discrete Wavelet Transform (HDWT). The video size is reduced by compressing the video using HDWT. Then, the watermark is embedded into the video resulting from the compression process through HDWT for both the compressed video and the watermark image, where the LL coefficient information of the watermark is embedded into the LL coefficients of the cover information. As for the place where the watermark appears, it is determined either by the user or at random. The proposed system was tested on color videos (.avi), and the results showed good transparency and robustness against some attacks through measures such as the peak signal-to-noise ratio (PSNR) and normalized cross correlation (NCC), respectively.

- [1] Proposed lossless visible video watermarking. The proposed system uses two methods, one of which is watermarking with monochrome images and the other with translucent images. The one-to-one compound mapping is used to implement these two methods. To obtain more typical visible watermarks in the video, two-fold, monotonically growing compound mapping is applied. The experimental results for the proposed system show that the algorithm recovers frames without loss of frame information and that it recovers nearly all of the frames from the watermarked video frames.

- [8] suggested an adaptive area selection approach with watermark embedding. First, they discriminated between salient and non-salient areas, which was done through a model of saliency-based visual attention (MSVA). The non-salient areas were then separated into blocks, and texture complexity was estimated for each block. Finally, the watermark embedding block with a modest distribution of image texture complexity was employed. The suggested technique offered more notable advantages due to more accurately defined saliency zones, secure watermark embedding, and a reduction in the assault on watermark images.

- [9] suggested an adaptive method for embedding visible watermarking in order to address the concerns about robustness, visibility, and transparency that afflicted some watermarking systems. Initially, super-pixel detection is used to detect protruding regions in the host image. Second, the embedding zone is found by recognizing flat, low-complexity regions. Third, while computing the watermark strength, the image texture complexity and grayscale distribution of the embedding region are considered. Finally, a visible watermark image is integrated into the host image using Just Noticeable Difference (JND). The results suggest that the proposed technique decreases the risks of visible watermark removal while maintaining a balance between the visibility and transparency of the visible watermark.

3. Theoretical Background

3.1 Discrete Wavelet Transform (DWT)

The objective of wavelet transforms is to decompose the input signal into components that are easier to deal with. DWT has a wide range of applications; one of them is in the area of image watermarking because it has many specifications that make the watermarking process robust [10]. The Haar wavelet is a simple example of a wavelet transform. The Haar transform decomposes the image signal into regions such that one region contains large numbers (averages in the case of the Haar transform) and the other regions contain small numbers (differences) [11]. L represents low frequency and H represents high frequency, and the subscript behind them represents the number of layers of transforms. The LL sub-band represents the lower resolution approximation of the original video, while the high-frequency and mid-frequency detail sub-bands LH, HL, and HH represent vertical edge, horizontal edge, and diagonal edge details, respectively. The coefficients of each sub-band may be calculated using the Haar filter as shown in equations (1), (2), (3), and (4) [12]:

$$\mathrm{LL}(x,y) = \frac{I(x,y) + I(x,y+1) + I(x+1,y) + I(x+1,y+1)}{2} \quad (1)$$

$$\mathrm{LH}(x,y) = \frac{I(x,y) + I(x,y+1) - I(x+1,y) - I(y+1,y+1)}{2} \quad (2)$$

$$HL(x,y) = \frac{I(x,y) - I(x,y+1) + I(x+1,y) - I(x+1,y+1)}{2} \tag{3}$$

$$HH(x,y) = \frac{I(x,y) - I(x,y+1) + I(x+1,y) - I(x+1,y+1)}{2} \tag{4}$$

Here, I : original image, x:width of image, y: length of image.
The procedure can be repeated to perform multi-level decompositions.

3.2 Arnold transform

Chaotic maps are very suitable tools and have wide applications in the digital image encryption area because of their special properties, such as the sensitivity of the initial condition and their non-periodicity and periodicity [13]. Arnold transformation is one of the chaos maps that are widely used in the area of image encryption. The Arnold transform is an inverse transform in two dimensions that has the following definition [14]:

$$\begin{pmatrix} x' \\ y' \end{pmatrix} = \begin{pmatrix} 1 & 1 \\ 1 & 2 \end{pmatrix} \begin{pmatrix} x \\ y \end{pmatrix} \ (\mathrm{mod}\ N)\ x, y \in 0, 1, \ldots, N-1 \tag{5}$$

In this case, the original image's pixel value is represented by (x, y), while the scrambled image's pixel value is represented by (x′, y′). The picture size is denoted by N.
The transform may be rewritten as follows:

$$\begin{cases} x' = (x + y) \bmod N \\ y' = (x + 2y) \bmod N \end{cases} \tag{6}$$

The following formula in Eq. (8) will get the inverse Arnold map [14]:

$$\begin{pmatrix} x' \\ y' \end{pmatrix} = \begin{pmatrix} 2 & -1 \\ -1 & 1 \end{pmatrix} \begin{pmatrix} x \\ y \end{pmatrix} \ (\mathrm{mod}\ N)\ x, y \in 0, 1, \ldots, N-1 \tag{7}$$

$$\begin{cases} x = (2x' - y') \bmod N \\ y = (-x' + y') \bmod N \end{cases} \tag{8}$$

4. The Proposed Work

The two steps of the proposed method are extraction and embedding. The block diagrams of these processes are shown in Figures 1 and 2, and each is described in the following subsections:

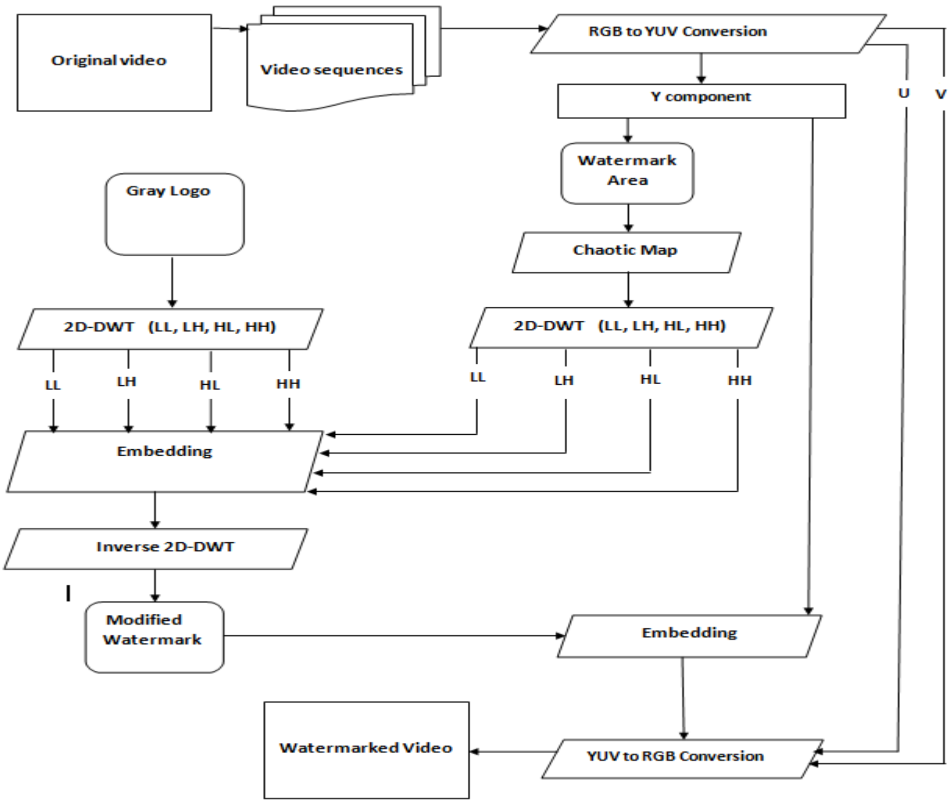


Figure 1: the structure of embedding a watermark

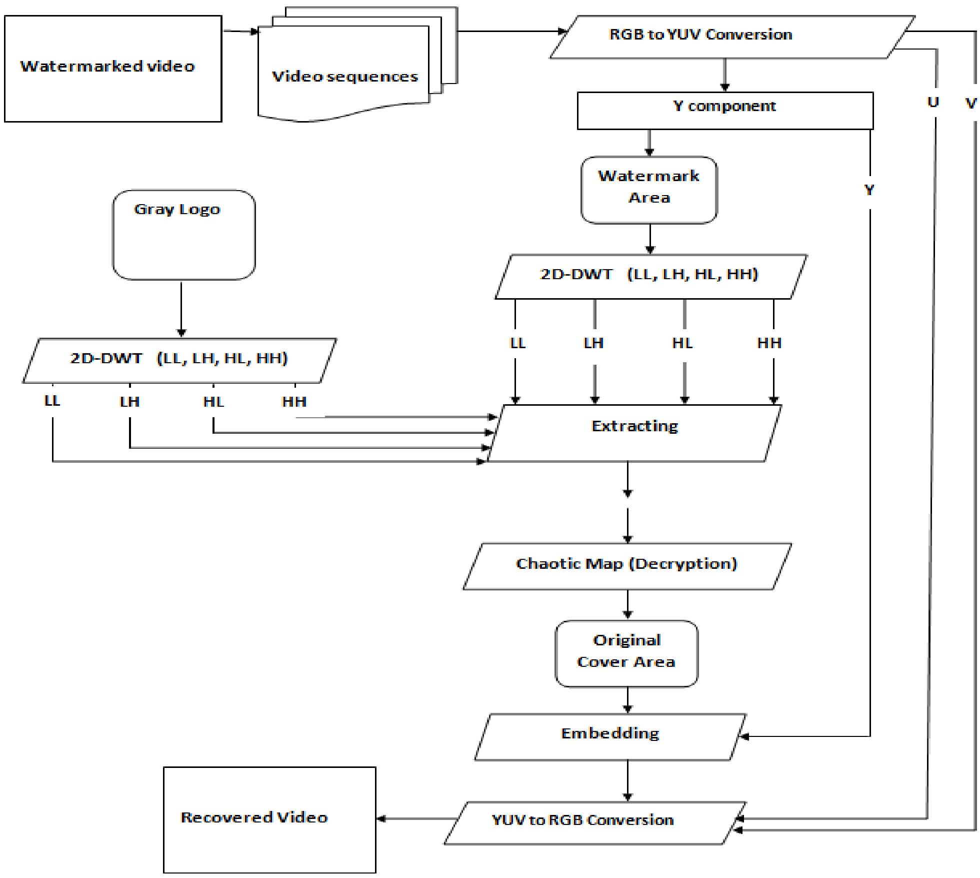


Figure 2: The structure of extracting a watermark

4.1. Embedding Process

The process of embedding the visible grayscale watermark information within the frames of the host YUV video is two-staged. The first stage is to use Arnold transform to create a jumbled watermark area. The watermark area is a selected part of the Y component. Then the confused watermark area information is embedded into the watermark. This is done by using a DWT transform for both the watermark and the confused information of the watermark area. By using the proposed equations (9–12), all the sub-bands of the confused watermark area are combined into the sub-bands of the watermark in reverse with a multiplication factor (α), where α is a proposed factor used to reduce the values of the watermark area sub-band information. As for the second stage, the modified watermark is integrated directly into the Y-component.

$$HH_w = HH_w + LL_c * \alpha \quad (9)$$
$$HL_w = HL_w + LH_c * \alpha \quad (10)$$
$$LH_w = LH_w + HL_c * \alpha \quad (11)$$
$$LL_w = LL_w + HH_c * \alpha \quad (12)$$

Where w denotes watermark information and c denotes cover information (watermark area). An algorithm (1) shows the full steps for the embedding process.

Algorithm (1) Visible Watermark Embedding	
Input	Video, α, NoF, Px, Py, ww, wl,k *\ (α multiplication factor), (NoF) number of frames, (Px) x position, (Py) y position, (ww) watermark width, (wl) watermark length, (k) encryption key
Output	Watermarked video
Begin End	Step1// load video and extract to the frames; Step2// read the watermark image; Step3//convert color model from RGB space to YUV; Loop for i← 1 to NoF Step4// select watermark area from Y component Wa←Y(Px:ww, Py:wl) *\ (wa) watermark area; Step5// confuse watermark area by Arnold Transform to generate E_wa *\ (E_wa) confused watermark area ; Step6// apply DWT transform for both confused watermark area and watermark; Step7// embed sub-bands of watermark area into sub-bands of watermark by equations(9-12); Step8//reconstruct watermark by IDWT inverse DWT to generate Mw *\ (Mw) modified watermark; Step9// integrate modified watermark (Mw) into Y component Y(Px:ww, Py:wl) ←Mw; End loop //i Step10// convert color space from YUV space to RGB;

4.2. Extraction Process

The extraction process is used to prove ownership of the watermarked video. Ownership is proven by the retrieval of the video without loss of information after the extraction process. The extraction process in the proposed algorithm is semi-blind, as it depends only on the encryption key and the watermark. Proposed equations (13-16) used for extracting the recovered watermark area.

$$LL_R = HH_{w'} + HH_w / \alpha \tag{13}$$
$$LH_R = HL_{w'} + HL_w / \alpha \tag{14}$$
$$HL_R = LH_{w'} + LH_w / \alpha \tag{15}$$
$$HH_R = LL_{w'} + LL_W / \alpha \tag{16}$$

Where R is recovered information, w' watermarked area information and w watermark information.
An algorithm (1) displays the whole extraction process.

Algorithm (1) Visible Watermark Extraction	
Input	Watermarked video, watermark, α, Px, Py, ww, wl,k *\ (α multiplication factor), (NoF) number of frames, (Px) x position, (Py) y position, (ww) watermark width, (wl) watermark length, (k) decryption key
Output	Recovered_Video
Begin End	Step1// load watermarked video and extract to frames; Step2// read the watermark image; Step3//convert color model from RGB space to YUV; Loop for i← 1 to NoF Step4// cut watermark area from Y component Wa ← Y(Px:ww, Py:wl) */(Wa) watermarked area; Step5// Apply DWT transform for both watermarked area and watermark; Step6// extract sub-bands of the watermarked area from sub-bands of the watermark by equations (13- 16;) Step7/ /reconstruct new sub-bands by IDWT inverse DWT to generate recovered watermark area (RWa); Step8// Apply Arnold transform with same key(k) to obtain unconfused (RWa) Step9// integrate a new area into Y component Y(Px:ww, Py:wl) ←RWa; End loop //i Step10// convert color space from YUV space to RGB space;

5. Experimental Results and Discussion

Several static (head and shoulders) and dynamic standard videos were used in this proposed watermarking scheme testing, as indicated in Table 1. A watermark of 32 x 32 pixels in size is utilized. MATLAB 2019b is used to implement the suggested system. The experiment was carried out using Windows 10 and a Pentium Core i5 CPU. Figure 3 presents some of the frames that belong to the video sequences and gray-level logo.

Table 1: Standard Videos

Id	Name	#frames	Resolution
1	Akiyo	300	352×288
2	Foreman	300	352×288
3	Mobile	300	352×288

(a) **(b)**

(c) **(d)**

Figure 3: (a) Akiyo Original frame, (b) Foreman Original frame, (c) Mobile Original frame, (d)) gray level logo

5.1Imperceptibility Tests

Imperceptibility is typically used in watermarking systems as a performance indicator. As a measure of imperceptibility, the PSNR was used [15]. The quality of the watermarked video is determined by its Peak Signal to Noise Ratio (PSNR). The PSNR is determined as follows [16]:

$$\text{PSNR} = 10\text{Log}10 \frac{255^2}{\frac{1}{w\times h}\sum_{x=1}^{w}\sum_{y=1}^{h}(I_{x,y} - I'_{x,y})^2} \quad (17)$$

Here, I and I' denote the original and watermarked video frames, respectively; (x, y) designates a pixel's location in the original and watermarked images (frames); and (w × h) indicates the width and height of the original video frame.

The average PSNR of all watermarked frames may be used to determine the PSNR of a watermarked video. The PSNR values of videos after incorporating a watermark are shown in Figure 4. A higher PSNR signifies better performance in terms of imperceptibility [4].

$$AV_{PSNR} = \frac{PSNR}{n} \quad (18)$$

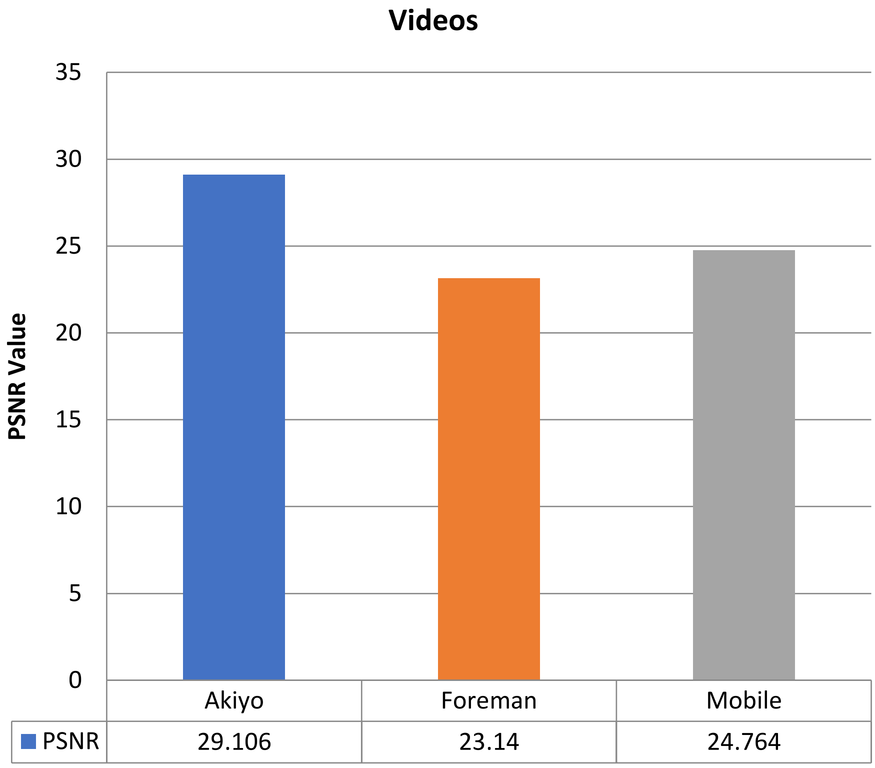
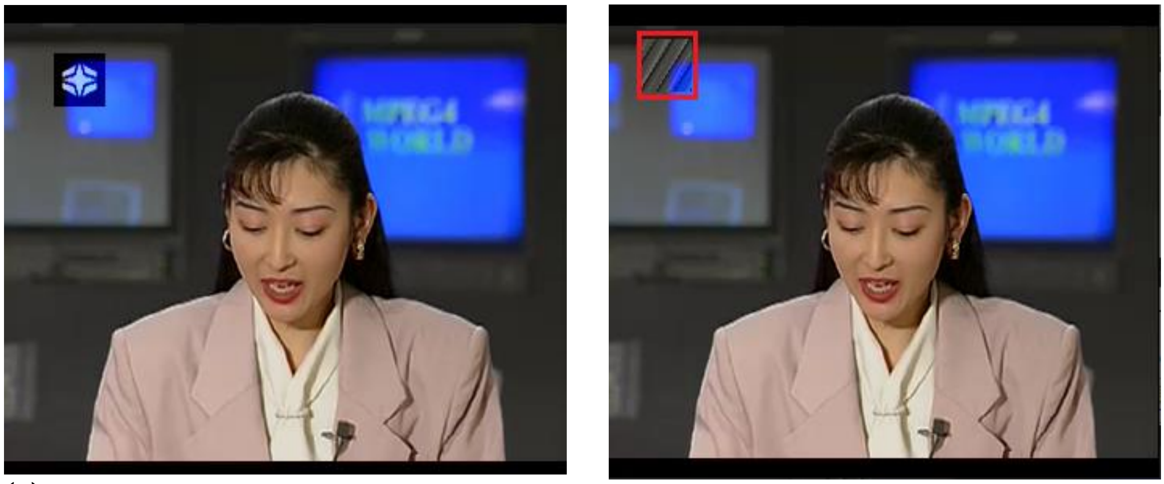


Figure 4: PSNR Values of Watermarked Videos

5.2 Removal attack test

This test is based on the visual result. When the process of extracting the watermark is illegal, the effect will be clear on the illegally recovered video frames, specifically the presence of deformation in the place of the logo that was removed. Figure 5 shows the visual result of illegal extractions.



(a) **(b)**

(c)

(d)

(e)

(f)

Figure 5: (a) Akiyo watermarked frame, (b) Akiyo recovered frame with illegal extraction, (c) Foreman watermarked frame, (d) Foreman recovered frame with illegal extraction, (e) Mobile watermarked frame, (f) Mobile recovered frame with illegal extraction.

The earlier outcomes demonstrate the power of the suggested algorithm in thwarting any unauthorized removal of the watermark. The reason is that the suggested method uses the Arnold transformation, which makes it possible for only those with the right algorithmic key to legally extract information and retrieve video frames without any loss of information.

5.3. Image distortion evaluation of recovered image

There are three classes of visible watermark techniques: reversible, permanent, and removable visible watermarking [17]. This paper's approach falls under the category of reversible visible watermarking. With the reversible method, the recovered image has the same quality as the host image. Figure 6 shows some of the recovered images after the legal extraction process.

Mean square error (MSE) and structural similarity (SSIM) values were calculated to further ascertain whether the restored image is identical to the original image. The MSE is defined as follows [18]:

$$\mathrm{MSE} = \frac{1}{\mathrm{w}\times\mathrm{h}} \sum_{i=1}^{\mathrm{w}} \sum_{j=1}^{\mathrm{h}} (\mathrm{O}_{i,j} - \mathrm{R}_{i,j})^2 \qquad 19$$

Where O and R denote the original and recovered video frames, respectively; (i, j) represent a pixel's location in the original and watermarked images (frames); and (w × h) indicate the width and height of the original video frame.

The SSIM demonstrates the similarities between the recovered and original video frames. The SSIM value ranges between 0 and 1 and should be close to 1 for maximum performance, as defined in [19]:

$$SSIM(O,R) = \frac{(2\mu_i \mu_j + C_1)\ (2\sigma_{ij} + C_2)}{(\mu_i^2 + \mu_j^2 + C_1)(\sigma_i^2 + \sigma_j^2 + C_2)} \qquad 20$$

Where the mean intensity of i and j are μ_i and μ_j. the variance of i and j are σ_i, σ_j the co-variance of i and j is σ_{ij}, respectively. And, C1 , C2 are the variables for stabilizing.

The MSE and SSIM values of each pair of comparison images are 0 and 1, respectively, as shown in Table 2, indicating that the proposed method can accurately and completely remove the visible watermark pattern from the watermarked image while preserving the integrity of the original host image. The reason behind these results is that the proposed method takes advantage of the frequency domain by using the DWT transform to hide the information of the watermark area that can be retrieved easily by using a legal algorithm with a legal key.

(a) **(b)**

(c) **(d)**


(e)


(f)

Figure -6 (a) Akiyo watermarked frame, (b) Akiyo recovered (c) Foreman watermarked frame, (d) Foreman recovered frame (e) Mobile watermarked frame, (f) Mobile recovered frame

Table 2: MSE and SSIM values between original and recovered frames

Id	Name	MSE value	SSIM value
1	Akiyo	0	1.00
2	Foreman	0	1.00
3	Mobile	0	1.00

6. Conclusion

The main goal of this paper is to propose an anti-removable logo and a reversible video watermarking algorithm by double embedding using DWT and a chaotic map by confusing the pixels of the cover area using the Arnold transform and transforming both the confused cover area and the watermark image with the DWT transform. Finally, all sub-bands of the confusing watermark area are embedded into sub-bands of the watermark image and then integrated into the frame. The results of this method show good robustness against illegal removal of watermarks. Also, the proposed method provides reversibility by maintaining the lossless format of the recovered frames after the legal extraction process of the watermark, where the MSE and SSIM values between the original and recovered frames are 0 and 1, respectively.

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