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HIGH SECURITY VIDEO WATERMARKING SCHEME BASED ON 3-D DCT AND 2-D DWT WITH ARNOLD MAP ALGORITHM

Zahraa Talal Al-Mokhtar[1]

Abstract

A digital watermarking for video is an effective method to protect the video copyright. In this paper, we will focus on the frequency domain of watermarking algorithms, our study based on dividing the original video into multi frames and each frame is manipulated by using 2-D DWT and 3-D DCT. The watermark binary image is coded by Arnold cat map and Peano-Raster Scanning to increase the security of the information and produce the information as multi 8X8 blocking data. After that, the coded watermark image is embedded into the video frames. The proposed method is used Peak Signal to Noise Ratio (PSNR), Mean Square Error (MSE), Normal Cross Correlation (NCC) and (NHD) to measure the performance of the method. The Matlab 2015a program and its GUI tools are used to apply this proposed algorithm.

1.Introduction

The basic procedure for digital watermarking is to embed some hidden information into multimedia data, while the quality of the watermarked data is retained, and the watermark can still be detected under different kinds of intentional and unintentional attacks. An effective watermarking scheme is distinguished by three characteristics, namely, 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 [1].

- Imperceptibility: A degree that an embedded watermark remains unnoticeable when a user views the watermarked digital media. The information should embed the watermark in the regions of the video frame in which imperceptibility is least affected [2].
- Robustness: The resilience of an embedded watermark against being removed by incidental and intended attacks. Major attacks on the videos are filtering, adding noise, Gaussian and scaling [2].
- Capacity: The amount of information that can reliably be hidden when the scheme provides the ability to change digital data [3].
- Security: The ability of the watermark to resist against attempts by a sophisticated attacker to remove it or destroy it via cryptanalysis, without Modifying the video itself [1].

These four requirements of watermarking make a square. Improvement in any one of them, affects the others negatively. We have to find the correct balance between these conflicting requirements of watermarking [2].

The Watermark detection is classified into three categories according to using original host image or video in the detection part: Non-blind, blind, and semi-blind watermarking. Non-blind watermarking requires the original image or video to detect the watermark. A blind technique does not require the original image and logo to detect watermark. Semi-blind watermarking technique requires the key and the watermarked document for detection [4].

Video watermarking techniques are implemented into multi domain to embed and detect process; such as spatial domain, frequency domain watermarking.

Spatial domain watermarks are directly embedded into the original video data. The embedded watermark signals are usually added to the luminance component, and sometimes some color components are added to, or added to the color components in all. The advantage is simple and has a lower complexity, but it cannot be perceived in the robustness [5].

In frequency domain techniques, the host image or video is first converted into frequency domain by transformation method such as DCT, DFT, DWT, etc then, transform domain coefficients are modified by the watermark data [6].

Supriya A. Patil and Navin Srivastava proposed a hybrid digital video watermarking scheme based on Discrete Wavelet Transform (DWT) and Principal Component Analysis (PCA). PCA helps in reducing correlation among the wavelet coefficients obtained from wavelet decomposition of each video frame [7]. Khandve Ashwini, Udhane Priyanka ,Parkar Shalaka, and Kulthe Sagar proposed a watermarking of video with text data by applying the Quick Response (QR) Code method. The QR Code is generated to be watermarked via a robust video watermarking method based on the SVD and DWT [8]. Rupachandra, et al. proposed a video watermarking scheme based on visual cryptography, scene change detection and DWT. The scheme uses an identical sub-band watermark for the same scene, but different parts in different scenes [9]. Semin Kim, et al., proposed a novel modality fusion method designed for combining spatial and temporal fingerprint information to improve video copy de-

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tection performance [10]. Antonio Cedillo-Hrenanderz, et al., proposed a transcoding resilient watermarking scheme based on spatio-temporal HVS and DCT. The quantization index modulation (QIM) algorithm is used to embed and detect the watermark in 2D-DCT domain [11]. Marwen Hasnaoui, et al., proposed a multiple-symbol QIM video watermarking. In this research, we will explain the frequency domain based non-blind video watermarking with Dual transformation domains and Arnold Cat Map with Peano-Raster Scanning.

The rest of the paper is organized as follows: in section 2, The Background of Arnold Cat Map (ACM) transformation, 2D-DWT and 3D-DCT transformation are briefly proved. Details of the proposed embedding and extracting scheme are described in Section 3. Section 4 presents a variety of Fidelity measure which used to measure the efficiency of video algorithm, section 5 contain the GUI designed to explain Experiment Results and Analysis. Finally we conclude the paper in Section 6.

2. Background

In this section, the concepts of Arnold Cat Map and Peano-Raster Scanning, 2D-DWT and the 3D-DCTare briefly described.

2.1 Arnold Cat Map

Arnold's CAT MAP (ACM) or Arnold transform (AT), proposed by Vladimir Arnold in 1960, is a chaotic map which when applied to a digital image randomizes the original organization of its pixels and the image becomes imperceptible or noisy [12].

There are several reasons to use this mapping approach [12]:

1. The mapping is one-to-one mapping; therefore, there is a One-to-one relationship between the plaintext images and Cipher text image to avoid the coordinate position of con flict.
2. Two-dimensional chaotic map has large key space, and the stable structure.
3. Arnold Cat Map makes the image scrambling fast.
4. This Transform is simple structure. it can be achieved through matrix operations.

As shown in Figure 1, it is named as Cat mapping. An image of Cat is under mapping as follows: the linear stretch is carried out firstly, and then dividing operation is done and folded. The operations will be repeated so on and eventually reach the encryption of the image [12].

Definition:

2D ACM for any NxN square image is described in Equation (1), where (xn,yn) and(xn+1,y n+1) are the locations of the pixels before and after ACM respectively [12].

$$\begin{pmatrix} X_{n=1} \\ Y_{n+1} \end{pmatrix} = \left[A \begin{pmatrix} X_n \\ Y_n \end{pmatrix} \right] ModN \qquad (1)$$

Since det. of A=1, Cat mapping is unique. The Lyapunov index of the Cat mapping is [12] as shown in Equation (2 a & b).

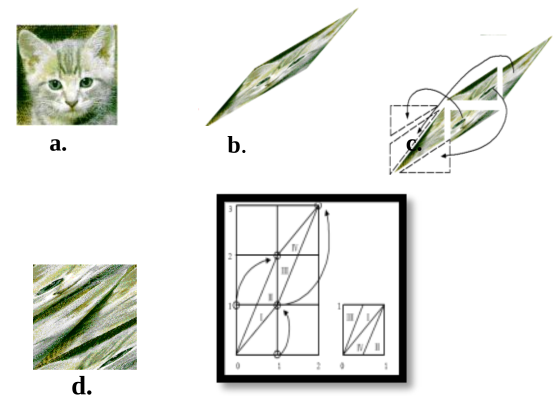

Figure.1 Arnold Cat Map operation
(a) The original Image.
(b) The linear stretch
(c) The dividing image
(d) The folding operation
(e) The Scheme of ACM operation.

$$\lambda_1 = \ln\left(\frac{3+\sqrt{5}}{2}\right) > 0 \qquad (2)\ a$$

$$\lambda_2 = \ln\left(\frac{3-\sqrt{5}}{2}\right) < 0 \qquad (2)\ b$$

2.1.1 Discreteness of Cat Mapping

Using Cat mapping for image encryption, it is necessary to carry out the pre-processing first. The processing procedures are as follows. First of all, parameters are initialized. The initialization could be carried out through modifying the elements in matrix A. considering a general Cat mapping is described in Equation (3) [12]:

$$\begin{pmatrix} X_{n+1} \\ Y_{n+1} \end{pmatrix} = A_d \begin{pmatrix} X_n \\ Y_n \end{pmatrix} (Mod1) \qquad (3)$$

Where $A_d = \begin{pmatrix} ab+1 & a \\ b & 1 \end{pmatrix} a,b \in N$

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The Cat mapping is a unique function, which has the no-minus Lyapunov coefficient. Secondly, the Cat mapping is extended to N×N and then carry out the discretization operation [12].
The extended function is still a one-to-one mapping. It is easy to proof that the parameter a, b have the cycle N. Thus, it could be expressed as equation (4):

$$\begin{pmatrix} (a+k_1N)(b+k_2N) & a+k_1N \\ b+k_2N & 1 \end{pmatrix}\begin{pmatrix} X_n \\ Y_n \end{pmatrix} = \begin{pmatrix} ab+1 & a \\ b & 1 \end{pmatrix}\begin{pmatrix} X_n \\ Y_n \end{pmatrix} \quad (4)$$

2.1.2. Cyclicity of Cat Mapping

Since an image is a set of limited points, the results of iteration could have cyclicity. For example, in the beginning, the image will be chaos when the positions of different pixels changing. The chaos could last for a certain time when the iteration carries on. However, due to the characteristics of the iteration system, the pixels are able to move back to their original positions. That means, after a certain time, the image could be recovered after a change. This is the cyclicity of Cat mapping as seen in Figure 2 [12].

$$A = \begin{pmatrix} 1 & 1 \\ 1 & 2 \end{pmatrix} \quad (5)$$

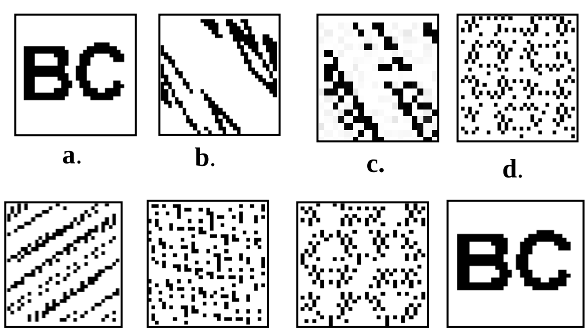

Figure.2 (a) Original watermark, Number of iteration in ACM: (b) 1, (c) 2, (d) 90, (e) 102, (f) 188, (g) 190 (h) 192.

2.2 The Peano-Raster Scanning

In this study, the Peano is used to increase the security of the proposed method. The Peano Scan as shown in figure 3 [13], is used to convert the 8X8 block of the 2D DCT coefficients into one dimension in special scanning of pixels then the raster scan is used to built the new 8X8 blocks from 1D Peano matrix by making every 8 pixel from Peano matrix is row in the modification block. This two scanning as shown in Figure 4 are important to protect the information even the attacker reach to extract the 8X8 blocks of information from host video, the attacker cannot get the information directly.

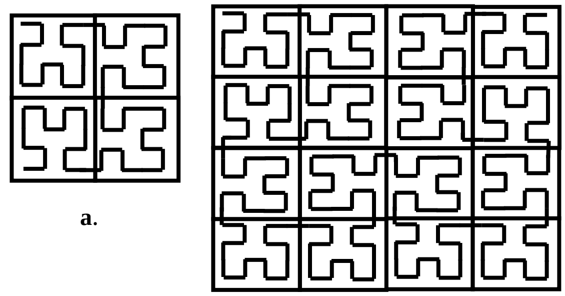

Figure.3 the Peano algorithm: (a) 8X8 Peano scan. (b) 16X16 Peano Scan.

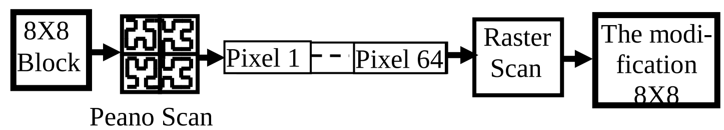

Figure.4 the Peano Raster Scanning.

2.3Two dimensional Discrete Wavelet Transform (2D DWT):

The 2D DWT (Discrete Wavelet Transform) are mostly used in watermarking applications. With the help of DWT, a digital signal is decomposed into lower frequency approximation components (LL), horizontal (HL), vertical (LH) and diagonal (HH) detailed components. The DWT transform can be of various levels (2, 3, 4 or even more). Spatial localization and multi-resolution makes an effective and robust DWT. [14]

2.4 Three Dimensional Discrete Cosine Transform (3D-DCT):

A digital signal can be converted into different frequency components using discrete cosine transform. DCT can be one as well as two or three dimensional, and can be applied on images, audio or video signals. The equation for DCT Transform includes only the cosine functions to work like basis functions. DCT operates only on real-valued signals and spectral coefficients. Generally the middle frequency components are selected to insert the watermark [15].
In this approach the 3D DCT is defined by applying the 2D DCT on each 8X8 block of LL frame groups as shown in Figure 5 (the scan is implemented block by block on each frames) then the DC coefficient of each 8X8 blocks is read from frame1, frame2, frame 3 and frame4 in parallel to calculate 1-D DCT. The Scan shape is frame by frame as shown in figure 6 [15].

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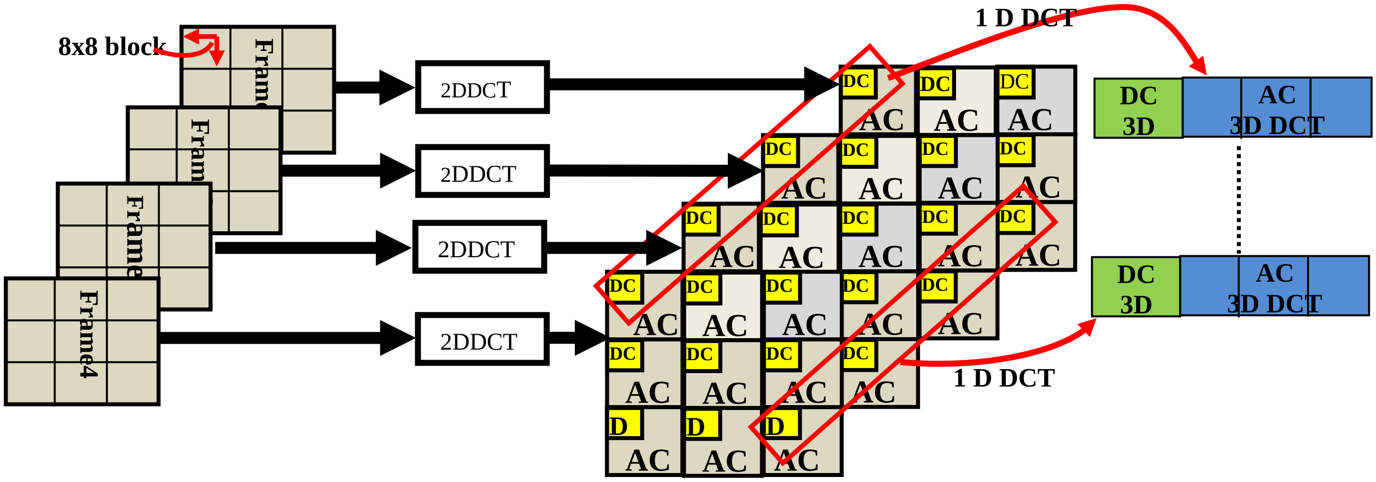

Figure.5 the 3D DCT procedure

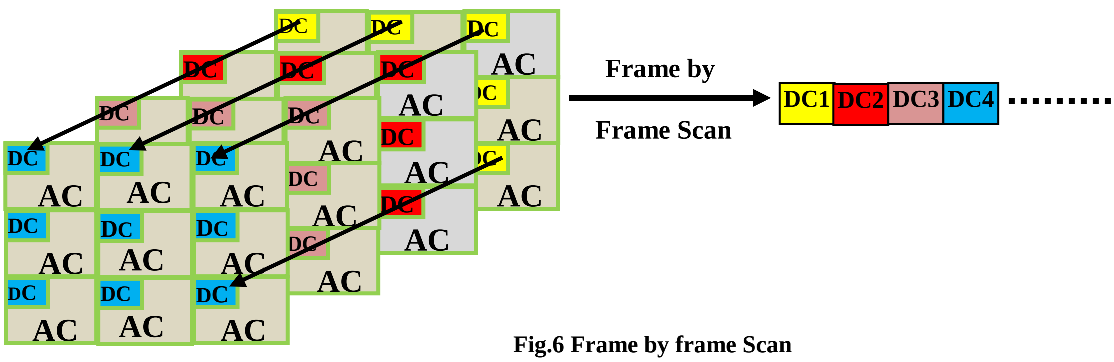

Fig.6 Frame by frame Scan

3. The proposed video watermarking

3.1 Watermark Embedding Process

The embedding processes consist of two parallel processing (Watermark image processing and color video processing) and then the results of these parallel processing is adding together as described below.

3.1.1 Watermark image processing

1. Select the binary image with 32x32 pixels or more as Watermark information.
2. Apply Arnold Cat Map described in 2.1 and apply the Equation (1) and (5) to the Binary image.
3. Divide the Arnold coded image into 8X8 block, so the 32x32 coded watermark information convert to 16 sub-Band 8X8 blocks watermark information.`
4. Apply the 2D DCT into each sub band block of water mark information.
5. Apply the Peano Raster Scanning on each 8X8 blocks. These steps from (1) to (5) are described in the red Block of figure 7.

3.1.2 Color video processing

1. Convert the color video into grayscale multi frames, then Using these frames to embed the Watermark information.
2. Apply one level 2D DWT on all N frames to produce LL,LH,HL and HH Sub bands on each frame.
3. Divide all frames into M groups, each group contain 4-Frame.
4. Apply the 3D DCT on LL only of each group separately as described on section 2.4. The color video processing are explained in the Blue block of figure 7.

3.1.3 Embedding processing

1. Aadding the 8X8 modification Blocks of watermarking Information with the DC Coefficients of 3D DCT results.
2. Implement the inverse 3D DCT algorithm to each group of frames.

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3. Merge all groups together to produce the total frames of Video.
4. Apply the inverse one level 2D DWT of all frames.
5. Restore the watermarked color video sequences as shown The embedding process is the green part of figure 7.

3.2 Watermark Extraction Process

The extraction process is similarity to the embedding process. Figure 8 shows the process of the extraction scheme.

The proposed algorithm is non blind algorithm, so we need to work on the embedded video and the original video to extract watermark information.

4. Fidelity measure

The fidelity measure is performed between tow frames, one frame of original video and another frame of the watermarked video. Then the fidelity criteria are performed in all frames between the two videos and calculating the average value of these criteria. The most popular of these measurements are MSE, PSNR, NCC and NHD.

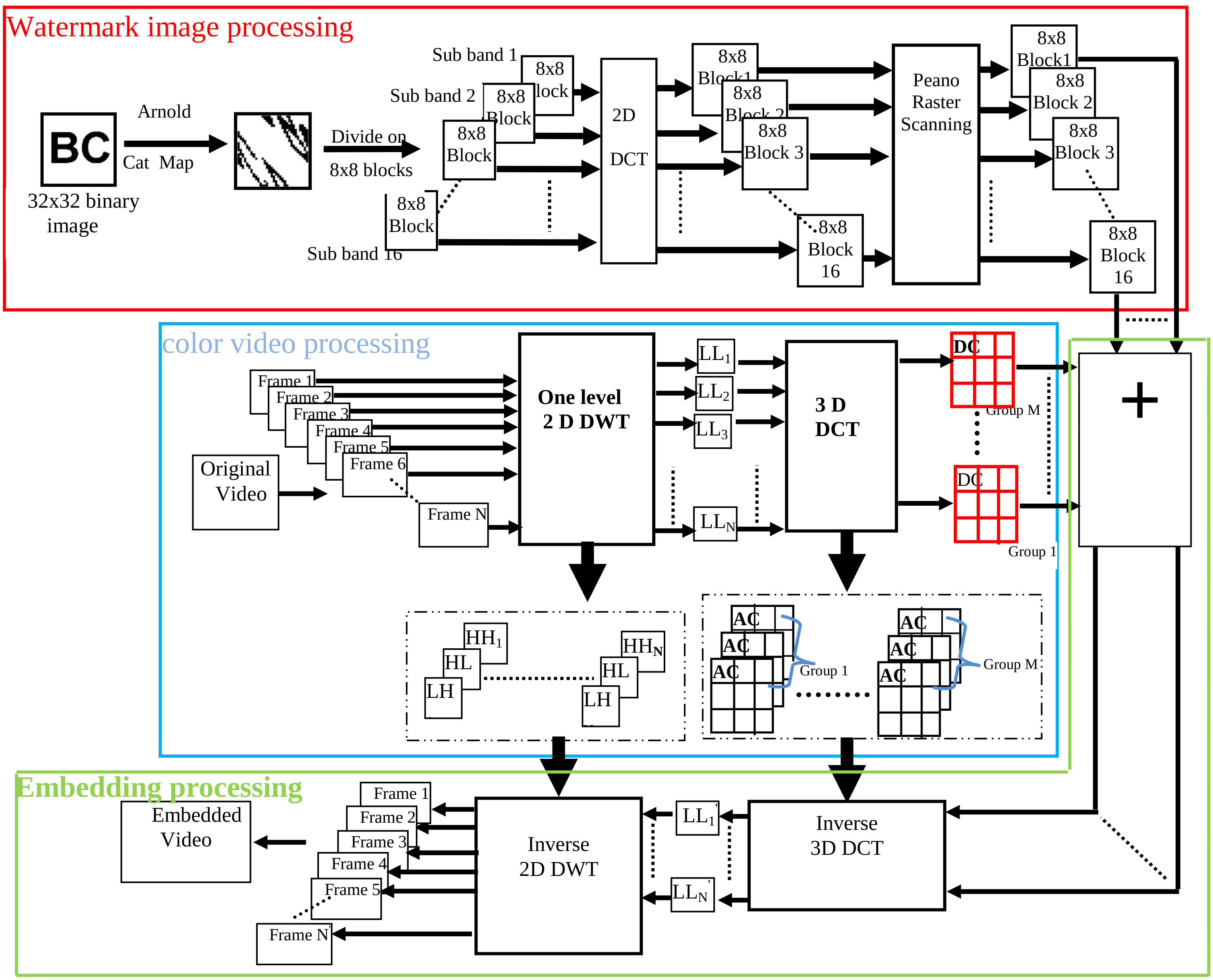

Figure.7 The Embedding process of proposed algorithm.

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4.1 Mean Squared Error:

The mean squared error (MSE) in an image watermarking is to estimate or measures the average of the squares of the Errors between original frame [16]. Fo (i,j,k) and water-mark frame Fw (i,j,k) , as shown in equation (6) and (7).

$$MSE(k) = \frac{\sum_{i=1}^{M}\sum_{j=1}^{N}(F_w(i,j,k) - F_o(i,j,k))^2}{M * N} \quad \text{For one frame} \quad (6)$$

$$MSE_{average} = \frac{\sum_{k=1}^{L} MES(K)}{L} \quad \text{For all frames} \quad (7)$$

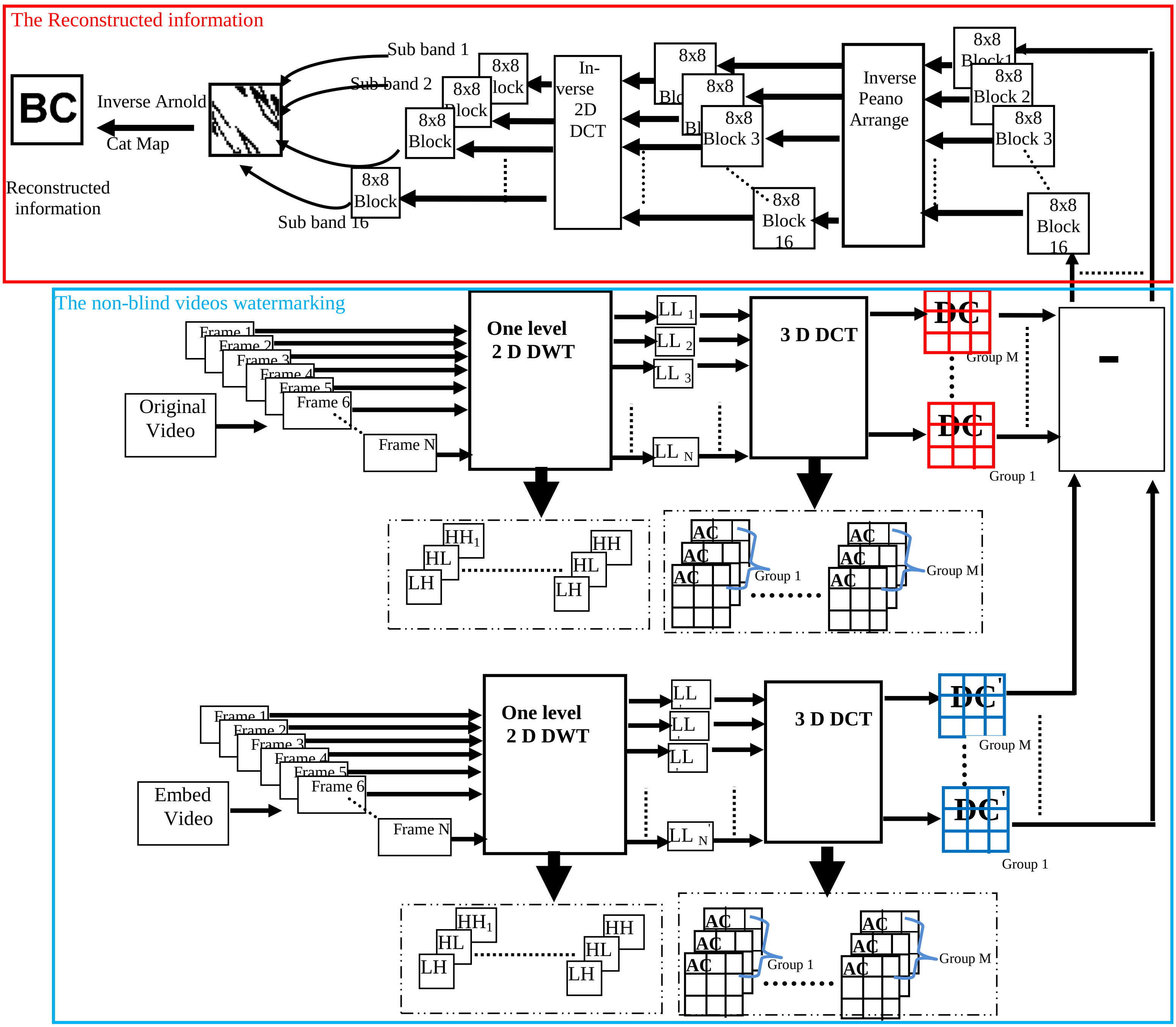

Figure.8 The Extracting process of proposed algorithm.

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Where M is the number of row in each frame; N is the number of column in each frame; L is the number of frames in the video.

4.2 Peak Signal to Noise Ratio

PSNR is more computable and can be used to provide a generic bound for the watermarking capacity. So, we use the PSNR in video watermarking are described [16] as shown in equation (8) and (9).

$$PSNR(k) = 10 * \log_{10} \frac{255^2}{MSE(k)} \quad \text{For one frame} \quad (8)$$

$$PSNR_{average} = \frac{\sum_{k=1}^{L} PSR(k)}{L} \quad \text{For all frames} \quad (9)$$

4.3 Normalized Cross Correlation

Normalized Cross Correlation (NCC) is used to measure the Robustness of watermarking. The NCC is calculating the Similarity between original and Extracted watermark frames of videos. The NCC can be computed as follows [16].

$$NCC(k) = \frac{\sum_{i=1}^{M} \sum_{j=1}^{N} \left(F_o(i,j,k) * F_w(i,j,k) \right)}{\sum_{i=1}^{M} \sum_{j=1}^{N} F_o(i,j,k)} \quad \text{For one frame} \quad (10)$$

$$NCC_{average} = \frac{\sum_{k=1}^{L} NCC(k)}{L} \quad \text{For all frames} \quad (11)$$

4.4 Normalized Hamming Distance

Normalized Hamming Distance (NHD) is the degree of closeness between original watermark (W) and the extracted watermark image (W '), the normalized Hamming distance (NHD) is the similarity measure. Normalized Hamming distance is defined as in the equation (12) [17].

$$NHD(W, W') = \frac{1}{N_w} \sum_{i=1}^{N_w} W(i) \oplus W'(i) \quad (12)$$

Where Nw is the length of watermark image and $\oplus$ the exclusive-OR operator. The NHD ranges between 0 and 1. Ideally, two perceptually similar images should have a distance close to 0.

5. Experiment Results and Analysis

To analyze the proposed video watermarking algorithm, we use a color video to embed the 32x32 binary image watermarking information as shown in Table.1. The Matlab 2015a is used to execute this algorithm and build GUI interface to appear the results of this algorithm. As shown in Figure 9.

Table.1 The Video Sequences and Watermark Image.

	
Watermark	**Xylophone**

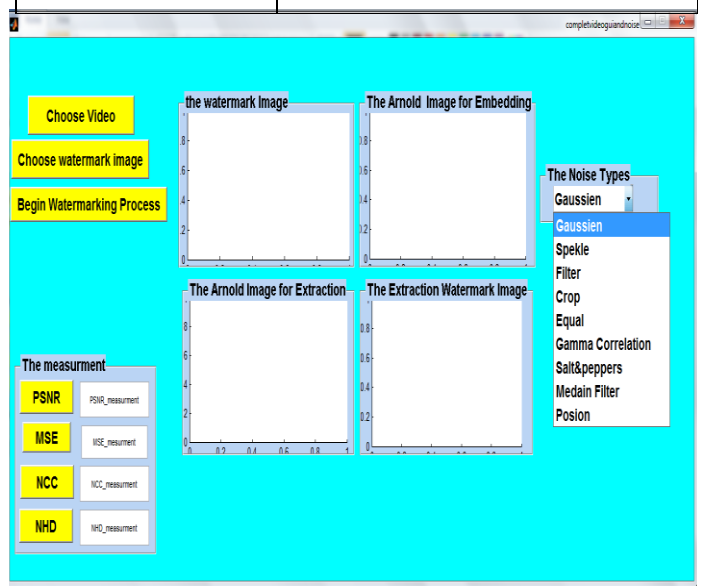

Figure.9 the GUI interface designed

In this GUI tool anyone can press the buttons to execute the proposed algorithm.
Each buttons are explained as follows:

1- The **Choose video button** is used to load the host color video from any part of Computer.
2- The **Choose Watermark Image button** is used to load the watermark information.
3- The **Begin Watermarking Process button** is used for Executing the Embedding and extracting the proposed Video watermarking algorithm.
4-The **four windows** are used to display the watermark Information and the effect of using Arnold CAT MAP in The embedding side and extracting side.

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5-The **PSNR button, MSE button, NCC button and NHD button** can press to Calculate and display these measurements. Table.2 shows the results of the proposed video algorithm without any type of noise.

Table.2 the results of the proposed video watermarking

PSNR (dB)	MSE	NCC	NHD
79.2454	$7.4447 * 10^{-25}$	1	0

6-**POP- UP Menu** is used to display many type of noise as shown in figure 9.

If you choose Gaussian noise, the parameters is selected as the mean is zero value and its variances ranging from 0.005 to 0.02. As shown in table.3. The results of The Speckle noise, Filter, Gamma correlation, median filter and posion noise are shown in Table.4. The salt & pepper noise density is set ranging from 0.01 to 0.04. (shown in Table 5).

Table.3 Extracted Results of Gaussian Noise Attacks.

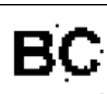
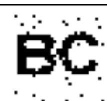
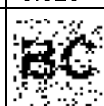
Variance	0.005	0.010	0.015	0.020
Extracted watermark				
PSNR (dB)	22.8659	19.9713	18.302	17.130
MSE	0.0321	0.0753	0.1516	0.2284
NCC	0.9860	0.9642	0.9399	0.9156
NHD	0.0049	0.0371	0.0977	0.1221

Table.4. the effect of many type of noise.

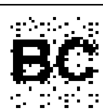
noise	Speckle	Filter	Gamma	Median filter	posion
Extracted watermark					
PSNR (dB)	20.198	29.095	39.2454	32.5866	27.6145
MSE	0.1559	0.2772	$7.734 * 10^{-29}$	0.01322	0.0105
NCC	0.9672	0.9951	0.99997	0.99888	0.9972
NHD	0.1035	0.1259	0	0	0

Table.5. the effect of Salt & pepper noise.

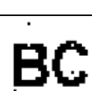
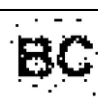
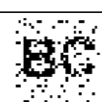
density	0.01	0.02	0.04
Extracted Watermark			
PSNR (dB)	25.1648	22.1985	19.2379
MSE	0.03853	0.1216	0.41656
NCC	0.9772	0.9544	0.91073
NHD	0.00488	0.04199	0.10937

Table 6 shows the result of the proposed method under Cropping attack. There are two type of cropping horizontal crop and vertical crop, the percentage of cropping is ranging

Table.6. the effect of cropping noise.

no. of cropping line	32 columns	96 columns	32 rows	96 rows
Extracted watermark				
PSNR (dB)	39.2454	39.2454	39.2454	39.2454
MSE	$7.73 * 10^{-29}$	$7.73 * 10^{-29}$	$7.73 * 10^{-29}$	$7.73 * 10^{-29}$
NCC	0.999997	0.999997	0.999997	0.999997
NHD	0	0	0	0

From 32 lines to 96 lines Corresponds to removing horizontal lines or vertical lines in the frame of embedding video.

6. Conclusion

In this paper, we proposed a color video watermarking technique robust against several signal processing distortions and frame-based attacks. To improve the robustness and security of the method, the Arnold Cat Map (ACM) transform is used during watermark embedding and Peano Raster scanning to increase the security of watermark information(This part of using ACM, 2 D DCT and Peano Raster scanning represent the main part of the proposed algorithm to save the information a way far of attackers). Then we apply 2D-DWT and pseudo 3D-DCT on the host color video. Finally we add the 2D DCT watermarks into Dc coefficients of the embedded video. During the watermark extraction, we do some of the corresponding reverse transformation to get the watermark. Although the proposed scheme still has limitations such as needing the original video to extract the watermark information because of non-blind algorithm. The proposed algorithm has high imperceptibility and robustness as described in the above results.

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Zahraa Talal AL-Mokhtar received the B.S. degree in computer Engineering from the Department of Computer Engineering from the University of Mosul, Iraq, in 2005, the M.S. degree in computer Engineering from the University of Mosul, in 2008. She has 4 years experience in teaching.
Her areas of interests and research include image processing, watermark image, and face recognition. Mrs. Zahraa may be reached at zah_ta84@yahoo.com.