Digital Video Watermarking in Lower Variance Sub-bands of Curvelet Transform

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Abstract:
The protection of multimedia data is becoming more important in video watermarking. The advancement of digital watermarking can help to overcome this difficulty. The major challenges in watermark techniques are robustness and invisibility. This research proposes an invisible and resilient video watermarking system. It uses transform domain in embedding the watermark. Only few frames are selected for watermarking using intensity based seed generation. The structural and textural properties of the selected frames are studied using phase congruency and entropy. Then curvlet transform is applied from which lower variance sub-bands are evaluated for future stages during the embedding phase. The proposed method is tested on three challenging videos and the performance is evaluated using Peak Signal to Noise Ratio (PSNR), Mean Square Error (MSE) and Normalized Correlation Coefficient(NCC).The efficiency of the proposed method is proved by comparing it with other transform domains. The proposed method outperforms the existing methods by a wide margin
Keywords: Video Watermarking, Embedding, Extracting, Robust, Curvelet Transform, Phase Congruency.
DOI: 10.24297/j.cims.2023.06.26

1. Introduction

Digital watermarking is a process or method of hiding secret data (signature, text, logo, image, audio, etc.) in the watermark form in digital multimedia like image, text, video and audio. Watermarks are classified into two types: invisible and visible. Visible watermarks can be seen with the naked eye or detected with the human ear, but invisible watermarks can only be detected with specific software, cannot be seen with the naked eye, it is inaudible, and are more resilient than visible watermarks. Digital watermarking embeds private symbols called watermarks into video data, which may then be utilized for criminal monitoring, copyright protection, ad tracking, content verification, fixing bugs, and other purposes. Using an object reader, this software transforms video to frame numbers. Video watermarking is a method of hiding data in which information or a message is concealed within a visible signal to the user. Watermarks may be placed in either images or videos, and the process of inserting a watermark in a video is known as video watermarking, while placing a watermark on an image is called as image watermarking [1].

Images and data can be hidden in various forms of video data, image data and audio data using watermarking techniques. Data is now accurately encrypted in the image form, making it considerably secure. In image displays, the image can be covered in photos, videos, music, and text. Following the development of image watermarking, scientists created video watermarking. The notion of video watermarking stems from the concept of image watermarking, in which unlawful embedding and copyright identification are embedded in the source image for image security and safety. Because video is a collection of specific digital pictures, or a succession of still images, video watermarking conceals data in video frames. Embedding watermarks in any selected frame in the video is known as video watermarking [2]. Figure 1 illustrates the process of video watermarking.

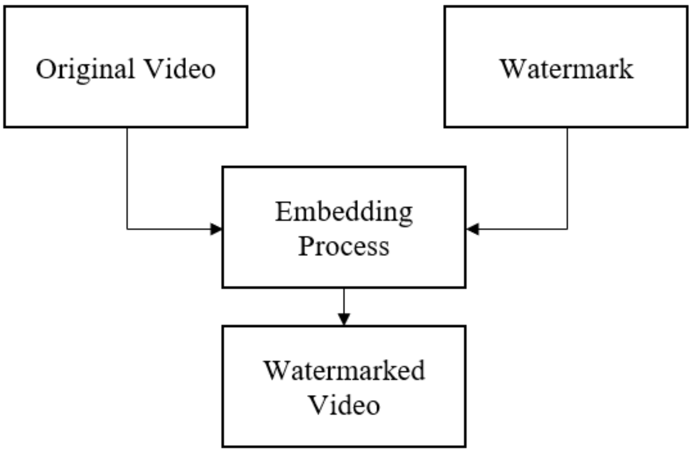

Figure.1. Embedding Process of Video Watermarking

There are two processes in the notion of digital watermarking. The first process is embedding and the second process is extraction. The process of inserting a watermark into a video stream is known as embedding. The technique of extracting the embedded watermark from a watermarked video is known as extraction. Figure 2 represents a typical watermark extraction procedure.

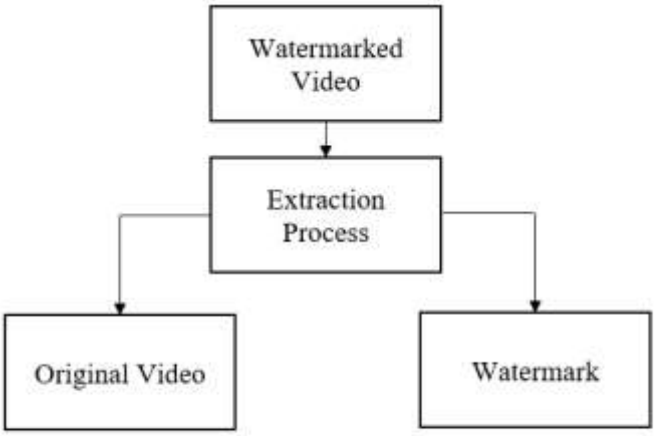

Figure.2. Extraction Process of Video Watermarking

Hiding bits in host video in video watermarking approaches could be divided into two major types: Spatial domain and transform domain. The former is a method of embedding and detecting watermarks by directly changing the video frame's pixel intensity values. In contrast, the latter modifies the host video’ s spatial pixel values based on the predetermined transforms. The transform domain approaches are resilient than spatial domain approaches because It spread the watermarks throughout the video frame’ s spatial domain, creating it complex to delete the watermarks by attacks such as scaling, cropping, geometrical, and rotation attack. The Discrete Wavelet Transform (DWT), Discrete Fourier Transforms (DFT), and Discrete Cosine Transforms (DCT) are the most often utilized transform domain algorithms [3].

The key advantage of transform domain approaches is overcoming the spatial domain's drawback. The original video frame is first altered using a pre-defined transformation approach in transform domain watermarking approaches. The watermark was then included in the frame's transformation coefficients. The inverse transform of the embedding procedure is utilized to obtain the watermarked video. Video watermarking differs from image watermarking, because of the larger size data and allowing the information to be embedded more redundantly and reliably [4].

The efficiency of the watermarking techniques is evaluated by some attacks. The attacks are categorized as noise, cropping, filters, and blurring in this context. A watermarking method is efficient when

- It is difficult to find out the frame and area of which is used for embedding the watermark (i.e. logo).
- Hacking is difficult.

This research proposes a robust and invisible video watermarking system. Most of the existing algorithms use DWT and DCT. This work uses DCT for embedding the watermark. This model is more computationally efficient and produces fewer errors than other transform algorithms such as DWT, DFT, and DCT. The remaining parts of the paper are arranged as follows: Section II discusses related works in transform domain approach. Section III discusses the proposed methodology with elaborate explanation. Section IV presents the experimental results and Section V concludes the work with the way to future work.

2. Related Works

The Redundant DWT in the Singular Valued Decomposition (SVD) has been used in [5] for a novel blind video watermarking method. Furthermore, to improve this technique, an effective meta heuristic optimization with multi-objectives optimization has been introduced. An adaptive compressed domain blind video watermark approach with DWT has been implemented in [6]. Various binary images created from the single watermarked image is initially placed in the video sequences using this approach. By altering the four sets of discrete wavelet coefficients, the spatial spread spectrum watermark has been directly integrated in the compressed bit streams. Bu this method has not been compared with other methods.

DWT and DCT have been utilized to create a comprehensive video watermarking technique in [7]. The video frames in this watermarking process are chosen randomly from the reference frames of the original host video. A secured graph-based transform, SVD, and hyper chaotic encryption hybrid approaches for video watermarking has been developed in [8]. This method has been created to address concerns about copyright protection and ownership identification.

An efficient compression-based safe digital watermarking using dual-tree complex wavelet transform and adaptive cuttlefish optimization technique have been implemented in [9]. The elliptic curve encryption technique has been used to encrypt the secret images. A multiple video watermark approach using H.265 video encoding and artificial jellyfish is implemented in [10]. In this case, DWT is used for each frame, and the DWT coefficients are optimized using an artificial jellyfish method. In [11], an efficient blind image watermarking strategy based on Principal Component Analysis (PCA) in the Redundant Discrete Wavelet (R-DW) domain is used. Also, to boost performance, an upgraded grey-wolf optimizer method has been used. A digital image watermarking system is presented in [12] by combining the DOST, DWT, and SVD. In [13], DWT and SVD are combined to provide digital video watermarking.

In [14], a fuzzy rule-based video watermarking in the DWT-SVD domain has been implemented. The KFS approach, which was implemented using a fuzzy inference system, enhanced authentication and accuracy in this case. To avoid the false positive problem, the PCA approach has been used. In [15], a multi-level video watermarking utilizing DWT has been introduced. In this work, DCT has been utilized to improve the authenticity of the input image and curvelet transform is used to integrate the images into the video.

An efficient watermarking algorithm based on optimal alpha, DCT and SVD has been developed in [16]. In this case, cuckoo search has been utilized to determine the best scaling factors for grey images watermarking in the domain of CWT-SVD transform. In [17], a technique for removing rain noise from video based on phase congruency has been developed. This approach has detected and removed rain streaks by utilizing their temporal, spatial, and chromatic features. A fuzzy-based digital video watermarking technique for copyright protection based on Cellular Automata Transform (CAT) and SVD has been implemented in [18]. This technique has offered copyright protection for numerous transform planes with high processing speed and data redundancy.

The blind video watermarking system using Dual-Tree Complex Wavelet Transforms (DTCWT), chrominance channel and SVD has been implemented in [19], which employed the signature-based technique for authentications. In [20], a watermarking approach based on the curvelet transform and quantization index modulation has been discussed. Toralamorphismhas been used to encrypt the mark for further security. In [21], a video watermarking approach has been presented by analyzing DWT and SVD transforms in addition to the ABC optimization algorithm. A cuckoo search approach and the secret sharing in domain of DWT-SVD for video watermark have been developed in [22]. To increase the security of the watermark, this solution employed the secret sharing mechanism.

A dual-embedded watermarking technique paired with particle swarm optimization has been implemented in [23]. The generalized Arnold transform is used to encrypt the watermark image, and hence the real host images and the encrypted watermarked images are processed using the DCT and multi-level DWT. In [24], a blind digital video watermarking approach based on DTCWT has been developed. The created watermark has been encoded in the lower frequency coefficients of the video frames' chrominance channel. The embedding procedure is done in the spatial domain to decrease the computational complexity of this approach.

In [25], a new algorithm for digital video watermarking based on a combination of chaotic systems, Cellular Automata (CA), and DNA sequences has been developed. A video watermarking algorithm based on Non-Sub sampled Cont our let Transform (NSCT), pseudo 3D-DCT and Non-negative Matrix Factorization (NMF) has been introduced in [26]. Combined with NSCT, 3D-DCT and NMF, the algorithm embeds the encrypted QR code copyright watermark into the NMF base matrix to improve the anti-attack ability of the watermark under the condition of invisibility.

Adnan Abdul-Aziz Gutub utilized counting-based secret sharing strategy to allow watermarking validation of ownership even if some fragments of the multimedia video-file is interfered [27]. The study modelled the system and implemented it to be tested to explore the relation between security and authenticity in relation to data dependency, as in order to provide fractional authentication. It is giving the user full authority in accepting the incomplete video watermarking proof in a percentage-based analysis.

A novel video watermarking technique that is blind and robust to according attacks has been developed [28]. This method uses the integration of the DTCWT and SVD to achieve robustness against geometric attacks. n [29], wavelet domain has been focused for video compression.

3. Proposed Methodology

As shown in Fig. 1 and 2, a typical video watermarking process consists of embedding and extraction phases. The proposed approach embeds a binary watermark into selected video frames by decomposing the frames into sub-bands and then applying proposed algorithm to the sub block of the lower frequency sub bands. The watermark is incorporated in sub-blocks. The extraction of watermark is accomplished in the same way, but in reverse manner. Figure 3 shows the block diagram of the proposed watermarking method. The details of each block are explained in the subsequent paragraphs.

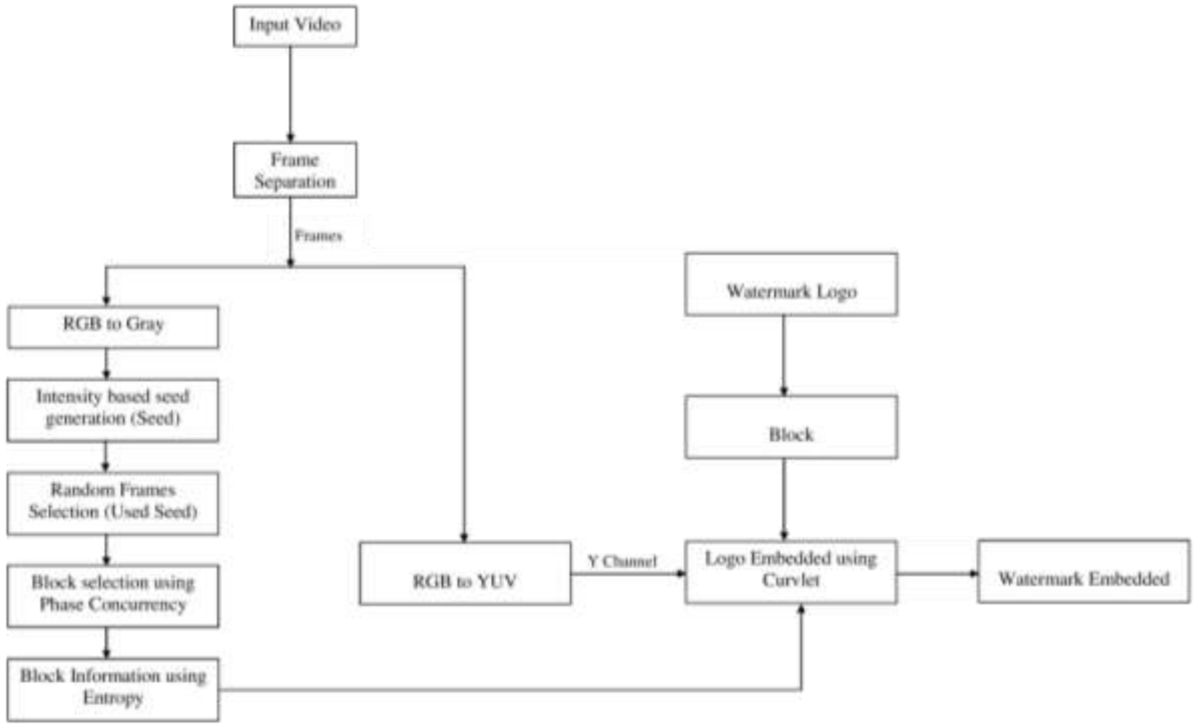

Fig. 3 Block Diagram of Proposed Method

The proposed method consists of seed generation, frame selection, embedding and extraction phases. Initially the input video is converted to gray scale video.

Intensity Seed Generation:

In the proposed method, we select third frame to generate seed value. It is converted to YUV format (Y - Luma, U and V – Chrominance channel). In this work, the Y channel alone is considered which looks like the gray scale version of image. From the Y channel of the third frame, seed is generated based on intensity. Using the seed value, key frames are selected to embed the watermark.

In the gray-scale converted third frame, 11 elements are obtained by selecting the centre row and column. These elements are sorted using sort command. After sorting, the middle element is selected as seed value. The following figure illustrates an example of seed value generation.

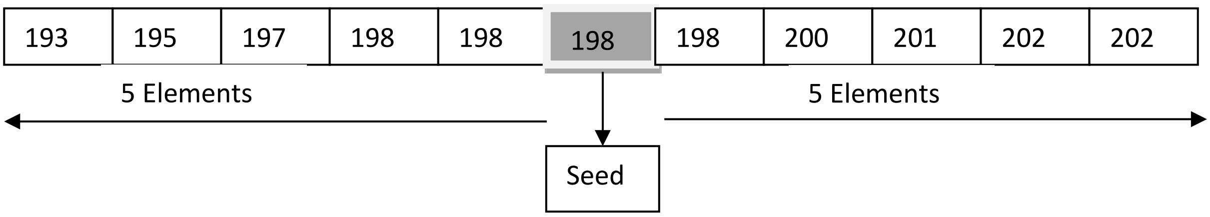

Fig. 4 Illustration of Seed Generation

Algorithm: 1 Seed Generation

Input: Frame F

Output: Seed Value

Steps:

//Convert RGB to gray-scale of F

F←rgb2gray(F)

//Fetch center row and column only 11 elements

S←F(256:256, 256:266)

G←sort(S)

//Select the middle element

Seed←G(1,6)

Frames selection:

In Frame selection, frames are shuffled using random generation. Select the frame using random permutation but the seed value is fixed depending on the video intensity. We select particular percentage of frames from the randomly generated frames for further processing. For example if we are having 200 frames, we can select only two frames (1%). This is illustrated in Fig. 5. Let us consider the selected framessel_{frames} in the input video of size N as

$$sel_{frames} = \{f_1, f_2, \ldots, f_n\}\ where\ n > N \quad (1)$$

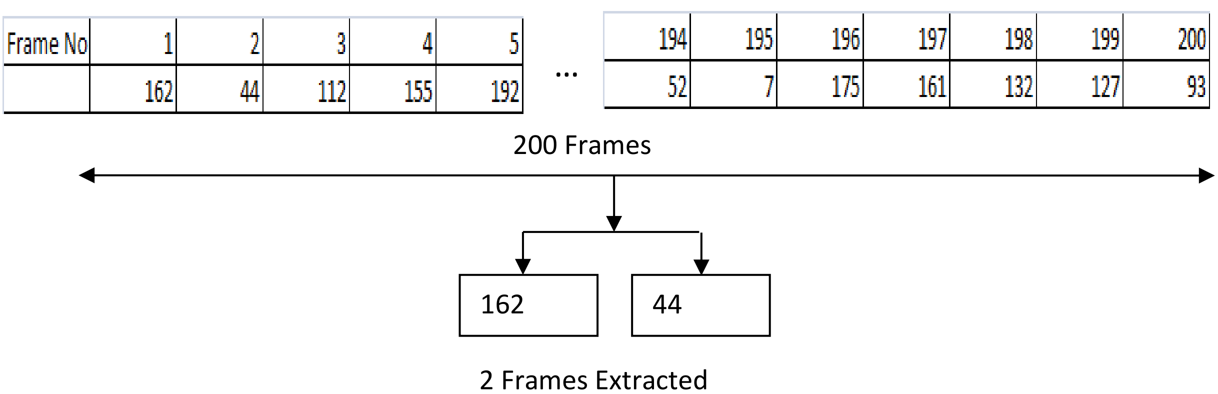

Fig. 5 Process of Frame Selection

Embedding:

After frame selection, we embed the secret image in one of the selected frames. The frame is divided into four equal-sized blocks. Then the structural and textural information is studied by phase congruency and entropy respectively. Based on these information, the watermark is embedded in one of the blocks using curvelet.

As the frames are divided into four blocks, the secret image is resized to half the size of the video frame. For example, if the frame size is [512,512], then the secret image is resizedto [256,256].The following are the steps to embed the secret image in video.

Convert the secret image to binary image *secret_binary*.

Convert the mov files into RGB data.

For each frame in sel_{frames}, divide the frame into 4 blocks:

$[B_1, B_2, B_3, B_4]$ (2)

Calculate entropyE for each block(Texture information can be obtained).

$E = \{entropy(B_1), entropy(B_2), entropy(B_3), entropy(B_4)\}$ (3)

The entropy obtained in the above equation is a single value for each block.

Apply Phase Congruency PC method for each block (the edge significant values can be obtained for structural information).

$PC_{B_1} = phasecong(B_1)$ (4)

$PC_{B_2} = phasecong(B_2)$ (5)

$PC_{B_3} = phasecong(B_3)$ (6)

$PC_{B_4} = phasecong(B_4)$ (7)

In the above equation, phasecong is the function which calculates phase congruency of a 2D data. The level and scale for calculating phase congruency is set to (5, 3) in this research.

The phase congruency returns edge significant value for each pixel in the block. Hence it is converted to a single value for each block. If the value of phase congruency is zero, then no edge. If phase congruency value is 1, then the pixel is highly edge significant. If the value of phase congruency is greater than 0.2, then the pixel is most edge significant. Hence we find the number of pixels whose edge significant values are greater than 0.1. It is divided by total number of pixels in the block to find the percentage of edge significant pixels in each block. Now the PC will look like

$$PC = \left[\frac{length\left(find\left(PC_{B_1}>0.1\right)\right)}{block_{size}}, \ldots, \frac{length\left(find\left(PC_{B_4}>0.1\right)\right)}{block_{size}}\right] \quad (8)$$

Where $find$ gives all the of pixels whose PC is greater than 0.1, $length$ gives the count and $block_{size}$ is the size of the block.

E is sorted in descending order and the top two highest values are taken for further processing. Let us consider B_2 and B_3 has highest entropies. Among these, one is selected whose PC is greater.

The above two steps select the block for embedding. The selected block number is saved for extraction process. Assume the selected block is saved as *sel_block*

The selected frame is converted toYUV format. We again have a threshold for entropy in this moment. If the entropy of the block is greater than 5, the embedding process is done. Otherwise, the frame is skipped.

The Y coefficient of the selected block is converted to curvelet coefficients using

$$CV = cvt(sel\_block, level, scale) \quad (9)$$

where level = 2 and scale =4.

Then the binary secret image is embedded into the curvelet coefficients.

$$emb_{blk} = CV\{1,1\} + embedding_{strength} * secret\_binary \quad (10)$$

Finally, the inverse curvelet transform is applied. Now the watermarked frame is in the original video.

4. Extraction Process:

The final phase in video watermarking is the extraction phase. The reverse of embedding is done in extraction phase. The following are the steps done in extraction process.

For each selected frame in the watermarked video, the frame is converted to YUV.

Divide the original and watermarked frame into blocks.

The watermarked block number is identified by the flag already saved during embedding process.

Curvelet transform is applied to the watermarked block and the original block with the same level and scale.

The extraction is done using

$$ext\_watermark = (CVw\{1,1\} - CV\{1,1\}) / \ embedding_{strength} \quad (11)$$

Where ext_watermark is the extracted watermark, CVw and CV are the curvelet coefficient obtained from watermarked block and original block respectively.

5. Experimental Analysis

The results of the proposed video watermarking model are analyzed detailed in this section. The proposed model is implemented using MATLAB 2018a on a PC running Windows OS-10, equipped with an Intel Core i7 CPU operating at 2.9 GHz and 8 GB of RAM. The proposed model has been tested using three publicly available videos: Salesman, Rhino and Cat. All the videos are in AVI format. Each video consists of above 300 frames at 30 fps (frames per second). We have used 200 frames from each sample for testing. The frame size of each video is "512×512". Figure 4 represents the sample frames of each video used in this research.

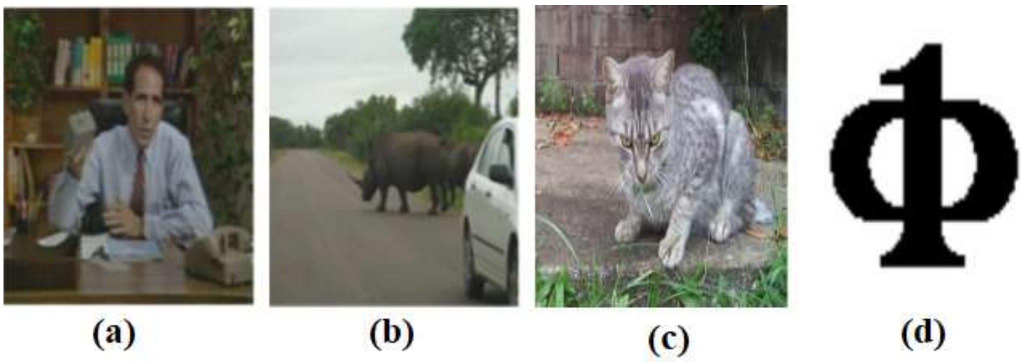

Figure.4. Sample Frames from Videos a) Salesman.avi, b) Rhino.avi, c). Cat.avi, d) Watermark Image

Mean Square Error (MSE): The error is the difference in values between the resulting and actual data. The actual difference or error between the expected/ideal outcome and the calculated or achieved result is given by the mean of the square of this error. Where $(M \times N)$ is the MSE between the original and distorted frames,

$$MSE = \frac{1}{M \times N} \sum_{i=1}^{M} \sum_{j=1}^{N} (W(i,j) - W'(i,j))^2 \quad (12)$$

Where *W* and *W* were the pixel values at position (*i, j*) of the actual and deformed frames, correspondingly. High PSNR values represent that watermarking is less perceptible.

Peak Signal to Noise Ratio (PSNR): The PSNR was used to calculate the difference between the watermarked, attacked and original video frames. In most circumstances, a high PSNR indicates that the reconstruction is of greater quality; however, this is not always the case. In terms of mean squared error, PSNR is given by,

$$PSNR = 10\log_{10}\left(\frac{255^2}{MSE}\right) \quad (13)$$

Normalized Correlation Coefficient (NCC): If the value of NCC is near to one, both the embedded and extracted watermarks will be comparable or associated. If the value of NCC is near to zero, it indicates that the data is uncorrelated or dissimilar. The NCC is the measure of the robustness of watermarking, with a maximum value of 1. The NCC is determined as follows,

$$NCC = \frac{\sum_{i=1}^{M}\sum_{j=1}^{N}(W(i,j)\times W'(i,j))}{\sum_{i=1}^{M}\sum_{j=1}^{N}W(i,j)^2} \quad (14)$$

where W and W' denote the original and extracted watermarks, correspondingly.

Figure 5 represents the watermarked frames in the video. Table 1 displays the results obtained by the proposed method. It also compares the results of the proposed method with RDWT-SVD and DWT-SVD methods. The attacks in watermarking are categorized as noise, cropping, filters, and blurring in this context. All these attacks are done in the proposed method and the PSNR, MSE and NCC values are shown in Table 1.

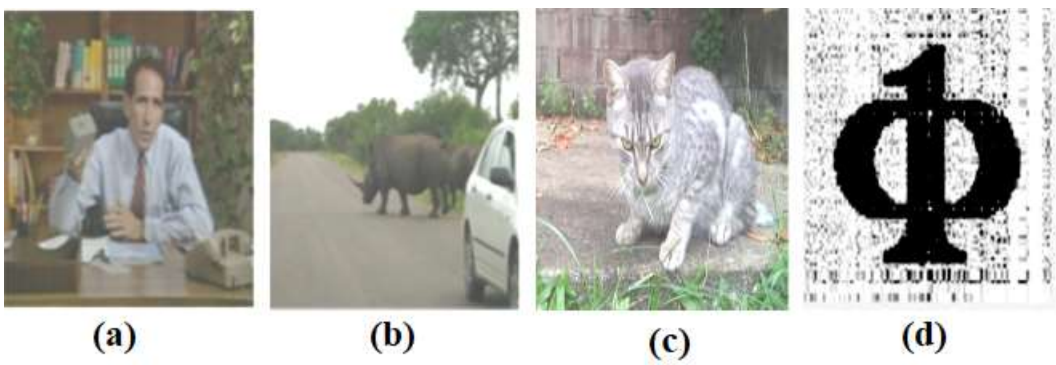

Figure.5. Watermarked Video Frames a) Salesman.avi, b) Rhino.avi, c) Cat.avi, d) Extracted Watermark

Table.1.Performance Analysis Comparison of Proposed Model with Attacks

Input Videos		PSNR			MSE			NCC		
		RDWT-SVD	DWT-SVD	Proposed	RDWT-SVD	DWT-SVD	Proposed	RDWT-SVD	DWT-SVD	Proposed
1	Noise	51.66	51.03	52.19	0.93	1.01	0.71	0.72	0.70	0.76
1	Filter	54.32	53.84	55.98	0.97	2.08	0.72	0.73	0.71	0.76
1	Cropping	51.88	51.22	53.73	0.80	2.35	0.64	0.73	0.72	0.77
1	Blurring	52.16	52.01	53.78	0.80	1.99	0.65	0.73	0.72	0.80
2	Noise	51.44	50.17	52.91	0.92	1.07	0.75	0.74	0.72	0.78
2	Filter	54.13	54.10	56.27	0.96	2.55	0.73	0.75	0.73	0.80
2	Cropping	51.60	51.27	53.81	0.81	1.48	0.65	0.75	0.74	0.82
2	Blurring	52.56	52.21	54.47	0.80	1.19	0.68	0.76	0.74	0.81
3	Noise	51.33	51.06	54.90	0.92	1.90	0.77	0.79	0.76	0.92
3	Filter	54.72	54.18	56.68	0.97	2.53	0.78	0.80	0.77	0.93
3	Cropping	52.15	52.88	53.24	0.81	1.72	0.66	0.80	0.77	0.95
3	Blurring	52.98	52.12	54.36	0.80	1.45	0.64	0.82	0.78	0.96

From the Table 1, it is analyzed that the PSNR obtained by the proposed method for various attacks in all videos are increased approximately by 2. Also, there is an appreciable amount of reduction in MSE. The NCC values are also increased when compared to DWT-SVD and RDWT-SVD.Figures 6–8 show a graphical comparison of PSNR, MSE, and NCC performance.

Figure 6 represents the PSNR performance comparison of the video-1 evaluated with attacks. The proposed model attained the best PSNR value 55.98 from evaluating video-1. The highest PSNR value was recorded from evaluating video-3 with 56.68 and 56.27 in video-2.

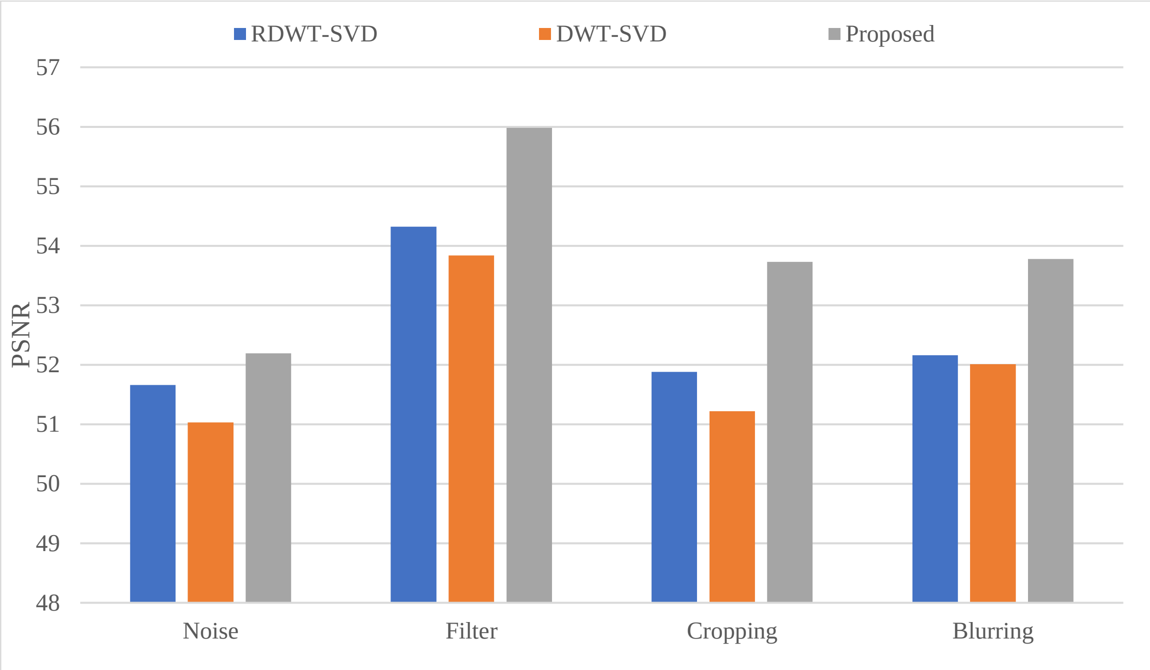

Figure.6. Comparison of PSNR Rate of Salesman.avi Video

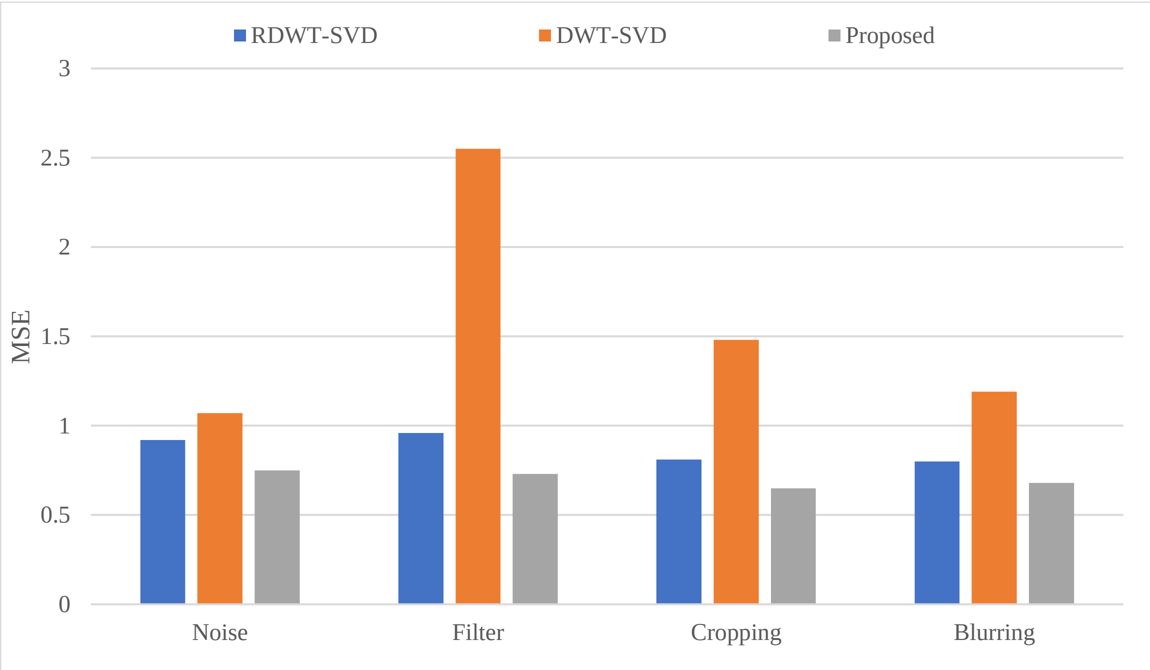

Figure.7. Comparison of MSE Rate of Rhino.avi Video

Figure 7 represents the MSE performance comparison of the video-2 evaluated with attacks. The proposed model attained the best MSE value 0.64 from evaluating video-2. The proposed modelobtained lowest MSE values from evaluating different attacks in all the videos compared to other methods.

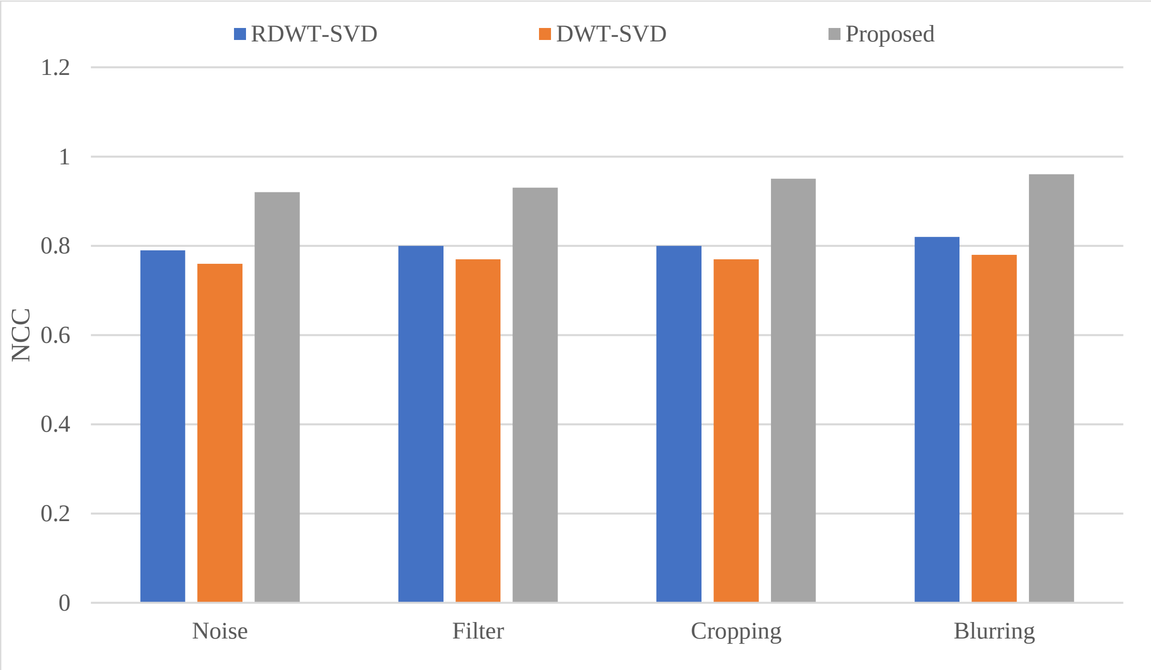

Figure.8. Comparison of NCC Rate of Cat.avi Video

Figure 8 represents the NCC performance comparison of the video-3 evaluated with attacks. The proposed model attained the best MSE value 0.96 from evaluating video-3. The proposed model obtained best MSE values from evaluating different attacks in all the videos compared to other methods. According to the experimental data, the proposed model achieved the highest performance values when compared to the current techniques. Thus it outperforms the existing methods.

The existing DWT based method obtains very less NCC and PSNR values whereas the proposed curvelet based method obtains higher results and with less MSE.

6. Conclusion

In this research, a robust and invisible video watermarking system is proposed. The proposed method randomly selects few frames using intensity based seed generation. Among the selected frames, the frames which have high textural and structural properties are given to curvelet transform. The above mentioned properties are studied using entropy and phase congruency. After selecting frames, lower variance sub bands are used to embed the watermark. The extraction is done in the reverse manner. The proposed method is examined using three videos with various attacks. The performance of the proposed method is evaluated using PSNR, MSE and NCC. The results are compared with existing methods such as DWT-SVD and RDWT-

SVD. The proposed method outperforms the existing methods by a wide margin. In the future, the proposed method may be tested with a larger number of videos and it can be improved further with sophisticated optimization methods.

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