



A Survey of Digital Video Watermarking Schemes

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ABSTRACT

Digital watermarking is a technique or act of hiding a secret information (text, signature, logo, audio, image etc.) in the form of a watermark into a digital multimedia such as text, image, audio and video. There are two classes of watermark; visible and invisible. Visible watermark is viewable by the human eye or detectable by human ear while invisible watermark is only detectable with special software, it cannot be seen by human eye or inaudible and it is more robust than the visible watermark. Digital video watermarking is a recent technology and has become an area of concern because most reported copyright violation and distribution transpires in video media content. However, researchers have come up with several techniques in trying to tackle these challenges. A review of the prevailing digital video watermarking techniques is presented in this paper.

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INTRODUCTION

In fear of outsized scale piracy, numerous content owners are disinclined to make their content available to new Internet-based content distribution systems. In order to battle piracy, there is a need for content owners to find a reliable way to control illegal distribution of their media, while upholding ease of access for authorized users (Van Huyssteen, 2012). This compelled the use of watermarking. Digital watermarking is a technique or act of hiding a secret information (text, signature, logo, audio, image etc.) in the form of a watermark into a digital multimedia such as text, image, audio and video (Thind & Jindal, 2015). There are two classes of watermark; visible and invisible. Visible watermark is viewable by the human eye or detectable by human ear while invisible watermark is only detectable with special software, it cannot be seen by human eye or inaudible and it is more robust than the visible watermark (Ghosh *et al.*, 2012). A watermark is said to be expedient if it is robust to various attacks, as well as insertion of other watermark (Pfitzmann, 2000). These attacks

could be intentional or unintentional (Liu & He, 2005). Digital watermarking mainly comprises of two processes namely embedding and extraction, where embedding is the process of concealing the watermark in the host signal and extraction is the process of recovering back the watermark from the watermarked signal (Gupta *et al.*, 2017). Digital watermarking can be classified according to the host signal, which are as follows (Sinha *et al.*, 2014): (1). Text Watermarking, (2). Audio Watermarking, (3). Image Watermarking and (4). Video Watermarking.

BACKGROUND

Digital Video Watermarking Processes

The concept of digital watermarking comprises of two scenarios. The first scenario is the embedding process and the second scenario is the extraction process (Peter *et al.*, 2010) as shown in figure 1.1 and figure 1.2 respectively.

1. **Embedding:** is a process of inputting a watermark into a video signal. A typical watermark embedding process is represented in a block diagram below.

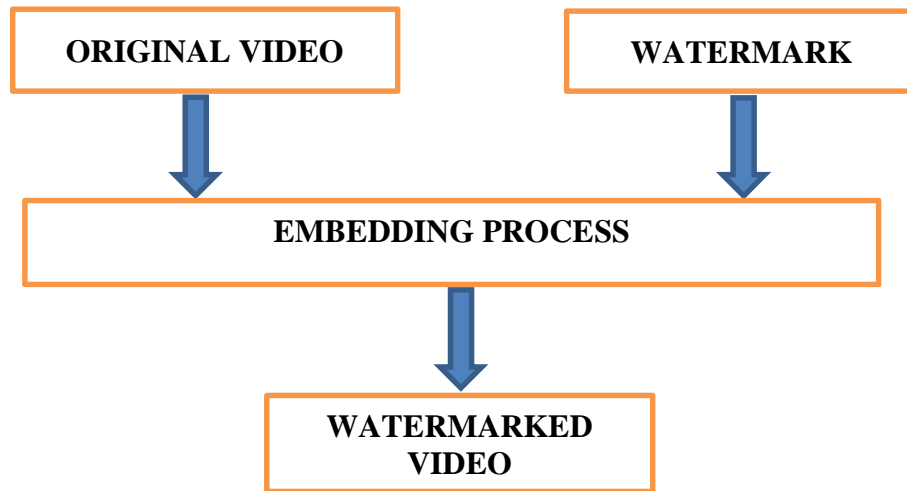


Figure 2.1: Watermark Embedding Process (Hindavi Iskande1, 2015).

Extraction: is a process of recovering the embedded watermark from the watermarked video. A typical watermark extraction process is represented in a block diagram below

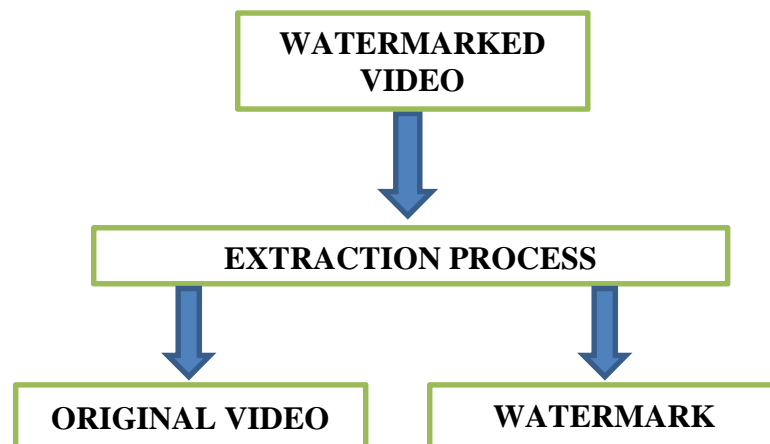


Figure 2.2: Watermark Extraction Process (Hindavi Iskande1, 2015).

Requirements for Video Watermarking

There is a need for video watermarking to meet some basic requirements based on the application of use. Outlined below are some properties in video watermarking which must be considered in designing a watermarking technique (Khuteta, 2017).

Imperceptibility

Imperceptibility is an important property in digital watermarking since a watermark embedded in a host video is additional information to the

original video which could be visible or invisible. Imperceptibility is the ability of the artifacts produced by the watermark not to modify, affect or degrade the quality of the original video. A watermark is said to be imperceptible if the Human Visual System (HVS) or Human Audio System (HAS) cannot detect the differences between the watermarked signal and the original signal (Paul, 2011). The PSNR is often used to evaluate the visual quality of most watermarking techniques which in most cases does not actually give the true

perceptual quality of the video due to the non-linear behavior of the HVS or HAS (Patel *et al.*, 2014).

Robustness

Robustness of a watermarking scheme is the ability of a watermark to be resilient after the watermarked video has been subjected to attacks like signal processing attacks, geometric attacks etc. Robustness is one of the major requirements of digital watermarking. After embedding the watermark into the host signal, distortion may likely occur on the host data during transmission from encoder to decoder (Tao et al, 2014). This distortion can be intentional or un-intentional. A watermarking scheme cannot be robust against all attacks although requirement is application dependent therefore the robustness of digital watermarking can be classified based on the application of use as follows (Patel *et al.*, 2014):

1. **Robust:** A robust watermark should be difficult to remove when subjected to attacks being intentional or un-intentional. This type of watermark is applicable in copyright protection, broadcast monitoring, copy control etc.
2. **Semi-fragile:** the watermark is designed to tolerate some attacks like lossy compression, analog to digital conversion whereas it is susceptible to intentional attacks such as geometric attacks. It is applicable in video authentication.
3. **Fragile:** the watermark is designed to be easily destroyed if any slight modification is made on the watermarked frame. Fragile watermarking is solely used for protection and verification of digital content.

Data payload

The data capacity or payload size of a watermark refers to the amount of information bit that can be embedded into the host signal (Potkar & Ansari, 2014). The data capacity of a watermark varies in accordance with the application of use. In

generality, a 64Kb payload size of a watermark is considered appropriate for most applications (Mane & Chiddarwar, 2013). It is necessary to put into consideration the payload size that a watermarking technique can embed in order not to distort the original signal (Zhou *et al.*, 2016).

Computational Complexity and Time Complexity

One of the key requirements of video watermarking is that embedding and extraction process should be fairly fast and also should have low computational complexity (Khuteta, 2017). Computational complexity can be described as the efficiency and resources a watermarking algorithm takes to encode and decode. High computational complexity implies more software and hardware resources used. Computational Time is the time taken for watermarking algorithm to encode and decode a watermark (Singh *et al.*, 2012). The less time taken by an algorithm can improve the efficiency. Computational simplicity usually preferred in limited resource environments such as mobile devices and also real time applications requires both speed and efficiency (Dubey & HL, 2016).

VIDEO SHOTS

A video shot is said to be a series of continuous identical or similar video frames captured by a single camera. A collection of shots forms the video (Gauch *et al.*, 1999).

Video Frame: A video frame is the smallest unit of a video. A collection of frames forms a shot (Gauch *et al.*, 1999). Frames are classified into three as follows: i-frame. b-frame and p-frame (Gauch *et al.*, 1999).

Pixel: The smallest unit of an image (Blinn, 2005).

Video Watermarking Techniques

A handful of video watermarking techniques are in existence; these techniques are classified based on their domain of operation which are (Zhou *et al.*, 2016).

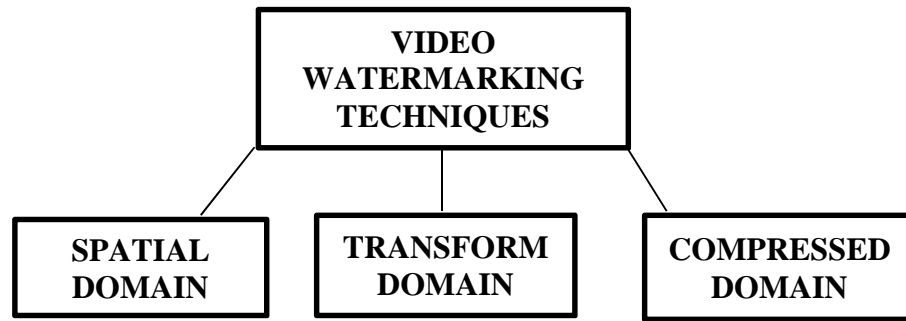


Figure 2.3: Video Watermarking Techniques.(Mane, 2013)

Spatial Domain

Watermark embedding in spatial domain is a process of directly adding or modifying the pixel value of the embedding channel of the video frame. The computational time of embedding and extraction is less because there is no need for the frame to be transformed.(Singh & Chadha, 2013) It can be applied for real time applications (Cox *et al.*, 2002). The advantages of spatial domain watermarking are simplicity, less computational time and low computational complexity (Scholar, 2014). Some of the techniques which use spatial domain watermarking are(Mane & Chiddarwar, 2013):

Least Significant Bit (LSB): One of the easiest approach into which the watermark is embedded within the least bits over the original video, in this technique, the least significant bit which convey a lesser amount of pertinent information are substituted with the watermark bits which makes it imperceptible (Cox *et al.*, 2008). The watermark can be spread all over the video frame or can be in the selected location of the frame (Singh & Chadha, 2013). However, the watermark can be simply deleted as the Least Significant Bit is susceptible to various attacks (Singh & Chadha, 2013).

Correlation based techniques: In this technique a pseudo random noise generated is added to the luminance channel of cover media pixels. Watermark $W(x, y)$ is added with the original signal $O(x, y)$, by the following equation.

$$O_w(x, y) = O(x, y) + K * W(x, y) \quad (2.1)$$

Where K denotes gain factor and O_w is the watermarked signal. When the value of K increases

the robustness increases but the quality of the watermark decreases (Gupta *et al.*, 2016). To extract the watermark, the exact pseudo-random noise generator algorithm is applied using the same key, and the correlation computation is done between the noise pattern and the watermarked video. When the correlation surpasses a particular threshold T , the watermark is detected(Pik-Wah, 2004).

Transform Domain

The main advantage of transform domain techniques is addressing the setback of spatial domain (Shojanazeri *et al.*, 2013). In the transform domain watermarking techniques, firstly the original video frame is transformed by a pre-defined transformation technique. Then the watermark is embedded in the transformation coefficients of the frame. In order to obtain the watermarked video, the inverse transform of the process used to embed is performed (Preeti Parashar1, 2014). Some of the frequently used techniques in transform domain includes (Manthalkar *et al.*, 2010):

1. Discrete Wavelet Transform (DWT)
2. Singular Value Decomposition (SVD)
3. Discrete Cosine Transform (DCT)
4. Discrete Fourier Transform (DFT)
5. Discrete Stockwell Transform (DST)

COMPARISON BETWEEN VIDEO WATERMARKING TECHNIQUES

Table 2.1 shows the summary of comparison of video watermarking techniques based on the requirements or features of digital watermarking.



Table 2.1: Comparison of Digital Video Watermarking Techniques based on the requirements of Digital Watermarking (Khuteta, 2017).

FEATURES	LSB	DFT	DCT	DWT	SVD	DOST
Robustness	Low	High	High	High	High	Very High
Imperceptibility	High	Average	Average	Average	Average	Average
Security	Low	High	Average	Average	High	Very High
Data Payload	Less	Average	High	High	High	High
Computational Complexity	Less	Average	Average	Very High	High	Less
Computational Time	Less	High	High	Very High	High	Less
Error Probability	Less	Less	Less	Less	Less	Less

Table 2.2: Advantages and Disadvantages of Video Watermarking Techniques (Asikuzzaman & Pickering, 2017; Yusof & Saparon, 2015).

Techniques	Merits	Demerits
DWT	<ol style="list-style-type: none"> 1. Excellent Spatio frequency analysis (DWT captures both frequency & location information) 2. Good energy compaction 3. Good for signal processing attacks 4. Higher compression ratio which is relevant to human perception 	<ol style="list-style-type: none"> 1. Less robustness against geometric attacks. 2. It lacks shift invariance 3. Noise/blur near edges of images or video frames
DFT	<ol style="list-style-type: none"> 1. It is Rotation Scaling and Translation invariant. Hence it can be used to recover from geometric distortion. 2. Good resistant against scaling and rotation attacks 	<ol style="list-style-type: none"> 1. Not robust to some geometric attacks like cropping & shearing 2. Loss of time frequency analysis can result to difficulties in processing 3. Not compatible with standard video compression techniques (MPEG etc.)
DCT	<ol style="list-style-type: none"> 1. Good energy compaction properties. 2. Compatible with JPEG, MPEG and H.26x compression standards. 3. Easier computation compared with DFT 	<ol style="list-style-type: none"> 1. Limited protection against geometric attacks. 2. Block effect (higher compression ratio makes the blocks visible) 3. It is computationally expensive.
SVD	<ol style="list-style-type: none"> 1. Good resistance against geometric and signal processing attacks (high robustness) 2. High energy compaction 3. Small perturbation added to a frame does not cause a significant change. 	<ol style="list-style-type: none"> 1. High false positive outcomes 2. Computationally expensive.



DOST	<ol style="list-style-type: none">1. Reduces the information redundancy of the DST to the minimal and leads to the maximum efficiency of a representation.2. It has shift invariant property.3. It has the ability of maintaining the phase properties of Stockwell Transform and Fourier Transform which enables it to maintain the capacity of reconstructing back to time domain.	<ol style="list-style-type: none">1. Its non-redundancy provides a coarse time-frequency representation such representation may not always be sufficient to reveal all the details within a specific signal.
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In could be observed from Table 2.2 that the DOST offers the most vital advantages when compared with other techniques.

APPLICATIONS OF VIDEO WATERMARKING

There are diverse applications of Video Watermarking some of which includes:

I. Fingerprinting: It is a technique of uniquely assigning a watermark to a particular person in the form of a fingerprint. This is for the purpose of tracing the source of illegal copy by the video content owner. This technique is mostly used in movie theater (Saini & Shrivastava, 2014).

II. Copyright Protecting: It is one of the main applications of watermarking, where by the content owner embeds a watermark that carries the copyright information in an original video, which when extracted, can be used to prove ownership. This is mostly used in litigation cases (Doerr & Dugelay, 2003).

III. Broadcast Monitoring: This application is mostly used in commercial advertisements to verify whether the advert has been broadcasted as contracted. It can also be used to trace unauthorized broadcast station (Saini & Shrivastava, 2014).

IV. Tamper Detection: In tamper detection, a fragile watermark is used. In a case where the watermark is destroyed or degraded, it signifies tampering and the digital content cannot be trusted (Jabade & Gengaje, 2011).

TYPES OF ATTACKS IN WATERMARKING: the attacks on watermarking can be broadly classified into two, intentional attacks and unintentional attacks.

Intentional Attacks: these are attacks that are deliberate attempt to stop a successful extraction process. It can be classified into two: Geometric Attacks and Removal Attacks

Geometric Attacks: in this category of attack, the focus is not to remove the watermark but rather an attempt to de-synchronize the extraction process of

the video sequence using geometric distortions such as (Kuo *et al.*, 2008):

Rotation Attack: Rotating the watermarked video can change the ratio aspect of the video where by causing de-synchronization of the video frame (Potkar & Ansari, 2014)

Removal Attack: This category of attack is aimed at removing the watermark from the video frames and possibly inputting a fake watermark (Potkar & Ansari, 2014).

Unintentional Attacks: Unintentional attacks are caused by normal signal processing operations such as A/D conversion and D/A conversion, Video compression, Noise.

Noise Attack: This is an unwanted random signal that causes distortion on a signal. Some of these attacks includes; salt and pepper noise, speckle noise and Gaussian. noise (Potkar & Ansari, 2014).

Attacks specific to Video Watermarking: Due to the redundant information in video, this leads to some attacks that are peculiar to video watermarking. Attackers take advantage of this redundant information. These attacks include:

I. Frame Dropping: Due to the presence of inherent redundancy in video data, changes between frames in a shot are little because the frames are almost identical. This leads to no significant damage if some frames are dropped. Therefore attackers try to remove this identical frame and form their own video sequence (Tabassum & Islam, 2012).

II. Frame Swapping: This is an attack where by the frames in a shot are swapped in order to de-synchronize the order of the video sequence so that the watermark cannot be extracted (Tabassum & Islam, 2012).

III. Frame Adding/Insertion: This type of attack where by an attacks attempts to insert a malicious frame into the video shot in order to modify the video and possibly claim ownership of the digital content (Chan *et al.*, 2005).

Performance Evaluation Parameters of Watermarking Algorithms

The performance analysis for watermarked video and extracted watermark is evaluated on the basis of robustness and imperceptibility.

Peak Signal to Noise Ratio (PSNR): PSNR measures the degradation in the watermarked frame with respect to the host video (i.e. the quality of a watermarked video). The higher the value of the PSNR the more similar is the watermarked video is to the original video (Chono *et al.*, 2008). This metric is defined in decibels as (ITU-T Rec. J.147, 2002):

$$P = 10 \log_1 \frac{L \times L}{M}$$

(2.2)

The perceptual quality of the algorithm is acceptable if the PSNR is equals or greater than 35dB (ITU-T Rec. J.147, 2002).

Mean square error (MSE): MSE is measured by an average squared difference between reference video and watermarked video. It can be calculated as (Jalil & Mirza, 2009):

$$MSE = \frac{1}{X \times Y} \sum_{i=1}^X \sum_{j=1}^Y (X(i, j) - X'(i, j))^2$$

(2.3)

where:

$X(i, j)$ = Original video

$X'(i, j)$ = Watermarked video

X = Numbers of row in the frame

Y = Numbers

DIGITAL WATERMARKING SCHEMES

Agarwal *et al.*, (2011) developed a robust video watermarking algorithm using multi band wavelet transform in the frequency domain. Video frames were selected randomly from reference frames of the original host video. The proposed scheme embedded data into specific frequency bands in the wavelet domain by applying DWT and DCT collectively on each considered video frame. High frequency bands were selected, on which DCT is applied. The mid-frequency coefficients of these DCT coefficients were altered by low frequency coefficients of the watermark to be embedded. By randomly selecting reference frames, the watermark could be retrieved from the watermarked video. Experimental results showed that there was no perceptible distortion in the embedded video. The proposed method was robust and can stand various

attacks with the embedded video having high PSNR. However, by randomly selecting video frames the frame with the optimal location for the embedding of the watermark might be overlooked. This could have affected the robustness of the scheme.

Sundararajan and Yamuna, (2013) developed a Discrete Wavelet Transform (DWT) based video watermarking scheme. In the proposed scheme, a grey scale image was embedded into a digital video data. The video sequence was partitioned into a number of frames for the embedding of the watermark image. The grey scale image to be used as the watermark was sliced into bit planes and each bit of the image was analyzed. DWT was used for the decomposition of the image. The sliced bit plane image was arranged and each arranged watermark image was embedded into the frames of the segmented shots during the watermark embedding. Experimental results showed that the proposed method yielded superior PSNR values which improved robustness and imperceptibility and showed increase NC for grey scale watermark images. The presence of redundancy in the video frames renders the method vulnerable to certain attacks like frame dropping and frame swapping.

Agrawal and Khurshid, (2014) developed a digital watermarking scheme that embedded an invisible and robust watermark information into video streams of MPEG-1, MPEG-2, H.264/AVC, MPEG-4 standards. Shot segmentation technique was applied to the original video sequence and it was segmented into a number of non-overlapping shots. For the embedding process, the audio watermark was converted into a 9-bit plane by the use of bit plane slicing. The audio watermark was then embedded into the video frames of the video signal. The video frames had R, G and B components. The blue channel was selected for embedding as this channel is more resistant to changes compared to red and green channels and the human eye is less sensitive to the blue channel. The trade-off between transparency and robustness was considered as an optimization problem and it was solved using Genetic Algorithm-Particle Swarm Optimization (GA-PSO) based hybrid optimization technique. The GA was used in generating the chromosome while the PSO was used for selecting the optimal location for embedding the audio watermark in the video sequence. The performance evaluation was based on the PSNR and NC metrics. The results obtained showed improvements for



various sequences with the proposed video watermarking scheme compared to existing schemes for geometrical attacks like rotation and cropping. However, the presence of redundancy in the segmented frames makes the video watermarking scheme vulnerable to frame attacks that prey on redundancy.

Sulthana and Sreekanth, (2014) developed a novel video watermarking scheme based on Discrete Wavelet Transform (DWT) for ownership protection, authentication and content integrity confirmation in digital form. In the proposed scheme, the input video sequence was partitioned into a number of frames. This partitioning was done for the embedding process. Each grey scale image or frame was sliced into bit planes in order to analyze each bit of the image. The sliced bit plane images were permuted with each permuted watermarked image embedded into each frame of the segmented sequence with the aid of the watermarking embedding. The watermark recovery is achieved with the help of the watermark extraction process. DWT is used in the decomposition of the image. Results obtained using the proposed scheme was compared with an existing scheme based on PSNR and NC. The results proved that the proposed scheme was efficient in terms of robustness and imperceptibility. However, the scheme remains prone to certain attacks like frame dropping, frame averaging, that take advantage of redundancy in the scheme.

Anjaneyulu and Ramashri, (2015) proposed a Hybrid Discrete Wavelet Transform-Singular Value Decomposition (Hybrid DWT-SVD) based Video Watermarking method using Improved Artificial Bee Colony Optimization Algorithm to protect to protect copy right of images. The input video sequence was segmented, using shot segmentation, into shots before the embedding process. The segmented video shots were then divided into a number of frames for the embedding process. In the proposed method, the SVD and DWT were used to decompose the images in the watermarked image in order to improve robustness. The artificial bee colony optimization algorithm was used for generating random frames for the watermark embedding process. Results obtained for the proposed method when subjected to several attacks showed an improvement in the watermarking scheme having the optimization technique over a technique with no optimization technique. However, the hybrid optimization algorithm used has an increase in

computational complexity and time. Also, the proposed method is vulnerable to attacks that take advantage of redundancy in the frames.

Sundararajan and Yamuna, (2016) developed a cuckoo search and ABC algorithm based video watermarking scheme using audio watermark. The audio watermark is converted into 9 bits using bit plane slicing for embedding into the host video. The input video sequence was converted into shots and the shots were partitioned into frames. The frames were selected for embedding using cuckoo search algorithm and finding the optimal location for embedding was carried out using ABC algorithm by calculating the PSNR and NC of the frame. An appropriate watermark extraction procedure was used to extract the audio data that was embedded in the video data. Results obtained shows that the scheme was robust against salt and pepper attack, rotation attack, but not robust against cropping attack, and if subjected to attacks like frame dropping and frame swapping the scheme will not be robust to these attacks due to the existence of the redundancy. Azeem *et al.*, (2016) proposed a new robust video watermarking technique based on Discrete Cosine Transform (DCT) using H.264/Advanced Audio Codec luma components. Video frames were extracted from the host video sequence. Each frame was watermarked using multi-level DCT. The frames were decomposed into three components: Y, U and V. One luma component was selected for the watermark embedding from components U or V. 2D-DCT was applied to all blocks of each frame in the V luminance. The modified Y, U and V components were combined to create the watermarked video frame. The watermarked video sequence was obtained after the watermarked video frames were reconstructed. Experimental results showed that the proposed method was imperceptible and robust to a wide range of signal and video processing attacks like Gaussian noise, cropping, over writing. However, the increased complexity of the proposed method means an increase in computational time. Also, attacks that take advantage of redundancy in video frames make the proposed method vulnerable to attacks like frame averaging and frame dropping.

Asha and Bhagya, (2017) developed a video watermarking scheme using DWT as a transformation technique and alpha blending technique for embedding and extraction. The input video was segmented into non-overlapping shots and then converted into frames. All the video frames



were decomposed using DWT. The watermark was split into four quadrants and decomposed using DWT and embedded into the transformed frames using alpha blending embedding techniques. The modified frames were combined together and IDWT was applied to form the watermarked video. The watermark extraction was achieved using alpha blending extraction technique. Experimental results show that the proposed scheme recorded a high PSNR and low MSE which implies that the scheme is robust. However the proposed scheme was not imperceptible and was not subjected to any attack and if subjected to attacks it will not be robust which will in turn reduce the PSNR and increase the MSE in their work. Also the decomposition of all the frames in the proposed scheme introduce redundancy and high computational complexity which further increases the possibility of MSE in the scheme. In addition, the redundancy in frames makes the scheme more vulnerable to attacks that take advantages of redundancy in frames such as frame dropping, frame swapping and frame insertion.

Kumar *et al.*, (2017) proposed a Robust Video Watermarking method using Wavelet Transforms and Singular Value Decomposition against noise and frame attacks. In the proposed method, a video signal was divided into frames. The key frame was selected using key frame selection procedure. This was done by extraction the frames one by one. The histogram difference between two consecutive frames was calculated. A threshold was obtained using the mean and standard deviation. The histogram difference between consecutive frames was then compared with the threshold obtained. A key frame was selected if the histogram difference was greater than the threshold. This procedure was repeated until the end of the video. R, G, B was transformed to Y, U, V with the DWT applied to the key frame in the Y segment. SVD was then applied for each band bringing about lattices: U_y , S_y , V_y . The watermark image was also decomposed to obtain U_w , S_w and V_w . The watermark was then embedded into the the appropriate band of the Y segment. Simulation results showed the proposed method yielded improved PSNR yielding robustness against noise attacks and frame attacks. However, the proposed method has an increased computational cost resulting in increased computational time. The proposed method also has the problem of vulnerability to attacks due to redundancy.

Anjaneyulu and Ramashri, (2017) proposed a Hybrid Discrete Wavelet Transform-Principal Components Analysis based Video Watermarking for copyright protection using Ant Colony Optimization Technique. In the proposed method, before the watermark was embedded, the video sequence was segmented into shots and the shots were divided into a number of frames. PCA and DWT were applied on the watermark image. The PCA was used as a linear transform technique to convey the information about the image to principal components. DWT was used to decay the image into four sub bands (LL, LH, HL, HH) so as to choose the best sub band to embed the watermark. The Ant Colony Optimization technique was used to generate random frames for the embedding process. To improve the efficiency of the video watermarking method, watermark embedding and watermark extraction were carried out. The result of the watermarking process was the watermarked video. Results obtained when the watermarked video sequence was subjected to several attacks showed that the proposed method achieved improvement in terms of robustness with higher values of PSNR when compared to existing methods. However, by using a hybrid optimization technique there is an increase in the computational complexity of the method. The presence of redundancy in the frames also renders the watermark vulnerable to certain attacks like frame averaging and frame dropping.

CONCLUSION

The previous section has described a couple of digital watermarking schemes. The parameters considered were highlighted and the results obtained, were discussed with their attendant strength and weaknesses. Possible modifications were also suggested as well. The discussed schemes show improved performance in terms of robustness and imperceptibility etc. From the foregoing, improvements can be made by considering the usage of more efficient techniques in order to obtain enhanced results.

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