A Robust Scheme for Digital Video Watermarking based on Scrambling of Watermark

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ABSTRACT
The swift growth of communication networks has directed to situation that assists on-line e-commerce of digital properties. Subsequently, digital data holders can rapidly and immensely transfer multimedia contents athwart the Internet. This leads to broad curiosity in multimedia security and multimedia copyright protection. This paper proposes a robust scheme for digital video watermarking based on scrambling & then embedding the watermark into different parts of the source video according to its scene change. Proposed algorithm is robust against the various attacks like dropping of frame, averaging and collusion. The work is started with a comprehensive investigation of modern watermarking technologies, and perceived that none of the standing arrangements is proficient of resisting all the attacks. Hence, we propose the notion of embedding different fragments of a lone watermark into dissimilar scenes of a video. The efficiency of the scheme is tested over a sequence of research, in which a number of typical image processing attacks are tested, and the robustness of the scheme is revealed using the standards of the latest Stirmark test.

Keywords
Digital watermarking, discrete wavelet transform (DWT), hybrid, scene change, video.

1. INTRODUCTION
With the rapid progression of the Internet and multimedia systems in disseminated situations, it is meek for digital data holders to relocate multimedia properties athwart the Internet. So, there is necessity of copyright protection for digital contents [2][6][7][14]. Conventionally, encryption techniques were employed to defend the tenure of media. These techniques, however, do not safeguard against illicit copying after the media have been successfully transmitted and decrypted. Recently, digital watermarking techniques are exploited to preserve the copyright [1][9][14][17].

In digital watermarking, a pattern is embedded as watermark in to the source media. Digital watermarking is heavily used as a method of Intellectual Property Rights (IPR) protection. Watermarking schemes are of two types, visible watermarking where the watermark is clearly visible & invisible watermarking where watermark is hidden in the source media. Variations of invisible watermarking schemes have been proposed over the past few years. So, this paper also considers the invisible watermarking scheme.

There are two types of watermark, a robust watermark, which is designed to resist attack (malicious or not) in order to detect the mark. Secondly, a fragile watermark, which gets vanished when the source document is corrupted. It can be really useful in judiciary process, for example, where it is imperative to be certain, that whatever being used is genuine. This paper proposes a robust watermark, with the aim to protect the copyrights of the source video.

This paper is organized into four sections. The previous section covers the Introduction. Next section describes literature review & findings. Section III describes the details of the proposed scheme. The experimental results are shown in Section IV. Section V presents a conclusion and the future work.

2. LITERATURE SURVEY
Various comprehensive investigations on the existing watermarking technologies have been accomplished. And it has been discerned that none of the recent watermarking schemes can resist all sorts of attacks. With this outcome, this paper proposes a robust scheme for digital video watermarking based on scrambling & then embedding the watermark into different parts of the source video according to its scene change.

Certain watermarking schemes of each class have been preferred for enactment and various tests are accomplished to relate their robustness. Literature review reveals that watermarking schemes can be crudely divided into two classes: spatial domain, and transformed domain. Some of the spatial domain techniques discussed are:

Least significant bit (LSB) based watermarking scheme: The most straightforward method of watermark embedding would be to embed the watermark into the least significant bits of the cover object. LSB substitution, however, despite its simplicity brings a host of drawbacks. Although, it may survive transformations such as cropping, any addition of noise or lossy compression is likely to defeat the watermark. An even better attack would be to simply set the LSB bits of each pixel to 1, fully defeating the watermark with negligible impact on the cover object [21].

Threshold based correlation watermarking scheme: G. Langelaar et. al. [11] has discussed the threshold and non threshold based watermarking scheme.

Direct sequence watermark using m-frame: B. Mobasseri [3] has applied a direct sequence spread spectrum model to the watermarking of digital video. The watermarked video is robust to video editing attempts such as sub-sampling, frame reordering etc.

Now, some of the transform domain techniques are:

Discrete Fourier transform (DFT) with template matching: In this, the watermark is added as a template in the Fourier transform domain, to render the method to be robust against general linear transformations and common image processing operations such as compression, rotation, scaling, and aspect ratio changes [25].

Discrete wavelet transform (DWT) based watermarking scheme: The original image is transformed using wavelet transform and flags are created with the secret key. The secret key is the thing needed to extract the flags and compare these extracted flags with the original ones created during the watermark embedding process. To criticize the robustness of the scheme a comparison of the extracted flag with the original flag after applying several attacks such as JPEG compression, collusion, resize and noise addition were carried out [12].

Discrete Cosine Transform (DCT) based watermarking: The DCT allows an image to be broken up into different frequency bands, making it much easier to embed watermarking information into the middle frequency bands of an image. The middle frequency bands are chosen such that they avoid the most visual important parts of the image (low frequencies) without over-exposing themselves to removal through compression and noise attacks (high frequencies). In [8] author utilizes the middle-band DCT coefficients to encode a single bit into a DCT block. DCT-based watermarking scheme is the most robust to lossy compression.

Multistage spread spectrum [18]: The spread spectrum method has the advantage that the watermark extraction is possible without using the original unmarked image. The simulation results show the robustness of the watermark to image degradations such as lossy compression as in JPEG and MPEG, spatial filtering, cropping etc.

Featured based watermarking scheme: In this paper [22], based on a multi-scale SIFT (scale invariant feature transform) detector and bandelet transform theory, Pan-Pan Niu et. al. propose a new content based image watermarking algorithm with good visual quality and reasonable resistance towards desynchronization attack. This scheme is not only robust against common signal processing attacks such as sharpening, noise adding, JPEG compression, etc., but also robust against the desynchronization attacks such as rotation, translation, scaling, row or column removal, cropping, etc.

Dither modulations based watermarking scheme: C.H. Wu et. al. [5] discusses a flexible particle swarm optimization (PSO) based dither modulation (DM) watermarking scheme in H.264/AVC compressed video. The scheme can cope with different filter attacks.

Genetic Algorithm (GA) based watermarking scheme: A robust digital image watermarking scheme based on singular value decomposition (SVD) and a tin genetic algorithm (Tiny-GA) is proposed in this paper [4]. The singular values of a cover image are modified by multiple scale factors to embed the watermark image. Since the values of scale factors determine the watermark strength; therefore, Chih-Chin Lai uses the Tiny-GA to search the proper values in order to improve the visual quality of the watermarked image and the robustness of the watermark. Experimental results demonstrate that the scheme is able to withstand a variety of image processing attacks.

Scene based watermarking scheme: This scheme is robust against frame averaging & statistical analysis attacks. Shu Ching Chen et. al. [24] have detected the scenes using unsupervised segmentation and object tracking. The watermark is then embedded in the different scenes of the video.

To evaluate the algorithms, the Stirmark 4.0 benchmark program mainly designed for evaluation of image watermarking [10], [13], [19] is used. Each attack is considered by itself and is applicable after watermarking. Designing of a benchmarking tool for evaluation of the watermarking scheme is a crucial job. These tools are very useful and demanding for the watermarking community.

By observing these literatures, in this paper we have listed the following findings:

1) The watermark is not robust to the attacks which are explicitly embattled to videos, such as frame dropping, swapping, averaging, and collusion.
2) The bit rate of the watermark is low. Some algorithms embed only one bit information as the watermark.
3) None of the prevailing watermarking schemes is resistive to all the attacks.
4) A transform domain watermarking scheme is more robust than a spatial domain.
5) Scene changes are detected using low level features which are highly susceptible for noise addition attacks.
6) There are many tools for evaluation of image watermarking but till date no such effective tool for evaluation of video watermarking scheme is yet designed.

Hence, this paper provides a solution by applying the scene change detection algorithm with video watermarking scheme, to make the scheme robust against various video attacks like frame dropping. This is due to the same part of the watermark being embedded into the frames of a scene. For different scenes, different parts of the watermark are used, making the scheme robust against frame averaging and collusion.

3. PROPOSED WATERMARKING SCHEME

The proposed scene based watermarking scheme is shown in figure 1. This scheme mainly consists of four parts, including: preprocessing of watermark, preprocessing of video, embedding of watermark, and extraction of watermark. Details are described in the subsequent sections.

3.1 Preprocessing of Video

Upper part of the figure 1 shows the preprocessing of video. Here, a raw video (i.e. avi file) is taken as the input. Initially, video is decomposed into frames & then numbers of scenes are detected say *m*. Scene change detection is done using high level features which is shown in the figure 2. Scene change detection using low level features like histogram difference [23] is one of the pioneer techniques to identify the scene change, but luminance or color is sensitive to small changes, so these low level features cannot give a satisfactory answer to the problem of scene change detection. To solve these problems, a tale algorithm for scene change detection is applied which gives better results as compared to the previously applied algorithms. Here, *Scene Index* will hold the frame numbers of the first frame from which there is scene change & *Number of scene* will hold the number of scene change found say *m.* For feature extraction, edges of both the frames are computed & then block processing is done using average intensity. Finally edge comparison is done

for finding the difference between two frames. If this difference is greater than some threshold (here it will be 0.5 which gives better results) then the scene change is detected.

Algorithm for scene change detection is as shown in figure 3. According to the algorithm, initially video is taken as input. In second step, it is decomposed into frames. Some variables like *i, k, SceneIndex, NumberOfScenes* are initialized in step3. In step 4, the value of *i* is compared with the *number_of_frames* (contains the number of frames in the input video), if both the values are same the algorithm returns the result of scene change with *SceneIndex* which holds the index of the first frame from the new scene is detected and *NumberOfScenes* contains the number of scene change detected in step 16. Otherwise steps 6 to 14 will be repeated till the value of *i* gets match with *number_of_frames*. In step 6, we read the two frames from the *frame* array, where every frame is converted into image. These images are then converted in to binary images using edge detection where *sobel* filter is used, as which gives better results in step 7. In step 8, block processing is done using average intensity. Function *aiv()* is written, which returns the average intensity of every block for the supplied image. Then after edge difference is computed in step 9. In step 10, we compute the absolute summation of the edge difference which is compared with some *threshold* (here 0.5) in step 11. If this difference is greater than *threshold* then scene is detected and the value of *j* contains the index of first frame from new scene change which is detected, is assigned to array of *SceneIndex*. Also the value *NumberOfScenes* and value of *k* is incremented by one and value of *i* and *j* are reinitialized. And, if scene change is not found then value of *j* is incremented by one in step 12. In this way step 6 to 14 will be repeated till the value of *i* gets match with *number_of_frames.*

After scene change detection, all the frames are transformed into wavelet domain using Discrete Wavelet Transform (DWT). The frames are decomposed in 4-level sub-band by separable two-dimensional (2D) wavelet transform. It produces a low-frequency sub-band LL, and three series of high-frequency sub-bands LH, HL, and HH as shown in figure 4. According to the energy distribution, LL is the most vital then LH, HL, and HH. Our scheme is based on 4-levels DWT, which is determined by experimentations. If less than 4-level is applied, the competency of the scheme would be decreased; if larger than 4-levels is applied, the quality of the watermark video is affected.

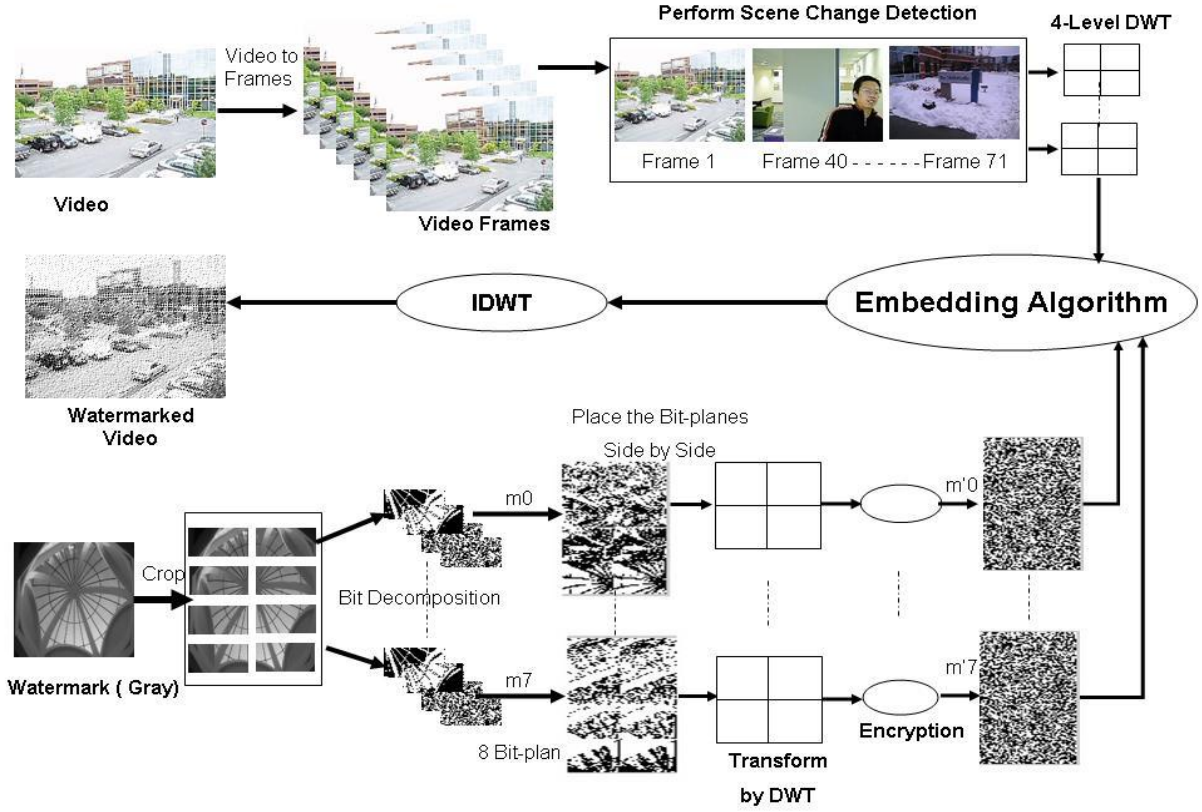

Fig 1: Proposed Scheme for Digital Video Watermarking

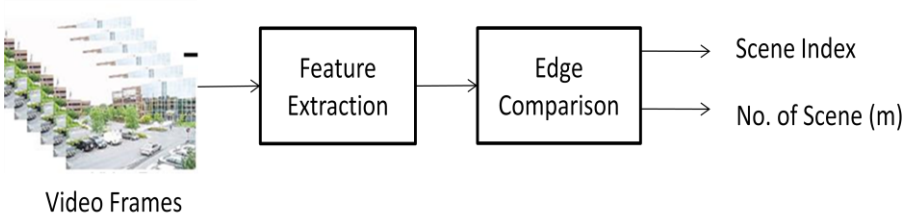

Fig 2: Framework for Scene Change Detection

Steps of algorithm for Video Preprocessing

1. *Take a raw video as an input i.e. avi file.*
2. *Decompose input video into frames.*
3. *Perform scene change detection using high level features.*
4. *Transform all frames into 4-level wavelet domain using 2D DWT.*

Finally all these frames are supplied to Watermark Embedding Algorithm.

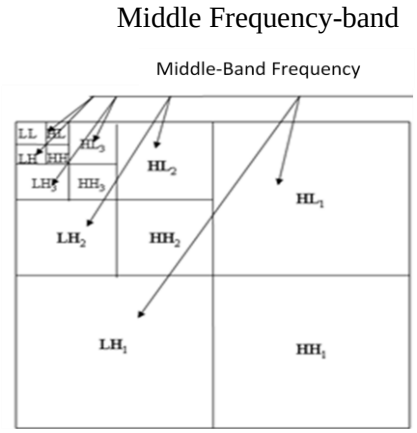

Fig 4: 4-level decomposition using 2D DWT

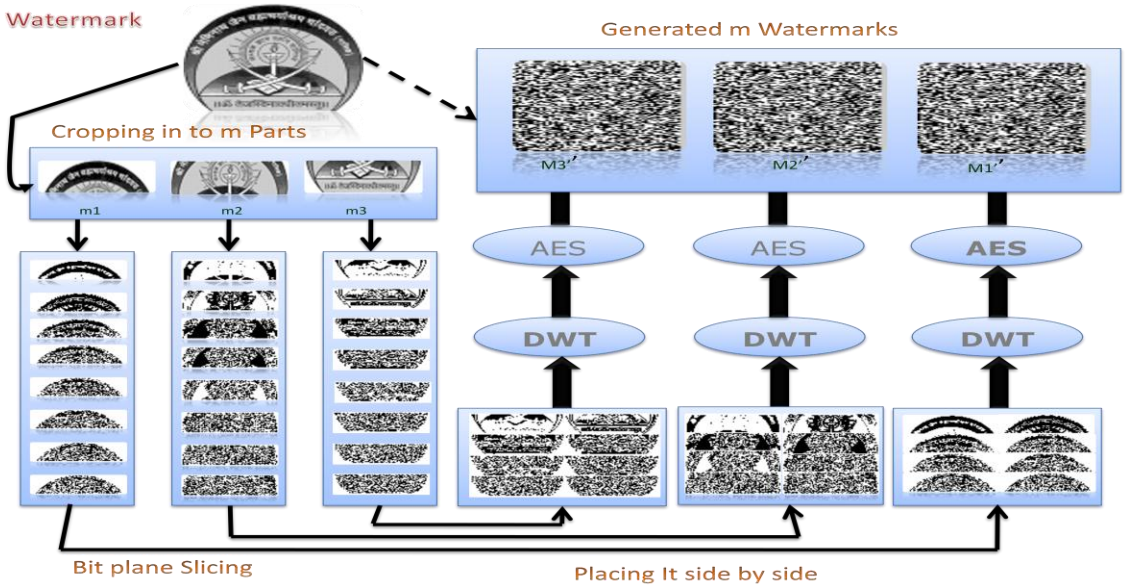

Fig 5: Preprocessing of a watermark (here *m* = 3)

3.2 Preprocessing of Watermark

Lower part of the figure 1 shows preprocessing of the watermark. Initially, input image (grayscale) is taken as watermark. This watermark is cropped into *m* (where *m* is number of scenes detected from scene change detection algorithm) small parts and pre-processing of every part is done to form a different watermark. After cropping a big watermark in to m small parts, each small part/image is decomposed into 8 bit-planes, and a large image can then be obtained by placing the bit-planes side by side only consisting of 0s and 1s. These processed images are used as watermarks, and totally independent watermarks are obtained. To make the scheme more robust, the processed watermarks are transformed to the wavelet domain using 2D-DWT. Finally, all these watermarks are encrypted using the algorithm described in [25] for enhancing the security. Entire preprocessing of the watermark is modeled in figure 5. Where SNJB (Shri Neminath Jain Bramhacharyashram)'s Logo is used as input image / watermark.

Steps of algorithm for Watermark Preprocessing

1. *Take a gray scale image as an input.*

2. *Input image is cropped in to m different small parts.*
3. *Every individual small part of the watermark is decomposed into 8-bit planes.*
4. *All decomposed 8-bit planes are placed side by side to form a big watermark.*
5. *Transform all watermarks into single-level wavelet domain using 2D DWT.*
6. *All these watermarks are encrypted.*

Finally all these different watermarks are supplied to Watermark Embedding Algorithm.

3.3 Embedding of watermark

This process is the heart of this scheme where all the different parts of watermarks are embedded in to different scene of the video. Embedding is done by changing position of some DWT coefficients with the following condition:

if $W_j = 1$ **then**

Exchange $\max(C_i, C_{i+1}, C_{i+2}, C_{i+3}, C_{i+4})$

else

Exchange $\min(C_i, C_{i+1}, C_{i+2}, C_{i+3}, C_{i+4})$

end if

Where C_i is the i^{th} DWT coefficient of a video frame, and W_j is the j^{th} pixel of a corresponding watermark image [16]. When the j^{th} pixel of watermark *Wj* = 1, we perform an exchange of *Ci* with the maximum value from $C_i, C_{i+1}, C_{i+2}, C_{i+3}, C_{i+4}$. When *Wj* = 0, we perform an exchange of *Ci* with the minimum value from $C_i, C_{i+1}, C_{i+2}, C_{i+3}, C_{i+4}$.With this algorithm, the retrieval of the embedded watermark does not need the original image. The higher frequency coefficients of the watermark like HH band are embedded to higher frequency parts of the video frame, and only the middle frequency wavelet coefficient of the frame (middle frequency sub band like HL or LH band) is watermarked [8].

3.4 Watermark Detection

The video is processed to detect the watermark. In this step, a watermarked video is decomposed in to frames, and then scene changes are detected. Also, each video frame is transformed to the wavelet domain with 4-levels 2D-DWT. The watermark is then extracted with the following condition: where *WCi* is the i^{th} DWT coefficient of a watermarked video frame, and *EWj* is the j^{th} pixel of the extracted watermark [18]. When the watermark is greater than median value among $WCi, WC_{i+1}, WC_{i+2}, WC_{i+3}, WC_{i+4}$, then extracted watermark is considered as one, i.e., *EWj*=1; otherwise, it is considered as zero, i.e. *EWj*=0. With this algorithm, the retrieval of the embedded watermark does not need the original video; this is an important property to video watermarking which leads to blind watermarking.

If $WC_i > median(WC_i, WC_{i+1}, WC_{i+2}, WC_{i+3}, WC_{i+4})$ **then**

$EW_j = 1$

Else

$EW_j = 0$

end if

As an identical watermark is used for all frames within a scene, multiple copies of each part of the watermark may be obtained.

The watermark is recovered by averaging the watermarks extracted from different frames. This reduces the effect if the attack is carried out at some designated frames.

4. EXPERIMENTAL RERSULTS

The performance of the proposed video watermarking scheme is evaluated through several experiments: the experiment with various dropping ratio, the experiment with frame averaging and statistical analysis, and the test of robustness with Stirmark 4.0 [19], [20]. Another DWT-based watermarking scheme, which embeds an identical watermark in all frames of the source video, is implemented to compare with the proposed scheme. We use the normalized correlation (NC) to measure the similarity of the extracted and the referenced watermarks to evaluate our scheme in the experiments. Formula given below computes correlation coefficient of the *A* and *B*. Here *A* is frame of original video & *B* is the frame of watermarked video.

$$r = \frac{\sum_m \sum_n (A_{mn} - \overline{A})(B_{mn} - \overline{B})}{\sqrt{\left(\sum_m \sum_n (A_{mn} - \overline{A})^2\right)\left(\sum_m \sum_n (B_{mn} - \overline{B})^2\right)}}$$

Where $\overline{A} = \texttt{mean2(A)}$, and $\overline{B} = \texttt{mean2(B)}$.

The table 1 shows the comparison of the DWT based watermarking, scene based watermarking scheme with histogram difference & scene based watermarking scheme with block processing, edge detection and comparison i.e. higher level features. Comparison is based on NC values of the watermark which is recovered after applying various classes of attacks. Here value 0.65 for Lossy Compression attack is treated as the NC value after watermark is recovered from attacked watermarked video. The NC value up to 0.5 and above is considered as watermark can be recovered and detected though it has been disturbed by various attacks.

Table 1: Summary of NC values for three listed schemes.

Attack Class	DWT based watermarking scheme	Scene based Watermarking Scheme based on histogram difference	Scene based Watermarking Scheme based on higher level features i.e. block processing, edge detection and comparison
Lossy Compression	0.61	0.62	**0.65**
PSNR	0.80	0.76	**1.0**
Add Noise	0.63	0.60	**0.75**

Median Filter	0.54	0.54	0.50
Cropping	0.68	0.66	**0.69**
Rescale	0.63	0.62	**0.65**
Rotation	0.60	0.61	0.60
Affine	0.55	0.55	0.50
Frame Dropping	0.9	0.68	**0.74**
Colluding	0.82	0.53	**0.56**

As per figure 6, it is clear that though the entire scene from watermarked video is dropped, still the watermark is recovered. DWT based watermarking scheme provides better results than other two. But the proposed scheme is better than the existing scheme of scene based watermarking based on histogram difference.

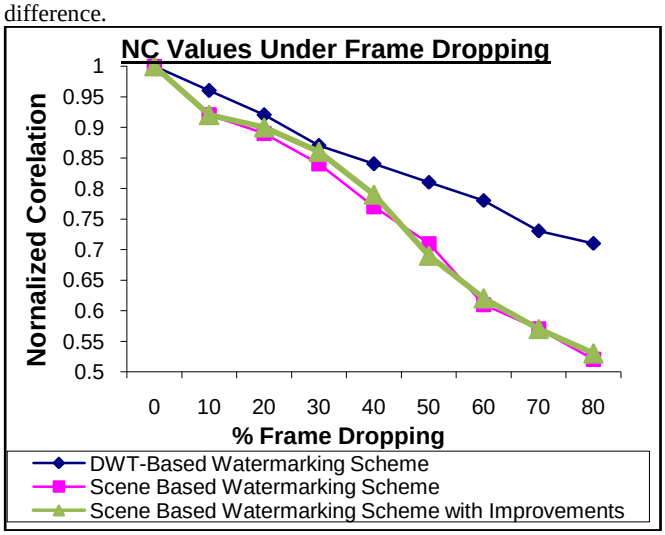

Fig 6 Experimental result with frame dropping attack

a. ***Experiment with Frame Averaging and Statistical Analysis***

Frame averaging and statistical analysis is another common attack to the video watermark. When attackers collect a number of watermarked frames, they can estimate the watermark by statistical averaging and remove it from the watermarked video [15]. Firstly, noise estimation would be done on similar frames of the video. As watermark can be considered as noise in a frame. If the frames are similar, they can be compared and the noise is estimated. After the noise is estimated, the watermark can be considered as the watermark. It will be compare with the frames to be attacked and remove the watermark in the video frames. Experiments have been conducted to evaluate the proposed scheme under this attack, and the results are shown in figure 7. It is found that the proposed scheme can resist to statistical averaging quite well. This is because our scheme crops a watermark into pieces and embeds them into different frames, making the watermarks resistant to attacks by frame averaging for the watermark extraction. The identical watermark used within a scene can prevent attackers from taking the advantage of motionless regions in successive frames and removing the watermark by comparing and averaging the frames statistically [24]. On the other hand, independent watermarks used for successive, yet different scenes can prevent the attackers from colluding with frames from completely different scenes to extract the watermark.

b. Experiment with cropping attack:

Here, watermarked video is cropped using various cropping ratios (i.e rectangle of windows) and watermark is extracted from cropped video. Figure 8 shows the results of the watermarking schemes after cropping attack. As per the graph it is, clear that the proposed scheme gives better results than other two. Here, cropping of every frame is done using Stirmark 4.0 & then video is formed from all the cropped frames.

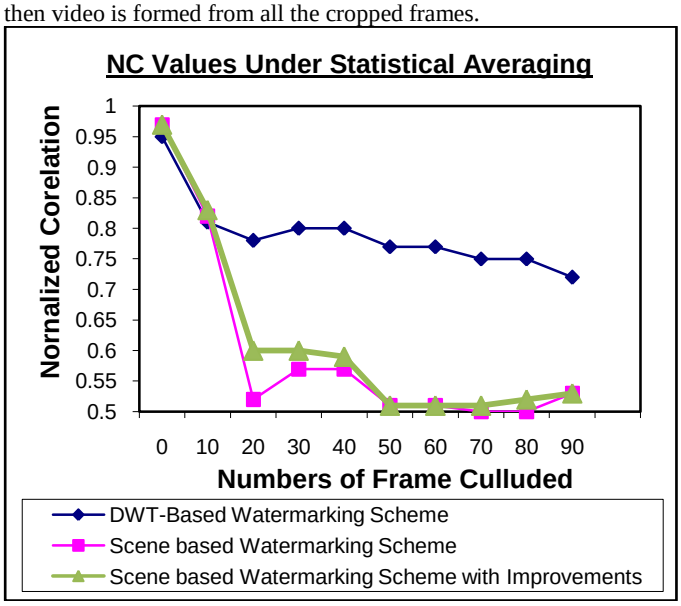

Fig 7 Experimental result with frame averaging attack

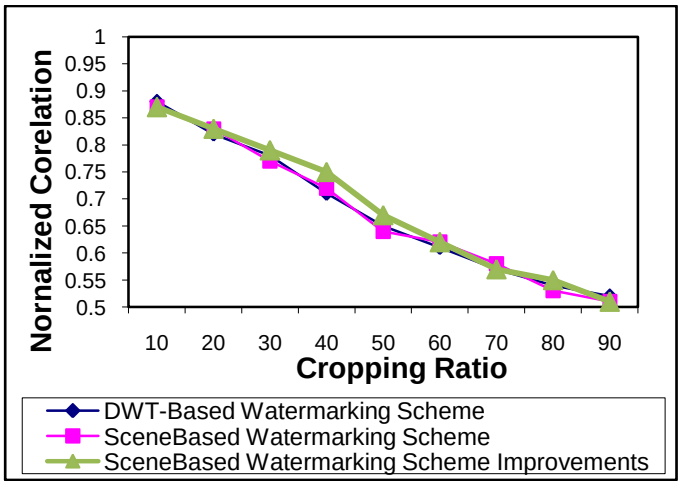

Fig 8 Experiment with cropping attack

The algorithms ability to make the watermark resistant to these attacks was analyzed and better results were inferred from the table 1 & graph given from Fig 6 to 8. In this way the proposed scheme is robust against various attacks like Frame dropping, statistical averaging & various image processing attacks like cropping, rotation, scaling etc.

5. CONCLUSION AND FUTURE SCOPE

This paper proposes an innovative scene-based video watermarking scheme. The process of this comprehensive video watermarking scheme, including watermark preprocessing, video preprocessing, watermark embedding, and watermark detection, is described in detail. Some experiments are conducted to demonstrate that our scheme is robust against attacks like frame dropping, frame averaging, and statistical analysis, and the robustness against the common image processing attacks is tested with Stirmark benchmark. Our scheme is verified to be resistant against attacks based on video characteristics and image processing techniques. This proposed watermarking scheme can be enhanced by combining with audio watermarks for error correction capabilities and the hybrid scheme for attack resisting.

6. ACKNOWLEDGMENTS

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