Video Quality Evaluation Using DWT-SPIHT Based Watermarking Technique

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Abstract— **The video quality analysis is very important in today's video broadcasting and transmission quality control because the quality is a key factor in customer satisfaction. This paper presents a full reference based video quality evaluation technique, using the application of watermarking. Frames with low complexity value are selected for the insertion of the watermark, on the selected video frames; DWT is applied up to third level to get the DWT coefficients. Then SPIHT encoding/decoding is applied which helps in finding the significant coefficients for the insertion of watermark. The significant coefficients are converted into bit-planes and 3rd bit plane (from LSB side) of each coefficient is selected for watermark. The SPIHT algorithm ensures that the watermark bits are inserted uniformly throughout the frames. After embedding the watermark, the IDWT is applied and we get the watermarked frames which are then incorporated in the video file. The simulation results show no visible difference between watermarked frame and original frame. The video quality is estimated in terms of peak signal to noise ratio (PSNR), structure similarity (SSIM) and true detection rates (TDR) against various attacks like Salt pepper noise, rotation Gaussian noise and compression attacks. The results indicate that the proposed technique for quality evaluation of the video, accurately calculates the quality of a video and also it is robust against various attacks.**

Keywords— Digital Image Watermarking; Discrete Wavelet Transform; Set Partitioning in Hierarchical Trees; Structure Similarity; PSNR; TDR.

I. Introduction

In the recent years with the advent of the Internet, the digital data is being generated in abundance. This has urged the requirement for computerized rights authority, which can protect the copyright of the owner and the solution is to use digital watermarking [1]. A watermark is a digital data that is embedded into the multimedia data such that it can be discovered or extracted at later times for the proof of ownership. The main intent of digital watermarking is to embed information imperceptibly and robustly in the cover data. Watermark may contain the information about the source, ownership, receiver, copy control etc. After watermark embedding, the original cover media becomes slightly modified, and the modified content is called the watermarked content.

Various watermarking schemes are available to hide copyright marks and other information in digital images, video, audio and other multimedia sources [2] [3].

There are numerous applications of digital watermarking like transaction tracking, copy control, authentication, database linking, etc. [4]. One of the most recent applications of the watermarking is for the quality evaluation of images/videos [5].

The quality of the video stream at the receiver has to be evaluated so that the broadcaster can guarantee certain quality of the video. Various methods are available in the literature to comment on the quality of the video but the most recent one is using the application of watermarking. A watermark is embedded in the video frames and later on at the receiver side we extract the watermark and check its quality. To check the quality of the detected watermark three types of quality matrices are available i.e. full-reference based, semi-reference based and no-reference based quality metrics [6] [7]. In the proposed video quality evaluation scheme, the full- reference based quality metric is used. In the next section review of the related work in the field of watermarking as a quality evaluation tool is presented.

II. Related Work

In the recent times the image/video quality evaluation has attracted many researchers across the globe. Also the video watermarking is not just the simple extension of the image watermarking as proposed by Doerr & Dugelay [8] and Sadiq et al. [9] have described a blind video quality metric using a watermarking technique to ensure the persistence of a quality of watermarked video compared to the original. This technique also guarantees the watermark invisibility to Human visual system (HVS). The technique is robust against frame dropping, frame swapping and frame averaging attacks because all the video frames are watermarked by the same watermark. The results of video quality metric are based on PSNR and SSIM. The drawback of this technique is that, if we have the watermark data in every frame then this will lead to the quality degradation of the video.

Paulikas [10] have proposed a no-reference based video quality estimation technique in which the quality is measured in terms of Video Quality Metrics (VQM) scores. The author has discussed the problem of estimating the subjective video quality of distorted video sequences for mobile video streaming. This method is primarily suitable for mobile devices that have limited computational power.

Thakur et al. [11] have described several watermarking techniques on digital video and raised the quality issues. It is concluded that the size of the .avi video files after watermarking increase much more than the .mpeg. Quality degradation is analyzed using the PSNR and SSIM. Also it has been concluded that the SSIM based quality metric's results are more accurate than PSNR based because results based on SSIM are more closer to the subjective quality evaluation.

Wang et al. [12] have proposed a method using the DWT and the watermark is inserted in DWT domain using the quantization. This method provides accurate measures of image quality under JPEG compression attack. The quality is measured in terms objective quality metrices like PSNR, weighted PSNR and Watson just noticeable difference. But this method does not address the problem of local distortion and cross block weighting.

Wang et al. [13] have proposed a fragile digital video watermarking scheme that can work as an automatic quality monitoring system. In this scheme, the change in the PSNR value and the Watson JND value can be tracked. This method does not find the probable locations where the watermark should be inserted, such that the watermarked frame has a good imperceptibility.

Jadhav and Kolhekar [1] has described dynamic 3D-DCT with the help of scene change detection and compared the results with static DCT. It is observed that the values (scene change) do not change much, the quality metrics are based on the MSE (mean square error) and the frame error rate. This paper content low motion activity static 3D-DCT technique that is efficiently avoiding the complexity of the dynamic 3D-DCT activity. For better visual quality the dynamic 3D-DCT can be implemented.

Jamzad et al. [14] have proposed a method, to secure the watermarked image with respect to usual attacks. The limitation of this method is that it forces one to limit the maximum number of bits that can be embedded into a block.

Wang et al. [6] have described a scheme that designed to estimate image quality in terms of the existing full-reference quality metrics. Quality is estimated using PSNR, Weighted PSNR (wPSNR), Watson just noticeable difference (JND) and SSIM (structural similarity). After reviewing the related work in image/video quality evaluation it can be concluded that there is still a scope for a method that can accurately calculate the quality of a video using the application of the watermarking. Our study presented in this paper will address this problem.

This paper is organized as follows: Watermarking embedding and extraction procedure, tree structure based watermark embedding, and analysis of image complexity bit plane method are briefly described in Sections III. Section IV represents Quality evaluation parameters. Then, in Section V the results of the proposed scheme are illustrated. In Section VI, a Statistical analysis of proposed scheme is given. Finally, the conclusions and the future work are presented in Section VII.

III. THE PROPOSED SCHEME

The proposed scheme for the video quality evaluation is divided into two parts: Watermark embedding and watermark extraction

A. Watermark Embedding

The watermark embedding process is as shown in the Fig. 1.

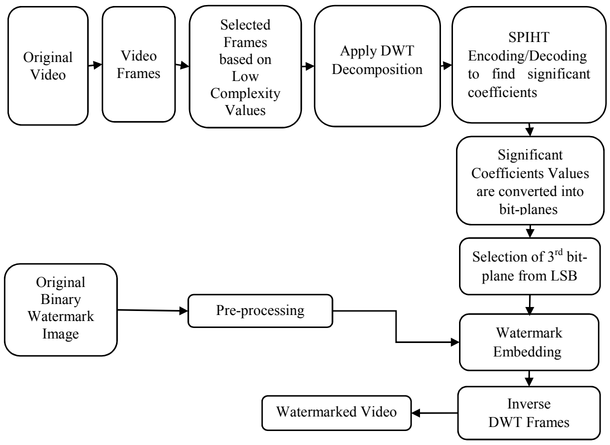

Fig. 1. Proposed watermark embedding process

The embedding of the watermark is achieved using the following steps:

1) Decomposing the video file into its frames and frame Selection
2) Apply third level DWT on selected frames
3) Selection of significant DWT coefficients using SPIHT
4) Convert the watermark into the binary image and embed it into the selected DWT coefficients
5) Apply the Inverse DWT and insert the watermarked frames into the video file

Step I:

A video file of .mp4 is selected for the quality evaluation purpose. The video file is of 15 seconds duration with frame rate of 25fps. The video file is decomposed into its frames by using the following steps:

1) Read input 'original' video file
2) Define an output folder
3) Get the number of frames
4) Set the current status of number of frames to zero
5) For loop
    a) Traverse and process from frame 1 to last frames
    b) Reading individual frames

c) Resize the video frames to 512x512 (resizing of frames is done because quad-tree decomposition requires all the frames to be of same dimension)

d) Save the frames and the current progress of the file/frames end of for loop

After decomposing the video file into its frames, for the selection of frames (for watermarking), the complexity of each frame is calculated. The frame complexity analysis evaluates the details the different frames are having. If the frame's complexity is more then it indicates that the image is having more detailed information. The quality of a more complex frame degrades faster against the same distortion in comparison to a less complex frame [12]. So by the complexity analysis, the frames with less complexity values will be selected for watermarking.

The quad-tree decomposition based complexity analysis is used for a better match with the DWT. The content complexity of the cover image is assessed using the following equation [13].

$$Complexity = \sum_{i=1}^{N} N \times 2^{i} \quad \ldots\ldots (1)$$

Where, N is the number of quad-tree decomposition nodes, 'i' is the highest decomposition level. Then, the calculated complexity values of all the images in our image are normalized. The normalized complexity value is used as the complexity index that locates in [0, 1]. For the insertion of the watermark, only those frames should be selected which have lesser complexity [6]. To increase the robustness, less complex frames in a particular sequence (1st, 25th, 50th, 75th and so on the last one is 375th) are selected for watermarking. So a total of 16 frames are selected for watermarking in coming steps.

Step II:

Load video frames from the directory created under step I and then define specify the level of decompositions as 3, the four different sub-bands will we generated after first level of decomposition: approximation, horizontal, vertical and diagonal detail coefficient storage [15][16].

For next level the approximation coefficient storage will be further decomposed into fur sub-bands and so on up to third level of decomposition.

The above mentioned is achieved as below:

Apply n level decomposition

nlevel=3;

For loop jlevel=1: up to higher-level

[ca{jlevel},ch{jlevel},cv{jlevel},cd{jlevel}]=dwt2 (start image,'wname')

Wavelet_name='haar'

[LO_D, HI_D, LO_R, HI_R] = wavlet_filters ('Wavelet_name')

Four output filters are:

LO_D, the decomposition low-pass filter

HI_D, the decomposition high-pass filter

LO_R, the reconstruction low-pass filter

HI_R, the reconstruction high-pass filter

For loop end

After decomposition of first level apply w_codemat (ca{nlevel})

For ilevel = nlevel:-1:1

Construct sub-bands

For loop end

End of code

Step III:

In this step in order to find the significant coefficients from all the different sub-bands (of different levels) of DWT except LL3 sub-band (because selecting a coefficient in LL3 will reduce the PSNR value) a threshold value (T) is calculated as below:

Set T=2n

n=floor (log 2(max (max(c (i, j))))

This will give us a list of significant and insignificant coefficients (along with their coordinates)

SPIHT coding algorithm was introduced by Said and Pearlman [17]. SPIHT is the improved version of EZW coding algorithm introduced by J. M. Shapiro [18]. SPIHT algorithm has remained as most preferred method in adaptive watermarking as well as in image compression [17][19][20][21][22].

Step IV:

The significant coefficients obtained in step-III are converted into bit-planes. The robustness of the watermarking scheme is achieved by the selecting the appropriate bit plane for watermark embedding. The watermark bits are not embedded into the LL sub-band of the DWT decomposed image and the watermark bits are embedded into the 3rd plane from LSB side. All the correlated DWT coefficients across the sub-bands are grouped together using the SPIHT algorithm (in step-III). For the watermarking based quality estimation, it is imperative to embed the watermark throughout the cover image. So that, even if the watermarked image is locally tampered, the extracted watermark can still reflect the quality degradation of the cover image.

After selecting the bit-planes, we are ready to replace this plane by the watermark bits. A binary image is used as a watermark for copyright protection. In this procedure, a two dimensional original watermark is organized column by column into the one dimensional sequence. The Binary Watermark bits are inserted into the selected bit planes of the selected DWT coefficient bit using the following equation:

$$P_W = \begin{cases} p, if\ p = w \\ w, if\ p \neq w \end{cases} \dots\dots\dots\dots\dots\dots\dots\dots\dots\dots (2)$$

Here ‘p’ corresponds to the bit of the selected bit-plane of the selected coefficient and ‘w’ corresponds to the watermark bit.

Step-V

After the insertion of the watermark bits, the inverse DWT is applied on the selected frames to get the watermarked frames in spatial domain. Original frames in the video file will be replaced by the corresponding watermarked frames to get the watermarked video.

B. Watermark Extraction

The extraction of the watermark is as shown in Fig. 2.

The extraction of the watermark is achieved using the following steps:

1) Extraction of watermarked frames from the video file
2) From the watermarked frames the watermark is extracted

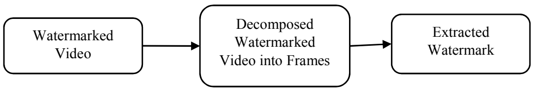

Fig. 2. proposed watermark extracting process

For extraction as shown in Fig. 2, watermarked video is again decomposed into video frames and watermarked frames are selected to extract the watermark sequence.

IV. Quality Evaluation Parameters

The proposed scheme is simulated in the MATLAB environment under various. The original binary watermark bits are compared to the extracted watermark bits for finding the bit error rate, as well as TDR. The quality of the detected watermark is calculated using following parameters:

A. True Detection Rates

The true detection rates (TDR) is defined as:

$$TDR = \frac{\text{Number of correctly detected watermark bits}}{\text{Total number of watermark bits}} \dots (3)$$

The TDR indicates the degradation of the watermark. The smaller value of TDR, the more severe the degradation of the watermark. With the decrease of the quality, the TDR values decreases monotonically [23].

B. Peak Signal-to-Noise Ratio

It mathematically measures the image/video’s quality in terms of MSE. PSNR is utilized to estimate the imperceptibility, a term used to evaluate the similarity between an original image and a watermarked image. The PSNR can be define as follows:

$$MSE = \sum_{i=1}^{M}\sum_{j=1}^{N}\frac{(O(i,j) - W_m(i,j)^2)}{M \times N} \dots\dots\dots\dots (4)$$

In the ideal case, PSNR should be infinite, and MSE should be zero. But this is not possible for watermarked image, Therefore the large value of PSNR and small value of MSE is desirable

$$PSNR = 10\log_{10}\frac{(max \times max)}{MSE}\ dB \dots\dots\dots\dots (5)$$

Where, the original image size is M and N and max=255 for the gray image, (O): original image (Wm): watermarked image.

C. Structural Similarity

It measures image/video quality based on perceptual experience. Based on the assumption, the human visual system is highly adapted to extract structural information from the viewing field. The SSIM is defined as below:

$$SSIM = \frac{(2\mu_x\mu_y + C_1)(2\sigma_{xy} + C_2)}{(\mu_x^2 + \mu_y^2 + C_1)(\sigma_x^2 + \sigma_y^2 + C_2)} \dots\dots\dots\dots (6)$$

Where μ, σ & are mean, variance and covariance of the images and $C1$, $C2$ are the stabilizing constant. SSIM values lie between (0, 1) and for similar images have SSIM near to 1.

V. Simulation Results

A. Estimation of Peak Signal to Noise Ratio and Structure Similarity Values

The quality of the watermarked frames (in terms of PSNR and SSIM) shown in Table I are more than 44 dB in PSNR, which indicates that the watermark embedding process did not have significant impact on the video quality.

TABLE I. QUALITY OF THE WATERMARKED FRAMES

Watermarked Video Frames No.	PSNR(dB)	SSIM
1	45.1552	0.9986
25	44.9609	0.9985
50	42.9268	0.9978
75	43.4243	0.9983
100	45.3661	0.9988
125	45.2227	0.9987
150	44.0994	0.9982
175	44.2477	0.9982
200	42.1965	0.9973
225	44.0134	0.9984
250	45.4797	0.9987
275	45.4306	0.9984
300	44.3167	0.9981
325	43.5806	0.9980
350	41.6981	0.9968
375	44.5489	0.9981

B. Evaluation of PSNR and SSIM values after attack

PSNR and SSIM are values calculated, after various attacks (i.e. salt and pepper noise at the 0.002, Gaussian noise by 0.025, Rotation by 2 degrees, Rotation by 5 degrees, Rotation by 10 degrees and Rotation by 50 degrees (anti-clockwise) compression attack at quality factor 10, 20, 30, 40 and 50. These attacks are performed on the same frame (frame no. 25) and corresponding to that, PSNR and SSIM value estimated. PSNR and SSIM results are following, which is shown in the Table II:

TABLE II. VALUES OF VARIOUS ATTACKS

Sr. No.	Name of the Attack	Strength of the attack	PSNR	SSIM
1	Salt and pepper noise	0.002	35.3952	0.9391
2	Gaussian noise	0.025	19.8438	0.1709
3	Rotation	2 degree	23.1275	0.6381
		5 degree	19.9670	0.5793
		10 degree	17.9274	0.5402
		50 degree	13.8801	0.4321
4	Compression attack	10	32.8788	0.8455
		20	36.2245	0.9201
		30	38.0073	0.9443
		40	39.0826	0.9558
		50	39.8951	0.9672

The above table indicates that the PSNR and SSIM values are reasonably good under various attacks which show the robustness of this watermarking scheme.

VI. STATISTICAL ANALYSIS

A. True Detection Rates

TDR values corresponding to various frames are calculated before performing any attack. These TDR values are plotted against PSNR and SSIM values. In Fig. 3 shows the calculated TDR vs. PSNR values. When the PSNR value decreases, the TDR value also decreases monotonically. In Fig. 4 shows the calculated TDR vs. SSIM values. When the SSIM value decreases, the TDR value also decreases monotonically by calculating the TDR values, we can comment on the quality of the watermark. Higher the value of TDR, the better will be the quality. This is proved from Fig. 3 and Fig. 4 that the TDR values are higher for those frames in which PSNR and SSIM are higher, which indicates that the quality of the video file is better in that direction. Therefore the TDR can be used in connection with PSNR and SSIM to evaluate the quality.

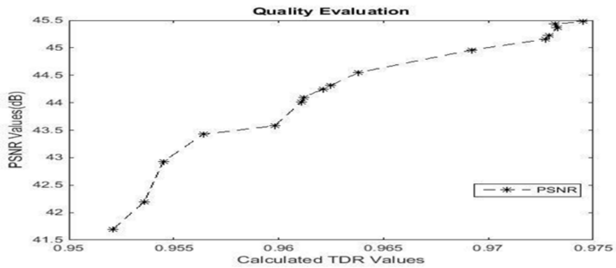

Fig. 3. Estimated TDR values vs. PSNR values (dB)

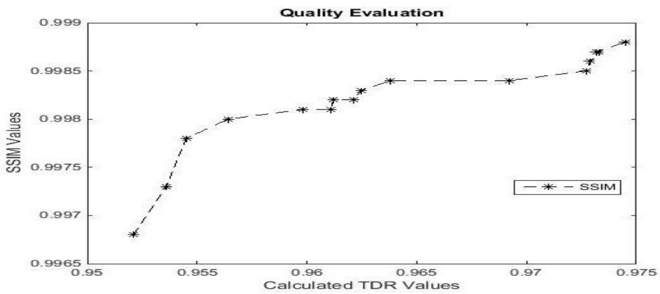

Fig. 4. Estimated TDR vs. SSIM values

VII. CONCLUSION AND FUTURE SCOPE

In this paper, a video quality estimation method based on digital watermarking scheme which combines set partitioning trees with DWT has been implemented. Applying SPIHT on DWT coefficients increases the robustness of the algorithm. So, the proposed scheme satisfies the requirement of imperceptibility and robustness for a video watermarking scheme. Simulation results show that the proposed scheme is robust against various video processing attacks. The robust, full reference based watermarking scheme is used for evaluating the quality of a digital video. The quality is measured in terms of PSNR, SSIM (of watermarked frames) and TDR values (of extracted watermark). From the TDR values we can comment on the quality of the video file. On an average the estimated TDR value of the video file (taken for this research) is 0.9639 (approximately). So it can be said that the quality of the video is degraded approximately by 3.61 % of the original video quality. As a future scope this work can be extended for the color video file.

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