ISSN 0735-2727, Radioelectronics and Communications Systems, 2018, Vol. 61, No. 1, pp. 1–12. © Allerton Press, Inc., 2018.
Original Russian Text © D. Shukla, M. Sharma, 2018, published in Izvestiya Vysshikh Uchebnykh Zavedenii, Radioelektronika, 2018, Vol. 61, No. 1, pp. 5–21.

Robust Scene-Based Digital Video Watermarking Scheme Using Level-3 DWT: Approach, Evaluation, and Experimentation

Dolley Shukla[1*] and Manisha Sharma[2]**
[1]*Shri Shankaracharya Technical Campus, Bhilai, India*
[2]*Bhilai Institute of Technology, Durg, India*
**e-mail: dolley020375@gmail.com*
***e-mail: manishasharma1@rediffmail.com*
Received in final form July 26, 2017

Abstract—This paper presents a robust digital video-watermarking system for copyright and copy protection. The proposed method applies the combination of discrete wavelet transform (DWT) and scene-change-detector. For better understanding, this approach can be presented in the form of four stages. The first stage is finding the frame where the watermark is to be inserted. The analysis of watermarking using the level-3 decomposition of LL subband with DWT is described in the second stage. Transparency and the robustness have been analyzed under fifteen different attacks in the third stage. Improvement in the robustness and transparency, as compare to watermarking using different levels of LL subband is calculated in terms of the normalized correlation and the structural similarity index in the fourth stage. The experimental result reveal that the proposed method yields the extracted watermark image and watermarked video of good quality and can sustain different image processing, JPEG compression and geometrical attacks. Empirical results prove the improvement in the performance as the decomposition level increases from level-1 to level-3. Comparative analysis with the existing schemes proves the improved robustness, better imperceptibility and the reduced computational time of the proposed scheme.

DOI: 10.3103/S0735272718010016

1. INTRODUCTION

Copyright protection is the major problem in the area of multimedia security due to the quick growth of internet distribution possibilities. In order to manage different illegal activities such as authentication, copying and distribution of data without permission etc. [1], a copyright/copy protection system is required.

One of the classical approaches to multimedia security is to employ encryption technologies. However, once the content is decrypted, there is nothing to protect it. Therefore, the digital watermarking has emerged as a technique for the protection of intellectual property rights such as copyright protection [2], data authentication [3], and fingerprinting and so on. Watermarking techniques are based on data types used, i.e. text-based watermarking [4], image watermarking [5], video-watermarking [6], audio-watermarking [6] and 3D watermarking [7].

Video watermarking techniques are based on the image watermarking. However, due to a large volume of inherently redundant data between frames, video watermarking introduces some issues. Two domains are proposed for video watermarking, i.e. spatial domain [8] and the transform domain [9]. The spatial domain techniques are the simplest and easiest watermarking techniques, but they have a low information-hiding capacity, and a watermark can be easily erased by lossy compression. On the other hand, the transform domain approaches insert a watermark into transform coefficients of the original video frame, yielding more information embedding and more robustness against watermarking attacks.

Embedding in every frame of video requires large computational time and computational complexity [10, 11]. Therefore, to reduce the computational time, scene-based video watermarking has been proposed [12]. The motion part of video is used for embedding [13]. A combined DWT and DCT technique was used by Waserman [14]. The different part of the same watermark is embedded into different scenes of the video for watermarking [15], the watermark is inserted in the frame having high intensity, texture, and motion [16]. This technique requires large computational time and complexity.

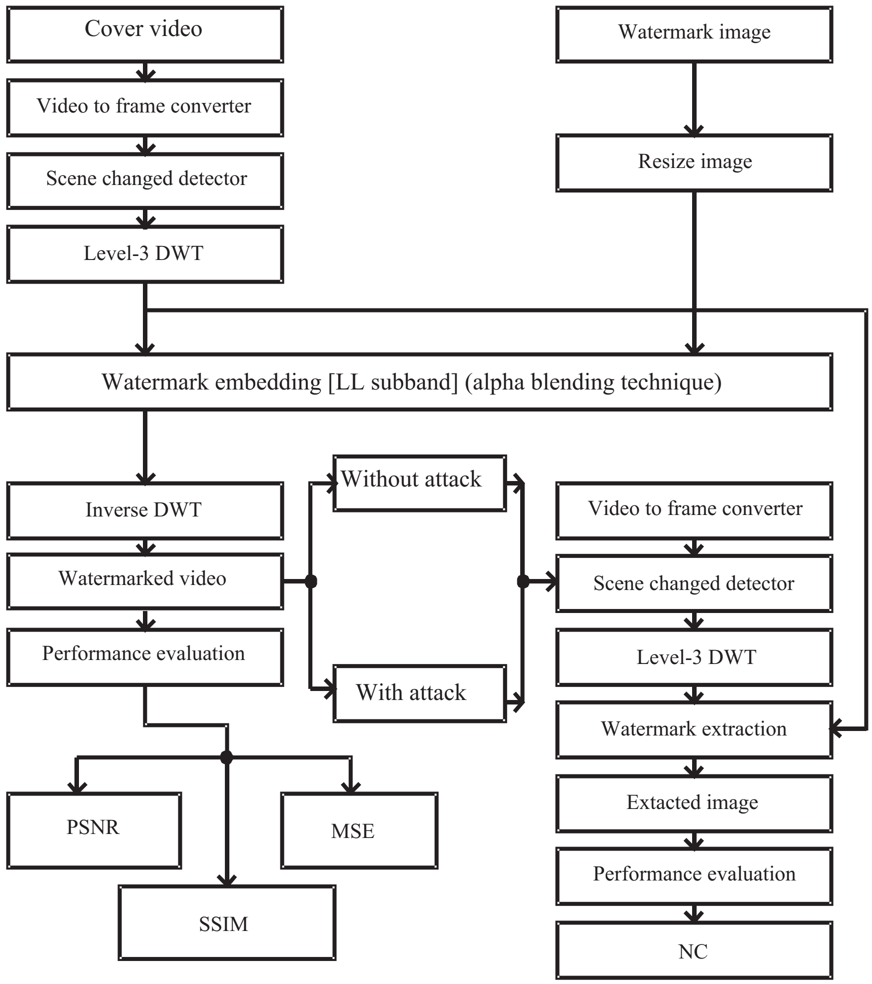


Fig. 1. Illustration of proposed approach [Scene-based video watermarking].

To improve the robustness, a quantization watermarking method [17] ELM (extreme learning machine) based video watermarking [18] and scene-based watermarking scheme [19] for video watermarking using special domain are among some other watermarking techniques. Frequency domain technique is also applicable in digital cinema [20, 21].

1.1. Origin of the Problem

The above-suggested works need to be improved in issues related to imperceptibility, resistance to different attacks and the efficiency of the system in copyright protection and copy protection of video data. Thus, there is a requirement for the development of an efficient video copyright protection algorithm having a good visual quality of watermarked video, possessing the advantage of comparatively less storage space and less computational complexity. Therefore, a novel watermarking system is required for copyright and copy protection.

1.2. Contribution and Outline of the Paper

The chief contribution of this paper is to develop an enhanced technique for producing watermarked video with high imperceptibility and robustness. Therefore, a scene-based video watermarking system based on level-3 DWT has been designed to improve the performance. The proposed method demonstrates significant improvement in different parameter values as compared to the watermarking using level-1 and level-3 decomposition. Also, the performance of a different watermarking technique has been reviewed for determining the best embedding technique.

2. MATERIALS AND METHODS

2.1. Proposed Methodology

In the proposed method, the combination of DWT and scene change detector is applied (Fig. 1). The algorithmic process consists of two steps. The first step is the extraction of the scene-changed frame, which is to be extracted by employing a scene-change detector with the use of correlation-based SESAME and HiBiSLi method. The second step performs the level-1 and level-3 wavelet decompositions for the original cover video.

In this study, level-1 and level-3 of LL subband of 2D-Daubechies DWT decompositions are used for embedding in the original cover video frames. The details of scene-change detection, embedding and extraction process of the proposed method are described in Sections 2.2, 2.3, 2.4, 2.5 and 2.6. Robustness of the scheme is tested under various attacks, such as image processing, filtering, geometrical and video frame attacks. One of the novel approaches of this project implies that for improving the performance, the watermark is embedded in frames, where abrupt scene-change occurs, using the three-level decomposition.

2.2. Video Preprocess-Scene Change Detector

The first and foremost task in this project was to design a scene-change detector, whose functionality is to detect abrupt scene changes from raw video. The scene-change detector detects the abrupt scene changes using a successive estimation of statistical measure, i.e. correlation between frames. For further refinement, the method is applied up to 4 levels.

To remove similar frames, a filtering method is used at the initial stage that filters out the similar frames at the early stage. The filtering method consists of the histogram, binary search, and the linear interpolation.

a. Histogram. Histogram collects similar scene values in the same bin and tries to find out the range of cut-off for the maximum number of elements.

b. Binary Search Algorithm. The binary search method is used to calculate an approximate/rough cutoff value. Binary search is based on sorting of arrays. A binary search starts with comparing the center element of the array with the target value. By comparing the target value with the center element, the search is shifted in the upper or lower half of the array.

c. Linear Interpolation. Linear interpolation is often used to approximate a value of some function using two known values of that function at other points. The error of this approximation is given as

$$R_x = (f_x - p_x), \tag{3}$$

where p denotes the linear interpolation polynomial defined above

$$P(X) = f(x_0) + \frac{f_{x_1} - f_{x_0}}{x_1 - x_0}(x - x_0). \tag{4}$$

2.3. Watermark Construction

An efficient watermarking system requires a well-designed watermark that most easily adapts the cover data and must give a better robustness under the degradation of perceptual quality. In the proposed watermarking system, the color image is chosen as a watermark image. Then the image is converted into a grayscale image of size $N \times N$, i.e. 256×256.

2.4. Watermark Embedding Algorithm

For embedding process, video data is divided into frames. Discrete wavelet transforms using Daubechies wavelet is applied in that frame, where a scene-change occurs. Discrete wavelet transform separates the image into four components, a lower resolution approximation (LL), a vertical (LH), a horizontal (HL) and diagonal (HH) ones. The proposed algorithm embeds the watermark image into LL subband. After resizing, the original watermark image is embedded into LL subband. The process is explained in detail as follows:

WATERMARK EMBEDDING ALGORITHM

Input: Cover video with frame size $M \times M$ and watermark image of size $N \times N$.

Output: Watermarked video

Step 1. Choose an appropriate watermark image of size 256×256 and the video as a cover video.

Step 2. Apply the preprocessing step for the watermark image and convert the watermark image to gray image using an RGB-to-gray converter.

Step 3. Resize the watermark image into 32×32.

Step 4. Apply the preprocessing for the cover video and convert into the frame using the video to frame converter.

Step 5. Apply scene-change detector algorithm using a successive estimation of statistical measure, i.e. correlation.

Step 6. Convert the scene-changed frame into a gray level one by applying the RGB-to-gray converter.

Step 7. Resize the scene-changed cover video frames into 256×256 size.

Step 8. Decompose frames, where scene change occurs, by applying level-1 2D-DWT for the scene-changed frames. The frame is converted into four subbands (LL, LH, HL, and HH) of size $M/2 \times M/2$, i.e. 128×128 size, 3 details and 1 approximation.

LL—the approximation looks just like the original. All the energy is contained in the LL subband.

LH, HL, and HH—allow us to achieve a higher accuracy.

HH—the high-frequency components are usually used for watermarking since the human eye is less sensitive to changes in edges.

Step 9. Apply level-2 and level-3 decomposition for LL subband of cover video.

Step 10. The alpha-blending is then used to insert the watermark in that frames of cover video, where scene changes were detected. In this technique, the level-3 decomposed components of the cover video frame, where scene-change was detected and the watermark are multiplied by a scaling factor and are added. We have taken alpha = 0.05.

For embedding:

$$\text{ELL} = \text{VLL} + \text{alpha} * \text{img\_resized\_to\_vll};$$

$$\text{ELH} = \text{VLH};\ \text{EHL} = \text{VHL};\ \text{EHH} = \text{VHH};$$

where VLL is the low frequency approximation, VLH, VHL, VHH are the high frequency approximations of cover video, alpha is the embedding factor.

Step 11. Inverse DWT is applied to the watermarked video frames to generate the final secure watermarked video.

2.5. Watermark Detector and Extraction Algorithm

The detection and extraction process performs the reverse of embedding. It involves watermarked video preprocessing, detection (i), and extraction (ii) watermarked video post processing (iii).

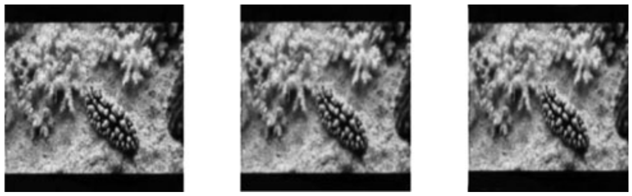
(i) It performs the conversion of watermarked video into frames and then it checks for the scene-changed frames. With the verification of the scene-changed frame, it detects the presence of a watermark. If there is a scene-changed frame, it shows that the “watermark is present”.

(ii) An extraction is the inverse operation of embedding. For extraction, the subtraction operation is performed between the level-3 LL subband of watermarked video frame and cover video frame.

(iii) It is used to prove the ownership or provide the copyright protection, if watermark image is extracted from a particular scene-changed watermarked frame. Then the extracted image is recovered by resizing and converting the image into an unsigned 8-byte wide integer.

This process is explained in detail as follows:

Cover video frame Level-1 DWT Level-3 DWT



(a) (b) (c)

Fig. 2. Embedded video [Imperceptibility].

Original watermark Level-1, 128×128 Level-3, 32×32

(a) (b) (c)

Fig. 3. Extracted watermark image [Robustness].

WATERMARK EXTRACTION ALGORITHM

Input: Watermarked video
Output: Extracted Image

Step 1. Consider watermarked video.

Step 2. Apply preprocessing for cover video and convert it into the frame using a video-to-frame converter.

Step 3. Apply scene-change detector algorithm using a successive estimation of statistical measure, i.e. correlation and HiBiSLi.

Step 4. Convert the scene-changed frame into a gray level image by applying an RGB-to-gray converter.

Step 5. Resize the scene-changed watermarked video frames into 256×256 size.

Step 6. Apply DWT for scene-changed watermarked video frame, which decomposed the image into four subbands.

Step 7. Apply alpha blending for LL frequency components, which are used for embedding process

$$\mathrm{ILL} = (\mathrm{ELL} - \mathrm{CLL})/\mathrm{alpha},$$

where ILL is the extracted/recovered watermark image from low-frequency approximation of embedded video, ELL is the low-frequency approximation of embedded watermarked video frame, CLL is the low-frequency approximation of the cover video frame.

Step 8. Extracted image is converted into the normal form using unit 8.

3. EXPERIMENTAL RESULTS

The proposed scheme were implemented in MATLAB R2015a with i5 processor. For experiments five video sequences of different frame sizes and frame rates in mp4 format were considered, i.e. documentary, news, children, AD, and sports. Watermark images were 256×256 images in JPG, TIF and PNG formats. Figs. 2, 3 show the documentary.mp4 and pepper.jpg elements used for obtaining experimental results.

The three-step operation is performed for the proposed scheme. A watermark image is embedded into the scene-change-detected frame using the LL subband of DWT. The performance of proposed method is measured in terms of imperceptibility, robustness and channel capacity. Peak signal to noise ratio (PSNR) and the mean square error (MSE) are used in order to evaluate the quality measurement of imperceptibility characteristics. The normalized correlation and bit error rate are used to evaluate the robustness of the system as mentioned in Table 1.

The experimental results in Tables 2 and 3 show that the successive estimation of statistical measure with correlation method requires 25.094 s of computational time that for video scene detection is less as compared to the histogram difference method. The threshold value for the measures is calibrated by using 512 standard Google images and the difference between their pairs. Calibrated threshold values for correlation measure is equal to 0.2451. The FFMPEG software has been used as a reference for calculating different parameters.

Detected frames are as same as FFMPEG output frames. Comparative analysis with other existing SCD (scene change detection) technique shows that the proposed system gives the precision and recall values equal to 100 and 85%, respectively.

Table 1. Performance evaluation parameter chart

Parameter	Mathematical equation	Remarks
PSNR (peak signal to noise ratio)	$\mathrm{PSNR} = 10\log_{10}\left(\frac{255^2}{\mathrm{MSE}}\right)$	MSE is mean square error [Imperceptibility measurement]
MSE (mean square error)	$\mathrm{MSE} = \frac{1}{mn}\sum_{i=1}^{m}\sum_{j=1}^{n}(W(i,j) - W'(i,j))$	$W(i,j)$ is pixel intensity value at coordinate (i, j) of original watermark image, $W'(i,j)$ is pixel intensity value at ordinate (i, j) of extracted/ recovered watermark image [Imperceptibility measurement]
SSIM (structured similarity index)	$\mathrm{SSIM}(X,Y) = \frac{(2\mu_X\mu_Y + C_1))(2\sigma_{XY} + C_2)}{(\mu_X^2 + \mu_Y^2 + C_1)(\sigma_X^2 + \sigma_Y^2 + C_2)}$	μ_X, μ_Y are average of X and Y, σ_{XY} is covariance of X and Y, μ_X^2, μ_Y^2 are variance of X and Y, C_1, C_2 are two variables [Transparency measurement]
NC (normalized correlation)	$\mathrm{NC} = \frac{\sum_{i=0}^{M-1}\sum_{j=0}^{N-1}[W(i,j) * W'(i,j)]}{\sqrt{\sum_{i=0}^{M-1}\sum_{j=0}^{N-1}[W^2(i,j)]}\sqrt{\sum_{j=0}^{N-1}\sum_{i=0}^{M-1}\sum_{j=0}^{N-1}(W^2(i,j))}}$	M, N are the width and height of watermark image, $W(i,j)$ is pixel intensity value at coordinate (i, j) of original watermark image, $W'(i,j)$ is pixel intensity value at ordinate (i, j) of extract-ed/recovered watermark image [Robustness measurement]
Precision	$\mathrm{Precision} = \frac{\text{True positive}}{(\text{True Positives} + \text{False Positives})}$	Scene change detector performance evaluation parameter
Recall	$\mathrm{Recall} = \frac{\text{True Positive}}{(\text{True Positives} + \text{False Negatives})}$	Performance evaluation parameter of scene-change detector
F-measure	$\text{F-measure} = 2 * \frac{\text{Precision} * \text{Recall}}{\text{Precision} + \text{Recall}}$	Performance evaluation parameter of scene-change detector

3.1. Scene-Change Detector Output

The output represents the scene-change frames with frame number displayed (Fig. 4).

Since all the scenes of video are detected as a scene-changed frame along with three missed scenes, Table 2 presents the precision and recall values equal to 100 and 85%, respectively. Tables 3 and 4 show the comparative analysis with histogram-based method that proves the effectiveness of the system in terms of computational time, precision and recall values.

3.2. Watermarking with Level-3 Decomposition

3.2.1. Encoder and decoder output [Imperceptibility and robustness]

The accurate measurement of imperceptibility as perceived by a human observer is a great challenge in video processing. The reason is that the amount and visibility introduced by the watermarking attacks of documentary video strongly depend on the actual video content. The PSNR is used to measure the perceptual

Table 2. Performance evaluation of scene-change detector using parameters

Type of video	Reference method	Method used	No. of scenes detected	No. of actual scenes detected	No. of missed scenes	No. of false scenes	Precision	Recall	F-measure
Documentary.avi	FFMPEG	Correlation	17	17	3	0	100%	85%	0.9189

Table 3. Scene-change detector output in terms of computational time

No.	Video category	Method	No. of scenes detected	Computational time
1.	Documentary.mp4	FFMPEG	20	—
2.		Correlation	17	25.0094 s
3.		Histogram difference	7	25.3122 s

Table 4. Comparative analysis with existing technique

No.	Method	Description	Precision	Recall
1.	Colour histogram with scaling of histogram metric [22]	Histogram scaling method with scaling	90.47%	88.37%
2.	Novel technique	SESAME and HiBiSLi	100%	85%

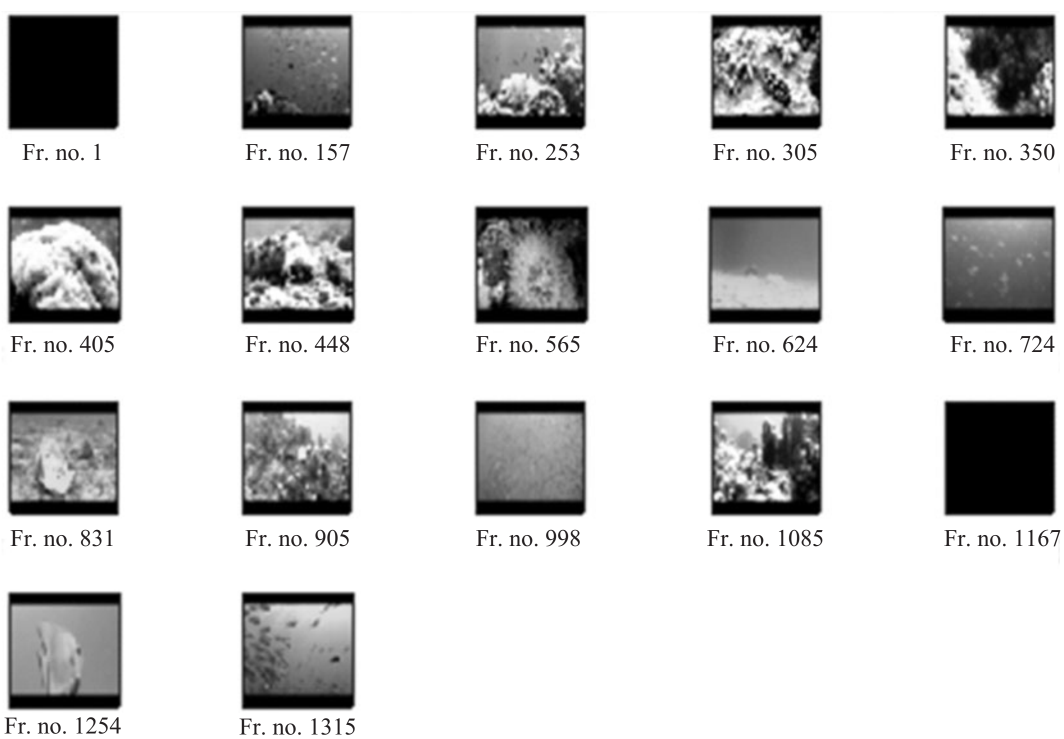


Fig. 4. Scene change frames.

Table 5. Performance measurement of the encoder and decoder

Cover video (.avi)	Watermark image (.jpg)	MSE	PSNR	NC	Similarity index
Documentary	Pepper	0.013138	66.94542	0.95425	1.0000
Documentary	Mandril	0.010671	67.84858	0.91127	1.0000

Table 6. Performance measurement of decoder [Normalized correlation]

No.	Attack category	Attack	Normalized correlation
1.	Image proccessing attack	Salt and pepper noise	0.92067
2.		Gaussian noise	0.41932
3.		Speckle noise	0.95409
4.		Gaussian LPF	0.95426
5.		Blurring	0.95230
6.		Sharpening	0.90600
7.		Normal blur	0.86414
8.		Motion blur	0.89728
9.	JPEG compression	JPEG compression	0.95236
10.	Geometrical attack	Rotation	0.90765
11.		Resizing	0.93784
12.		Stretching	0.94996

quality. Table 5 presents the maximum PSNR value (67.848589) for documentary video with mandril as a watermark image. In order to measure the decoder performance, the normalized correlation (NC) has been considered, in this case, the pepper.jpg shows the highest NC value.

3.2.2. Attack analysis

In order to evaluate the robustness, twelve attacks of three different categories, i.e. image processing, geometrical attacks and JPEG compression, are performed for watermarked video using the parameter normalized correlation. The watermark image is retrieved by using the proposed algorithm, and the NC value of the recovered watermark is displayed in Table 6.

The maximum NC value amounts to 0.95426 in case of the Gaussian low-pass filter. Under the category of geometrical attacks we used resizing, rotation and stretching attacks. Maximum NC value under exposure to geometrical attacks amounts to 0.94996 in case of stretching by (1.5×1.5). Since the designed system is resilient to geometrical attacks, it can be used for the copy protection applications.

3.2.3. Encoder and decoder output [Embedding at different levels]

This section represents the comparative analysis of video watermarking system (Fig. 2a), when the embedding process is performed using the level-1 and level-3 decompositions for watermarking (Fig. 3a).

Table 7. Performance evaluation at different levels of DWT

Level	Cover video	Watermark image	MSE	PSNR	SSIM	NC
Level-1	Documentary.avi	Pepper.jpg (128×128)	0.0133640	66.727133	1.000000	0.93289
Level-3	Documentary.avi	Pepper.jpg (32×32)	0.0131382	66.945420	1.000000	0.95425
Level-1	Documentary.avi	Mandril.jpg (128×128)	0.0107402	67.820000	1.000000	0.81301
Level-3	Documentary.avi	Mandril.jpg (32×32)	0.0106713	67.848589	1.000000	0.91127

Table 8. Performance evaluation of channel capacity

Channel Capacity	Level-3	Level-1
Payload	$0.0156 \times (N' / N)$	$0.25 \times (N' / N)$

Table 7 and Fig. 2b,c indicate the higher imperceptibility of the system with level-3 decomposition as compared to level-1. Table 7 and Fig. 3b,c present the decoder performance at different levels of embedding.

The reduction in the value of MSE by 1.68 and 0.335% improvement in the PSNR value due to increasing the decomposition level from level-1 to level-3 show the improvement in imperceptibility as shown in Fig. 2b,c. The robustness improvement in terms of the normalized correlation at different decomposition levels shown in Fig. 3b,c. The result shows the enhancement by 2.289% in terms of NC.

4. PERFORMANCE ANALYSIS

In order to prove the robustness and imperceptibility of the proposed system, the comparative analysis of the performance of the proposed method and watermarking using level-1 and level-3 decomposition was carried out in terms of SSIM and NC.

4.1. Imperceptibility and Robustness Assessment (in terms of SSIM and NC)

The improvement in imperceptibility with the increasing number of the decomposition level in terms of SSIM is presented in Fig. 5a. Figure 5b presents the comparative robustness assessment in terms of NC for watermarking using level-1 and level-3 decomposition, respectively, for different noise attacks at embedding factor 0.05. It is observed that the highest NC value of 1.0 is obtained against the frame swapping and the value of 0.95236 against the JPEG compression for both levels of decomposition. However, the lowest NC value of 0.41932 is obtained against the Gaussian noise attack for the same images. The experimental results show that as the level of decomposition increases, the performance also increases.

4.2. Payload/Embedding Capacity Assessment

In the proposed algorithm, a 32×32 size watermark image and the cover video frame of size 256×256 are considered. For N the number of frames equal to N in the given cover video, one can embed a maximum of

$$\frac{N' \times \text{Watermark image size}}{N \times \text{Cover frame image size}}, \tag{5}$$

where N' is the number of scene-change frames and N is the total number of frames in the video.

$$\text{Level-3 payload} = N' \times (32\times32)/N \times (256\times256) = 1/\,8\times8\ (N' / N) = 0.0156 \times (N' / N).$$

Channel capacity for level-1 and level-3 decomposition is presented in Table 8.

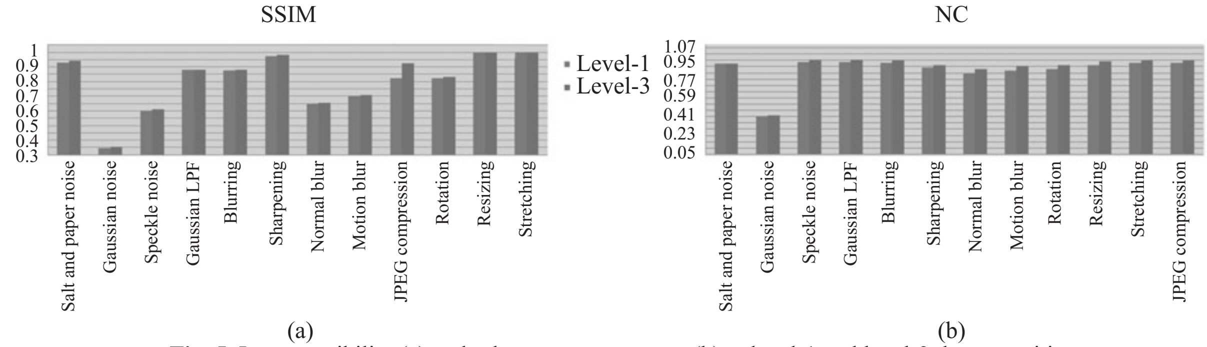


Fig. 5. Imperceptibility (a) and robustness assessment (b) at level-1 and level-3 decomposition.

5. COMPARATIVE ANALYSIS AND COMPUTATIONAL COMPLEXITY

This section reviews and compares the performance of some already existing schemes. Robustness of the proposed method is proven using fifteen different attacks, while the other authors worked with only seven or four attacks. Leelavathy [23] worked with multi-wavelet domain. It is already proven that (SESAME and HiBiSLi)-based method requires less computational time as compare to the scene-change histogram method.

As follows from Table 9, the PSNR value for the proposed system is higher than that for the other. The NC value is 1 and the BER = 0.00, while the other algorithm attained lower values of PSNR and NC. The structural similarity index is also calculated. Table 10 proves that the scene-based watermarking requires less computational time (30 s) as compared to the computational time of watermarking in every frame of video (100 s). The total time complexity of proposed algorithm is $[O(n) + O[\log_2(n)]]$ i.e. approximately $[O(n)]$. This means that the computational time complexity is linear in terms of the number of frames. The detection time per frame is 0.176 s.

The proposed scheme runs on the general-purpose processor Intel i5. If algorithms run on specific processors, with DSP pipeline architecture or through programming optimization techniques, the speed can be improved and the processing time can be reduced that may be used for real time applications.

6. CONCLUSION AND OUTLOOK

A novel and robust video watermarking technique based on 2D-disrete wavelet transform using level-3 decomposition is presented using Daubechies wavelets. Low frequency coefficients of wavelet (LL subband) are used for embedding. This technique embeds an invisible watermark into the scene-changed video frame using alpha-blending technique and this watermark can be easily recovered by the extraction technique.

To detect the scene-changed frame, a novel (SESAME & HiBiSLi)-based scene-change detection method was used. Imperceptibility in terms of PSNR and SSIM has been determined. The processing time for scene-change detection and the channel capacity are calculated.

The proposed method can effectively sustain the image processing attacks, geometrical attacks, and JPEG compression and can maintain a good performance in terms of robustness, transparency, and embedding capacity. The proposed algorithm makes possible the copy protection and the protection of the video copyright.

The empirical result of the comparative analysis of watermarking shows that the recovered watermark image is better for level-3 discrete wavelet transform than for the level-1 discrete wavelet transform. Improvement in the robustness and transparency in terms of different parameters for level-3 proves the effectiveness of the proposed scheme. All the results obtained for the recovered images and the watermark are identical with the original images. The proposed combined DWT and SESAME based watermarking method enhances the NC and PSNR performance as compared to the DWT method applied to all frames and reduces the computational time.

In Future

1. The future work will focus on developing a secure technique providing copy protection to the embedded video.

Table 9. Comparative analysis based on different parameters

Method	Technique used	PSNR	MSE	NC	SSIM	BER	Attacks	No. of attacks
[23]	Histogram difference method [Discrete Multi-wavelet Domain]	50.6419	—	0.3360	—	—	Withstand seven attacks: salt & pepper noise, Gaussian noise, speckl noise, Poisson's noise, Wiener filter, cropping	7
[10]	Scene based watermarking [DCT domain]	37.141	—	1	—	0.030	Tolerate geometrical attacks, low robustness under scaling, frame dropping and frame insertion	4
[24]	DWT [embeddi-ng in each frame] [LL subband]	55.011	0.2052	0.87802	—	—	No attack analysis	0
Proposed method	LL subband [SESAME]	68.2849	0.00965	0.79835	1.000	0.000	Fifteen different types of attacks, such as image processing attacks geometrical, video, noise attack, filtering	15

Table 10. Comparative analysis [Computational time]

No.	Method	Computational time		
		Encoder	Decoder	Total
1.	Watermark is embedded into all frames	80 s	20 s	100 s
2.	Watermark is embedded only into scene-changed frames (proposed method)	27 s	3 s	30 s

2. This study is concentrated on the correlation based scene-change detection method, while the future study can be focused on the pixel-difference-based method for scene-based watermarking.

3. The aim is to evaluate the performance of the algorithm under multiple attacks.

ACKNOWLEDGMENTS

The authors would like to thank Electronics and Telecommunication Engineering department, Bhilai Institute of Technology, Durg (C.G), India for providing facilities to carry out this study. We would also like to thank the editor and the anonymous reviewers for their valuable suggestions.

REFERENCES

1. http://en.wikipedia.org/wiki/Copyright (22 Jan. 2013).
2. Yuk Ying Chung, Fang Fei Xu, "A secure digital watermarking scheme for MPEG-2 video copyright protection," *Proc. of Int. Conf. on Video and Signal Based Surveillance*, AVSS'06, 22–24 Nov. 2006, Sydney, Australia (IEEE, 2006), p. 84. DOI: 10.1109/AVSS.2006.12.
3. A. Tiwari, M. Sharma, "Novel watermarking scheme for image authentication using vector quantization approach," *Radioelectron. Commun. Syst.* **60**, No. 4, 161 (2017). DOI: 10.3103/S0735272717040021.
4. Y.-W. Kim, K.-A. Moon, I.-S. Oh, "A text watermarking algorithm based on word classification and inter-word space statistics," *Proc. of Seventh Int. Conf. on Document Analysis and Recognition*, 6 Aug. 2003, Edinburgh, UK (IEEE, 2003), pp. 775–779. DOI: 10.1109/ICDAR.2003.1227767.
5. J. Xuehua, "Digital watermarking and its application in image copyright protection," *Proc. of Int. Conf. on Intelligent Computation Technology and Automation*, ICICTA, 11–12 May 2010, Changsha, China (IEEE, 2010), pp. 114–117. DOI: 10.1109/ICICTA.2010.625.
6. Y.-Y. Lee, S.-U. Park, C.-S. Kim, S.-U. Lee, "Temporal feature modulation for video watermarking," *IEEE Trans. Circuits Syst. Video Technol.* **19**, No. 4, 603 (2009). DOI: 10.1109/TCSVT.2009.2014011.
7. C.-X. Wang, X. Nie, X. Wan, W. B. Wan, F. Chao, "A blind video watermarking scheme based on DWT," *Proc. of Fifth Int. Conf. on Intelligent Information Hiding and Multimedia Signal Processing*, 12–14 Sept. 2009, Kyoto, Japan (IEEE, 2009), pp. 434–437. DOI: 10.1109/IIH-MSP.2009.29.
8. K. Thangadurai, G. Sudha Devi, "An analysis of LSB based image steganography techniques," *Proc. of Int. Conf. on Computer Communication and Informatics*, ICCCI, 3–5 Jan. 2014, Coimbatore, India (IEEE, 2014). DOI: 10.1109/ICCCI.2014.6921751.
9. Majid Masoumi, Shervin Amiri, "A high capacity digital watermarking scheme for copyright protection of video data based on YCbCr color channels invariant to geometric and non-geometric attacks," *Int. J. Computer Applications* **51**, No. 13, 13 (Aug 2012). DOI: 10.5120/8101-1693.
10. M. Asikuzzaman, M. J. Alam, A. J. Lambert, M. R. Pickering, "A blind digital video watermarking scheme with enhanced robustness to geometric distortion," *Proc. of Int. Conf. on Digital Image Computing Techniques and Applications*, DICTA, 3-5 Dec. 2012, Fremantle, WA, Australia (IEEE, 2012), pp. 1–8. DOI: 10.1109/DICTA.2012.6411696.
11. Th. Rupachandra Singh, Kh. Manglem Singh, Sudipta Roy, "Robust video watermarking scheme based on visual cryptography," *Proc. of World Congress on Information and Communication Technologies*, WICT, 30 Oct.-2 Nov. 2012, Trivandrum, India (IEEE, 2012), pp. 872–877. DOI: 10.1109/WICT.2012.6409198.
12. Yan Liu, Jiying Zhao, "A new video watermarking algorithm based on 1D DFT and Radon transform," *Signal Processing* **90**, No. 2, 626 (2010). DOI: 10.1016/j.sigpro.2009.08.001.
13. M. Masoumi, Shervin Amiri, "A blind scene-based watermarking for video copyright protection," *AEU - Int. J. Electron. Commun.* **67**, No. 6, 528 (2013). DOI: 10.1016/j.aeue.2012.11.009.
14. Jakob Wassermann, "New robust video watermarking techniques based on DWT transform and spread spectrum of basis images of 2D Hadamard transform," *Proc. of Int. Conf. on Multimedia Communications*, *Services and Security* (Springer Berlin Heidelberg, 2013), pp. 298–308. DOI: 10.1007/978-3-642-38559-9_26.
15. Th. Rupachandra Singh, Kh. Manglem Singh, Sudipta Roy, "Video watermarking scheme based on visual cryptography and scene change detection," *AEU - Int. J. Electron. Commun.* **67**, No. 8, 645 (2013). DOI: 10.1016/j.aeue.2013.01.008.
16. Chien-Chuan Ko, Yung-Lung Kuo, Jeng-Muh Hsu, Bo-Zhi Yang, "A multi-resolution video watermarking scheme integrated with feature detection," *J. Chinese Institute Engineers* **36**, No. 7, 878 (2013). DOI: 10.1080/02533839.2012.747057.
17. X. Zhu, J. Ding, H. Dong, K. Hu, X. Zhang, "Normalized correlation-based quantization modulation for robust watermarking," *IEEE Trans. Multimedia* **16**, No. 7, 1888 (2014). DOI: 10.1109/TMM.2014.2340695.
18. Charu Agarwal, Anurag Mishra, Arpita Sharma, Girija Chetty, "A novel scene based robust video watermarking scheme in DWT domain using extreme learning machine," in *Extreme Learning Machines 2013: Algorithms and Applications*, Vol. 16, p. 209-225 (Springer International Publishing, 2014). DOI: 10.1007/978-3-319-04741-6_15.
19. P. S. Venugopala, H. Sarojadevi, Niranjan N. Chiplunkar, Vani Bhat, "Video watermarking by adjusting the pixel values and using scene change detection," *Proc. of Fifth Int. Conf. on Signal and Image Processing*, ICSIP, 8-10 Jan. 2014, Bangalore, India, South Korea (IEEE, 2014), pp. 259–264. DOI: 10.1109/ICSIP.2014.47.
20. H. Kelkoul, Y. Zaz, "Digital cinema watermarking state of art and comparison," *Int. J. Computer*, *Electrical*, *Automation*, *Control Inf. Eng.* **11**, No. 2, 287 (2017). URI: http://scholar.waset.org/1307-6892/10006722.
21. D. Shukla, M. Sharma, "A novel scene-based video watermarking scheme for Copyright Protection," *J. Intelligent Syst.*, 1 (2017). DOI: 10.1515/jisys-2017-0039.
22. P. Adhikari, N. Gargote, J. Digge, B. G. Hogade, "Abrupt scene change detection," *Int. J. Computer*, *Electrical*, *Automation*, *Control Inf. Eng.* **2**, No. 6, 1 (2008). URI: http://scholar.waset.org/1307-6892/9318.
23. N. Leelavathy, E. V. Prasad, S. S. Kumar, "A scene based video watermarking in discrete multiwavelet domain," *Int. J. Multidisciplinary Sci. Eng.* **3**, No. 7, 12 (2012). URI: http://www.ijmse.org/Volume3/Issue7/paper3.pdf.
24. D. Shukla, M. Sharma, "Performance evaluation of video watermarking system using discrete wavelet transform for four subbands," *Proc. of Int. Conf. on Cyber Security*, ICCS, 13–14 Aug. 2016, Kota, India (Rajasthan Technical University, 2016).