



A Robust Discrete Wavelet Transform Based Adaptive Watermarking Scheme in YCbCr Color Space against Camcorder Recording in Cinema/Movie Theatres

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Abstract

Camcorder-based piracy is increasing nowadays because of the high quality of camcorder devices. The most affected industries are theatre and cinema. To defeat theatre piracy which causes huge loss to the motion picture industry of the world, here in this paper, a robust discrete wavelet transform (DWT) based video watermarking approach has been presented in which a payload formed with date-time of the show, registration number of theatres, and six-digit zonal Improvement code (ZIP) of the theatre location embedded in the movie before it plays back in the theatre. To assure that the video and the algorithm are of good quality and robustness, the adaptive watermarking pattern has been used to minimize the watermarking area in the host video. In this study, YCbCr color space has been adopted to use luminance factor of the image to watermark because the luminance part of the image is the least sensitive to the human visual system. This approach shows the convincing robustness against the geometrical attack and camcording attack, which is the most affecting factor in camcorder piracy. As the proposed approach is good enough to disclose the place and time of piracy, it may deter the pirate to do piracy.

Keywords: Camcorder piracy; Watermarking; DWT; YCbCr; Adaptive; Cinema; Theatre.

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1. Introduction

If the internet continues to evolve, pirated videos can be shared easily and more popular. This is one of the major problems confronted by the film industry of the world. Ding *et al.*^[1] reported that 90% of pirated videos come from someone who sits in a theatre secretly and records the played video. Lee *et al.*^[2] explained that a digital watermarking method is incorporated into a video in a way that most viewers cannot see. Digital watermarking is not a file metadata but a signal hidden within the whole image file. This is crucial to note,

because it ultimately has to work with a second-hand recording of the video on the projector. Detecting facts, for examples, the holders of the copyright, the name of the theatre, date and time of the video replay, is necessary to explain how the video has been recorded without permission. Though watermarking may be challenging to be located, to find the most addressed theatres and the most frequent period piracy exist to impose improved practices, offenders themselves will be useful and discover the conditions, in which the film is stolen.^[3] Although it is not feasible to prohibit people in a theatre and filming video from bringing their mobile, watermarking scheme may definitely deter the pirate to do piracy. In certain instances, there are more steps, notably with online distribution of video instead of on the road, which may help us capture the perpetrator after a video has been taken.

The most extreme of the watermark attacks is the geometrical distortion. Various watermark ideas for geometric distortion are placed out for digital images. For example, Li *et al.*^[4] proposed that the watermark should not be brittle and broken after alteration for authentication. If the watermark is correctly recovered, then the video is authentic. The watermark generation module has been developed that

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includes copyright details, time stamp and video signature as inputs and generates a copyright and authentication watermark.^[4] The details essential for watermark extraction separate the watermarking algorithms into two blind and non-blind groups. If the original video is needed during extraction, the algorithms are otherwise called blind algorithms. The sender must submit the recipient with the initial video labeled with a watermark.

Three methods are considered in a previous works for the usage of video watermarking algorithms.^[4] A video as chronological images and the image watermarking algorithm must be deemed the easiest and most transparent solution. Another insight can be used to create modern robust video watermarking algorithms and to analyze the temporal component. A compressed video stream is another solution and the features of these compression requirements can be implemented in order to achieve an appropriate watermarking algorithm. Fig. 1 represents a block diagram of basic watermarking process.

In comparison to literature, the proposed watermarking system has a high embedding strength, excellent imperceptibility and good robustness against so many geometrical attacks, non-geometrical attacks and hybrid attacks (including geometrical and non-geometrical attacks). The suggested watermarking method employs a new system for the integration of watermark. In order to prevent heavy loss, the compression is used utilizing various imaging compression methods, the host image’s luminance (Y) channel in the YCbCr (Y is luma factor, and Cb and Cr are blue and red difference chroma of the image) color space system has been used, instead of the RGB (Red, Green and Blue) color space. The proposed method of watermarking is based on discrete wavelet transform (DWT) transformation that transforms the spatial domain to the frequency domain. Firstly, all frames of the video will be transformed in the frequency domain while DWT approach is used.^[4]

This paper makes the major contributions as follows. The proposed approach is stable in randomly distorted geometries.

2. Related work

There are relatively few findings on video watermarking technologies for camcorder capturing. A researcher recommends the LACF (local autocorrelation function)-based technique to protect against the camcorder recording in the theater.^[5] The embedded watermark is extracted by eliminating geometric distortion parameters using the LACF after the watermark pattern is restored. However, it is hard to use the LACF peaks, since the peaks are not visible after a number of signal processing attacks. Even geometrically distortion-related combinations are not robust. Because the video content of adjacent frames is identical, authors have found video watermarking procedures to adjust the overall pattern in sequential frames to reveal a watermark bit. The downside of these techniques is that they only serve as regular footage. When used in the high-definition images, the algorithms generate a low invisibility. Few studies on the copyright in multimedia videos have been carried out.

Although most of these tests concentrate on standard definition videos, the accuracy of watermarked videos is significantly impaired when implemented in high-definition videos.^[6] Moreover, the methodology of the studies is robust for traditional video watermark attacks only and does not answer the attacks by camcorders. Video watermarking techniques in high-definition have been suggested, they attain a high video efficiency, but are still susceptible to camcorder threats. The watermark should be fairly resilient to data distortions induced by processing or device noises.^[7,8] The watermarks also must resist the threat of numerous attacks in the complicated Big Data world, such as damage, destruction, or deletion of embedded watermarks. Many researchers performed a profound research and made many changes to satisfy the above two watermarking criteria. There are also relatively fewer watermarking algorithms for video. For video, a color model is an abstract approach that explains color using a series of colors. Researchers have recently focused on the integration of wavelet-based watermarking techniques to enhance the robustness of watermarked images against non-

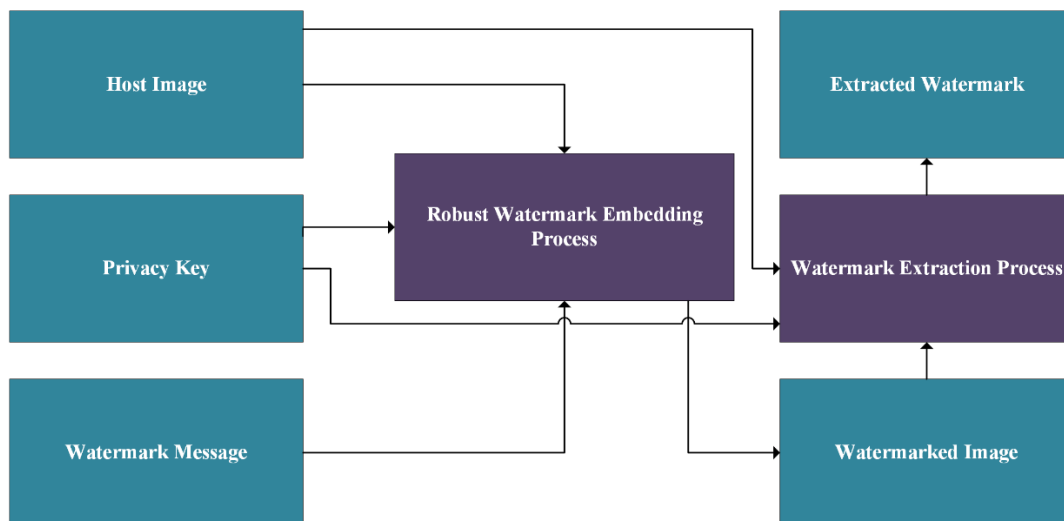


Fig. 1 Basic process of digital watermarking.

geometric and geometric attacks. The approach suggested recommends the use of Y-Channel in YCbCr as the safest place to conceal data where JPEG compression resistance and noise added tolerance are major concerns. For scaling and rotation resistance, Cr channel is the best alternative, whereas Cb channel is a better option for crop resistance.^[9] The space of YCbCr is used to mark watermarks for optimum assaults threats.

Another research explores the robustness of the watermarking method for color images utilizing various color spaces to combine them.^[10] The watermarking device utilizes redundant signal spaces perceptually to add watermarks. The robustness comparison reveals that uniform color spaces actually have a great deal of perceived redundancy while incorporating high-strength watermarking signals that can withstand multiple threats.

Frequency-domain-based methods are used for a variety of various uses, such as watermarking algorithms that utilize frequency-domain activity (DWT).^[10,11] The cover data's frequency-domain is split into various frequencies. Discrete Fourier transforming (DFT), stationary wavelet transformation (SWT), discrete cosine transforming (DCT), complex wavelet transforming (CWT) etc. are sub-classified as the domain frequency watermark system.^[12] The DWT separates the image into a variety of sub captions. The high frequencies subframes provide details regarding edge and low frequency components (smoothness data) Again, sub-images are classified into low and high-frequency images sub-images.^[13-15] The improvement in picture quality allows the low frequency sub-image to be dramatically degraded. The use of high-frequency sub-images is common for watermarking attacks since evidence indicates that the human visual system (HVS) is normally less susceptible to high-frequency coefficients. The most significant images for the incorporation of watermarks are often classified as high-frequency sub-images.

A comprehensive watermarking method for invisible watermarking of digital video is presented in the present work. Watermarking is carried out in YCbCr color field in the DWT domain transition. The generated watermark was first scrambled using Arnold transformation to make undetectable. YCbCr is selected because it models the HVS closely. The methodology offers a stable mechanism immune to diverse attacks. The payload generated is the combination of date, time and location of the video playback.^[16]

The remaining of the paper is structured accordingly. Preliminaries works are in section 3 and quickly covers the YCbCr color paradigm and its connection to RGB color. Arnold scrambling process with a short statement on DWT and its usage with watermarking is provided. The suggested watermarking framework is presented in Section 4. Section 5 describes tests and analysis of implemented work. Discussion and conclusion have been covered in section 6 and 7, respectively.

3. Preliminaries

Watermark embedding in the host file to protect content from copyright infringement is very common, but the robustness of the embedded watermark depends on the method that follows at the time of embedding. Thus, three key principles of image processing have been merged here in the proposed approach to include a robust watermark embedding approach that is robust against geometric attack, noise, crop, frame drop, frame averaging and many more. In the proposed solution DWT, YCbCr color model and the adaptive design of watermarking have been taken together to render the proposed algorithm more stable against the various attack like frame averaging, frame crop, rotation, scaling, *etc.*

3.1 Color Space YCbCr

The image color is often displayed as numbers and the color pattern determines how the color intensity of an image is viewed. There are several color models available for processing the images, but some of them, such as RGB, YCbCr, YUV, and HSV, are common because of their applicability.^[17-20] Here, the YCbCr color model was adopted for processing in the presented work. Y stands for luma (brightness), Cb and Cr are more receptive to the HVS compared to Cb and Cr for the blue difference and red difference chroma portion. The input image is in RGB and can then be translated using Equation 2 to the YCbCr color model, Equation 1 represents the conversion of YCbCr color space image into RGB and this will be required in the reverse process.

RGB color model to YCbCr color model.

$$\begin{pmatrix} R \\ G \\ B \end{pmatrix} = \begin{pmatrix} +1.000 & -0.000 & +1.403 \\ +1.000 & -0.344 & -0.714 \\ +1.000 & +1.773 & +0.000 \end{pmatrix} \begin{pmatrix} Y \\ Cb - 128 \\ Cr - 128 \end{pmatrix} \quad (1)$$

YCbCr color model to RGB color model

$$\begin{pmatrix} Y \\ Cb \\ Cr \end{pmatrix} = \begin{pmatrix} +0.299 & +0.587 & +0.114 \\ -0.169 & -0.331 & +0.500 \\ +0.500 & -0.419 & -0.081 \end{pmatrix} \begin{pmatrix} R \\ G \\ B \end{pmatrix} + \begin{pmatrix} 0 \\ 128 \\ 128 \end{pmatrix} \quad (2)$$

Until watermarking, RGB to YCbCr is applied to the image, and YCbCr to RGB is applied to the image while the watermarked image is displayed.

3.2 Discrete Wavelet Transform

One of the very popular image transformation technique DWT is used very frequently and transforms digital images from a spatial domain to a frequency domain.^[20] The other transformation methods are DCT, FFT, and CWT. It is commonly used in signal modulation, denoising of sensor data and many more domain and purposes, including digital image processing, DWT offers more accurate image representation and color analysis. One of the uses for image processing requires the decomposition of images into constant bandwidth frequency channels.^[21-23] Four sub-bands or sub-images are splitted by DWT transformation. Fig. 2 shows the 3-level of

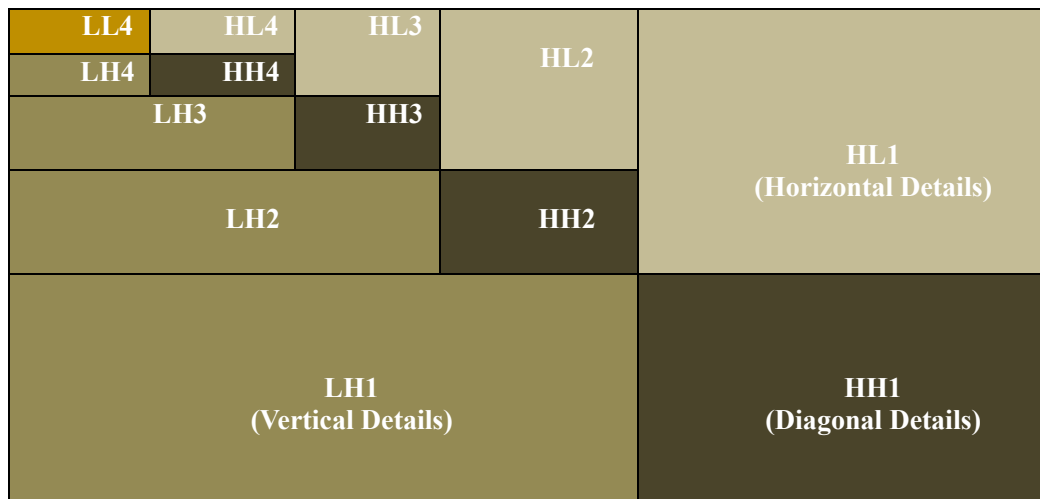


Fig. 2 4-level-DWT transformation (LL represent approximation and LH, HL and HH represent detailed coefficient of a transformed image).

DWT transformation of an image. The estimated subsection (LL) of the image created matrix includes the average matrix created image or a dull digital image definition, and the accurate subsection (HL) consists of the digital picture's edge region. Generally, inserting watermark data into the low frequency (LL) or approximated sub-image would readily deteriorate the picture quality, but inserting concealed features into vertical, horizontal and diagonal sub-images in the high frequency and the digital picture would not cause any apparent damage. Multi-level wavelets decomposes further until subfigures comply with the watermark criteria. DWT not only promotes the invisibility, but also improves the safety by dispersing hidden knowledge over the entire picture during the reverse transition.

3.3 Arnold Transformation

Digital image screwing turns an image into a nonsensical one and preprocesses digital image contents, often called a mask, during hiding. Image scrambling technology is based on data hiding methodology that offers a without encryption algorithm for data hiding. There have also been numerous new battle algorithms and thus more countries are paying more attention to the topic, culminating in a revolution in network information warfare.^[24,25] Matrix point (x, y) transformation in the unit square, which translates to the same matrix point (x', y'), and Equation 3 is the scrambling method proposed by Arnold for unit matrix.

$$\begin{bmatrix} x' \\ y' \end{bmatrix} = \begin{bmatrix} 1 & 1 \\ 1 & 2 \end{bmatrix} \begin{bmatrix} x \\ y \end{bmatrix} (mod 1) \tag{3}$$

This transformation is regarded as Arnold scrambling in two-dimensional. Arnold two-dimensional scrambling mod 1 has been modified in a way that is unique to the digital image of size N.

$$\begin{bmatrix} x' \\ y' \end{bmatrix} = \begin{bmatrix} 1 & 1 \\ 1 & 2 \end{bmatrix} \begin{bmatrix} x \\ y \end{bmatrix} (mod N) \tag{4}$$

where x, y, x' and y' are pixel position in image and N is dimension of the image. Unit size image is not of use so the

scrambling method needs to be upgraded for higher dimension image as given in Equation 4.

4. Proposed approach

The proposed approach of watermarking is mainly robust against the geometrical attack, it is essential because the camcorder recording is more prone toward the geometrical attack because of the recording angle and distance. Here is the proposed section whole approach is presented in three-part watermark generation, embedding and extraction of watermark. Fig. 3 represents the process of embedding and extraction of the proposed approach.

4.1 Watermark Generation

One of the very crucial part of the watermarking process is that as much information is added in the host video, the more perceptibility of the watermark is, and then it will be very difficult to extract the embedded watermark. The major step is to decide the most ideal approach to encode minimal information to create a watermark since more information is attempted to be imbedded into a video frame, the harder it is to conceal this information, and the harder it will be to get back the embedded watermark.^[10]

Based on the purpose of watermarking, one can decide their payload to be added in video, as the purpose of proposed approach is to find the time and place of piracy so payload is developed according to that consideration only:

- 1) Date and time of show, and it is added as a reference hour. A reference date has been set, and the hours passed between actual show time and reference date is called as reference hour here in the proposed work.
- 2) Seven-digit Indian pin code of the location of theatre, where movie has been presented.
- 3) A 3-digit registration id of the movie theater.

The above set of information is sufficient to disclose the timestamp and place of piracy. In the proposed work, the above defined information has been arranged in order to form

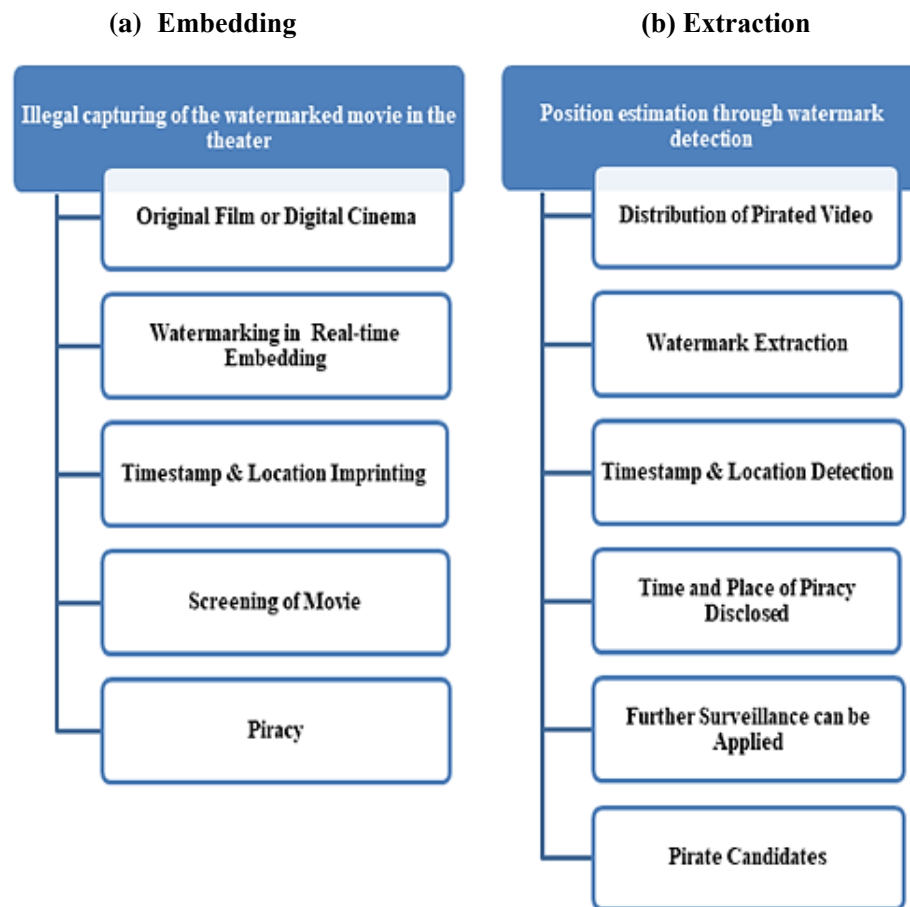


Fig. 3 Proposed work flow.

a payload and in ordering firstly reference hour, then pin code and registration number of theatres. This ordering can keep payload minimum because it uses pin code or theatre registration first then if leading digit will be 9 then it will increase the length of payload. The possibility of leading digit 9 in reference hour will be only possible after approx. 600 years because the reference number has been set according to that and it has been discussed in detail with the following example.

As an example:

1) Suppose a movie has been scheduled at 3:00 PM on 12 January 2020 and our unchanged reference date is 1 January 1999, then the reference hour is 184344 (as many hours passed between two dates).

2) It is assumed that the movie play back at my house in Anand and its pin code is 388315.

and 3) the given three-digit registration number is 111. According to the ordering suggested the final payload would be 184344388315111. Fig. 4 represents the classification of the generated timestamp.

The generated payload will be converted in binary and then it will be converted in a matrix form and image watermark that will be later embedded in the video.

The binary form of the payload is: 010100111101010010000010111001000001001111100111. Now this payload can be used to get the basic watermark.

The image, which will be added in video (Movie before playback in theatre), is called as the watermark image. The watermark image can be created of any length, which suits and follows the HVS so here in the proposed work the watermark image size has been taken as 17 × 17 gray level image and in the generated image, the payload will be arranged as, pixel of

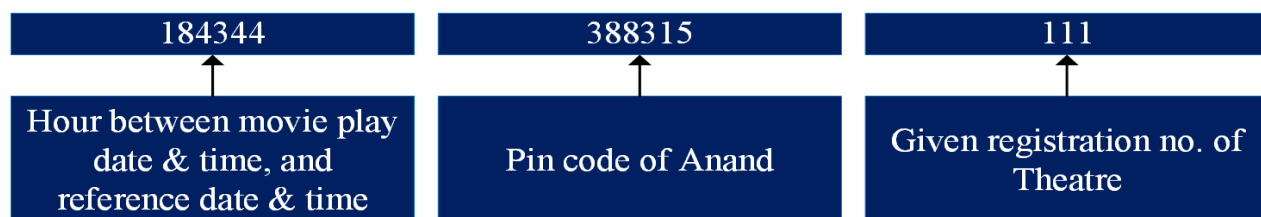


Fig. 4 Classification of the time stamp.

row 2 and column 16 will be marked white, that will be utilize to know the correct rotation and it will be helpful if any rotation attack applied by attacker. Binary converted payload of length 49 bit (if not of 49 then leading 0 can be added) has been arranged in 17×17 binary image as shown in Fig. 5.

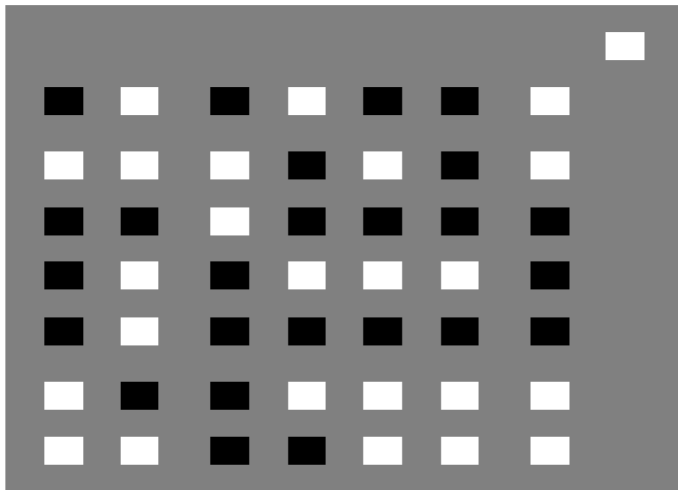


Fig. 5 17×17 basic watermark (W_b) image with payload, from left (column 2) to right (column 14), from top (row 4) to bottom (row 16), a bit is either black for zero or white for one.

Now this basic watermark can be tiled as per the size of video frame and as shown in Fig. 6.

The proposed work architecture is shown in Fig. 7. It represents the flow of the watermark embedding and extraction as well as the watermark generation process. The architecture diagram helps to understand the whole process in a pictorial manner.

4.2 Embedding of generated watermark in host video

Now in this section, the generated watermark will be added into the video and the video is nothing but a collection of

frames. In these frames, only the generated watermark will be added. So firstly, the video has to be processed and all frames need be extracted and then watermarking is applied on these frames as proposed in the following step-by-step process:

Step 1: Read the basic watermark (W_b).

Step 2: Apply Arnold transform using Equation 5 on basic watermark to get the scrambled watermark so that no one can detect it.

$$W_{ab} = AT(W_b) \tag{5}$$

where W_{ab} is the Arnold transformed basic watermark and W_b is the basic watermark.

Step 3: Get the scrambled periodic watermark (P_{ab}) after tiling the W_{ab} as per host video frame size.

Step 4: Extract frames from video.

Step 5: Repeat step 6 to 12, M_f time, where M_f is number frame in host video.

Step 6: Convert frame to image (F_h to I_h), where F_h represents the host frame and I_h represents the host image.

Step 7: Apply RGB to YCbCr using Equation 6 on the host image (I_h) and consider Y part only for further processing.

$$I_{Yh} = YCbCr(I_h) \tag{6}$$

Step 8: Apply 3-level DWT to Y component of frame and consider HL part only for the further processing.

$IHL_{Yh} = DWT^3(I_{Yh})$ (Taken only HL part of transformed image)

Step 9: Embed the periodic watermark (P_{ab}) in the host image I_{Yh}^{HL} using Equation 7

$$WI(x, y) = IHL_{Yh}(x, y) + \eta \lambda(x, y) * P_{ab}(x, y) \tag{7}$$

where η is the global wait factor and $\lambda(x, y)$ is the local wait factor of the periodic watermark pixel (x, y) and WI is the watermarked image.

Step 10: Apply inverse DWT on the watermarked image (WI).

Step 11: Apply YCbCr to RGB.

Step 12: Apply image to frame.

Step 13: Combine all frames to get watermarked video.

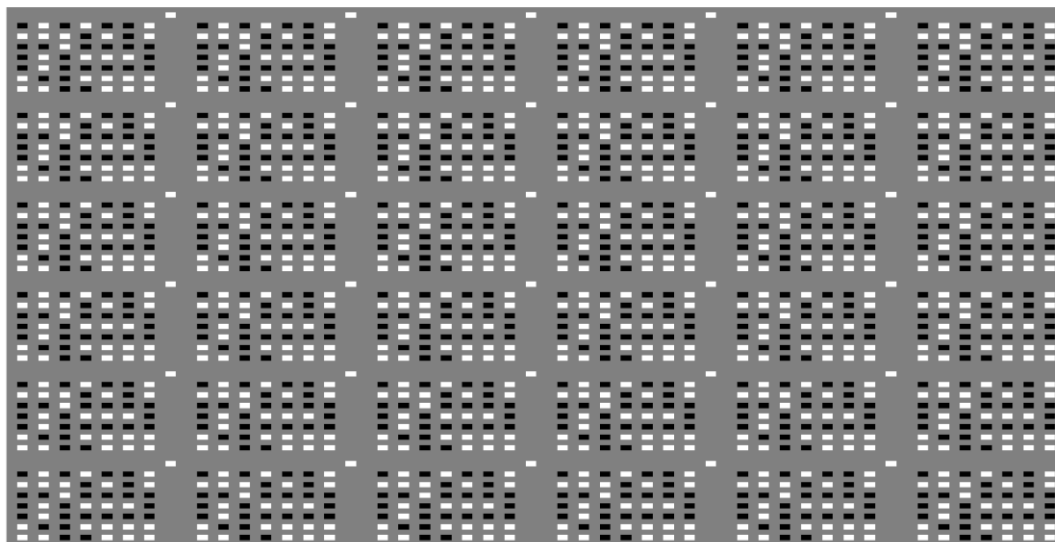


Fig. 6 Periodic watermark (P_w) after tiling the basic watermark (W_b).

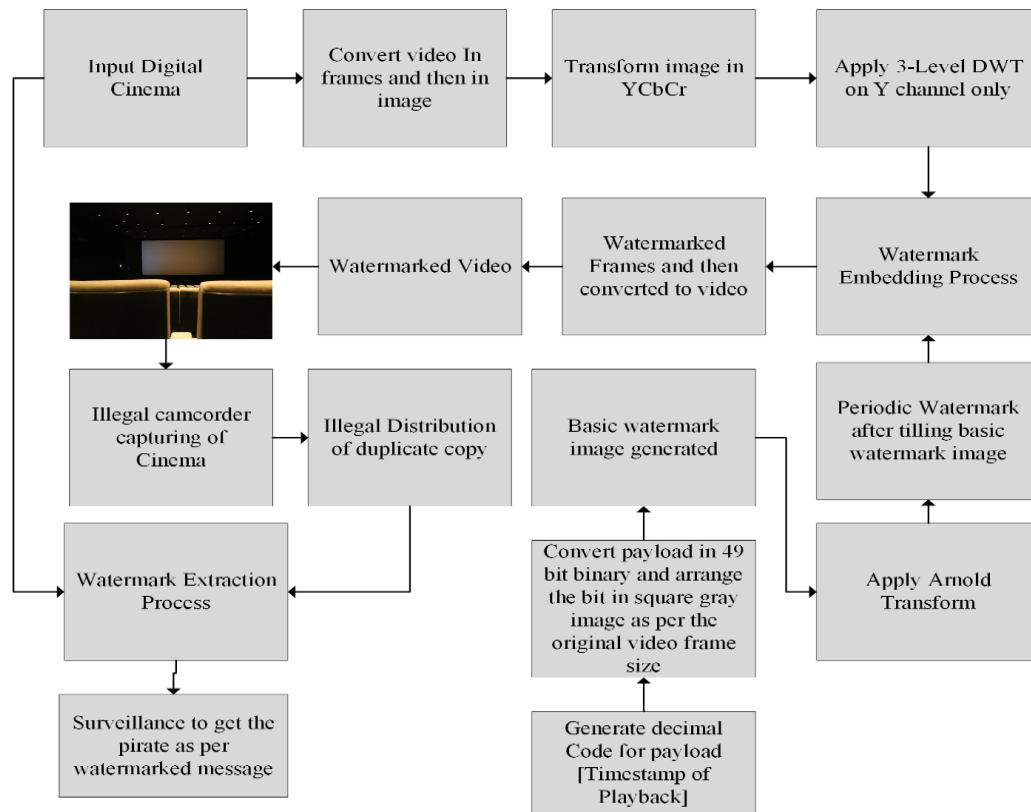


Fig. 7 Architecture of proposed approach.

Fig. 8(a) shows the original video frame before watermark and the proposed approach watermarked the timestamp without any artifact as shown in watermarked video frame Fig. 8(b) and after seeing it, it is clear that visual experience of user is unaffected. The quality of the camcorder recorded video is good enough to entertain the audience of the pirate person as shown in Fig. 8(c).

4.2 Watermark Extraction

The suggested solution uses an adapted blind extraction technique, in which the original video is not needed while

removing the embedded watermark. If a video is taken, it can often be difficult to synchronize with time. In addition, it can involve encoding and transcoding. Therefore, it is crucial how to find the correct points at the start extraction process. A synchronization sequence before the watermark sequence is the technique for resolving this issue. Until detecting the frame rate is translated to the initial frame rate, the detection window is moved over a frame before a compatibility pattern is located centered on a hamming gap between the sequence extracted and the inserted.

Step by step process to extract the embedded watermark is

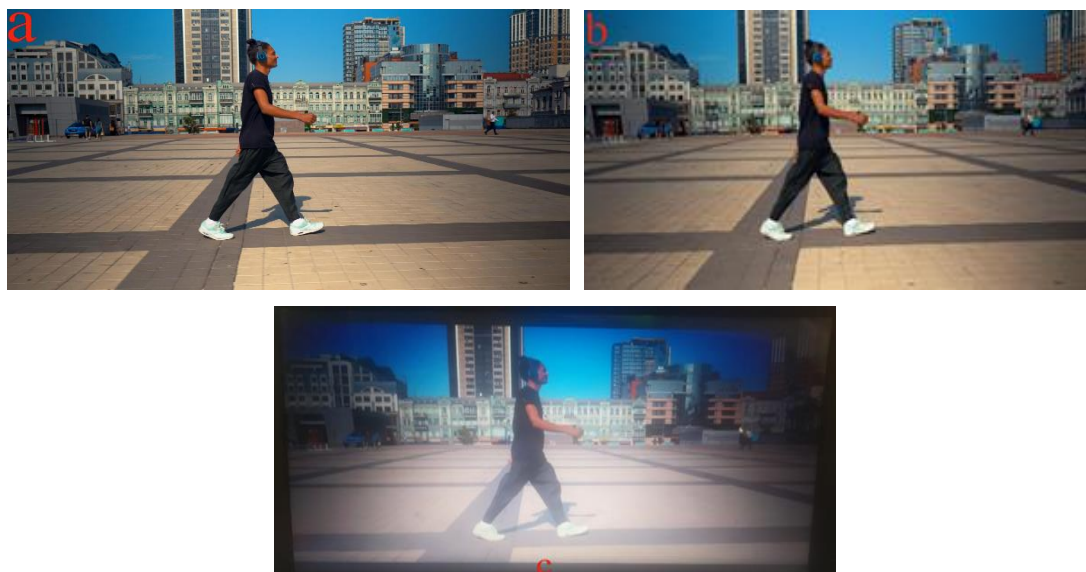


Fig. 8 (a) Original video frame, (b) watermarked video frame and (c) Camcorder recorded watermarked video frame.

as follows:

Step 1: Single-shot videos groups the watermarked file in a small length video. Since a video is too small and does not have an embedded watermark pair, this video is neglected because it is short in length.

Step 2: One video is chosen from the chosen one-shot, take one-quarter of the field in the center of the Y channel clip of 5 consecutive frames as the detection area, change the RGB space into YCbCr space, and apply DWT transformation. Then the luminance patterns are obtained in the detection region on the next five frames.

Step 3: As the correct synchronized consecutive frame is obtained, the watermark bit can be easily extracted. Provided that the frame loss may be triggered in the video, the transmission may lead to failure to detect the watermark. In this case, switch to the next consecutive frames till the time embedded watermark not get extracted successfully for the recognition of place and time of piracy.

Step 4: Run step 2 to step 3 till all the chosen shots are not completed. And in the end watermark has been extracted.

Figs. 9(a) and 9(b) are original and extracted watermark before applying any attack and pre-processing respectively. Extracted watermark Fig. 9(b) is just extracted from original watermarked video frame.

5. Experimental Result and Analysis

The proposed approach has been implemented and tested on MATLAB 2021a, and five video files of high quality have been used for experimental purpose as described in Table 2. Several attacks were applied on the watermark embedded file. The peak signal to noise ratio (PSNR) of the attacked and the original frame were compared. The reason to take various video files to test the performance is to check the robustness of proposed approach in all possible scenario of cinema industry. For example, many animated movies are also released, so the performance of proposed approach in that case has been tested through Animation. Mov file as mentioned in

Table 1. For the performance measurement of the proposed approach, two popular parameters have been adopted, i.e., NCC (normalized cross-correlation) and PSNR (peak signal to noise ratio).

Table 1. Details of the video file used in experiment [All are Stok Video free for research purpose].

Sr. No.	Video file name	Duration (Second)	No. of frame	File type
1	Man Walking	11	330	MPEG
2	Beach	79	1975	MPEG
3	Forest	36	864	MPEG
4	Meeting	26	650	MOV
5	Animated	18	540	MOV

Video details as given in Table I have been taken from stock video repository, and are licensed free for research purpose.

Mathematical formula to calculate PSNR is as mentioned in Equation 8:

$$PSNR(I, WI) = \frac{255^2}{\frac{1}{MN} \sum_{i=0}^{M-1} \sum_{j=0}^{N-1} [I(i, j) - WI(i, j)]^2} \quad (8)$$

where $I(i, j)$ and $WI(i, j)$ are the host and watermarked image and M and N are the image size.

Mathematical formula for the NCC is as mentioned in Equation 9:

Mathematical formula for the NCC is as mentioned in Equation 9:

$$NCC = \frac{\sum_{i=0}^{M-1} \sum_{j=0}^{N-1} WI(i, j) \times EI(i, j)}{\sqrt{\sum_{i=0}^{M-1} \sum_{j=0}^{N-1} WI^2(i, j) \times \sum_{i=0}^{M-1} \sum_{j=0}^{N-1} EI^2(i, j)}} \quad (9)$$

where WI and EI are watermarked and extracted images, and M and N are the image size.

The calculated average PSNR of the watermarked video with the original video has been marked as 49.77 dB.

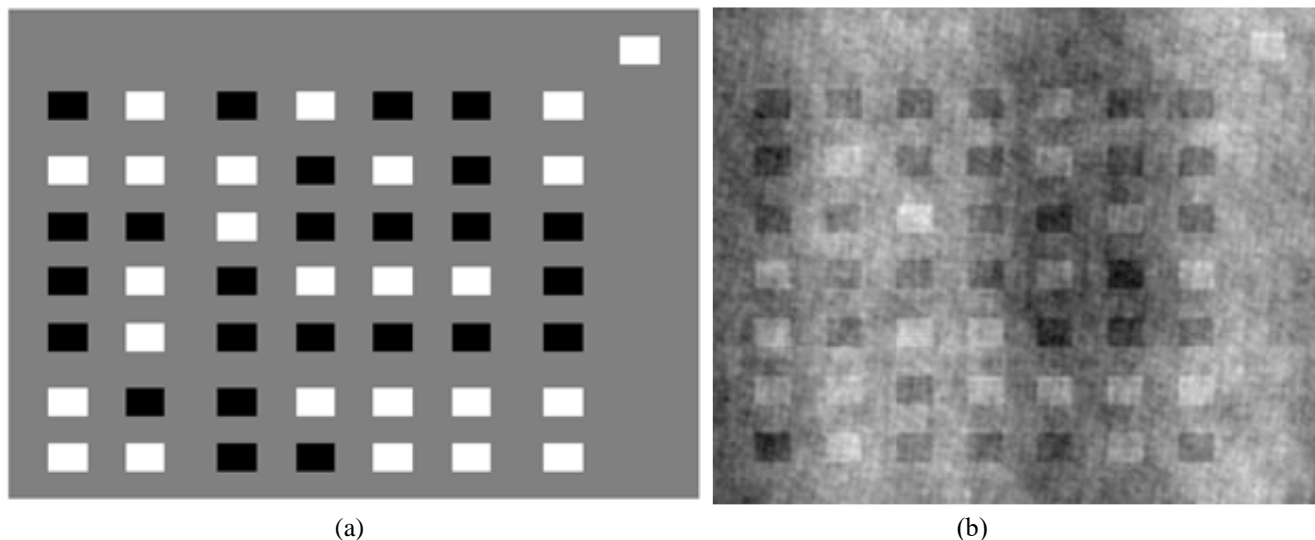
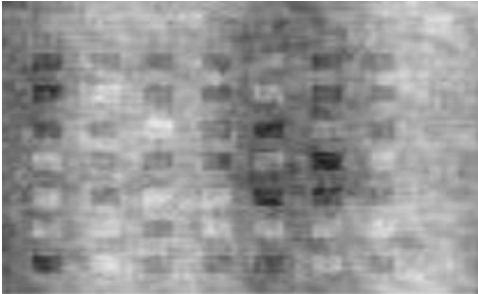
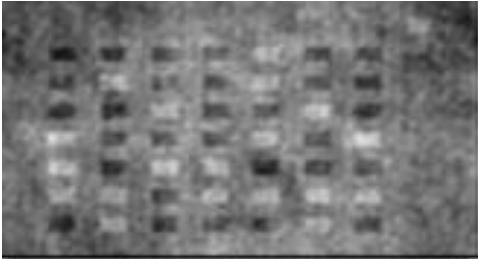
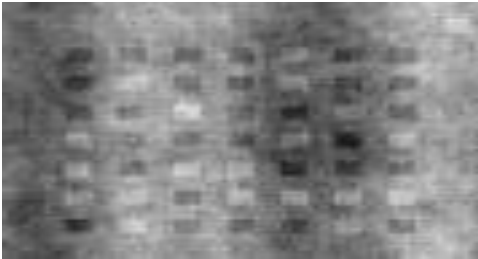

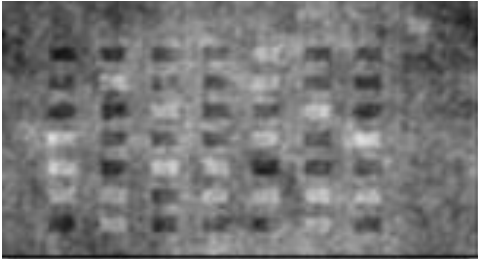
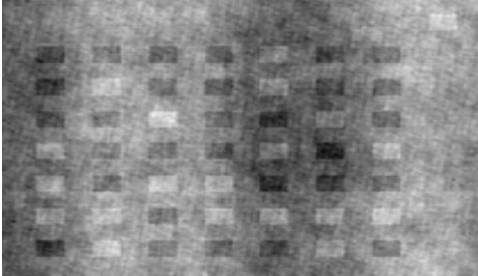


Fig. 9 (a) Original watermark image and (b) extracted watermark image.

Table 2. Average NCC value after the attack and extracted watermark frame.

Sr. No.	Type of attack	NCC	Extracted watermark
1	Blurring	0.8754	
2	Crop	0.9254	
3	Salt and pepper noise (Density = 0.001)	0.8724	
4	Gaussian Noise (mean=0, variance=0.001)	0.8854	
5	Frame removal	0.9265	
6	Frame averaging	0.9125	

Continued

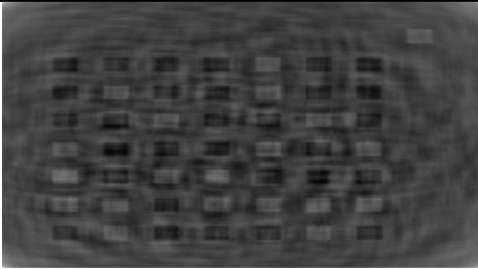
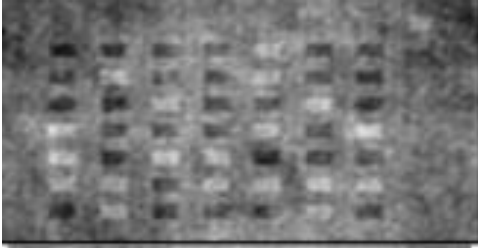
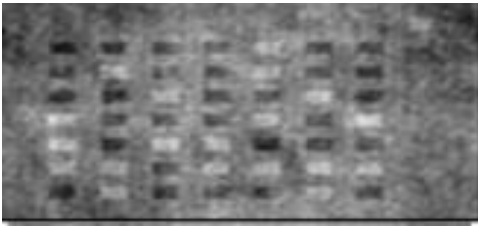
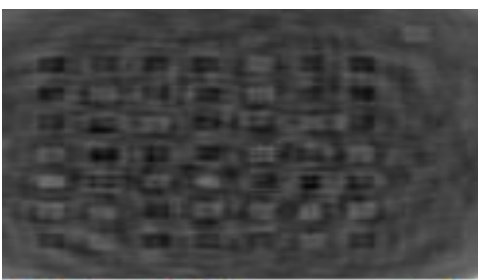
7	MPEG-4	0.9147	
8	Rotation (6°)	0.9252	
9	Frame resizing	0.8925	
10	Second hand recording	0.8180	

Fig. 10(a) shows the robustness of the algorithm against various geometrical attack and camcording attack. From the figure, it is also clear that the NCC value for animated video file is low in comparison to the other video files. Fig. 10(b) shows the result of NCC for the extracted watermark, which is extracted from camcorder recorded video after applying several attacks on recorded video. It is clearly visible that the quality of extracted watermark in comparison to original file watermark is little bit down.

The extracted watermark and calculated average NCC for the extracted watermark after various attacks have been presented in Table 2.

In Table 2, the comparison of proposed work performance with previous research work has been shown. For the performance comparison, several attacks have been considered, for example, the frame removal, and frame averaging, noise, crop, frame resizing and Cam cording. From the comparison table, it is very clear that the proposed work is invariant against rotation attack and produces the substantial watermark message after camcording attack, which is lagging in previous works. In comparison Table 3, the NCC value

between embedded, and extracted watermark through proposed algorithm has been calculated.

6. Discussion

The major objective of the research carried out was to propose a robust watermarking scheme against the camcorder based illegal recording of the movie from theatre. During the study of the related work, many research papers have been considered, in which there was a discussion about camcorder-based piracy, but not in a single paper robustness of the given algorithm against various attacks after camcorder recording was given. In recent papers, the authors have tested their given algorithm robustness before camcorder attack, in which all have almost the same results. During experiment of the proposed work, it was found that during camcorder recording of movie from theatre, few unintentional attacks were automatically applied in recorded video, which affected the detection and extraction of the embedded watermarking. The major effect of the unintentional attack was the distance of recording. When the distance of movie screen and pirate was more than 10 meters, then it was very difficult to extract the

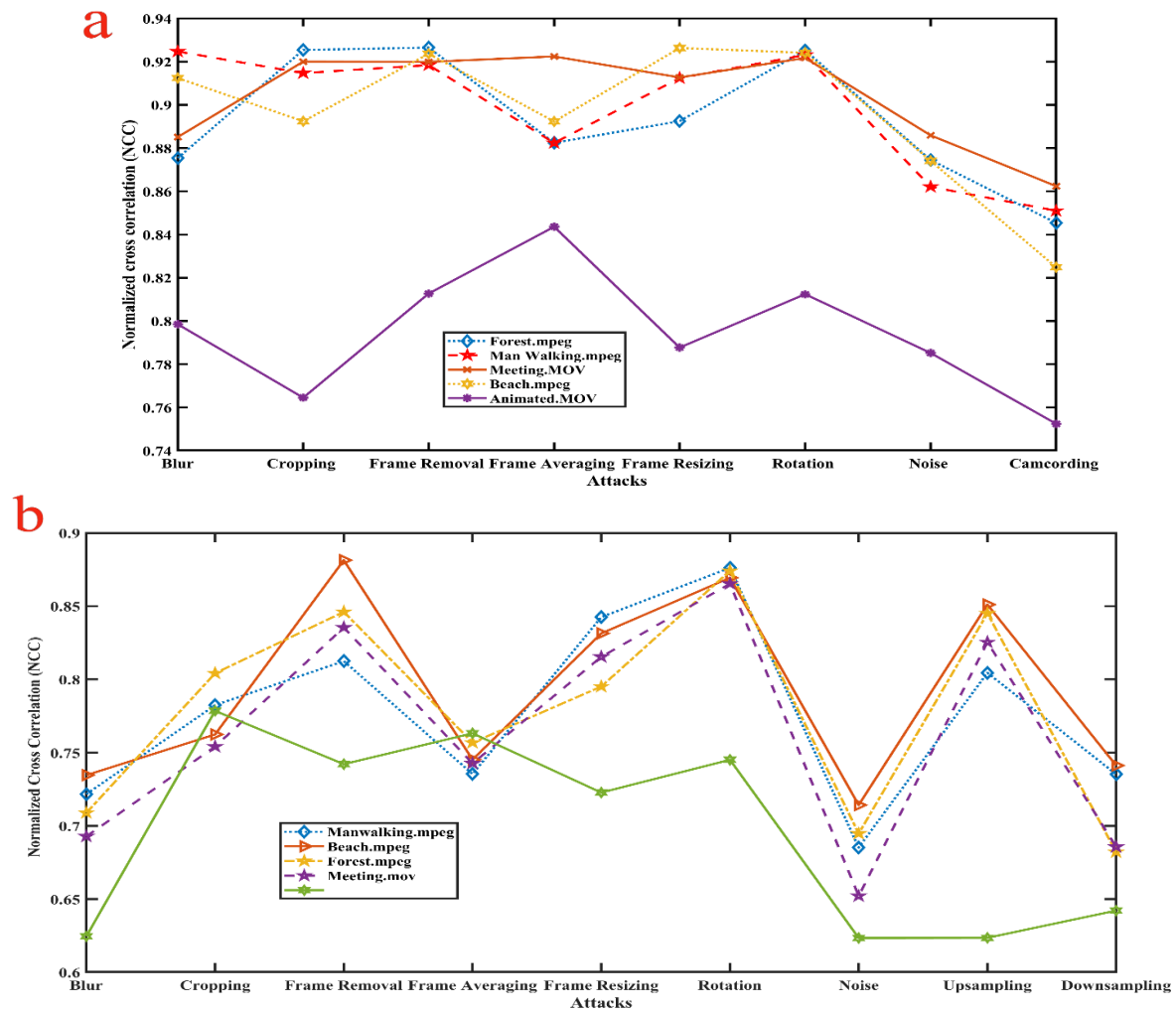


Fig. 10 (a) NCC between original watermark and extracted watermark after applying various attack and (b) NCC between original watermark and extracted watermark from camcorder recorded file.

Table 3. Comparison of work with Previous work.

Approach	Gosavi <i>et al.</i> [18]	Mareen <i>et al.</i> [20]	Proposed Work
Type of domain	DCT	DT-CWT	DWT
PSNR (dB)	48.94	48.73	49.77
Evaluation parameter	NCC	NCC	NCC
Gaussian noise	0.8923	-	0.8854
Compression	0.904	0.95	0.9147
Salt and pepper	-	0.89	0.8724
Camcorder recording	0.7547	0.7084	0.7634
Rotation	-	0.9341	0.9552
Cropping	-	-	0.9240
Median filter	0.9632	-	0.9517
Attack	Blur	-	0.8754

embedded watermark. From the experimental analysis, it was found that the proposed work is invariant to the viewing angle of pirate because of provision added in the watermarked image to show the orientation of payload message against rotation.

7. Conclusion

A robust discrete wavelet transform (DWT) based watermarking approach against camcorder piracy has been presented. The whole research work has been carried out in three phases. The first phase was to generate a robust watermark message, the second part was to embed a watermark message and the third part to extract the

watermarked message from recorded video. The YCbCr color space has been adopted for watermarking because the human visual system (HVS) is more susceptible to the image color. The purpose of the proposed approach is to deter the pirate from piracy in theatre because the watermark message is generated in the way that reveals the time and place of camcorder recording. This may help for the surveillance of the place and theatre, which prohibits the piracy. The proposed approach has been shown to be invisible and to be resilient to various attacks like rotation, frame dropping, geometric attack and camcorder recording.

8. Limitation and Future Work

The research was carried out with two main goals in mind: the first was to successfully extract a watermark message from the camcorder recorded video, and the second was to deter and estimate the position of the pirate in the theater. The research clearly shows that the proposed approach is good enough to extract the watermark as well as good enough to know the time and place of piracy, but it is not good enough to estimate the pirate's position in the theater. This research can be extended to estimate the pirate's position in the theater using distortion approximation in extracted watermark and local auto correlation function.

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Supporting information

Not Applicable.

Conflict of interest

There are no conflicts to declare.

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