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A robust video watermarking technique based on key-frames extraction and contourlet transform

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Abstract

Video watermarking has encountered many types of attacks that can have some affection on the embedded watermark. Security, strength, and reliability are the essential challenges for any video watermarking technique. This research uses a Contourlet Transform for video watermarking system, the watermark image was included in the Contourlet Transform low-frequency coefficients for each video key frames to get the best possible quality and strength against various types of video attacks. Furthermore, the performance of the method was estimated through usage infusibility analysis measurements such as the Peak Signal-to-Noise ratio (PSNR), the Normalized correlation (NC), and the Structural Similarity Index Measurement (SSIM) between original video and the watermarked one. The average PSNR,NC,and SSIM for watermarking were 55.00 dB,1.00,and 0.99, respectively, according to the test results. Hence, Normalized cross-correlation (NCC) and correct bitrate ratio (BCR) were calculated as measures of strength between the extracted watermark and the original watermark. The results showed how this approach is very robust. It also put the system's robustness and imperceptibility to the test against various types of video attacks.

Keywords: Video Watermarking, Contourlet Transform (CT), Frequency Domain, Imperceptibility Analysis, robustness Analysis, Key Frames.

Introduction

The communication, processing and storage of digital information has brought about deep changes in our community (Abdou & Saleh, 2015). It is possible to steal, copy, or interact with information. Actions may be random or willful. The process of adding data, such as a watermark, inside an audio, an image, or a video object is known as watermarking. A watermark might also be text, an image, or an icon. The embedded watermark can later be identified or extracted to validate the identification of the host object (Cox, Kilian, Leighton, & Shamoon, 1997; Khan, 2011; Kumar & Amit, 2017). The video watermark system is intended to include information that may be invisible, usually for copyright protection applications within videos (Christian & Shelth, 2017). The watermark should be robust enough against a variety of types of video processing attacks. An approach to robust video watermarking technologies initiated from the concept of a versatile human vision system that depends on the H.264 / SVC standard (Choi, Do, Choi, & Kim, 2010). Video watermarks may be described as a form of sequence of bits added into a video file to identify the copyright information for file (owner, rights, etc.) (Xia, Boncelet, & Arce, 1998).

Digital watermark Systems should achieve the following four important features.

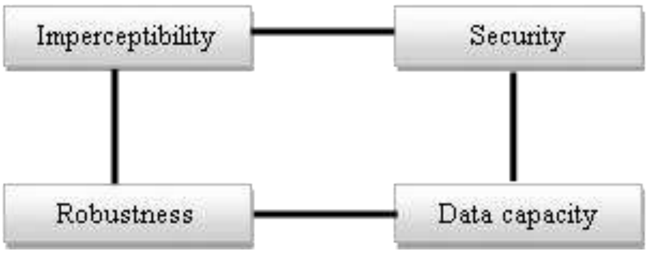
a) Imperceptibility: the embedded watermark has no effection on the quality of the original video (i.e. there is no difference between the host and watermarked videos in many tests such that the Human Vision Test), and the watermark should be invisible.
b) Robustness: for different types of video attacks such as Gaussian noise, Poisson noise, Salt & pepper noise attacks, compression, median filtering, frame cropping, frame averaging, and frame dropping

attacks (Keyvanpour & Boreiry, 2017), the embedded watermark should be strong. All efforts to remove the embedded watermark that the system has added should have an effect on the quality of the watermarked video (Abdou & Saleh, 2015).

c) Security: even if the watermarking algorithm is recognized, unauthorized users are unable to discover or obtain watermarks from the watermarked video without having key information.
d) Data capacity: the amount of data that can be embedded into the original video file to get the watermarked video (Cao & Wang, 2019).

FIGURE 1 shows the tradeoff between these features.

FIGURE 1. Tradeoff Rectangle of watermarking techniques.



Watermarking techniques come in a variety of types that may be used for a different applications (C.S 2005; Husain, 2012; Schyndel, Tirkel, & Osborne, 1994).

Watermarkimg Properties

Robust and Fragile Watermarking:

Robust watermarking is the technique by which the editing in the watermarked video does not has an effect on the embedded watermark and can be clearly extracted. However, The fragile watermark can described as a technique in which the embedded watermark is lost when the watermarked video is edited.

Visible and Invisible (Transparent) Watermarking:

Visual watermarks are the type where an embedded video watermark appears when viewing content. Watermarks that really are transparent (invisible) are undetectable and cannot be identified by simply displaying the digital content.

Public and Private Watermarking:

Watermarked video viewers are able to detect its watermark in public watermarking, but they are not allowed to detect its watermark in private watermarking.

Symmetric and Asymmetric Watermarking:

Asymmetric watermarking is a method of watermark detection and embedding in which various keys are used. However, Symmetric watermarking employs only one key for watermark detection and embedding.

Blind and Non-Blind Watermarking:

In blind watermarking, to extract/detect the watermark, the host video is not necessary. Whereas, in the extraction/detection of watermarks, the host video is required if the watermark is not blind.

Challenges in video watermarking

Embedding Watermark Image in Spatial Domain Methods

The watermark was embedded in the source image/video using spatial domain watermarking methods that modify the intensity of image pixels directly. Under various types of video attacks such as lossy compression and low-pass filter, spatial domain watermarking can easily be effected. The main objective of these methods is to be based on simple pixels with low computational complexity (Boreiry & Keyvanpour, 2017). For the above reasons, for real-time applications, most of the spatial domain approaches are valid. Multiple methods such as Least Significant Bit (LSB), Spread Spectrum, Code Division Multiple Access (CDMA) method, Region-Based Energy Modification (RBEM) can be used in the spatial domain for watermark embedding (Bender, Gruhl, Morimoto, & Lu, 1996; Cox et al., 1997). The Spread Spectrum Coding technique was used as an example for previous work on spatial domain methods by (Cox et al., 1997). The watermark was represented as a sequence of symbols. A signal suggested by the chip was used to represent the symbols. A pseudo-random series of zeros and ones were the chips. As observed, cognitively meaningful significant coefficients are more accurate for watermark embedding. In addition, (Manoj & Arnold, 2013) suggested a system in which the host video and the watermark were split into separate frames in order to have a uniform distribution of the included watermark for almost the entire video. This technique achieved robustness against common types of video attacks like Frame Dropping, Frame Averaging and enhancing color, Cropping, Filtering, Adding some noise in the frames. (Venugopala, H., Niranjan, & Vani, 2014), the authors implemented a method to embed series of eight-bit-plane images, that extracted from the watermark image, into various scenes of video frames. The method was blind watermarking technique, the original video was not necessary to extract the watermark. The technique was robust against video processing attacks like temporal shifts attacks and frame dropping attack. A technique based on motion vector and linear block codes was developed by (Pan, Xiang, Yang, & Guo, 2010). The modification of the approach was 2 bits out of 6 bits of high amplitude motion vectors. The average PSNR of the methods was equivalent to 37 dB and the system was robust against H.264 compression. Including additional protection against attacks, (Lee & Chen, 2000) improved the Least Significant Bit technique by generating a Pseudo-Random number to detect the pixels used for embedding based on a given key. (Jue, Min-qing, & Juan-li, 2011) developed a system that selected some video frames and no more than 55 bits for interframe (B-Frames or P-Frame) macroblocks. The vectors of motion with the greatest amplitude are used. The results of the method measurements were strong, an average PSNR equal to 36.27 dB, as well as the method was robust enough against some compression attacks like H.264/AVC compression. (Kimpan, Lasakul, & Chitwong, 2004) presented a new block size approach based on adaptive watermarking in which the host image was partitioned into multiple blocks of variable sizes . The watermark was then placed in the partitioned blocks by analysing each block's brightness. (Bhardwaj, Verma, & Jha, 2018) have presented a method based on probability block-based watermarking for coloured images with constant block size. The image was divided into a number of square blocks, each size 8*8. The selected pixel intensity was modified in order to add a watermark bit value. The proposed method stay robust against famous image processing attacks, such as image scaling, image filtering, The method was failed with image cropping attack.

Embedding Watermark Image in Frequency Domain

In frequency domain watermarking techniques, the watermark was inserted into the coefficients of the digital transformation of the host image or host video frame that was perceptually a lot of significant in keeping with the Human visual system (Gupta, Gupta, & Chandra, 2016). Also, the coefficients calculated from the spatial region values are good candidates to include watermarks for low, medium and high frequency coefficients for data embedding. After applying frequency conversion on the host image, this category embedd a watermark by modifying the coefficients of the transformed data. Transform domain watermarking technique is more resistant to various types of attacks in general.

Discrete Cosine Transform(DCT), Discrete Fourier Transform (DFT), Discrete Wavelet Transform (DWT), Contourlet Transform (CT) are the most frequency domain transformations. These transformations are commonly used, and the coefficients obtained can be used to insert the watermark (Arti & Ajay, 2015; Bender et al., 1996; Christian & Shelth, 2017; Gupta et al., 2016; Husain, 2012; Johnson & Katzenbeisser, 2000; Khan, 2011; Sethuraman & Srinivasan, 2016; Shafali & Shivi 2016; Shojanazeri, Adnan, & Ahmad 2013; Shukla, Tiwari, & Dubey, 2016; T.Jayamalar & V.Radha, 2010; U, P, P, Sadique, & U, 2019).

Discrete Fourier Transform (DFT) based watermarking:

This is the most common conversion for watermarking. DFT is used to transform digital multimedia from the spatial domain to frequency domain. To ensure that the image resolution is not changed, the watermark is placed in higher frequency bands.

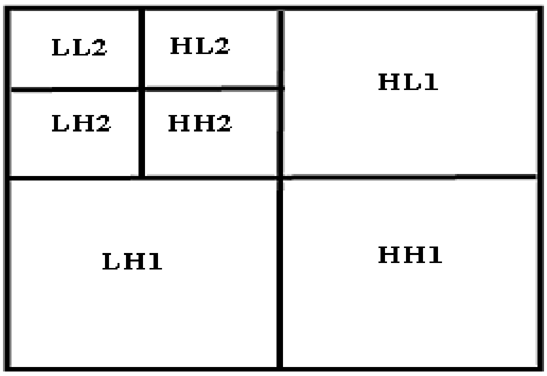
Discrete Cosine Transform (DCT) based watermarking:

In the DCT transforming formula, only the cosine functions are used as basis functions. In DCT, only real-valued signals and spectral coefficients are used; the watermark is often embedded in the middle frequency content. The host video is first transformed using frequency-domain techniques, and then the transformation coefficients are changed by inserting the watermark data. Finally, the watermarked video frame is generated by applying the inverse transformation (Shojanazeri et al., 2013). When comparing with spatial domain methods, DCT-based video watermarking is very efficient and robust against image processing attacks like low-pass filtering, adjusting brightness,adjusting contrast, and blurring. But DCT has many problems like Computational complexity, low resistance against some process as rotation, cropping and changing size (Arti & Ajay, 2015).

Discrete Wavelet Transform (DWT) based watermarking:

DWT is very convenient and is mainly used in watermark systems. As shown in Figure 2, a digital signal is decomposed into low-frequency approximate components (LL), horizontal (HL), vertical (LH), and diagonal (HH) detailed components (Abdou & Saleh, 2015). Here, each video frame is divided into 4 subbands, and odd coefficients and even coefficients are separated. The following watermark information is included in the LL subband. DWT is an effective and powerful watermark processing system. DWT has been used with other mathematical concepts such as Singular Value Decomposition (SVD) or other transformations like Principal Component Analysis (PCA) to get best results for watermarking systems (Sethuraman & Srinivasan, 2016).

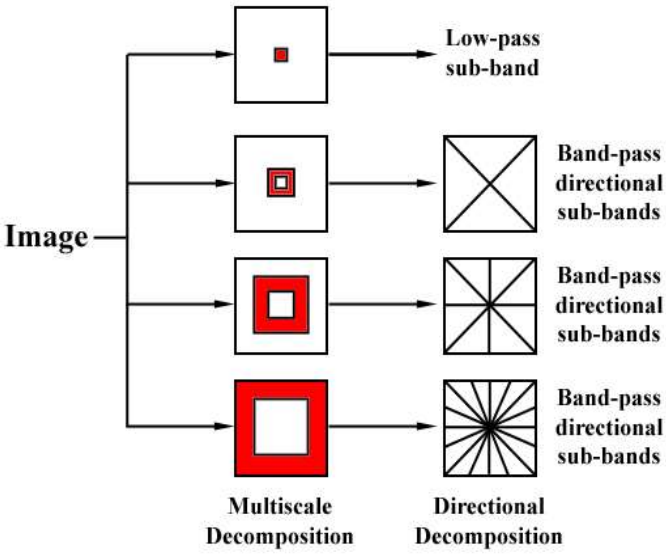
FIGURE 2. Second Level DWT Decomposition.



Discrete Contour Transform (DCT) based watermarking:

Because of its two-dimensional representation of images, the Contourlet Transform provides a flexible multi-resolution localised, multi-directional for images (Do & Vetterli, 2005). Contourlet transform as a pyramidal directional filter bank using Laplacian – shaped Decomposition (LD) and Directional Filter Bank (DFB). LP captures point discontinuities, while DFB generates these point discontinuities in a linear structure (Do, 2001). The design of the decomposition transformation, as shown in Figure 3, is to achieve the smooth contour attributes of the anisotropic scaling capture curve relationship to provide a rapid and structured curve in the form of a decomposition sampled signal (Do & Vetterli, 2005).

FIGURE 3. Contourlet Transform.



Related Work

(Jadhav & Kolhekar, 2014) proposed a method of splitting the original video into RGB frames and YCbCr frames. The watermarks were included in the Y-component. Then the author implemented dynamic 3D-DCT. Almost no change was observed for all MSE values, but there is a significant change in visual quality. Thanh et al. developed an algorithm based on KAZE Features in (Thanh, Hiep, Tam, & Tanaka, 2014). The embed and extract areas are generated by matching the feature points of multiple frame areas for every frame of the video. The watermark was then embedded into the matching region's of DCT domain of randomly produced blocks. On the other hand, the embbedded areas of the watermarked video to extract the watermark was synchronized by the decoder using KAZE characteristic matching. The proposed method was robust against attacks such as geometric attacks, video processing, temporal attacks, etc., but at a high computational cost. On the other hand, By extracting a 3D block from the video, DaWen presented a blind $3D - \text{Wavelet watermarking}$ approach for videos. The motivating block with complex texture is chosen to incorporate the watermark based on the video characteristics of the $\text{Human Visual System}$ (HVS). Various attacks like additive Gaussian noise, frame dropping and averaging, and lossy compression are robust to the suggested approach but was not robust for filtering attacks (Xu, 2007). Moreover , (Ejima & Miyazaki, 2000) Proposed a method for images and videos based on DWT. For each video frame, The wavelet coefficients were calculated. Then the watermark was embedded in the LL subband of all frames. The watermark is fragile for some image processing and video processing attacks, like Frame Swapping, Averaging, and median filtering. The embedding time was long because the watermark was embedded in every frame and the method cannot realize the concept of real-time applications.

(Chetan & Raghavendra, 2010) proposed a DWT-based method for digital video watermarks. DWT is applied to the video and various watermarks are applied to the various frames of the video. Watermarks were included in the mid-frequency bands HL and LH. The watermark was embedded in the middle frequency band HL and LH. This watermarking algorithm was robust against the attacks like frame dropping, averaging and compression but was not robust enough against other attacks like filtering, frame swapping. (Al-Taweel & Sumari, 2009)presented a 3D-DWT-based video watermarking system. A DWT of three-level was used, and a watermark was inserted in the LL subband coefficients that were chosen. This method proved resistant to image attacks including Downscaling, Cropping, and Rotation, as well as filters such as Low-Pass, Weiner, and Median. The technique, but was fragile with noise addition and full video processing attacks. (Makbol & Khoo, 2013) proposed a hybrid watermark technique in which redundant DWTs (RDWTs) and SVD are used to embed a watermark in an image. In the embedding process,The image is transformed using RDWT from the level one decomposition, and afterwards SVD is applied to all subbands. The watermark is embedded in each subband, and then the reverse RDWT is applied to these subbands to provide a watermarked image. Extract the watermark from all subbands. The proposed scheme preserves a high imperceptibility of the image. For almost all attacks except noise, the LL subband appears to be more robust than the other subbands. The experiment achieved high robustness to Geometric and Non-Geometric attacks. This method is computationally expensive. (Cruz-Ramos, Reyes-Reyes, Nakano-Miyatake, & Pérez-Meana, 2010) proposed a video watermarking system that was blind and robust to frame attacks. The video was embedded with the 2D binary image in the DWT domain of the video frames. The method was robust against some attacks like MPEG-2 compression, noise addition, frame dropping and swapping but was not stand against geometric distortions, filtering, and some other video process attacks.

Radu O. Preda [43] (Preda & Vizireanu, 2010) presented a strong watermarking approach based on multi-level wavelet decomposition. A wavelet decomposition of level two was applied and the binary watermark image was included in the wavelet Horizonal, Vertical and Diagonal subbands coefficients. Binary watermark bits were distributed across multiple wavelet coefficients using keys and error correction codes. The proposed method was strong against multiple attacks such as Scaling, Translation, and Rotation, but was not resistant to some video processing attacks. (Faragallah, 2013; Naved & Rajesh, 2013; Thind & Jindal, 2015) proposed a video watermarking schema based on singular value decomposition and the DWT domain. The video frames were transformed with the second level of decomposition for DWT. The watermark was embedded in the SVD for LH,HL and HH sub-bands, and then an error correction code was found. This method was robust against several common image processing attacks but not robust against some video processing attacks like Frame Dropping, Swapping and filtering. The execution time for embedding and extraction takes more time. (Rajab, Al-Khatib, & Al-Haj, 2015) developed a watermarking approach that employed a hybrid DWT and SCHUR decomposition. The DWT of level two was performed on the video frames, after that, the SCHUR was applied to the resulting detailed vertical for the DWT, then the watermark embedded in the output upper diagonal of SCHUR matrix . This technique was robust for some of the image and video processing attack like Salt and Pepper, Gaussian Noise, Frame Swapping and Averaging but was not robust against the frame Dropping attack. (Tabassum & Islam, 2012) developed a video watermarking approach that used third Level DWT based on identical frame extraction. The video was segmented into shots. One video frame, known as an identical frame, was chosen from each clip for watermark insertion. The watermark was added using the DWT of level three and the HH subband coefficients for each selected frame.The propped approach had strong robustness against common attacks such as Salt & Pepper noise adding, Gaussian noise adding, Cropping,Frame Dropping and Frame Adding. The method maybe not robust enough against other attacks like Frame Averaging, MPEG compression. Furthermore,(Singh, 2018) presented a video watermarking approach for the DWT domain that seems to be blind and robust . The extracted key and motion frames on the blue channel were decomposed using the first level of DWT, and the watermark bit was inserted by altering two random detailed diagonal coefficients (HH sub-band). To further security,the cat map for watermark was was obtained before being included. The proposed method was shown to be resistant to attacks like Frame Dropping, Averaging, Swapping, Cropping,noise attacks (Impulse and Gaussian),Blurring, Rotation, Gamma Correction, and Sharpening.. The suggested approach has a trouble with JPEG compression. (Basha, Hedayath, & Jaison, 2017) presented a Significant Frame Selection (SFS) and quantization of coefficient difference in the Lifting Wavelet Transform domain (LWT). The third level decomposition for LWT was applied for the selected frames are obtained. For the selected frames, the third level decomposition for LWT was used. The watermark was inserted in the detailed horizontal subband (LH3) by quantizing the coefficient difference of the two highest frequency components of relevant frame-blocks. This approach was resistant to Scaling, Cropping, Gaussian noise, Median filter, Average filter, Histogram Equalization, and JPEG compression. Video attacks like frame Dropping, Averaging, Switching, and Cropping were not tested. (Adul & Mwangi, 2017) conducted a comparison analysis to measure the effects of the SVD/DWT hybrid in the video watermarking algorithm. After video frames extraction,the DWT was performed and the detailed diagonal coefficients were chosen to perform SVD, then the watermark was added in the resulted SVD matrix. The blind proposed schema was robust against some attacks like Median filtering and Histogram Equalization. The video attacks like Frame Averaging, Dropping was not covered in the paper. (Li, Wang, & Dong, 2017) proposed an MPEG2 video watermarking technology-based Discrete Cosine coefficient. The results showed that this watermarking algorithm satisfied the general requirements for embedding capacity. The extracted watermark from this approach was noisy, but it passed a visual test.

(Gaj, Rathore, Sur, & Bora, 2017) proposed a watermarking scheme that was robust against the distortion. The hosted video was divided into Segments using SIFT, then the second level 3D-DWT was applied. The SIFT points were calculated from low frequency (LL) sub-band for the frames to embed the watermark there. The propped technique proved resistant against Projection attack and Frame Blending. (Ponnisathya, Ramakrishnan, Dhinakaran, Ashwanth, & Dhamodharan, 2017) created CHAOTIC Map-Based for Video Watermarking Using DWT And SVD. The resulted map was utilised to choose the keyframe in order to decrease the temporal complexity for embedding. Then the Two-level DWT decomposition was applied in the video sequence. The LL subband was selected for embedding and extraction of the binary watermark after performed the SVD for the keyframes for host video. This technique withstood many forms of image and video processing assaults such as frame dropping, Swapping ,and averaging; however, the authors did not test the effect of image processing attacks. (J & P, 2016) proposed an approach for video watermarking using scene change detection. This method serves as a second-level discrete wavelet

(DWT), singular value decomposition (SVD). The result was high robustness particularly to Frame Dropping,Swapping and MPEG compression. (Cao & Wang, 2019) presented a watermarking algorithm for colored videos based on the hyper-chaotic Lorentz system. The colored watermark images were scrambled by the hyper-chaotic Lorentz system. The video's non-motion frames were identified. The chaotic sequence was then used to choose a specific frames from among the non-motion frames. Following that, particular frames were applied to the DWT. Finally, the encrypted watermark was placed in the DWT sub-bands of choice.For different image and video attacks, the results demonstrated great imperceptibility and robustness. (Kapil & Shaloo, 2019) presented a robust and dynamic video watermarking framework. First, the V-Frames were extracted from the host video under framerate evaluation. Second, the DWT applied for extracted V-Frames then the unique video frame list called UV-Frames was evaluated. The Watermark was encoded using ECC (Elliptic Curve Cryptography). The most secure region over the frame was selected to embed the encoded watermark. The proposed approach increased the efficiency, robustness, and security against a variety of attacks.

(Yoo & Kim, 2017) demonstrated a real-time watermarking scheme that was resistant to a variety of attacks. The watermark was embedded in the video frame's ROI, which was derived from DWT sub-bands of each frame in the uncompressed video. The introduced scheme met real-time processing, invisibility, and attack resistance requirements . (Qi, Li, Yang, & Cheng, 2008) proposed an intelligent fragile watermarking scheme. This approach used Contourlet transforms for detection and recovery of tampering in the information content of the image. Further, the approach inntroduced by (Chetan & Nirmala, 2016) did not perform satisfactorily for HandWritten document images. Hence, in this work, a novel intelligent fragile watermarking technique is proposed using Contourlet transforms and investigates the effectiveness of Contourlets over Curvelets in detection and recovery of tampering in the information content, especially for handwritten document images. This technique also aims to improve the fidelity of the watermarked images and also time is taken for watermarking by using fewer Contourlet coefficients for embedding than Curvelets. (Zhu, Zhang, & Li, 2017) proposed a method based on the Contourlet transform. The method had good invisibility, and the robustness was improved. The watermark was embedded into the low-frequency components sub-bands. The proposed method improved the robustness and invisibility. The method had no great advantage in countering rotation attacks and histogram equalization attacks. (Ananthaneni & Nelakuditi, 2017) presented a hybrid algorithm that used Contourlet Transform, DCT transform and Singular Value Decomposition (SVD). And the result was compared with a hybrid that used DWT, DCT, and SVD. The results showed that the provided approach was much more robust against all types of attacks such as filtering, compression, cropping, and so on. The approach cannot be used for real-time watermarking. (Sadreazami & Amini, 2018) presented a Contourlet-based image watermarking technique based on the local statistical characteristics and inter-scale interdependence of image Contourlet coefficients. The distribution of the Contourlet coefficients was modelled using a Bi-Variate Gaussian Distribution in this technique. In the presence of attacks as Filtering, Compression, Noise, Cropping, and Scaling. For robustness, the presented scheme outperforms current approaches. (Zhang & Sun, 2019) suggested a visual saliency and Contourlet transform-based image watermarking approach. The approach increased imperceptibility and robustness by embedding information into the highest singular value of a low-pass subband block. (X.-y. Wang, Zhang, Wen, Yang, & Niu, 2019) proposed a locally effective image watermark detection approach based on Non-subsampled Contourlet Transform (NSCT) coefficients, and then appropriately represented the NSCT coefficient differences with such a ranked set sample RSS-based Cauchy distribution. Watermarking enhanced perceptual quality while also providing resistance to well-known attacks.

Singular Value Decomposition (SVD) and Sharp-Frequency localised Contourlet Transform (SFLCT) were proposed by (Najafi & Loukhaoukha, 2019) as a secure and robust technique . Both the watermarked and the original images were applied to the SVD and SFLCT. The implemented schema emphasized the significance for imperceptibility, capacity, and robustness in the face of a variety of attacks. For Depth-Image-Based Rendering (DIBR) 3D images, (Chen & Zhao, 2017)presented a blind watermarking technique. After applying quantization to particular sub-bands, the watermark was embedded and extracted in Contourlet Domain. The difference between quantized and unquantized Contourlet coefficients is used to extract watermarks.Images attacks like Noise addition, compression, and geometric such as rotation, scaling, and cropping were all highly resistant to the suggested approach. (Sharma, Agarwal, Khanwalkar, Singh, & Kumar, 2018) presented a multiple transform domain image watermarking scheme (DWT and CT). The lower frequency (LL) subband was produced after applying the DWT to the host.The LL subband was deconstructed using the second level Contourlet Transform, and the watermark was included in the CT domain's detail subband.. The suggested approach was more robust against attacks like Histogram Equalization, Cropping, Gaussian Noise, and Scaling without losing image quality, but not against JPEG Compression. (alias Sathya & Ramakrishnan, 2018) proposed a Fibonacci-based keyframe selection and scrambling technique for video watermarking in DWT-SVD. The number of scene changes in the video were counted using the histogram difference method. Fibonacci-Lucas transform scrambled the selected watermark and then the watermark was split into many sub-watermarks, each corresponding to the number of keyframes in the scene that were picked. The sub-watermarks were embedded in the LH subband of DWT for the keyframes.

Performance Evaluation

Any watermark system's performance is primarily measured in two ways: imperceptibility and robustness. Subjective evaluation also includes the examination of human eyes. In addition, objective evaluation criteria like the Peak Signal-to-Noise Ratio (PSNR) and Structural Similarity Indexes (SSIM), as well as Normalized Cross-Correlation (NC), were used to assess the imperceptibility and robustness of the watermarking system (T.Jayamalar & V.Radha, 2010).

Imperceptibility assessment

The host's capacity to hide the watermark information is referred to as imperceptibility. The following measures can be used to determine imperceptibility.

Mean Square Error (MSE)

The squared difference average between the original and the watermarked images is used to compute the Mean Square Error. A high MSE implies that the watermarked image and the original have a low correlation factor.

$$\mathrm{MSE} = \frac{\sum_{i=1}^{M}\sum_{j=1}^{N}\left(f(i,j)-f'(i,j)\right)^2}{M*N} \qquad \textbf{(1)}$$

Where the host image is f, the watermarked is f', and each of them of size M by N.

Peak Signal-to-Noise Ratio (PSNR)

PSNR is often used as the major measure for evaluating image quality by comparing the pixels of two images, similar to the Mean Square Error (MSE), alternatively it may be defined as the ratio between the original and the reconstructed images. The lower the distortion, the higher the PSNR value, which is generally measured in decibels (dB).

$$\mathrm{PSNR} = 10 * \log_{10}\left(\frac{\mathrm{MAX}_c^2}{\mathrm{MSE}}\right) \quad \textbf{(2)}$$

Where, $\mathrm{Max_c}$ is the highest possible pixel value in the image, for an $8-$ bit image, $\mathrm{MAX_c} = 2^8 - 1 = 255$.Structural Similarity Indexes (SSIM) (Z. Wang, Bovik, Sheikh, & Simoncelli, 2004)

Zhou Wang et al.introduced the Structural Similarity Index Measure. It may be considered as a measure of visual quality. The Human Visual System (HSV) claims that The SSIM value ranges from 0 to 1.The value is positively linked with the closeness of the two images. The SSIM of two images,x and y,is as described in the following:

$$\mathrm{SSIM}(x,y) = [l(x,y)]\alpha \cdot [c(x,y)]\beta \cdot [s(x,y)]\gamma \quad \textbf{(3)}$$

Where

$$l(x,y) = 2\mu_x\mu_y + C_1\mu_x^2 + \mu_y^2 + C_1, \quad \textbf{(4)}$$

$$c(x,y) = 2\sigma_x\sigma_y + C_2\sigma_x^2 + \sigma_y^2 + C_2, \quad \textbf{(5)}$$

$$s(x,y) = \sigma_{xy} + C_3\sigma_x\sigma_y + C_3 \quad \textbf{(6)}$$

Where $\mu_x, \mu_y, \sigma_x, \sigma_y$,and σ_{xy} are the local means, standard deviations, and cross-covariance for images x and y. If α = β = γ = 1 (the default for Exponents), and $C_3 = \frac{C_2}{2}$ (default selection of C3) the index simplifies to:

$$\mathrm{SSIM}(x,y) = \left(2\mu_x\mu_y + C_1\right)\left(2\sigma_{xy} + C_2\right)\left(\mu_x^2 + \mu_y^2 + C_1\right)\left(\sigma_x^2 + \sigma_y^2 + C_2\right) \quad \textbf{(7)}$$

For colored images, the method for averaging the three color SSIM value gets from the use of channel components

$$\mathrm{MSSIM}(x,y) = \frac{1}{3}\sum_{i=1}^{3}\mathrm{SSIM}(x_i, y_i) \quad \textbf{(8)}$$

Imperceptibility assessment

The ability of a watermark method to resist different attacks is known to as robustness. The measures of Normalized Correlation (NC) and Bit $-$ Error Rate (BER) are being used to evaluate the robustness of a system against attacks.

Normalized Correlation (NC)

For NC in percentage, 1 indicates the identical image and 0 represents uncorrelated images. Normalized Correlation in percentage is defined as follows:

$$\mathrm{NC} = \frac{\sum_{i=1}^{N1}\sum_{j=1}^{N2}(W(i,j)\times W\prime(i,j))}{\sqrt{\sum_{i=1}^{N1}\sum_{j=1}^{N2}W(i,j)}^2\sqrt{\sum_{i=1}^{N1}\sum_{j=1}^{N2}W\prime(i,j)}^2} \quad \textbf{(9)}$$

Where W and W' denote the original and extracted watermarks, respectively, while N1 and N2 denote the watermark size. NC has a range of 0 to 1, with 1 being the expected value.

Bit Error Rate (BER)

The proposed scheme's watermark extraction accuracy is measured using the Bit-Error Rate (BER). As a percentage, it's as follows: In absolute numbers, a greater BER indicates a higher error, and vise - versa.

$$\mathrm{BER} = \frac{1}{N1\times N2}\sum_{i=1}^{N1}\sum_{j=1}^{N2}|W(i,j) - W'(i,j)| \quad \textbf{(10)}$$

Bit Correlation Rate (BCR)

The Bit Correlation Rate (BCR) is a metric that measures the degree of correlation between the original and extracted watermarks. A greater correlation is indicated by a higher BCR in percentage, and vice versa.

$$BCR = \frac{\sum_{i=1}^{N1}\sum_{j=1}^{N2} W(i,j) \oplus W'(i,j)}{\sum_{i=1}^{N1}\sum_{j=1}^{N2} W(i,j)^2} \quad (11)$$

The Proposed Algorithm

Watermark Embedding Algorithm

Step 1: from the host video, the key frames were extracted as the following steps.

a) The video was divided into 20 patches.
b) Average frame was calculated for each patch.
c) The MSE was calculated between each frame and the mean frame.
d) Two minimum tires with minimum MSE are specified as keyframes from the respective batch.
e) Key frames extracted from the Akiyo video shown in Figure 4.

Step 2: Apply a four-level Contourlet to each blue channel for the selected main frame. Output coefficients were divided into 32 subdomains after both hierarchical decomposition and directional decomposition.
Step 3: Subdomain number 1, low traffic subdomain, has been chosen to insert the watermark.
Step 4: The selected subdomain's dimensions were the same as the binary watermark image's. The watermark and low frequency CT subdomains were both split into non-overlapping blocks, with the watermark blocks in LSBs corresponding to low subdomain coefficients. This choice was reached as a tradeoff between the watermark's durability and its lack of awareness.
Step 5: Apply Contourlet Transform Inversion to reconstruct the watermarked frame.
Step 6: Calculate the error between the original frame and the watermark one by the following measurements PSNR, MSE and SSIM.
Step 7: Finally, the average of the PSNR, MSE, and SSIM were calculated.

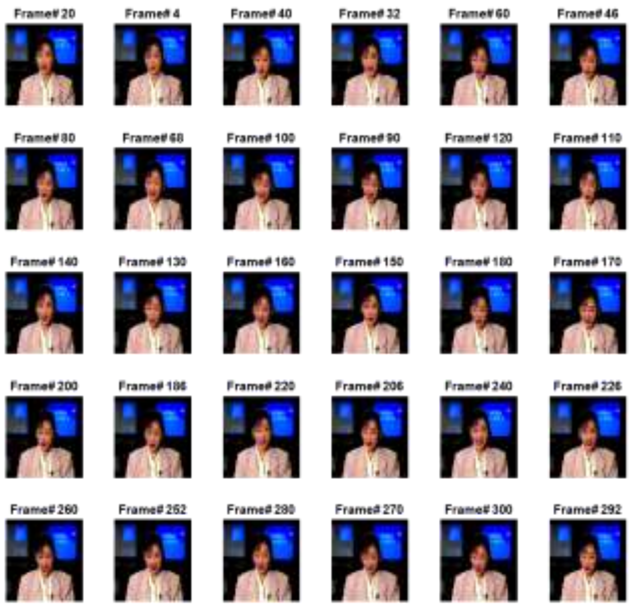
Watermark Extraction Process

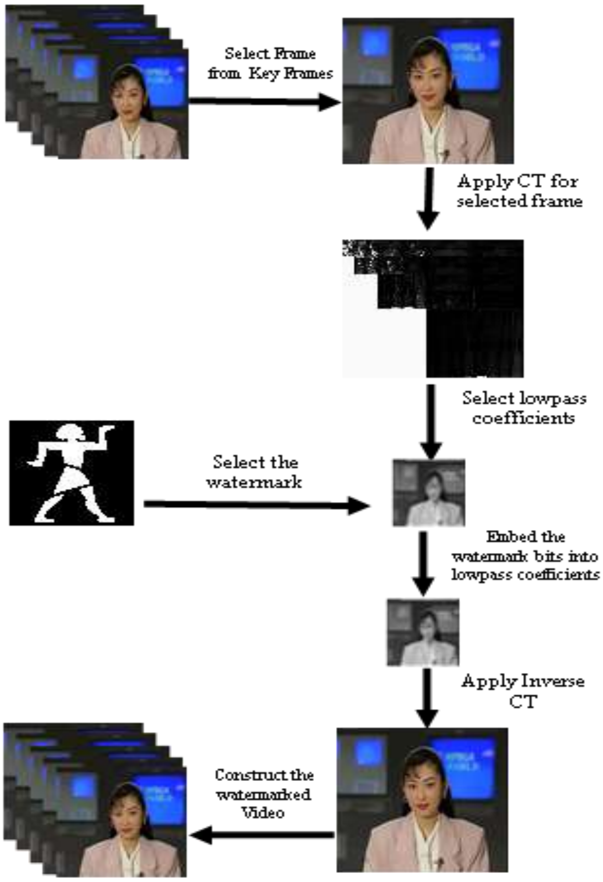
The proposed method is a blind procedure (we need both original video and watermarked video in the extracting process). The following steps will shows the process of extracting the digital watermark:

Step 1: From both of the host video and watermarked video, can be extracted the key frames from them.
Step 2: For each blue colour channel, apply the four-levels contourlet to both video frames corresponding frames.
Step 3: The lowpass subband, number one, was chosen for watermark extraction for both the original and watermarked videos.
Step 4: Selected sub-bands are divided into blocks.
Step 5: Construct the 3D watermark through the corresponding blocks subtraction.

FIGURE 4. Extracted Key Frames

FIGURE 5. Watermark embedding process





$$W(i,j,k) = \begin{cases} 1 & , |L(f(i,j)) - L(f'(i,j)))| \geq 0.5 \\ 0 & , \quad \text{otherwise} \end{cases} \quad (12)$$

Where $L(f(i,j))$ is the lowpass coefficients for the CT of the original video frame, $L(f'(i,j))$ is the lowpass coefficients for the CT of the watermarked video frame k is the frame number.

Step 6: After finishing all video frames, to extract the binary watermark from the 3D watermark, calculate the average watermark between all frames.

Step 7: The similarity between the original and the extracted watermarks is computed. Calculate the NC, BCR, and PSNR ratios between the original and extracted watermarks.

VI. Experimental Results

In this section, the proposed scheme was tested with the data set of benchmark videos such as Foreman and Akiyo. The obtained results were analyzed and compared with other existing schemes. The sample frames of the selected videos were shown in Figure 6. All the videos were of size 512 × 512 with a number of frames 300. The binary watermark images of size 32 × 32 were presented in Figure 7. The performance analysis of the proposed method was calculated by using the robustness and imperceptibility measurements. For robustness, the normalized correlation (NC) and bit error rate (BER) were calculated between the original and extracted watermark. For imperceptibility, the average peak-signal-to-noise-ratio (PSNR) and Structural Similarity Indexes (SSIM) were calculated between selected original video frames and watermarked video.

The practice test was carried out on PC has the following specification: Operating System: Windows 8.1 Pro 64-bit: Intel(R) Core(TM) i7-3632QM CPU @ 2.20GHz (8 CPUs), Memory: 6144MB RAM and MATLAB version: 9.6.0.1072779 (R2019a).

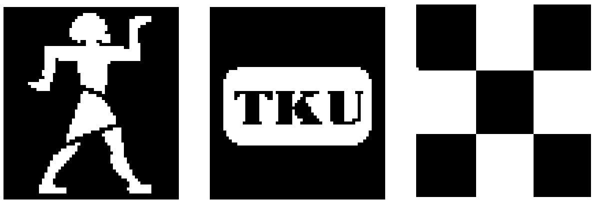
Comparisons were made usage the references (Adul & Mwangi, 2017; alias Sathya & Ramakrishnan, 2018; Bhardwaj et al., 2018; Cao & Wang, 2019; Gaj et al., 2017; J & P, 2016; Kapil & Shaloo, 2019; Singh, 2018). Figure 8 and Figure 9 showed the comparing of the suggested technique with the other average modern algorithms PSNR and SSIM for various videos.

The practice test was established on PC has the following specification: Operating System: Windows 8.1 Pro 64-bit: Intel(R) Core(TM) i7-3632QM CPU @ 2.20GHz (8 CPUs), Memory: 6144MB RAM and MATLAB version: 9.6.0.1072779 (R2019a).

FIGURE 6. Standard benchmark video

(a) Akiyo (b) Foreman

FIGURE 7. Binary Watermarks



The proposed method was tested against both image processing attacks and video processing attacks. The image processing attacks included noise attacks and filter attacks. **Error! Reference source not found.** and **Error! Reference source not found.** described both PSNR and SSIM as measurements for imperceptibility. The values for PSNR was above 38 dB and SSIM was closed to 1, then the performance of the proposed method after the watermarked video was attacked by different types of noise, filtering, and rotation, obtained a good result that indicated good imperceptibility except in rotation attacks compared with the recent techniques used in comparison operation. TABLE III and TABLE IV contain the comparison results for both NC and BER between the compared methods and the proposed method. The values NC is quite close to 1.00 and BER to 0. For robustness analysis showed that the proposed method was robust against image and video processing attacks except in case of rotation attack. Furthermore, watermarked frames can keep their invisibility against a variety of attacks. This verified the imperceptibility and robustness of the proposed watermarking algorithm.

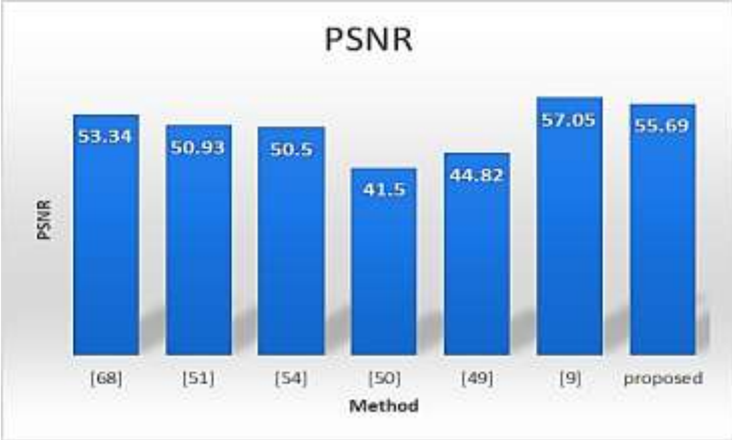


FIGURE 8. PSNR between compared methods and proposed

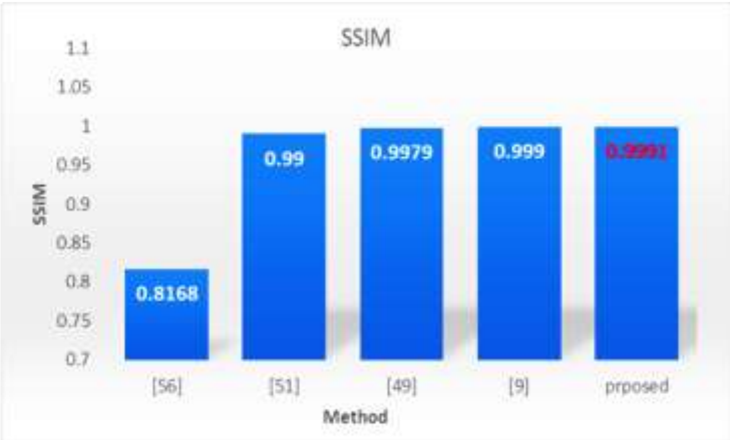


FIGURE 9. SSIM between compared methods and proposed

Video processing attacks

Frame Swapping, Cropping, Averaging, and Dropping are types of video attacks.

Frame swapping

Swapping two frames in a similar scene of the video can be used to change frames. Because the watermark was embedded in the video frames in this paper, frame swapping attacks had no effect on the watermark extraction.. In experimental results, we selected a random frame for swapping of two adjacent frames in different video scenes. The proposed method for frame swapping attack for swapping percentage from 10% to 50% frames. The values for NC and BER indicated that the proposed method had a good performance for these ranges and showed a sufficient imperceptibility and also robustness versus swapping attack.

Frame dropping

The process was carried out by dropping some video frames with various percentages of the video frames, unlike frame swapping attacks. We picked a random frame for the dropping of various video frames in distinct video scenes in our tests. Because the watermark is included in the video frames, frame dropping attacks have no effect on the watermark extraction process. The proposed technique for frame dropping attack with frame dropping percentages ranging from 10% to 50%. The method's results were good for these ranges, as well as sufficient imperceptibility and also robustness versus dropping attacks.

Frame averaging

The watermark may be extracted using a frame averaging attack by combining successive frames with different percentages and calculating the average pixels of the frames. During the simulation test. The suggested approach for frame averaging attack uses averaging frames ranging from 10% to 50%. The results showed good performance for these ranges, as well as sufficient imperceptibility and also robustness versus frame averaging.

Frame cropping

By cropping an area from video frames with different percentages, the watermark could be extracted from a cropped video. Frame Cropping was supposed to crop from 10% to 50% of each video frame using suggested approach. For these ranges, the results showed acceptable performance, as well as sufficient imperceptibility and also robustness versus frame cropping.

Image processing attacks

Gaussian noise attack

The suggested method for the Gaussian attack that had mean equal zero and variances between 0.01 and 0.05 on the watermarked video and corresponding extracted watermarks . The PSNR was more than 40, and the NC was closer to 1, showing good imperceptibility and robustness to Gaussian noise.

Rotation attack

The proposed method for rotation attack with rotation angles 5°,20°,45°,90°, and 180°. The proposed method was suffered from this type of image processing attack, then the method needs to be developed to overcome this attack.

Gamma correction attack

The method introduced for Gamma Correction attack having values in interval [0.6,1.0]. The experimental results for attacked watermarked video having gamma values and corresponding extracted watermark showed a good imperceptibility and robustness against gamma correction attack.

JPEG compression attack

The results for attacked watermarked video for Factor Quality values between 50 and 90, the proposed method showed good performance for these ranges, as well as good imperceptibility and robustness against JPEG Compression.

Table 1. PSNR in different types of attacks

Attack	**(Singh, 2018)**	**(Cao & Wang, 2019)**	**Proposed**
Gaussian noise (0.01,0.05,0.1)	27.96	20.3	41.16
	27.96	19.45	40.72
	25.17	17.48	40.31
Salt & pepper with noise densities (0.01,0.05,0.1)		26.05	35.98
	--	19.08	35.48
		14.13	34.87
Gauassian Correction (0.6,0.7,…,1.0)		17.49	40.59
		20.55	41.75
	--	24.51	41.46
		30.60	41.15
		44.62	40.86
Median Filter with different mask sizes			41.82
			41.19
		26.08	
			40.67
		31.98	
			40.25
			39.85
Poisson noise	--	30.484	39.75287
Histogram Equalization		9.5674	39.94646
Rotation ($5°, 20°, 45°, 90°, 180°$)		57.81	28.34
	29.40	59.30	26.99
	29.42	60.26	26.38
		57.10	25.87
		57.04	27.46
JPEG Compression with quantity factor (90,80,…,50)	37.94		41.64
	36.52		42.38
	35.37	--	43.14
	34.46		43.72
	33.79		44.58
Frame swapping with precentages (10% , 20%,30% and 40%)	44.82	57.03	46.58
Frame dropping with precentages (10% , 20%,30% and 40%)	44.82	57.05	46.5812
Frame Average precentages with (10% , 20%,30% and 40%)	44.82	44.62	46.5801
Frame Cropping with precentages (10% ,	19.67	--	36.88

20% and 30%)	16.38	34.49
	14.10	31.82

Table 2 SSIM in different types of attacks

Attack	**(Singh, 2018)**	**(Cao & Wang, 2019)**	**Proposed**
Gaussian noise (0.01,0.05,0.1)	0.95	0.397	0.988
	0.92	0.401	0.995
	0.89	0.390	0.982
Salt & pepper with noise densities (0.01,0.05,0.1)		0.801	0.919
	--	0.390	0.927
		0.207	0.934
Gauassian Correction (0.6,0.7,…,1.0)	0.88		0.99
	0.93		0.99
	0.97	--	0.994
	0.99		0.994
	0.99		0.993
Median Filter with different mask sizes			0.995
	--	0.835	0.994
		0.990	0.993
			0.991
Poisson noise	--	0.886	0.990
Histogram Equalization		0. 613	0.958
Rotation ($5^\circ, 20^\circ, 45^\circ, 90^\circ, 180^\circ$)		0.996	0.5427
		0.997	0.407
		0.999	0.321
		0.996	0.276
		0.995	0.244
		0.997	0.213
		0.999	0.178
JPEG Compression with quantity (90,80,…,50)	0.9948		0.9948
	0.9931		0.9941
	0.9916		0.9929
	0.9903		0.9919

	0.9890		0.9908
Frame swapping with precentages (10% , 20%,30% and 40%)	0.9979	0.999	0.9984
Frame dropping with precentages (10% , 20%,30% and 40%)	0.9979	0.999	0.9984
Frame Averaging with precentages (10% , 20%,30% and 40%)	0.9979	0.999	0.9984
Frame Cropping with precentages (10% , 20% and 30%)	0.7653 0.629 0.5055	--	0.972 0.889 0.672

Table 3. NC in different types of attacks

Attack	**(Singh, 2018)**	**(Cao & Wang, 2019)**	**Proposed**
Gaussian noise (0.1)	0.9904	0.707	0.969
	0.9395	0.700	0.959
Salt & pepper with noise densities (0.1)	0.9948 0.9946 0.9948 0.9946 0.9946		0.971 0.974 0.971 0.971 0.971
Median Filter with different mask sizes	--	0.783 0.839	0.969 0.974
Poisson noise	--	0.728	0.971
Histogram Equlization	--	0.694	0.966
Rotation ($5°, 20°, 45°, 90°, 180°$)	--	--	0.429 0.404
JPEG Compression with quantity (90,80,…,50)	0.948 0.713 0.559 0.506 0.483	--	0.981 0.978 0.976 0.976 0.976
Frame swapping with precentages (10% , 20%,30% and 40%)	0.996	0.618	0.981

Frame dropping with precentages (10% , 20%,30% and 40%)	0.996	0.618	0.981
Frame Average with precentages (10% , 20%,30% and 40%)	0.996	0.618	0.981
Frame Cropping with precentages (10% , 20% and 30%)	--	--	0.707698 0.876501 0.63524

Table 4. BER in different types of attacks

Attack	**(Singh, 2018)**	**(Cao & Wang, 2019)**	**Proposed**
Gaussian noise (0.01,0.02,0.03)	0.99 1.24 1.46	--	0.013 0.170 0.307
Salt & pepper with noise densities (0.1)	--	--	0.036
Gauassian Correction (0.6,0.7,…,1.0)	0.53		0.0117
Median Filter with different mask sizes	--	--	0.0127 0.0107
Poisson noise	--	--	0.0117
Histogram Equlization	--	--	0.0137
Rotation ($\mathbf{5^\circ}$ **and** $\mathbf{20^\circ}$)	8.93 10.71	--	0.3565 0.3184
JPEG Compression with quantity (90,80,…,50)	0.052 0.287 0.440 0.494 0.517	--	0.0127 0.0137 0.0117 0.0127 0.0127
Frame swapping with precentages (10% , 20%,30% and 40%)	0.41 0.41 0.41 0.53	--	0.0078 0.0078 0.0078 0.0071
Frame dropping with precentages (10% , 20%,30% and 40%)	0.41 0.41 0.41 0.53	--	0.0078 0.0078 0.0078 0.0071
Frame Averaging with precentages (10% , 20%,30% and 40%)	0.41 0.41	--	0.0078 0.0078

	0.41		0.0078
	0.53		0.0071
Frame Cropping with precentages (10% , 20% and 30%)	--	--	0.1367 0.0635 0.1162

Table 5. Imperceptibility and robustness for the proposed method

	Attack	Watermarked Frame	Extracted Watermark		Attack	Watermarked Frame	Extracted Watermark
1	Frame dropping attack 10%	 PSNR = 46.58 SSIM = 0.9984	 NC = 0.981 BER=0.0078	**2**	Frame Averaging attack 10%	 PSNR = 46.58 SSIM = 0.9984	 NC = 0.981 BER=0.0078
3	Frame swapping attack 10%	 PSNR = 46.58 SSIM = 0.9984	 NC = 0.981 BER=0.0078	**4**	Salt & Pepper noise attack Variance = 0.01	 PSNR = 35.98 SSIM = 0.919	 NC = 0.959 BER=0.036
5	Median Filter Mask size = [3×3]	 PSNR = 41.824478 SSIM = 0.995	 NC = 0.968553 BER=0.0127	**6**	Gamma correction attack Gamma = 0.10	 PSNR = 40.594162 SSIM = 0.971	 NC = 0.971 BER=0.0117
7	Frame cropping attack 30% crop			**8**	JPEG compression attack Quality =90		

		PSNR = 31.82 SSIM = 0.672	NC = 0.63524 BER=0.1162	PSNR = 41.64 SSIM = 0.976	NC = 0.976 BER=0.0127
9	Rotation attack Angle = 5°	 PSNR = 28.34 SSIM = 0.5427	 NC =0.42862 BER=0.3565		

Conclusion

This paper introduces a developed Discrete Contourlet Transform method. The proposed scheme provides a robust video watermarking technique for embedding watermarks in the CT domain's lowpass coefficients. The effectiveness of the present scheme was verified through a number of experiments performed on different videos under standard image processing attacks and video processing attacks. Comparison with other existing techniques reflected that the proposed scheme had a good imperceptibility and resistance against different types of video processing attacks and image processing attacks. The method has a good robustness level and can satisfy security needs. Our future plans are to improve the performance against rotation attacks and to improve the complexity of the proposed method by using an efficient method to extract the keyframes and work on them instead of work on all video frames.

REFERENCES

1. Abdou, M., & Saleh, A. (2015). A Robust Time Efficient Watermarking Technique for Stereo Images. Journal of Computational Engineering.
2. Adul, V., & Mwangi, E. (2017). A robust video watermarking approach based on a hybrid SVD/DWT technique. Paper presented at the 2017 IEEE AFRICON.
3. Al-Taweel, S. A., & Sumari, P. (2009). Robust video watermarking based on 3D-DWT domain. Paper presented at the TENCON 2009-2009 IEEE Region 10 Conference.
4. alias Sathya, S. P., & Ramakrishnan, S. (2018). Fibonacci Based Key Frame Selection and Scrambling for Video Watermarking in DWT–SVD Domain. Wireless Personal Communications, 102(2), 2011-2031.
5. Ananthaneni, V., & Nelakuditi, U. R. (2017). Hybrid digital image watermarking using contourlet transform (CT), DCT and SVD. International Journal of Image Processing, 11(3), 85.
6. Arti, B., & Ajay, K. (2015). Digital Video Watermarking Techniques: A Review. International Journal Of Engineering And Computer Science, 6(5), 21328-21332.

7. Basha, Hedayath, S., & Jaison. (2017). Survey on patended and unpatented video watermarking techniques. Paper presented at the 4th International Conference on Advanced Computing and Communication Systems (ICACCS).

8. Bender, W., Gruhl, D., Morimoto, N., & Lu, A. (1996). Techniques for Data Hiding. IBM Systems Journal, 35, 313-336.

9. Bhardwaj, A., Verma, V. S., & Jha, R. K. (2018). Robust video watermarking using significant frame selection based on coefficient difference of lifting wavelet transform. Multimedia Tools Applications, 77(15), 19659-19678.

10. Boreiry, M., & Keyvanpour, M.-R. (2017). Classification of watermarking methods based on watermarking approaches. Paper presented at the Artificial Intelligence and Robotics (IRANOPEN).

11. C.S , L. (2005). Multimedia Security: Steganography and Digital Watermarking Techniques for Protection of Intellectual Property. Idea Group Publishing.

12. Cao, Z., & Wang, L. (2019). A secure video watermarking technique based on hyperchaotic Lorentz system. Multimedia Tools Applications, 1-21.

13. Chen, L., & Zhao, J. (2017). Robust contourlet-based blind watermarking for depth-image-based rendering 3D images. Signal Processing: Image Communication, 54, 56-65.

14. Chetan, K., & Nirmala, S. (2016). An intelligent blind semi-fragile watermarking scheme for effective authentication and tamper detection of digital images using curvelet transforms. In Advances in Signal Processing and Intelligent Recognition Systems (pp. 199-213): Springer.

15. Chetan, K., & Raghavendra, K. (2010). DWT based blind digital video watermarking scheme for video authentication. International journal of computer applications, 4(10), 19-26.

16. Choi, D., Do, H., Choi, H., & Kim, T. (2010). A blind MPEG-2 video watermarking robust to camcorder recording. Signal processing, 90(4), 1327-1332.

17. Christian, A., & Shelth, R. (2017). Secured digital video authentication system. International Journal of Scientific Research in Science Technology, 3(3), 223-227.

18. Cox, J., Kilian, J., Leighton, T., & Shamoon, T. (1997). Secure Spread Spectrum Watermarking for Multimedia. IEEE Transactions on Image Processing, 6, 1673-1687.

19. Cruz-Ramos, C., Reyes-Reyes, R., Nakano-Miyatake, M., & Pérez-Meana, H. (2010). A blind video watermarking scheme robust to frame attacks combined with MPEG2 compression. Journal of applied research technology, 8(3), 323-337.

20. Do, M. N. (2001). Directional Multiresolution Image Representations, Ph. D. Thesis. Department of Communication Systems, Swiss Federal Institute of Technology Lausanne.

21. Do, M. N., & Vetterli, M. (2005). The contourlet transform: an efficient directional multiresolution image representation. IEEE Transactions on Image Processing, 14(12), 2091-2106.

22. Ejima, M., & Miyazaki, A. (2000). A wavelet-based watermarking for digital images and video. IEICE Transactions on Fundamentals of Electronics, Communications Computer Sciences, 83(3), 532-540.

23. Faragallah, O. S. (2013). Efficient video watermarking based on singular value decomposition in the discrete wavelet transform domain. AEU-International Journal of Electronics Communications, 67(3), 189-196.

24. Gaj, S., Rathore, A. K., Sur, A., & Bora, P. K. (2017). A robust watermarking scheme against frame blending and projection attacks. Multimedia Tools Applications, 76(20), 20755-20779.
25. Gupta, G., Gupta, V., & Chandra, M. (2016). Review on video watermarking techniques in spatial and transform domain. In Information Systems Design and Intelligent Applications (pp. 683-691): Springer.
26. Husain, F. (2012). A survey of digital watermarking techniques for multimedia data. MIT International Journal of Electronics Communication Engineering, 2(1), 37-43.
27. J, P., & P, G. (2016). An efficient video watermarking approach using scene change detection. 1st India International Conference on Information Processing (IICIP), 1-5.
28. Jadhav, A., & Kolhekar, M. (2014). Digital watermarking in video for copyright protection. Paper presented at the 2014 International Conference on Electronic Systems, Signal Processing and Computing Technologies.
29. Johnson, N. F., & Katzenbeisser, S. (2000). A survey of steganographic techniques. Paper presented at the Information hiding.
30. Jue, W., Min-qing, Z., & Juan-li, S. (2011). Video steganography using motion vector components. Paper presented at the 2011 IEEE 3rd International Conference on Communication Software and Networks.
31. Kapil, J., & Shaloo, B. (2019). Frame Selective and Dynamic Pattern Based Model For Effective And Secure Video Watermarking. International Journal of Computing, 18(2), 207-219.
32. Keyvanpour, M.-R., & Boreiry, M. (2017). Classification and evaluation of watermarking attacks in the field of video watermarking. Paper presented at the 2017 5th Iranian Joint Congress on Fuzzy and Intelligent Systems (CFIS).
33. Khan, M. K. (2011). Research advances in data hiding for multimedia security. Multimedia Tools Applications, 52(2-3), 257-261.
34. Kimpan, S., Lasakul, A., & Chitwong, S. (2004). Variable block size based adaptive watermarking in spatial domain. Paper presented at the IEEE International Symposium on Communications and Information Technology, 2004. ISCIT 2004.
35. Kumar, & Amit. (2017). Digital Image Watermarking for User Selection System as Visible and Invisible Techniques. Conference Proceedings.
36. Lee, Y.-K., & Chen, L.-H. (2000). High capacity image steganographic model. IEE Proceedings-Vision, Image Signal Processing, 147(3), 288-294.
37. Li, J., Wang, Y., & Dong, S. (2017). Video watermarking algorithm based DC coefficient. Paper presented at the 2017 2nd International Conference on Image, Vision and Computing (ICIVC).
38. Makbol, N. M., & Khoo, B. E. (2013). Robust blind image watermarking scheme based on redundant discrete wavelet transform and singular value decomposition. AEU-International Journal of Electronics Communications, 67(2), 102-112.
39. Manoj, K., & Arnold, H. (2013). Robust Digital video watermarking using reversible data hiding and visual cryptography. Proceedings of 24th IET Irish Conference on Signals and Systems (ISSC), 1–6.

40. Najafi, E., & Loukhaoukha, K. (2019). Hybrid secure and robust image watermarking scheme based on SVD and sharp frequency localized contourlet transform. Journal of information security applications, 44, 144-156.

41. Naved, A., & Rajesh, Y. (2013). Dual Band Watermarking using 2-D DWT and 2-Level SVD for Robust Watermarking In Video. Int. J. Sci. Res., India, 2319-7064.

42. Pan, F., Xiang, L., Yang, X.-Y., & Guo, Y. (2010). Video steganography using motion vector and linear block codes. Paper presented at the 2010 IEEE International Conference on Software Engineering and Service Sciences.

43. Ponnisathya, S., Ramakrishnan, S., Dhinakaran, S., Ashwanth, P. S., & Dhamodharan, P. (2017). CHAOTIC map based video watermarking using DWT and SVD. Paper presented at the 2017 International Conference on Inventive Communication and Computational Technologies (ICICCT).

44. Preda, R. O., & Vizireanu, D. N. (2010). A robust digital watermarking scheme for video copyright protection in the wavelet domain. Measurement, 43(10), 1720-1726.

45. Qi, W.-f., Li, X.-l., Yang, B., & Cheng, D. (2008). Document watermarking scheme for information tracking. Journal on Communications, 29(10), 183-190.

46. Rajab, L., Al-Khatib, T., & Al-Haj, A. (2015). A blind DWT-SCHUR based digital video watermarking technique. Journal of Software Engineering Applications, 8(04), 224.

47. Sadreazami, H., & Amini, M. (2018). A robust image watermarking scheme using local statistical distribution in the contourlet domain. IEEE Transactions on Circuits Systems II: Express Briefs, 66(1), 151-155.

48. Schyndel, R. G., Tirkel, A., & Osborne, C. F. (1994). A Digital Watermark. Proceedings of IEEE International Conference on Image Processing (ICIP), 86-90.

49. Sethuraman, P., & Srinivasan, R. (2016). Survey of digital video watermarking techniques and its applications. Engineering Science, 1(1), 22-27.

50. Shafali, B., & Shivi , S. (2016). Survey on Digital Video Watermarking Techniques. International Journal of Advanced Research in Computer and Communication Engineering (IJARCCE), 5(9).

51. Sharma, R., Agarwal, N., Khanwalkar, K., Singh, M., & Kumar, D. (2018). Robust Image Watermarking Technique Using Contourlet Transform and Optimized Edge Detection Algorithm. Paper presented at the 2018 5th International Conference on Signal Processing and Integrated Networks (SPIN).

52. Shojanazeri, H., Adnan, W. A. W., & Ahmad , S. M. S. (2013). Video watermarking techniques for copyright protection and content authentication. International Journal of Computer Information Systems Industrial Management Applications, 5(1), 652-660.

53. Shukla, D., Tiwari, N., & Dubey, D. (2016). Survey on digital watermarking techniques. International Journal of Signal Processing,Image Processing,Pattern Recognition, 9(1), 239-244.

54. Singh, K. M. (2018). A robust rotation resilient video watermarking scheme based on the SIFT. Multimedia Tools Applications, 77(13), 16419-16444.

55. T.Jayamalar, & V.Radha. (2010). Survey on digital video watermarking techniques and attacks on watermarks. International Journal of Engineering Science and Technology, 2, 6963-6967.

56. Tabassum, T., & Islam, S. M. (2012). A digital video watermarking technique based on identical frame extraction in 3-Level DWT. Paper presented at the 2012 15th International Conference on Computer and Information Technology (ICCIT).
57. Thanh, T. M., Hiep, P. T., Tam, T. M., & Tanaka, K. (2014). Robust semi-blind video watermarking based on frame-patch matching. AEU-International Journal of Electronics Communications, 68(10), 1007-1015.
58. Thind, D. K., & Jindal, S. (2015). A semi blind DWT-SVD video watermarking. Procedia Computer Science, 46, 1661-1667.
59. U, S. K., P, T. P., P, N. P., Sadique, A. M., & U, S. A. (2019). Digital Watermarking—An Overview and a Possible Solution. In Information and Communication Technology for Intelligent Systems (pp. 447-455): Springer.
60. Venugopala, P. S., H., S., Niranjan, N. C., & Vani, B. (2014). Video Watermarking by Adjusting the Pixel Values and Using Scene Change Detection. Proceeding of IEEE fifth International Conference on Signals and Image Processing, 259-264.
61. Wang, X.-y., Zhang, S.-y., Wen, T.-t., Yang, H.-y., & Niu, P.-p. (2019). Coefficient difference based watermark detector in nonsubsampled contourlet transform domain. Information Sciences, 503, 274-290.
62. Wang, Z., Bovik, A. C., Sheikh, H. R., & Simoncelli, E. P. (2004). Image quality assessment: from error visibility to structural similarity. IEEE Transactions on Image Processing, 13(4), 600-612.
63. Xia, X.-G., Boncelet, C. G., & Arce, G. R. (1998). Wavelet transform based watermark for digital images. Optics Express, 3(12), 497-511.
64. Xu, D.-W. (2007). A blind video watermarking algorithm based on 3D wavelet transform. Paper presented at the 2007 International Conference on Computational Intelligence and Security (CIS 2007).
65. Yoo, G., & Kim, H. (2017). Real-time video watermarking techniques robust against re-encoding. Journal of Real-Time Image Processing, 13(3), 467-477.
66. Zhang, Y., & Sun, Y. (2019). An image watermarking method based on visual saliency and contourlet transform. Optik, 186, 379-389.
67. Zhu, J., Zhang, H., & Li, X. (2017). Information hiding based on gray relation and contourlet transform. Paper presented at the 2017 14th International Computer Conference on Wavelet Active Media Technology and Information Processing (ICCWAMTIP).