A Non-Blind Hybrid Video Watermarking Scheme based on Singular Value Decomposition and Contourlet Transform

Venkata Narasimhulu.C[#1], Satya Prasad.K[#2]

Abstract- In this paper, a new non-blind hybrid video watermarking scheme is proposed based on singular value decomposition (SVD) and contourlet transform (CT).The contourlet transform is a directional multi-resolution expansion, which can represent smooth contours of the images efficiently compared to wavelet transform. The proposed algorithm embeds four binary watermarks in four different scenes of a video. The video frames of each scene and binary watermarks are first decomposed using contourlet transform and then singular value decomposition is applied to selected directional high pass sub band. The singular values of video frame of each scene are modified by singular values of respective binary watermarks using additive algorithm. The hybrid scheme improves the performance of the watermarking scheme compared to the earlier techniques. The experimental results shows that the proposed watermarking scheme is robust for video processing operations such as cropping, rotation, histogram equalization, compression, variety of noises, frame dropping, frame averaging and frame swapping etc., The comparative analysis reveal that the proposed watermarking scheme out performs the video watermarked schemes proposed recently.

Keywords – Video watermarking, Contourlet Transform, Singular value decomposition, Peak Signal to Noise Ratio, Normalized Correlation Coefficient.

I. Introduction

The advancement of technology in the field of multimedia and the availability of high speed networks enabled us to reproduce and distribute data easily and with almost no loss in quality.

Venkata Narasimhulu C Geethanjali College of Engineering & Technology, Cheeryal Andhra Pradesh, India
E-mail: narasimhulucv@gmail.com

Satya Prasad. K Jawaharlal Nehru Technological University, Kakinada Andhra Pradesh, India
E-mail: prasad_kodati@yahoo.co.in

Under such a scenario, the protection of digital data has become increasingly important. In recent years, digital watermarking is one of the best potential tools for multimedia authentication and copyright protection by embedding some information into the multimedia data. This embedding information can be later extracted from or detected in the multimedia to make an assertion about the data authenticity. Digital watermarks remain intact under transmission / transformation, allowing us to protect our ownership rights in digital form. Absence of watermark in a previously watermarked image would lead to the conclusion that the data content has been modified. A watermarking algorithm consists of watermark structure, an embedding algorithm and extraction or detection algorithm. In multimedia applications, embedded watermark should be invisible, robust and have a high capacity. Invisibility refers to degree of distortion introduced by the watermark and its affect on the viewers and listeners. Robustness is the resistance of an embedded watermark against intentional attack and normal video processing operations such as noise, filtering, rotation, scaling, cropping and lossey compression etc. Capacity is the amount of data that can be represented by embedded watermark. [1] Watermarking of still image and video is a similar problem but it is not identical. New problems, new challenges show up and have to be addressed. Watermarking of digital video introduces some issues that generally do not have counterpart in images. Due to large amount of data and inherent redundancy between frames, video signals are highly susceptible to pirate attacks ,including frame averaging ,frame dropping, frame swapping, collusion, statistical analysis, etc.,. Many of these attacks may be accomplished with little or no damage to the video signal.[2]

The video watermarking technique may be classified in two ways based on whether the watermark is embedded in the spatial domain or in the transform domain. In spatial domain, the simplest method is based on embedding the watermark in the least significant bits (LSB) of image pixels. However, spatial domain techniques are not resistant enough to video compression and other video processing operations.

Transform domain watermarking schemes such as those based on the discrete cosine transform (DCT),the discrete wavelet transform (DWT), contourlet transforms(CT) along with numerical transformations such as Singular value Decomposition (SVD) and Principle component analysis (PCA) typically provide higher robustness to video manipulations.[3]

In the transformed domain techniques, the DWT algorithms perform better than other transform domain algorithms since DWT has a number of advantages over other transforms including time frequency localization, multi resolution representation, superior HVS modeling, linear complexity and adaptivity and it has been proved that wavelets are good at representing point wise discontinuities in one dimensional signal. However, in higher dimensions, e.g. image/video, there exists line or curve-shaped discontinuities. Since, 2D wavelets are produced by tensor products of 1D wavelets they can only identify horizontal, vertical, diagonal discontinuities (edges) in images/video, ignoring smoothness along contours and curves. Contourlet transform was then proposed as an improvement of wavelet transform. The contourlet is a directional multi resolution expansion, which can represent images/videos containing contours efficiently. [4] Contourlet transform (CT) possess all features of wavelets and also shows a high degree of directionality and anisotropy. One of the unique properties of contourlet transform is that we could have any number of directional decompositions at every level of resolutions. [5]

The main objective of this paper is to achieve more robustness and imperceptibility against various attacks by combining the SVD and Contourlet transform properties. The proposed method is compared with another which is based on wavelet transform and PCA. The peak signal to noise ratio (PSNR) between the original video and watermarked video, the normalized correlation coefficients (NCC) were calculated with and without attacks. The results show high improvement detection reliability using proposed method. The rest of this paper is organized as follows. Section II describes the contourlet transform, section III describes singular value decomposition, section IV illustrates the details of proposed method, Experimental results and conclusion are included in section V and section VI respectively.

II. Contourlet Transform

Contourlet transform is a multi resolution and multidirectional transformation technique which is used in image analysis for capturing contours and fine details in images. [4] The contourlet transform is composed of basic functions oriented at different directions in multiple scales with flexible aspect ratios. This frame work should form a basis with small redundancy unlike other transform techniques in image processing. Contourlet representation contains basis elements oriented at variety of directions much more than few directions that are offered by other separable transform techniques. One way to obtain a sparse expansion for image with smooth contours is first apply a multistage wavelet like transform to capture the edge points, and then using a local directional transform to gather the nearby edge points into contour segments. With this insight, one can construct a double filter bank structure shown in figure 1(a) where the Laplacian pyramidal (LP) filter is used to capture the point discontinuities, followed by a directional filter bank (DFB) to link point discontinuities into linear structures. The overall result is an image expansion using basic elements like contour segments, and thus it is named contourlet transform. The combination of this double filter bank is named pyramidal directional filter bank (PDFB). An example of frequency partitioning of a PDFB is shown in fig1 (b). [5]

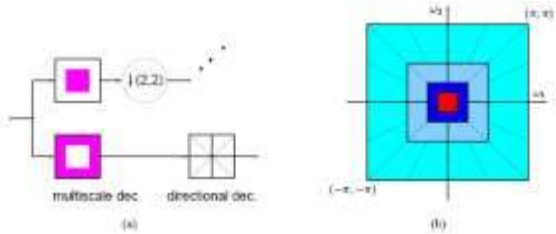


Fig.1 (a) Block diagram of the contourlet filter bank.
Fig.1 (b) Resulting frequency division where the no. of directions is increased with frequency

The directional decomposition is implemented through an *l*-level tree structured decomposition that leads to 2^l sub bands with wedge shaped frequency partition. Fig. 2 shows the directional decomposition at every level obtained using contourlet transform. The number of directional decompositions can be chosen different and it makes this transform unique. From fig. 2, it is apparent that L is the low pass version of the images and V, X, Y and Z are the directional bands at different levels.

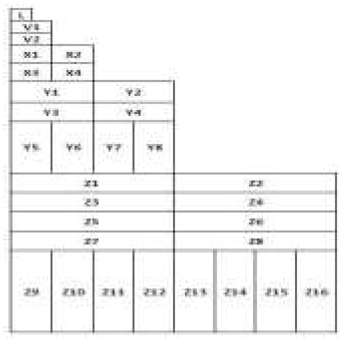


Fig 2: Contourlet transform decomposition

Directional bands in four levels of multi resolutions are divided into 2, 4, 8 and 16 directional sub bands from coarse to fine scales respectively. In this method, high frequency version sub-band „Y8" is selected for watermark embedding as discussed in section IV. [6]

III. Singular Value Decomposition

Singular value decomposition (SVD) is a popular technique in linear algebra and it has applications in matrix inversion, obtaining low dimensional representation for high dimensional data, for data compression and data denoising. If A is any N x N matrix, it is possible to find a decomposition of the form

$$A=USV^T$$

$$A = [u_1\ u_2 \ldots u_n] \begin{bmatrix} \lambda_1 & & & \\ & \lambda_2 & & \\ & & \ddots & \\ & & & \lambda_n \end{bmatrix} [v_1\ v_2 \ldots v_n]^T$$

Where U and V are orthogonal matrices of order N x N and N x N such that $U^TU=I, V^TV=I$, and the diagonal matrix S of order N x N has elements λ_i (i=1,2,3,..n), I is an identity matrix of order N x N.

The diagonal entries are called singular values of matrix A, the columns of U matrix are called the left singular values of A, and the columns of V are called as the right singular values of A

The main idea of this approach is to find the SVD of an original video and then modify its singular values to embed the watermark. Some SVD based algorithms are purely SVD based in a sense that only SVD domain is used to embed watermark into original video. Recently some hybrid SVD based algorithms have been proposed where different types of transform domains including discrete cosine transform (DCT), discrete wavelet transform (DWT), etc are used to embed watermark into original video frame. Here the proposed scheme uses Contourlet transform (CT) along with SVD for watermarking to obtain better performance compared to existing algorithms.

IV. Proposed Algorithm

In this paper, Contourlet Transform and SVD based hybrid technique is proposed for video watermarking. The robustness and visual quality of watermarked video for different video scenes is tested with two quantifiers such as PSNR and NCC. In the proposed hybrid algorithm, the watermarked bits are not embedded directly on the contourlet coefficients, but rather on the elements of the singular values of the frame of contourlet high pass sub band which results from two level contourlet decomposition. It is investigated whether the CT-SVD advantages over wavelet transform and PCA for video watermarking with their extra features would provide any significance in terms of watermark robustness and invisibility. The watermark embedding and extraction algorithms are explained in 4.1 and 4.2.[7][8][9][10][11][12][13][14]

4.1 Watermark Embedding Algorithm:

The proposed video watermark embedding algorithm is shown in Figure3. The steps of watermark embedding algorithm are as follows.

Step1: Separate the original video into four scenes.

Step2: Apply two level Contourlet Transform to first video scene and first watermark image to decompose them into sub bands.

Step3: Apply SVD to chosen high pass sub-band of each frame of first scene and first watermark image.

Step4: Modify the singular values of high pass sub-band coefficients of first scene with the singular values of high pass sub-band coefficients of first watermark image using additive algorithm.

i.e. $\lambda_{I''} = \lambda_I + \alpha\, \lambda_W$,…….(1)

Where α is scaling factor,[15] λ_I is singular value of video scene frame , λ_W is singular value of watermark and $\boldsymbol{\lambda_{I''}}$ becomes singular value of watermarked video frame.

Step5: Apply inverse SVD on modified singular values obtained in step4 to get the high pass sub-band coefficients of watermarked video frame.

Step6: Apply inverse Contourlet Transform to the high pass sub-band coefficients obtained in step 5 to get the watermarked video scene.

Step7: Apply the same Steps from Step2 to Step6 for second, third and fourth video scenes and second, third and fourth watermark images.

Step8: Combine four watermarked video scenes to obtain the watermarked video.

4.2 Watermark Extraction Algorithm:

The proposed video watermark extraction algorithm is shown in Figure 4. The watermark extraction requires both the original and the watermarked video. The steps of watermark extraction algorithm are as follows.

Step1: Separate the watermarked video into four scenes.

Step2: Apply two levels Contourlet Transform to first scene of watermarked video scene.

Step3: Apply SVD to chosen high pass sub-band of watermarked video frames of first scene.

Step4: Extract the singular values from high pass sub-band coefficients of first scene of watermarked and original video

$\lambda_W = (\lambda_{I''} - \lambda_I)/\alpha$ ………(2)

Where α is scaling factor which is used in embedding process, [5] λ_I is singular value of original video scene frame, λ_W is singular value of extracted watermark and $\lambda_{I'}$ is singular value of watermarked video frame.

Step5: Apply inverse SVD on modified singular values obtained in step four to get the high pass sub-band coefficients of extracted watermark image.

Step6: Apply inverse Contourlet Transform to the high pass sub-band coefficients obtained in step five to get the extracted watermark image.

Step7: Apply the same Steps from Step2 to Step6 for watermarked video scenes 2, 3 and 4.to obtain the extracted watermark 2, 3 and 4

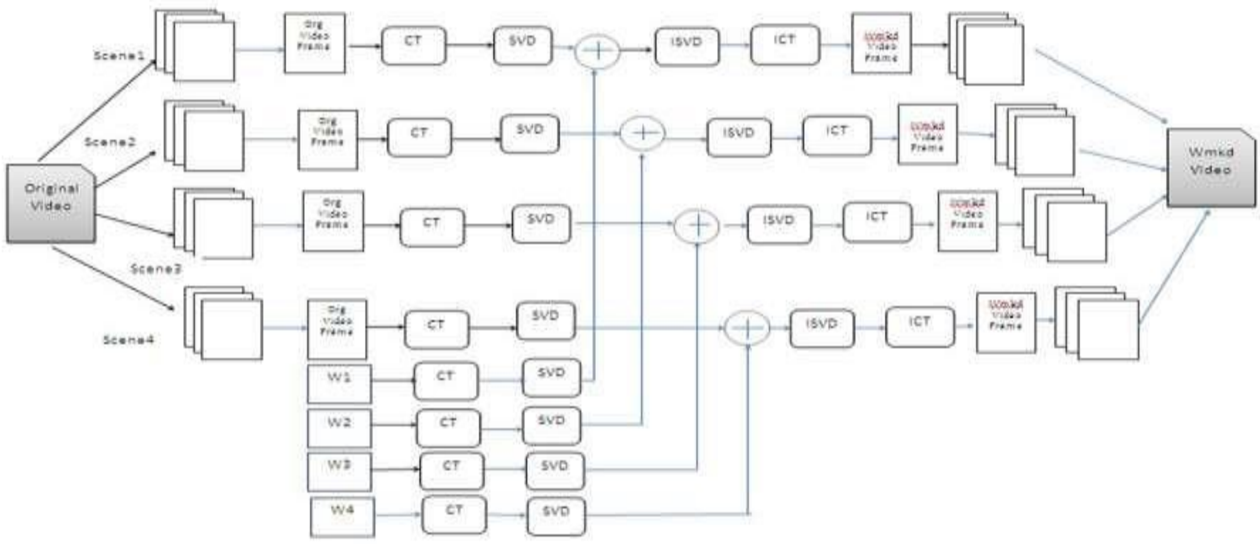


Fig.3 Watermark embedding algorithim

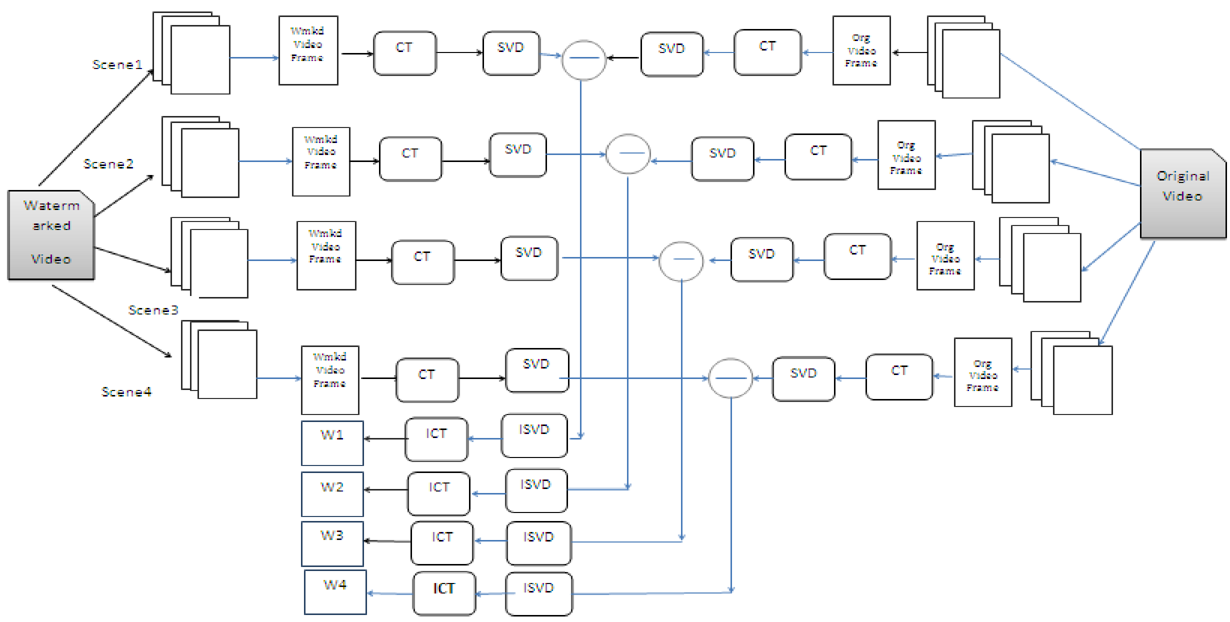


Fig.4 Watermark extracting algorithim

V. Experimental Results

The “foremen.avi” with 120 frames of size 256x256 is used as original video in our experiments. The original video is separated into four scenes of equal number of frames. and four binary images “ksp.bmp”, ”cvn.bmp”, ”jntuk.bmp”, ”ece.bmp” of size 256x256 are used as original watermarks. The watermarks are embedded in all RGB color spaces of each frame. The experiment is performed by taking scaling factor alpha (α) as 12. The results show that there are no perceptible visual degradations on the watermarked video shown in table 1 with an average PSNR of 80.1731db and the watermarks are extracted from the video scenes with an average NCC around unity and extracted watermarks are also shown in table 1. MATLAB 7.6 version is used for testing the robustness of the proposed method.

TABLE I
ORIGINAL & WATERMARKED VIDEO, ORIGINAL & EXTRACTED WATERMARK IMAGE WITH PSNR AND NCC

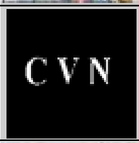
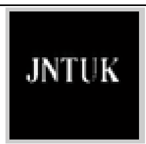
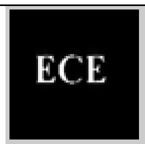
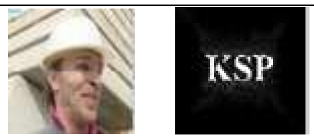
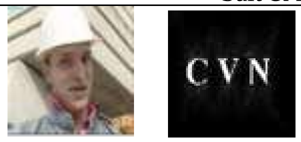
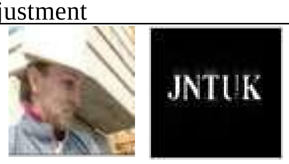
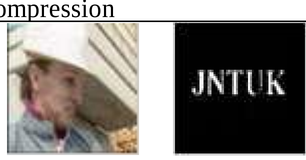
Name of the Frame and image\ Number of scenes	**Scene1 (1 to 30 frames)**	**Scene2(31 to 60 frames)**	**Scene3 (61 to 90 frames)**	**Scene4 (91 to 120 frames)**
Original Video frame				
Original Watermark image				
Watermarked Video frame with Average PSNR in db	 79.8962	 83.9605	 77.4340	 79.4013
Extracted Watermark image with Average NCC	 0.9920	 0.9919	 0.9920	 0.9922

TABLE II
PSNR VALUES OF 120 WATERMARKED FRAMES OF THE “FOREMEN.AVI” VIDEO

Frame	PSNR									
1-10	79.1371	78.3089	78.7092	79.4453	80.8108	79.8841	80.2043	80.1635	80.4586	79.5392
11-20	79.9880	80.2618	79.6375	78.8858	80.1500	80.4055	80.0648	79.2701	79.6192	80.6208
21-30	80.2474	82.3637	80.9976	80.5502	80.3873	80.3381	79.5816	78.7823	79.2621	78.8137
31-40	86.1315	83.0766	83.7568	83.0524	84.7522	84.8782	84.5619	84.8138	85.5972	83.7192
41-50	84.9576	86.3668	83.8758	83.1603	84.7642	83.3264	82.8743	82.6094	81.2078	82.2571
51-60	85.1541	83.9234	84.7642	85.3512	83.4378	82.8916	85.8230	83.2215	82.5105	81.9999
61-70	77.1227	77.4951	78.1635	77.4286	79.4077	77.5435	78.2736	77.3546	78.3546	77.8120
71-80	77.9154	79.0626	78.4588	78.4434	77.2940	78.9921	77.7661	77.2653	76.9204	76.8566
81-90	76.0086	76.3680	76.3128	77.1834	76.8138	76.3732	76.1573	76.1853	76.8977	76.7901
91-100	78.1263	78.5957	79.2009	79.3668	79.8034	80.7851	79.2188	79.0747	78.5140	78.4434
101-110	78.4482	78.9357	79.0565	79.8034	79.9617	80.6178	79.7683	79.6522	79.8973	79.7012
111-120	79.9709	79.4331	79.2783	79.3795	79.1950	79.4729	79.2840	79.6760	79.7656	79.6138
	Average PSNR : 80.1731 db									

TABLE III
EXTRACTED WATERMARKS WITH AVERAGE NCC FOR DIFFERENT ATTACKS ALONG WITH ATTACKED WATERMARKED VIDEO FRAME

Salt & Pepper Noise			
 AverageNCC : 0.9593	 AverageNCC : 0.9606	 AverageNCC : 0.9588	 AverageNCC : 0.9726
Gaussian Noise			
 AverageNCC : 0.8343	 AverageNCC : 0.8400	 AverageNCC : 0.8559	 AverageNCC : 0.8776
Row column Removal			
 AverageNCC : 0.9041	 AverageNCC : 0.8876	 AverageNCC : 0.8650	 AverageNCC : 0.9738
Auto Crop			
 AverageNCC : 0.9352	 AverageNCC : 0.8709	 AverageNCC : 0.8955	 AverageNCC : 0.9155
Histogram equalization			
 AverageNCC : 0.9385	 AverageNCC : 0.9569	 AverageNCC : 0.8771	 AverageNCC : 0.9034
Median filtering			
 AverageNCC : 0.9653	 AverageNCC : 0.9514	 AverageNCC : 0.9509	 AverageNCC : 0.8680
Contrast adjustment			
 AverageNCC : 0.9719	 AverageNCC : 0.9699	 AverageNCC : 0.9729	 AverageNCC : 0.9775
Weiner filtering			
 AverageNCC : 0.9832	 AverageNCC : 0.9822	 AverageNCC : 0.9805	 AverageNCC : 0.9837
Blurring			

 AverageNCC : 0.9384	 AverageNCC : 0.9071	 AverageNCC : 0.9228	 AverageNCC : 0.8993
Shearing			
 AverageNCC : 0.9475	 AverageNCC : 0.9094	 AverageNCC : 0.9238	 AverageNCC : 0.9546
Frame swapping 1 and 31			
 AverageNCC : 0.9827	 AverageNCC : 0.9812	 AverageNCC : 0.9805	 AverageNCC : 0.9837
JPEG2000 compression			
 AverageNCC : 0.9840	 AverageNCC : 0.9833	 AverageNCC : 0.9816	 AverageNCC : 0.9846
Frame Averaging			
 AverageNCC : 0.9832	 AverageNCC : 0.9822	 AverageNCC : 0.9805	 AverageNCC : 0.9837
Frame Dropping			
 AverageNCC : 0.9682	 AverageNCC : 0.9822	 AverageNCC : 0.9805	 AverageNCC : 0.9837

Various intentional and non-intentional attacks are tested for robustness of the proposed watermark algorithm includes JPEG2000 compression, low pass filtering, Rotation, Histogram Equalization , Median Filtering, Salt &Pepper Noise, Weiner Filtering, Gamma Correction, Gaussian Noise, Rescaling , Blurring ,Contrast Adjustment , cropping, Dilation, Row Colum removing, color to Gray scale conversion and shearing etc.

The proposed algorithm is compared with Salwa A.K Mostafa algorithm [13], in which the watermarking is done by using wavelet transform and PCA. In our proposed method the PSNR obtained is 80.1731db and watermark image can survive up to 18 attacks compared to Salwa A.K Mostafa algorithm.

In Table I, the normalized correlation coefficient values for different attacks are shown with extracted watermark and attacked watermarked image. The quality and imperceptibility of watermarked video is measured by using PSNR. The PSNR is calculated separately for each scene using eq.3 [16] with respect to the respective color space of video. The final PSNR of watermarked image is taken as mean of PSNR obtained with all scenes. The similarity of extracted watermark with original watermark embedded is measured using NCC. The NCC is calculated using eq. (4) for the all frames of each scene [17] and their mean is taken as the resultant Normalized Correlation coefficient.

$$PSNR = 10\log\left[\frac{\max(I(i,j))^2}{\sum_{x,y}(I'(i,j)-I(i,j))^2}\right] \quad \ldots\ldots(3)$$

Normalized Correlation Coefficient

$$Ncc = \frac{\sum_m\sum_n (A_{mn}-\bar{A})(B_{mn}-\bar{B})}{\sqrt{\left(\sum_m\sum_n (A_{mn}-\bar{A})^2\right)\left(\sum_m\sum_n (B_{mn}-\bar{B})^2\right)}} \quad \ldots\ldots(4)$$

VI. Conclusion

In this paper, a non blind hybrid video watermarking scheme is proposed for video copyright protection using contourlet transform and singular value decomposition. Watermark is embedded in all video scenes by modifying singular values of high sub band coefficients with respect to watermark high sub band coefficient with suitable scaling factor. The robustness of watermark is improved for common video processing operations by combining both the concepts of contourlet transform and singular value decomposition. The proposed algorithm shows an excellent robustness to attacks like JPEG, JPEG2000 compressions, Histogram equalization, Salt and Pepper Noise, Shearing, Cropping, Weiner Filtering, Gaussian Noise, Row Column Removal and Contrast adjustment. The proposed method shows higher robustness to maximum no of attacks compared to Salwa A.K Mostafa algorithm.

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C.V Narasimhulu

He received his Bachelor degree in Electronics and Communication Engineering from S.V. University, Tirupati, India in 1995 and Master of technology in Instruments and Control Systems from Regional Engineering College Calicut, India in 2000.He is currently pursuing the Ph.D degree in the department of Electronics and Communication Engineering from Jawaharlal Nehru Technological University Kakinada, India. He has more than 16 years experience of teaching under graduate and post graduate level. He is interested in the areas of signal processing and multimedia security.

K.Satya Prasad

He received his Ph.D degree from IIT Madras, India. He is presently working as professor in the department of Electronics and Communication Engineering, JNTU college of Engineering Kakinada and Rector of Jawaharlal Nehru Technological University, Kakinada, India. He has more than 30 years of teaching and research experience. He published 50 research papers in international and 55 research papers in National journals and conferences. He guided 8 Ph.D theses and 20 Ph.D scholars are under his guidance. His area of interests includes Digital Signal and Image Processing, Communications, Adhoc networks etc..,