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Resilience of Various Attacks on Watermarks Using Hybrid Video Watermarking Algorithm

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Abstract:

Watermarking with unaffected detection and high robustness capabilities is still a challenging problem. The success of a digital watermarking technology depends greatly on its robustness to withstand attacks which are aimed at removing or destroying the watermark from its host data. This paper provides analysis of a number of digital watermark attacks and the experimental results are provided to show the effect of these attacks on watermarks using hybrid video watermarking technique based on DWT, DCT and SVD. The main idea of this paper is to develop an algorithm which can be robust to various attacks, that embeds the watermark information without much distortion to the host video by modifying the frequency coefficients of the frames, while making it possible to extract the watermark by using the inverse algorithm. Based on human visual systems perception of video content, which is used to embed a watermark such that its amplitude is kept below the distortion sensitivity of the pixel and thus preserving the video quality. The operation of embedding and extraction of the watermark is done in frequency domain, and it is checked for different signal processing, geometric and noise attacks. This paper has conducted a comprehensive research with special emphasis on the malicious attacks against digital watermarking.

Keywords **— Attacks, robustness, watermarking, DWT, DCT, SVD, PSNR, CF**

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I. INTRODUCTION

Digital video watermarking is a technique for embedding additional data along with video signal. Embedded data is used for copyright owner identification. A number of video watermarking techniques are proposed [1]. These techniques take advantage of different ways in order to embed a robust watermark and to maintain the original video signal fidelity. Watermarking is a potential method for protection of ownership rights on digital audio, image and video data. First, an overview of the current attacking methods will be discussed. Second, attacks are described by exploiting knowledge about the statistics of the embedded and retrieved watermark. The full strength of attacks can be achieved by introducing additional noise, where the attacker tries to combine the watermark and the additive noise to impair watermark communication as much as possible while fulfilling a quality constraint on the attacked video. With a sophisticated quality constraint, it is also possible to exploit human perception like the human auditory system in case of audio watermarks and the human visual system (HVS) in case of image and video watermarks. Apparently any image watermarking technique can be extended to watermark videos, but in reality video watermarking techniques need to meet other challenges than that in image watermarking schemes such as large volume of inherently redundant data between frames, the unbalance between the motion and motionless regions, real-time requirements in the video broadcasting etc. Watermarked video sequences are very much susceptible to pirate attacks such as frame averaging, frame swapping, statistical analysis, frame dropping and compressions. Digital data is easy to manipulate and modify for ordinary people. This makes it more and more difficult for a viewer to check the authenticity of a given digital document which can be either audio, image or video. In general the importance of properties of efficient watermarks will vary depending upon the application.

Some of the properties are listed as:

Robustness- The watermark should be reliably detectable after alterations to the watermarked document. Robustness means that it must be difficult (ideally impossible) to defeat a watermark without degrading the marked document severely.
Imperceptibility- To preserve the quality of the marked document, the watermark should not noticeably distort the original document. Ideally, the original and marked documents should be perceptually identical.
Security- Unauthorized parties should not be able to read or alter the watermark. Ideally, the watermark should not even be detectable by unauthorized parties.
Fast embedding and retrieval- The speed of a watermark embedding algorithm is important for applications where documents are marked “on-the-fly” (i.e., when they are distributed). The large bandwidth necessary for video also requires fast embedding methods. However, since ownership disputes will likely take weeks or months to resolve, a watermark recovery algorithm may emphasize reliable detection over speed. For some of the applications, it is necessary to recover the watermark without requiring the original, unmarked document.
Multiple watermarks- It may also be desirable to embed multiple watermarks in a document.
Unambiguity -A watermark must convey unambiguous information about the rightful owner of a copyright, point of distribution. This requirement is a cryptographic and protocol issue.

This paper mainly focuses on robustness, imperceptibility, and security properties; those are typically the most important. While speaking about robustness, we often natter about attacks on a watermark. An attack is an operation on the watermarked document that can be done intentionally or unintentionally, may degrade the watermark and make the watermark harder to detect. For text documents, an attack might consist of photocopying. For images and video, compression (JPEG or MPEG), filtering, cropping, resizing, and other signal processing manipulations (even printing and rescanning) must not destroy the watermark.

The watermarking algorithms can be classified into two categories: spatial-domain techniques (spatial watermarks) and frequency-domain techniques (spectral watermarks) [2]-[3]. The spatial-domain techniques directly modify the intensities or color values of some selected pixels while the frequency-domain techniques modify the values of some transformed coefficients. The simplest spatial-domain image watermarking technique is to embed a watermark in the least significant bits (LSBs) of some randomly selected pixels. The watermark is invisible to human eyes but the watermark can be easily destroyed if the watermarked data is low pass filtered or removing the least significant bits of the pixel. The main advantages of pixel based methods are that they are conceptually simple and have very low computational complexities and therefore are widely used in video watermarking where real-time performance is a primary concern. However, they also exhibit some major limitations. The need for absolute spatial synchronization leads to high susceptibility to de-synchronization attacks and watermark optimization is difficult using only spatial analysis techniques. The frequency-domain technique first transforms the each frame of the video into a set of frequency domain coefficients. The transformation may adopt either discrete wavelet transform (DWT), discrete cosine transform (DCT), discrete Fourier transforms (DFT), or singular value decomposition (SVD). The watermarks are then embedded in the transformed coefficients of the frames such that the watermarks are invisible and more robust for some signal processing operations. Finally, the coefficients are inverse transformed to obtain the watermarked video. In this paper, attacks on watermarks using hybrid video watermarking algorithm are presented.

II. ATTACKS ON WATERMARKS

Generally, attacks on a watermarking scheme can be classified into two basic categories as: i) Common signal processing operations and ii) Geometric distortions [4]-[5]. The common signal processing operations include median filtering, noise contaminating, and compression. Many techniques have been tried and proved to be effective against common signal processing operations. But dealing with geometric distortions is an important part because they produce synchronization errors and thus makes it difficult to detect watermarks preserved in distorted video. Because of such attacks, many of the watermarking algorithms turn out to be ineffective, so it is a current area of research. Geometric transformations modify the spatial relationship between pixels of an image as it is having no reference except the coordinates of each pixel. So if the image is undergoing any kind of transformation, the watermark detection becomes very problematic and the whole purpose of adding the watermark is defeated. It is basically consists of two operations: a spatial transformation of coordinates and intensity interpolation that assigns intensity values to the spatially transformed pixels. These transformations include rotations, cropping and translations which are easily represented with the help of mathematical equations. And some intentional attacks like frame averaging, frame dropping and frame swapping are also described which are very specific for video watermarking. Brief overview of attacks:

i) Frame averaging: Frame averaging is a common attack to the video watermarking. It collects a number of watermarked frames and statistically averages them to remove watermark. Therefore, the total frame number will become less. The detected watermark image after frame averaging is compared with the original to evaluate the watermark strength.

ii) Frame dropping: As a video contains a large amount of redundancies between frames, it may suffer attacks by frame dropping. The robustness is tested by dropping some frames from the video sequence. Therefore the total number of frames will be decreased. Then the extracted watermark from the reduced frames will be compared with the original watermark to illustrate the robustness.

iii) Frame swapping: Frame swapping is another significant video watermarking attack which can distort the embedded watermark. It swaps the watermarked frames either randomly or selectively, and then watermark is extracted from swapped frames to prove the effectiveness of proposed algorithm.

iv) Compression: This is generally an unintentional attack which appears very often in multimedia applications. Practically all the audio, video and images that are currently being distributed via Internet have been compressed. If the watermark is required to resist different levels of compression, it is usually advisable to perform the watermark insertion task in the same domain where the compression takes place. For instance, DWT domain watermarking is more robust to JPEG compression than spatial domain watermarking.

v) Gaussian noise: Gaussian noise one of the widespread noise which consistently distributed over the signal.This means that each pixel in the noisy image is the sum of the true pixel value and a random Gaussian distributed noise value. As the name indicates, this type of noise has a Gaussian distribution, which has a bell shaped probability distribution function.

vi) Salt & Pepper noise: Salt and Pepper noise is caused generally due to errors in transmission. The salt and pepper noise affected pixels can have the value of 0 or 255. By finding the difference in the calculated mean by leaving the affected pixel, replacing only the affected noisy pixel will give better results than replacing all the pixels from the given image. If the noise is removed to the extent possible, the PSNR will increase and MSE will decrease. So the filtering technique which provides more PSNR and less MSE reduces noise from the noisy image. Any algorithm that produces better results without the prior knowledge about the noise density, which leads to the ultimate solution to the noise removal and also maintains consistency in performance.

vii) Rotation attack: When rotation or scaling is performed on the watermarked image, then the extraction of watermark is more difficult because the embedded watermark and the locally generated version do not share the same spatial pattern anymore. Obviously, it would be possible to do exhaustive search on different rotation angles and scaling factors until a maximum value of correlation is found, but this is prohibitively complex.

viii) Average or mean filtering: A mean filter is a linear spatial filter. It acts on an image or frames of the video by reducing the intensity variation between adjacent pixels. The mean filter is nothing but a simple sliding window spatial filter that replaces the centre value in the window with the average of all the neighboring pixel values including itself. By doing this, it replaces pixels that are unrepresentative of their surroundings. It is implemented with a convolution mask, which provides a result that is a weighted sum of the values of a pixel and its neighbors. The mask or kernel is a square. Often a 3×3,4x4, 5x5 square kernels are used. If the coefficients of the mask sum up to one, then the average brightness of the image is unchanged. Otherwise the brightness of the image may lose or effected. The mean or average filter works on the shift-multiply-sum principle.

ix) Median filtering: A median filter is a nonlinear filter distinctive from the mean filter. The median filter as well pursues the moving window principle like to the mean filter. A 3×3, 5× 5, or 7× 7 kernel of pixels is inspected over pixel matrix of the entire image or frame. The median of the pixel values in the window is worked out, and the center pixel of the window is substituted with the computed median. Median filtering is done by, first sorting all the pixel values from the adjacent neighborhood into numerical order and then replacing the pixel being considered with the middle pixel value. Note that the median value must be written to a separate array or buffer so that the results are not corrupted as the process is performed. The median filter was the accepted nonlinear filter for removing impulse noise, because of its good denoising power and computational efficiency. Median Filter is more effective in situations where white and black spots appear on the image or video frames.

x) Sharpening: It is a powerful tool for emphasizing the intensity transitions at edges and line structures. Human perception is highly sensitive to edges and fine details of an image which are composed of high frequency components. The attenuation and enhancement of high frequency components leads to degradation or improvement in visual quality. The extracted watermark from sharpened video will be checked with host to judge the power of watermark.

xi) Histogram equalization: It is a powerful technique to improve the contrast of images or frames of video. Histogram equalization accomplishes the distribution by effectively spreading out the most frequent intensity values. Though it is suitable for overall image enhancement, it fails to preserve the brightness features of the original image. By extracting the watermark, the efficiency of present algorithm will be projected.

xii) Cropping: This is very common attack in many cases, if the attacker is interested in a small portion of the watermarked entity, such as parts of a certain picture or frames of a video sequence. With this in mind, in order to survive, the watermark needs to be spread over the dimensions where this attack takes place.

After applying the proposed attacks on the watermarked video, the information of the original host data and watermark are needed in the extracting process. This research work presents a novel and robust color video watermarking scheme of embedding color and gray watermarks into host video [6]-[7]. This technique shows efficient extraction of Watermark with high PSNR of embedded watermarks. The proposed algorithm is experimented in frequency domain in which combination of DWT, DCT and SVD is applied on the video [8]-[9]. In the proposed algorithm, the singular values of DCT transformed coefficients of the DWT decomposed data are modified with that of watermarks at various scaling factors. The selected value of scaling factor with the chosen attack shows the impact on the quality of the video and watermarks. The proposed algorithm is more secure, robust and efficient because of use of DWT, DCT and SVD [10].

III. PERFORMANCE EVALUATION AND SIMULATION RESULTS

Performance evaluation and testing of the proposed algorithm using MATLAB reveals that it is fairly robust against a wide range of signal processing operations, geometric and intended attacks [11]. The attacker is motivated to reduce the maximum rate of reliable communication by exploiting the HVS and the possibility to remove the watermark based on different models. The watermark can be easily predicted and removed from flat areas rather than from the areas of edges and textures. Due to this the watermarks are embedded in middle and high frequency coefficients of frames of host video. In this research paper, the advancement of digital video watermarking technology has reviewed an analysis of number of attacks on watermarks. The analysis on embedded and extracted watermarks was carried out using MATLAB tool in the frequency domain. Using the results of the experiments, it has been observed that the existing techniques have different sensitivity and robustness levels to different attacks. The extracted watermarks from the watermarked video sequences are clear enough even after the watermarked video had suffered from various attacks. The perceptual quality and resilience of retrieved watermarks was investigated in subjective and objective phases. In objective analysis, the metrics PSNR, MSE and CF are used to test robustness of watermarks. The performance metrics between original watermarks and retrieved watermarks from attacked video under various attacks are shown in Table 1**.**

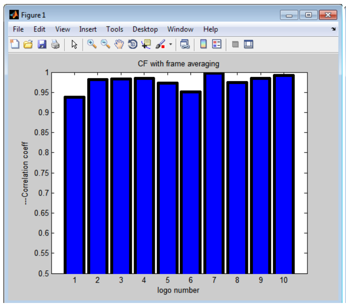
In this scenario, attacked 120 frames watermarked video with 10 individual watermarks is used for analysis [12]. Here the video is partitioned into 10 groups of each 12 frames and each group is embedded with one individual logo out of 10 different gray and color logos. In frame averaging attack, first 3 frames of each group are averaged and replaced with new one. Now the embedded logos are recovered from the averaged groups of each 10 frames [13]. Then the recovered logos are compared with original logos using metrics CF, PSNR and MSE. The plot of CF with frame averaging attack is shown in Figure 1(a). In the next case, first 6 frames from each group are removed from attacked video. The logos are retrieved from remaining 6 frames of each group. The plots of CF with frame dropping, compression and randomly swapped frames are shown in Figure 1(b), (c) and (d). We have investigated the algorithm performance for Gaussian noise, Salt & Pepper noise, rotation attack, median filtering and average filtering attack by using CF shown in Figure 1(e) to (i).

In many cases the degradation and distortion of the image or video come from noise addition. The watermark information is also degraded by noise addition and resulted in difficulty in watermark extraction. In this experiment, Gaussian noise is added with mean value 0 and finite variance to estimate the robustness of the watermark. The noise variance is varied from 0.001 to 0.1 that causes the reduction in CF and PSNR values. With this noise addition, the variations of PSNR and CF with different values of variances at chosen scaling factor of 0.5 are shown in Figure 2 (a) and (b).

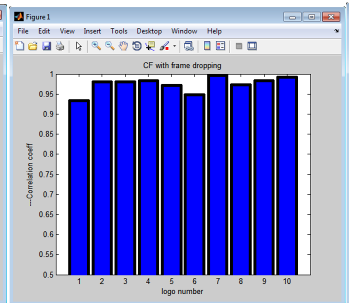
From the plot, it has been observed that the values of CF and PSNR decreases with increase in variance of Gaussian noise at the selected scaling factor value.

TABLE I
PSNR, MSE & CF BETWEEN ORIGINAL AND EXTRACTED WATERMARKS

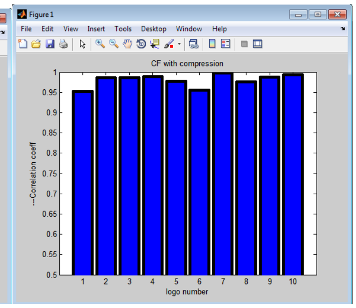
Logo no.			1	2	3	4	5	6	7	8	9	10
S.No	attacks	metrics										
1	Frame averaging	CF	0.9379	0.9821	0.9826	0.9851	0.9725	0.9515	0.9972	0.9742	0.9841	0.9920
		PSNR	36.563	38.925	37.788	40.591	38.273	38.760	45.232	38.375	40.308	37.893
		MSE	14.492	8.9555	11.670	5.7691	9.7406	8.8983	1.9868	9.5576	6.1150	10.652
2	Frame dropping	CF	0.9339	0.9803	0.9809	0.9839	0.9713	0.9474	0.9970	0.9736	0.9839	0.9916
		PSNR	36.327	38.257	37.243	40.174	38.210	38.436	44.991	38.363	40.270	37.795
		MSE	15.148	9.7130	12.268	6.2460	9.8189	9.3193	2.0601	9.4774	6.1100	10.802
3	Compression	CF	0.9530	0.9859	0.9868	0.9892	0.9776	0.9555	0.9976	0.9758	0.9878	0.9931
		PSNR	37.063	39.076	38.092	41.126	38.484	38.775	45.732	38.390	40.912	38.076
		MSE	12.786	8.0439	10.089	5.0163	9.2175	8.6215	1.7372	9.4199	5.2704	10.126
4	Frame swapping	CF	0.9558	0.9855	0.9831	0.9430	0.9849	0.8758	0.9728	0.9879	0.9473	0.9837
		PSNR	40.555	41.466	39.924	38.155	40.747	37.388	39.565	39.404	38.377	37.238
		MSE	9.0547	5.8288	8.1799	10.783	6.2107	12.537	7.6885	7.6775	10.043	12.815
5	Gaussian	CF	0.5744	0.7891	0.8245	0.7543	0.8669	0.5486	0.8794	0.9164	0.78122	0.9277
		PSNR	33.347	33.913	33.757	34.415	36.579	34.028	34.132	36.026	34.177	34.259
		MSE	30.085	26.408	27.376	23.524	14.293	25.716	25.106	16.236	24.851	24.386
6	Salt &pepper	CF	0.7890	0.9121	0.9303	0.9116	0.9408	0.8045	0.9652	0.9575	0.9116	0.9700
		PSNR	34.276	35.182	34.901	36.354	37.223	35.616	36.413	37.155	35.980	35.366
		MSE	24.295	19.719	21.036	15.055	12.323	17.843	14.854	12.519	16.407	18.899
7	Rotation	CF	0.9470	0.97680	0.9832	0.9772	0.9862	0.9564	0.9933	0.9897	0.9730	0.9917
		PSNR	36.760	38.000	37.615	39.232	39.057	38.405	42.573	38.809	38.538	37.707
		MSE	13.710	10.307	11.274	7.7630	8.0793	9.3873	3.5953	8.5529	9.1040	11.024
8	Median filtering	CF	0.9966	0.9992	0.9986	0.9979	0.9969	0.9983	0.9997	0.9981	0.9981	0.9990
		PSNR	45.881	49.739	46.362	46.400	41.828	50.052	53.462	40.700	45.977	43.005
		MSE	1.7000	0.7268	1.6916	1.5019	4.2693	0.7716	0.2940	5.5516	1.6438	3.2657
9	Average filtering	CF	0.9821	0.9870	0.9937	0.9941	0.9988	0.9927	0.9974	0.9995	0.9976	0.9993
		PSNR	38.817	39.172	40.513	42.877	45.366	42.645	45.600	47.452	45.316	44.999
		MSE	8.5717	7.9072	6.1481	3.3760	1.9166	3.5505	1.7920	1.1756	1.9142	2.0760
10	Sharpening	CF	0.9432	0.9590	0.9764	0.9749	0.9922	0.9783	0.9937	0.9975	0.9868	0.9959
		PSNR	35.810	36.805	36.945	39.077	40.887	39.510	43.130	43.161	40.645	39.242
		MSE	17.069	13.582	13.294	8.0483	5.3046	7.3093	3.1633	3.1406	5.6048	7.7444
11	Histogram equalization	CF	0.8549	0.9527	0.9334	0.8967	0.8905	0.6735	0.9589	0.9194	0.9430	0.9767
		PSNR	35.006	36.587	35.288	36.640	37.091	35.759	38.686	37.638	37.523	36.436
		MSE	20.533	14.267	19.372	14.096	12.702	17.264	8.7999	11.203	11.500	14.774
12	Left cropping	CF	0.9570	0.9890	0.9876	0.9884	0.9772	0.9591	0.9981	0.9789	0.9884	0.9931
		PSNR	37.279	39.655	38.252	40.862	38.503	38.940	46.207	38.437	41.016	38.060
		MSE	12.166	7.0407	9.7378	5.3314	9.1767	8.3003	1.5572	9.3175	5.1462	10.1630
13	Right cropping	CF	0.9646	0.9905	0.9897	0.9921	0.9850	0.9664	0.9982	0.9787	0.9880	0.9935
		PSNR	37.780	40.033	38.700	41.854	39.026	39.330	46.386	38.439	40.963	38.147
		MSE	10.840	6.4552	8.7750	4.2437	8.1371	7.5969	1.4951	9.3136	5.2089	9.9650
14	Top cropping	CF	0.9422	0.9830	0.9848	0.9888	0.9763	0.9510	0.9972	0.9744	0.9877	0.9938
		PSNR	36.601	38.589	37.741	41.022	38.376	38.584	45.242	38.376	40.784	38.229
		MSE	14.220	8.9987	10.940	5.1389	9.4500	9.0186	1.9446	9.4499	5.4295	9.7770
15	Bottom cropping	CF	0.9490	0.9844	0.9886	0.9937	0.9849	0.9518	0.9973	0.9750	0.9905	0.9952
		PSNR	36.844	38.778	38.640	42.523	39.051	38.670	45.429	38.369	41.490	38.628
		MSE	13.447	8.6148	9.0180	3.6396	8.0907	8.8587	1.8627	9.4658	4.6138	8.9243



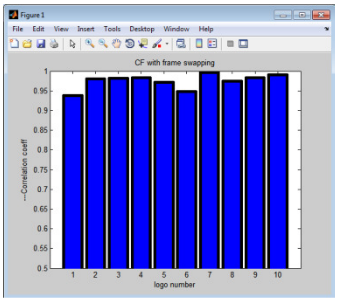
(a) Frame averaging effect



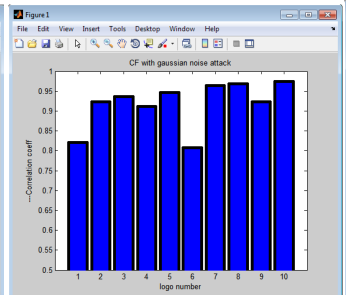
(b) frame dropping effect



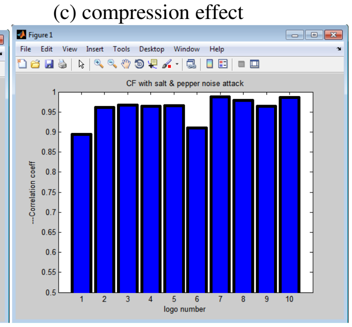
(c) compression effect



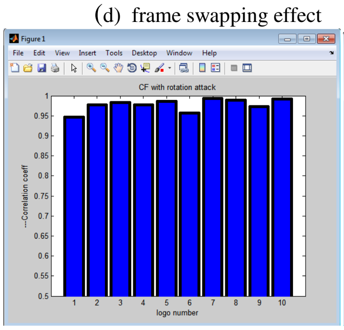
(d) frame swapping effect



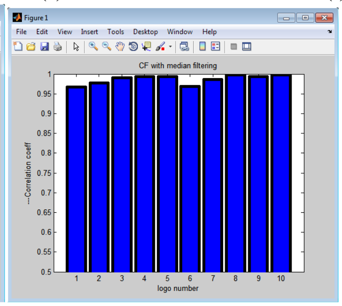
(e) Gaussian noise effect



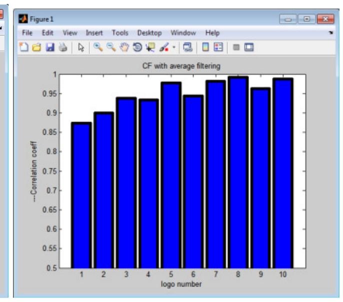
(f) Salt & Pepper noise effect



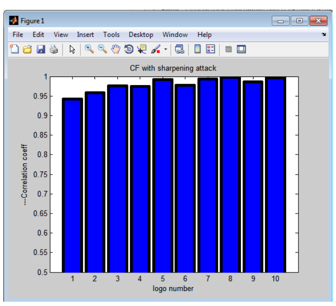
(g) rotation effect



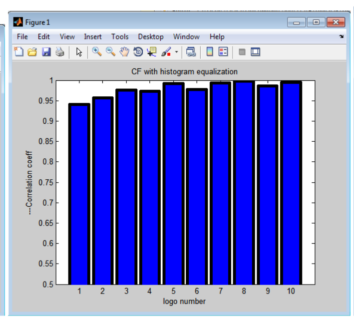
(h) median filtering effect



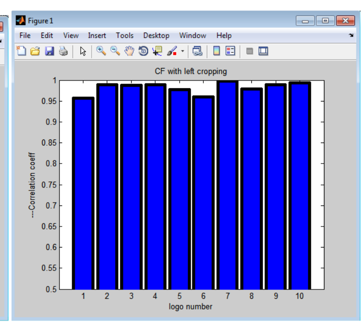
(i) average filtering effect



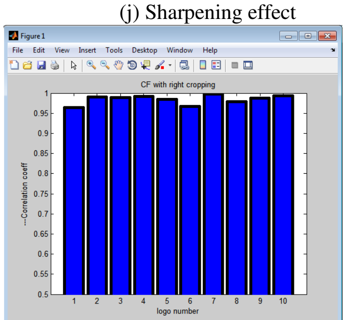
(j) Sharpening effect



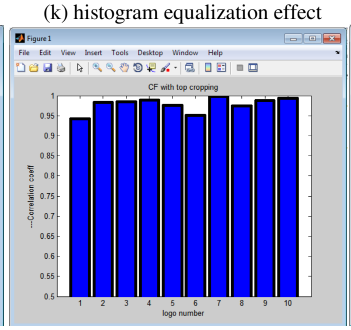
(k) histogram equalization effect



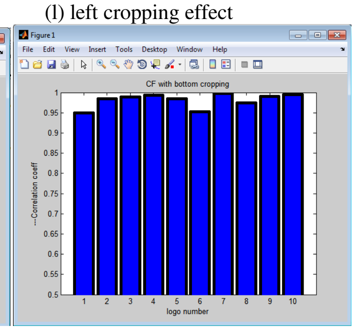
(l) left cropping effect



(m) right cropping effect



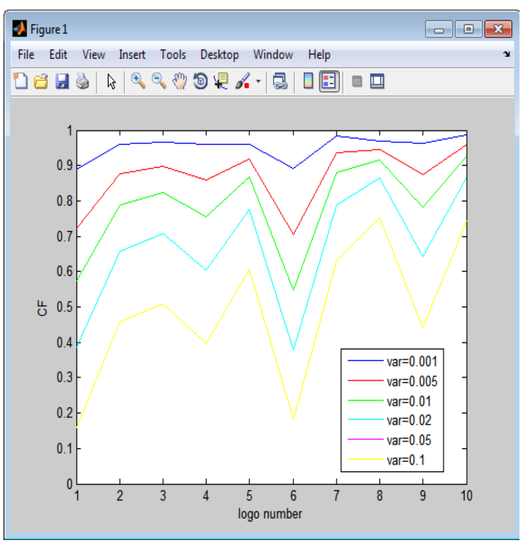
(n) top cropping effect



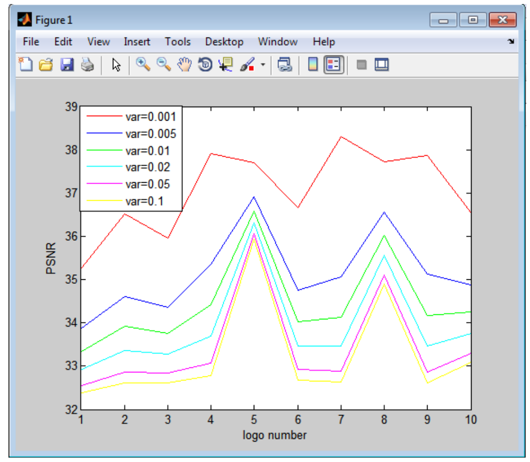
(o) bottom cropping effect

Fig. 1 plot for CF between original and recovered watermarks under various attacks

The performance of proposed algorithm with salt and pepper noise at various noise density values is analyzed. Robustness of watermarks is greatly affected by noise density at the same scaling factor of 0.5. Because more number of coefficients will be modified due to addition of Salt & Pepper noise and hence results in bad recovery of watermark at larger value of density. The effect of density of noise on CF and PSNR are shown in Figure 3(a) and (b). From Figure 3, it has been observed that CF and PSNR values are reducing with increasing noise density. The CF results of sharpening and histogram equalization attack are shown in Figure 1(m) and (n).The algorithm copes very well with cropping attack in either direction (left, right, top and bottom), for which CF plots are shown in Figure 1(l) to (o).

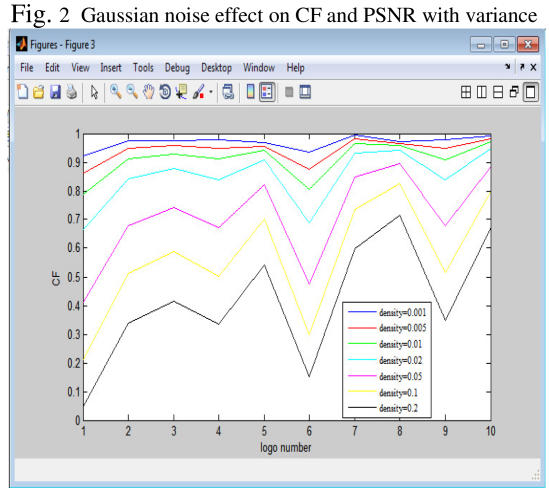


(a) plot of CF with variance

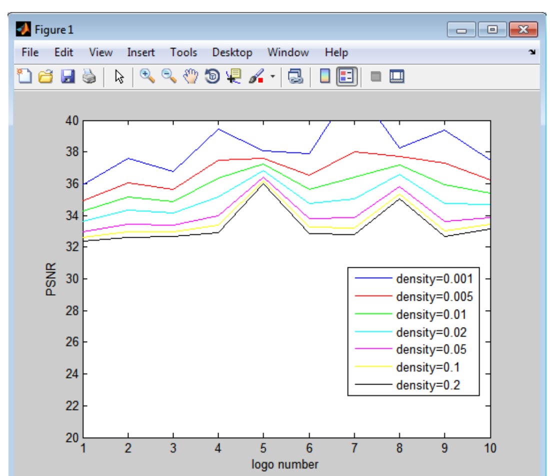


(b) plot of PSNR with variance

Fig. 2 Gaussian noise effect on CF and PSNR with variance



(c) plot of CF with noise density



(d) plot of PSNR with noise density

Fig. 3 Salt & Pepper noise effect on CF and PSNR with density

IV. CONCLUSIONS

This paper interprets the effectiveness of hybrid video watermarking algorithm against various attacks on watermarks. As a result, video watermarking is a potential approach for protection of ownership rights on digital video. This paper provides a general view for the classification of attacks against the robustness of the digital watermarking scheme. The experimental results show that the proposed scheme is highly robust against various distortions such as Gaussian noise and salt and pepper noise, mean and median filtering, cropping and compression, sharpening, histogram equalization, frame dropping and averaging, frame swapping and rotation. The simulation results shows that high quality watermarked video with high PSNR is obtained by embedding the watermark at the desired scaling factor without affecting the robustness of watermark. Also embedding the watermarks using hybrid algorithm improves both the quality of watermarked video and the robustness of the watermarks. The watermark embedding at a scaling factor above 0.5 will sustains all types of attacks. This tested algorithm has a good embedding capacity without reducing the quality of watermarked video and watermark. It can be clearly seen from the results that the quality and robustness of retrieved watermarks against all specified attacks are good.

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