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A New DCT based Color Video Watermarking using Luminance Component

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Abstract: *This paper presents a new blind secure video watermarking algorithm using DCT (discrete cosine transform). In this proposed algorithm cover video is divided into frames and watermark is inserted into selected frames. For selected video frames two-dimensional 8×8 discrete cosine transform is carried out on luminance component. Finally binary watermark is embedded into mid frequency DC coefficients by adjusting coefficients DCT(4,3) and DCT(5,2). Experimental results shows that the proposed algorithm is imperceptible as well as robust against wide variety of signal and video processing attacks like Gaussian noise, Salt –pepper noise, Gaussian filter, Median filter, Histogram Equalization etc. The technique is fairly acceptable and watermarked video is of good quality, achieves high PSNR. The technique shows efficient extraction of watermark with NC value of the retrieved watermark as 1.*

Keywords: *DCT (Discrete Cosine Transform), Luminance (Y component), MSE (Mean Square Error), Normalized Correlation (NC), PSNR (Peak Signal to Noise)*

I. Introduction

Now a day's people are highly dependent on network technology, the users of networks especially over the Internet are increasing enormously. The increased importance of digital content invites new challenges for securing the distribution of digital media. This copyright misuse is the motivating factor in developing new watermarking techniques. Watermarking [1-6] can be used for copyright protection. There is a need for video watermarking [1, 2] as most of the information on Internet these days is in the form of videos as well. Video watermarking is a technology in which there is embedding of various copyright information in video frames [3, 6, 7]. Digital watermarking algorithms are classified into frequency domain and spatial domain algorithms. Spatial domain algorithms embeds watermark by directly modifying pixels of carrier signal [8, 9] while Frequency domain algorithms embeds watermark by modifying frequency bands [10, 11]. Frequency domain watermarking is more secure and robust as compare to spatial domain watermarking. We are developing an algorithm for video watermarking in frequency domain using DCT which embeds binary watermark in video frames. Each bit of binary watermark is embedded into different 8×8 sized DCT block of Y (Luminance) channel of selected frame. Proposed method is blind and invisible as well as robust against variety of video processing attacks.

In literature DCT transform has been successfully used for digital watermarking. In the proposed algorithm DCT is used for video watermarking in frequency domain. DCT divides carrier signal into low, middle, and high frequency bands [10]. DCT watermarking is classified into two types: Global DCT watermarking and Block-based DCT watermarking. In the Global DCT watermarking, the DCT computation is performed on the whole image, while in the Block-based DCT the image is divided into non-overlapping blocks and DCT computation is performed on each block separately to obtain low-frequency, mid-frequency and high-frequency sub-bands . J. R. Hemandez, M. Amado have proposed image watermarking in DCT domain [11]. Masoumi, M., Amiri, have Proposed video watermarking in YCbCr color space [12]. S. Feng, D. Lin, S. C. Shie and J. Y. Guo proposed a DCT-based technique they converted RGB space to YUV space and embedded watermark in Y component [15]. Jaya Jeswani and Tanuja Sarode have proposed a blind image watermarking using DCT in RGB color space by modifying middle frequency coefficients DCT(4,3) and DCT(5,2) [17].

The paper is organized as follows: Section 1 presents introduction. An introduction to DCT transform is given in section 2. Section 3 describes proposed algorithm with DCT coefficients selection, watermark embedding and extraction algorithms. Experimental results before and after applications of attacks are given in section 4. Finally conclusion of proposed algorithm is given in section 5.

II. Preliminaries

Discrete Cosine Transform

DCT(Discrete Cosine Transform)is a popular frequency domain watermarking technique [17]. DCT divides carrier signal into three frequency bands namely low, middle, and high frequency bands. It is frequency domain watermarking technique as watermark is embedded into one of these three bands, carrier signal pixels are not modified directly. Fig. 1 below shows three DCT Regions, F_L is used to denote the lowest frequency components of the block, F_M is used to denote the middle frequency components, $F_H$is used to denote the higher frequency components.

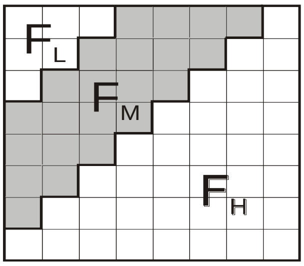


Fig. 1: DCT Regions

The definition of 2-D DCT can be given as follows:

$$C(u,v)=\alpha(u)\alpha(v)\sum_{x=0}^{N-1}\sum_{y=0}^{N-1} f(x,y)\cos\left[\frac{(2x+1)u\pi}{2N}\right]\cos\left[\frac{(2y+1)v\pi}{2N}\right] \text{For } u, v = 0, l, 2,..., N-1 \quad (1)$$

Above equation 1 converts image from spatial domain to frequency domain,
Image can be transformed back to spatial domain by applying inverse DCT given in equation 2:
The definition of 2-D inverse DCT can be written as follows:

$$f(x,y)=\sum_{u=0}^{N-1}\sum_{v=0}^{N-1}\alpha(u)\alpha(v)C(u,v)\cos\left[\frac{(2x+1)u\pi}{2N}\right]\cos\left[\frac{(2y+1)v\pi}{2N}\right] \quad \text{For } x, y = 0, 1, 2,..., N-1 \quad (2)$$

$$\alpha(u), \alpha(v) = \begin{cases} \sqrt{1/N} & \text{for } u, v=0 \\ \sqrt{2/N} & \text{for } u, v=1, 2,....., N-1 \end{cases} \quad (3)$$

In this paper for watermark embedding middle frequency bands are selected because moreof the video energy lies on low-frequency sub-band which contains the most important visual contents of video which effects quality of watermarked video, high frequency sub-band is usually removed through noise attacks.

III. Proposed Method

Proposed method is divided into three subsections section A explains DCT Coefficients Selection section B describes watermark insertion process and section C describes watermark extraction process.

A. DCT Coefficients Selection

For watermark embedding DCT coefficients DCT (4,3) and DCT(5,2) have been selected because both are middle frequency components and in JPEG quantization table both are having same value as 22. The choice in selecting the two locations is dependent on the content of the JPEG quantization table given below in table I.

Table I: JPEG Quantization Table

16	11	10	26	24	40	51	61
12	12	14	19	26	58	60	55
14	13	16	24	40	57	69	56
14	17	22	29	51	87	80	62
18	22	37	56	68	109	103	77
24	35	55	64	81	104	113	92
49	64	78	87	103	121	120	101
72	92	95	98	112	100	103	99

B. Watermark Embedding Process

Inputs: Color video frames and binary watermark
Outputs: Watermarked video frames

The steps are as follows:

1. Take cover video of size M×N and select some video frames where watermark is to be embedded. Binary watermarkof size n×n is also taken as an input.
2. Selected frames are decompose into 3 components: Y, U and V.
3. Select Luminance component for watermark embedding and divide it into 8×8 sized blocks.
4. Determine watermark size based on cover image and block size by :
   $$\textbf{watermark\_size=M×N/block size}^2 \quad \textbf{(4)}$$
5. Check watermark size if it is less than the watermark size calculated by equation 4 than pad the watermark out to the watermark size with ones.
6. Transform each block using DCT.
7. Embeds watermark bit=0 when DCT (5,2) is greater than or equal to DCT(4,3) and embeds watermark bit=1 when DCT (5,2) is less than DCT (4,3).
8. If watermark bit=0, then DCT(5, 2) should be greater than or equals to DCT(4, 3) and if DCT(5, 2) less than DCT(4, 3) then swap these two values .
9. If watermark bit=1, then DCT(5, 2) should be less than DCT (4, 3) and if DCT (5, 2) greater DCT (4, 3) then swap these two values.
10. Adjust difference between DCT(5, 2) and DCT (4, 3) such that their difference = k.
11. Transform block back into spatial domain by IDCT which gives watermarked frame.
12. Combine modified Y and U, V components to create watermarked video frame.
13. Repeat the same procedure till all the selected frames are watermarked.

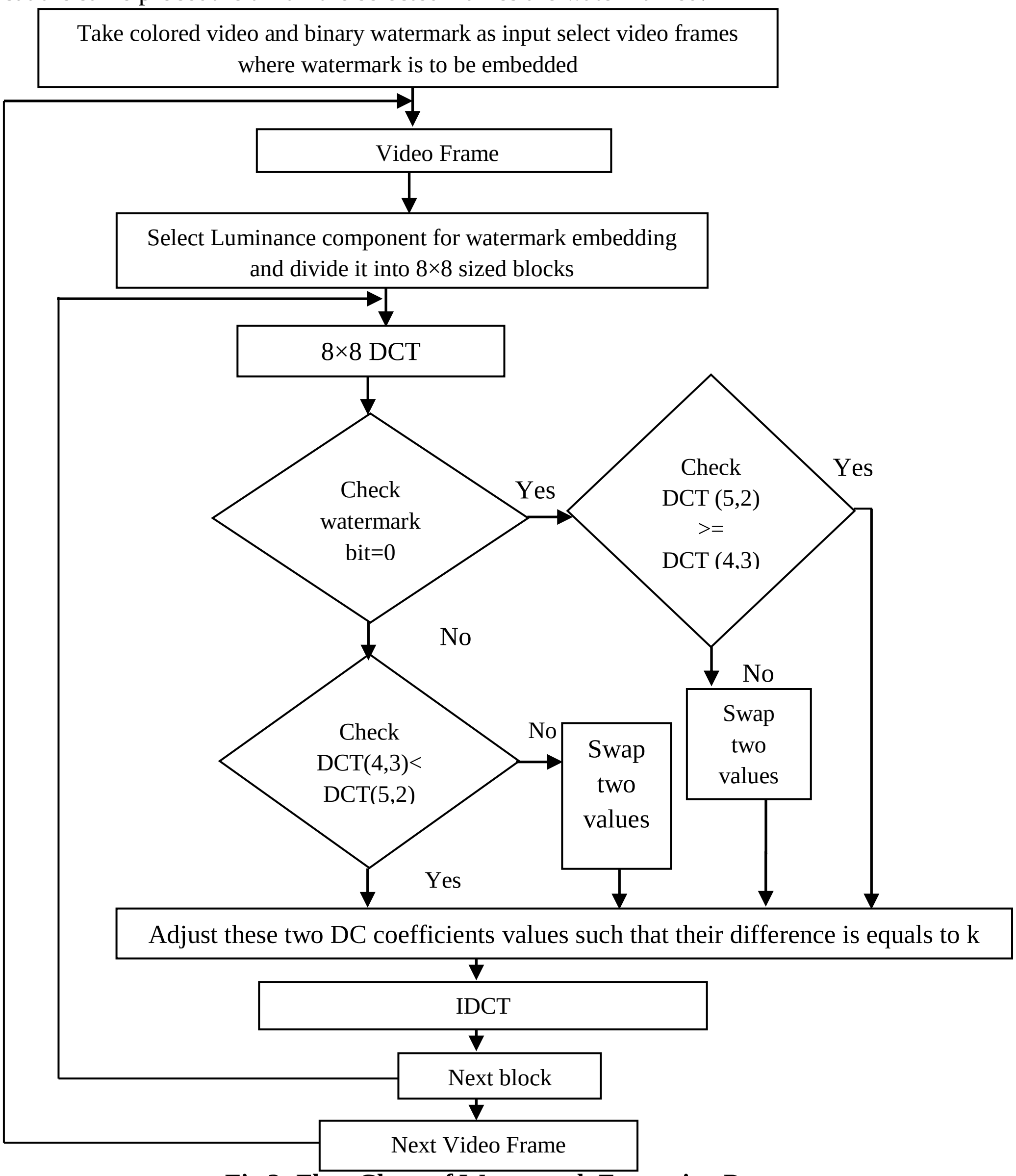


Fig.3: Flow Chart of Watermark Extraction Process

C. Watermark Extraction Process

Input: Watermarked Video Frames
Output: Binary watermarks extracted from all Watermarked Frames
Steps:

1. Take watermarked video frames of size M×N as an input.
2. Each watermarked video frame and decompose into 3 components: Y, U and V.
3. Two-dimensional 8×8 discrete cosine transform is carried out on luminance component.
4. If DCT (5, 2) greater than or equal to coefficient of DCT (4, 3), make watermark bit=0 else watermark bit=1.
5. Reshape the recovered watermark image into n×n.
6. Repeat the procedure till all the watermarks are extracted from the watermarked video frames.

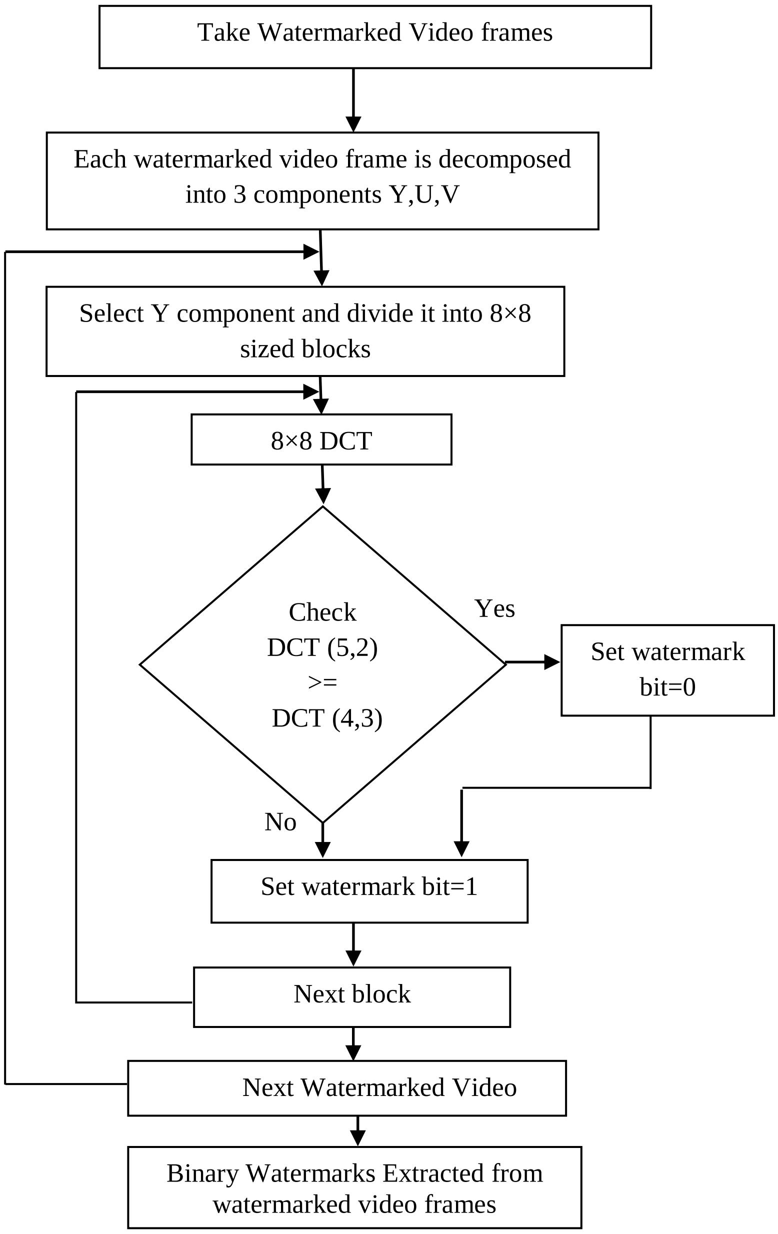


Fig.3: Flow Chart of Watermark Extraction Process

Fig.2 and Fig. 3 gives flow chart of watermark embedding and extracting process respectively.

IV. Experimental Results

The proposed video watermarking algorithm is implemented on Intel Core i5-3210M, 1.8 GHz, 4GB RAM machine and Matlab R2011b.The proposed method is tested on different videos like News, Ice, Crew, Soccer of size 256×256 and binary watermark (8.bmp) of size 32×32 is used as watermark. For evaluating the performance of proposed algorithm Peak Signal to Noise Ratio (PSNR), Mean Square Error (MSE) and Normalized correlation (NC) performance evaluators are used.

$$\mathbf{MSE} = \frac{1}{MN}\sum_{i=1}^{M}\sum_{j=1}^{N}[I(i,j) - I'(i,j)]^2 \quad (5)$$

$$\mathbf{PSNR} = 10\, log_{10}\left(\frac{255^2}{MSE}\right) \quad (6)$$

Where, M, N = size of the original video frame,
I(i, j) = pixel values at location (i, j) of the original video frame,
I'(i, j) = pixel values at location (i, j) of watermarked video frame

$$\mathbf{NC} = \frac{\sum_i \sum_j w(i,j)w'(i,j)}{\sum_i \sum_j w(i,j)^2} \quad (7)$$

W(i,j) = pixel values at location (i, j) of the original watermark,
W'(i,j) =pixel values at location (i, j) of the extracted watermark

(a) (b) (c) (d)

Fig. 4 Cover Videos (a) News (b) Ice (c) Crew (d) Soccer

Table II: PSNR values of first nine watermarked frames of the News.y4m video at different values of k

Quality Factor K	PSNR									Average
1	45.3948	46.3186	46.3031	46.2931	46.2757	46.2800	46.2956	46.2009	46.1932	46.1745
2	45.3635	46.2812	46.2674	46.2568	46.2459	46.2478	46.2529	46.1664	46.1672	46.1388
3	45.3108	46.2112	46.1992	46.1906	46.1806	46.1860	46.1788	46.1006	46.0942	46.0725
4	45.2826	46.1478	46.1346	46.1273	46.1077	46.1257	46.1273	46.0465	46.0302	46.0144
5	45.2291	46.0679	46.0665	46.0364	46.0269	46.0403	46.0329	45.9669	45.9609	**45.9364**
6	45.1703	45.9814	45.9848	45.9757	45.9453	45.9640	45.9587	45.8901	45.8990	45.8632
7	45.1152	45.9230	45.9220	45.9063	45.8831	45.8974	45.8949	45.8319	45.8294	45.8003
8	45.0448	45.8604	45.8551	45.8477	45.8090	45.8330	45.8387	45.7710	45.7679	45.7364
9	44.9915	45.8083	45.7942	45.7796	45.7570	45.7879	45.7858	45.7143	45.7066	45.6805
10	44.9367	45.7496	45.7196	45.7164	45.6903	45.7000	45.7162	45.6542	45.6449	45.6102

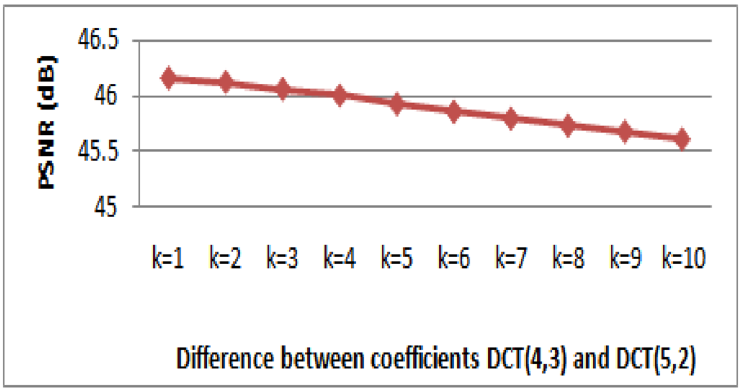


Fig.5:Peak Signal to Noise Ratio Chart at different Values of k

From above table II it can be concluded that as the value of k increases PSNR of watermarked frames decreases. Fig.5 shows Peak Signal to Noise Ratio chart at different values of k. Here k indicates minimum coefficient difference between DCT(4,3) and DCT(5,2).Fig. 6 below shows results of watermark embedding using proposed algorithm on 1st frame and 48th frame respectively. Original watermark and extracted watermark from 1st frame and 48th frame respectively are shown in Fig. 7.First 48 frames of video News.y4m are selected for watermark embedding and Table III, Table IV shows PSNR and MSE values of first 48 watermarked frames respectively at k=5.Value of k selected is 5 because it gives optimum performance and after attack also watermark is extracted with some distortion. Fig. 8 shows PSNR and MSE charts of 48 watermarked frames.

(a) (b) (c) (d)

Fig.6 (a) 1st frame of News.y4m video (b) 1st Watermarked frame of News.y4m video(c) 48th frame of News.y4m video (d) 48th Watermarked frame of News.y4m video

(a) (b) (c) (d)

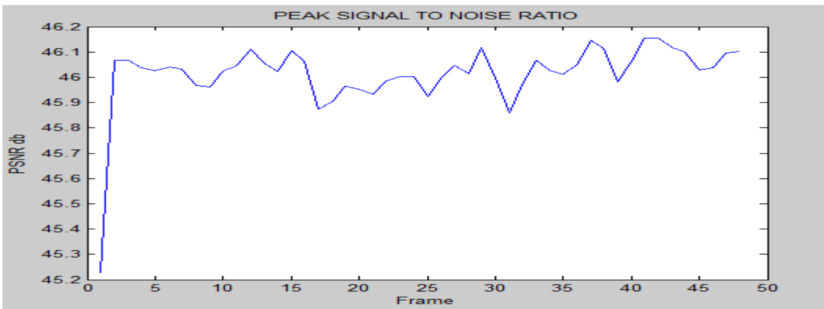
Fig.7(a) Original Watermark(b) Watermark extracted from 1st frame of News.y4m video(c) Original Watermark(d) Watermark extracted from 48th frame of News.y4m video

Table III: PSNR values of first 48 watermarked frames of the News.y4m Video

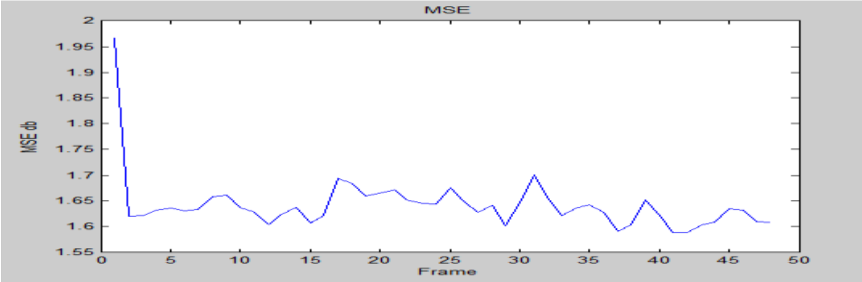
Frames	**PSNR at k=5**							
1-8	45.2291	46.0679	46.0665	46.0364	46.0269	46.0403	46.0329	45.9669
9-16	45.9606	46.0241	46.0479	46.1100	46.0572	46.0245	46.1043	46.0634
17-24	45.8748	45.9035	45.9653	45.9518	45.9331	45.9861	46.0025	46.0039
25-32	45.9223	45.9933	46.0465	46.0135	46.1171	45.9975	45.8599	45.9712
26-40	46.0661	46.0263	46.0107	46.0488	46.1461	46.1133	45.9831	46.0650
41-48	46.1544	46.1535	46.1162	46.1006	46.0290	46.0372	46.0956	46.1010
Average	**46.0135 (dB)**							

Table IV: MSE values of first 48 watermarked frames of the News.y4m Video

Frames	**MSE at k=5**							
1-8	1.9659	1.6207	1.6212	1.6325	1.6360	1.6310	1.6338	1.6588
9-16	1.6612	1.6371	1.6281	1.6050	1.6246	1.6369	1.6071	1.6223
17-24	1.6943	1.6832	1.6594	1.6646	1.6718	1.6515	1.6452	1.6447
25-32	1.6759	1.6487	1.6287	1.6411	1.6024	1.6471	1.7002	1.6572
26-40	1.6213	1.6362	1.6421	1.6278	1.5917	1.6038	1.6526	1.6217
41-48	1.5887	1.5890	1.6027	1.6085	1.6352	1.6321	1.6104	1.6083
Average	**1.6425(dB)**							



(a)



(b)

Fig.8: (a) Peak Signal to Noise Ratio Chart (b) Mean Square Error chart

Table V. Experimental results of common signal and video processing attacks on News.y4m video

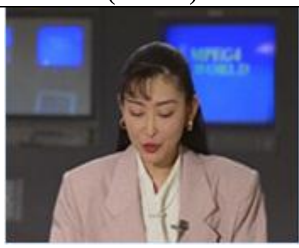
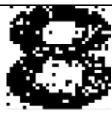
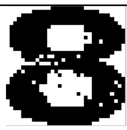
Attacks	Gaussian Noise (0.005)	Salt-Pepper Noise(0.001)	Speckle Noise (0.0004)
Attacked images	 (256×256)	 (256×256)	 (256×256)
PSNR(dB)	29.1268	28.8216	29.1459
Extracted Watermark	 (32×32)	 (32×32)	 (32×32)
NC	0.6551	0.6246	0.7134
Attacks	Gaussian Filter (3×3)	Median Filter (3×3)	Histogram Equalization
Attacked images	 (256×256)	 (256×256)	 (256×256)
PSNR(dB)	29.1346	29.2262	29.1297
Extracted Watermark	 (32×32)	 (32×32)	 (32×32)
NC	0.8442	0.4968	0.9283

Table VI: Results of video watermarking on different test cover videos

Test Carrier Videos	Average PSNR of Watermarked Frames	MSE of Watermarked Frames	Average NC of Extracted watermarks
News	46.0135	1.6425	1
Ice	45.6489	1.7848	1
Crew	46.6249	1.4256	1
Soccer	46.5829	1.4394	1

Results of various attacks are shown in Table V with PSNR and NC values after application of attacks. Table 4 below shows results of watermarking on different test videos namely NEWS, ICE, CREW, SOCCER. It shows average PSNR of watermarked video along with MSE and NC value of extracted watermarks. It can be seen that in all the different test videos PSNR achieved is high and NC value is 1 means extracted watermark is same as that of original watermark.

V. Conclusion

Various video watermarking algorithms have been proposed in spatial and frequency domains but very few algorithms are proposed for color videos. In this paper a frequency domain color video watermarking is proposed by using DCT. Proposed algorithm is blind video watermarking algorithm so at the time of watermark extraction original video frames are not required and recovery of watermark is lossless and having NC value as 1 without any attack. Proposed method is robust and secure because watermark is inserted in only Y component and chrominance component that is u and v are untouched. The proposed method is fairly acceptable and can be used as a non-blind video watermarking algorithm. The performance of proposed algorithm is measured by computing the Peak Signal to Noise Ratio (PSNR) and Normalized correlation (NC). The proposed method achieves average PSNR as 45.98 dB and NC as 1. Experimental results show that proposed method is imperceptible as well as robust against variety of attacks like salt- pepper noise, Gaussian noise, Speckle noise and filtering attacks like Median filter, Gaussian filter etc. Thus, proposed can be used as a non-blind video watermarking algorithm.

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