Combined DCT – CS Theory based Digital Watermarking Technique for Color Images

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ABSTRACT
In this paper, a digital watermarking technique using new signal processing theory called compressive sensing have been implement and analysis for different embedding monochromic watermark images into color cover images. In order to implement of technique, first convert watermark image into its sparse domain and then convert into linear measurement vector using basis matrix and measurement matrix. Then embed this linear measurement vector into color cover image using mid band coefficient based DCT watermarking technique. This paper is also give comparison of this technique for different mid band coefficient with traditional approach of DCT based watermarking technique. Watermarked image have been verified on the parameters of PSNR, BER, SSIM and Payload Capacity. This technique is providing more Payload Capacity compare to traditional approach of DCT based watermarking technique.

General Terms
Digital Watermarking, Copyright Protection

Keywords
Compressive Sensing, Sparse Domain, Payload Capacity, SSIM, Color Image Watermarking

1. INTRODUCTION
Digital Watermarking of multimedia data like images, videos and speech has become very active research area over the last few decades. A general idea of digital watermarking is such that embedding and detection of secure information or message as a watermark from other multimedia information [1, 2]. Digital watermarking is the process of embedding information into cover media that can identify where media came from or who has rights to it [3, 4]. Digital watermarking is used for copyright protection, fingerprinting, copy protection, broadcast monitoring, data authentication, indexing, medical safety and data hiding of multimedia information [1]. When researcher work in digital watermarking area are focus on four different points likes which information is use as cover medium, which information is use as watermark, which approach is use to embed watermark into host medium and how many bits to be embed into host medium in term of payload capacity. Also the size of watermarked data creates bandwidth problem when transmit through communication channel. This paper shows CS theory based color watermarking technique and how CS theory will improve payload capacity of watermarking technique which is already existed.

2. OVERVIEW OF COMPRESSIVE SENSING
When take sample of any signals or images, there are follow conventional approach of Shannon's sampling theory which is said that sampling rate must be at least twice the maximum frequency present in the signal which is called Nyquist rate [5]. In 2006, Candès et al. [6] mathematically proved that the original signal can be reconstructed accurately from part of transform coefficients of its. Based on this theory, Candès and Baraniuk proposed the concept of "Compressive Sensing or sampling theory" [6, 7 and 8]. They are many advantages in compressive sensing theory and its break limitation of Shannon- Nyquist Theorem's sampling theory. It is a necessary condition for application of compressive sensation theory on any signal or image, the signal or image must be sparse on its transform domain. The signal or image can be defined as sparse if and only if when signal or image having few number of non-zero elements [7]. When applied compressive sensing theory of any signal or image, first step is convert signal or image into its sparse domain using different transformation. For any image, few non-zero elements or sparse elements can be get using transformation like discrete Fourier transform, discrete cosine transform and discrete wavelet transform [13].

3. PROPOSED APPROCH FOR WATERMARKING TECHNIQUE
In this paper, watermarking technique is demonstrated using combination of compressive sensing theory and mid band coefficient of DCT for different still color images. The new approach for watermarking technique is shown is figure 1 where cover image is color and secure watermark image is monochromic. This watermarking technique is divided into four different steps which are described below.

3.1 Compressive Sensing Procedure
In this paper, Discrete Cosine Transform (DCT) is used for construct orthogonal transformation matrix. Then generate measurement matrix using random seed which is same for encoder and decoder. Finally generate linear measurement vector using orthogonal transformation matrix, measurement matrix and original watermark image. This approach described in below steps:

- Apply Discrete Cosine Transform (DCT) on monchromic watermark image and chose non-zero elements of sparse domain for generation of transformation matrix.
- Then generate measurement matrix using length of non zero elements of sparse coefficients and sampling coefficients which is less than 1.

- Finally convert monochromic watermark into linear measurement vector using below formula:

  Watermark linear measurement = measurement matrix × transformation matrix × original image (1)

  $$x = \psi \times f \quad (2)$$

  $$Y_m = \phi \times x \quad (3)$$

$$Y_m = \phi \times \psi \times f \quad (4)$$

In formula (3, 4), Ψ is represent orthogonal transformation matrix, *Ym* is represent linear measurement vector of watermark, ϕ is the measurement matrix which is same for construct side and recovery side, *f* is the original watermark image.

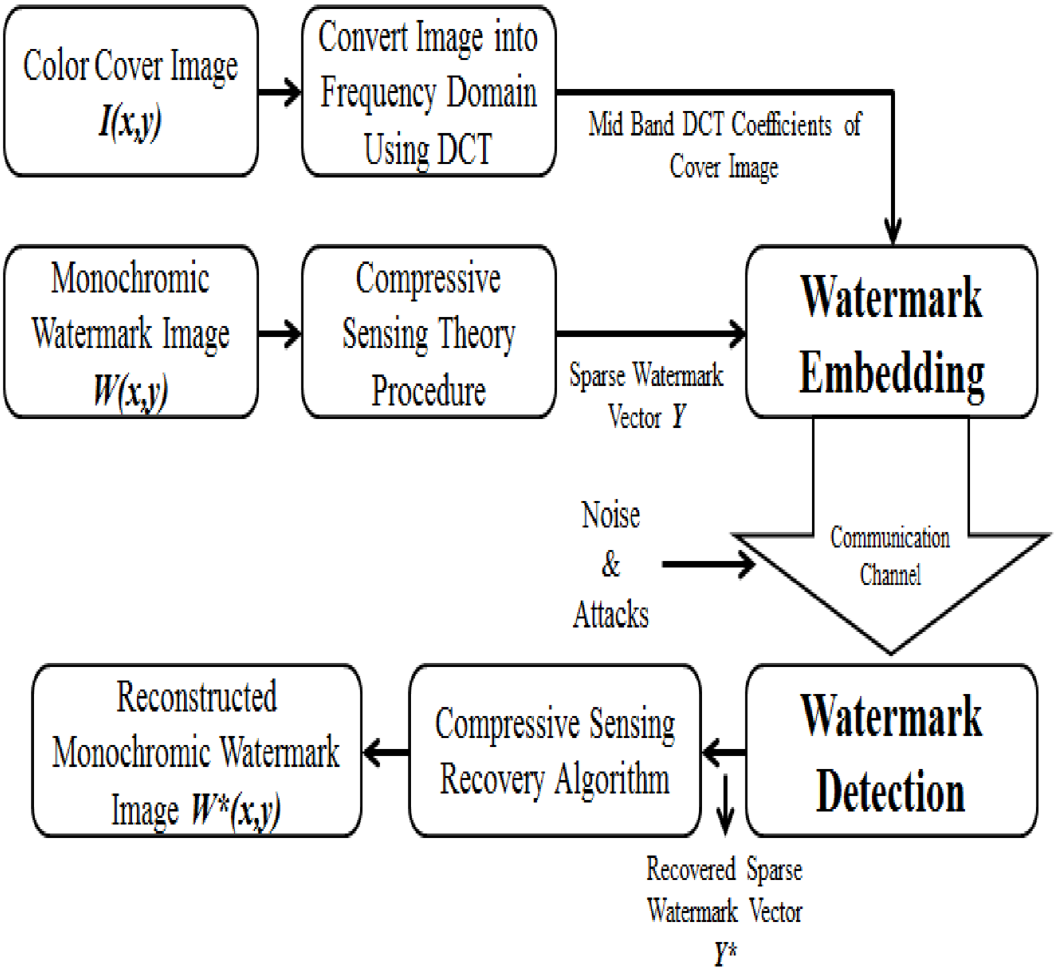


Figure 1: Block Diagram of Color Image Watermarking Using Combined Mid Band DCT Coefficients – CS Theory Procedure

3.2 Watermark Embedding

Ingemar J. Cox and other researchers described modified mid band DCT coefficients based watermarking technique for copyright protection of images [1, 9, 10 and 11]. Using this technique for embedding linear measurement vector into cover color image because DCT allows an image to be broken up into different frequency bands like low, middle and high. The middle frequency bands are chosen because low frequencies coefficients having most visual information of image and high frequencies coefficients have vulnerable against attacks likes compression and noise. Then two locations X_i (u_1, v_1) and X_i (u_2, v_2) are chosen from the F_M region for comparison. If two locations are chosen such that they have identical quantization values such that any factor of one coefficient will scale to other by the same values. The robustness of the watermark can be improved by gain factor k which constant value and value is chosen such that $X_i(u_1, v_1) - X_i(u_2, v_2) > k$ [1]. Coefficients that do not meet these criteria are modified though the use of random linear measurement vector to then satisfy the relation. The steps of embedding linear measurement vector into color cover image are described below [1 and 15]:

- Decompose color cover image into 8×8 block and calculate DCT of each block.
- For each block

  If linear measurement vector value is zero

  If dct_block (5, 2) < dct_block (4, 3)

      Swap them

  Else If (5, 2) > (4, 3)

      Swap them

  If (5, 2) – (4, 3) < k

(5, 2) = (5, 2) + k/2;

(4, 3) = (4, 3) - k/2;

Else

(5, 2) = (5, 2) - k/2;

(4, 3) = (4, 3) + k/2;

Then move to next block.

- Finally take inverse DCT and generate color watermarked image.

3.3 Watermark Detection

The steps of extracting linear measurement vector into color cover image are described below [1, 15]:

- For extraction, the watermarked image is broken up into same 8×8blocks and calculate DCT of each block.
- For each block

  If dct_block (5, 2) > dct_block (4, 3)

  Message = non-zero elements;

  Else

  Message = zero value;

- Then move to next block.
- Finally extracted linear measurement vector from watermarked image.

3.4 Reconstruction of Watermark Image from Linear Measurement Vector using OMP Algorithm

Next step is reconstructing secure monochromic watermark image from extracted linear measurement vector. For this purpose, Orthogonal Matching Pursuit (OMP) algorithm are chose because of easy to implement and faster compare to other CS reconstruction algorithm [12, 13]. OMP algorithm is apply on extracted linear measurement vector using measurement matrix and length of non-zero sparse elements and taken inverse DCT to reconstruct secure watermark image at detector side.

4. DISCUSSION OF QUANTITATIVE MEASURES

The quantitative measures likes Bit Error Rate (BER), Peak Signal to Noise Ratio (PSNR), structural similarity index measures (SSIM) and Payload Capacity percentage can be used to evaluate for watermarking technique and comparison this watermarking with existed watermarking technique base on DCT domain [2, 14]. The watermark image resistance against different attacks is defined as robustness and can be measured by the Bit Error Rate (BER) which is defined as the ratio of total number of extracted bits to the total number of embedded watermark bits [2].

$$BER = \frac{TotalNo.ofExtractedWatermarkBits}{TotalNo.ofEmbeddedWatermarkBits} \qquad (5)$$

The SNR and PSNR are used for quality of measurement of watermarked image. These parameters are described imperceptibility of watermarking technique against different attacks [2]. Mean Square Error (MSE) value between watermarked image and cover image is required to calculate PSNR value which is given in equation number 6. For color image, the MSE value is taken over all pixels values of each individual channel and is average with the number of color channels. The calculate PSNR and SNR value using equation number 7 and 8 respectively [2].

$$MSE = \frac{1}{M \times N} \sum_{x=1}^{M} \sum_{y=1}^{N} \left\{ I(x,y) - I^*(x,y) \right\}^2 \qquad (6)$$

$$PSNR_{dB} = 10 \times \log_{10} \left(\frac{Max^2}{\sqrt{MSE}} \right) \qquad (7)$$

$$SNR_{dB} = 10 \times \log_{10} \left(\frac{\sum_{x=1}^{M} \sum_{y=1}^{N} I^{*2}(x,y)}{\sum_{x=1}^{M} \sum_{y=1}^{N} \left\{ I(x,y) - I^*(x,y) \right\}^2} \right) \qquad (8)$$

Where, *I(x, y)* is original cover image and $I^*(x, y)$ is watermarked image.

The structural similarity index measures (SSIM) are used for similarity between two images using below equation [16]:

$$SSIM(W,W^*) = \frac{\sum_{i=1}^{N} W(x,y) \times W^*(x,y)}{\sqrt{\sum_{i=1}^{N} W_{(x,y)}^2} \times \sqrt{\sum_{i=1}^{N} W_{(x,y)}^{*2}}} \qquad (9)$$

Where, *N* is no. of pixels of watermark, *W(x, y)* is original watermark image and $W^*(x, y)$ is extracted watermark image.

In this paper, SSIM is use for find similarity between original watermark image and reconstructed watermark image which is acceptable for human perception. The payload capacity percentage is use for find how many bits can be embed into cover medium and defined by ratio of bytes of embed data and bytes of cover medium which is given below equation [2]:

$$PC(\%) = BytesofHiddenData / BytesofHostMedium \qquad (10)$$

5. EXPERIMENTAL RESULTS

For the evaluation and comparison of the techniques, experiments conducted on 256×256, 512×512 color cover images and 50×20, 64×64, 256×256 monochromic watermark images which is shown in figure 2 and 3 respectively.

(a) (b)

Figure 2: Different Color Cover Image (a) Lena (256×256) (b) Peppers (512×512)

Here DCT function of MATLAB used for generate linear measurement vector for monochromic watermark image. Then quantitative analysis of CS Theory based watermarking technique using comparison of mid band DCT coefficients in frequency domain [1, 9, 10 and 11] and generate watermarked image for applying different attacks likes JPEG Compression, Rotation and adding noise in watermarked image for robustness and imperceptibility check.

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

Figure 3: Different Monochromic Watermark Image (a) Face (256×256) (b) Flower (256×256) (c) Circle (64×64) (d) Text (50×20)

For evaluation of technique, take lena.bmp image as cover image and text.bmp image as watermark image and generate watermarked image using comparison mid band DCT coefficients technique [1, 9, 10 and 11] for different coefficients like 50 and 100. The resultant image using DCT coefficients value 50 is shown in figure 4. The results are summarized in table 1 where average value of MSE is 30.55; average value of PSNR is 67.33 and average value of SSIM is 0.98 for different attack. The payload capacity for these images is 1.53.

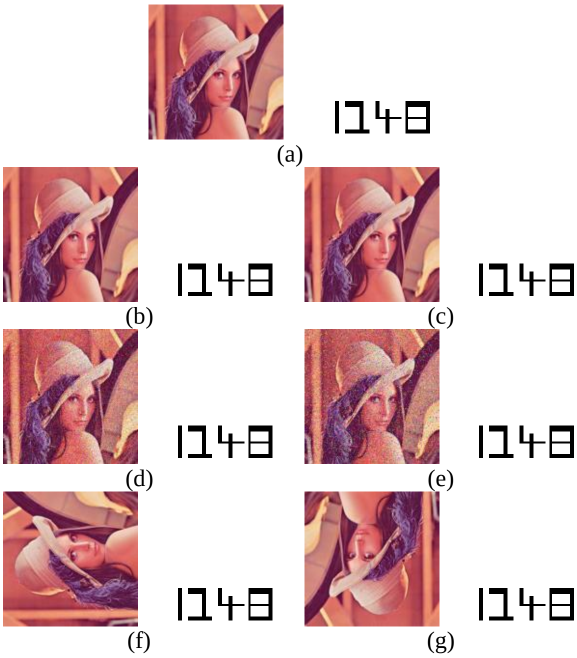


Figure 4: Watermarked Image and Recover Watermark Image using Comparison of Mid band DCT Coefficients and gain factor k = 50

(a) Original Watermarked Image and Recover Watermark Image
(b) JPEG Compression attack using Q = 80
(c) JPEG compression attack using Q = 60
(d) Gaussian Noise attack
(e) Salt & Pepper Noise attack
(f) Rotation attack using degree = 90
(g) Rotation attack using degree = 180

Then take peppers.bmp image as cover image and circle.bmp image as watermark image and generate watermarked image using comparison mid band DCT coefficients technique for different coefficients like 50 and 100. The resultant image using DCT coefficients value 100 is shown in figure 5. The results are summarized in table 2 where average value of MSE is 32.84; average value of PSNR is 66.65 and average value of SSIM is 0.975 for different attack. The payload capacity for these images is 1.56.

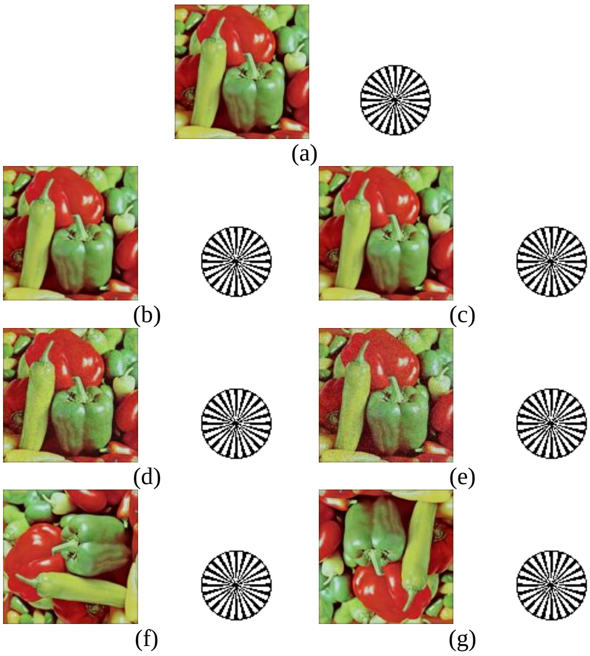
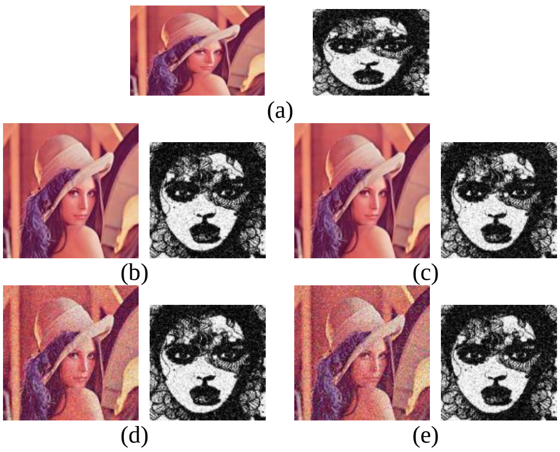
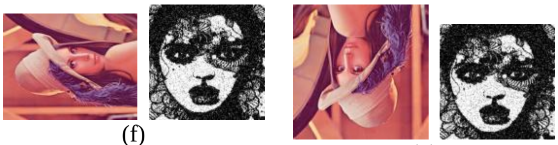


Figure 5: Watermarked Image and Recover Watermark Image using Comparison of Mid band DCT Coefficients and gain factor k = 100

(a) Original Watermarked Image and Recover Watermark Image
(b) JPEG Compression attack using Q = 80
(c) JPEG compression attack using Q = 60
(d) Gaussian Noise attack
(e) Salt & Pepper Noise attack
(f) Rotation attack using degree = 90
(g) Rotation attack using degree = 180

Then take lena.bmp image as cover image and face.bmp image as watermark image and generate watermarking image using combined Compressive Sensing theory and comparison mid band DCT coefficients technique for different coefficients like 50 and 100. The resultant image using DCT coefficients value 50 is shown in figure 6. The results are summarized in table 3 where average value of MSE is 30.55; average value of PSNR is 67.33 and average value of SSIM is 0.92 for different attack. The payload capacity for these images is 100.





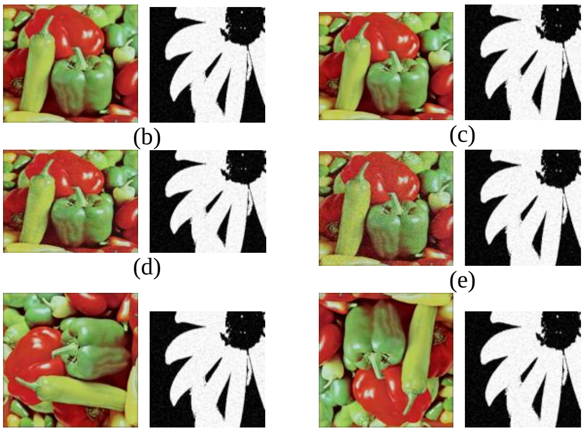
(f) (g)

Figure 6: Watermarked Image and Recover Watermark Image using Comparison of Mid band DCT Coefficients – CS Theory and gain factor k = 50

(a) Original Watermarked Image and Recover Watermark Image
(b) JPEG Compression attack using Q = 80
(c) JPEG compression attack using Q = 60
(d) Gaussian Noise attack
(e) Salt & Pepper Noise attack
(f) Rotation attack using degree = 90
(g) Rotation attack using degree = 180

Also take peppers.bmp image as host image and flower.bmp image as watermark image and generate watermarked image using comparison mid band DCT coefficients technique for different coefficients like 50 and 100. The resultant image using DCT coefficients value 100 is shown in figure 7. The results are summarized in table 4 where average value of MSE is 32.55; average value of PSNR is 66.76 and average value of SSIM is 0.99 for different attack. The payload capacity for these images is 25.

(a)



(b) (c) (d) (e) (f) (g)

Figure 7: Watermarked Image and Recover Watermark Image using Comparison of Mid band DCT Coefficients – CS Theory and gain factor k = 100

(a) Original Watermarked Image and Recover Watermark Image
(b) JPEG Compression attack using Q = 80
(c) JPEG compression attack using Q = 60
(d) Gaussian Noise attack
(e) Salt & Pepper Noise attack
(f) Rotation attack using degree = 90
(g) Rotation attack using degree = 180

Table 1Quantitative Measures of Comparison Mid Band DCT Coefficient based Watermarking Technique for lena.bmp as cover image and text.bmp as watermark image using gain factor k = 50

Results	No Attack	JPEG Attack		Gaussian Attack	Salt & Pepper Attack	Rotation Attack	
		Q = 80	Q = 60	μ = 0, σ = 0.02	Density = 0.1	Degree = 90°	Degree = 180°
Computation Time (Sec)	1.57	3.23	3.31	3.01	3.18	2.98	3.01
MSE	16.94	17.81	18.22	30.46	34.95	47.04	48.44
PSNR (dB)	71.68	71.24	71.05	66.59	65.39	62.81	62.56
SNR (dB)	33.42	28.02	26.42	12.39	10.35	6.45	6.13
SSIM	1	1	1	1	1	1	1
BER	0	0	0	0	0	0	0
Payload Capacity (%)	1.53						

Table 2 Quantitative Measures of Comparison Mid Band DCT Coefficient Watermarking Technique for peppers.bmp as cover image and circle.bmp as watermark image using gain factor k = 100

Results	No Attack	JPEG Attack		Gaussian Attack	Salt & Pepper Attack	Rotation Attack	
		Q = 80	Q = 60	μ = 0, σ = 0.02	Density = 0.1	Degree = 90°	Degree = 180°
Computation Time (Sec)	4.43	6.13	6.33	6.01	6.33	6.18	5.97
MSE	19.71	19.46	19.72	31.99	36.38	51.09	51.51
PSNR (dB)	70.37	70.48	70.36	66.16	65.05	62.09	62.02
SNR (dB)	27.5	29.49	27.99	11.53	9.16	4.04	4.2
SSIM	0.975	0.975	0.975	0.975	0.975	0.975	0.975
BER	0.22	0.22	0.22	0.22	0.22	0.22	0.22
Payload Capacity (%)	1.56						

Table 3. Quantitative Measures of Combined CS Theory - Comparison Mid Band DCT Coefficient based Watermarking Technique for lena.bmp as cover image and face.bmp as watermark image using gain factor k = 50

Results	No Attack	JPEG Attack		Gaussian Attack	Salt & Pepper Attack	Rotation Attack	
		Q = 80	Q = 60	μ = 0, σ = 0.02	Density = 0.1	Degree = 90°	Degree = 180°
Computation Time (Sec)	122.63	126.45	122.38	123.35	122.38	132.44	123.5
MSE	16.95	17.81	18.23	30.44	34.95	47.04	48.45
PSNR (dB)	71.68	71.25	71.05	66.59	65.39	62.81	62.56
SNR (dB)	33.33	28.02	26.39	12.39	10.37	6.45	6.13
SSIM	0.92	0.92	0.93	0.92	0.92	0.92	0.92
BER	0.07	0.11	0.31	0.19	0.26	0.52	0.5
Payload Capacity (%)	100						

Table 4. Quantitative Measures of Combined CS Theory - Comparison Mid Band DCT Coefficient based Watermarking Technique for peppers.bmp as cover image and flower.bmp as watermark image using gain factor k = 100

Results	No Attack	JPEG Attack		Gaussian Attack	Salt & Pepper Attack	Rotation Attack	
		Q = 80	Q = 60	μ = 0, σ = 0.02	Density = 0.1	Degree = 90°	Degree = 180°
Computation Time (Sec)	110.19	110.49	103.94	106.36	108.42	110.4	103.43
MSE	19.71	19.45	19.73	31.98	36.39	51.09	51.51
PSNR (dB)	70.37	70.48	70.36	66.16	65.04	62.09	62.03
SNR (dB)	27.5	29.53	27.99	11.54	9.14	4.04	4.2
SSIM	0.99	0.99	0.99	0.99	0.99	0.99	0.99
BER	0.16	0.13	0.12	0.15	0.18	0.55	0.48
Payload Capacity (%)	25						

Form results, below observation are made:

1. This combined DCT – CS theory based watermarking technique having doesn't effect on quality of watermarked image based on higher PSNR values.
2. This combined DCT – CS theory based watermarking technique having more Payload Capacity compare to existed watermarking technique in frequency domain.
3. This combined DCT – CS theory based watermarking technique having more computation time compare to existed watermarking technique in frequency domain.

6. CONCLUSIONS

This paper is based on quantitative analysis of combined new signal acquisition theory called Compressive Sensing (CS) theory and comparison of mid band DCT coefficients for Color Image Watermarking. The results shows that combined DCT – CS theory based watermarking technique is quite good as compared to existed DCT watermarking technique in term of payload capacity of embedding data. This also fact is evident from the average SSIM and Payload Capacity (in percentage) values of 0.95 and 62.5 of Combined DCT – CS theory based watermarking technique with compare to average SSIM and Payload Capacity (in percentage) values of 1 and 1.54 of existed DCT based watermarking technique. This technique is also robust against different attack which is indicate by average BER value is near 0.2 with compare to average BER value of existed technique is 0.22. This technique is use for embed gray scale watermark image into color image and for data protection over noisy communication channel.

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