Combined DWT-DCT Digital Image Watermarking for Improving Imperceptibility and Robustness

Choodarathnakara A L and Manjunatha A

Government Engineering College, Kushalnagar, Karnataka, INDIA

Sneha K K and Chandana V A

Government Engineering College, Kushalnagar Karnataka, INDIA

ABSTRACT

The combined DWT-DCT technique presented in this paper offers better imperceptibility, reduces execution time and improves robustness in comparison to Discrete Wavelet Transform (DWT) and Discrete Cosine Transform (DCT) digital watermarking techniques. The proposed DWT-DCT hybrid technique uses 2-levels DWT and DCT subsequently. Then it spreads the watermark with PN-sequence with a certain key in the DCT transform after decompose the host image with DWT in level 2 to generate the final watermarked image. Such combination allowed us to exploit the individual advantages derivable from the separate use of the DWT and DCT methods. Results of DWT-DCT showed improved performance in terms Peak-Signal-to-Noise-Ratio (PSNR) and Normalized Correlation (NC) than that of DWT and DCT alone itself. Therefore, the proposed DWT-DCT technique ensures additional imperceptibility and robustness against Gama Correction and Histogram Equalization.

Keywords

Digital Image; Watermarking; DCT; DWT.

1. INTRODUCTION

Image watermarking is the process of inserting hidden information in an image by introducing modifications of minimum perceptual disturbance. Robustness, perceptual transparency, capacity and blind watermarking are four essential factors to determine quality of watermarking scheme. Image watermarking system consists of two main processes namely, the embedding process and extracting process. During the embedding process, the watermark data is embedded into the multimedia data known as watermarked data. In the extracting process, embedded watermark data is extracted from the watermarked data and recover the original information multimedia data. The fundamental requirements in most digital watermarking schemes are; invisibility: the embedded watermark should be perceptible to ensure the optimal image quality after the procedure of watermark embedding; robustness: the embedded watermark should be hard to remove, and it could be restored even though the watermarked image is altered or changed by a certain type of attack. If the estimated watermark is same as that of original watermark, that proves the authentication of data. During the sending of the watermarked data on network, the attacker may destroy the data and change in the data can be detected by comparing the extracted watermark with the original watermark.

Ahmed S. Salama and Mohamad Amr Mokhtar [1] proposed IMD-WC-T technique guarantees additional imperceptibility, reduced execution time and gave more robustness against Gama Correction and Histogram Equalization. Imperceptibility (PSNR in dB) is 41.28 and for DWT, DCT, HFT is 49.6, 29.8, and 37.0149 respectively. Robustness is at Gama Correction value of 0.5. Zhi Zhang et al. [2] achieved robustness of the scheme proposed and also evaluated under different attacks which include salt and pepper noise, Gaussian noise, and other attacks. The experimental results are conducted to verify the effect of false positive problem which exists in most watermarking. The PSNR achieved is 102.2821, 96.2615, 102.2821 for image capacity of 32×32, 64×64, 128×128.

Ritu Gill and Rishi Soni [3] have implemented robust watermarking by adding noise and attacks for better quality of results. It was more improved by embedding coefficients in different areas and more testing was performed on digital image watermarking for better protection by applying more attacks such as tempering, cropping etc. Suresh Kuri and Gururaj Kulkarni [4] proposed the inverse transformation that will give the extracted watermark. Robustness test is carried out with various attacks on the different images and calculation of performance metrics. The results show better imperceptibility and robustness to common image processing attacks. For Gaussian noise PSNR is 82.1432 and with Salt & Pepper noise PSNR is 86.2013. For JPEG compression PSNR is 81.1129 for 25% and PSNR is 75.5068 for 50%. The high PSNR value demonstrates that the algorithm has better imperceptibility.

M Veni and T Meyyapan [5] presented invisible quality of watermarked image with higher PSNR value of 47.2724 as compared to existing method. The PSNR of Peppers is 47.2717 for NC is 1. This achieves the perceptual quality, strength and protection. Chunhua and Jingbing Li [6] proposed watermark scheme for medical images which has strong robustness, and can embed much more data compared with the existing watermarking techniques. Compression Quality of PSNR (dB) for 80% is 29.27.

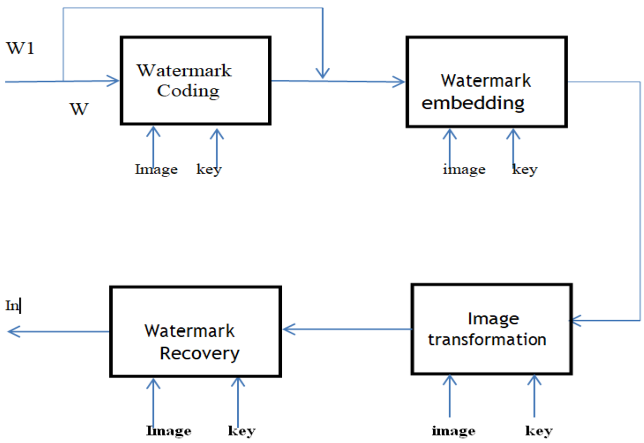
Zid Yong Meng et al. [7] implemented to make the watermark more robust, embed the watermark into the low-frequency coefficients of DCT effective and robust for noise jamming, filtering, cutting and JPEG compression. Kaushik Deb et al. [8] proposed that the weighted correction is also used to improve the imperceptibility. The extracting procedure reverses the embedding operations without the reference of the original image. The experimental results show that the proposed algorithm apparently preserves superior image quality and robustness under various attacks such as JPEG compression, cropping, sharping, and contrast adjustments.

Dimple Bansal and Manish Mathuria [9] proposed the watermarking scheme by combining the features of DWT and DCT. Red color component of the image is used for applying the DWT for embedding the watermark. After this, the DCT is implemented on the 8X8 block of the image. Using this functionality more secure and robust image was found. U.S.N. Raju et al. [10] have introduced hybrid watermarking technique which combines DCT and DWT to produce the watermarked image.

The main objective of this paper is to provide the protection for digital multimedia data from illegal issues by proposing combined DWT-DCT watermarking scheme. The second objective is to improve the fundamental requirements in digital watermarking like imperceptibility and robustness.

2. DIGITAL IMAGE WATERMARKING SCHEMES

Based on the domain in which watermark is inserted, these techniques are divided into two broad categories namely Spatial and Frequency Domain method. Embedding the watermark into spatial domain component of the original is straight forward method. For example LSB scheme in spatial domain modifies lower order bits of cover image to embed the watermark. It has the advantage of low complexity and easy implementation but problem with this scheme is low security. Frequency domain schemes are more persistent to general image processing than spatial domain algorithm. In frequency domain, the watermark is embedded into transform coefficients of host image after applying DCT and DWT transform. As compared to spatial domain watermarking methods, frequency domain watermarking methods are more complex and have high robustness against various attacks. If the watermark is embedded in perceptually most significant components, the scheme would be robust to attacks but the watermark may be difficult to hide. On the other hand, if the watermark is embedded in perceptually insignificant components, it would be easier to hide the watermark but the scheme may be less resilient to attacks. The Fig 1 represents general digital image watermarking framework and Fig 2 shows the single level decomposition of DWT based watermarking scheme.



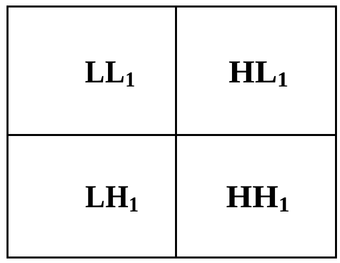


Fig 1: Digital Image Watermarking Framework **Fig 2: Single level Decomposition of DWT**

2.1 DCT-Domain Watermarking

A DCT is a Fourier related transform similar to Discrete Fourier Transform (DFT) but uses only real numbers. DCTs are equivalent to DFTs of roughly twice the length, operating on real data with even symmetry (since Fourier transform of real and even function is real and even). Using DCT, an image is easily split into pseudo frequency bands and is inserted into middle band frequencies because there is a conflict between robustness and transparency.

2.2 DWT-Domain Watermarking

2D-DWT method is used to decompose the image into four sub bands namely LL, LH, HL & HH where LL-Low frequency band, LH-Horizontal high frequency band, HL-Vertical high frequency band and HH-Diagonal high frequency band. Since, wavelets reflect the anisotropic properties of HVS more precisely. Watermark detection at lower resolutions is computationally effective because at every successive resolution level there are few frequency bands involved. As LL band contains largest wavelet coefficients, scale factor is chosen accordingly up to 0.05 for LL and 0.005 for other bands. For this pair of values, there is no degradation in watermarked image. High resolution sub-bands help to easily locate edge and texture patterns in an image. Wavelet coding schemes are especially suitable for applications where scalability and tolerable degradation are important.

2.3 DWT-DCT Based Watermarking

This approach utilizes the wavelet coefficients of the cover image to embed the watermark. Any of the three high frequency sub bands of wavelet coefficients can be used to watermark the image. The DCT coefficients along with the wavelet coefficients are calculated to singular values. The singular values of the cover image and watermark are added to form the modified singular values of the watermarked image. Then the inverse DCT transform is applied followed by the inverse DWT. Watermark embedded using this algorithm as shown in Fig 3 is highly imperceptible and is robust against all sorts of attacks. The proposed method was found to satisfy all the requisites of an ideal watermarking scheme such as imperceptibility or fidelity, robustness and good capacity. Also, the method is robust against different kinds of mentioned attacks.

3. PROPOSED DWT-DCT WATERMARKING PROCESS

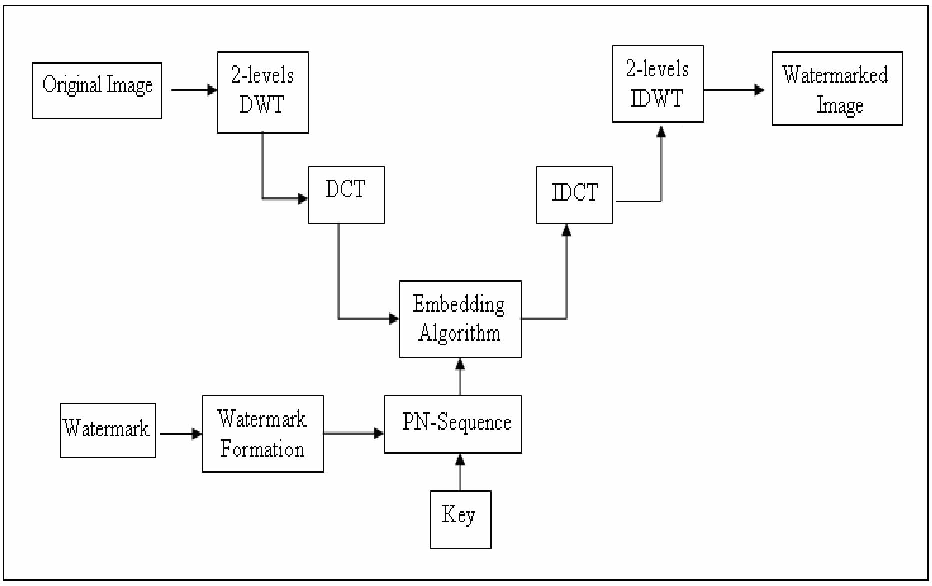


Fig 3: Combined DWT-DCT Watermark Embedding Procedure

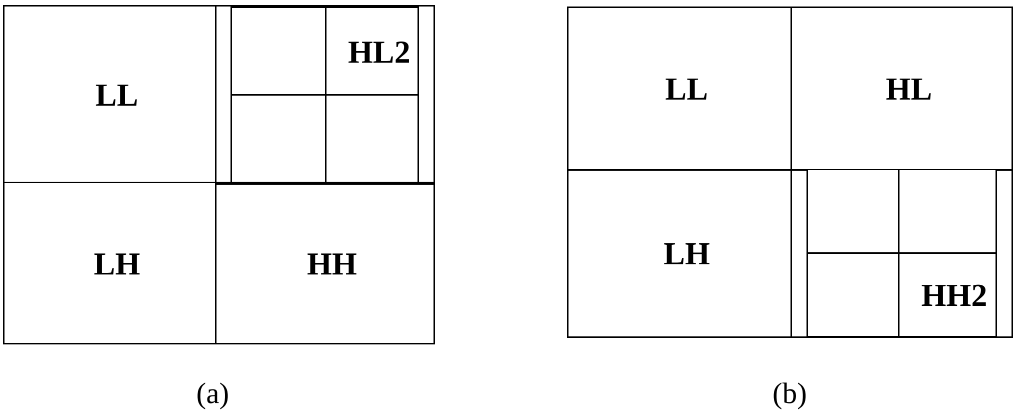


Fig 4: (a) Multi-resolution DWT-HL1 sub-bands of the original image

(b) Multi-resolution DWT-HH1 sub-bands of the original image

The Proposed algorithm combines advantages of DCT and DWT techniques. The Fig 3 shows combined DWT-DCT watermark embedded process and the step by step procedure is enumerated as follows:

3.1 Combined DWT-DCT Watermark Embedding Algorithm

Step 1: Apply DWT to decompose the cover host image into four non-overlapping multi-resolution sub-bands: LL1, HL1, LH1 and HH1.

Step 2: Apply DWT again to sub-band HL1 to get four smaller sub-bands and choose the HL2 sub-band as shown in Fig 4(a). Or apply DWT to sub-band HH1 to get four smaller sub-bands and choose the HH2 sub-band as shown in Fig 4(b).

Step 3: Divide the sub-band HL2 (or HH2) into 4 x 4 blocks.

Step 4: Apply DCT to each block in the chosen sub-band (HL2 or HH2) .

Step 5: Re-formulate the grey-scale watermark image into a vector of zeros and ones.

Step 6: Generate two uncorrelated pseudo-random sequences. One sequence is used to embed the watermark bit 0 (PN_0) and the other sequence is used to embed the watermark bit 1 (PN_1). Number of elements in each of the two pseudo-random sequences must be equal to the number of mid-band elements of the DCT transformed DWT sub-bands.

Step 7: Embed the two pseudo-random sequences PN_0 and PN_1 with a gain factor in the DCT transformed 4x4 blocks of the selected DWT sub-bands of the host image.

Embedding is not applied to all the coefficients of the DCT block, but only to the mid-band DCT coefficients. If we denote ***X*** as the matrix of the mid band coefficients of the DCT transformed block, then embedding is done as follows:

If the watermark bit is 0 then

X '= X + _ * PN_0

otherwise,

if the watermark bit is 1 then,

X '= X + _ * PN_1

Step 8: Apply inverse DCT to each block after its mid-band coefficients have been modified to embed the watermark bits as described in the previous step.

Step 9: Apply the inverse DWT on the DWT transformed image, including the modified sub-band to produce the watermarked host image.

3.2 DWT-DCT Watermark Extraction Algorithm

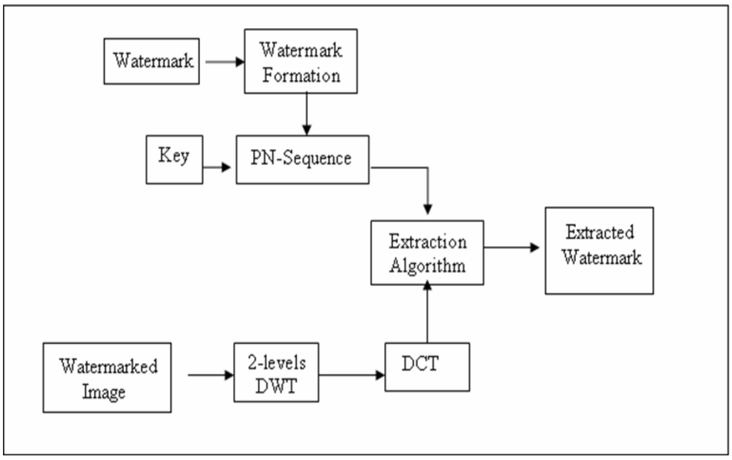


Fig 5: Combined DWT-DCT watermark extraction procedure

The Fig 5 depicts the combined DWT-DCT watermark extraction procedure and here the original host image is not required to extract the watermark. These steps are elucidated as follow:

Step 1: Apply DWT to decompose the watermarked image into four non-overlapping multi-resolution sub bands: LL1, HL1, LH1 and HH1.

Step 2: Apply DWT to HL1 to get four smaller sub-bands and choose the sub-band HL2, as shown in Fig 4(a) Or apply DWT to the HH1 sub-band to get four smaller sub-bands and choose the HH2 sub-band as shown in Fig 4(b).

Step 3: Divide the sub-band HL2 (or HH2) into 4X4 blocks.

Step 4: Apply DCT to each block in the chosen sub-band (HL2 or HH2) and extract the mid- band coefficients of each DCT transformed block.

Step 5: Regenerate the two pseudo-random sequences (PN_0 and PN_1) using the same sequence used in the watermark embedding procedure.

Step 6: For each block in the sub-band HL2 (or HH2), calculate the correlation between the mid-band coefficients and the two generated pseudo-random sequences (PN_0 and PN_1). If the correlation with the PN_0 was higher than the correlation with PN_1, then the extracted watermark bit is considered as 0, otherwise the extracted watermark is considered as 1.

Step 7: finally reconstruct the watermark using the extracted watermark bits, and compute the similarity between the original and extracted watermarks.

4. EXPERIMENTAL RESULT ANALYSIS

We have used MATLAB and have taken various input images on which a watermark has been embedded. Input image and watermark image is as shown. Then we have achieved a watermarked image with the help of the algorithm as described in the paper and eventually we have extracted the watermark. Also, the PSNR value and the NC values of the various images are calculated.

4.1 Peak Signal to Noise Ratio (PSNR)

The heart measure here is the numerical PSNR values obtained using each of the four methods under analysis (and also the visual quality of the watermarked images themselves). But due to brevity the inherent distortions in the watermarked versions obtained using each of the four methods are not easily visible, hence we constrain the comparison to the numerical PSNR values. It is a metric which is used regularly to find the quality of the watermarked image. It by considering the following formula,

$$PSNR = 10\log_{10}\frac{255^2}{MSE} \quad (1)$$

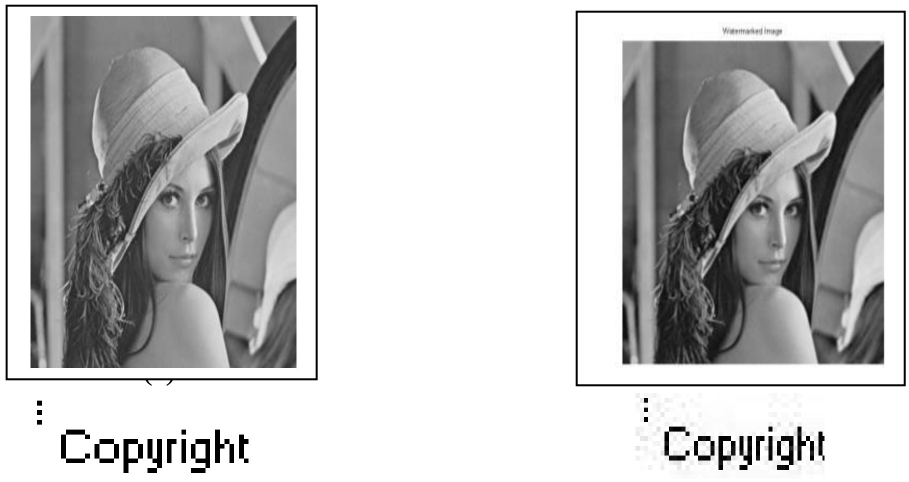
$$MSE = \frac{1}{M*N}\sum\sum(error.*error) \quad (2)$$

4.2 Normalized Correlation (NC)

It is one of the metrics used to find the quality of extracted watermark image with respect to the original watermark image.

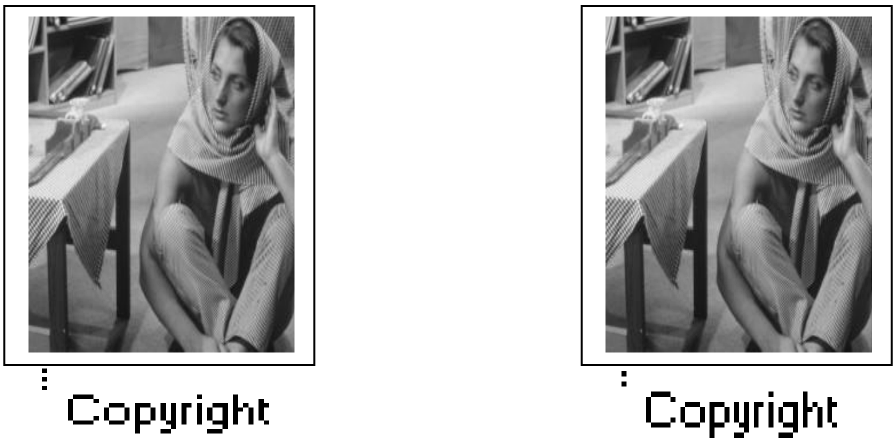
$$NC = \frac{\sum_{i=1}^{M_1}\sum_{j=1}^{M_2} w(i,j)\cdot w'(i,j)}{\sqrt{\sum_{i=1}^{M_1}\sum_{j=1}^{M_2}[w(i,j)]^2}\sqrt{\sum_{i=1}^{M_1}\sum_{j=1}^{M_2}[w'(i,j)]^2}}$$

Here, w(i, j) is the original watermark, w'(i, j) is the extracted watermark.



(b) (d)

Fig 6 (a) Original Input Lena Image for Watermarking (b) The Watermark Image (c) Invisible Watermarked Image (d) Watermark Recovered from Watermarked Image

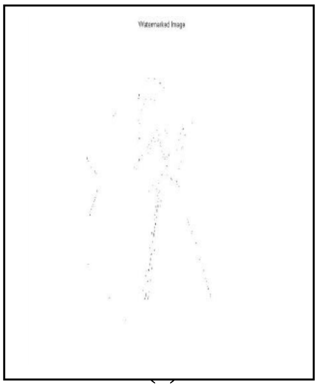


(b) (d)

Fig 7 (a) Original Input Barbara Image for Watermarking (b) The Watermark Image (c) Invisible Watermarked Image (d) Watermark Recovered from Watermarked Image

Fig 6(a) is the original input Lena image used for watermarking (lena.jpg). Fig 6(b) is the watermark copyright image data used for Lena image during embedding process (copyright.bmp). Fig 6(c) is the output image that contains hidden watermark i.e., the output after embedding process called watermarked image (wlena.jpg). Fig 6(d) is the watermark recovered from watermarked Lena image i.e., the output of the extraction process called original watermark information (Re_wlena.jpg).

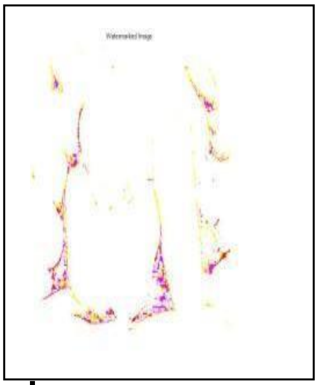
Fig 7(a) is the original input Barbara image used for watermarking (barbara.jpg). Fig 7(b) is the watermark copyright image data used for Barbara image during embedding process (copyright.bmp). Fig 7(c) is the output image that contains hidden watermark i.e., the output after embedding process called watermarked image (wbarbara.jpg). Fig 7(d) is the watermark recovered from watermarked Barbara image i.e., the output of the extraction process called original watermark information (Re_wbarbara.jpg).



(b)

(d)

Fig 8 (a) Original Input Cameraman Image for Watermarking (b) The Watermark Image (c) Invisible Watermarked Image (d) Watermark Recovered from Watermarked Image



(b)

(d)

Fig 9 (a) Original Input Veg Image for Watermarking (b) The Watermark Image (c) Invisible Watermarked Image (d) Watermark Recovered from Watermarked Image

Fig 8(a) is the original input Cameraman image used for watermarking (cameraman.jpg). Fig 8(b) is the watermark copyright image data used for Cameraman image during embedding process (copyright.bmp). Fig 8(c) is the output image that contains hidden watermark i.e., the output after embedding process called watermarked image (wcameraman.jpg). Fig 8(d) is the watermark recovered from watermarked Cameraman image i.e., the output of the extraction process called original watermark information (Re_wcameraman.jpg).

Fig 9(a) is the original input Veg image used for watermarking (veg.jpg). Fig 9(b) is the watermark copyright image data used for Veg image during embedding process (copyright.bmp). Fig 9(c) is the output image that contains hidden watermark i.e., the output after embedding process called watermarked image (wveg.jpg). Fig 9(d) is the watermark recovered from watermarked Veg image i.e., the output of the extraction process called original watermark information (Re_veg.jpg).

Table I. Peak Signal to Noise Ratio (PSNR) between Original and Watermarked Images

Sl. No.	Original Image	Watermarked Image	PSNR
1.	Lena.jpg	wlena.jpg	65.6653
2.	Barbara.jpg	wbarbara.jpg	65.3709
3.	Cameraman.jpg	wcameraman.jpg	66.5132
4.	Veg.jpg	wveg.jpg	68.4147

Table II. Normalized Correlation (NC) between Original and Watermarked Images

Sl. No.	Original Image	Watermarked Image	Normalized Correlation
1.	Lena.jpg	wlena.jpg	0.9431
2.	Barbara.jpg	wbarbara.jpg	0.9177
3.	Cameraman.jpg	wcameraman.jpg	1
4.	Veg.jpg	wveg.jpg	0.9683

Table I shows PSNR values for digital watermarking using combined DWT-DCT technique which decides about the image quality. The PSNR value is more than the range 30 to 60, so good quality of watermarked image is found, which proves imperceptibility of water mark in the watermarked images. Table II provides correlation coefficient values calculated between original and watermarked image. This finds out the similarity of original image with watermarked image, which would be within 0 to 1. The results obtained for individual images ensure robustness in the watermark since it is more than 0.9 i.e., same as that of original image even though various attacks from hackers during transmission. Thus robustness of the watermarking scheme helps in easy identification of the watermark image data after recovery.

5. CONCLUSION

In this research work, digital image watermarking is performed by using combined DWT-DCT approach. This dual watermarking scheme is much appreciable in terms of best quality in digital watermarking. The proposed combined DWT-DCT technique provides PSNR value more than the range 30 to 60 for all individual images, which ensures imperceptibility of watermark. Further, result proves the robustness by yielding correlation co-efficient values above 0.9 for all recovered watermark images. Therefore, this research work concludes that the watermarked image is identical and watermark can be easily identified after recovery.

ACKNOWLEDGMENT

Acknowledgements are due towards beloved students Dimpal H L USN: 4GL14EC012, Guru Prasad B S USN: 4GL14EC017 and Punitha H G USN: 4GL14EC040 and Anil Kumar R USN: 4GL15EC400. Special thanks to teaching and non-teaching faculty of GEC, Kushalnagar for their encouragement and guidance.

REFERENCES

[1] Ahmed S. Salama and Mohamed Amr Mokhtar, 2016. "Combined Technique for Improving Digital Image Watermarking", 2nd IEEE International Conference on Computer and a Communications.

[2] Zhi Zhang, Chengyou Wang and Xiao Zhou, 2016. "Image Watermarking Scheme Based on Arnold Transform and DWT-DCT-SVD", IEEE.

[3] Ritu Gill and Rishi Soni, 2017. ''Digital Image Watermarking using 2-DCT and 2-DWT in Gray Images'', ICICCS, International Conference on Intelligent Computing and Control Systems.

[4] Suresh Kuri and Gururaj Kulkarni, 2017. ''Robust Digital Image Watermarking using DWT, DCT and Probabilistic Neural Network'', ICEECCOT, International Conference on Electrical, Electronics, Communication, Computer and Optimization Techniques.

[5] M. Veni and T. Meyyappan, 2017. ''DWT DCT based New Image Watermarking Algorithm to Improve the Imperceptibility and Robustness", ICEICE, International Conference on Electrical, Instrumentation and Communication Engineering.

[6] Chunhua Dong and Jingbing Li, 2017. ''A DWT-DCT Based Robust Multiple Watermarks for Medical Image".

[7] Zid-Yong Meng, Ping-Ping Yu, Guo-Qing Yu, 2012. ''Copyright Protection for Digital Image Based On Joint DWT-DCT Transformation'', Proceedings of the 2012 International Conference on Wavelet Analysis and Pattern Recognition, Xian.

[8] Kaushik Deb, Md. Sajib Al-Seraj, Md. Moshiul Hoque, and Md. Iqbal Hasan Sarkar, 2012. "Combined DWT-DCT Based Digital Image Watermarking Technique for Copyright Protection'', 2012 7th International Conference on Electrical and Computer Engineering.

[9] Dimple Bansal and Manish Mathuria, 2017. ''Color Image Dual Watermarking using DCT and DWT Combine Approach'', ICEI, International Conference on Trends in Electronics and Informatic.

[10] U. S. N. Raju, Kamalakanta Sethi, Sunaina Choudhary and Priyanka Jain, 2015, "A New Hybrid Watermarking Technique using DCT and DWT based on Scaling Factor".