International Journal of Innovative Technologies
WWW.IJITECH.ORG
ISSN 2321-8665
Volume.06, Issue.01,
January-June, 2018,
Pages:0152-0158

A Novel ARDWT based Secure Blind Watermarking System

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Abstract: Authenticity and copyright protection are two major issues in handling digital multimedia which are solved by watermarking. This paper aims to develop a novel watermarking technique which utilizes the concept of Adaptive Redundant Discrete Wavelet Transform (ARDWT). In order to achieve the objectives Singular Value Decomposition (SVD) transformation is used along with Discrete Wavelet Transform (DWT). Here Contrast-Limited Adaptive Histogram Equalization (CLAHE) approach is amalgamated with RDWT and SVD to establish an adaptive approach in order to improve the characteristics of image which may lost while embedding or extracting. Experimental results are provided in terms of MSE (Mean Square Error), PSNR (Peak Signal to Noise Ratio) ,WPSNR(Weighted Peak Signal to Noise Ratio) to satisfy Imperceptibility, CC (Correlation Coefficient), MSSIM (Multi-scale Similarity Structure Index) to satisfy Robustness and to demonstrate the effectiveness of the proposed algorithm.

Keywords: Watermarking, Discrete Wavelet Transform, Singular Value Decomposition, Mean Square Error, Peak Signal To Noise Ratio, Contrast-Limited Adaptive Histogram Equalization.

I. INTRODUCTION

By means of the extensive use of the digital products, it has become more convenient for the users to acquire and transforming the digital multimedia. Though, a negative effect rises all at once that digital multimedia copyright is getting suffered from serious threat. It has become easy for the hackers or cyber criminals to forge the data available in the internet. More than that they are not restraining their timid work only up to copying, they are misusing them subsequent to financial crisis. To overcome this problem, a technique called the Novel Blind watermarking was proposed. Novel watermarking technique based on ARDWT-SVD to embed a watermark image is offered which can be as large as the cover image. A digital watermark is a bit of information inserted in the digital media and concealed in the digital content in such a way that it is tied up with the data. Digital Watermarking provides the way or technology by which the owner can conceal his/her information, for e.g., a number or text, in digital media, such as images, video or audio. The embedding is done by changing the content of the digital data, which means the information is not embedded in the frame around the data. A general method for digital watermarking is shown in Fig.1. Here, initially the secret signature (watermark) is implanted into the cover image by using a secret key at the coder (C). The secret key notations shall be chosen such that they do not contain daily usage words or related to the personal names in order not to lead to any clues for further processing by a third person. Only the administrator of the data knows the key and so, it is impossible to take out the message from the image without the knowledge of the key. After that, the watermarked image is passed through the transmission channel. While transmitting, however, some possible attacks happen in the transmission channel namely, lossy compression, geometric distortions, any signal processing operation, digital-analog & analog-digital conversion and so on. After the watermarked image passes through these possible operations, the message is extracted at the decoder (D) only with the help of key.

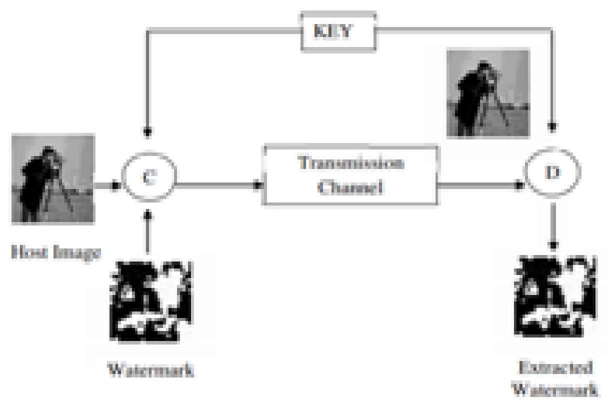

Fig.1. General method for digital watermarking.

II. PREVIOUS WORK

In [5], the authors have combined DWT with the SVD technique. In that work, they have applied SVD to every sub-band as well as the embedded singular values of the watermark into the sub-bands only after disintegrating the host image into the four sub-bands. In [6] DWT is united with the SVD technique for hiding the singular values related to the watermark in the high frequency band (HH) of an image. The watermarking algorithm has outperformed the conservative DWT algorithm with regard to the robustness against compression, cropping attacks [7] and the Gaussian noise when this DWT is associated with SVD technique. DWT-SVD-based watermarking method was proposed by Lai and Tsai In [8]. In this method, firstly the original image is decomposed by means of the DWT decomposition, and then the singular values related to the high frequency sub-bands in the vertical as well as the horizontal directions (LH and HL) are altered by the watermark. A robust watermarking scheme is presented by Gupta and Raval [9] which is based on the singular values replacement and DWT. The primary element of the watermark is implanted into the singular values related to the diagonal high frequency sub-band (HH). Although this accomplishes robustness under different attacks to a certain level, and then the extracted watermark will have a poor quality of the image. Despite good performance of DWT methods in Watermarking, they suffer from drawbacks. To overcome the drawbacks of DWT based watermarking, one solution is the use of Adaptive Redundant Discrete Wavelet Transform (ARDWT).

III. DISCRETE WAVELET TRANSFORM (DWT)

DWT is a mathematical tool for hierarchically decomposing an image. It is useful for non-stationary signals. Discrete wavelet transform (DWT) algorithms have widely accepted as a standard tool for discrete-time signal and image processing in various fields in research and industry.

A. Watermark Extraction Process for DWT based Image Watermarking

Watermark extraction and host image restoration is performed in this process at the receiving side. To realize watermark extraction and detection process, DWT is realized on watermarked image. The block diagram for watermark extraction is shown Fig.2.

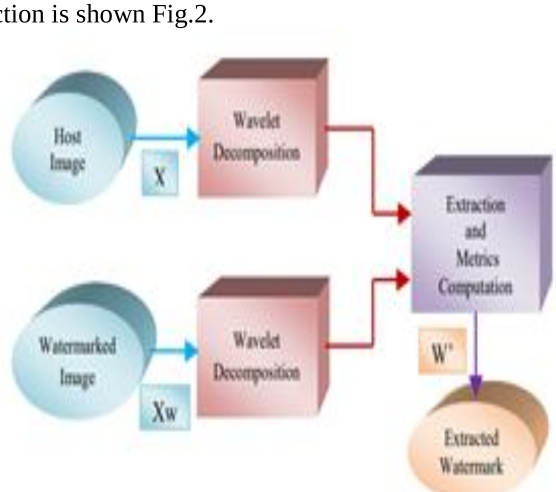

Fig.2. Block Schematic for Watermark Extraction for DWT based Image Watermarking.

The steps for extracting watermark from watermarked image in the proposed DWT based image watermarking are as follows.

- Extraction process is non-blind and requires host image for extraction purpose. Wavelet transform is applied on host image as well as watermarked image.
- Comparison of watermarked image and host image is carried out to extract embedded watermark.
- The viewer can compare retrieved watermark with original watermark visually. Subjective or qualitative analysis of extracted watermark is carried out by observing extracted watermark as watermark inserted is a visually recognizable and meaningful pattern such as logo.
- Watermark detection is based on cross correlation between original watermark and extracted watermark. Objective or quantitative analysis is carried out by calculating performance parameter, correlation coefficient (CC).

B. Limitations of Discrete Wavelet Transform

Though the standard DWT is a powerful tool, it has three major limitations that are described below particularly for signal and image processing tasks.

Shift Sensitivity: If shifting of input signal in time domain causes an unpredictable change in transforms coefficients said to shift variant. It has been observed that the standard DWT is seriously disadvantaged by the shift sensitivity that arises from down samplers in the DWT implementation. Shift sensitivity is an undesirable property because it implies that DWT coefficients fail to distinguish between input signal shifts. The down samplers are responsible for shift sensitivity.

Poor Directionality: An m- Dimensional transform (m>1) suffers poor directionality when the transform coefficients reveal only a few feature orientations in the spatial domain. The separable 2-D DWT partitions are in the frequency domain into three directional sub-bands. 2-D DWT can resolve only three spatial-domain feature orientations: HL, LH and HH. Natural images contain number of smooth regions and edges with random orientations; hence poor directionality affects the optimal representation of natural images with of the separable standard 2-D DWT as shown in Fig.3.

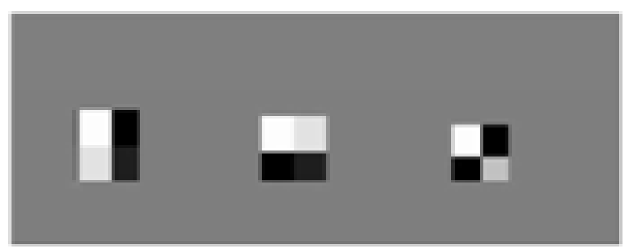

Fig.3. Directionality of standard 2D DWT.

Absence of Phase Information: For a complex valued signal or vector, its phase can be computed by its real and imaginary projections. Digital image is a data matrix with a finite support in 2- D. Filtering the image with 2D- DWT increases its size and adds phase distortion. Human visual system is sensitive to phase distortion. Furthermore, 'Linear phase' filtering can use symmetric extension methods to avoid the problem of increased data size in image processing. Phase information is valuable in many signal processing applications such as e.g. in image compression and power measurement. Most DWT implementations use separable filtering with real coefficient filters associated with real wavelets resulting in real-valued approximations and details. Such DWT implementations cannot provide the local phase information. All natural signals are basically real-valued, hence to avail the local phase information, complex-valued filtering is essential to avail local phase.

IV. SVD (SINGULAR VALUE DECOMPOSITION)

Singular value decomposition (SVD) is a fundamental mathematical analysis tool used to analyze matrices. It is a linear algebra technique used to solve any mathematical problems. SVD transform is a linear algebra transform which is used for factorization of a real or complex matrix with numerous applications in various fields of image processing.

SVD of an Image: As a digital image can be represented in a matrix form with its entries giving the intensity value of each pixel in the image, SVD of an image A with dimensions M x M is given by:

$$A = USV^T \quad (1)$$

Where, U and V are orthogonal matrices and S known as singular matrix is a diagonal matrix carrying non-negative singular values of matrix M as shown in Fig.4. The columns of U and V are called left and right singular vectors of M, respectively. They basically specify the geometry details of the original image. Left singular matrix i.e., U represents the horizontal details and right singular matrix i.e., V represents the vertical details of the original image. The diagonal values of matrix S are arranged in decreasing order which signifies that importance of the entries is decreasing from first singular value for the last one, this feature is employed in SVD based compression techniques.

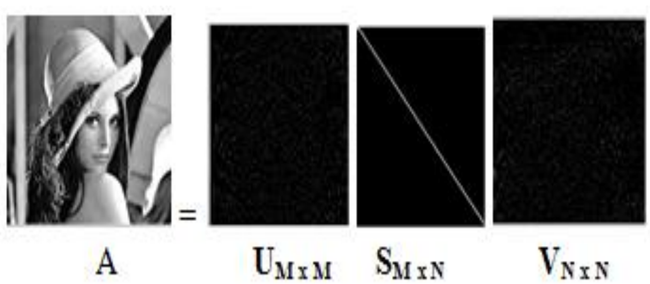

Fig.4. SVD of an Image (LENA).

Advantages of SVD in Image Processing (Watermarking) Applications:

- The size of the matrices from SVD transformation is not fixed and can be a square or a rectangle.
- The Singular Values of an image have very good stability, i.e. when a small perturbation is added to an image, its singular Values do not vary rapidly;
- Singular Values represent algebraic image properties which are intrinsic and not visual.
- The singular value are unique, however, the matrices U and V are not unique.

V. PROPOSED METHOD: ARDWT

A. Watermarking Embedding

Block Diagrams and Process Flow: Embedding of the Image as shown in Fig.5.

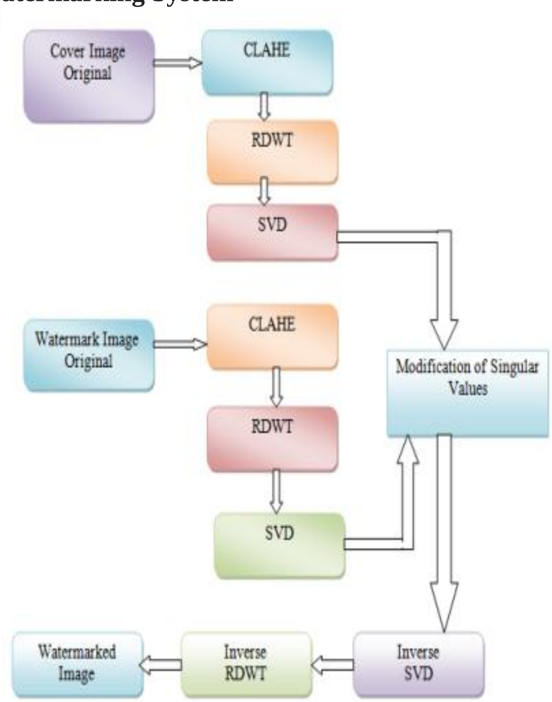

Fig.5. Embedding Image Process.

The steps of watermark embedding algorithm are as follows:

- Apply RDWT to the cover image which is filtered with contrast Limited adaptive Histogram Enhancement approach to decompose it into LL, HL, LH, and HH sub bands.
- Apply SVD to the low frequency sub band LL of the cover image.
- Apply RDWT to the visual watermark.
- Apply SVD to the low frequency sub band of watermark.
- Modify the singular values of the cover image with the singular values of watermark image.
- Apply inverse SVD on the transformed cover image with modified singular values.
- Apply inverse RDWT using the modified coefficients of the low frequency bands to obtain the watermarked image.

B. Watermark Extraction

Extraction of the Image:

The steps of watermark Extraction algorithm are as follows:

- Using RDWT, decompose the watermarked image I* into 4 sub bands: HH, HL, LH and LL.
- Apply SVD to low frequency sub band.
- Extract the singular values from low frequency sub band of watermarked and cover image as shown in Fig.6.
- Apply inverse SVD to obtain low frequency coefficients of the transformed watermark image.
- Apply inverse RDWT using the coefficients of the low frequency sub band to obtain the watermark image.

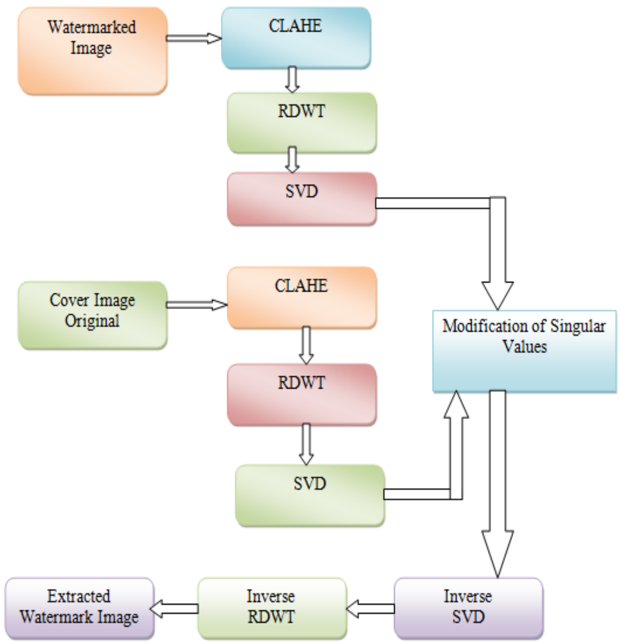

Fig.6. Extraction Image Process.

VI. STATISTICAL PARAMETERS

Correlation Coefficient (CC): Used to indicate compatibility of original image and watermark image. It shows similarity between two images. Range 0 to 1. Mathematically

$$CC = \frac{\sum_i \sum_j w(i,j) w'(i,j)}{\sqrt{\sum_i \sum_j w(i,j)^2 . \sum_i \sum_j w'(i,j)^2}} \quad \mathbf{(2)}$$

Where $w(i,j)$ is original Image and $w'(i,j)$ is watermarked image.

Peak Signal to Noise Ratio (PSNR): Quality of the Watermarked image is evaluated on the basis of PSNR. It is calculated between original image and watermarked image. It shows the degree of noise present in image. It is the ratio between max possible power of a signal and the power of corrupting noise that affects the fidelity of its representation. Larger the value of PSNR, more similar to the watermarked image to the original image [10].

Mathematically

$$\text{PSNR} = 10 \log\left(\frac{255^2}{\text{MSE}}\right) \text{dB} \quad \mathbf{(3)}$$

Where E is Mean Square Error.

Weighted Peak Signal to Noise Ratio (WPSNR): It is the extension of traditional PSNR Simple approach to adopt the classical PSNR for watermark application consists of the introduction of different weights for the perceptually different regions oppositely to PSNR where all regions are treated with the same weight. WPSNR takes into account the fact that human eye is less sensitive to changes in textural areas than in smooth areas. Just like PSNR, high value of WPSNR indicates that the image is less distorted [10, 11].

Mean Square Error (MSE): It measures the average of the square of the "error." The error is the amount by which the pixel value of original image differs to the pixel value of modified image. Better the perceptual quality of the image is possible for low values of MSE. The embedding distortion performance is usually measured by the Mean Square Error. It should be as low as possible, since a better perceptual quality of the image is possible for lower values of MSE. Logarithmic unit is dB [10].

Mathematically

$$E = \frac{1}{M \times N} \sum_{i=1}^{N} \sum_{j=1}^{M} [(w(i,j) - w'(i,j)]^2 \quad \mathbf{(4)}$$

Where E is MSE, M and N are the height and width of image respectively $w(i,j)$ is pixel values of original Image and $w'(i,j)$ is pixel values of watermarked image.

Multi-scale Similarity Structure Index (MSSIM): MSSIM in point of fact measures the perceptual difference between two similar images. It cannot evaluate which of the two images is better, that must be contingent from perceptive which the "original" is and which has been subjected to supplementary processing such as data compression. Contrasting PSNR, MSSIM is based on noticeable structures in the image.

VII. EXPERIMENTAL RESULTS AND DISCUSSION

Experimental results of this paper is as shown in bellow Figs. 7 to 22.

Stage 1: Embedding the Image

Fig.7. Original Gray scale Image of LENA.

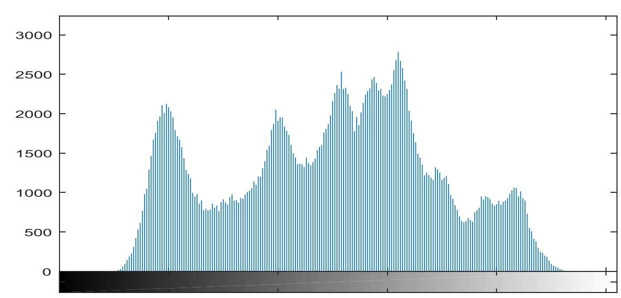

Fig.8.Histogram Plot of Original Gray scale Image of LENA.

Fig.9.Input Image (CLAHE Filtered image).

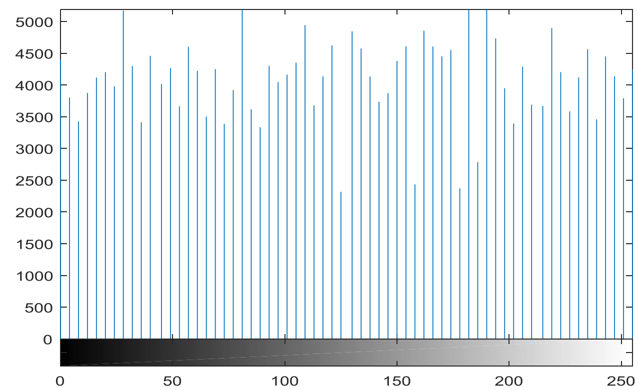

Fig.10.Histogram plot of figure 5.3.

Fig.11. Original Watermark image.

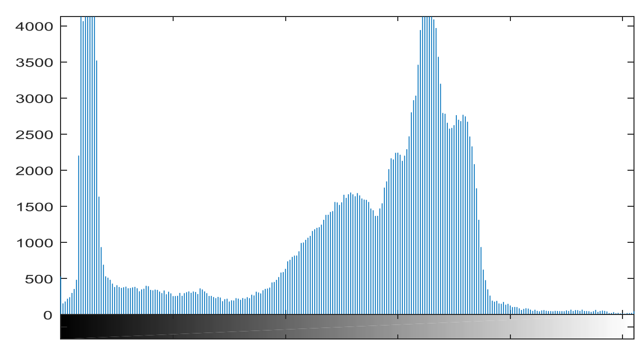

Fig.12. Histogram plot of Original Watermark image.

Fig.13. Input Watermark.

(CLAHE filtered version of Original Watermark image)

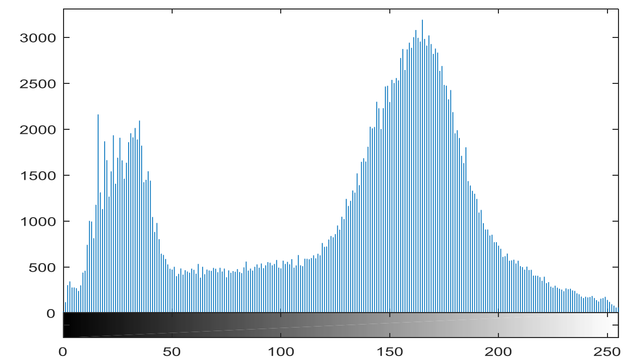

Fig.14. Histogram plot of 5.7.

Fig.15. Watermarked Image.

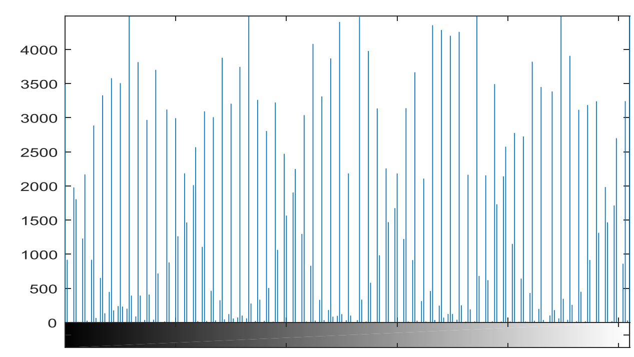

Fig.16. Histogram Plot of Watermarked Image.

Fig.17. Input and water marked Images.

Stage 2: Extraction Process

Fig.18. Watermarked image(Cover Image).

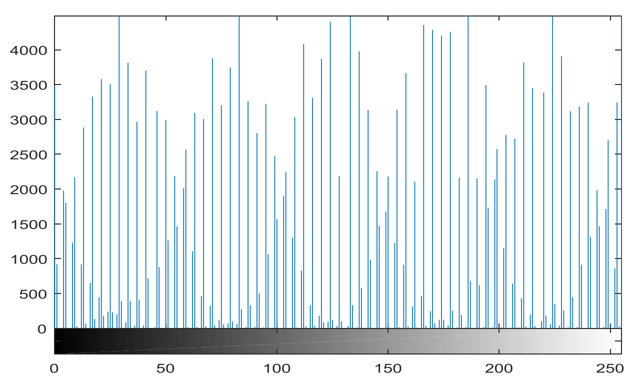

Fig.19. Histogram plot of Watermarked Image.

Fig.20. Histogram plot of Fig .5.14 .

Fig.21. Extracted Watermark Image.

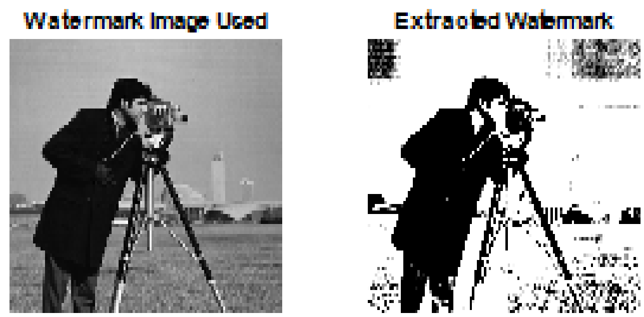

Fig.22. Water mark image used and extracted Watermark Image.

A. Objective Analysis (Statistical Analysis)

The subjective analysis indicates there is a loss of the intensity levels. But the exact analysis and objective representation of the embedding and extraction process of the watermark is analyzed based on the statistical parameters Correlation Coefficient, Peak Signal to Noise Ratio (PSNR), Weighted PSNR, Mean Square Error (MSE), Multi-scale Similarity Structure Index (MSSIM).Statistical Analysis is also called as objective analysis because the entire discussion depends on Image attributes of the images in the processing are involved.

TABLE I: Statistical Parameters Comparison

Parameter	Existing Method (RDWT)		Proposed Method (ARDWT)	
	Embedding Image	Extracting Image	Embedding Image	Extracting Image
CC	0.6532	0.6893	0.7672	0.8642
PSNR	6.3725	17.7543	7.8194	18.6174
WPSNR	12.236	39.7634	14.542	46.763
MSE	5.822	5.863	3.852	3.874
MSSIM	0.9612	0.9915	0.9912	1.000

It is clearly visible in this research work that the CC for proposed method has the values nearer to 1 making the ARDWT better than RDWT the existing method. Similarly PSNR and WPSNR values are better for propose method, whereas MSE is least for proposed method when compared to existing method. PSNR and WPSNR are independent of Human Visual System (HVS) parameters and hence they are inapt scales to assess prospective research results. MSSIM It indicates the similarity index is better for ARDWT than RDWT.

B. Graphical Representation Analysis

The above tabulated parameters have been presented in graphical form for the purpose of visual perception of the behavior of parameters on a coordinate axis. The graphical analysis is separated here for Embedding process and Extracting process in order to have a vivid perception and interpretation of the values for both existing and proposed methods. These graphs will aid the researchers for an obvious understanding.

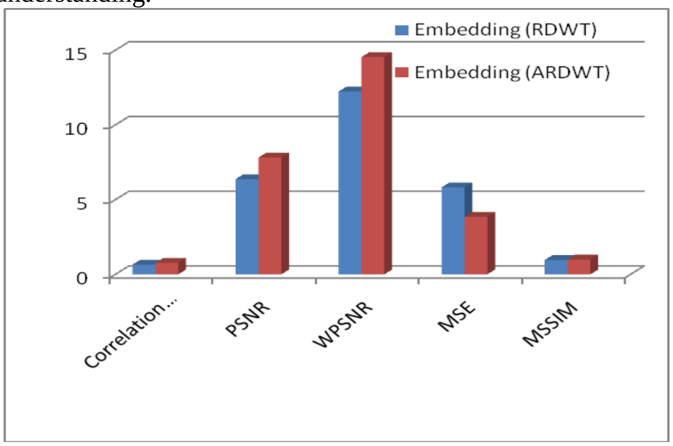

Fig.23. Graphical representation for embedding process.

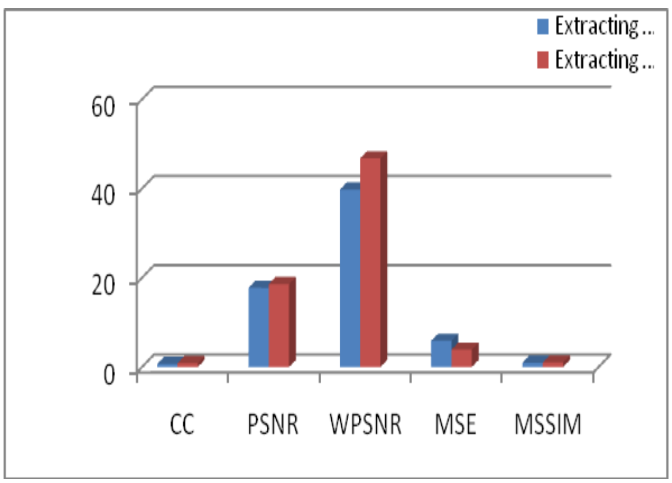

Fig.24. Graphical representation for extracting process.

From the figs.23 and 24 it is apparent and vivid that proposed method is better and promising in connection with the obtained image attributes.

VIII. CONCLUSION

Proposed technique results have shown that technique presented in this work is very helpful for watermarking and de watermarking authentication and also sustain more security and exact correlation between original watermark and extracted watermark. This work has been investigated both subjectively and objectively. In statistical comparison embedding and extraction process of the watermark is analyzed based on the statistical parameters Correlation Coefficient, Peak Signal to Noise Ratio (PSNR), Weighted PSNR, Mean Square Error (MSE), and Multi-scale Similarity Structure Index (MSSIM). From all these parameters and their analysis it has been perceived that proposed ARDWT is better in all aspects when compared to the existing methods.

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