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Abstract- With the rapid use of digital data in information technology and multimedia, piracy and malicious manipulations have become a common concern, thus it is inevitable that the digital content is protected. Hence copyright protection has become a vital issue. Digital watermarking has emerged as a solution to this problem. In this paper, a watermarking technique is proposed and implemented. In which the original image is sorted out to another form by applying zigzag process followed by DCT and SVD. Watermark is then embedded by modifying the singular values and extraction of watermark is the inverse process of embedding. The deliberated algorithm gives good Peak Signal to Noise Ratio (PSNR) which ensures good imperceptibility and Normalized Cross Correlation (NCC) which ensures more robustness against different kinds of noise such as Histogram equalization, JPEG compression, Speckle noise, Gaussian noise, Salt and Pepper noise, Cropping, Rotation, Sharpening and so on. The human eyes are more sensitive to noise in lower- frequency band than higher frequency. The zigzag scanning process is implied for energy distribution from high to low frequency as well as from low to high frequency with the same manner.

Keywords: watermarking, zigzag process, sorted out image, DCT, SVD.

I. Introduction

Digital watermarking is the method of embedding data into digital multimedia content without changing the content of original information. This is used to verify the credibility of the content as well as to recognize the identity of the digital content's owner. In digital image watermarking procedure, the inserted watermark should not degrade the visual perception of an original image and must be robust. So, it must endure the attacks such as, gamma correction histogram equalization, cropping and so on.

Digital Image watermarking is implemented in two ways - spatial domain and frequency domain. In spatial domain, the pixel intensity value of the image is directly modified like LSB is modified to achieve high visual perception. The spatial domain techniques have proven to be less robust against attacks like cropping, JPEG compression. In frequency domain the signal or image is transformed into discreet coefficients which are then modified to insert the watermark. Inverse transformation is used to get back the modified coefficients from original signal or image. Insertion, in transformed domain proves to be more robust against attacks like cropping, JPEG compression. Commonly used frequency-domain transforms are the Discrete Cosine Transform (DCT), Discrete Wavelet Transform (DWT), Discrete Fourier Transform (DFT) and Singular Value Decomposition (SVD). Of the frequency domain transforms, DCT and SVD increase the factor result that helps to achieve effective watermarking. In watermarking, there are some factors that measure the quality of watermarking. These are robustness, imperceptibility and Capacity. Robustness is a measurement which indicates how difficult is to remove or destroy watermark from watermarked image. Normalized Cross Correlation (NCC) is used to measure the similarity and difference between the original watermark and extracted watermark which actually measure the robustness. If NCC value is greater, then it is more robust. This value is generally plotted from 0 to 1. Imperceptibility is related to the quality of host image in presence of the watermark. If we cannot distinguish between host image and watermarked image, it is called imperceptibility. Basically imperceptibility depends on similarity between host image and watermarked image. Imperceptibility is measured by PSNR (Peak signal to Noise Ratio). Capacity indicates how much information is embedded into a digital content. In the proposed method, firstly zigzag process is applied to sort out the image to another form. Then DCT is applied on sorted out image to compress the size of image and SVD is applied on DCT compressed image to get singular values which is used to add watermark image. Finally embedding algorithm is implemented. The paper is organized by: Section 2, focuses on overview of terminologies. Section 3, gives details the proposed methodology, watermark embedding and extraction algorithms. In section 4, gives experimental performance results and comparison. Finally conclusion is given in section 5.

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II. Overview of Terminology

The theories which are related with the proposed method is described here shortly.

a) Discrete Cosine Transformation (Dct)

The DCT is the most popular transform function used in signal processing. It transforms a signal from spatial domain to frequency domain. Due to good performance, it has been used in JPEG standard for image compression. It is a technique applied to image pixels in spatial domain in order to transform them into a frequency domain in which redundancy can be identified. The one-dimensional DCT is useful in processing one-dimensional signals such as speech waveforms. To analyze two-dimensional (2D) signals such as images, we need a 2D version of the DCT. The 2D DCT and 2D IDCT transforms is given by the equation 1 and 2.

Two Dimensional (2D) DCT:

$$F(x,y) = C(x)C(y)\sum_{i=0}^{N-1}\sum_{j=0}^{N-1} f(i,j)\cos\left[\frac{\pi(2i+1)x}{2N}\right] * cos\left[\frac{\pi(2j+1)x}{2N}\right] \quad (1)$$

Two Dimensional (2D) IDCT:

$$f(i,j) = C(x)C(y)\sum_{i=0}^{N-1}\sum_{j=0}^{N-1} F(x,y)\cos\left[\frac{\pi(2i+1)x}{2N}\right] * cos\left[\frac{\pi(2j+1)y}{2N}\right] \quad (2)$$

Where, $f(i,j)$and $F(x,y)$are respectively the pixel value and the DCT coefficient and

$$C(x), C(y) = \begin{cases} \sqrt{\frac{1}{N}}, & x,y = 0 \\ \sqrt{\frac{2}{N}}, & otherwise \end{cases}$$

b) Singular Value Decomposition (Svd)

The Singular Value Decomposition (SVD) is one of the most important matrix decomposition technique used in computer vision. A very powerful set of techniques dealing with sets of equations or matrices that are either singular or numerically very close to singular. SVD allows one to diagnose the problems in a given matrix and provides numerical answer as well. Any m x n matrix A (m >= n) can be written as the product of an m x n column-orthogonal matrix U, an n x n diagonal matrix with positive or zero elements, and the transpose of an n x n orthogonal matrix V. SVD matrix can be represented by the equation:

$$A = U.S.V^T$$

Where,

$$S = \begin{bmatrix} s_1 & 0 & . & 0 & 0 \\ 0 & s_2 & & . \quad 0 & 0 \\ . & . & . & . & . \\ 0 & 0 & . & s_{n-1} & 0 \\ 0 & 0 & . & 0 & s_n \end{bmatrix}$$

And

$$U^TU = V^TV = I$$
$$VV^T = I$$
$$s_1, s_2, \ldots\ldots s_{n-1}, s_n \geq 0$$

The diagonal elements of matrix **S** are the singular values of matrix **A** and non-negative numbers.

c) Zigzag Process

A zigzag array is a square arrangement of the first N^2 integers, where the numbers increase sequentially as you zigzag along the anti-diagonals of the array. The zigzag scanning process is applying for energy distribution from high to low frequency as well as from low to high frequency with the same manner. The zigzag process gives a sorted out matrix from original matrix. For a graphical representation of zigzag scanning process is shown in fig. 1.

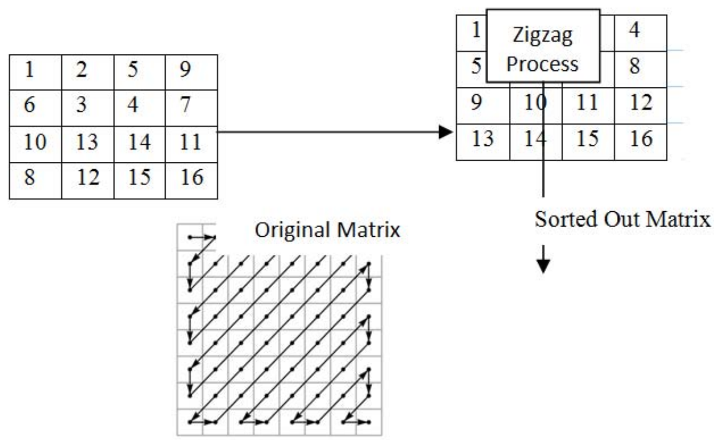


Figure 1: Zigzag scanning process

III. Proposed Methodology and Algorithm

a) Embedding Process

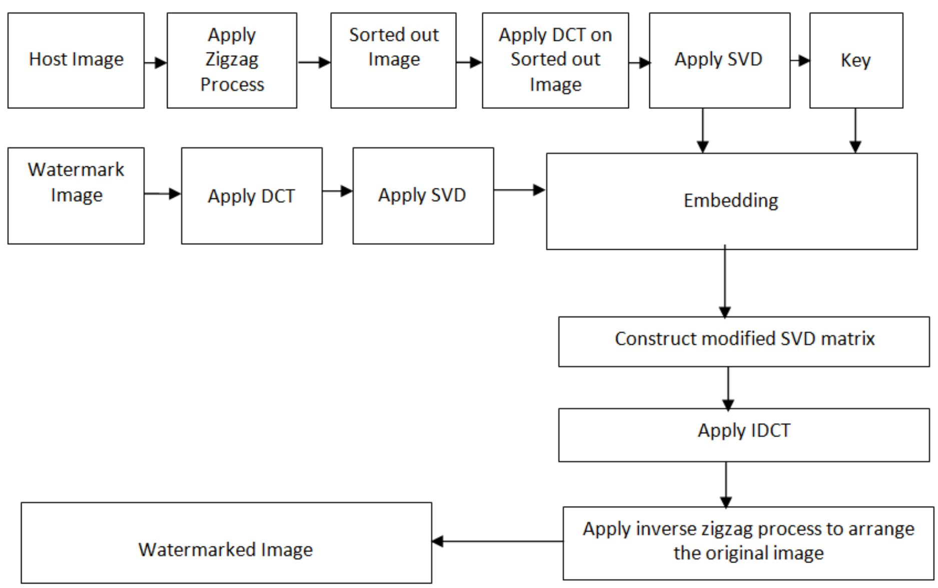


Figure 2: Watermark Embedding process

b) Extraction Process

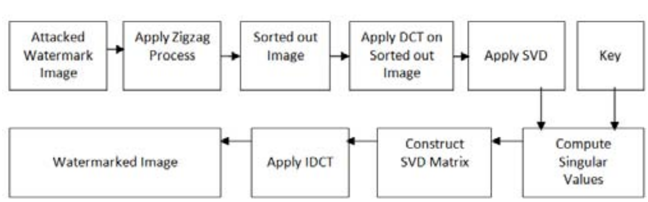


Figure 3: Watermark Extraction process

c) Watermark Extraction Process

1. Input host image HI and apply Zigzag sequence to sort out the image SI.
2. Apply DCT on Sorted out image SI to compress it.
3. Apply SVD to produce U, S singular values and V matrix.
4. Input watermark wi to embed with host image.
5. Apply DCT on watermark image.
6. Apply SVD to produce Uw, Sw singular values and Vw matrix.
7. Modifying singular values of host image with watermark image by using $S_{wi} = S_i + \alpha * S_w$
8. Construct Modified SVD matrix to produce SW.
9. Apply inverse DCT on SW get SD.

10. Apply inverse zigzag process on SD to order the original position of image and finally get watermarked image WI.

d) Watermark Extraction Algorithm

1. Input watermarked image WI and apply Zigzag sequence to sort out the image si.
2. Apply DCT on Sorted out image si to reduce the redundant signal.
3. Apply SVD to produce singular values S.
4. Apply SVD to produce Uw, Sw singular values and Vw matrix.
5. Modifying singular values of watermarked by using $S_w = (S_{wi} - S_i)/\alpha$
6. Construct the SVD matrix to produce sw.
7. Apply IDCT on SW to get watermark image wi.

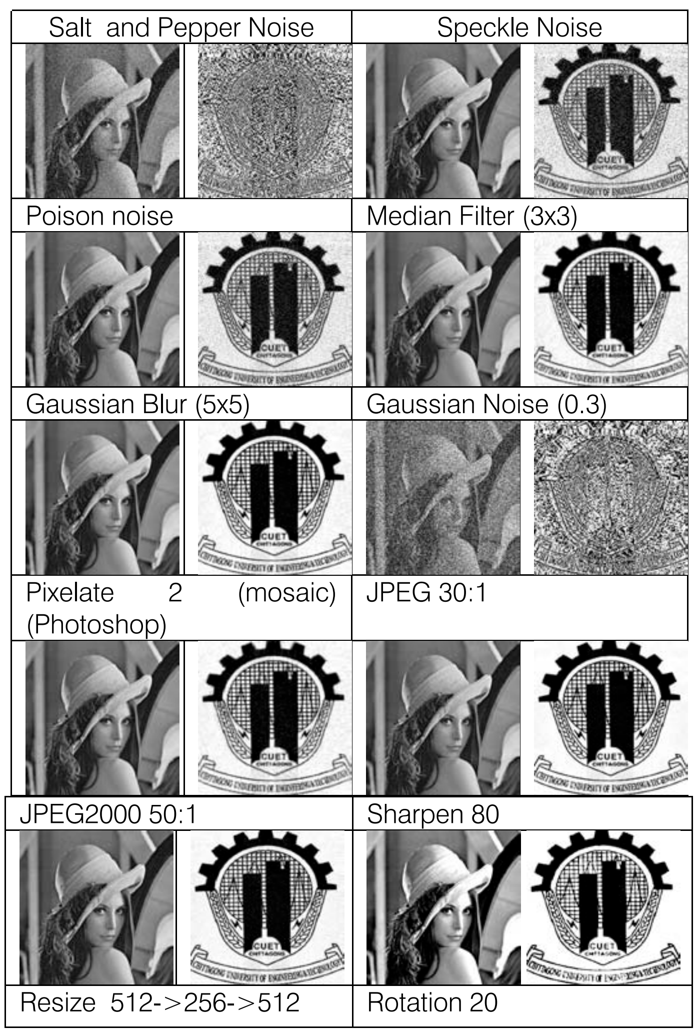
IV. Experimental Results

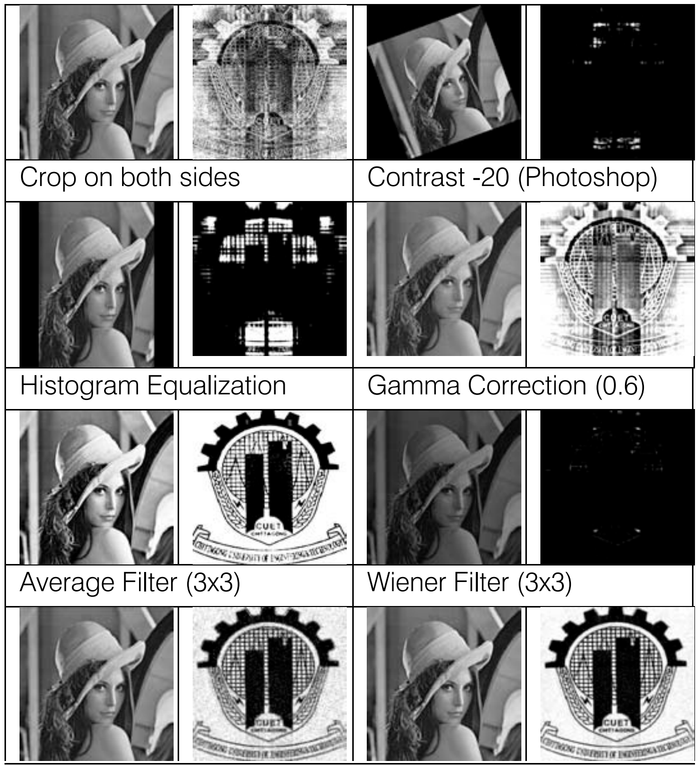
The proposed method is simulated using MATLAB 9 with Processor Intel core 2 duo 2.2 GHz, RAM 2 GB and it tested for the various host and watermark images. Here some experimental results are given. With the host image Lena and watermark image CUET logo are described broadly that helps to analysis the proposed method properly.

Table 1: PSNR and NCC Values of Different Images Without Applying Attack

Host image	Watermark image	PSNR	NCC
Lena	CUET logo	31.4550	0.9976
Living room	CUET logo	31.4114	0.9959
Baboon	Copyright image	30.4195	0.9906
Birds	Cameraman	35.0406	0.9829
Boat	CUET Logo	30.0704	0.9980
Fruits	Copyright image	30.5127	0.9945

Attacked watermarked image and corresponding extract watermark image.





Crop on both sides | Contrast -20 (Photoshop)

Histogram Equalization | Gamma Correction (0.6)

Average Filter (3x3) | Wiener Filter (3x3)

To evaluate the performance of the proposed method we need to compute PSNR (Peak Signal to Noise Ratio) and NCC (Normalized Cross Correlation) values. Normally, PSNR is used to measure imperceptibility between the original image and watermarked image. PSNR is defined by the eqn. (4). And NCC is used to measure robustness i.e. how similar the original and extract watermark image. NCC value can be calculated by the defined eqn. (5).

$$PSNR = 10\log_{10}\left(\frac{255^2}{MSE}\right) \quad (4)$$

Where,

$$MSE = \frac{1}{M \times N}\sum_{m=1}^{M}\sum_{n=1}^{N}[I(m,n) - I_w(m,n)]^2$$

And

$$NCC = \frac{\sum_i \sum_j w(i,j)\, w'(i,j)}{\sum_i \sum_j |w(i,j)|^2} \quad (5)$$

Table 2: Performance results comparison in terms of NCC values

Attacks	Existing Method DWT-SVD (ref : 6)	Proposed Method DCT-SVD
Gaussian Blur (5x5)	0.8850	0.9845
Sharpen 80	0.6990	0.9179
Average Filter (3x3)	Not given	0.8428
Median Filter (3x3)	Not given	0.9233
Wiener Filter (3x3)	Not given	0.9528
Contrast -20 (Photoshop)	0.7380	0.3529
Gaussian noise 0.3	0.8650	0.2186

Speckle noise	Not given	0.6395
JPEG 30:1	0.9930	0.9976
JPEG2000 50:1	0.9890	0.9509
Pixel-ate 2 (Photoshop)	1.0000	0.9640
Salt & Pepper noise	Not given	0.2569
Resize 512->256->512	0.9400	0.1928
Rotation 20	0.9630	0.3567
Crop on both sides	0.9850	0.4188
Poisson noise	Not given	0.7168
Histogram Equalization	0.8230	0.9449
Gamma correction 0.6	0.9970	0.3808

V. Conclusion

In this paper, a DCT-SVD watermarking method using zigzag scanning sequence to sort out image is proposed that gives good PSNR and NCC values to ensure the imperceptibility and robustness. From Table 1 and 3, it is observed that the proposed method gives good PSNR and NCC values that fulfill the algorithmic requirements. The proposed method is superior to the existing method for Gaussian blur, sharpening, JPEG compression, histogram equalization and different kinds of filtering attacks. But in some geometric attacks such as rotation, resizing, cropping and in pixilation the proposed method dose not gives improved results. In future the proposed algorithm can be improved against different kinds of geometric attacks and will try to combine DWT, DCT and SVD domain to ensure better performance and further it can be extended to color images.

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