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Performance Analysis of Combined Discrete Fourier Transformation (DFT) and Successive Division based Image Watermarking Scheme

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Abstract*: A combined Discrete Fourier Transformation (DFT) and Successive Division based image watermarking scheme has been proposed in this article. Due to intrinsic parameters: Imperceptibility, Data Embedding Capacity and Time of Execution, many spatial domain approaches are less efficient. Many frequency domain approaches satisfies imperceptibility and data embedding capacity, but utilizes more execution time. The proposed algorithm is a hybrid technique under frequency domain, which embeds watermark into host using Discrete Fourier Transformation (DFT) and successive division. Through DFT better imperceptibility is noticed and the algorithm utilizes very less execution time compared to other existing approaches. Performance analysis is done based on similarity between original and retrieved watermark images. The experimental results are better compared to other existing techniques.

***Index Terms*: Watermarking, Spatial Domain, Similarity, Imperceptibility, Frequency Domain**

I. INTRODUCTION

Identity for the authorized user and distribution path of digital data can be provided by the means of digital watermarking technique [1-2]. It is a process of embedding copyright information into digital data with or without modifying data samples [3-4]. Images are the major class of multimedia [5-6]. Digital image represents information in pictorial custom [7-8]. In digital image watermarking process, authentication and protection are provided by watermark to host image and host to watermark respectively [9].

Digital watermarking principle is classified into spatial and frequency domain approaches [10-11]. Robustness, invisibility and data embedding capacity are the three major parameters to be considered while developing an efficient watermarking scheme [12]. Along with this, similarity between retrieved and original watermark images is also important. Contingent on the implanting domain selected, the imperceptibility and robustness have considerable effect on data embedding capacity of the algorithm. Frequency domain embedding techniques have more advantage over spatial domains in terms of better toughness to repel several signal processing influences and attacks. These techniques supports more data embedding capacity and much robust to malicious security attacks. Based on the applications, watermarking techniques are classified as robust, fragile and semi fragile techniques. And further classified as blind, semi-blind and non blind approaches based on information required for extraction and detection processes [13]. Imperceptibility is another significant facet of robust watermarking techniques, which defines the eminence of retrieved watermark when watermarked image is exposed for various deliberate or inadvertent threats [14]. A proficient watermarking scheme should resist such security attacks and provide better imperceptibility.

Discrete Wavelet Transform (DWT), Discrete Cosine Transform (DCT) and Discrete Fourier Transform (DFT) are the well-known data embedding techniques [15]. Shift variant problem is one of the major issues in DWT based data embedding techniques. This delinquent happens owing to down sampling course tailed by de-noising in each stage [16]. It reasons significant alteration in wavelet coefficients of cover due to slight modifications, leading to an erroneous abstraction of information [17].

Since digital image watermarking algorithms are characterized based on robustness, imperceptibility, data embedding capacity and time of execution, these parameters are correlated to each other [17]. Less the data embedding capacity, better will be the robustness and imperceptibility, and vice-versa. Similarly, better the robustness and imperceptibility, more will be the time of execution and vice-versa.

Thongkor K et. al. [18] described a combined Wiener filtering and noticeable distortion based digital image watermarking scheme. The algorithm embeds watermark with 2/243th size of host and provides slightly less correlation between original and retrieved watermark images. A hybrid technique using Singular Value Decomposition (SVD) and sharp frequency localization Contourlet Transform (CT) based method has been described by Najafi E et. al. [19]. The algorithm provides bulk data embedding capacity. Time of execution is unnoticed in the technique. Abbasi et al. [20] proposed a new digital image watermarking scheme based on Riesz transformation.

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The scheme involves simple addition and quantization technique to embed the watermark into host. The algorithm embeds watermark with 1/4th size of host and results with slightly less similarity between original and retrieved watermark images.

In combined Homographic transformation and Singular Value Decomposition (SVD), the watermark is embedded into host using SVD algorithm with the help of reflectance component by the homomorphic transform. The method embeds bulk watermark into host and results with slightly less similarity between original and retrieved watermark images [21]. Fan D et al. [22] described a new digital image watermarking algorithm in Contourlet domain using adaptive quantization. The algorithm supports less data embedding capacity by inserting watermark image of size 1/256th size of host. The algorithm results with better similarity between original and retrieved watermark images. Seok Lee et. al. [23] proposed a new digital image watermarking technique based on variation prediction mapping and Discrete Wavelet Transformation (DWT). The algorithm results with very less data embedding capacity of 1/768th size of host.

In combined histogram and entropy based digital image watermarking scheme, the host image is divided into blocks. These blocks are called on the basis of entropy. The algorithm results with less data embedding capacity with 45/65536th size of host [24]. Tanya et. al. [25] proposed a new data embedding scheme using DWT and two level SVD. The algorithm embeds watermark of 1/32th size of host indicating less data embedding capacity and results with better similarity between original and retrieved watermark images. Zhuhong Shao et. al. [26] described a hybrid watermarking technique using Orthogonal Fourier transformation and chaotic maps. The algorithm results with bulk data capacity by embedding watermark of 1/16th size of host. Better similarity is observed between original and retrieved watermark images. But time of execution is unnoticed in the technique.

Savakar et. al. [27] proposed a new digital image watermarking technique using two level DWT sub bands. The algorithm results with very less data embedding capacity by inserting watermark of 125/32768th size of host. Better similarity is observed between original and retrieved watermark images. Lai et al. [28] proposed a combined DWT and SVD based digital image watermarking scheme. The algorithm embeds watermark of 1/4th size of host and takes slightly more execution time for both watermarking and de-watermarking processes. In hybrid DWT and SVD based algorithm, the watermark of 1/4th size of host indicating bulk data embedding capacity. The algorithm utilizes more execution time data embedding and de-watermarking processes [29]. Liu et. al. [30] proposed a new watermark embedding approach in SVD domain. The algorithm supports better data embedding capacity by inserting 1/8th size of host and takes more execution time for both watermarking and de-watermarking processes.

Based on the above aspects, a robust watermarking scheme is developed in frequency domain, which utilizes very less execution time and gives better similarity between original and retrieved watermark images compared to other existing techniques. The paper is organized as follows: Section 2 describes methodology. Performance analysis is described in Section 3 and Section 4 concludes the proposed scheme.

II. PROCEDURE

Watermarking and De-watermarking processes are the two major junctures in the algorithm. In the watermark embedding process, the host image is first subjected for Fast Fourier Transformation (FFT). The watermark image of size 1/16th host is then concatenated to build a bulk watermark image of same size as host is first subjected for concatenation to get a bulk watermark. The pixel intensities in the bulk watermark are reduced using successive division method and embedded into transformed host. The embedded host is then subjected for IFFT before transmission. In the de-watermarking process, the watermarked image is first subjected for FFT and then watermark is separated from the host. Then the watermark is subjected for successive multiplication to enhance the pixel intensities. Finally, filtering and block wise truncation are done to get individual watermarks from bulk image with reduced noise stratums. Fig. 1 shows the flow diagram of proposed watermarking scheme.

A. Watermark Embedding Process

Step1: Watermark image $\frac{M}{4}$ X $\frac{N}{4}$ is imperiled for row and columnwise concatenation to get a bulk watermark n X n, same as that of the host.

$$\theta' = \begin{bmatrix} \theta & \theta & \theta & \theta \\ \theta & \theta & \theta & \theta \\ \theta & \theta & \theta & \theta \\ \theta & \theta & \theta & \theta \end{bmatrix} \quad (1)$$

Step2: Cover image M X N is subjects for Discrete Fourier Transformation.

$$\mu(k) = \sum_{j=1}^{xy} \delta(j)\, \omega_{MN}^{(j-1)(k-1)} \quad (2)$$

Where,

$$1 \le x \le M$$
$$1 \le y \le N$$
$$\omega_{NM} = e^{\frac{(-2\pi i)}{NM}}$$

Step3: The bulk Watermark is imperiled for progressive division process with an operator of 2/3 (maximum pixel value in the image) in order to scale down the intensity of each pixel.

$$\theta'' = \left\{ \frac{\theta'}{\left(\frac{2}{3}\right) Maximum\ pixel\ intensity} \right\} \quad (3)$$

Step4: The DFT host image and the de-intensified watermark are subjected for embedding process corresponding to each pixel.

$$\varepsilon'(x,y) = \mu(x,y) + \theta''(x,y) \quad (4)$$

Where,

$\varepsilon'(x,y)$ → Watermark embedded image

$\mu(x,y)$ → Cover image

$\theta''(x,y)$ → Compressed watermark

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Step5: The embedded watermarked image is then subjected for Inverse Discrete Fourier Transformation (IDFT) corresponding to each pixel.

$$\delta'(j) = \frac{1}{MN}\sum_{k=1}^{xy} \varepsilon'(j)\, \omega_{MN}^{-(j-1)(k-1)} \qquad (5)$$

Where,

$$1 \le x \le M$$
$$1 \le y \le N$$
$$\omega_{NM} = e^{\frac{(-2\pi i)}{NM}}$$

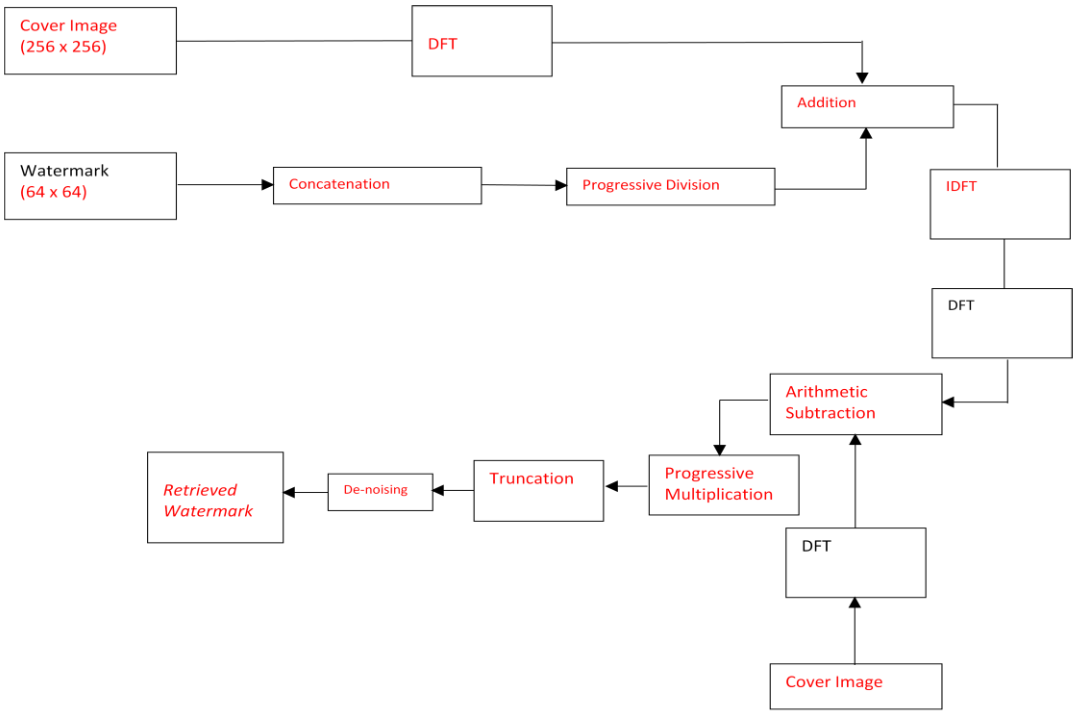

Fig.1 Watermarking and De-watermarking processes

B. De-watermarking Process

Step1: Cover image (M X N) and watermark are imperiled to DFT.

Step2: The DFT watermarked image and DFT host image are subjected for de-watermarking process corresponding to each pixel.

$$\theta''(x,y) = \varepsilon'(x,y) - \mu(x,y) \qquad (6)$$

Where,

$\varepsilon'(x,y) \rightarrow$ Watermark embedded image

$\mu(x,y) \rightarrow$ Cover image

$\theta''(x,y) \rightarrow$ Compressed watermark

Step3: The obtained watermark is then intensified to get bulk watermark image using successive multiplication process.

$$\theta' = \left\{\theta'' * \left(\frac{2}{3}\right) \textit{Maximum pixel intensity}\right\} \qquad (7)$$

Step4: De-noising is done with the bulk watermark to eliminate remove noise contents.

Step5: Each pixel in the retrieved multiple watermarks is matched with neighbouring pixels and considering the median value to frame the final watermark.

Step6: The filtered image is then imperiled for row-column wise truncation to obtain identical watermarks of $1/16^{th}$ size of host.

III. PERFORMANCE ANALYSIS

Fifteen standard images are taken for consideration from University of Granada, Dept. of Computer Science and Artificial Intelligence Computer Vision Group (CVG) for the analysis. The anticipated process is realized using Matlab software. Watermark to Document Ratio (WDR) and Correlation (NC) and between cover and watermarked images. In the above analysis, the proposed approach has proven better outcome compared to other approaches as tabulated below. The algorithm exploits very less computational time for both watermarking and de-watermarking processes compared to other prevailing techniques.

Table 1 Revelation of images under each stage of algorithm

 Host image	 Watermark Image
 Transformed Host	 Bulk Watermark Image
 Transformed Bulk Watermark	 Final Watermarked Image

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Table 2 **Comparison of WDR and Correlation between cover and watermark embedded images**

Images	WDR (dB)	Correlation(NC)
Lena	-87.7824	**1** (DWT)[3]
		0.984 (DCT) [3]
		0.994 (HFT) [17]
	-70.3132 [11]	**0.999** (IMD-WC-T) [17]
		0.9999
Cameraman	**-89.4073**	
	-68.6253 [11]	**0.9999**
Barche	**-89.6959**	**0.9999**
Peppers	**-88.9783**	
	-69.2068 [11]	**0.9999**
Donna	**-87.1015**	
	-71.0641 [11]	**0.9999**
Carnev	**-74.443**	
	-80.0757 [11]	**0.9999**
Foto	**-90.1087**	**0.9999**
Galaxia	**-86.0418**	
	-67.8158 [11]	**0.9999**
Leopard	**-85.2025**	**0.9999**
Mapasp	**-94.3281**	**0.9999**
Mare	**-89.4123**	**0.9999**
Mesa	**-89.9068**	**0.9999**
Montage	**-88.5184**	
	-69.1729 [11]	**0.9999**
Pallon	**-88.9023**	**0.9999**
Vacas	**-87.8834**	**0.9999**

A. Execution Time

Intel i3 processor @ 1.7 GHz, 4GB DDR RAM and Windows 8 OS. Time of execution is measured separately for watermarking and de-watermarking processes.

Table 3 Comparison of execution time in seconds

	G&E [29]	**L&T [30]**	**DWT& SVD [28]**	**SHT [11]**	**Proposed scheme**
Watermark embedding	2.989	5.701	2.107	0.11	**0.037**
Watermark extraction	2.301	3.964	1.086	0.47	**0.42**

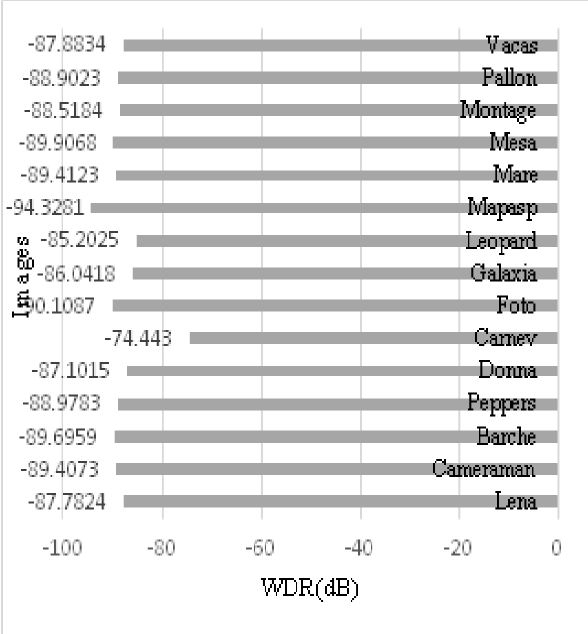

Fig.2 Plot of WDR(dB) between host and watermark

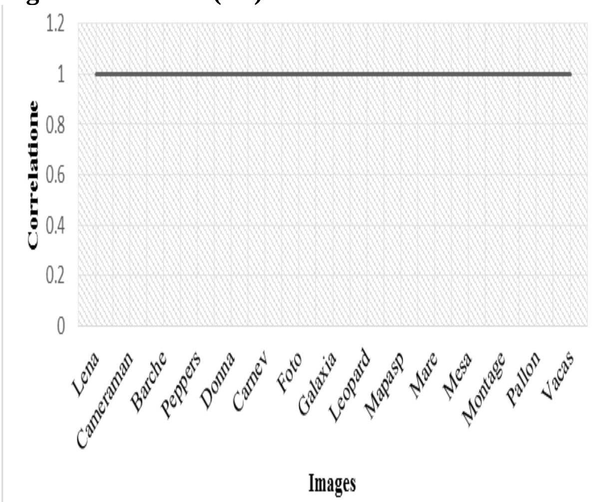

Fig.3 Plot of correlation (NC) between original and retrieved watermark

IV. CONCLUSION

The proposed frequency domain approach embeds watermark image into host using combined DFT and successive division methods. The algorithm utilizes about 154 times less execution time for embedding process and about 10 times less execution time for De-watermarking process compared to other existing frequency domain approaches. Better WDR is obtained with an average value of -88dB and an average NC value of 0.9999 are observed from the proposed technique compared to most popular techniques. The algorithm provides data capacity by embedding watermark with 1/16th size of the host image, which is common with the other algorithms. With these considerations, the proposed algorithm is an enhanced alternative to many time and frequency domain approaches. Further, DWT can be considered instead of DFT to get still better results and more data embedding capacity than other watermarking schemes.

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