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Digital Image Watermarking Technique Based on ROI Using DCT and DWT Hybrid Technique

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Abstract Watermarking is the process of inserting predefined patterns into multimedia data in a way that the degradation of quality is minimized and remain at an imperceptible level. Many digital watermarking algorithms have been proposed in special and transform domains. Least Significant Bit (LSB), Discrete Cosine Transform (DCT) and Discrete Wavelet Transform (DWT) are the common used for watermarking techniques In this paper, a hybrid watermarking technique based on DCT and DWT is proposed. An implementation of the two standalone watermarking techniques is carried out as well. A comparison between the three techniques is presented. This comparison was carried out using PSNR, MSE, and SSIM. The SSIM results were very close to 1 using DWT and the hybrid proposed technique, which means that the recovered watermarks from watermarked image were not distorted in those two cases compared with DCT. The MSE calculated values show that the smallest MSE value was obtained from the DWT, followed by hybrid technique then DCT, whereas the greatest PSNR values were obtained from DWT followed by hybrid proposed technique. The findings showed that the proposed hybrid technique was similar to DWT and more efficient compared to DCT technique.
Keywords: Watermark, DCT, DWT, Watermarked Image.

طريقة هجينة للعلامة المائية الرقمية تعتمد على الاجزاء المهمة من الصور باستخدام تقنية محول جيب التمام ومحول المويجات

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الملخص العلامة المائية هي عملية إدخال أنماط محددة مسبقًا في بيانات الوسائط المتعددة بطريقة لا تؤثر على جودتها وتبقى في مستوى غير محسوس. تم اقتراح العديد من خوارزميات العلامة المائية الرقمية في مجالات خاصة وتحويلات. تعتبرطريقة البت الأقل أهمية (LSB)، وطريقة تحويل جيب التمام (DCT)وتحويل المويجات (DWT) من الطرق الأكثر شيوعًا واستخداما في تقنيات العلامات المائية. في هذه الورقة، تم اقتراح تقنية العلامات المائية الهجينة المعتمدة على طريقتي DCT و DWT وتم مقارنتها مع الطريقتين السابقتين كلا على حده. عملية المقارنة بين التقنيات الثلاثة اجريت باستخدام المقاييس المعروفة والمتمثلة في PSNR و MSE و SSIM . كانت نتائج SSIMقريبة جداً من 1 باستخدام DWT والتقنية الهجينة المقترحة، مما يعني أن العلامات المائية المستردة من صورة ذات علامة مائية لم يتم تشويهها في هاتين الحالتين مقارنةً بطريقة DCT . كذلك نلاحظ من قيم MSE انه تم الحصول على أصغر قيمة لمتوسط الخطأ MSE كانت باستخدام طريقة DWT ، تليها التقنية هجينة المقترحة ثم طريقة DCT ، في حين تم الحصول على اكبر قيم PSNR من طريقةDWT متبوعة باتقنية الهجينة المقترحة. أظهرت النتائج أن التقنية الهجينة المقترحة كانت مماثلة لطريقة DWT وأكثر كفاءة مقارنة بتقنية DCT
الكلمات المفتاحية: العلامة المائية، محول جيب التمام، محول المويجة، صورة العلامة المائية.

I. Introduction

With the rapid development of the World Wide Web, emergence of the broadband networks and the cheap digital devices usage of the multimedia data increased drastically during the last decade. Digital (multimedia) data is very easy to copy and it is often copied without considering the copyright. Because of this, the distributors or the owners of the multimedia data are forced to use such schemes which prevent digital right violations automatically. [1]

Digital watermarking came as a technique and a tool to overcome shortcomings of current copyright laws for digital data. The specialty of watermark is that it remains intact to the cover

work even if it is copied. Therefore, to prove ownership or copyrights of data, watermark is extracted and tested. It is very difficult for counterfeiters to remove or alter watermark. As such the real owner can always have his data safe and secure [1].

Watermarking can be described as the process of embedding data (logo or text) in a signal, such as video, image or audio, that identifies the copyright information of the file, such as author and rights [1]. A watermarking technique is made up of two main basic algorithms: the embedding and the extraction algorithms. The embedding algorithm embeds the data on the cover media, while the extraction algorithm detects the data and decodes its content [1]. There are two basic types of digital watermarking: visible watermarking, and invisible watermarking. Visible watermarks are illustrated using visible descriptions, such as logo or stamp, to identify the owner. The watermark signal is visible in the image, video, or text. Some well-known examples of visible watermark are the logos of TV channels, companies, and governmental organizations [2]. On the other hand, the invisible watermark is not visible to the naked eye, and through this method, images, and other documents, such as PDF files, are protected from being copied, modified, or printed [2].

Watermarking algorithms can be implemented using spatial and transform domains. The techniques in the spatial domain have relatively low-bit capacity and are not resistant to lossy image compression and other image processing procedures, as a simple noise in the watermarked image may damage the watermark data [3]. However, transform (frequency) domain-based techniques have the capacity to embed more bits of data for watermark and are relatively more robust to attack. Discrete Cosine Transform (DCT) and Discrete Wavelet Transform (DWT) are some of the transforms used for watermarking in the frequency domain [4]. Several watermarking algorithms have been proposed using standalone DCT and DWT [5], [6]. Hence, this study a combination or a hybrid of the two techniques DCT and DWT is proposed and tested on ROI images.

II. MATERIALS AND METHODOLOGY

This study uses the grayscale image as an original image and Region of Interest (ROI) image of the original image as the watermark. The ROI image is chosen manually as a watermark and then it is embedded into the original image in DWT, DCT and DWT+DCT domains. The three techniques were executed and evaluated using three different 8-bit grey scale cover images in BMP image formats. The three grey scale cover images are illustrated Figure 1, whereas the watermarking ROI images used in this study were illustrated in Figure 2.

Fig. 1. The Original Cover Images: (a) Lena, (b) Boy, (c) Koala

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Fig. 2. The Watermarking ROI Images

A. The Proposed Technique

In the wavelet transform domain, high frequency parts represent detailed information of image's edge, contour and texture and so on. Embedding watermarking in high frequency places cannot be easily detected as people are not easily conscious of it, but after processing or attacking, high frequency parts has poor stability. Most energy of image is centralized in low frequency. Low frequency coefficients are nearly unchanged to common attack therefore watermarking information embedded in low frequency coefficients has better robustness. DCT separates images into parts of different frequencies where less important frequencies are discarded through quantization and important frequencies are used to retrieve the image during decompression. Since the human eye is more sensitive to noise in lower-frequency components than in higher-frequency ones and information hidden in higher-frequency components might be discarded. Therefore, in this proposed technique the watermark will be embedded into the middle-frequency range of the original image

In this algorithm, the DCT is applied to each 8×8 blocks of the original image while the DWT is applied to the ROI image. 1-level DWT is used to decompose ROI image into four sub-bands which are LL, LH, HL, HH. The LL sub band of ROI is selected to be embedded in the DCT coefficients of each block in the original image. The algorithm for watermark embedding is described in the following block diagram.

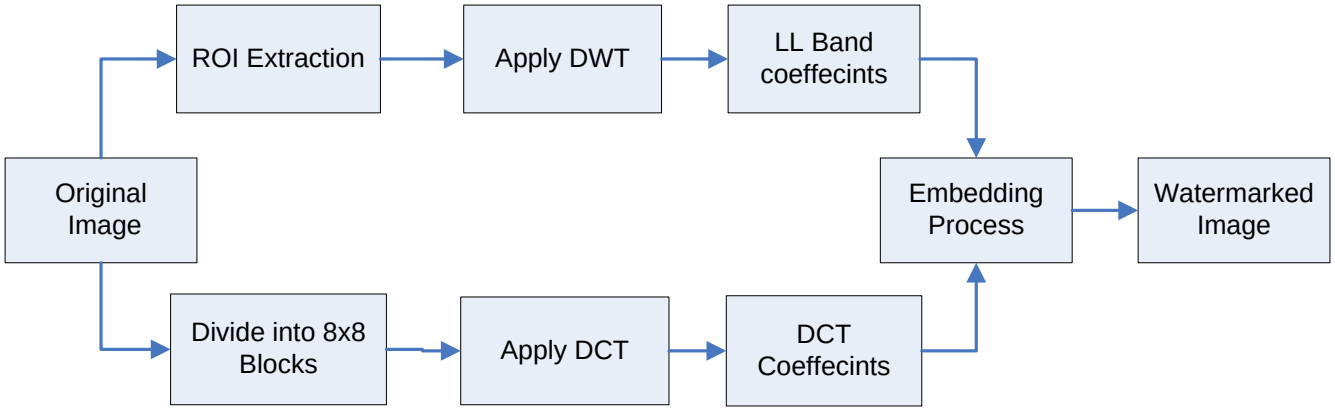

Fig. 3. Block Diagram of the Proposed Hybrid Technique – Embedding Stage

B. Evaluation Process

Two of the most common error metrics used to compare the various image watermarking techniques is the Mean Square Error (***MSE***) and the Peak Signal to Noise Ratio (***PSNR***). Both ***MSE*** and ***PSNR*** are objective performance evaluation methods that treat the image simply as a matrix of numbers.

The ***MSE*** produces an estimation of the amount that the original image differs from the watermarked image and perhaps corrupted image. Given an image ***f(i, j)*** and an image ***f'(i , j)*** of equal dimensions, the *MSE* is defined to be: [7]

$$MSE = \frac{1}{NM}\sum_{1=0}^{N-1}\sum_{j=0}^{M-1}\left[\left| f(i,j) - f^{*}(i,j)\right|^{2}\right] \qquad (1)$$

Where:

M, N is the image dimensions
f(i,j) is the original image
f'(i,j) is the watermarked image

The other common performance measure for the watermarking efficacy is Peak Signal-to-Noise Ratio (***PSNR***). It is a ratio between the maximum possible power of a signal and the power of corrupting noise that affects the fidelity of its representation. The formula for ***PSNR*** calculation is given by [7]:

$$PSNR = 20\log\left(\frac{2^{B}-1}{MSE}\right) \quad \text{dB} \qquad (2)$$

Where *B* is the bit depth of the image. For an 8-bit image, the ***PSNR*** is computed by [7]:

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

The third common performance measure used in this study is the Structural Similarity Index Measure (***SSIM***), which is a well-known quality metric used to measure the similarity between two images, The ***SSIM*** can be calculated as follows:[8], [9]:

$$SSIM = \frac{(2\mu_x\mu_y + C_1)(2\sigma_{xy} + C_2)}{(\mu_x^2 + \mu_y^2 + C_1)(\sigma_x^2 + \sigma_y^2 + C_2)}$$

Where :

μ_x : the average of x
μ_y : the average of y
σ^2_x : the variance of x
σ^2_y : the variance of x
σ_{xy} : the covariance of x and y
$C_1 = (k_1 L)^2$, $C_2 = (k_2 L)^2$: two variables to stabilize the division with weak denominator
L : the dynamic range of the pixel-values
K_1=0.01, k_2=0.03

Note that the ***SSIM*** has a value between 0 - 1. Similar images have ***SSIM*** near to 1 [8], [9]

III. RESULTS PRESENTATION

Four 512x512 grayscale BMP images, as shown in Figure 1, were used as cover images; the size of every cover image was 257 kilo-bytes. The watermark that was hidden inside these images was 50x50 ROI images of each original image. This section discusses the evaluation of the watermarked images after the embedding process, and evaluation of the recovered watermarks after the extracting process.

The following figures show the original cover image and the watermarked image embedded with the watermarking image using three different techniques which are DCT, DWT and the proposed hybrid technique.

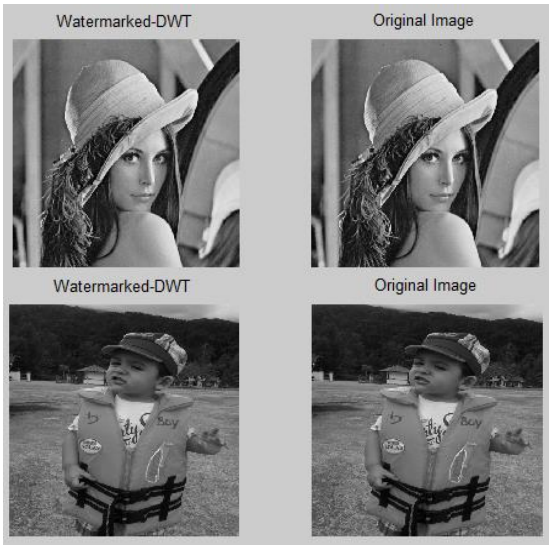

Fig. 4 Original and Watermarked Images using DWT

Fig. 5 Original and Watermarked Images using DCT

Fig. 6 Original and Watermarked Images using Hybrid Technique

Visually observation from the above figures, it can be noted that there is no difference between the original and the watermarked images in these three domains. On the other hand and to be more accurate, some distortion is noticed for the watermarked images in DCT domain. This is because the proposed algorithm depends on the similarity between the values of the coefficients for original image and ROI image which is considered as a watermark image to be embedded.

The obtained result for the recovered watermarks of DWT, DCT and DWT+DCT hybrid algorithms is shown in Figures 7, 8 and 9 respectively. The eye of lena in Lena image and the head of boy in Boy image were selected as ROI (watermark) images.

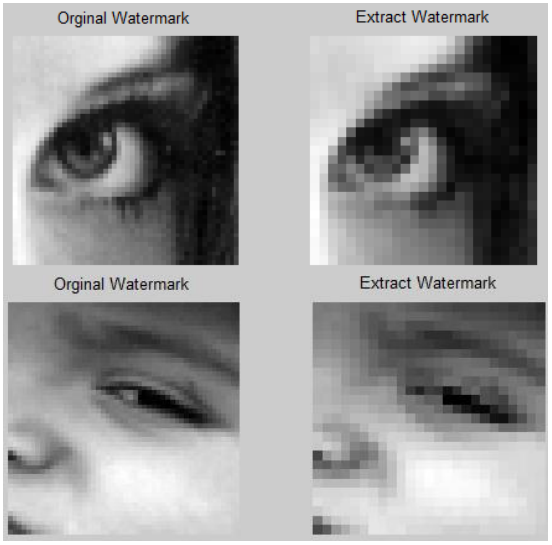

Fig 7. The Original and Extracted Watermark Images using DWT

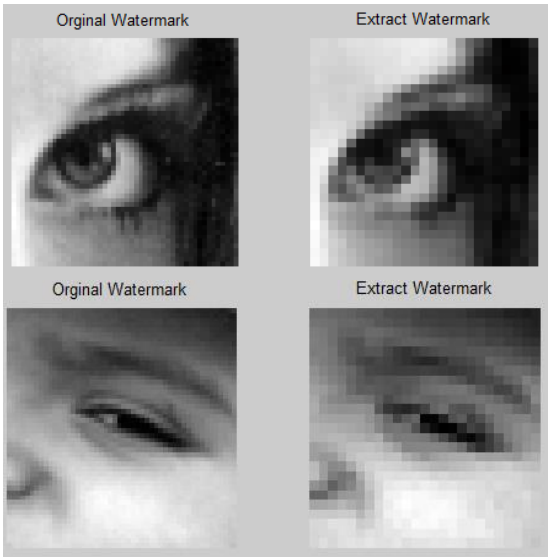

Fig 8. The Original and Extracted Watermark Images using DCT

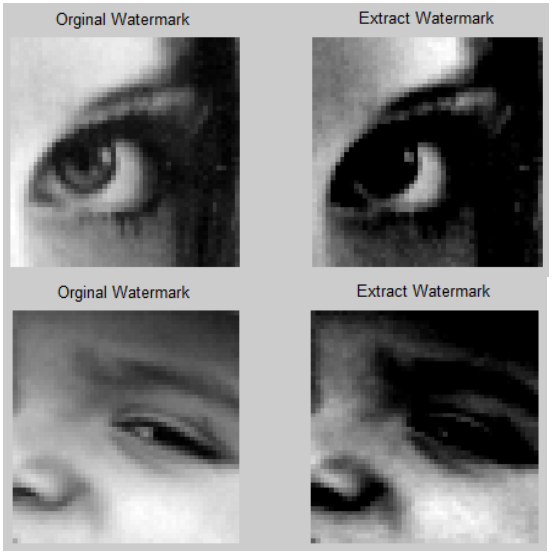

Fig 9. The Original and Extracted Watermark Images using Hybrid Technique

It is noticed that the recovered watermark in DWT domain has also the highest quality. Nevertheless, as a visual observation, all three algorithms have an acceptable quality for their recovered watermarks to be clear adequacy for the recipient.

In addition to the above subjective evaluation, an analysis of the image quality assessment is discussed in details and comparative between the three proposed algorithms is done based on Mean Square Error (MSE) and Peak-Signal-to-Noise Ratio (PSNR) for the watermarked images. Furthermore, Structural Similarity Index Measure (SSIM) is used to evaluate the recovered watermarks. These three parameters will give a clear distinction and evaluation of the three proposed algorithms.

As described before, the lowest value of ***MSE*** means less error, and the highest value of ***PSNR***. is good because it means that the ratio of signal to noise is high The typical values for the ***PSNR*** are between 30 dB and 40 dB. Therefore, if the PSNR of the watermarked image is more than 30, it is difficult to notice the differences between the watermarked image and the original image using the naked eye. [10]

The obtained MSE and PSNR results are plotted in figures 9 and 10 respectively.

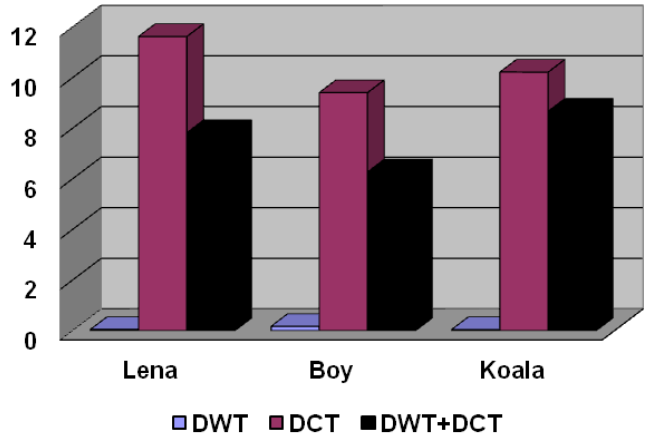

Fig. 10. The MSE Values of the DWT , DCT and Hybrid Techniques.

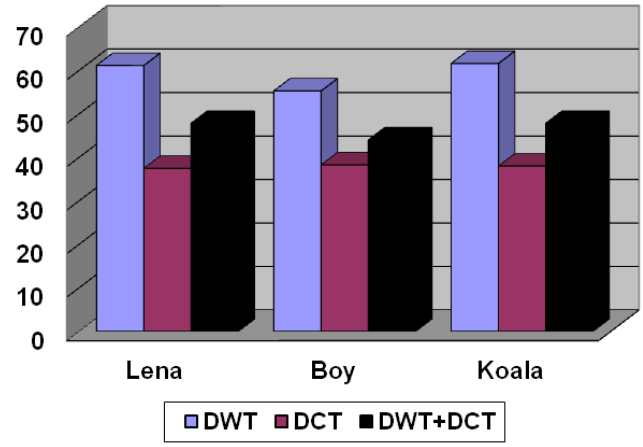

Fig. 11. The PSNR Values of the DWT , DCT and Hybrid Techniques.

From figure 10, it can be noticed that the lowest MSE values were obtained from using DWT followed by the proposed hybred technique then the highest was obtained from using DCT. This means that the recovered watermark image contains on more errors in DCT compared with the DWT and the hybrid techniques. Consequently, from figure 11, it can be seen that the highest PSNR values were obtained from using the DWT followed by the proposed hybrid technique then the DCT. This indicates that the quality of the recovered watermark images was better in the case of using the DWT and the proposed hybrid technique compared with the DCT technique.

Despite this difference between all three algorithms, the results are acceptable since the values of PSNR for three algorithms are above 30 dB.

As it was mentioned, the other objective evaluation measure used in this study is the ***SSIM*** index which is a decimal value between 0 and 1. The value 1 can only be given in the case of two identical sets of data. The recovered watermark images before and after the extraction phase were evaluated using the ***SSIM***. The obtained ***SSIM*** values are presented in figure 12.

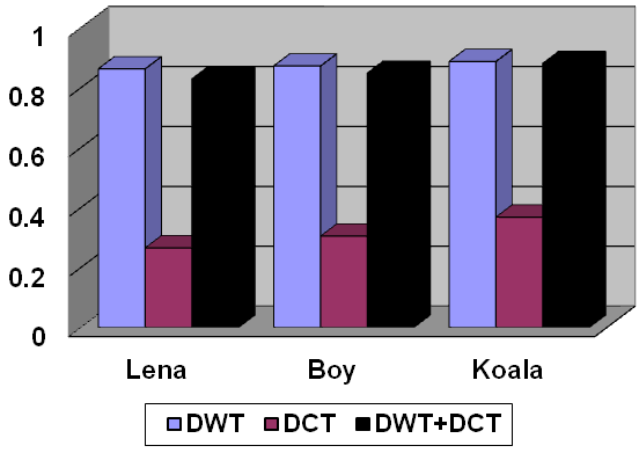

Fig. 12. The SSIM Values of the DWT , DCT and Hybrid Techniques.

From the above figure, it can be seen that the values of the ***SSIM*** are approximately equal to 0.8 in the case of using the DWT and the proposed hybrid technique. This indicates that the recovered watermark images from the watermarked images were similar in terms of the quality in both cases, whereas the ***SSIM*** values obtained from using the DCT were less than 0.5 which means the recovered watermark images were degraded and distorted compared with the original watermarks.

IV. CONCLUSION

In this study, three different transform watermark techniques based on ROI have been successfully implemented and evaluated. These techniques are DWT, DCT, and a hybrid between DWT and DCT. A comparison between the three techniques was presented. The comparison process was carried out using the MSE, PSNR, and SSIM measures.

The obtained results from those three measures showed that the best quality of the recovered watermark images was obtained from using the DWT followed by the proposed hybrid technique.

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