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PIXEL INTENSITY INDICATOR ALGORITHM USING 2D-DCT WATERMARKING FOR COLOURED IMAGE

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Abstract

Networking and computer facilities are becoming cheap and more widespread. Digital watermarking has been offered as an appropriate apparatus for recognizing the creator, source, distributor, vendor, or official consumer of files or images. Two domains exist for embedding watermarks: frequency and spatial. In the frequency domain, information is embedded in the coefficients of a transformed image. The transformations comprise of Discrete Cosine Transform (DCT), Discrete Fourier Transform (DFT), and Discrete Wavelet Transform (DWT). However, if the embedded information is too much, the color image quality will be degraded significantly. Therefore, this paper supposed a new algorithm that chooses the best split channel of red, green, and blue before the execution of the digital watermarking process. The proposed algorithm is called Pixel Intensity Indicator Algorithm (PIIA); this algorithm can be considered as a metric, a measure, or an indication about image imperceptibility. The suggested method has been applied before the most popular approach Two-Dimensional Discrete Cosine Transform (2D-DCT). Many properties have been used to evaluate the watermarking algorithm. This work focuses on the imperceptible property of the watermark that has been tested through matching or comparing the original image with the watermarked one. Several performance metrics are used, such as Mean Squared Error (MSE), Peak Signal to Noise Ratio (PSNR) and Structural Similarity Index (SSIM).

Keywords: 2D-DCT, Digital image watermarking, Image steganography, Imperceptibility, Pixel intensity.

1. Introduction

Watermark is a drawing affected on a piece of paper for production purposes and used for copyright identification; this watermark can be a logo, a pattern, or another image. In the modern era, the great growth of communications via the internet provides access to digital multimedia communication; this presents new chances to steal copyrighted material. Digital watermarking has been offered as an appropriate apparatus for recognizing the creator, source, distributor, vendor, or official consumer of an image or a file.

The first persons whose usage the term "Digital Watermarking" are Komatsu and Tominaga [1]. It is usually used to recognize ownership of the copyright for a signal. The steganography is closely related to watermarking; however, there are some characteristics between them, and this paper is focused on image watermarking rather than steganography. Watermarking mostly related to image authentication, while steganography deals with hiding data, and this data should imperceptible to any interceptors [2].

The embed process of image watermarking can be done in two domains: the frequency and spatial. In the spatial domain [3], such as the traditional method of Least Significant Bit (LSB), in this technique, the watermark data simply place into a host image by direct altering certain grey pixels of the host image. The advantages of this method are ease of implementation and low complexity; however, the implanted information may be easily noticed by computer analysis or can be easily attacked (low robustness). In the frequency domain [4] the transformations comprise of Discrete Cosine Transform (DCT), Discrete Fourier Transform (DFT), and Discrete Wavelet Transform (DWT), in these methods the watermark data inserted into the coefficients of a transformed image. But, if the embed data is too much in this domain, the image quality will be tainted significantly.

Therefore, this research highlights this disadvantage and suggests solutions to overcome this problem. Another technique is joining both these two domains of watermarking to improve robustness and get less complexity called hybrid domain [5].

The rest of this paper is structured as follows: Section 2 discusses the watermarking or embedding process that has been adopted, section 3 discusses the related work of this research, section 4 describes the proposed algorithm. Section 5 introduces the evaluation process. Section 6 gives the experimental results, and finally, section 7 presents the conclusions.

2. Watermarking Process

The embedding process that has been selected for digital watermark after applying the proposed algorithm is the 2D-DCT. The first persons who introduced the DCT in image processing is Ahmed et al. [6]. Image watermarking and steganography applications consider DCT as the most significant technique. For example, the experiment of adding 20% Gaussian noise to the watermarked image, the best results are gained by using DCT transformation against Gaussian Attack [7]. As well, the best results are shown in image contrast manipulation DCT, while DWT was the best for compressing image using RIOT (Radical Image Optimization Tool) application.

The cosine function is preferred than the sine function due to a blocking effect on image compression. The DCT is like DFT with the advantage of keeping the average power of the transformed signal in low range frequency for which human eyes are less sensitive. Assume that $f(x,y)$ is the image in the spatial domain of $M \times N$matrix size and $F(u,v)$ is the image in the frequency domain, the equation for the 2D-DCT is [7]

$$F(u,v)\ c(u)c(v) \sum_{x=0}^{M-1} \sum_{y=0}^{N-1} f(x,y) \cos\frac{(2x+1)u\pi}{2M} \cos\frac{(2y+1)v\pi}{2N} \tag{1}$$

The 2D-DCT inverse transform can be represented as [7]

$$f(x,y) = \sum_{x=0}^{M-1} \sum_{y=0}^{N-1} c(u)c(v)F(u,v) \cos\frac{(2x+1)u\pi}{2M} \cos\frac{(2y+1)v\pi}{2N} \tag{2}$$

where $0 \le x \le M-1, 0 \le y \le N-1, 0 \le u \le M-1, 0 \le v \le N-1, c(v)$ and $c(u)$are the transform parameters and it defined as follows [7]

$$c(v) = \begin{cases} \frac{1}{\sqrt{N}} & , v = 0 \\ \sqrt{\frac{2}{N}} & , 1 \le v \le N-1 \end{cases} \tag{3}$$

$$c(u) = \begin{cases} \frac{1}{\sqrt{M}} & , u = 0 \\ \sqrt{\frac{2}{M}} & , 1 \le u \le M-1 \end{cases} \tag{4}$$

3. Related Work

As mentioned, two domains exist for embedding watermarks: frequency and spatial domains. For spatial domain such as LSB method, Sahu and Swain [8-12] were succeeded in achieving high hidden data capacity regrading to low image pixel distortion by using a different technique. While in the frequency domain, the embedded data process in image watermarking includes [4]: the following transformations: Discrete Cosine Transform (DCT), Discrete Fourier Transform (DFT), and Discrete Wavelet Transform (DWT). Several papers based on DCT have been presented, which focused on the size of the allocated memory, the complexity and the frequency coefficients of a transformed image. Tsai and Yang [13] suggested a method that, based on the decomposition of the 2D-DCT to a single pair D, they regrouped coefficients depending on the symmetric property of yield. This method decreased the computation time to only 24 multiplication. They embed (32*32) data in an image of size (256*256). If the embedded data is too much, the image quality will be tainted significantly. Therefore. Zhang et al. [14] suggested a method based on 2D-DCT. They did not divide the 2D into 1D, and this conserves storage space. They split the original image to RGB components then embed data in the remaining two colours since they were set to zero, data vector is transformed into a color channel in a specific complementary technique to keep close to the original pixel value or facilitate a way to restore original pixel value. This method provided high embedded data capacity but need more time to be executed. Nikolaidis [15] proposed generating zeros that accommodate bitstream of data to be embedded; non-zero coefficients, which equate to a specific absolute value, will be transformed into bit 1. Each bit equal to 1 will embed a bit of data. But this method didn't decrease the complexity.

Therefore, this research highlights these disadvantages and suggests solutions to overcome the problem of degraded image quality due to a huge embedded data watermarking process. Many metrics have been used to indicate image quality before and after the watermarking process (image imperceptibility [16]). This research presented an algorithm that gives the priority of the best color channel (Red, Green, and Blue) regarding image quality before steganography or watermarking process execution.

The idea of indication has been used by many researchers to give an indication of the problem statement [17]. For example, Gutub -[18] used a technique of least two significant bits on one of the three channels Red, Green, or Blue as an indicator of secret data existence in the other two channels for LSB method (provide secured steganography method).

4.PIIA Algorithm

The Pixel Intensity Indicator Algorithm (PIIA) should be applied before the watermarking process to give the indicators about color cover image and how many red, green, and blue pixels are distributed overall the cover image. As mentioned before, if the embed data is too much using the frequency domain of the watermarking process, the image quality will be degraded significantly [5]. Hence this paper focuses on this disadvantage and proposes solutions to overcome this problem. PIIA has been suggested as a guide to provide information about the cover image color intensity (red, green, and blue) and which channel is ideal for the watermarking or steganography process.

Figure 1 shows the block diagram of the PIIA and watermarking process. In this diagram, firstly, the three RGB color channels of the cover image are separated. Secondly, the proposed method (PIIA) has been applied for each channel individually to provide the indicator about that channel. Then the 2D-DCT transform has been used. The watermark information (embedding information) is transformed into an RGB channels (same Gaussian noise embedded for each channel). Finally, a 2D-DCT inverse transform has been used to reconstruct the three RGB channels. So, the watermarked RGB image is obtained. Moreover, Fig. 2 demonstrates how the watermark information of Gaussian spread-spectrum noise has been inserted in Fig. 2(a) and extracted Fig. 2(b) [16].

Figure 3 illustrates the principle diagram of the proposed algorithm (PIIA). As an example, this diagram shows how PIIA gives the value of indication for the red channel only as an output of the cover image. This indication is the result summation for the ones of two logical matrices (binary matrices); the first logical matrix is produced from the logical operation (greater than) between the corresponding pixels of red and green channels (x). In comparison, the second matrix is produced from the logical operation (greater than) between the corresponding pixels of red and blue channels (y).

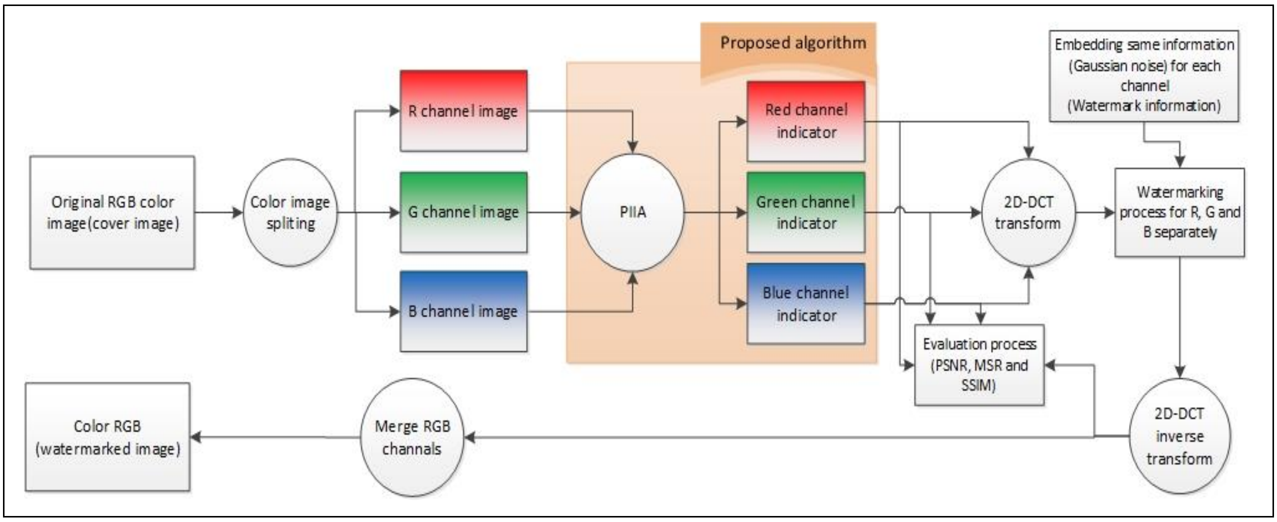
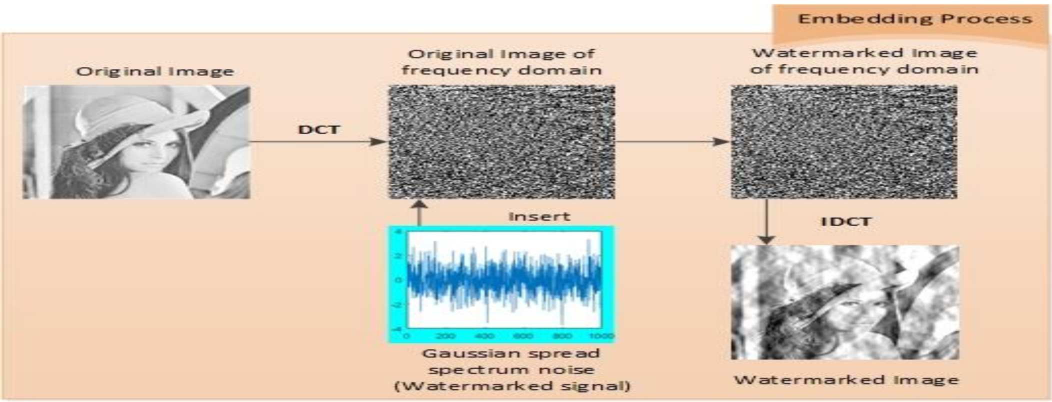
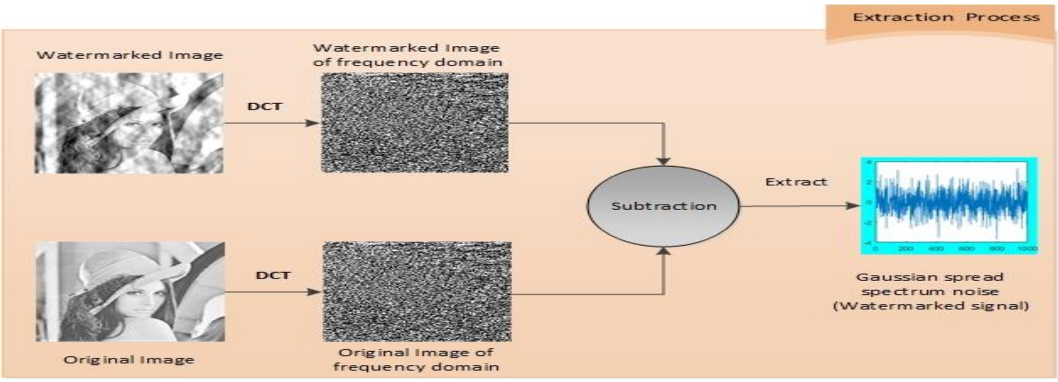


Fig. 1. The block diagram of the watermarking process.



(a) Embedding process.



(b) Extraction process.

Fig. 2. Embedded and extracted watermarking schemes [16].

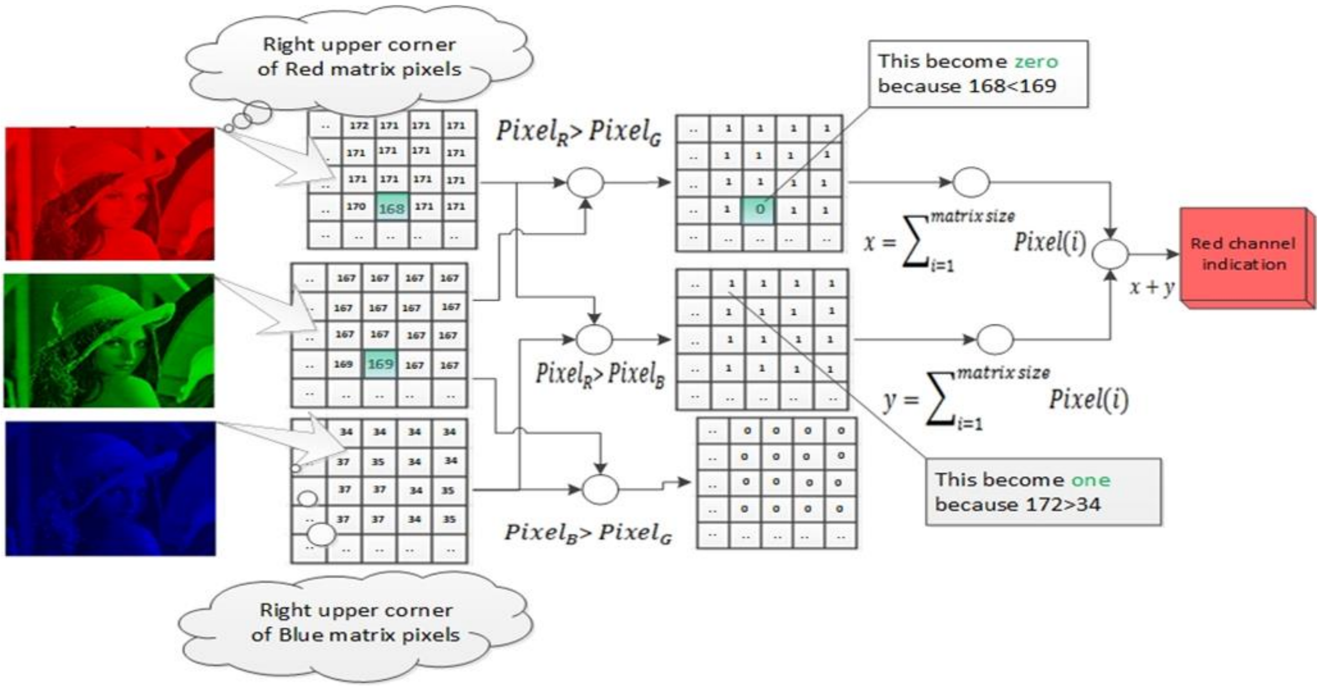


Fig. 3. The principle operation of PIIA for red channel indicator.

5. Evaluation Process

The evaluation process has occurred before and after the watermarking process, as shown in Fig. 1. Many functions have been used to examine the watermarking algorithm by comparing the image before and after the watermarking process. The ideal digital watermarking technique must be imperceptible, robust against any attack, and high hidden data capacity [16].

5.1. Imperceptibility

The embedded watermark information in the computerized picture ought to be perceptually undetectable to human eyes according to the Human Visual System (HVS) parameters. The imperceptibility is performed by contrasting the original image with the watermarked one. The proposed PIIA can be considered as a metric, a measure, or an indicator of image imperceptibility. Several tests or functions are usually used in this regard as follows:

5.1.1. MSE

The Mean-Squared Error (MSE) is between the original and watermarked images. It is one of the earliest tests that were executed to examine the similarity between the two images. The following equation represents it:

$$MSE = \frac{1}{m \times n} \sum_{i=0}^{m-1} \sum_{j=0}^{n-1} \| A(i,j) - B((i,j) \|^2 \qquad (5)$$

where A is the image before the watermark process while B is after, $m \times n$ is the size of images B and$A$.

5.1.2. PSNR

Peak Signal to Noise Ratio (PSNR) is an improved test; it takes the signal strength into consideration (not error only). Eq. (6) defines its formula.

$$P\,S\,N\,R = 20 \times \log_{10}\left(\frac{MAX}{\sqrt{MSE}}\right) \tag{6}$$

where MAX is the maximum gray value of the images A and$B$, the higher PSNR value indicates a lower distortion rate. It represents the obtained image quality.

5.1.3. SSIM

The two earlier error metrics are not appropriate to measure what similarity means to the human visual system (HVS), hence, to solve this problem, Structural Similarity (SSIM) is recommended and suggested by Wang et al. [19] as defined in the following equation:

$$S\,S\,I\,M = \frac{(2\mu_x\mu_y+c1)(2\sigma_{xy}+c2)}{(\mu_x^2+\mu_y^2+c1)(\sigma_x^2+\sigma_y^2+c2)} \tag{7}$$

where "μ" is the mean, "σ" is variance and "σ_{xy}" is the covariance of the images." $c1, c2$" are constants of the stabilizing. The value of SSIM is between 0-1. If SSIM is equal to one, then the two images are completely similar.

5.2. Robustness

Robust watermarks are typically used for copyright protection to declare legal ownership. Robust watermarks must be designed to survive difficult (hopefully impossible) to detect or delete the embedding information. The robustness of a watermark technique can be calculated by carrying out attacks on the watermarked image and measuring the similarity of the original image (cover image) to the watermarked image. Examples of these attacks are the compression (such as JPEG) and noise (such as Speckle, Salt & Pepper, Gaussian, and Poisson) attacks. This paper has used Gaussian noise as embedding information instead of real watermark information to test the proposed algorithm.

5.3. Capacity

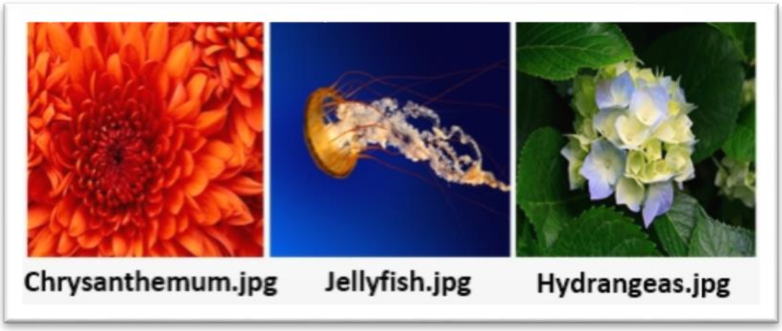
The digital watermarking technique usually must have a high capacity to embed information, taking into consideration imperceptibility and robustness against attacks [17]. Capacity limitations of the watermark technique can be effectively assessed by expanding the length of the watermarking message, e.g., [20] Succeeded increase from standard 4th to 8th LSB layer of embedding information regarding imperceptivity.

6. Experimental Results

In this section, the experimental results have executed hardware platforms: (Intel Core i7-4500 CPU with @ 1.80 GHz and RAM of 8 G.B.). Experimental environments (software platform) was the $MATLAB^{®}$ R2017a running under a 64-bit Windows 8 operating system.

The image's properties that have been used in the experiments are 24-bit color images of the resolution 512×512 pixels for different image file extensions, as shown in Fig. 4 images (a) standard cover images [7, 14, 21] and (b) non-standard cover images. These six RGB images have selected randomly regarding its colour’s distribution; three are standardly used with the experiment's articles of image watermarking [7, 14, 21], and three are not standard (windows 7 sample photos). The pixels intensity for red, green, and blue channels can determine by using human vision, such as in Fig. 4(b) (e.g., chrysanthemum.jpg image has a red pixel channel intensity greater than other channels) while in Fig. 4(a) the human vision couldn't determine which channel has the greatest pixel intensity (e.g., baboon.jpg).

(a) Standard cover images [7, 10, 12].



(b) Non-standard cover images.

Fig. 4. Cover images that have used in the experiments.

Figure 5 illustrates the GUI that has been developed to execute the proposed algorithm (PIIA) using $MATLAB^{®}$.

Table 1 shows imperceptibility result tests after 2D-DCT has applied of image watermarking process. However, depending on SSIM and as in Table 1 (e.g., Lenna.png image), the smallest SSIM metric value is 0.79771 of the red channel, you can see the greatest value of PIIA indicator is also for the red channel (the greatest intensity of the color is red that equal to 518858); hence the algorithm is recommended to avoid the watermarking operation using the red channel, and it should be in green then/or blue channels, so the algorithm has succeeded to give the indication to void embedding data using red channel (the watermarking should be in the two other channels).

Table 2 demonstrates the priority for the watermarking process of red, blue, and green channels according to PIIA results (e.g., CHRYSANTHEMUM.JPG image), the priority of channel is blue (117097), green (468451) than red (1572864) respectively to obtain best quality image after watermarking process.

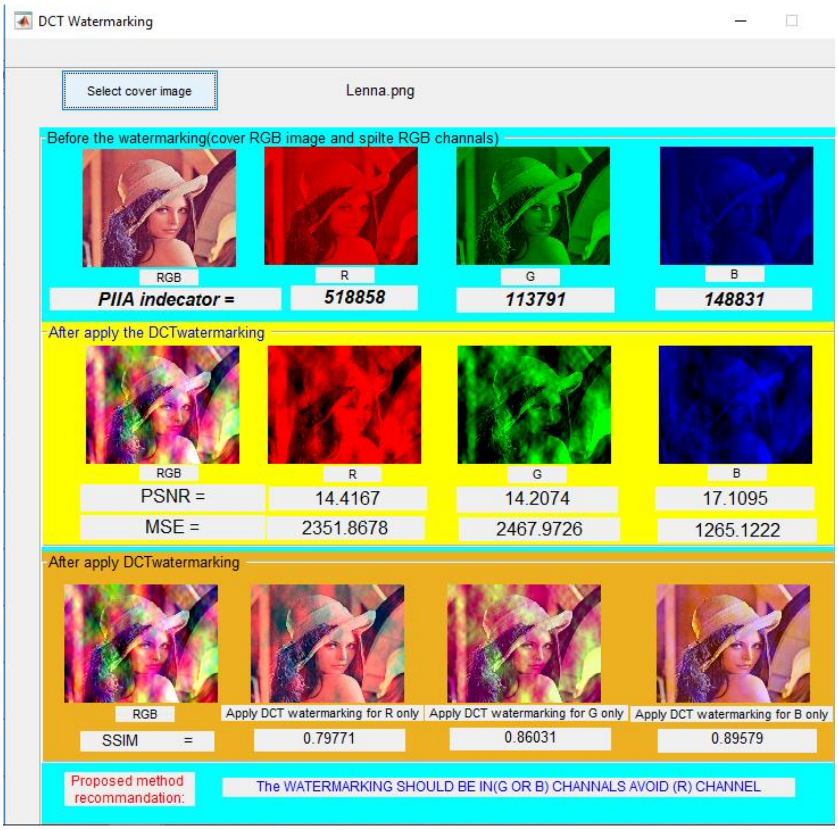


Fig. 5. The GUI that has developed to implement the proposed method.

Table 1. Imperceptibility tests for standard and non-standard cover images.

ƆVER IAGE NAME	**Channel**	**PIIA indicator**	**SSIM**	**PSNR**	**MSE**
LENNA.PNG	**Red**	**518858**	**0.79771**	4.4167	2351.868
	Green	113791	0.86031	4.2074	2467.973
	Blue	148831	0.89579	7.1095	1265.122
BABOON.JPG	Red	271683	0.72699	3.2464	3079.249
	Green	**337905**	**0.70671**	5.1457	1988.419
	Blue	166964	0.80142	3.2575	3071.379
AIRCRAFT.TIF	Red	86176	0.71279	8.0513	1018.482
	Green	310896	0.63011	7.064	1278.446
	Blue	**351839**	**0.62295**	0.2356	615.918
CHRYSANTHEM.JPG	**Red**	**1572863**	**0.96215**	8.8197	853.311
	Green	468451	0.98705	9.5222	725.878
	Blue	117097	0.99585	9.5003	72.954
JELLYFISH.JPG	Red	93299	0.92407	6.743	1376.502
	Green	207460	0.91137	8.1129	1004.125
	Blue	**448267**	**0.86093**	7.5185	1151.409
HYDRANGEAS.JPG	Red	219143	0.75261	6.4067	1487.324
	Green	**467103**	**0.68583**	6.6569	1404.071
	Blue	57858	0.74544	7.0406	1285.351

Table 2. Channel watermarking process priority according to PIIA results.

Cover Image Name	Optimum	Moderate	Worst
LENNA.PNG	Green	Blue	Red
BABOON.JPG	Blue	Red	Green
AIRCRAFT.TIF	Red	Green	Blue
CHRYSANTHEMUM.JPG	Blue	Green	Red
JELLYFISH.JPG	Red	Green	Blue
HYDRANGEAS.JPG	Blue	Red	Green

7. Conclusions

In this paper, an algorithm is developed, which is called Pixel Intensity Indicator Algorithm (PIIA). PIIA is suggested as a guide to provide information about the cover image color intensity (red, green, and blue). Also, it provides the ideal channel for steganography or the watermark process. This algorithm should be applied before the watermarking process, in order to give the indicators about color cover image and how many red, green, and blue pixels are distributed overall the cover image. The embedded watermark information in the digital image should be perceptually invisible to the eyes of the human as reporting by the Human Visual System (HVS) parameters. The imperceptibility is performed by contrasting the original image with the watermarked one. The proposed PIIA may be considered as an additional but not unique metric or measure of indication for imperceptibility image property. The embedding process that has been chosen for digital watermark after applying the proposed algorithm of this research is 2D-DCT.

Nomenclatures

A	Image before the watermark process
B	Image after the watermark process
$c1$	Stabilization constant
$c2$	Stabilization constant
$c(u)$	Transform parameters
$c(v)$	Transform parameters
cos	Cosine function
$F(u,v)$	Image in the frequency domain
$f(x,y)$	Image in the time domain
$\log_{10}$	Logarithm
MAX	Maximum gray value of the images *A* and *B*
$M \times N$	Image matrix size
$Pixel_R$	Pixel of red matrix channel
$Pixel_G$	Pixel of green matrix channel
$Pixel_B$	Pixel of blue matrix channel
$>$	Relational operation
$\sum$	Summation
$\surd$	Squire root

Greek Symbols

μ	Mean

π	Pi = 3.14159
σ	Variance
σ_{xy}	Covariance

Abbreviations

2D-DCT	Two Dimension Cosine Fourier Transform
DCT	Discrete Cosine Transform
DFT	Discrete Fourier Transform
DWT	Discrete Wavelet Transform
IDCT	Inverse Discrete Cosine Transform
GB	Gaga Byte
HVS	Human Visual System
LSB	Least Significant Bit
MSE	Mean Squared Error
PIIA	Pixel Intensity Indicator Algorithm
PSNR	Pick Signal to Noise Ratio
RGB	Red Green Blue
RIOT	Radical Image Optimization Tool
SSIM	Structural Similarity Index

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