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Research Article

Fuzzy Watermarking for Colour Images based on Fusion of Discrete Wavelet Transform (DWT) Technique and Histogram Stretching

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Abstract: This study presents a method of scheming colour image by using fuzzy watermarking through Discrete Wavelet Transform (DWT) and histogram stretching methods. This study aims further at achieving and developing robustness, imperceptibility and available capacity of cover image for the watermarked image, which can withstand against various attacks. Digital watermarking techniques are used to protect the copyrights of multimedia data by embedding secret information in the host media, for example, embedding in images, audios, or videos. Many watermarking techniques have been proposed in the literature to solve the copyright violation problems, but most of these techniques failed to satisfy both imperceptibility and robustness requirements. In this research, adaptive RGB colour image fuzzy watermarking technique is proposed. The host image is converted from RGB to YCbCr colour space to preserve imperceptibility and robustness, then, Cb component is extracted and partitioned into four quadrants. While the Histogram Stretching will be used to convert the Watermark image to 4-bits plan to preserve the capacity for watermarking.

Keywords: 4-bits plan, Discrete Wavelet Transform (DWT) technique, fuzzy watermarking, histogram stretching, RGB colour image

INTRODUCTION

There is no doubt that using the internet has become ubiquitous in the 21st century and it is quite true that everyone feels it is an indispensable part for the future of business communication. Going by the systematic digital data attainment and its conversion for the contemporary purpose is quite simple. Hence, copyright is an unavoidable issue to protect intellectual contributions (Rehman and Saba, 2014; Neamah *et al*., 2014). Tsai *et al*. (2000) and Wu (2002) highlighted recently that, through analyzing the trend of studies in digital watermark for audio, image or video data; it could be seen that watermarking techniques are the only way to prove legal ownership.

Watermarking algorithms can be classified based on the domain used for watermark embedding. Studies have shown that two popular techniques; spatial and transform watermarking techniques exist. Spatial domain watermarking techniques are useful for higher data embedding applications (Muhsin *et al*., 2014, Rehman *et al*., 2013). Transform domain watermarking techniques are suitable in applications where robustness is of prime concern. These techniques as proposed include, Discrete Cosine Transform (Chandramouli *et al*., 2001) Discrete Fourier Transform (Premaratne, 1999) Discrete Wavelet Transform; Discrete Hadamard Transform (Anthony *et al*., 2002); Contourlet Transform (Jayalakshmi *et al*., 2006) and Singular Value Decomposition (Mohan and Kumar, 2008) are some of the useful transformations for image processing applications.

With the introduction of the JPEG2000 standard digital image, watermarking schemes that are derived from Discrete Wavelet Transform (DWT) are becoming a robust area attracting lots of attention. Nearly all watermarking schemes consider Discrete Cosine Transform known as DCT method of preference. A summary are available in Cox *et al*. (2008). Though, study result shows that DWT has the potentials of enhancing the strength of watermark against intentional and unintended attacks. The primary reason would be that the former JPEG standard depended on DCT and today using the creation of JPEG 2000, schemes according to DWT are widely attaining interest. Though, watermark robustness varies using the underlying changed algorithms', provisions must automatically get to harden a watermark against attacks. The methods are, e.g. multiple embedding Nasir *et al*. (2008) and the use of Error Correction Codes (ECC) are being used to restore the embedded watermark.

DWT is basically a recent method used in place of an image but in a new time and frequency scale. The basic function of DWT is decomposing the input signal to multi-resolutions. "DWT can be used to decompose input signal that poses as image into low frequency

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(LL) and high frequency (HL, LH and HH). HL here means the horizontal detail, while LH stands for the vertical detail and HH for the diagonal part. The lowest frequency band which serves as the optimal approximation of the original image, is influenced using the DWT decomposition progressions technique which represent the maximum scale and distinguishing degree" (Santhi *et al*., 2008). The main aim of this study work is to come up with a proposed method of scheming color image by using watermark through Discrete Wavelet Transform (DWT) and histogram stretching methods. This study aims further at achieving and developing robustness, imperceptibility and available capacity of cover image for the watermarked color image, which can withstand against various attacks (Rehman and Saba, 2012; Elarbi-Boudihir *et al*., 2011).

PROBLEM BACKGROUND

It is generally believed that, many studies centers on the development of watermarking schemes for grayscale images than color images (Liu and Chou, 2007; Saba and Rehman, 2012). Consequently, available records show that, information hiding has been an important research area in recent years. However, the techniques to help address the issue of unauthorized copying, tampering and multimedia data delivery through the internet require urgent attention. Information hiding techniques currently involves merely the steganography and digital watermarking.

Currently, digital watermarking schemes concerning the data taken into account through getting rid of might be categorized as blind and non-blind approaches. In non-blind watermarking approaches, both data for actual host image and understanding statistics about watermarked image are known inside the amount of watermark recognition and extraction (Tao and Eskicioglu, 2004). In contrast, in blind approach finding the watermark and not mention for the original image is preferred (Al-Otum and Samara, 2010). You find several difficulties regarding the blind watermarking approaches. On one hand, high effectiveness of blind watermarking may also be proven. Therefore, a completely new technique referred to as semi-blind watermarking was introduced. Within this kind of watermarking approach, only the original watermark or perhaps the watermarked multimedia statistics are known (Tao and Eskicioglu, 2004; Shieh and Athaudage, 2006).

An issue surrounding using the internet today is users "stealing" other individual's images and taking advantage of them on the web site without permission. It's impossible to prevent someone from installing images out of your web pages. If you are an artist, you'll most likely wish to safeguard your images by watermarking them.

PROBLEM STATEMENT

Immediate digital image watermarking is certainly an urgent requirement for several today's programs such as digital cameras and smart phone cameras. Evaluating two watermarking techniques, transform domain watermarking approaches require greater computational complexity over spatial domain techniques (Kougianos and Mohanty, 2011). This could further be as a result of forward and inverse changes in the transform-domain watermarking approaches. However, it is common to understand that, there are difficulties with spatial-domain techniques. For instance, high embedding errors in ISB bit-planes result in many researchers employing low-order bit-planes for instance LSB for data hiding (Maity *et al*., 2007). However, the lower-order bit-planes techniques does not contain visually significant information so, the embedded watermark may be simply corrupted or transformed by unauthorized clients without affecting on visual effects. Abolghasemi *et al*. (2010) for instance recommended a technique using co-occurrence matrix and bit-plane clipping that could find out the hidden data in LSB.

Studies have revealed the existence of several diversities of attacks against watermarking methods. For example Basu *et al*. (2010), experimental investigations showed that watermarking approaches in the past were prone to several kinds of malicious attacks. Consequently, in order to identify the ownership of the digital media, they had to be made unavailable to extract the embedded watermark (s). Additionally, several attacks against watermarking schemes may be too complex to model (Cox *et al*., 2008). Consequently, a universal watermarking approach that could withstand several kinds of attacks and, concurrently, satisfies the conventional as well as the embedding capacity needs getting a minimal complexity isn't discovered yet. In this case, approximation approaches may be used to have the ability to discover the possession in the attacked watermarked image with low computational complexity. The best way to develop a solution that could withstand against various kinds of attacks is lacking the knowledge of their exact actions.

Ibrahim and Kuan (2011) employed watermarking technique using DWT and encryption canny edges, so as to include an watermark image include the cover image. Through the use of this method researcher was able to get acceptable results for PSNR and NCC after shedding a number of potential attacks. The main requirements for watermarking are: Imperceptibility, Robustness and capacity. Managed researcher attention imperceptibility and robustness, but neglected capacity, so were some of the extracted watermark pictures after the attack prone to damage because the size of watermark image. Therefore, it is necessary to attention

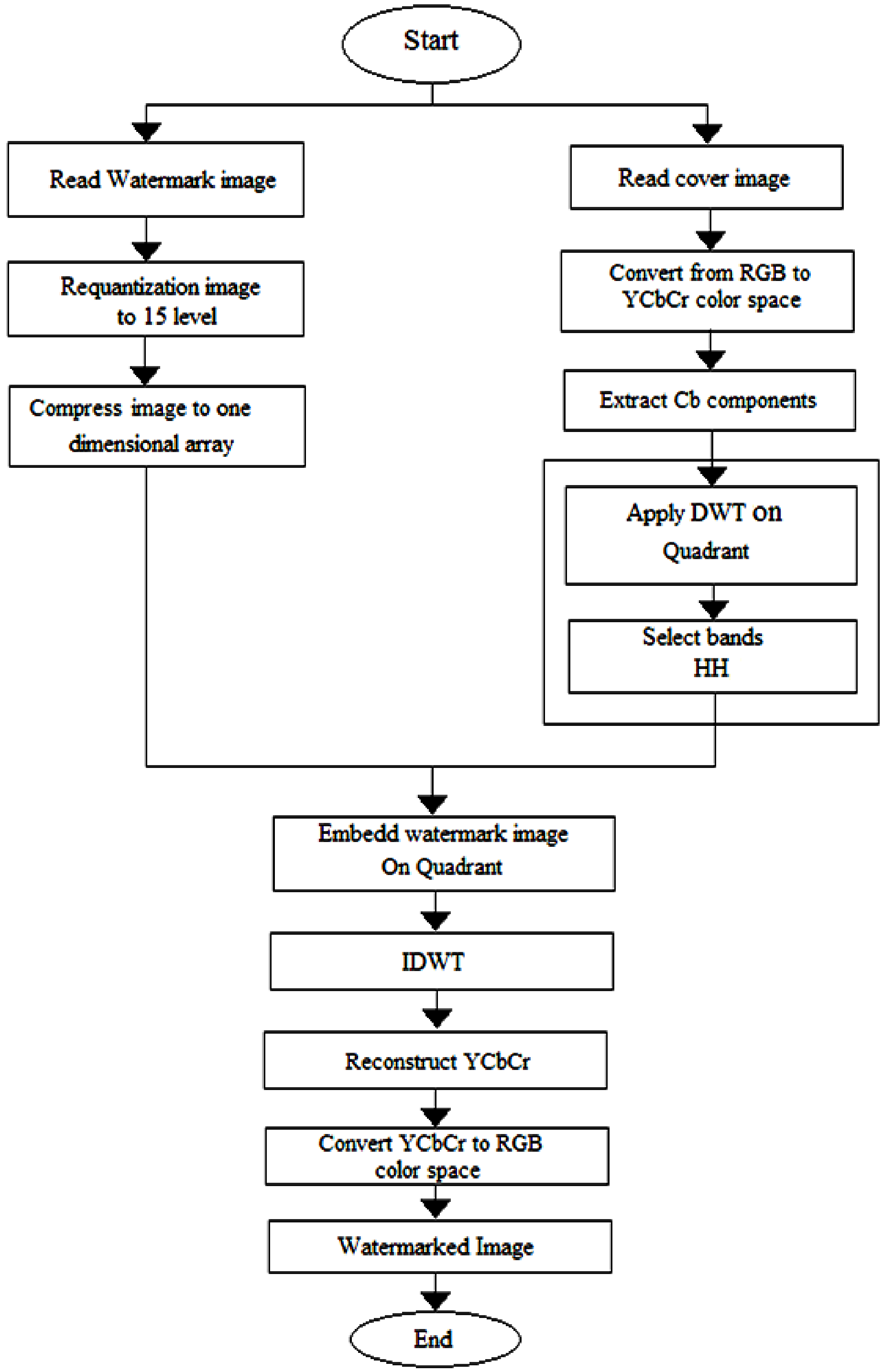


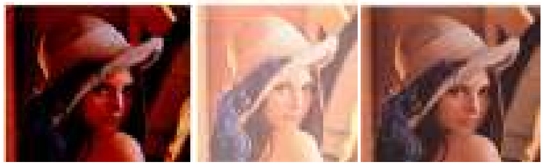
Fig. 1: Embedding Stage

imperceptibility and robustness and capacity simultaneously to get the best results extracted after a number of potential attacks.

RESERCH METHODOLOGY

The research tactic of the proposed watermarking method can be explained in Fig. 1. This approach is to ensure that the embedding process takes into account the main goals of watermarking, (i.e., imperceptibility, robustness and capacity).

Requantization image: One of the most important factors in information hiding is the size for the hidden data, which is an active factor in the issue of hiding capacity and PSNR ratio. Reducing the size of the



(a) (b) (c)

Fig. 2: Image quantization, a: Is the dark image, b: Is the light image, c: Is the quantized image

(a) (b)

Fig. 3: Lena image has been converted, a: 0-255 range, b: 0-15 range

hidden leads to increasing the efficiency of hiding technique (Bauschke, 2003). Because the data compression is not the main issue of our work, data compression will not be used in details or as a professional stage. Image requantization or image normalization is generally used for image enhancement by histogram stretching.

In image, pixel values vary from (0-255), while in some other images these values are condensed in a partial range of original range (0-255). Sometimes, the pixel values are near zero value which means image will be in the dark view. While image view is in light are if pixel values are near (255) values.

The image requantization is used to restretch pixel values into the original range (0-255). Figure 2 illustrate image quantization where a: is the dark image, b: is the light image and c: is the quantized image.

The process of requantization can be performed by next equation" Histogram Stretching" (González and Woods, 2008):

$$I_{new} = \frac{I_{old} - Min}{Max - Min} * Range_{new} + Start \quad (1)$$

where, I new is the new obtained value after stretching, I old is the original image pixel value before stretching, Range is the new range that image value will be converted to, Max, Min is the maximum and minimum values pixel before stretching, start is the new starting values, which is in our case equal to zero.

Image stretching is used essentially for converting values from a range to another. This research attends to utilize image equalization in our work in opposite manner, i.e. converting the values from (0-255) range to (0-15) range. Values of this range will need only (4) bits for representation, as shown in Fig. 3, Illustrate Lena image has been converted into two Ranges which, a: 0-255 range, b: 0-15 range. The 0-15 range is a dark image, which will use it in our work which will be useful in next step (Image Compression).

Image compression: From the past stage, image pixel values are converted from (0-255) range into (0-15) range. Thus, converted values need only (4) bit from each byte to represent them, which means a half byte will be empty for all image bytes. In this case, each bytes will combined into one dimensional array that leads to get the half size for the same image.

After the stage for apply histogram equalization to change the level for image from (0-255) to (0-15) level, as shown previously, now will compress the image by change the array for this image to one dimensional array to be ensure compress the image to a half of original image. As shown in Fig. 4.

Convert RGB to YCbCr color space: The researchers are using YCbCr color space recently because of YCbCr color space is more robust and has higher imperceptibility than RGB color space (Khalili, 2003). Y represents the luminance component and CbCr represent blue and red chrominance components respectively. In other hand RGB color space represents

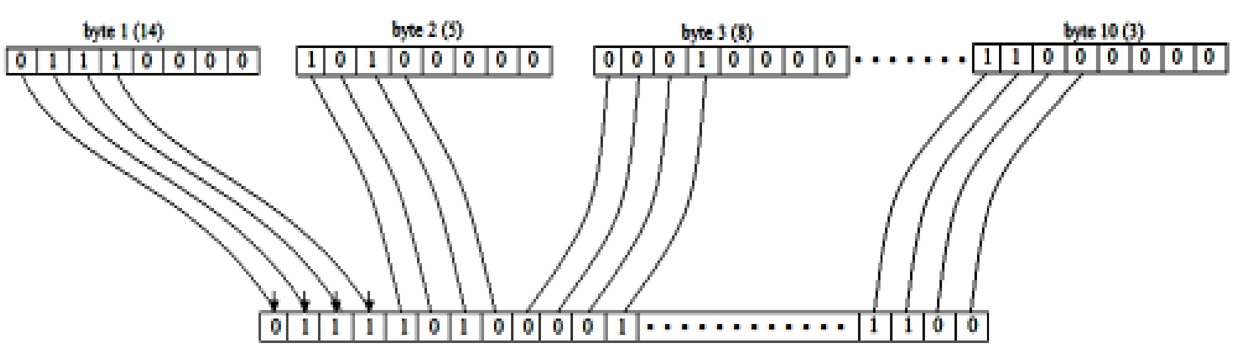


Fig. 4: Compress image by change to one dimensional array

(a)

(b)

Fig. 5: RGB colour to YCbCr colour image

red, green and blue channels respectively. Figure 5 shows converting host image from RGB to YCbCr color space. The main difference between YCbCr and RGB color space is that YCbCr color space represents the color as brightness with two more color signals which are Cb and Cr, while RGB represents the color as red, green and blue. Next Eq. 2 shows transformations between RGB color space and YCbCr color space (Chai and Bouzerdoum, 2000):

$$\begin{bmatrix} Y \\ Cb \\ Cr \end{bmatrix} = \begin{bmatrix} 16 \\ 128 \\ 128 \end{bmatrix} + \begin{bmatrix} 65.481 & 128 & 24.966 \\ -37.0.797 & -74.203 & 112 \\ 112 & -93.786 & -18.214 \end{bmatrix} \begin{bmatrix} R \\ G \\ B \end{bmatrix} \quad (2)$$

Extract Cb components: Partitioning is dividing a particular image into multiple parts; in general, the purpose of image partitioning is changing the representation of image to be more ease in processing and analyzing. In proposed technique, the Cb component extracted from host image to preserve the

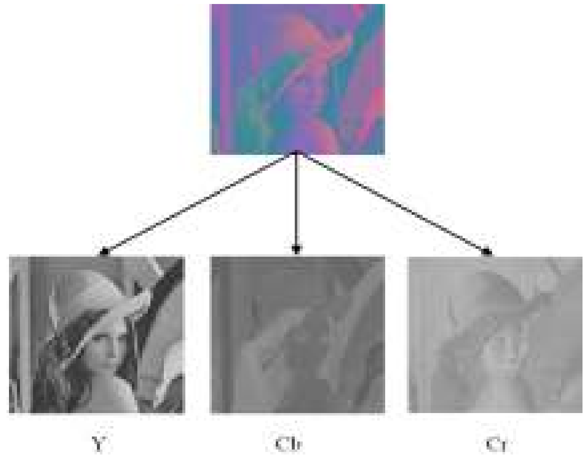


Fig. 6: Extracting Y, Cb, and Cr components

invisibility to HVS, Fig. 6 shows extracting Y, Cb and Cr components individually. The purpose of image partitioning is finding the best part for embedding watermark image, before applying DWT on the part. One of these parts will be chosen for embedding. The part which has the highest imperceptibility represents the best part for embedding the watermark. The experiences for the proposed method prove the Cb is the best part for embedding to be ensuring higher imperceptibility. Figure 6 illustrate extract Cb part.

Apply DWT for cover image: Discrete Wavelet transform (DWT) is a mathematical tool for hierarchically decomposing an image (Hong and Hang, 2006). The watermark image is converted into level (0-15) and converted into one dimensional array, as mentioned previously, will read the cover image and apply DWT algorithm to split the image to four bands to maintain the imperceptibility. The select quadrant of host image decomposed by using discrete wavelet transform (DWT), DWT produced the frequency sub-bands is LL, HL, LH and HH bands. The HH band will be selected to embedding the watermark image. As shown in Fig. 7 that illustrates how to apply DWT on the host image.

Embedded watermark image in cover image: Embedding is hiding secret image or private label or a video or a specific text inside the cover image without significant distortions on the cover image. Embedding provides a sure way to determine the owner of the image, one of the most important characteristics of Embedding is imperceptibility. There is lots of method to embed; the research will use one of them to embedding the watermark image in the cover image as will describe that.

After converting cover image into four Bands using DWT algorithm and selection the HH band as shown in Fig. 8 and depending on the size of the watermark image to ensure imperceptibility and robustness. After

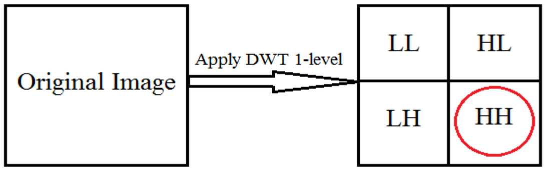


Fig. 7: Apply DWT on the host image

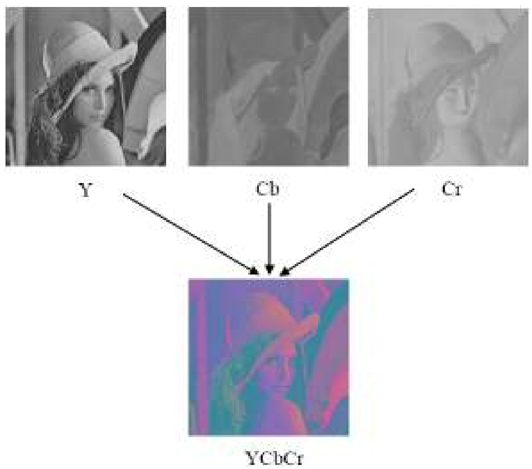


Fig. 8: Reconstruction YCbCr

converting image watermark to level (0-15) and compressed it to a half from original size by change it to one dimensional array from 0 and 1 as previously mentioned, the next step is embedding a watermark image inside the cover image in HH band, equation 3, is the formula for embedding which are WI is the output of the watermarking system, H be the host image, b is an appropriate scaling factor (Sulong *et al*., 2012; Hajisami *et al*., 2011; Singh *et al*., 2009):

$$WI = H + b * W \qquad (3)$$

where,
WI = Watermarked image
H = The value of host image
b = The scale factor (0.005)
W = The watermark image (Binary)

Wavelet reconstruction (IDWT): To return the image back from the frequency domain to the spatial domain, Inverse Discrete Wavelet Transform (IDWT) applied. All new frequency sub-band coefficients of selected quadrant will be reconstructed using IDWT. Both high and low pass filter will inverse selected quadrant form frequency to the spatial domain with the same decomposition level. This process will generate one watermarked quadrant.

Reconstruction YCbCr: Finally, the quadrants will be combined again to get YCbCr color space watermarked image, then YCbCr will be converted to RGB color

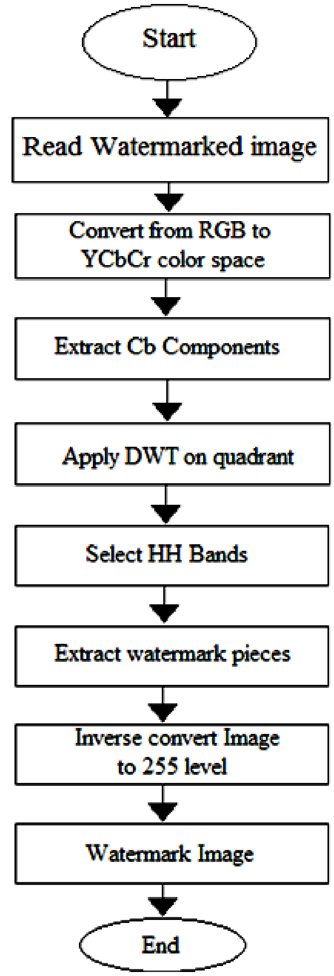


Fig. 9: Extract Stage

space to get final watermarked image form. The following Fig. 8 illustrates reconstruction process.

Extract stage: Extraction stage is to separate the watermark image of the cover image without causing any significant impact on the watermark image and the cover image. The following scheme illustrates how to extract the watermark image from cover image (Fig. 9).

Apply DWT for Cb component: In this stage, after reading the cover image will convert RGB color to YCbCr like do it in embedding stage and then extract Cb and apply DWT to extract watermark image pieces as will shown that in details. Apply DWT algorithm to split the image to four bands. The select quadrant of host image decomposed by using Discrete Wavelet Transform (DWT), DWT produced the frequency sub-bands is LL, HL, LH and HH bands. Then select the HH sub-band to get watermark pieces.

Extract watermark image: This stage illustrates how to extract the pieces of watermark image from the HH sub-band of cover image. After read the watermarked image and apply DWT to division into four sub-band then select the HH sub-band, will get the pieces of watermark image (Sulong *et al*., 2012; Hajisami *et al*., 2011; Singh *et al*., 2009) by the following formula 6.

$$W = (WI - H)/b \tag{4}$$

where,
W = The Watermark image (Binary)
WI = The Watermarked image
H = The Value of Host image
b = The Scale factor (0.005)

Inverse convert image: After get the pieces of watermark image from the HH2 sub-band will inverse the requantization to convert the level for watermark image from (0-15) level to original level (0-255) and ensure to enhance the image after convert it. Equations 5, illustrate the convert watermark image to (0-255) level (González and Woods, 2008):

$$X_{old} = \frac{X_{new}}{R} * 255 + \text{Start} \tag{5}$$

where,
Xold = The original value before convert level
Xnew = The current value, after convert the level
R = The current range (15)
Start = The byte will be start for the image (0)

Wavelet reconstruction (IDWT): To return the image back from the frequency domain to the spatial domain, Inverse Discrete Wavelet Transform (IDWT) applied. All new frequency sub-band coefficients of selected quadrant will be reconstructed using IDWT. Both high and low pass filter will inverse selected quadrant form frequency to the spatial domain with the same decomposition level. This process will generate one watermarked quadrant.

Imperceptibility measuring: Peak Signal to Noise Ratio (PSNR) used to measure the quality between original and watermarked image, increasing PSNR related to the quality of reconstructed watermarked image. The following is PSNR formula:

$$MSE = \frac{1}{m\,n}\sum_{i=0}^{m-1}\sum_{j=0}^{n-1}[I(i,j) - K(i,j)]^2$$

The PSNR is defined as:

$$PSNR = 10 \cdot \log_{10}\left(\frac{MAX_I^2}{MSE}\right) = 20 \cdot \log_{10}\left(\frac{MAX_I}{\sqrt{MSE}}\right) \tag{6}$$

where, m n is the image size of watermark and host image, I (i, j) is the Host image pixel value, K (i, j) is the Watermark image pixel value, MSE is Mean Square Error for (I, K).

Robustness measuring: To measure the similarity between original watermark image and extracted watermark correlation used as the following Eq.7:

$$NCC = \frac{\sum_i\sum_j W_{ij}\, W'_{ij}}{\sum_i\sum_j (W_{ij})^2} \tag{7}$$

where, W i j and W' i j are the pixel values at the position (i, j) of the original and the extracted watermark by that 1 ≤ (i, j) ≤ 32, respectively.

RESULTS AND DISCUSSION

In this section results are presented of the proposed watermarking based on Discrete Wavelet Transform (DWT). The evaluation of these results presented in this chapter by using standard images which are Lena, Baboon, pepper, Tiffany and Airplane as a host images.

The results will get it from embedding a watermark image in standard RGB colour images which are Lena, Baboon, pepper, Tiffany and Airplane images. The host image are transformed into frequency domain using Discrete Wavelet Transform (DWT), DWT resulted to four sub-bands frequencies which are LL, HL, LH and HH. One watermark image has been embedded in sub-band (HH) of host images.

The scale factor (b) is used to increase the robustness of watermarking and (b = 0.005) has been chosen for it. The size of the host images is (512×512) byte and the size for watermark image is (128×128). The coming figures illustrate the steps of embedding result implementation before the attacks for selected images.

There are a lot of researchers prefer use YCbCr , because the YCbCr give more robust and higher imperceptibility in embedding stage from RGB color space (Khalili, 2003), Y is the luminescent component represents and CbCr represents color components blue and red, respectively. While RGB color space represents the Red, Green and Blue, respectively.

Apply DWT on CB components: The high frequency components are usually used for watermarking since the human eye is less sensitive to changes in edges (Kashyap and Sinha, 2012). We will apply DWT to split the Cb component to four sub-band which are LL, HL, LH and HH bands, then chose the HH sub-band for imbedding the watermark image. The Fig. 10 illustrate the result after apply DWT on Cb part for Lena image.

There are a lot of researchers prefer use YCbCr, because the YCbCr give more robust and higher

Fig. 10: Apply DWT on Cb component

Fig. 11: Requantization image

imperceptibility in embedding stage from RGB color space (Khalili, 2003). Y is the luminescent component represents and CbCr represents color components blue and red, respectively. While RGB color space represents the Red, Green and Blue, respectively.

Requantization and compress watermark image: One of the most important factors in information hiding is the size for the hidden data, which is an active factor in the issue of hiding capacity and PSNR ratio. Reducing the size of the hidden is leads to increasing the efficiency of hiding technique. Image Requantization is generally used for image enhancement by histogram stretching. But in proposed methode will use the histogram stretching to change the level for watermark image from (0-255) to (0-15) level, that for compress the image to half of the original size. To be all the byte for new image use four bit and useless four as we shown in Fig. 11 illustrate the result after change the level to (0-15) the image will be like dark.

After requantization watermark image, now it has 4 bits in each byte for the new watermark image. The technique will change the watermark values into one dimensional array as shown in the Fig. 12.

Testing and evaluation before attack: This section will test and evaluate the results for the proposed method in this research depending on two criteria such as, PSNR and NCC. In the begging, the research will test the watermarked image which results from embedding the watermark image in Cb component for the cover image depending on PSNR.

As mentioned in chapter three, the (PSNR) used to measure the quality between original and watermarked image, where, the increasing in PSNR lead to the quality of reconstructed watermarked image. Therefore, this research will measure the PSNR for several watermarked images such as, Lena, Baboon, Pepper, Tiffany and Airplane. Figure 12 explain the watermarked images after applying the embed technique. Table 1 shows the PSNR ratio for the watermarked images as shows in Fig. 13.

Watermarked image after attacks: The following lines will explain the result after applying various attacks for three images which are Lena and Baboon respectively. The common attacks are Gaussian noise, Salt and Peppers, etc. The following sentences illustrate results after attack.

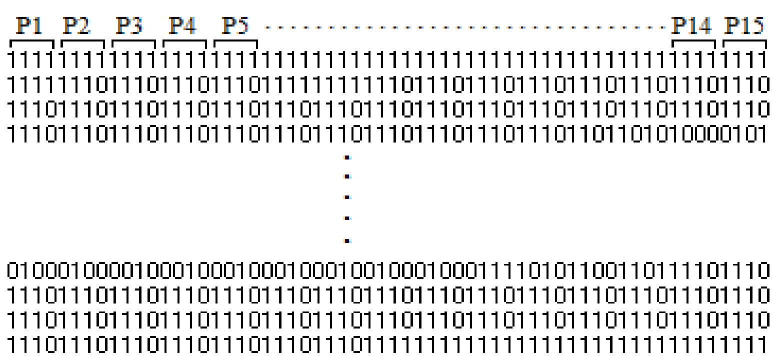


Fig. 12: Watermark image in one dimensional array

(a) (b) (c) (d) (e)

Fig. 13: The watermarked images, (a) Lena, (b) Baboon, (c) Pepper, (d) Tiffany, (e) Airplane

Table 1: Explain the PSNR ratio for watermarked image

Images	PSNR (db)
Lena	54.73
Baboon	54.46
Pepper	54.72
Tiffany	54.69
Airplane	52.27

Table 2: Summary of results

Attacks	Measurement	Lena	Baboon
Gaussian noise	PSNR	21.120	20.930
	NCC	0.9920	0.9951
Salt and pepper	PSNR	26.030	25.980
	NCC	0.9982	0.9978
Sharpening	PSNR	23.430	20.710
	NCC	0.9018	0.9341
Median filter	PSNR	27.850	22.730
	NCC	0.9927	0.9971
Rotation	PSNR	21.910	18.720
	NCC	0.9985	0.9928
JPEG compression	PSNR	32.920	29.980
	NCC	0.9982	0.9982

In the Table 2, will explain the summary of the results of some a potential attacks which are: Gaussian Noise, Salt and Pepper, Sharpening, Median Filter, Rotation and JPEG compression attacks with two measurements which are PSNR and NCC.

CONCLUSION

This study has presented watermarking approach embedded with discrete wavelet transform and high frequency sub-band (HH1). This fusion is effective for watermarking as human eye is not able to detect edge changes (Kashyap and Sinha, 2012). The high frequency areas are more imperceptibility than low and middle frequency areas and less sensitive to the human visual system, but it is low robustness. That is the main idea of this thesis, which is how to embed in this sub-band without low robustness for embedded.

The problem solved by concerning (robustness) and finds the best quadrant for embedding. Histogram stretching equation used to compress the watermark image before embedding in the quadrant of the cover image, also the benefit for using histogram stretching equation to ensure enhanced the watermark image after extracting stage. The Histogram stretching equation applies for watermark image to compress the image before embedding to get more robustness and enhanced the image after extract it. In addition to that watermark image convert it to one dimensional array and spread over of cover image. This strategy helped to gain imperceptibility, robustness and capacity at the same time. The problem solved by concerning (HVS) to find the best quadrant for embedding.

REFERENCES

Al-Otum, H.M. and N.A. Samara, 2010. A robust blind color image watermarking based on wavelet-tree bit host difference selection. Signal Process., 90(8): 2498-2512.

Abolghasemi, M., H. Aghaeinia, K. Faez and M.A. Mehrabi, 2010. Detection of LSB±1 steganography based on co-occurrence matrix and bit plane clipping. J. Electro. Imag., 19(1).

Anthony, T.S.H., J. Shen, S.H. Tan and A.C. Kot, 2002. Digital image-in-image watermarking for copyright protection of satellite images using the fast hadamard transform. Proceeding of the IEEE International Geoscience and Remote Sensing Symposium, 6: 3311-3313.

Basu, D., A. Sinharay and S. Barat, 2010. Bit plane index based fragile watermarking scheme for authenticating color image. Proceedings of the First International Conference on Integrated Intelligent Computing (ICIIC '10), pp: 136-139.

Bauschke, H.H., 2003. Recompression of JPEG images by requantization. IEEE T. Image Process., 12(7): 843-849.

Chai, D. and A. Bouzerdoum, 2000. A bayesian approach to skin color classification in YCbCr color space. Proceedings of the TENCON 2000, Kuala Lumpur, 2: 421-424.

Chandramouli, R.R., G. Benjamin and R. Collin, 2001. A multiple description framework for oblivious watermarking. Proceedings of the Security, Watermarking and Multimedia, 4314: 585-593.

Cox, I.J., M.L. Miller, J.A. Bloom, J. Fridrich and T. Kalker, 2008. Digital Watermarking and Steganography. 2nd Edn., Morgan Kaufmann Publishers.

Elarbi-Boudihir, M., A. Rehman and T. Saba, 2011. Video motion perception using optimized Gabor filter. Int. J. Phys. Sci., 6(12): 2799-2806.

González, R.C. and R.E. Woods, 2008. Digital Image Processing. Prentice Hall, NY.

Hajisami, A., A. Rahmati and M.B. Zadeh, 2011. Watermarking based on independent component analysis in spatial domain. Proceedings of the UKSim 13th International Conference on Modelling and Simulation, pp: 299-303.

Hong, W. and M. Hang, 2006. Robust digital watermarking scheme for copy right protection. IEEE T. Signal Proces., l2: 1-8.

Ibrahim, R. and T.S. Kuan, 2011. Steganography Algorithm to Hide Secret Message inside an Image Computer Technology and Application, 2: 102-108.

Jayalakshmi, M., S.N. Merchant and U.B. Desai, 2006. Digital watermarking in contourlet domain. Proceedings of the 18th International conference on Pattern Recognition, 3: 861-864.

Kashyap, N. and G.R. Sinha, 2012. Image watermarking using 3-level discrete wavelet transform (DWT). I. J. Modern Edu. Comput. Sci., 3: 50-56.

Khalili, M., 2003. A comparison between digital image watermarking in tow different color spaces using DWT2. National Academy of Science of Armenia Yerevan, Armenia.

Kougianos, E. and S.P. Mohanty, 2011. Real-time perceptual watermarking architectures for video broadcasting. J. Syst. Software, 84(5): 724-738.

Liu, A.C. and C.H. Chou, 2007. Robustness comparison of color image watermarking schemes in uniform and non-uniform color spaces. Int. J. Comput. Sci. Netw. Secur., 7(7): 239-248.

Maity, S.P., M.K. Kundu and T.S. Das, 2007. Robust SS watermarking with improved capacity. Pattern Recogn. Lett., 28(3).

Mohan, B.C. and S.S. Kumar, 2008. A robust image watermarking scheme using singular value decomposition. J. Multimedia, 3(1): 7-15.

Muhsin, Z.F., A. Rehman, A. Altameem, T. Saba and M. Uddin, 2014. Improved quadtree image segmentation approach to region information. Imaging Sci. J., 62(1): 56-62.

Nasir, I., Y. Weng and J. Jiang, 2008. Novel multiple spatial watermarking technique in color images. Proceeding of the 5th International Conference on Information Technology: New Generations, pp: 777-782.

Neamah, K., D. Mohamad, T. Saba and A. Rehman, 2014. Discriminative features mining for offline handwritten signature verification. 3D Res., 5(3).

Premaratne, P., 1999. A novel watermark embedding and detection scheme for images in DFT domain. Proceedings of IEE 7th International Conference on Image Processing and Applications, 2: 780-783.

Rehman, A. and T. Saba, 2012. Neural network for document image preprocessing: State of the art. Artif. Intell. Rev., DOI: 10.1007/s10462-012-9337-z.

Rehman, A. and T. Saba, 2014. Features extraction for soccer video semantic analysis: Current achievements and remaining issues. Artif. Intell. Rev., 41(3): 451-461.

Rehman, A., S. Alqahtani, A. Altameem and T. Saba, 2013. Virtual machine security challenges: Case studies. Int. J. Mach. Learn. Cybern., DOI: 10.1007/s13042-013-0166-4.

Saba, T. and A. Rehman, 2012. Effects of artificially intelligent tools on pattern recognition. Int. J. Mach. Learn. Cybern., 4(2): 155-162.

Santhi, V., N. Rekha and S. Tharini, 2008. A hybrid block based watermarking algorithm using DWT-DCT-SVD techniques for color images. Proceeding of the International Conference on Computing Communication and Networking, pp: 1-7.

Shieh, W. and C. Athaudage, 2006. Coherent optical orthogonal frequency division multiplexing. Electron. Lett., 42: 587-589.

Singh, J., P. Garg and A.N. De, 2009. Audio watermarking using spectral modifications. Int. J. Inform. Commun. Eng., 5(4): 297-301.

Sulong, G.B., H. Hasan, A. Selamat, M. Ibrahim and Saparudin, 2012. A new color image watermarking technique using hybrid domain. Int. J. Comput. Sci. Issues, 6(1): 109-114.

Tao, P. and A.M. Eskicioglu, 2004. A robust multiple watermarking scheme in the discrete wavelet transform domain. Internet multimedia management systems. Proceedings of the SPIE, Bellingham, WA, 5601: 133-144.

Tsai, M.J., K.Y. Yu and Y.Z. Chen, 2000. Joint wavelet and spatial transformation for digital watermarking. IEEE T. Consum. Electron., 46(1): 241-245.

Wu, C.W., 2002. One the design of content-based multimedia authentication systems. IEEE T. Multimedia, 4(1): 385-393.