Robust DWT Based Color Image Watermarking Scheme

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Abstract*— *This paper presents a robust Discrete Wavelet Transform (DWT) based color image watermarking technique using YCbCr color model. Watermark text data is transformed into QR code for enhanced security and a varying length text can be watermarked in an efficient manner. The proposed method uses diagonal components from DWT of the cover and watermark image. A high retrieval rate of watermarks is obtained with an appropriate embedding strength. It has high resistance to most watermarking attacks and retrieves the exact watermark information even from low quality watermarked images.

Keywords*— *digital image watermarking; color model; QR code; robustness; wavelet transform.

I. INTRODUCTION

Digital image watermarking techniques provide a way to secure the rights of the content owner and help in establishing the ownership of the digital images. These techniques add some valuable information in the image in such a way that the perceptual quality of the image remains intact. Various techniques have been proposed to achieve this purpose. Images are watermarked either at pixel level or transformed into some other transform domains such as Discrete Fourier Transform (DFT), Discrete Cosine Transform (DCT) and DWT, etc. Some techniques use hybrid combinations of these transforms to achieve improved results.

A watermarking scheme should achieve higher values of three major quality parameters, i.e. robustness, imperceptibility and embedding strength of watermark information, which are non-commensurable in nature. Increase in one dimension may result in decrease in another dimension. The watermarking technique should suitably satisfy all the three constraints. Applicability of a technique also depends upon the objective of the watermarking for the particular application on hand.

DWT is a popular signal processing technique, now a day's used in various image processing applications. DWT of an image results in four different sub images named as Approximate, Horizontal, Vertical and Diagonal sub-bands. They are also represented as LL, LH, HL and HH frequency bands respectively, where L represents low frequency components and H represents high frequency components. Watermarking is done either in one or more of these regions according to the specified method [1, 2].

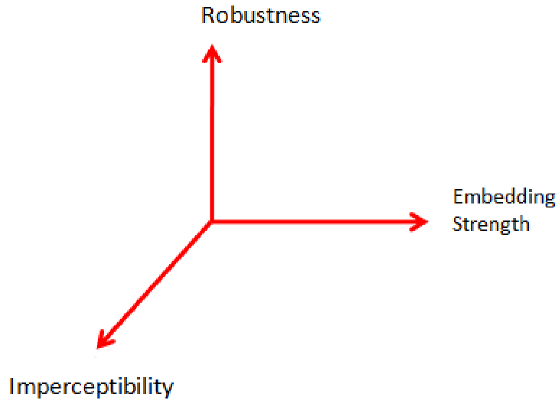

Fig. 1. Quality parameters of digital image watermarking and their relationships.

Approximate Sub-band (LL)	**Horizontal Sub-band (LH)**
Vertical Sub-band (HL)	**Diagonal Sub-band (HH)**

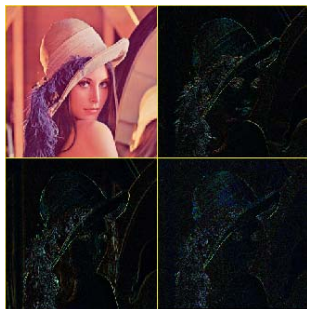

Fig 2. One Level decomposition using DWT transform.

Human visual system (HVS) plays an important role in determining the kind of image processing that is done. Digital watermarking techniques also employ the characteristics of HVS to enhance the quality of watermarked images [3, 4, 5]. Various color models have been proposed for different electronic devices and print media. These color models having their own specific features and application areas.

Color image watermarking is done through appropriate methods in different color spaces. Perturbations to watermarked image due to various reasons like compression, noise, transformation, filtering and masking etc. make it difficult to extract the exact watermark information. Use of YCbCr color space in watermarking enhances the invisibility of watermark in the cover image and stronger robustness in comparison to other existing techniques [6].

An approach for color image watermarking in YCbCr in DCT domain has been proposed, embedding a binary watermark selectively at very low frequency components of DCT [6]. QR code watermarking in DWT transform has been done in low frequency components with block wise image distribution [7], demonstrated adequate visual transparency and robustness against JPEG compression.

In this paper a new approach is proposed which uses DWT transform for watermarking using QR code in YCbCr color space. Proposed scheme shows its robustness against various image processing attacks. It has enhanced information retrieval with use of QR code, which is having a strong error correction code mechanism through which low quality of QR code watermark is also able to retrieve the exact watermark information. The organization of rest of the paper is as follows. Section II presents the preliminaries about YCbCr color space and QR code. Section III describes the proposed watermarking embedding and extraction schemes. Section IV presents the experimental results and analysis with the test images and watermark. Section V gives conclusion in brief.

II. PRELIMINARIES

This section presents an brief overview of the YCbCr color space, conversion formulas for Red Green Blue (RGB) to YCbCr conversion and vice versa and a short background about QR code.

A. YCbCr color model

YCbCr color space stores Y as luminance, Cb as blue difference and Cr as red difference of the image. Conversion formulas from RGB to YCbCr and vice versa are as follows.

RGB to YCbCr

$$\begin{bmatrix} Y \\ Cb \\ Cr \end{bmatrix} = \begin{bmatrix} +0.299 & +0.587 & +0.114 \\ -0.169 & -0.331 & +0.500 \\ +0.500 & -0.419 & -0.081 \end{bmatrix} \begin{bmatrix} R \\ G \\ B \end{bmatrix} + \begin{bmatrix} 0 \\ 128 \\ 128 \end{bmatrix}$$

$$Y \in [0,255], Cb \in [0,255], Cr \in [0,255]$$

C_b and C_r are related to Y component as follows.

$$C_b = 0.564\,(B - Y)$$

$$C_r = 0.713\,(R - Y)$$

YCbCr to RGB

$$\begin{bmatrix} R \\ G \\ B \end{bmatrix} = \begin{bmatrix} +1.000 & -0.000 & +1.403 \\ +1.000 & -0.344 & -0.714 \\ +1.000 & +1.773 & +0.000 \end{bmatrix} \begin{bmatrix} Y \\ Cb - 128 \\ Cr - 128 \end{bmatrix}$$

$$R \in [0,255], G \in [0,255], B \in [0,255]$$

Y component is considered as a suitable candidate color component for watermarking purposes in the proposed method as it contains the gray value information of an image [8, 9] and having high invisibility in cover image after watermarking [6].

B. QR Code

Automotive industry in Japan first introduced Quick Response (QR) Code in 1994. QR code is a two dimensional bar code read by the camera like imaging devices, stores data in four standardized encoding mode i.e. binary, numeric, alpha-numeric and kanji [10].

QR code is an efficient way to encode the information in pictorial manner having Reed – Solomon error correction code, which makes it more productive in practical applications. It holds several function patterns for performance enhancement with error correction and compensation for distortion occurred in the input data during the reading operation. It generates the size of the QR code with timing patterns during scanning process. Position detection patterns make it possible to read and process the data simultaneously. [11]

QR code in watermarking provides an enhanced security and flexibility as the varying length text data can be watermarked with similar watermarking properties. Proposed method with DWT and QR code enhances the chance of survival for watermark after various signal processing and geometric attacks on the watermarked image.

III. WATERMARKING SCHEME

A. Watermark Embedding

Input: RGB Cover Image (I_{RGB}), Watermark Text (W_{Text}) , Embedding Strength (α).

Output: RGB Watermarked Image (I_{WMDRGB})

1. Read I_{RGB} and convert it to YCbCr color space and get I_{YCbCr} .
2. Separate the Y component (I_Y) from the I_{YCbCr} .
3. Perform DWT transform on I_Y up to level 3 and separate the diagonal constituent (I_{YHH3}).
4. Input W_{Text} to QR code generator and get QR code watermark image (QW_{Img}).
5. Read QW_{Img} and perform DWT transform up to level 1 and separate the diagonal constituent (QW_{ImgHH1}).
6. Get new image diagonal constituent I_{YNEW_HH3} as follows:

   $$I_{YNew\_HH3} = I_{YHH3} + \alpha . QW_{ImgHH1}$$
7. Apply Inverse DWT using I_{YNew_HH3} and get I_{YNew}.
8. Get I_{WMDRGB} by converting I_{YNew} to RGB color space.

Embedding process reads the cover image, which is originally in RGB color space and converts this image into YCbCr color space and separates the Y color component. This Y color component is transformed using DWT up to level 3 using 'haar' wavelet transform and the diagonal constituent of this is segregated. The watermark text is converted into QR code using QR Code Generator, which is further transformed using DWT transform up to level 1 using 'haar' wavelet transform and the diagonal constituent is taken out. This diagonal constituent is multiplied to the specified embedding strength and added with the earlier segregated diagonal constituent of Y color component of cover image. Inverse DWT is performed using this resultant value and again converted into RGB color space to get the watermarked image.

B. Watermark Extraction

Input: RGB Cover Image (I_{RGB}), RGB Watermarked Image (I_{WMDRGB}), Watermark Image (QW_{Img}), Embedding Strength (α).

Output: Watermark Text ($W_{ExtText}$)

1. Read I_{RGB} and I_{WMDRGB} and convert both images to YCbCr color space as I_{YCbCr} and $I_{WMDYCbCr}$ respectively.
2. Separate the desired Y components I_Y and I_{YWMD} from I_{YCbCr} and $I_{WMDYCbCr}$ respectively.
3. Perform DWT transforms up to level 3 on I_Y and I_{YWMD} and segregate diagonal constituent I_{YHH3} and $I_{YWMDHH3}$ respectively.
4. Get diagonal constituent for watermark as follows:

$$I_{YExt\_HH} = (I_{YWMDHH3} - I_{YHH3}) / \alpha$$

5. Perform DWT transform up to level 1 on QW_{Img} and apply inverse DWT using I_{YExt_HH} to get extracted QR code QW_{EXTImg}.
6. Scan QW_{EXTImg} with QR code reader and get result as text ($W_{ExtText}$).

Extraction process reads the original cover image and watermarked image and converts them from RGB color space to YCbCr color space and segregate the Y components from both the images. DWT transforms are performed on these Y components individually up to level 3 using 'haar' wavelet transform and resultant diagonal constituent of cover image is subtracted from the diagonal constituent of watermarked image and result is factorized with embedding strength to get extracted diagonal constituent. This resultant value is used for inverse DWT transform with DWT transformed values of watermark image up to level 1 using 'haar' wavelet transform to extract the QR code. This QR code is scanned for output with QR code reader.

IV. Experimental Results and Analysis

Four images are considered as cover images and a watermark text is converted into QR code. QR code generator generates the QR code for the specified watermark text. This work considers images of size 512*512 and QR code watermark image of size 128*128.

Investigation is done on the effect of watermarking strength on the quality of extracted watermark image. Some common image processing attacks are performed on the watermarked images and the proposed watermarking scheme is examined for its efficiency and robustness against these attacks.

A. Images considered for watermarking

Images with different color and structural properties are considered for test purposes, which provide a variation in the quality and content of the images to be watermarked and hence also show the applicability of the proposed method on different type of images. Lena image has less bright areas and more similar color distribution. Peppers image has more contrast information with smooth areas. Baboon image contains components with lot of details. Taj Mahal image has more bright areas, lines and edges like structural elements.

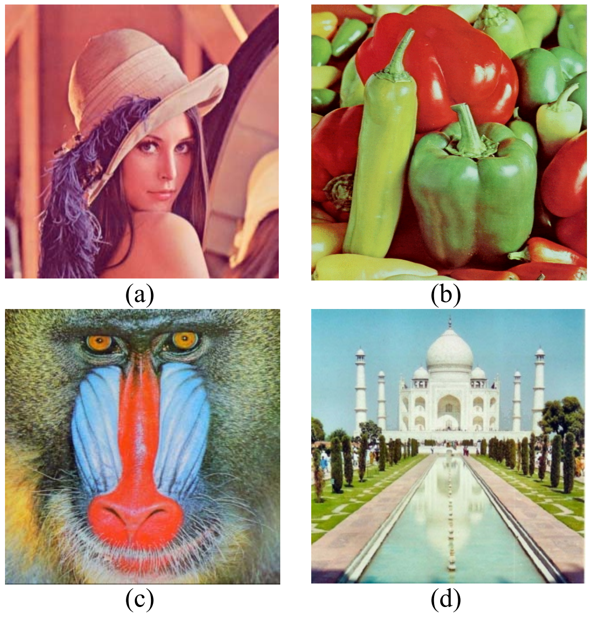

Fig. 3. Color Test Image Set (512 * 512 pixels) (a) Lena, (b)Peppers, (c) Baboon (d) Taj mahal

Watermark is a text input (i.e. DEI), which is processed with a QR code generator to get a QR code binary image. Test images are watermarked with this.

Fig. 4. QR code watermark (128 * 128 pixels) containing text: DEI

B. Effect of variation in embedding strength on Peak Signal to Noise Ratio (PSNR)

The qualities of watermarked images are being assessed using PSNR value between cover image and watermarked image. PSNR value is calculated as follows:

$$PSNR = 10.log_{10}\left[\frac{MAX_I^2}{\frac{1}{M \times N}\sum_{i=1}^{M}\sum_{j=1}^{N}[I(i,j) - I'(i,j)]^2}\right]$$

Where, I is the cover image and I' is the watermarked image. MAX_I is the maximum intensity value of the image. M and N are the number of rows and column in the images.

Experimentally, it has been observed that the value of α can vary from a range 20 to 60 for the test image set. Decreasing the values of α below the lower limit does not yield the watermark properly, while increasing the value of α beyond the higher limit starts decreasing the visual quality of the test images. Table I shows PSNRs for test images at different embedding strength.

TABLE I : IMAGE PSNRS AT DIFFERENT EMBEDDING STRENGTH (α)

Image	PSNR		
	α=20	α=40	α=60
Lena	54.9768	53.9865	52.2405
Peppers	54.7269	53.5940	51.6830
Baboon	54.9951	54.0010	52.2444
Taj Mahal	54.8741	53.8963	52.1747

Fig. 5 shows PSNR values at different levels of embedding strengths. It is clearly observed that the variation of PSNR values shows similar behavior at all the embedding strengths for the individual test image. This helps in deciding the exact amount of embedding strength preserving robustness and transparency for an individual type of image.

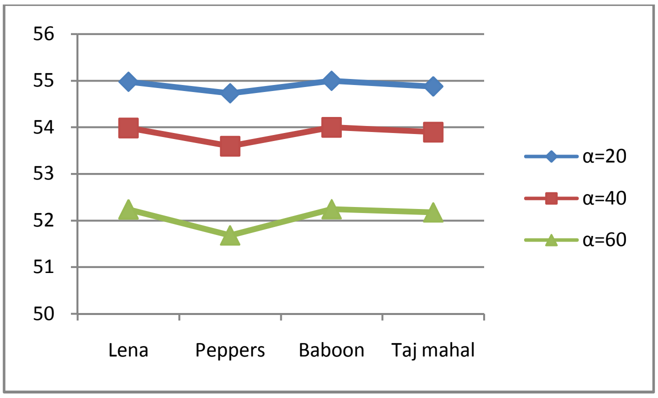

Fig. 5. PSNR values at α=20, α=40 and α=60.

C. Effect of variation in embedding strength on Normalized Correlation Coefficients (NC)

NC value shows the quality of extracted watermark with reference to the original watermark. NC is calculated as follows:

$$NC = \frac{\sum_{i=1}^{M}\sum_{j=1}^{N} W(i,j)W'(i,j)}{\sqrt{\sum_{i=1}^{M}\sum_{j=1}^{N} W^2(i,j)}\sqrt{\sum_{i=1}^{M}\sum_{j=1}^{N} W'^2(i,j)}}$$

Where, W is the original watermark image and W' is the recovered watermark image. M and N are the number of rows and column in the images.

TABLE II : WATERMARK NCS AT DIFFERENT EMBEDDING STRENGTH (α)

Image	NC		
	α=20	α=40	α=60
Lena	0.9940	0.9985	0.9993
Peppers	0.9925	0.9981	0.9992
Baboon	0.9876	0.9969	0.9986
Taj Mahal	0.9929	0.9982	0.9992

The variation in embedding strength value from an initial value of 20 to up towards 60, increases the NC value for the test images, shown in Table II. For test image Lena results have been demonstrated in Table III, with extracted QR code.

TABLE III: EXTRACTED WATERMARKS AND NC VALUES AT DIFFERENT EMBEDDING STRENGTH ON LENA IMAGE

α=20, NC = 0.9940	α=40, NC = 0.9985	α=60, NC = 0.9993

TABLE IV: NORMALIZED CORRELATION (NC) VALUES AND QR CODE RETRIEVAL RESULTS FOR VARIOUS IMAGE ATTACKS

Type of attack	Attack Value	NC (α=60)				QR Code Retrieved			
		Lena	Peppers	Baboon	Taj Mahal	Lena	Peppers	Baboon	Taj Mahal
Salt & Pepper Noise	1%	0.9873	0.9870	0.9885	0.9868	Yes	Yes	Yes	Yes
	2%	0.9782	0.9762	0.979	0.9766	Yes	Yes	Yes	Yes
	3%	0.9693	0.9665	0.9708	0.9665	Yes	Yes	Yes	Yes
	4%	0.9595	0.9576	0.9605	0.9573	Yes	Yes	Yes	Yes
Gaussian Noise [Mean = 0, V(Variance)]	V=0.01	0.9691	0.9698	0.9677	0.9685	Yes	Yes	Yes	Yes
	V=0.02	0.9683	0.9685	0.9663	0.9675	Yes	Yes	Yes	Yes
	V=0.03	0.9674	0.9682	0.9667	0.9690	Yes	Yes	Yes	Yes
	V=0.04	0.9671	0.9679	0.9674	0.9697	Yes	Yes	Yes	Yes

Cropping	¼	0.9969	0.9857	0.9729	0.9957	Yes	Yes	Yes	Yes
	½	0.9804	0.9723	0.9341	0.9736	Yes	Yes	Yes	Yes
	16 pixels	0.9923	0.9810	0.9679	0.9798	Yes	Yes	Yes	Yes
	32 pixels	0.9866	0.9715	0.9433	0.9538	Yes	Yes	Yes	Yes
Rotation	5^0	0.8201	0.8585	0.7249	0.6998	Yes	Yes	No	Yes
	10^0	0.8159	0.8604	0.7328	0.6945	Yes	Yes	No	Yes
	20^0	0.8175	0.8503	0.7272	0.6980	Yes	Yes	No	No
	45^0	0.7926	0.8013	0.7112	0.6700	Yes	Yes	No	No
Average Filtering	--	0.9934	0.9955	0.9753	0.9885	Yes	Yes	Yes	Yes
Motion Filtering	Length=5	0.9853	0.9924	0.9703	0.9723	Yes	Yes	Yes	Yes
	Length=10	0.9296	0.9616	0.8752	0.8723	Yes	Yes	No	Yes
Masking	[-1 -1 -1, -1 9 -1, -1 -1 -1]	0.8257	0.8663	0.7289	0.8150	Yes	Yes	No	Yes
Median Filtering	3*3	0.9962	0.9968	0.9751	0.9927	Yes	Yes	Yes	Yes
	4*4	0.9781	0.9865	0.9393	0.9686	Yes	Yes	Yes	Yes
	5*5	0.9849	0.9919	0.933	0.9664	Yes	Yes	Yes	Yes
JPEG Compression	QF=90	0.9972	0.9973	0.9972	0.9972	Yes	Yes	Yes	Yes
	QF=70	0.9969	0.9969	0.9966	0.9969	Yes	Yes	Yes	Yes
	QF=50	0.9947	0.9949	0.9923	0.9947	Yes	Yes	Yes	Yes
Histogram Equalization	--	0.9596	0.9817	0.9336	0.8966	Yes	Yes	Yes	Yes

TABLE V: RETRIEVED QR CODES FOR DIFFERENT TYPES OF ATTACKS (COVER IMAGE: LENA, WATERMARK EMBEDDING STRENGTH = 60)

Salt & Pepper Noise (4%)	Rotation (45^0)	Cropping (32 pixels)	JPEG Compression (QF= 50)	Average Filtering
Gaussian Noise [Mean = 0, V = 0.04]	Motion Filtering (length =10)	Median Filtering (5*5)	Masking [-1 -1 -1, -1 9 -1, -1 -1 -1]	Histogram Equalization

D. Watermark information retrieval after common image processing attacks

Extracted watermarks after some attacks in Table V for Lena test image demonstrate that the extracted watermark image is degraded after the attacks, but the exact watermark text information is extracted even from these watermarks. As given in Table IV, salt and pepper, Gaussian noise, cropping, averaging, motion, masking, median filtering, JPEG compression and histogram equalization for specified attack parameters result in successful watermark information retrieval in most cases except a few.

Table IV shows the values of NC of the watermark retrieved after performing various attack. It also shows whether the embedded text was successfully retrieved or not. Form the Table IV it is clear that the QR code extraction algorithm (that is used to extract the embedded text from the QR code after the watermark has been extracted from the watermarked image) is quite robust. It is able to retrieve the embedded text successfully even when the NC values are as low as 0.6945. This however varies with the region of watermark disrupted by the attacks. If the position blocks of QR code are not disrupted, there is a fairly chance that the embedded text would be retrieved successfully. Further, the QR code design itself provides for considerable payloads. Thus, required information can be successfully stored even though the size of the watermark image remains the same. This provides an additional benefit of using QR code as watermarks.

V. CONCLUSIONS

This technique provides a robust watermarking method with error correction mechanism by the QR code. Even distorted low quality watermarks yields exact information. Variation in embedding strength provides the flexibility to enhance the power of embedding and resistance against various types of image processing attacks. The approach has yielded promising results and motivates further work in this direction.

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