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Robust Image Watermarking Using QR Factorization In Wavelet Domain

K Ganga Devi Bhavani
Dept. of Computer Science Engineering
Pragati Engineering College
Surampalem, India
e-mail:devikakarla258@gmail.com

N Leelavathy
Dept. of Computer Science & Engineering
Pragati Engineering College
Surampalem, India
e-mail:drnleelavathy@gmail.com

B S N V Ramana Murthy
Dept. of Computer Science & Engineering
Pragati Engineering College
Surampalem, India
e-mail: ramanamurthy.b@pragati.ac.in

Abstract— A robust blind image watermarking algorithm in wavelet transform domain (WT) based on QR factorization, and quantization index modulation (QIM) technique is presented for legal protection of digital images. The host image is decomposed into wavelet subbands, and then the approximation subband is QR factorized. The secret watermark bit is embedded into the R vector in QR using QIM. The experimental results show that the proposed algorithm preserves the high perceptual quality. It also sustains against JPEG compression, and other image processing attacks. The comparison analysis demonstrates the proposed scheme has better performance in imperceptibility and robustness than the previously reported watermarking algorithms.

Keywords- *Wavelet Transform; Wavelet Bases; QR factorization; Quantization Index Modulation.*

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I. Introduction

Digitization has given an extraordinary chance to store and speak to information minimally. Notwithstanding, this advanced information can be effectively altered and made numerous duplicates without giving up the first quality. This has made the first proprietors of the computerized information to put an additional exertion for securing their information. In this way, a computerized watermarking of information is the main answer for ensure the verification and respectability of the information.

Digital Watermarking, which is an advanced watermarking having specialty of altering the cover information, for example, picture, sound, and video to implant a watermark which can be extricated or recognized at whatever point there is an issue of possession. Depending on the embedding, methods of digital watermarking can be categorized to specific domain i.e., spatial domain, transform domain, and hybrid domain. If a watermark is embedded directly into the pixels of image then it belongs to spatial domain. In this domain, the Least Significant Bit technique (LSB) is one of the widely acknowledged one. Whereas in transform domain, the watermarking is based on required management of transform coefficients. Though the embedding capacity in spatial domain is high, algorithms are not robust to common image processing attacks. Therefore, the transform domain algorithms are preferred over spatial domain techniques. Taking the advantage of both spatial and transform domains, the hybrid watermarking techniques are being developing.

Other Robust Image watermarking algorithms are framed in Fast Fourier Transform (FFT), Discrete Cosine Transform (DCT), Discrete Wavelet Transform (DWT), Singular Value Decomposition (SVD), QR factorization, etc.

Here, in this paper, a novel robust, image blind watermarking scheme in wavelet transform domain based on QR factorization, and QIM is proposed. Quantization is performed on the first row elements of R matrix with respect to watermark bits. This method is robust against the common image processing manipulations by maintaining perceptually invisible watermark with good quality. This technique is powerful against the regular picture handling controls by keeping up perceptually imperceptible watermark with great quality.

II. Related Works

A certain designs have been grown to encrypt the watermark into the source picture. Right from the design to alter LSB in spatial domain to encrypt the watermark in different transform domain to expand robustness. Each numerical transform domain method has its own points of interest and drawbacks when analyzed against manageability of assaults. Thus, enhanced methods have consolidated these transforms for watermarking.

Recently, research papers which have used QR factorization for robust watermarking have been noted. Song *et al.* [7], proposed a spatial domain watermarking scheme based on QR factorization. To obtain the robustness and to withstand over attacks on the watermark image a new method of image watermarking has been proposed such that the quality of the image is not reduced. Here, the source image or original image is divided into equal blocks of size such that non-overlapping blocks are formed. Now for each and every block, QR decomposition is applied. The elements in the first column of Q matrix coefficients (second and third row coefficients) in the obtained ***Q*** matrix are taken and manipulated / swapped to embed the watermark logo in the original image. To maintain the security of the algorithm, a pseudorandom circular chain (PCC) is obtained by logistic aligning to choose the blocks for embedding. This scheme or design can resist on attacks like cropping and noise addition. The disadvantage of the proposed algorithm is that the quality of watermarked image may be low if edge blocks are selected.

Naderahmadian and Khayat [5] scheme has implanted a watermark in DWT area of the source image. The LL sub band of the image is break down into equal block and these are QR factorized. The components of first column in R matrix are quantized according to the bits in watermark logo. Outcomes about exhibited that the design has low computational unpredictability and great power against normal image handling controls.

Chen and Zhu [1] proposed an image watermarking scheme based on blocks of image. For each and every equal sized block of source image, QR factorization is exercised and the R matrix is obtained. DCT transform is performed on the first row elements of R matrix. The DC coefficient obtained after DCT is quantized. Quantization is achieved based on Quantization Modulation Index. The perceptual quality of the watermarked image relies on the decision of threshold value to choose the block for embedding. This threshold value has to be determined for every cover image to watermark.

Getting inspired by these schemes, a new digital image watermarking algorithm with high robustness based on QR factorization in wavelet domain has developed. The algorithm is proposed for copyright protection, which does not require the actual source image for extracting logo image.

III. WAVELET

Wavelets are mostly used to represent the images of multiple resolutions. Wavelets not only represent but also used to analyse the multi-resolution images. Wavelets can also be processed on one dimensional signal also. Wavelets are profitable for image compression i.e., images of JPEG – 2000 standard and eliminating noise in the image.

A. Classification of wavelets

A wavelet is Wavelets are over limited intervals. The essential thought of wavelets transform is to represent an arbitrary function f(x) as linear combination of a set of such wavelets or basis functions are obtained by dilation (scaling) operations and translation (shift) operations. The principle motivation behind wavelet is to change the data from time-space domain which makes improved compression results. Wavelet Transform is broadly utilized in signal processing research, specifically in image compression. As there is no need of blocking the input image and its basis functions have variable lengths, wavelet based coding can avoid blocking artifacts which also provides progressive transmission of images.

A wavelet is a localized function that can be used to catch and narrate signal of useful, effective and helpful information. To represent signal as a function of time, wavelets provide efficient localization in both time and either frequency or scale. As noted from history, wavelet theory has been proved to be a powerful mathematical tool for analysis and synthesis of signals. It has also found successful application in remarkable diversity of disciplines such as physics, geophysics, numerical analysis, signal processing, biomedical engineering, statistics and computer graphics. In particular, abundance features of wavelet representations led to wide range of digital signal processing (DSP) applications. Wavelet techniques provide more flexibility than Fourier techniques, for better selection and appropriate representations of specific applications. The issue regarding wavelet theory is to design the wavelet systems.

Discrete wavelet transform (DWT) algorithms have become standard tools for discrete-time signal and image processing in several areas in research and industry. As DWT provides both frequency and location information of the analyzed signal, it is constantly used to solve and treat more and more advanced problems. The present book: Discrete Wavelet Transforms: Theory and Applications describes the latest progress in DWT analysis in non-stationary signal processing, multi-scale image enhancement as well as in biomedical and industrial applications.

B. COIFLETS Transform

With the desire of Ronald Coifman, Ingrid Daubechies come up with Coiflets which are discrete wavelets. This wavelet is near symmetric and those wavelets hold scaling operations with disappearing moments and has been used in many applications with the use of Calderón-Zygmund Operators. The idea of Coiflets has been originated from the Daubechies wavelet. It has an even more up above calculation and to overlap more uses windows. Six scaling and wavelet function coefficients are used to enhance in pixel balancing and distinct leads to a smoother wavelet and enhanced capabilities in various image-processing techniques (like de-noising images, etc.). As similar to both Haar and Daubechies, the filter follows the same structure, which calculates both moderate points and distinct points using six adjacent pixels with the same format. The mirror technique is followed by the Coiflet wavelet.

C. Haar Transform:

In 1910, A Hungarian mathematician named Alfred Haar made known about Haar functions. Haar wavelet Transform is of type discontinuous, and corresponds to a step function. It is same as similar to wavelet as Daubechies denoted as db1. Wavelet Transform Haar uses these functions to give an example of a boxlike normal system for the arena of square-centripetal operation on the periodic interval [0, 1]. The Properties of Haar Transform are asymmetric, orthogonal and biorthogonal.

Haar wavelet transform, for the given declared series of numbers taken as input, the can be handled to simply combine input values, keeping the difference and keep on forward the sum. This process is altered recursively, combining the sums to provide the next level, finally ending in differences and one final sum. The fundamental form of compression of Haar Wavelet transform which associate balancing and distinct points, holding detail coefficients, eliminating data and reconstructing the matrix in such a way that the obtained matrix should be related to the initial matrix. A Haar wavelet is the smoothest type of wavelet. Discrete form of Haar wavelets is similar to a mathematical operation called the Haar transform. With consideration of all other wavelet transforms, Haar transform handles as an Abstract type. Likewise to all wavelet transforms, the Haar transform divides a discrete signal into pair of sub-signals of half its length. Out of which, One sub-signal works on average or trend and the other sub-signal works on difference or fluctuation.

D. Daubechies Transform

The Daubechies wavelet transforms are characterized in the way as like the Haar wavelet transform by computing the current averages and differences over scalar products with scaling signals and wavelets. The only difference between the Daubechies and haar wavelet consists in how these scaling signals and wavelets are defined. One of the world best wavelet research invented Ingrid Daubechies, which are compactly supports orthonormal wavelets by making discrete wavelet analysis practically.

Although Daubechies wavelet returns non-linear phase type which has balanced frequency responses. As Overlapping windows are being used by Daubechies wavelets, the high frequency coefficient spectrum effects changes of all high frequency. Daubechies wavelets are suitable in compression and elimination of noise in audio signal processing.

The family names of Daubechies wavelets are composed of format dbN, where N is the number count in series, and db is the name of the wavelet.

The db1 wavelet is the same as Haar wavelet(dB1)
Properties: asymmetric, orthogonal, biorthogonal.

The dB2 wavelet Daubechies wavelet (dB2):
Properties: asymmetric, orthogonal, biorthogonal.

IV. QR FACTORIZATION

QR factorization (orthogonal triangular decomposition) is comparatively a faster computation useful in many applications. It is mainly used in finding least squares solution to solve linear equations of a system, to find inverse of a matrix, solving collection of simulations equations, and a few applications in mathematical computing. It is a decent technique for figuring the eigen values of a general matrix. It is well founded for rectangular and square matrices [3].

QR decomposition on a original matrix A can be decomposed as (2)

$$A_{m\times n} = Q_{m\times m} R_{m\times n}, \quad (2)$$

where Q is an orthogonal matrix $(Q^T \times Q = I)$ and R is an upper triangular matrix. It is been tentatively observed that the first row of matrix has bigger outright elements than other row elements. Hence, it has more energy compaction, and suitable for embedding [5]. There are different methods which can be used to compute QR decomposition.

The techniques for QR decomposition are Householder reflections, Gram-Schmidt ortho-normalization method, and the Givens rotations. Each decomposition method has a number of advantages and disadvantages because of the solution process.

V. PROPOSED SCHEME

The block diagram of the algorithm is shown in figures.

A. Watermark Embedding

Here, in proposed algorithm, Fig.1, cover image which is a binary image(i.e., an image holding all pixel values converted into binary values 0 or 1 by performing some mathematical operations on pixels) used as a watermark image. The selected watermark, $w \in \{0,1\}$ is 32×32 logo and is scrambled with a key, k_1, to be more secure. The watermark embedding and detection algorithm is similar to the algorithm proposed by Naderahmadian and Khayat [5] except for the domain of watermarking. The watermarking domain selected is wavelet transform instead of scalar wavelet.

The algorithm for embedding is as follows:

1. Subband decomposition level two is applied for wavelet transform for greater robustness using haar.
2. LL subband is selected and is divided into, 2×2 blocks.
3. QR factorization is applied to each block.
4. The elements in the first row of R matrix are selected to embed one bit watermark image.
5. Using a secret key k_2, one element is chosen to embed the watermark using quantization index modulation.
   If x stands for the elected coefficient then two quantizers $Qi(x)$,i={0,1} are determined based on watermark bit of the image.
   The quantizer is selected with a step size, Δ, is
   $$Q(x) = floor(x/\Delta)*\Delta + Ti,\ i = 0,1 \quad (3)$$
   where $T_0 = \Delta/4$, and $T_1 = 3*\Delta/4$
6. Inverse QR factorization is applied.
7. Inverse wavelet transform is applied

B. Watermark Detection

Here, in this scheme From Fig.2, algorithm for watermark extraction is designed as follows:

1. Subband decomposition level two is applied for 2D wavelet transform for greater robustness using haar.

2. LL subband is selected and is divided into 2×2 blocks.

3. QR factorization is applied to each block.

4. The elements in first row of R matrix are selected to embed one watermark bit.

$$\begin{aligned} &if \quad \mathbf{mod}(x,\Delta) \geq \Delta/2, \quad w'=1, \\ &else\ if \quad \mathbf{mod}(x,\Delta) < \Delta/2, \quad w'=0. \end{aligned} \tag{4}$$

5. The resultant watermark is inverse scrambled with the help of key, k_1 and compared with the input actual watermark image.

VI. EXPERIMENTATION AND RESULTS

With specific to check whether the robustness or power to withstand and strong of the proposed algorithm in wavelet transform domain, exercise is performed and observed on a database of 10 color images and 10 gray scale images having three planes from '*http://decsai.ugr.es/cvg/dbimagenes/*' database. The proposed algorithm is compared with existing other three schemes which have used QR factorization.

The outcomes figured are normal estimations of 20 pictures from the previously mentioned database. Notwithstanding Peak Signal to Noise Ratio (PSNR), other quality measurements are utilized to evaluate the execution of the calculations [8]. It can be seen that the proposed design has preferred quality over different algorithms.

The cover image or source image or original image that has been chosen is a color image 'Lena' of size 512×512. The size of the watermarked image is 32×32 as shown in Fig.3. The observation and testing of the proposed design scheme is performed at two sub band levels of wavelet decomposition and confirmed against different assaults as appeared in Table 2. The manageability and ability to withstand of the design over several attacks in image processing is observed to be better for 2nd sub band level decomposition of Wavelet Transform. The cover image watermark binary image taken as input and forms watermark image and the output will be extraction of logo image of binary values.

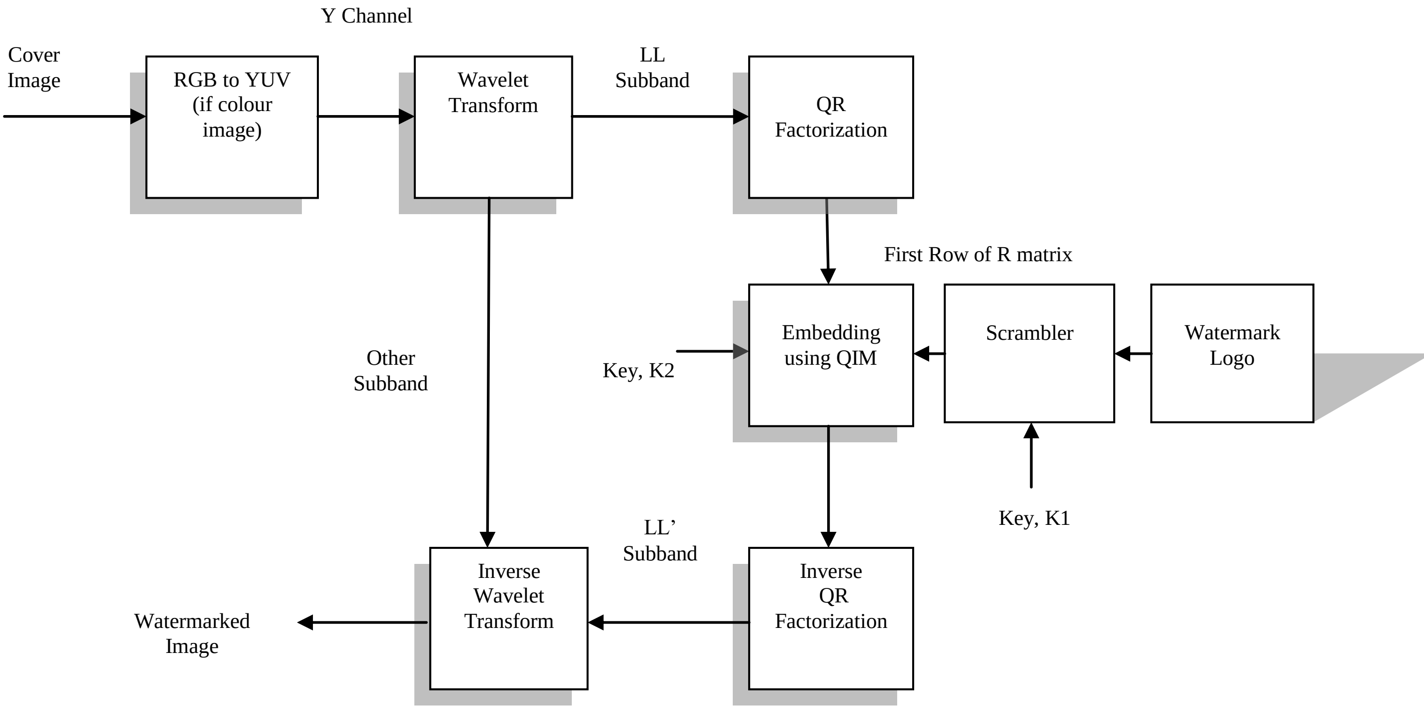

Figure 1: Block diagram of Embedding Scheme

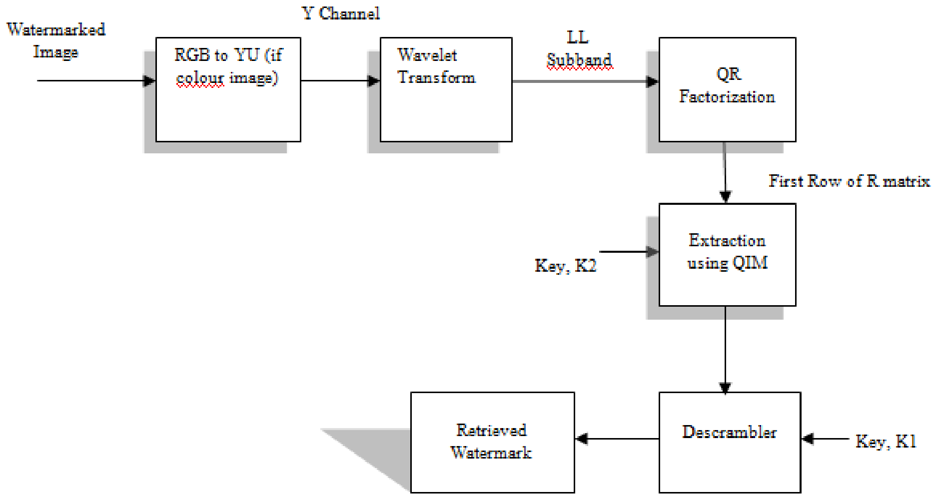

Figure 2: Block diagram of Extraction Scheme

Figure 3. (a) Cover Image Lena; (b) watermark

The algorithm is implemented using MATLAB R2013b.

1. Resizing assault at first diminishes or improves the image measure and recovers the picture to its unique size by bicubic addition. It is tried against
7. Three sorts of trimming are performed. A size of pixels at the middle, a fringe of 20 pixels on all sides, and ¼ of the image trimming is finished.

The performance of the proposed algorithm has shown good results against all the attacks as in Table 2. The cropping attack did not affect much for block based algorithm of Song et al. The JPEG compression results were found good for Naderahmadian and Hosseini Khayat algorithm as embedding is done in LL subband and did not work well for Song et al. algorithm. The NCC after noise attack is slightly better for Song et al. and Chun et al. methods than proposed algorithm. Looking at different assaults, the general execution of the proposed calculation is best to resize, lossy JPEG pressure, separating, and obscuring assaults. With the expansion in quantization step estimate heartiness against assaults increments however the picture quality reductions. So a

lessening/minimization and expansion of 10% and 25% in both the cases.

2. Lossy JPEG compressions for various pressure characteristics (30 to 100) are chosen.
3. Two kinds of noise inclusion assaults, i.e., salt and pepper noise, and Gaussian noise are included to the watermarked pictures.
4. Each watermarked picture is pivoted and after that the yield picture is trimmed to fit to an indistinguishable size from the info picture. The resultant picture is re-pivoted with a similar point.
5. Three kinds of filtering attacks are used i.e., middle filter with window size of [3×1], normal filter of window size of [3×1] , and Gaussian filter of two window sizes [3×1] and [3×3].
6. Blurring assault with two diverse plate sizes are performed i.e., circle size of 1.0, and 2.0.

tradeoff is taken and a step size of 20 is selected to obtain the results for comparison as given in Table 1.

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TABLE 1. Quality Assessment of watermarked image for various algorithms

Quality Assesment paramters	**Song et al. [7]**	**Chen et al. [1]**	**Naderahmadian and Hosseini-Khayat [5]**	**Proposed Method**
Parameters Assigned	*T=0.1*	*Q=44*	*Level = 1, Q=44*	*Level = 2, Q=20*
Algorithm Domain	*Spatial*	*DCT*	*Wavelet*	*Multiwavelet*
Mean Square Error	8.9907	1.8894	1.8278	**1.8155**
Peak Signal to Noise Ratio	38.5928	41.4534	43.5353	**45.5409**
Normalized Cross Correlation	1.0007	1.0009	1.0011	**1.0013**
Average Difference	-0.0951	-0.1398	-0.1209	**-0.1869**
Structural Content	0.9981	0.9965	0.9968	**0.9993**
Maximum Difference	79	12	**10**	**10**
Normalized Absolute Error	0.0058	0.0049	0.0046	**0.0047**

VII. CONCLUSION

The proposed scheme of design describes a robust blind image watermarking algorithm which associates the wavelet transform domain with QR factorization. QIM technique is utilized for watermark embedding. It has shown a good performance on strong robustness with imperceptibility. The proposed algorithm has proved good robustness against resizing, lossy JPEG compression, noise addition attacks, rotation, filtering, blurring, and cropping attacks maintaining a good quality watermarked image. The disadvantage of the proposed algorithm is its higher computational complexity than other algorithms. But the quality of the watermarked image is very good. As the embedded watermark is spread all over the image not like block based methods, removable attacks would destroy the cover image itself. Hence it is proved to be more secured.

TABLE 2. Normalised Cross Correlation (NCC) results comparison among different schemes based on robustness against various attacks.

Attack	**Description**	**Normalised Cross Correlation**			
		Song et al. [7]	**Nader-ahmadian and Hosseini-Khayat [5]**	**Chen et al. [1]**	**Proposed method**
		T=0.1	Q=32	Q=32	Q=44
No attack		38.5928	44.8930	42.8631	45.5409
Resizing	10% Minimizing	0.8985	0.7507	0.7727	0.8423
	25% Minimizing	0.5335	0.9045	1.0000	1.0000
	10% Maximizing	0.7848	0.4314	0.5252	0.5393
	25% Maximizing	0.9907	1.0000	1.0000	1.0000
JPEG Compression (Quality Factor)	30	0.3563	0.5402	0.4134	0.6040
	40	0.5819	0.7392	0.6777	0.8598
	50	0.6502	0.8890	0.8492	0.9772
	60	0.7265	0.9254	0.9545	0.9953
	70	0.7770	0.9814	0.9907	1.0000
	80	0.8809	1.0000	1.0000	1.0000
	90	0.9767	1.0000	1.0000	1.0000
	100	1.0000	1.0000	1.0000	1.0000
Noise	Salt & Pepper (0.001)	0.9860	0.8460	0.9165	0.9453
	Gaussian (m=0; var=0.001)	0.8897	0.6625	0.6547	0.9205
Rotation	1°	0.8319	0.8906	0.8462	0.8442
	4°	0.7591	0.8635	0.8066	0.8427
	10°	0.6493	0.8635	0.8310	0.7155
Filtering	Median [3×1]	0.0258	0.9637	0.9673	0.9814
	Average [3×1]	-0.0256	0.9769	0.8795	0.9728
	Gaussian [3×3]	0.9907	0.8985	0.9767	1.0000
Blurring	Disk (2.0)	0.1771	0.2919	0.3560	0.5424
	Disk (1.0)	0.8204	0.7145	0.8131	0.9048
Cropping	Centre (30×30)= 0	1.0000	0.9953	0.9906	0.9769
	Border (20)	0.6041	0.8977	1.0000	0.6048
	Corner (1/4)	1.0000	0.5985	0.5916	0.5386

REFERENCES

[1] Chen, H. Y., & Zhu, Y. S. (2012). A robust watermarking algorithm based on QR factorization and DCT using quantization index modulation technique.*Journal of Zhejiang University SCIENCE C*, *13*(8), 573-584.

[2] Goodman, T. N. T., Lee, S. L., & Tang, W. S. (1993). Wavelets in wandering subspaces. *Transactions of the American Mathematical Society*, *338*(2), 639-654.

[3] Irturk, A. U. (2007). *Implementation of QR Decomposition Algorithm using FPGAs* (Doctoral dissertation, UNIVERSITY OF CALIFORNIA).

[4] Lebrun, J., & Vetterli, M. (1998). Balanced multiwavelets theory and design.*Signal Processing, IEEE Transactions on*, *46*(4), 1119-1125.

[5] Naderahmadian, Y., & Hosseini-Khayat, S. (2010, October). Fast watermarking based on QR decomposition in wavelet domain. In *Intelligent Information Hiding and Multimedia Signal Processing (IIH-MSP), 2010 Sixth International Conference on* (pp. 127-130). IEEE.

[6] Selesnick, I. W. (1999). Interpolating multiwavelet bases and the sampling theorem. *Signal Processing, IEEE Transactions on*, *47*(6), 1615-1621.

[7] Song, W., Hou, J. J., Li, Z. H., & Huang, L. (2011). Chaotic system and QR factorization based robust digital image watermarking algorithm. *Journal of Central South University of Technology*, *18*(1), 116.

[8] Wang, Z., & Bovik, A. C. (2002). A universal image quality index. *Signal Processing Letters, IEEE*, *9*(3), 81-84.

[9] Xia, X. G., Geronimo, J. S., Hardin, D. P., & Suter, B. W. (1996). Design of prefilters for discrete multiwavelet transforms. *Signal Processing, IEEE Transactions on*, *44*(1), 25-35.