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PREFACE

Dear Distinguished Delegates and Guests,

The Organizing Committee warmly welcomes our distinguished delegates and guests to the 2010 International Conference on Networking and Information Technology (ICNIT 2010), 2010 International Conference on Database and Data Mining (ICDDM 2010), and 2010 The International Conference on Computational and Statistical Science (ICCSS 2010) held on June 11-12, 2010 in Manila, Philippines.

ICNIT 2010, ICDDM 2010 and ICCSS 2010 are sponsored by International Association of Computer Science and Information Technology (IACSIT), and supported by IACSIT Members and scholars all round the world. If you have attended a conference sponsored by IACSIT before, you are aware that the conferences together report the results of research efforts in a broad range of computer science and Information Technology. These conferences are aimed at discussing with all of you the wide range of problems encountered in present and future high technologies. ICNIT 2010, ICDDM 2010 and ICCSS 2010 are organized to gather members of our international community scientists so that researchers from around the world can present their leading-edge work, expanding our community's knowledge and insight into the significant challenges currently being addressed in that research. The conference Program Committee is itself quite diverse and truly international, with membership from the Americas, Europe, Asia, Africa and Oceania.

This proceeding records the fully refereed papers presented at the conference. The main conference themes and tracks are Networking and Information Technology. The main goal of these events is to provide international scientific forums for exchange of new ideas in a number of fields that interact in-depth through discussions with their peers from around the world. Both inward research; core areas of Networking and Information Technology and outward research; multi-disciplinary, inter-disciplinary, and applications will be covered during these events.

The conference has solicited and gathered technical research submissions related to all aspects of major conference themes and tracks. All the submitted papers in the proceeding have been peer reviewed by the reviewers drawn from the scientific committee, external reviewers and editorial board depending on the subject matter of the paper. Reviewing and initial selection were undertaken electronically. After the rigorous peer-review process, the submitted papers were selected on the basis of originality, significance, and clarity for the purpose of the conference. The selected papers and additional late-breaking contributions to be presented as lectures will make an exiting technical program. The conference program is extremely rich, featuring high-impact presentations.

The high quality of the program – guaranteed by the presence of an unparalleled number of internationally recognized top experts – can be assessed when reading the contents of the program. The conference will therefore be a unique event, where attendees will be able to appreciate the latest results in their field of expertise, and to acquire additional knowledge in other fields. The program has been structured to favor interactions among attendees coming from many diverse horizons, scientifically, geographically, from academia and from industry. Included in this will to favor interactions are social events at prestigious sites.

We would like to thank the program chairs, organization staff, and the members of the program committees for their work.

We are grateful to all those who have contributed to the success of ICNIT 2010, ICDDM 2010 and ICCSS 2010. We hope that all participants and other interested readers benefit scientifically from the proceedings and also find it stimulating in the process. Finally, we would like to wish you success in your technical presentations and social networking.

We hope you have a unique, rewarding and enjoyable week at ICNIT 2010, ICDDM 2010 and ICCSS 2010 in Manila, Philippines.

With our warmest regards,

The Organizing Committees
June 11-12 2010
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An Image Watermarking Scheme based on FWHT-DCT

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***Abstract*—Digital image watermarking is frequently used for many purposes, such as image authentication, fingerprinting, copyright protection, and tamper proofing. Imperceptibility and robustness are the watermark requirements of good watermarks. In this paper, we propose the Fast Walsh Hadamard transform (FWHT) combined with the Discrete Cosine Transform (DCT) as a new image watermarking scheme. The FWHT reorders the high-to-low sequence components contained in the signal. This scheme produces high perceptual transparency of the embedded watermark. Experimental results show that the proposed scheme has good visual perception and is robust against attacks.**

Keywords—Digital Image Watermarking; Imperceptibility; Robustness; Discrete Cosine Transform; Fast Walsh Hadamard Transform

I. INTRODUCTION

Image watermarking is the process of adding data or information, i.e. watermark, into a host image and it can be extracted to check for any abuse [1]. Image watermarking can be applied into many areas, such as broadcast monitoring, owner identification, proof of ownership, authentication, fingerprinting, copy control, covert communication, tamper detection, content protection, and copyright protection [2,3].

The image watermarking scheme consists of two processes, that is the watermark embedding and the watermark extraction. Imperceptibility and robustness are the most important requirements in watermarking. Imperceptibility is related to the visual quality of the watermarked image caused by embedding the watermark, while robustness is related to the resilience of the watermark from being extracted even after the watermarked image is altered or damaged [3,4].

Based on the technique uses to embed and detect a watermark, digital watermarking can be classified into either the spatial domain or frequency domain category. In the spatial domain, the watermark can be embedded into the least significant bits of the host image using the least significant bits (LSB) technique. In the frequency domain, the watermark can be embedded by modifying the transform coefficients using many transforms, such as the discrete cosine transform (DCT), the discrete fourier transform (DFT), and the discrete wavelet transform (DWT) [3].

Currently, there are many new schemes that have been developed to improve the watermark. Some of the schemes combine the transforms above with other transforms, such as Haar, Slant, Hartley, and Hadamard. The watermarking technique in the Hadamard domain is popular in the literatures.

Bhatnagar and Raman [5] proposed a robust watermarking scheme with multiresolution Walsh-Hadamard Transform using singular value decomposition (SVD). Li, Wang, Song, and Wen [6] proposed a blind multiple watermarking scheme using Hadamard transform. They have presented that this scheme is invisible and robust against attacks. Saeid and Hossein [7] proposed a blind digital watermark embedded with a proportional number of gray-level watermarks to the estimate of the two first Hadamard AC coefficients. In this paper, we propose the Fast Walsh Hadamard Transform (FWHT) combined with DCT as a digital image watermarking scheme. In this scheme, the FWHT to be applied on the original watermark before it embedded on the DC coefficients of the host image.

To describe our proposed scheme, we divide this paper into several sections. Section II presents the basic principles of the DCT and FWHT. Section III presents the image watermarking scheme based on the proposed FWHT-DCT scheme. Section IV consists of the experimental results of the watermarking performance using the FWHT-DCT scheme. The conclusions are presented in the Section V.

II. THE BASIC PRINCIPLES OF DCT AND FWHT

A. Discrete Cosine Transform (DCT)

The 2-D DCT is defined as [4]:

$$C(u,v) = \alpha(u)\alpha(v)\sum_{x=0}^{N-1}\sum_{y=0}^{N-1} f(x,y)\cos\left[\frac{\pi(2x+1)u}{2N}\right]\cos\left[\frac{\pi(2y+1)v}{2N}\right] \quad \text{for } u,v = 0,1,2,\ldots,N\text{-}1 \qquad (1)$$

The inverse transform (IDCT) is defined as:

$$f(x,y) = \alpha(u)\alpha(v)\sum_{u=0}^{N-1}\sum_{v=0}^{N-1} C(u,v)\cos\left[\frac{\pi(2x+1)u}{2N}\right]\cos\left[\frac{\pi(2y+1)v}{2N}\right] \quad \text{for } x,y = 0,1,2,\ldots,N\text{-}1 \qquad (2)$$

In the DCT-based watermarking scheme, the watermark bits are embedded in each $N\times N$-DCT block of the host image. The IDCT is used to reconstruct the watermarked image after the watermark is embedded into the host image.

B. Fast Walsh Hadamard Transform (FWHT)

Hadamard transform matrix is an orthogonal square matrix which only has 1 and -1 of element value. This transform is also known as Walsh-Hadamard transform. H_1 is the smallest Hadamard matrix, and it is defined as [8,9]:

$$H_1 = \frac{1}{\sqrt{2}}\begin{bmatrix} 1 & 1 \\ 1 & -1 \end{bmatrix} \tag{3}$$

The Hadamard matrix H_N of size N is constructed by Kronecker product between H_1 and H_{N-1}, where $N=2^n$, n is an integer number.

$$H_N = H_1 \otimes H_{N-1} = \begin{bmatrix} H_{N-1} & H_{N-1} \\ H_{N-1} & -H_{N-1} \end{bmatrix} \tag{4}$$

Eq. (5) shows an example of 4×4-Hadamard matrix, that is $H_2 = H_1 \otimes H_1$, obtained using Eq. (3) and Eq. (4).

$$H_2 = \frac{1}{2}\left[\begin{array}{cc:cc} 1 & 1 & 1 & 1 \\ 1 & -1 & 1 & -1 \\ \hdashline 1 & 1 & -1 & -1 \\ 1 & -1 & -1 & 1 \end{array}\right] \begin{matrix} \scriptstyle\text{Sign Changes} \\ 0 \\ 3 \\ 1 \\ 2 \end{matrix} \tag{5}$$

The number of sign changes along each row of the matrix in Eq. (4) is called the sequency of the row. These rows can be considered to be samples of rectangular waves with a subperiod of *1/N* units. These continuous functions are called Walsh's functions [9]. The Hadamard matrix is an orthogonal matrix and satisfies the following relation:

$$H \bullet H^T = I \tag{6}$$

The H is the Hadamard matrix, H^T is the inverse Hadamard matrix, and I is the unitary matrix. The Hadamard transform can be computed in $N \log N$ operations, using the Fast Walsh Hadamard transform algorithm. Suppose x is a signal vector, X is a spectrum vector, and H is the Hadamard matrix. The Walsh-Hadamard Transform (WHT) and Inverse Walsh-Hadamard Transform (IWHT) are defined as [8]:

$$\left.\begin{array}{r} WHT(x) = X = Hx \\ IWHT(X) = x = HX \end{array}\right\} \tag{7}$$

The WHT and IWHT are the forward and inverse of WHT_h, respectively. The sequency ordered Walsh-Hadamard transform (WHT_w) can be obtained by first carrying out the fast WHT_h and then reordering the components of X [8].

For an example, consider x = [1 2 3 4] is a signal vector of N=2 elements. The WHT matrix for this vector is:

$$H_h = \frac{1}{2}\begin{bmatrix} 1 & 1 & 1 & 1 \\ 1 & -1 & 1 & -1 \\ 1 & 1 & -1 & -1 \\ 1 & -1 & -1 & 1 \end{bmatrix} \quad and \quad H_w = \frac{1}{2}\begin{bmatrix} 1 & 1 & 1 & 1 \\ 1 & 1 & -1 & -1 \\ 1 & -1 & -1 & 1 \\ 1 & -1 & 1 & -1 \end{bmatrix} \tag{8}$$

The forward transform of x and the inverse of X can be found as:

$$X = \frac{1}{2}\begin{bmatrix} 1 & 1 & 1 & 1 \\ 1 & 1 & -1 & -1 \\ 1 & -1 & -1 & 1 \\ 1 & -1 & 1 & -1 \end{bmatrix}\begin{bmatrix} 1 \\ 2 \\ 3 \\ 4 \end{bmatrix} = \begin{bmatrix} 5 \\ -2 \\ 0 \\ -1 \end{bmatrix};\; x = \frac{1}{2}\begin{bmatrix} 1 & 1 & 1 & 1 \\ 1 & 1 & -1 & -1 \\ 1 & -1 & -1 & 1 \\ 1 & -1 & 1 & -1 \end{bmatrix}\begin{bmatrix} 5 \\ -2 \\ 0 \\ -1 \end{bmatrix} = \begin{bmatrix} 1 \\ 2 \\ 3 \\ 4 \end{bmatrix} \tag{9}$$

In this example, we have FHWT(x) = [5 -2 0 -1] as a FWH transform of x and IFWHT(X) = [1 2 3 4] = x as an inverse.

III. The Proposed Image Watermarking Scheme

A. Embedding the Watermark

The proposed watermark embedding for the FWHT-DCT scheme is shown in Fig. 1 by the following steps:

Step 1. Take the watermark W with $N \times N$ of size $N=2^m$ (m=1,2,...) and apply the FWHT on the watermark W to get the FWHT coefficient, that is W'=FWHT(W).

Step 2. Generate the two pseudorandom number (PN) sequences k_1 and k_2 using the same seed.

Step 3. Take the original image as the host image I and apply the DCT to each 8×8-block of the original image I to get the DC coefficients.

Step 4. Embed the PN sequences with gain factor α in the DC component X in order as follows:

$$X' = \begin{cases} X + \alpha * k_1, & if\, W > W' \\ X + \alpha * k_2, & otherwise \end{cases} \tag{10}$$

Step 5. Apply the inverse of DCT (IDCT) on DC component X' to reconstruct the watermarked image I'.

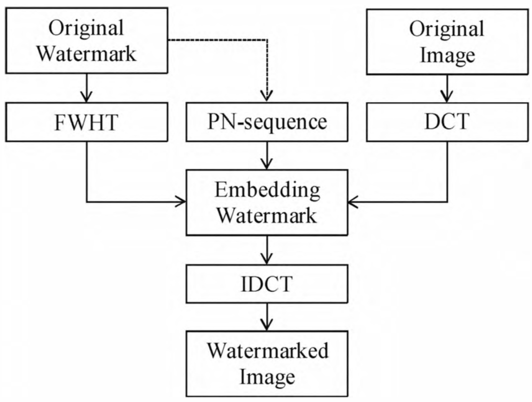

Figure 1. Watermark Embedding Scheme

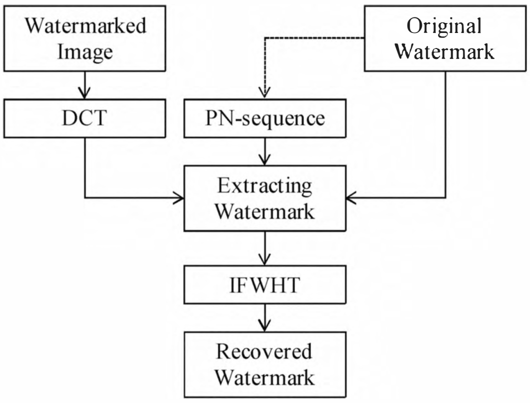

Figure 2. Watermark Extraction Scheme

B. *Extracting the Watermark*

The watermark extraction scheme is shown in Fig. 2, by the following steps:

Step 1. Apply the DCT to each 8×8-block of the watermarked image.

Step 2. Calculate and compare the correlation coefficient between the DC coefficients *X'* and the two PN sequences k_1 and k_2 to each 8×8-block of watermarked image.

$$W'' = \begin{cases} W', & if\ corr(X', k_1) < corr(X', k_2) \\ W, & otherwise \end{cases} \tag{11}$$

Step 3. Apply the inverse FWHT (IFWHT) on *W''* to reconstruct the recovered watermark.

C. *Performance Measurements*

In this work, we use the Peak Signal to Noise Ratio (PSNR) and the Normalized Cross Correlation (NCC) measure to analyze the performances of the proposed watermarking scheme. The PSNR, in decibels (dB), is used to evaluate the imperceptibility of the watermarked image [4], and is given by Eq. (12).

$$PSNR = 10.^{10}\log.\left[\frac{R^2}{\sum_{i=1}^{M}\sum_{j=1}^{N}[X(i,j) - X'(i,j)]^2}\right] \tag{12}$$

for i=1,2,…,M and j=1,2,…,N

The X is the original image, X' is the watermarked image, R is the maximum fluctuation in the input image data type, M and N are the number of rows and columns in the input images, respectively.

The NCC is used to evaluate the robustness of the watermark, by calculating the correlation (or the similarity) between the original watermark and the recovered watermark [4]. The NCC indicates the similarity between the extracted and the original watermark, and is given by Eq. (13).

$$NCC = \frac{\sum_{i=1}^{M}\sum_{j=1}^{N}[W(i,j)W'(i,j)]}{\sum_{i=1}^{M}\sum_{j=1}^{N}[W(i,j)]^2} \tag{13}$$

for i=1,2,…,M and j=1,2,…,N

The W is the original watermark, W' is the recovered watermark, and M and N are the number of rows and columns in the input images, respectively.

IV. EXPERIMENTAL RESULTS

In our experiments, we use the 'Lena' 512×512 gray scale image as a host image, while the original watermark is the 'Stamp' 64×64 gray scale image as shown in Fig. 3. Due to the characteristics of FWHT, it is necessary to note that this scheme only works on N×N size images. The experiment is performed using Matlab [10,11].

A. *Imperceptibilty and Robustness without Attack*

Based on the experimental results, the imperceptibility evaluation of the watermarked image gave a PSNR value of 84.89 dB as shown in Fig. 4. Without any attacks, the watermark could be recovered with on NCC value of 0.9993.

B. *Imperceptibility and Robustness after Attacks*

The imperceptibility and the robustness performance were also measured after they were subjected to interference caused by several attacks. We used several image processing operations as attacks, i.e. noise insertion, JPEG compression, cropping, rotation, and resizing.

Figure 3. Original image and watermark image

PSNR=84.89 dB NCC=0.9993

Figure 4. Watermarked image and recovered watermark without attack

PSNR=58.95 dB NCC=0.9984

Figure 5. Watermarked image and recovered watermark after noise insertion (d=20)

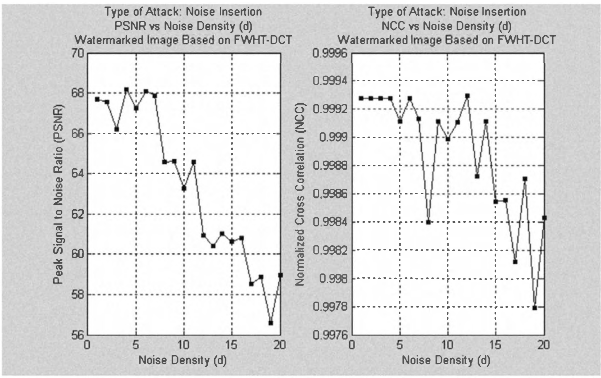

Figure 6. Imperceptibility and robustness after noise insertion

Noise Insertion: The pseudorandom noise signals were inserted into the watermarked image with the noise density d, as given in Eq. (14).

$$X' = X' + d * rand(N) \tag{14}$$

The imperceptibility and robustness after noise insertion using d=20 is shown in Fig. 5. The watermark could be recovered with NCC=0.9984. Increasing the coefficient value of the noise decreases the quality of perceptual invisibility of the watermarked image and also the robustness level of the recovered watermark, as shown in Fig. 6.

JPEG Compression: Experiments with JPEG compression on the watermarked image produced the results in Fig. 7, using the compression quality factor, Q=50. The watermark was be recovered. Unlike the noise insertion, increasing the quality factor of the JPEG compression increased the perceptual invisibility with high PSNR value.

PSNR=84.89 dB NCC=0.9993

Figure 7. Watermarked image and recovered watermark after JPEG Compression (Q=50)

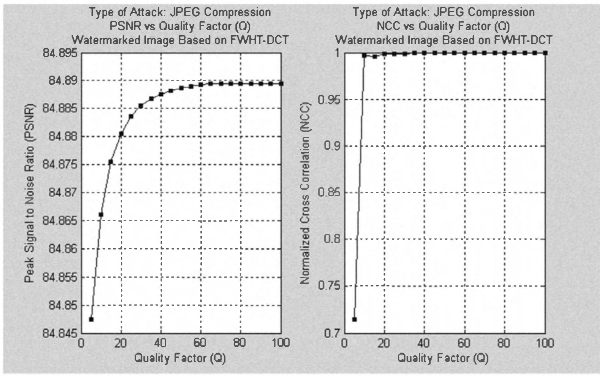

Figure 8. Imperceptibility and robustness after JPEG Compression

This scheme also has good robustness with high values of the compression quality factor. So, the watermark could be recovered with a high NCC, as shown in Fig. 8.

Cropping: In this experiment, a part of the watermarked image is cropped out. The copping area is defined from a certain specific rows and columns of the watermarked image. Experiments with higher values of the cropping area achieved the results as shown in Fig. 9.

The watermark could be recovered in these cases. Fig. 10 illustrates the imperceptibility and robustness after image cropping.

PSNR=84.52 dB NCC=0.9653

Figure 9. Watermarked image and recovered watermark after image cropping (10 rows of cropped area)

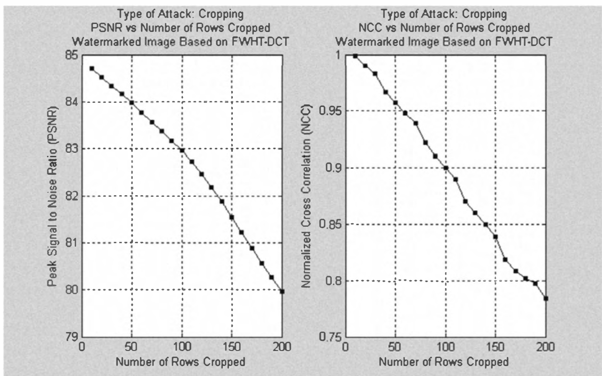

Figure 10. Imperceptibility and robustness after image cropping

PSNR=83.56 dB NCC=0.6624

Figure 11. Watermarked image and recovered watermark after image rotation (*degree*=120°)

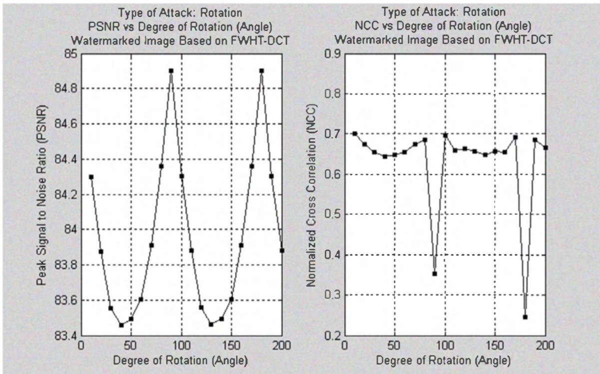

Figure 12. Imperceptibility and robustness after image rotation

Rotation: This experiment was performed by applying a degree of rotation on the watermarked image. The results are shown in Fig. 11. With the 120 degree of rotation, the watermark could be recovered with NCC=0.6624.

As shown in Fig. 12, the imperceptibility level shows a general downward trend when the degree of the image rotation increased. Improvements are noticed at rotations of 90 degree angles (i.e. 90 and 180 degrees).

Resizing: As shown in Fig. 13, the watermark could be recovered with low readability when the image was resized by a factor of image resizing values.

PSNR=84.73 dB NCC=0.7202

Figure 13. Watermarked image and recovered watermark after image resizing (*scale factor*=2x)

Enlarging further produced the results in Fig. 14, where the watermarked image had high perceptual invisibility. The watermark image could be recovered with high NCC values.

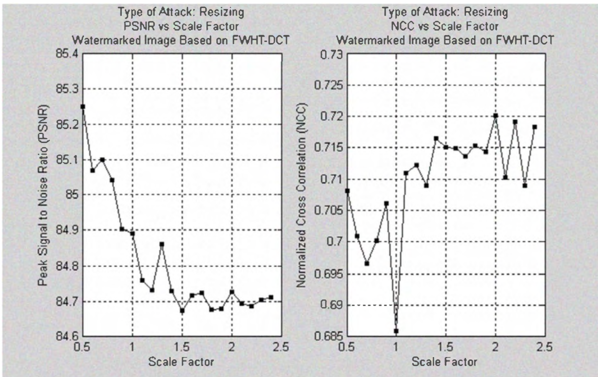

Figure 14. Imperceptibility and robustness after image resizing

V. CONCLUSION

In this paper, we propose the FWHT-DCT as a digital image watermarking scheme. We have presented the evaluation of the watermarking performances in imperceptibility and robustness as the watermarking requirements. The experimental results show that the proposed scheme has a good perceptual invisibility and is also robust against attacks.

REFERENCES

[1] M. Sharkas, D. ElShafie, N. Hamdy, "A dual digital-image watermarking technique," World Academy Science, Engineering and Technology, v5-33, 2005, pp. 136-139.

[2] I. J. Cox, M. L. Miller, J. A. Bloom, "Watermarking applications and their properties," Int. Conf. on Inf. Tech.: Coding and Computing, Las Vegas, March 2000, pp. 6-10, doi: 10.1109/ITCC.2000.844175.

[3] V. M. Potdar, S. Han, E. Chang, "A survey of digital watermarking techniques," Proc. IEEE International Conference on Industrial Informatics (INDIN'05), 3rd, Dec. 2005, pp.709-716, doi: 10.1109/INDIN.2005.1560462.

[4] M. M. El-Ghoneimy, "Comparison between two watermarking algorithms using DCT coefficient, and LSB replacement," Journal of Theoritical and Applied Inf. Tech., vol. 4, no.2, 2008, pp. 132–131.

[5] G. Bhatnagar, B. Raman, "Robust Watermarking in Multiresolution Walsh-Hadamard Transform," Proc. IEEE International Advance Computing Conference (IACC 2009), India, March 2009, pp. 894-899, doi: 10.1109/IADCC.2009.4809134.

[6] H. Li, S. Wang, W. Song, Q. Wen, "Multiple watermarking using Hadamard transform," Lecture Notes in Computer Science (LNCS), Vol. 3739, 2005, pp. 767-772.

[7] S. Saryadzi, N. A. Hossein, "A blind digital watermark in Hadamard domain," World Academy of Science, Engineering and Technology, v3-31, 2005, pp. 126-129.

[8] R. Wang., "Walsh-Hadamard Transform,"[Online]. Available: http://fourier.eng.hmc.edu/e161/lectures/wht/wht.html.

[9] William K. Pratt, Digital image processing, Fourth Edition, Wiley-Interscience, John Wiley and Sons, Inc., California, 2007.

[10] R. C. Gonzales, R. E. Woods, S. L. Eddins, Digital image processing using MATLAB, Pearson Education, India, 2004.

[11] "Fast Walsh-Hadamard Transform,"[Online]. Avalilable: http://mathworks.com/access/helpdesk/help/toolbox/signal/fwht.html.

[12] "Inverse Fast-Walsh Hadamard Transform,"[Online]. Avalilable: http://mathworks.com/access/helpdesk/help/toolbox/signal/ifwht.html