International Journal of Applied Research 2015; 1(12): 844-847

ISSN Print: 2394-7500
ISSN Online: 2394-5869
Impact Factor: 5.2
IJAR 2015; 1(12): 844-847
www.allresearchjournal.com
Received: 16-09-2015
Accepted: 18-10-2015

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Performance analysis of different orthogonal transform for image processing application

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Abstract
In modern communication technologies, the demand of image data compression increasing rapidly. This paper presents different methods for image compression like DCT, Walsh, Hadamard and Walsh Hadamard. Main objective of this paper is to achieve the higher compression ratio and lower the Mean square error. Different test images over different orthogonal transform are used to achieve the performance and coding efficiency. Hadamard transform gives less improvement in PSNR and large value of MSE as compare to walsh transform which gives better PSNR and Lesser MSE. Walsh-Hadamard enhances its performance and finally DCT gives least MSE and high PSNR.

Keywords: Walsh, Hadamard, Walsh-hadamard, DCT, MSE and PSNR

1. Introduction

Digital image compression techniques are used to reduce the size of an image. Suppose if we upload the 16MB image then it will take four minutes to download by the use of 64kbps channel, but if we use the compression techniques its size will reduced to 800 kb and the time that it will take to download is 12 seconds. Hence the demand of image compression becomes necessary [1].

Image compression is divided into two categories: Transform coding and spatial coding [2]. In transform coding we used different techniques like DFT, DCT, Walsh, Hadamard, and Walsh Hadamard [3]. In discrete Fourier transform computational complexity is very large as we have to calculate the sine and cosine terms. The remaining transforms method are orthogonal transform method in which we use forward transform kernel as well as inverse transform kernel. If we compress the image using forward kernel then it is necessary to use the inverse kernel to recover the original image.

Transform method are very useful for digital image compression. Image compression technique can be divided into two categories (1) Lossless (2) Lossy technique [4]. Lossless techniques compressed the image without losing the information but in case of lossy technique some information lost during compression. Hence above compression technique share common architecture. It’s become difficult to improve the performance of coding under these architecture. Hence to achieve high compression performance more techniques are induced in image coding and compression.

DCT (Discrete Cosine Transform) in past decade was very popular for image compressing the image, because it gives optimum performance and its implementation cost was very low. Compression techniques like JPEG [5] and MPEG [6] are based on DCT. In the image compression techniques main stages are transform and quantization, modelling and ordering and last stage is entropy coding. Compression encoding method is based upon DCT in which quantization table is used and which is determined by various quantization steps [7]. These quantization steps makes quantization table much complex. DCT, Walsh, Hadamard and Walsh Hadamard Transform brought forward in this paper which can be applied for image compression. In recent times, much of the research activities in image coding have been focused on the DWT, which has become a standard tool in image compression applications because of their data reduction capability [8]. Image compression methods are also based on the use of non-orthogonal filters such as Gabor wavelet transform [9].

Aim of this paper is to analyze the performance of different orthogonal transform. Walsh Hadamard transform and DCT gives the better performance as compare to Walsh, Hadamard Transform.

2. Walsh Transform

The Walsh Transform is an orthogonal transform where we use the forward transform kernel as well as inverse transform kernel. Forward Transform kernel is used to compress the image and if we want to recover that image then Inverse kernel is required. In Walsh Transform computational complexity is less as compared to DFT and DCT because there are no cosine and sine term as only addition and subtraction make the computation easy [10-11].

The Walsh transform uses square-waves and these vary from -1 to +1. The advantage of the Walsh transform is, it does not require floating-point math or transcendental functions. The inverse Walsh kernel is same as forward kernel.

Forward Kernel and inverse kernel are given below in 1 D form:

$$g(x,u) = \frac{1}{N}\prod_{i=0}^{n-1}(-1)^{[b_i(x)b_{n-1-i}(u)]} \quad (1)$$

$$h(y,v) = \frac{1}{N}\prod_{i=0}^{n-1}(-1)^{[b_i(y)b_{n-1-i}(v)]} \quad (2)$$

Forward and inverse kernel in 2-D form are given below:

$$g(x,y,u,v) = \frac{1}{N}\prod_{i=0}^{n-1}(-1)^{[b_i(x)b_{n-1-i}(u)+b_i(y)b_{n-1-i}(v)]} \quad (3)$$

$$h(x,y,u,v) = \frac{1}{N}\prod_{i=0}^{n-1}(-1)^{[b_i(x)b_{n-1-i}(u)+b_i(y)b_{n-1-i}(v)]} \quad (4)$$

2.1. Hadamard Transform

$$H_N = 1 \quad H_N = \begin{pmatrix} H_{N-1} & H_{N-1} \\ H_{N-1} & -H_{N-1} \end{pmatrix}$$

$$H_2 = \begin{bmatrix} 1 & 1 \\ 1 & -1 \end{bmatrix} \quad H_4 = \begin{bmatrix} 1 & 1 & 1 & 1 \\ 1 & -1 & 1 & -1 \\ 1 & 1 & -1 & -1 \\ 1 & -1 & -1 & 1 \end{bmatrix} \quad M_4 = \begin{bmatrix} 1 & 1 & 1 & 1 \\ 1 & 1 & -1 & -1 \\ 1 & -1 & -1 & 1 \\ 1 & -1 & 1 & -1 \end{bmatrix}$$

Natural order — Sequency order

$$\vec{Y}^{(4)} = \begin{pmatrix} y_0 \\ y_1 \\ y_2 \\ y_3 \end{pmatrix} = \begin{bmatrix} 1 & 1 & 1 & 1 \\ 1 & 1 & -1 & -1 \\ 1 & -1 & -1 & 1 \\ 1 & -1 & 1 & -1 \end{bmatrix} \begin{pmatrix} x_0 \\ x_1 \\ x_2 \\ x_3 \end{pmatrix} = M_4 \vec{X}^{(4)}$$

Fig 1: Hadamard Transform Matrix

The Hadamard transform is same as Walsh because it uses square waves of -1 to +1 in amplitude. The transform is easily calculated from multiply the image with Hadamard matrix: The Hadamard transform H_N is a 2^M x 2^Nmatrix the Hadamard matrix transforms $N=2^m$ real numbers into 2^n real numbers which is shown in figure 1:

Hadamard transform have a computational complexity of O (N^2). The hadamard transform as show in figure 2 given below, requires only $N \log N$ additions or subtractions.

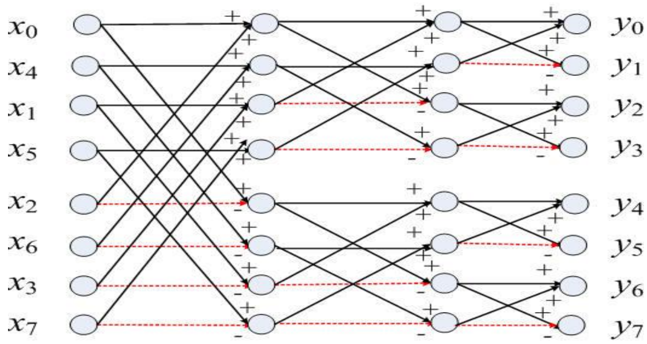


Fig 2: Computational Complexity in Hadamard Transform

2.2. Walsh Hadamard Transform

For representing sequency components which are contained in the signal in low-to-high order, we can re-ordering the rows and columns of Hadamard matrix (H) according to their sequencies. In order to convert a sequency (S) into their corresponding index number (k) in Hadamard order is a three-step process:

Representation S in binary form:

$$S = (S_{n-1}S_{n-2}.\cdots\cdots\cdots S_1S_0)_2 = \sum_{i=0}^{n-1} S_i \quad (5)$$

1. Next step is to convert S into Gray code:

$$g_i = S_i \oplus S_{i+1} \quad (i = 0,\cdots,n-1) \quad (6)$$

Here $\oplus$ represents the exclusive or and $S_n = 0$ by the definition.

2. Next step is to reverse the g_i to get k_i:

$$k_i = g_{n-1-i} = S_{n-1-i} \oplus S_{n-i} \quad (7)$$

Now k can be calculated as:

$$k = (k_{n-1}\,k_{n-2}\,k_{n-3}\cdot\cdot k_1\,k_0)_2 = \sum_{i=0}^{n-1} S_{n-1-i} \oplus S_{n-1} \quad (8)$$

Wherej=n-1-i or equivalently

i=n-1-j

$$\log_2 N = \log_2 8 = 3 \quad (9)$$

Let's take an example,

s	0	1	2	3	4	5	6	7
binary	000	001	010	011	100	101	110	111
Gray code	000	001	011	010	110	111	101	100
bit-reverse	000	100	110	010	011	111	101	001
k	0	4	6	2	3	7	5	1

We can calculated the Walsh-Hadamard matrix as

$$\mathbf{W} = \frac{1}{\sqrt{8}} \begin{bmatrix} 1 & 1 & 1 & 1 & 1 & 1 & 1 & 1 \\ 1 & 1 & 1 & 1 & -1 & -1 & -1 & -1 \\ 1 & 1 & -1 & -1 & -1 & -1 & 1 & 1 \\ 1 & 1 & -1 & -1 & 1 & 1 & -1 & -1 \\ 1 & -1 & -1 & 1 & 1 & -1 & -1 & 1 \\ 1 & -1 & -1 & 1 & -1 & 1 & 1 & -1 \\ 1 & -1 & 1 & -1 & -1 & 1 & -1 & 1 \\ 1 & -1 & 1 & -1 & 1 & -1 & 1 & -1 \end{bmatrix} \begin{matrix} 0 & 0 \\ 1 & 4 \\ 2 & 6 \\ 3 & 2 \\ 4 & 3 \\ 5 & 7 \\ 6 & 5 \\ 7 & 1 \end{matrix}$$

The first column on the right of the matrix is for the sequency S of the corresponding row, which is the index for the sequency ordered matrix, and the second column is the index K oftheHadamard ordered. We see that this matrix is still symmetric:

W [k, m] =W [m, k]

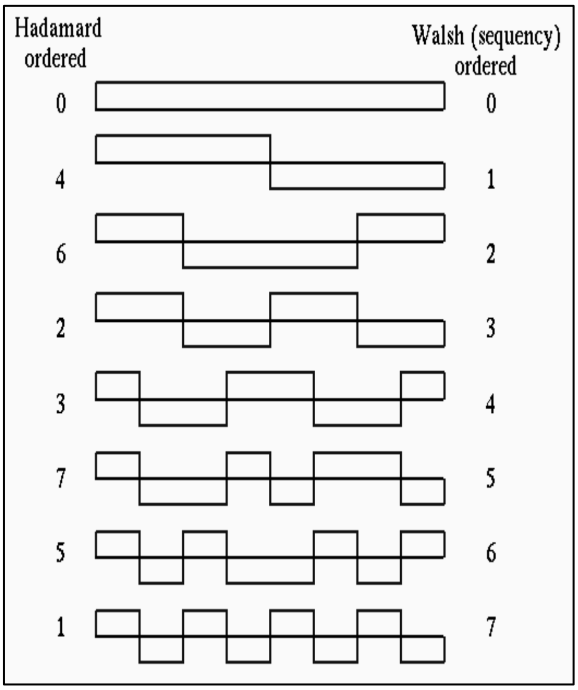
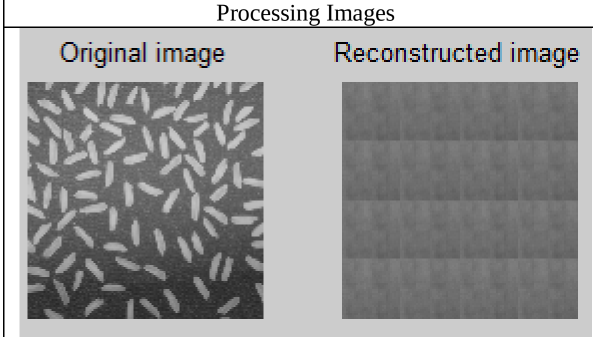
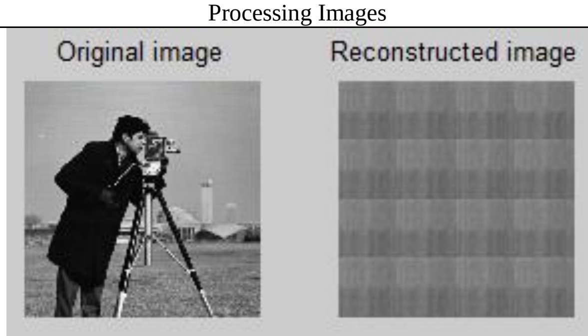
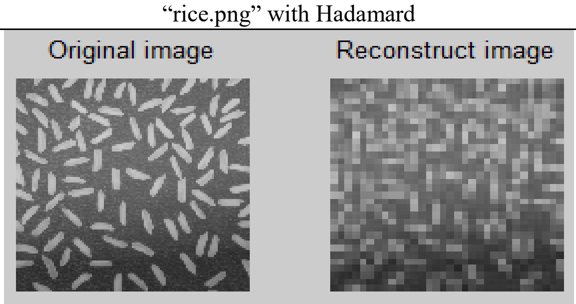
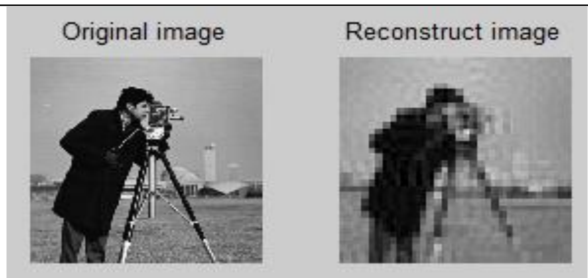
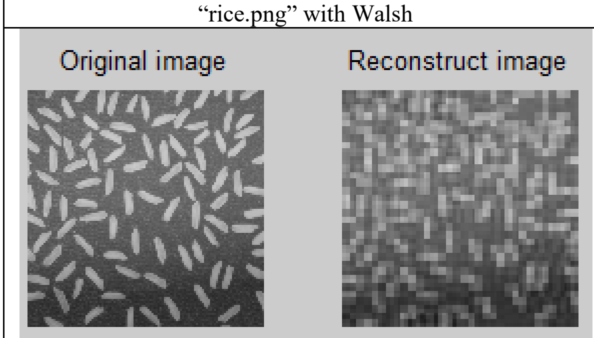
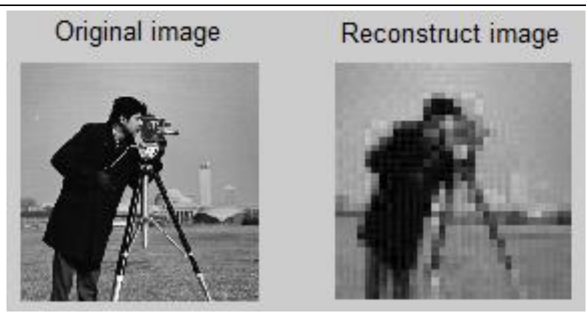
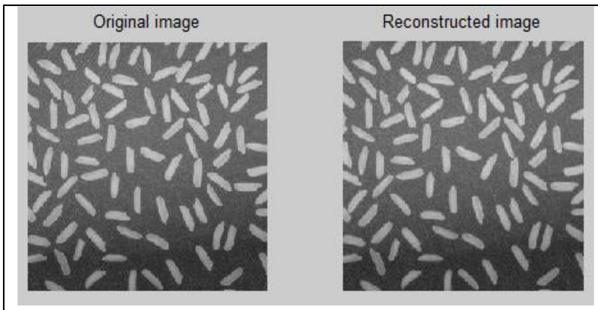


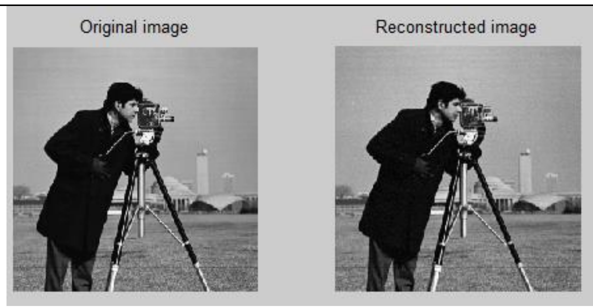
Fig 3: Sequency representation of walsh-hadamard

Table 1: Original Test images and their reconstructed images

Processing Images	Processing Images
 "rice.png" with Hadamard	 "cameraman.tif" with Hadamard
 "rice.png" with Walsh	 "cameraman.tif" with Walsh
 "rice.png" with Walsh-Hadamard	 cameraman.tif with Walsh-Hadamard



"rice.png" with DCT



Cameraman. tif with DCT

Table 2: The MSE & PSNR measurement of test images

	Image Compression Transforms							
Database Images	**Hadamard**		**Walsh**		**Walsh-Hadamard**		**DCT**	
	MSE	PSNR	MSE	PSNR	MSE	PSNR	MSE	PSNR
camaraman.tif	148.7362	26.4406	46.2742	31.5114	46.1091	31.5269	15.9224	36.1447
rice.png	76.0221	29.3554	70.5596	29.6792	68.8706	29.7845	17.3121	35.7813

3. Result Discussion

We have applied the different orthogonal transform like DCT, Walsh, Hadamard and Walsh Hadamard on two different test images. The Table 1 shows the original image and reconstructed image in matlab by applying all these transforms separately over two different images cameraman.tif and rice.png. Table 2 represents the peak signal to noise ratio (PSNR) and mean square error (MSE) values for different orthogonal transform for two different images. From Hadamard to Walsh Transform MSE reduces 68.88% and PSNR improves 16.09% and in case of Walsh to Walsh Hadamard MSE reduces 0.35% and PSNR improves 0.049% and from Walsh Hadamard to DCT MSE reduce 65.46% and PSNR improves 12.77%.

4. Conclusion

From the above discussion we can concluded that any orthogonal transform applied should have better PSNR and lesser MSE. Walsh Transform that we have studied have a PSNR of 31.5114 and MSE is 46.2742, but in case of Hadamard Transform PSNR gives a value of 26.4406 and MSE gives a value of 148.7362. Hence Performance of DCT transform improves as compare to other orthogonal transforms. We can also calculate compression ratio of these transform to evaluate their performance.

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