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Walsh Transform-based Image Compression for Less Memory Usage and High Speed Transfer

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ABSTRACT:
The rising use of digital imaging applications has recently boosted the demand for different image compressing algorithms. Picture compression is used to reduce unnecessary information from an image. We can store the vital information of a picture via image compression, reducing storage space, time, and transmission bandwidth. Although the results of lossy compression reconstruction are not similar to the original image the compression technique is essential to save a large amount of memory and increase the speed of transmission, especially when dealing with images. In this research a database of different five images was considered namely; woman, car, Lenna, peppers, and house with sizes of 33, 47, 40, 44, and 51 Kb respectively. The compression was fulfilled by Walsh transform with four compression ratios 5%, 10%, 15%, and 20%. The Walsh transform performed well and gave the highest average PSNR of 29.1904 during a 10% of compression ratio.

KEYWORDS: Walsh Hadamard Transform (WHT), Image Compression, Peak signal-to-noise ratio (PSNR), Mean Square Error (MSE), Database Image.

1. INTRODUCTION

Image compression is a way to cut the cost of transmission and storage. The two main categories of currently used image compression methods are lossless compression and lossy compression. To compress any image, redundancy must be removed. Sometimes images having large areas of the same color will have large redundancies and similarly images that have frequent and large changes in color will be less redundant and harder to compress and this is considered as the weak points of the previous works. Due to its effective compression and computational efficiency, the Walsh-Hadamard transform (WHT) is frequently employed in real-world image compression systems [1]. WHT-based image compression reduces the amount of data necessary to describe a picture in two different ways. The image's WHT coefficients are quantized first, then the quantized coefficients are entropy-coded. Quantization is the process of reducing the number of possible values of a quantity and lowering the number of bits required to express it. A lossy technique for lowering the color information associated with each pixel in a picture [2]. K.Veeraswamy [3] The Human Visual System (VHS) was used to design a quantization table for the Hadamard transform for image compression. In image compression (lossy), the quantization table is crucial because it raises the compression ratio without sacrificing visual quality. V. Orest and W. Mircea [4] The Walsh-Hadamard transform was used to improve SOM vector quantization for picture compression. Picture compression plays an important part in digital image transmission since it reduces bandwidth or storage

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requirements. In this system, they introduce a novel approach to lossy image compression: vector quantization of the original image using a Self-Organizing Map (SOM) with several dictionaries. The original image is divided into 8x8 blocks, and then the 2D-Walsh-Wavelet Transform (WWT) is applied to each 8x8 block in the low-frequency sub-band. Each sub-band is divided by a factor, and then Arithmetic Coding is applied to each sub-band separately. Arithmetic coding is used to transform, divide, and compress each 8x8 block from LL2 into its component DC values. [5]. because the Hadamard Transform's basis vectors can only take the binary value 1, they are ideal for digital hardware implementations of image processing methods. Because it involves easier integer operations, the Hadamard transform provides a significant speed advantage (compared to floating-point processing with DCT) and is easier to implement on hardware than many other standard transform algorithms. As a result, it is less computationally costly than several other orthogonal transformations [3]. Y. Asriningtias et.al. [6] Combining Wavelet transformation with Walsh filter by compression ratio 1.32 to obtain an average PSNR of 43.31 dB as the test results revealed that the proposed technique will perform best when it was used to compress photos with low brightness levels [6].V.kostrov et.al. [7] An orthogonal Walsh transformations instrument depend on fundamental Walsh functions was utilized to compress data during the transmission of aircraft photographs over the communication channel into embedded cyber-physical systems, yielding a mean square error (MSE) of 4 and a CR of 58 percent. The approach was detailed in section 2 of this study using the Walsh transform mathematical model. Section 3 addressed compressed picture performance, while Section 4 discussed results, and the report concluded with a conclusion.

2. METHODOLOGY

This section describes the database that has been used in this research by explaining in detail FFT, DCT, wavelet, and Walsh transform.

2.1. Database's Images

In this study, the pictures that were taken into consideration for compression were displayed in Fig.1. Made up of the following five pictures; a woman, car, Lenna, peppers, and house with sizes of 33, 47, 40, 44, and 51 Kb respectively with their images underneath each one.

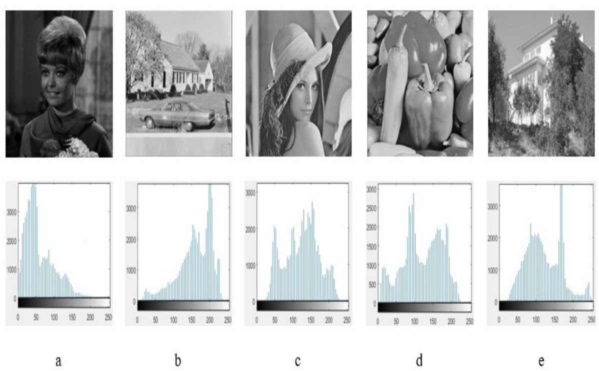

Fig. 1. Images and Its Histogram Dataset.

2.2. Walsh Transform Technique

An established image processing technique is the Walsh-Hadamard transform (WHT). The flexibility, energy compression, and robustness of these linear image transformations make them useful in image-processing applications. These transformations provide energy compression in cutting-edge methods while also successfully extracting the edges [8]. WHT is particularly appealing due to its simplicity and computing efficiency. The orthogonal basis vector components of WHT have only binary values (1 and 0). Image filtering, audio processing, and medical signal analysis all employ the WHT, which is an orthogonal, non-sinusoidal transform. To be more specific, WHT's processing, coding, and filtering of lunar images/signals is excellent. It is well-known for its ease of use and speed of calculation [9]. WHT is a Fourier transform substitute. It is simpler to calculate since it does not require any multiplication or division operations. The low computational complexity of such adjustments lowers the energy and time expenses of transmitting data through communication networks, which is why their usage is justified [10]. In WHT, each pixel is multiplied by one when the image is projected into basis pictures, whereas FFT requires complex multiplication. In terms of processing complexity, WHT is therefore more effective than FFT [8]. Simple addition and subtraction are used for all calculations. As a result, WHT-based application hardware implementation is made simpler. Therefore, it is advantageous in terms of energy use and computation. In this research, this Walsh transform was used to do different image compression ratios for the mentioned image dataset as shown in the flowchart of Fig.2.

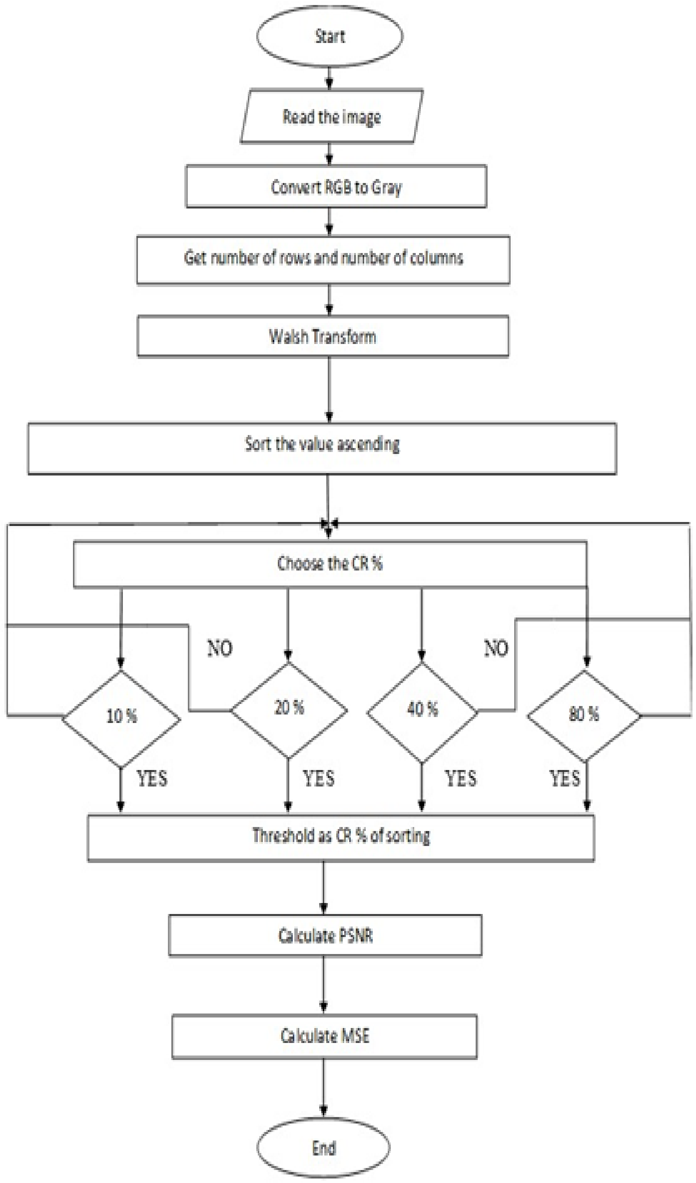

Fig. 2. Flowchart of choosing different CR%.

2.3. WHT Mathmematical Model

A picture C with pixels c(x, y) of size N - N is an example of a 2D WHT.

$$H(u,v) = \sum_{x=0}^{N-1}\sum_{y=0}^{N-1} c(x,y)g(x,y,u,v) \qquad (1)$$

Where H (u, v) is the resulting picture after the WHT transformation and g(x, y, u, v) is the WHT kernel function. The following is a great feature of WHT that has to do with energy efficiency.

$$\sum_{x=0}^{N-1}\sum_{y=0}^{N-1} |c(x,y)|^2 = \sum_{u=0}^{N-1}\sum_{v=0}^{N-1} |H(u,v)|^2 \qquad (2)$$

The spatial and Walsh-Hadamard domains both possess the feature of energy conservation. The WHT matrix's zero sequence term is used to calculate the image's average brightness [8].

$$H(o,o) = \sum_{x=0}^{N-1}\sum_{y=0}^{N-1} c(x\,,y) \qquad (3)$$

For 2D signals (Images of size N * N), the forward Walsh-Hadamard Transform (WHT) can be obtained by following the matrix equation.

$$Y = \frac{1}{N^2}(H_n \times H_n) \qquad (4)$$

Where, X is the input image, Y is the output transform matrix and H_n is the Hadamard or Walsh matrix. The inverse transform has the same operation as that of the forward transform and can be obtained as,

$$X = H_n\, Y\, H_n \qquad (5)$$

It is a separable transform, therefore, for 2D signals (images), the row wise and column wise 1D operation can provide 2D transform [8].

$$\text{Where } H_n = \begin{bmatrix} H_{11} & H_{12} & H_{13} & \dots H_{1N} \\ H_{21} & H_{22} & H_{23} & \dots H_{2N} \\ H_{31} & H_{32} & H_{33} & \dots H_{3N} \\ & & \dots & \\ H_{N1} & H_{N2} & H_{N3} & \dots H_{NN} \end{bmatrix} \qquad (6)$$

3. COMPRESSED IMAGE PERFORMANCE

The performance of a compressed picture (CR) can be assessed using the image quality metrics mean square error, peak signal-to-noise ratio, and compression ratio. The squared difference between an uncompressed and compressed image, as seen in Eq. (7), is referred to as MSE.

$$MSE = \frac{1}{m,n}\sum\sum\left(X_{i,j} - Y_{i,j}\right)^2 \qquad (7)$$

Where X represents the original image, Y denotes the estimated decompressed image, and m and n denote the individual image dimensions. On the other hand, PSNR describes the quantity of noise present in the output of a signal. Equation (8) provides a mathematical expression of it in logarithmic form.

$$PSNR = 20 \times \log_{10}\left(\frac{255^2}{MSE}\right) \qquad (8)$$

Compression Ratio: It simply refers to the percentage of the uncompressed photo size to the compressed photo size, as shown in Eq. (9). Lastly, the overall difference between the original and reconstructed pictures is computed by MSE and PSNR [11].

$$CR = \left(\frac{Orignal\ image\ size - Reconstructed\ image\ size}{Orignal\ image\ size}\right) \times 100 \qquad (9)$$

4. RESULT

In order to do compression for any image, histogram equalization should be done in preprocessing first by converting color images to gray colored using the statement ""rgb2gray" in mat lab. The histogram of the images (woman, car, Lenna, peppers, and house) is shown in Fig.3 Which shows clearly that the histogram of the 5% or 10 % compression ratio is uniformly distributed and better than the disrupted 15% or 20 % compression ratio. Hence, the feasibility of the images is very clear and acceptable within both compression ratios 5% and 10% as shown in Fig.4 While 15% and 20% gave unclear images because the mean square error is increased with increasing the compression ratio while PSNR is decreased.

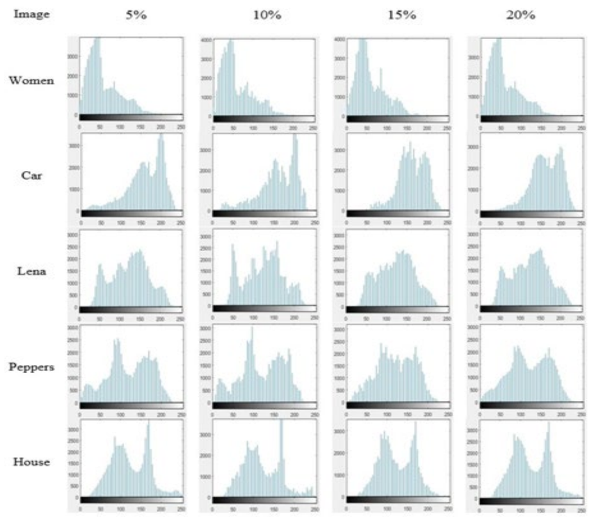

Fig. 3. Histogram of different images compressed by different compression ratios.

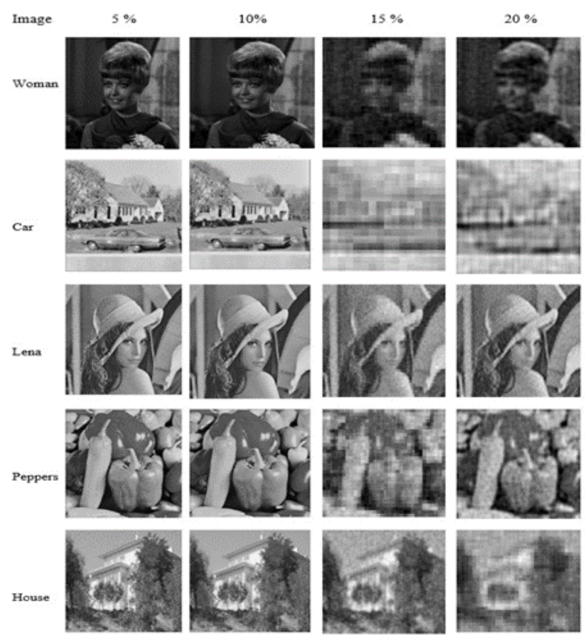

Fig. 4. Compression of different images by different compression ratios.

Table 1. Average PSNR values of different images with different CR%.

Compression ratio	Images				
	Woman	Car	Lenna	Peppers	House
10 %	29.69	23.13	29.51	22.8	20.78
20 %	26.71	18.85	20.68	18.88	18.44
40 %	24.79	17.65	18.54	17.41	11
80 %	23.09	16.45	17.09	16.40	8.31

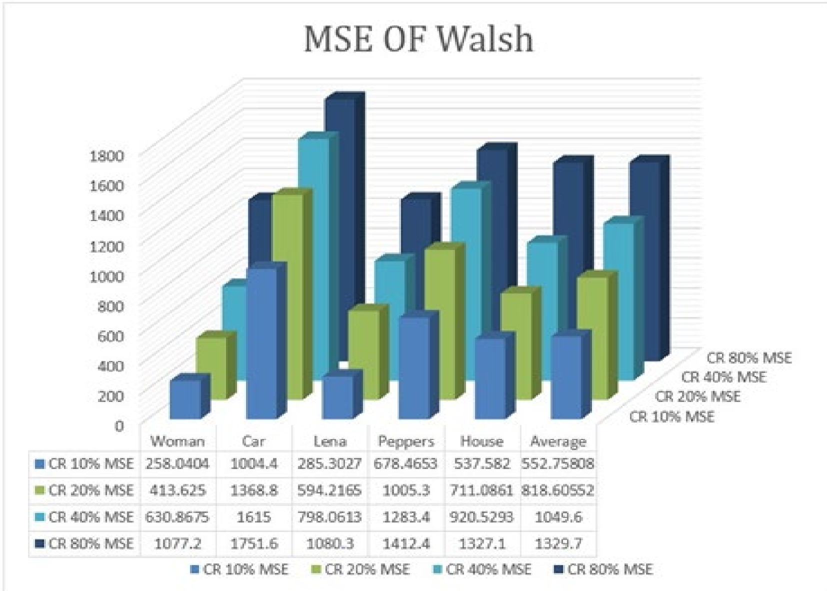

Fig. 5. Mean square error of compressed images by different CR%.

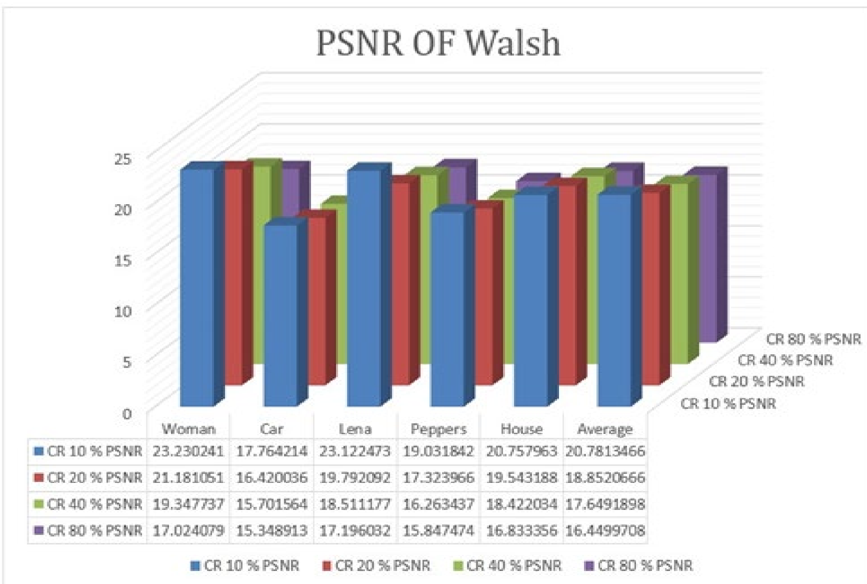

Fig. 6. PSNR of compressed images by different CR%.

5. CONCLUSION

For image compression purposes, the Walsh transform technique is preferred because it does not involve any multiplication or division operations only each pixel of the image is multiplied by one with simple addition and subtraction used to accomplish all calculations. Generally, the histogram of the 5% or 10 % compression ratio is uniformly distributed and better than the disrupted 15% or 20 % compression ratio. Therefore, the feasibility of the images is very clear and acceptable within both compression ratios of 5% and 10%. The Walsh transform technique was performed very well in image compression for different compression ratios by obtaining an average PSNR of 29.96%, 29.51% for both the woman and Lena images respectively and the minimum amount for the house image was 8.31 during 80% CR, because the MSE is increased especially when compression ratio was more than 10%.

Data Availability. Data underlying the results presented in this paper are available from the corresponding author upon reasonable request.

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Ethics. The authors declare that the present research work has fulfilled all relevant ethical guidelines required by COPE.

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