Content Based Face Image Retrieval in Walsh Hadamard Transform (WHT) Domain

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ABSTRACT

This paper investigates the problem of features selection, for Content Based Face Image Retrieval in Walsh Hadamard Transform (WHT) domain. The face image features extraction in the spectrum domain of natural and sequency order Walsh Hadamard Transform is analyzed. The coefficients of WHT contain integer values only, and the Hadamard transform is a very fast transform, it can be implemented using additions and subtractions operations only. Sheffield face database is used to evaluate the performance of different methods for constructing the feature vector. Euclidian and City Block distance measures are analyzed during this evaluation.

The investigation concludes that a proposed method of selecting small number of coefficients from first-row, first-column, and the diagonal, of the face image in WHT spectral domain, achieves high retrieval rate and less computational complexity for CBIR systems.

KEYWORDS

Face image retrieval, Content Based Image Retrieval (CBIR), Image retrieval in transform domain, Features selection for CBIR, Walsh Hadamard Transform (WHT).

1. INTRODUCTION

Face image retrieval is a process for finding a predefined number of images in a database that are similar to the query face image. Face image retrieval techniques can be used in applications such as *Crime prevention*, *Security Check*, *Medical Diagnosis*, etc. [1].

Content Based Image Retrieval (CBIR) methods can be assigned to one of two major approaches, spatial or transform domain techniques. Spatial domain techniques are mostly based on color, shape, or texture features that are extracted directly from images [2]. Transform domain methods utilize global information from images to perform image retrieval. The global information of an image is fundamentally represented by a small number of features derived from the spectrum of the image after transforming it from the special domain to the transform domain, using transforms such as Discrete Cosine Transform (DCT) [3,4], Discrete Wavelet Transform (DWT) [5,6], Contourlet Transform (CT) [7].

The retrieval efficiency and computational complexity are the main characteristics of CBIR systems. This paper investigates content based face-images retrieval using feature vectors obtained in WHT Transform domain. Different methods of features selection are also analyzed using City block and Euclidean distance measures.

Next section introduces Walsh Hadamard Transform (WHT) that will be used by the proposed features selection methods. Section3 presents the used face database. The experimental results are presented in section4.

2. FACE IMAGE RETRIEVAL IN WHT DOMAIN

To investigate face image retrieval, different features selection methods are utilized using WHT.

2.1. Walsh Hadamard Transform

The system of Walsh functions is the basis for Walsh transform. Walsh functions are orthogonal and have only +1 and -1 values [8]. In general, the Walsh transform can be generated by the Hadamard matrix as follows:

$$H_{2^k} = \begin{bmatrix} H_{2^{k-1}} & H_{2^{k-1}} \\ H_{2^{k-1}} & -H_{2^{k-1}} \end{bmatrix} \quad \begin{matrix} for\ \ k = 1,2,3,.... \\ H_1 = 1 \quad for\ \ k = 0 \end{matrix}$$

For k = 1, the 2 × 2 Hadamard matrix H_2 is defined by:

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

For k = 2, the 4 × 4 Hadamard matrix H_4 can be easily obtained using the formula:

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

The WHT was also used for face and signature recognition [8], because the output array of WHT coefficients contains integer values only, as a result Hadamard transform is a very fast transform, it can be implemented in ***O(N log₂ N)*** additions and subtractions.

In this research, we will proof that Walsh Hadamard transform can be used effectively in CBIR applications.

2.2. Natural and Sequency ordered WHT

By repeatedly applying the definition given above the 8 × 8 natural order Hadamard matrix is shown next.

$$H_8 = \begin{bmatrix} 1 & 1 & 1 & 1 & 1 & 1 & 1 & 1 \\ 1 & -1 & 1 & -1 & 1 & -1 & 1 & -1 \\ 1 & 1 & -1 & -1 & 1 & 1 & -1 & -1 \\ 1 & -1 & -1 & 1 & 1 & -1 & -1 & 1 \\ 1 & 1 & 1 & 1 & -1 & -1 & -1 & -1 \\ 1 & -1 & 1 & -1 & -1 & 1 & -1 & 1 \\ 1 & 1 & -1 & -1 & -1 & -1 & 1 & 1 \\ 1 & -1 & -1 & 1 & -1 & 1 & 1 & -1 \end{bmatrix} \quad \begin{matrix} \text{row} \\ 0 \\ 1 \\ 2 \\ 3 \\ 4 \\ 5 \\ 6 \\ 7 \end{matrix}$$

(matrix / row)

The sequency ordered Hadamard matrix is constructed by changing the row ordering of the above matrix, based on the number of sign changes in each row. The natural ordering is transformed into sequency order by reversing the bit order for the binary code (BC) of row index and then finding the Gray code (GC). An example of such transformation is given next:

BC (110) → Bit reversal (011) → GC (010)

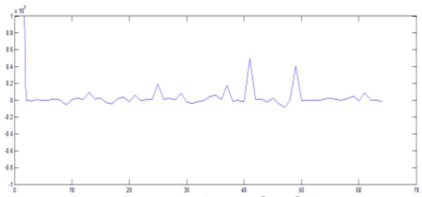
The 8 × 8 sequency order Hadamard matrix is given next.

$$Hs_8 = \begin{bmatrix} 1 & 1 & 1 & 1 & 1 & 1 & 1 & 1 \\ 1 & 1 & 1 & 1 & -1 & -1 & -1 & -1 \\ 1 & 1 & -1 & -1 & -1 & -1 & 1 & 1 \\ 1 & 1 & -1 & -1 & 1 & 1 & -1 & -1 \\ 1 & -1 & -1 & 1 & 1 & -1 & -1 & 1 \\ 1 & -1 & -1 & 1 & -1 & 1 & 1 & -1 \\ 1 & -1 & 1 & -1 & -1 & 1 & -1 & 1 \\ 1 & -1 & 1 & -1 & 1 & -1 & 1 & -1 \end{bmatrix} \quad \begin{matrix} \text{row} \\ 0 \\ 4 \\ 6 \\ 2 \\ 3 \\ 7 \\ 5 \\ 1 \end{matrix} \quad \begin{matrix} \text{Sign changes} \\ 0 \\ 1 \\ 2 \\ 3 \\ 4 \\ 5 \\ 6 \\ 7 \end{matrix}$$

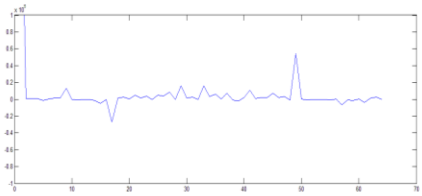
(matrix / row / Sign changes)

Using sequency order Hadamard matrix, the transformed data is ordered in increasing frequency which makes the process of feature selection systematic and fast. For the face image of size 64 x 64, given in Figure1, the signals representing first row, first column, and the diagonal of the spectrum obtained using natural order WHT are shown in Figure2a-c respectively. While the signals representing first row, first column, and the diagonal of the spectrum obtained using sequency order WHT are shown in Figure3a-c respectively. Figures 2 and 3 demonstrate clearly the compactness of the information at the first few spectral coefficients, of the first row, first column, and the diagonal when using the sequency order WHT.

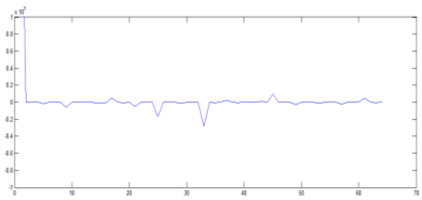
Figure1: Face image from Sheffield face database



a- First row (natural order)

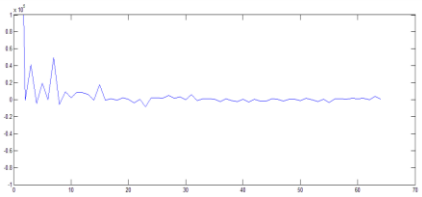


b- First column (natural order)

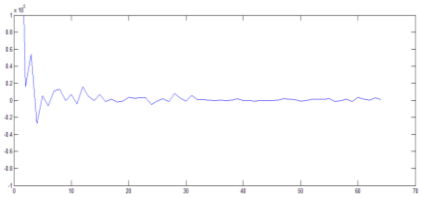


c- Diagonal (natural order)

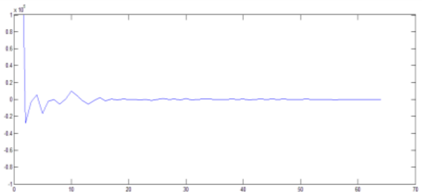
Figure2: Natural order WHT spectrum.



a- First row (sequency order)



b- First colum n (sequency order)

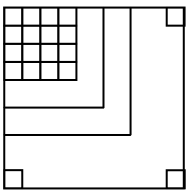


c- Diagonal (sequency order)

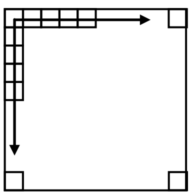
Figure3: Sequency order WHT spectrum.

2.3. Constructing the Feature Vector

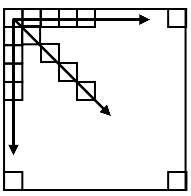
Features are, normally, extracted, starting from the upper left corner of WHT sequncy ordered spectrum in a block shape of size 4×4, 8×8, etc., as illustrated by Figure4a. In this research, features selection using different methods are analyzed. Figure4b,c,d show the proposed methods of selecting features from first-row-column, first-row-column-diagonal, first-row-column second-row-column etc. respectively.



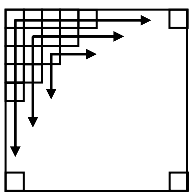
(a)



(b)



(c)



(d)

a- block shape
b- first-row-column
c- first-row-column-diagonal
d- first-row-column second-row-column etc

Figure4: Different methods of features selection.

3. FACE DATABASE

Sheffield (previously known as UMIST face database) [9] consists of 1012 images of 20 persons (subject), the images size is 220×220 pixels. These images are stored in Portable Gray Map (PGM) format. All these images are frontal, with little variations in pose, illumination, facial expressions, and accessories. Figure5 shows a sample from class *'h'* of these face images.

Figure5: Sample from class *h* Sheffield database.

To minimize execution time, for transforming images using WHT transform, the images are resized to 64×64 pixels as a preprocessing step.

4. EXPERIMENTAL RESULTS

Four experiments are carried out, the first shows the advantage of sequential order WHT over the natural order WHT, second experiment compares the proposed methods of feature extraction, the third experiment shows which of the distance measures, Euclidean or city block, is the most suitable distance measure to be used with the proposed methods. Fourth experiment concerns Retrieving a predefined percentage of the images that are in the same class as the query image.

For our analysis, each subject (with *N* images in the database), every image is considered as query image and the retrieval algorithm selects *N* images that have the smallest distance between their vector of coefficients and the vector of coefficients for the query image. Then the average retrieval rate is calculated.

First experiment: This experiment is carried out to show the effectiveness of sequential order WHT comparing with natural order WHT. In this experiment, several block sizes that are used to construct the feature vector from WHT spectrum are tested. For simplicity and speed of calculations, City block distance measure is used to find the similarity between images. Table1 shows the percentage of the correctly retrieved face images using Sheffield face database, Figure6 illustrates this results.

The results show clearly the advantages of using WHT sequency order for selecting features in transform domain, especially when the features vector consists of a very few features.

Table1: Average of retrieving all images in the class of the query image

Distance measure : City block			
Feature selector	**Block size**	**Natural order**	**Sequency order**
Top left corner block	2 x 2	25.489	47.319
	4 x 4	28.581	52.339
	8 x 8	36.290	54.658
	10 x 10	45.202	55.245
	12 x 12	45.668	54.923

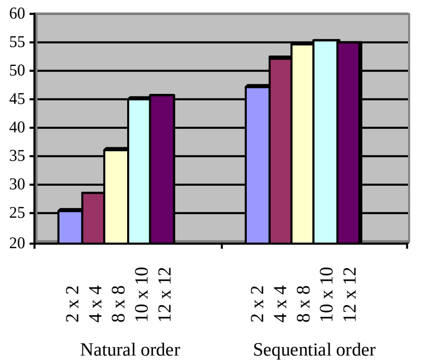


Figure6: Average of retrieving all images in the class of the query image

Second experiment: It concerns with the analysis of the proposed features selection methods. In this experiment, feature vectors are constructed using different numbers of features selected from sequncy ordered WHT spectrum, starting from upper left corner (DC value). The normally used "block shape" and the proposed methods of selecting features from "first-row-column", "first-row-column-diagonal", and "first-row-column second-row-column etc." are analyzed. The percentage of correctly retrieved face images are given in Table2, and Figure7, using city block distance measure.

Table2 Correctly retrieved face images

Distance measure : City block			
Feature selector	**Selected features**	**Total No of features**	**Sequency order**
First Row-column	8-8	**15**	**56.17**
	16-16	**31**	**58.68**
	24-24	**47**	**58.95**
	32-32	**63**	**59.05**
	48-48	**95**	**59.06**
	64-64	**127**	**59.13**
First Row-column and diagonal	8-8-8	**22**	**57.08**
	16-16-16	**46**	**59.29**
	24-24-24	**70**	**59.49**
	32-32-32	**94**	**59.62**
	48-48-48	**142**	**59.54**
	64-64-64	**190**	**59.58**
Multi-row-column	32-32_ 16-16	**92**	**56.36**
	32-32_ 16-16_ 8-8	**103**	**57.12**
	32-32_ 16-16_ 8-8_ 4-4	**104**	**57.09**
Block shape	2 x 2	**4**	**47.32**
	4 x 4	**16**	**52.34**
	8 x 8	**64**	**54.66**
	10 x 10	**100**	**55.25**
	12 x 12	**144**	**54.92**

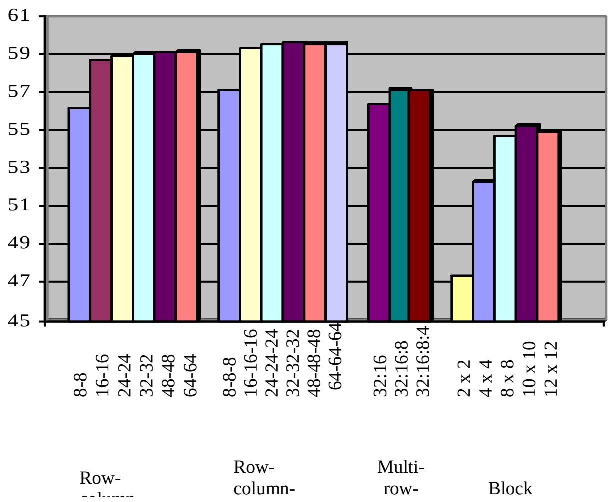


Figure7: Correctly retrieved face images

The results indicate the advantages of the proposed methods of selecting features from "first-row-column" and "first-row-column-diagonal". In addition to that, a feature vector consists of only 46 features taken from "first-row-column-diagonal" gives higher retrieval rate than any of the other three methods.

Third experiment: It is carried out to select the proper distance measure for calculating the similarity between face images. In this experiment, feature vectors are constructed from the spectrum of WHT sequency order, using the proposed methods of selecting features from "first-row-column", "first-row-column-diagonal". The City block and Euclidian distances measure are analyzed, and the percentage of correctly retrieved face images is given in Table3, and Figure8.

Table3: Analysis of image retrieval using Euclidian and city block distances measure

Transform type : WHT Sequential order			
Feature selector	**Selected features**	**Euclidean**	**City block**
First Row-column	8-8	**56.63**	**56.17**
	16-16	**58.35**	**58.68**
	24-24	**58.52**	**58.95**
	32-32	**58.63**	**59.05**
	48-48	**58.72**	**59.06**
	64-64	**58.82**	**59.13**
First Row-column and diagonal	8-8-8	**58.63**	**57.08**
	16-16-16	**60.21**	**59.29**
	24-24-24	**60.38**	**59.49**
	32-32-32	**60.45**	**59.62**
	48-48-48	**60.50**	**59.54**
	64-64-64	**60.54**	**59.58**

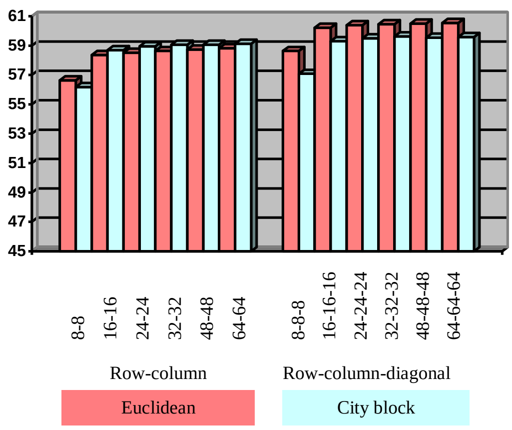


Figure8: Analysis of image retrieval using Euclidian and city block distances measure

The results indicate the advantages of using city block distance measure comparing with Euclidean measure, with respect to speed of calculations while improving or at least has similar (with ± 1%) retrieval rate.

Fourth experiment: In this experiment, for each subject (class of *N* images, for the same person, in the database), every image is considered as query image and the retrieval algorithm selects *N/5="20%"*, *N/3="33.3%"*, *2N/3="66.6%"*, *and N="100%"* images that have the smallest distance between their vector of coefficients and the vector of coefficients for the query image. The average retrieval rate is calculated. An example of such selections, if a class consists of 15 images, the retrieval system retrieves the first 3 images and finds how many of them are similar to the query image. And the same is done for retrieving the first 5, 10, and 15 images.
The CBIR performance using the proposed feature selection methods is compared, applying city block distance as similarity measures. The results of the average retrieval rate are given in Table4, when the number of top retrieved images from any class is considered as 1/5, 1/3, 2/3, and all relevant images of the total number of images in that class.

Table4: Retrieving a predefined percentage of the images in the class of the query image

Features Row-Col-Diag			Relevant images			
			20%	33.3%	66.6%	100%
8	8	0	97.59%	91.85%	71.13%	56.17%
16	16	0	98.25%	93.21%	73.97%	58.68%
32	32	0	98.14%	93.23%	74.57%	59.05%
64	64	0	97.89%	93.05%	74.51%	59.13%
8	8	8	98.10%	93.60%	72.92%	57.08%
16	16	16	98.34%	94.38%	75.52%	59.29%
32	32	32	98.21%	94.30%	75.70%	59.62%
64	64	64	98.20%	94.10%	75.64%	59.58%

The above table indicates that 20% of the relevant images are retrieved with an accuracy of 98.34% , when the feature vector is constructed using only 16 elements from the row, column, and diagonal (i.e. 1.12% of the total number of spectral coefficients) of the sequency ordered WHT of the face data base images. The same feature vector produces 94.38% of correctly obtained images, when 33.3% of the relevant images are retrieved. For retrieving all relevant images, the feature vector which is constructed by 32 elements from the row, column, and diagonal gives the best results (i.e. 59.62%).

5. CONCLUSION

The problem of features selection, for Content Based Face Image Retrieval in natural and sequency ordered Walsh Hadamard Transform (WHT) domain is investigated. The coefficients of WHT contain integer values only, and it is a very fast transform, it can be implemented using additions and subtractions operations only. Sheffield face database is used to evaluate the performance of different methods for constructing the feature vector. It is also shown that City Block distance measure gives results that are comparable with Euclidian distance measure, while it takes shorter execution time.

The investigation concludes that a proposed method of selecting small number of coefficients from first-row, first-column, and the diagonal, of the face image in the sequency ordered WHT spectral domain, achieves high retrieval rate and less computational complexity for CBIR systems.

6. ACKNOWLEDGEMENT

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