Walsh Transform over Row Mean and Column Mean using Image Fragmentation and Energy Compaction for Image Retrieval

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***Abstract*— Always the thrust for better and faster image retrieval techniques has nourished the research in content based image retrieval. The paper presents 32 novel image retrieval techniques using the feature vectors obtained by applying Walsh transform on row mean and column mean of full image, four fragments, sixteen fragments and 64 fragments of image. All the proposed CBIR techniques are tested on generic image database of size 1000 with 11 image classes. From the average precision and average recall values obtained by firing 55 queries on the image database it is found that use of row mean and column mean with image fragmentation improves the performance resulting in better image retrieval. In all these techniques to speed up the image retrieval process notion of energy compaction is introduced and tested for 100%, 95%, 90% and 85% of energy of feature vectors using Walsh transform.**

Keywords— CBIR, Walsh Transform, Row Mean, Column Mean, Image Fragmentation Energy Compaction.

I. INTRODUCTION

With the advancement in technology, a large amount of information in the form of images is being generated daily in various fields like architecture [15],[16], engineering designs [17], biometrics [8], satellite imagery [9],[14]. Also with the increasing capacity of the storage devices, the database of the image information is expanding allowing a huge amount of database images to be stored quite easily [1],[2],[3]. Even though storing these images is now easier, accessing or retrieving these images as per the requirement is a tedious job [4],[5]. Image retrieval has been an active topic for research for the past three decades [6],[10]. Visual content based image retrieval is a method which has proved effective over the contemporary text based image retrieval system [3],[7]. The main drawback of text based image retrieval system is subjectivity. The subjectivity in CBIR simply means that it varies from person to person. The image retrieved might be excellent for a person, but the same result might not be good enough for another [7],[11].

To overcome this difficulty content based image retrieval has proposed with a total change that, instead of retrieving the images using text keywords, they are retrieved based on the color [11],[12],[13] or shape [10]. Many techniques have been developed in this direction aiming to get images retrieved from the database more precisely [18],[19],[20],[21].

The paper uses Walsh transform [2],[19] along with the concept of image fragmentation [3] which has helped in increasing the performance of image retrieval. Further to speed up the process of image retrieval a novel technique of energy compaction is proposed to reduce the size of the feature vector.

Section II discusses Walsh transform. Section III gives Row Mean and Column Mean vector extraction from image. Concept of image fragmentation is elaborated in section IV. Energy compaction is explained in section V. Section VI discusses the proposed techniques and section VII discusses the implementation. Results are conversed in section VIII and conclusions are given in section IX.

II. WALSH TRANSFORM

Walsh transform matrix is defined as a set of N rows, denoted Wj, for j = 0, 1, ... , N - 1, which have the following properties:

- Wj takes on the values +1 and -1.
- Wj[0] = 1 for all j.
- $W_j x W_k^T = 0$, for $j \neq k$ and $W_j x W_k^T = N$, for j=k.
- Wj has exactly j zero crossings, for j = 0, 1, ..., N-1.
- Each row Wj is either even or odd with respect to its midpoint.

Walsh transform matrix is defined using a Hadamard matrix of order N. The Walsh transform matrix row is the row of the Hadamard matrix specified by the Walsh code index, which must be an integer in the range [0, ..., N - 1]. For the Walsh code index equal to an integer j, the respective Hadamard output code has exactly j zero crossings, for j = 0, 1, ... , N - 1.

For the full 2-Dimensional Walsh transform applied to image of size NxN, the number of additions required are $2N^2(N-1)$ and absolutely no multiplications are needed in Walsh transform .

III. ROW MEAN AND COLUMN MEAN VECTORS

If Fig.1 is representing the image with n rows and n columns, the row and column mean vectors [8], [22] for this image will be as given below.

Row Mean Vector =

[Avg(Row 1), Avg(Row 2), …., Avg(Row n)]

Column Mean Vector =
[Avg(Col. 1), Avg(Col. 2), …., Avg(Col. n)]

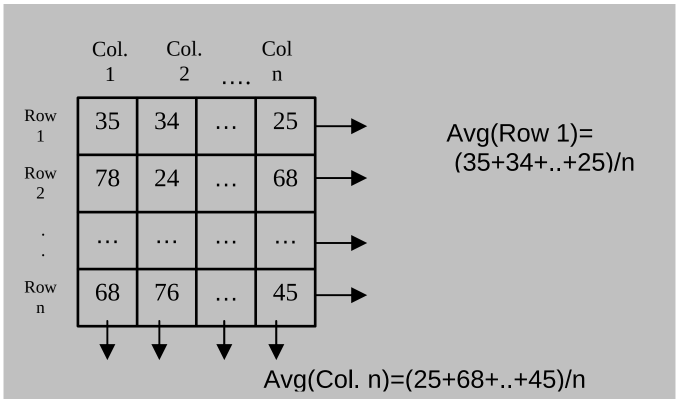


Figure 1. Sample Image Template (with size nxn) [8],[22]

A. *Row Mean Vector*

In this technique instead of taking the complete transformed image as a feature for image retrieval, only the row mean of the image is used. The Walsh transformed Row Mean is used as a feature to retrieve images from the database. The row mean vector is the set of averages of the intensity values of the respective rows.

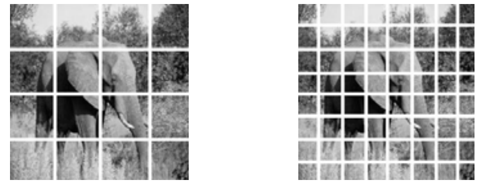
B. *Column Mean Vector*

This approach is similar to the row mean but here the column mean is used. The Walsh transformed column mean of the image is used as a feature vector to retrieve images from the database. The column mean vector is the set of averages of the intensity values of the respective columns. Using this approach also the average precision and recall is calculated by retrieving images in the same way as mentioned above.

IV. IMAGE FRAGMENTATION

Image fragmentation [3] means dividing any given image into non-overlapping cells or fragments. The size of each fragment is such that it divides the image into N equal parts and also keeping the size of each fragment the same. Here we have considered four, sixteen and sixty four non overlapping fragments as shown in figure 2. The size of feature vectors for respective number of fragments is shown in table I.

a. Single Fragments b. Four Fragments



c. Sixteen Fragments d. Sixty Four Fragments

Figure 2. Fragmentation of an image into single 4, 16 and 64 fragments respectively

TABLE I.
SIZE OF FEATURE VECTORS ACCORDING TO NUMBER OF FRAGMENTS

Fragments(size)→ Feature↓	**1x1**	**2x2**	**4x4**	**8x8**	**nxn**
Row Mean	1	4	16	64	n^2
Column Mean	1	4	16	64	n^2

V. ENERGY COMPACTION

Whenever any transform is applied to an image, the energy spectrum of the transformed image is such that the higher energy components are shifted to the higher side while the lower energy components are shifted to the lower side [18]. This has been used as a technique to reduce the feature vector size and simultaneously improve the precision and recall for image retrieval [18],[19].

The feature vector size for the row mean, column mean can be reduced by considering only a limited amount of energy percentage without lowering the performance of image retrieval. In this paper the new image retrieval techniques are proposed by using 85%, 90%, 95% and 100% energy coefficients. These percentage coefficients are obtained from the average energy compaction value. The average energy values can be obtained for each of the above specified feature vector techniques, by arranging them into a two dimensional array. Now, the average value feature vector is computed by adding corresponding values and dividing it by number of feature vectors. The number of feature vector used depends on the fragmentation technique used. Once the average vector is obtained, a transform is applied on it. By application of transform, the high frequency components are obtained at the higher side of the vector. We avoid the first DC coefficient in the process and adding the remaining cumulatively we can extract the number of coefficients to be considered for that respective energy percentage.

VI. PROPOSED TECHNIQUES

Total 32 novel image retrieval techniques are proposed by using Walsh transform with the concepts like energy compaction, row mean, column mean and image fragmentation. Walsh transform is implemented for the row mean and column mean of full image, four fragments, sixteen fragments and sixty four fragments. In each technique the energy of feature vector is considered as 100%, 95%, 90% and 85%. The list of proposed CBIR techniques is as follows.

For each 100%, 95%, 90%, and 85% energy coefficients

1. WALSH Full image Row Mean

2. WALSH Full image Column Mean
3. WALSH 4 fragments Row Mean
4. WALSH 4 fragments Column Mean
5. WALSH 16 fragments Row Mean
6. WALSH 16 fragments Column Mean
7. WALSH 64 fragments Row Mean
8. WALSH 64 fragments Column Mean

The table II shows the number of coefficients required for different energy compaction and the various fragmenting methods used to determine which fragmentation is best suited for gray image CBIR. As the % energy is reduced slightly the number of coefficients in each method reduce drastically, indicating lesser feature vector size and so faster image retrieval.

TABLE II.
SIZE OF FEATURE VECTORS ACCORDING TO FRAGMENTATION TECHNIQUE AND ENERGY PERCENTAGE WALSH TRANSFORM

Fragmentation Method and Feature Vector Technique	Per fragment Size of Feature vector for %				No.of Fragments (Multiplier)
	100 %	95 %	90 %	85 %	
Full Image Row Mean	256	27	14	9	1
Full Image Column Mean	256	40	21	14	1
4 Fragments Row Mean	128	27	7	6	4
4 Fragments Column Mean	128	29	15	14	4
16 Fragments Row Mean	64	18	11	7	16
16 Fragments Column Mean	64	24	14	10	16
64 Fragments Row Mean	32	14	9	6	64
64 Fragments Column Mean	32	15	11	7	64

VII. IMPLEMENTATION

The implementation of the three CBIR techniques is done in MATLAB 7.0. The CBIR techniques are tested on the image database of 1000 variable size images spread across 11 categories of human being, animals, natural scenery and manmade things. Sample images from each category are shown in Figure 3. To compare the techniques and to check their performance we have used the precision and recall. Total 55 (5 from each category of image database) queries are tested to get average precision and average recall of respective image retrieval techniques. The query and database image matching is done using Euclidian distance. The average precision and average recall are computed by grouping the number of retrieved images sorting them according to ascending values of Euclidian distances with the query image.

Figure 3. Sample images from the database having 11 categories, for a total of 1,000 images.

VIII. RESULTS AND DISCUSSION

The crossover point of precision and recall for the CBIR technique act as one of the important parameters to judge the performance [2],[18],[19]. For Walsh transform, using energy compaction, crossover plots of average precision and average recall for each fragmentation are computed and plotted against number of retrieved images. Cross over point for single fragment are shown in figure 4 and figure 5 and summed up in Table III. In row mean of full image 85% energy gives better performance as shown by higher crossover point (with a value of 0.33034) of average precision and average recall. In column mean of full image energy compaction is giving better results than 100 % energy, and in all 90 % energy is giving best results.

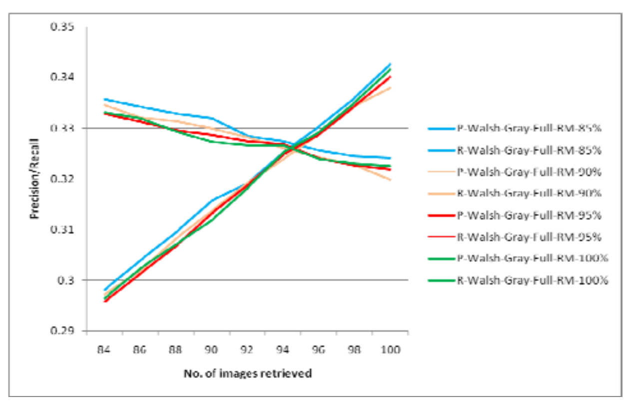


Figure 4. Cross over for Full image Walsh transform Row Mean Technique for 85%, 90%, 95%, 100%.

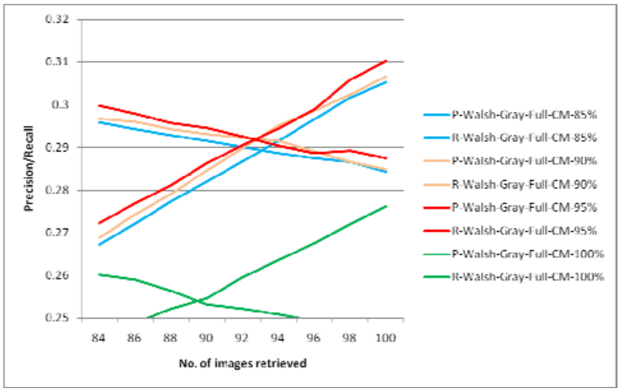


Figure 5. Cross over for Full image Walsh transform Column Mean Technique for 85%, 90%, 95%, 100%.

TABLE III

Walsh transform for full image (single fragment).

	WALSH Full Image		
	COEFF	***% ENERGY***	***VALUE***
ROW MEAN	9	85	0.33034
COLUMN MEAN	21	90	0.29511

Cross over points for 4 fragments are shown in figure 6 and figure 7. For the 4 fragments plot as shown in figure 6 for row mean it is observed that considering the entire energy that is 100% energy compaction, gives the best result at the crossover value of 0.33238. Also for column mean considering 95% enrgy compaction outperforms other crossovers as shown in Figure 7 at a value of 0.31387. The results of 4 fragments are summarized in table IV.

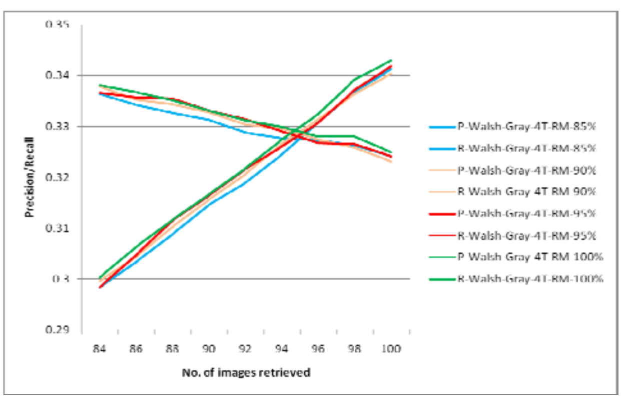


Figure 6. Cross over for 4 fragments Walsh transform Row Mean Technique for 85%, 90%, 95%, 100%.

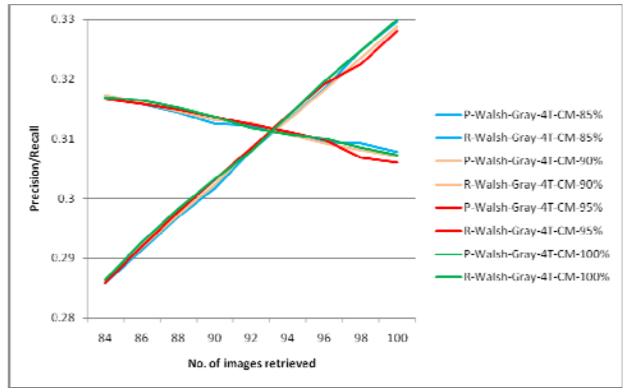


Figure 7. Cross over for 4 Fragments Walsh transform Column Mean Technique for 85%, 90%, 95%, 100%.

TABLE IV
Walsh transform for 4 fragments

	WALSH Transform 4 Fragments		
	COEFF	***% ENERGY***	***VALUE***
ROW MEAN	128	100	0.33238
COLUMN MEAN	29	95	0.31387

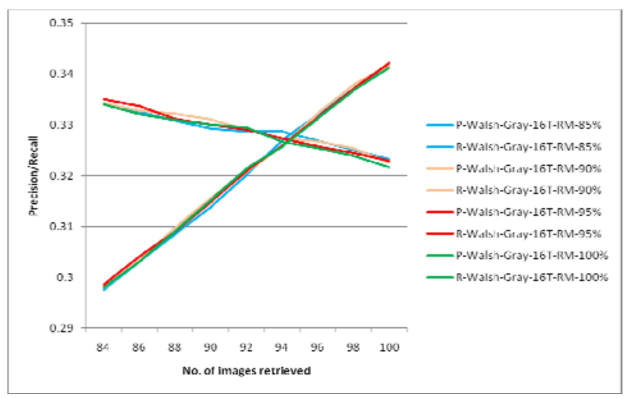


Figure 8. Cross over for 16 fragments Row Mean Technique for 85%, 90%, 95%, 100%.

Cross over for 16 fragments are shown in figure 8 and figure 9. It could be concluded from figure 8 that, for 16 fragments Row mean technique 85% energy compaction method outperforms other compaction techniques (with highest cross over point value 0.33205). However, the observation for 16 fragments Column Mean is different. As shown in figure 9, best performance is obtained by 95% energy with the obtained highest cross over value of 0.32542. The result is summarized in table V.

Figure 9. Cross over 16 fragments Column Mean Technique for 85%, 90%, 95%, 100%

TABLE V.

Walsh transform for 16 fragments

	WALSH Transform 16 Fragments		
	COEFF	*% ENERGY*	*VALUE*
ROW MEAN	7	85	0.33205
COLUMN MEAN	24	95	0.32542

Cross over for 64 fragments method for Walsh transform are shown in figure 10 and figure 11. As seen in figure 10, the crossover for 64 fragments row mean, 85% energy compaction is more efficient than other method with a crossover value of 0.32844. Similarly as seen in figure 11, the crossover for 64 fragments column mean, 85% energy compaction is more efficient than other method with a crossover value of 0.32734. The result of 64 fragments is tabulated as shown in table VI.

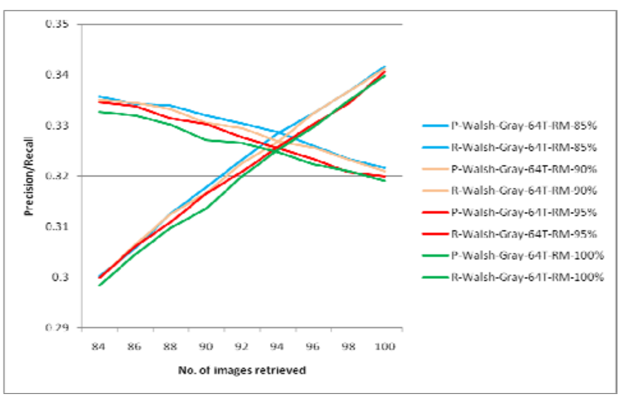


Figure 10. Cross over for 64 Fragments Walsh transform Row Mean Technique for 85%, 90%, 95%, 100%.

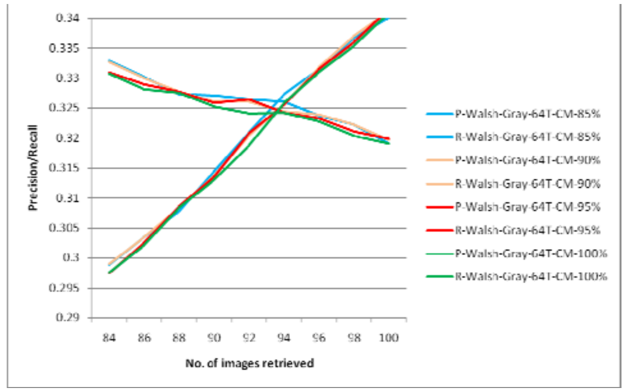


Figure 11. Cross over for 64 Fragmentss Walsh transform Column Mean Technique for 85%, 90%, 95%, 100%.

TABLE VI

Walsh transform for 64 fragments

	WALSH Transform 64 Fragments		
	COEFF	*% ENERGY*	*VALUE*
ROW MEAN	6	85	0.32844
COLUMN MEAN	7	85	0.32734

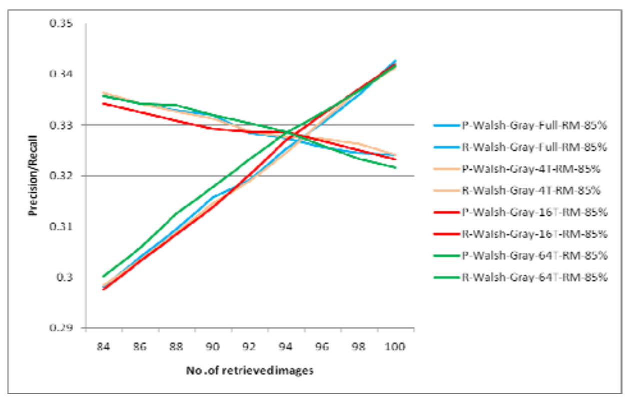


Figure 12. Cross over 85% Walsh transform Row Mean Technique for Full (1 fragment), 4 fragments, 16 fragments, 64 fragments.

Figure 13. Cross over 85% Walsh transform Column Mean Technique for Full (1 fragment), 4 fragments, 16 fragments, 64 fragments.

To determine which fragmentation is better, crossover plots for each energy compaction method are drawn. Following are Cross over plots for 85% energy Walsh transform as in figure 12 and figure 13. It is seen from figure 12 that for 85% energy compaction, for Walsh transform row mean, 64 fragments performs the best with a crossover value of 0.32844. Similarly for Walsh transform column mean, 64 fragments performs the best with a crossover value of 0.32734, while the full image performs worst.

Cross over plots for 90% Walsh transform energy is shown in following figure 14 and figure 15. Cross over for 90% Row mean Walsh transform in figure 14 clearly indicates 64 fragments technique is best performer for 90% energy. The highest cross over value obtained here is 0.32672. Other fragmentation techniques perform almost similarly. The cross over for 90% column mean Walsh transform shown in figure 15 indicates 64 fragments technique to be best with a value of 0.32569. Close to 64 Fragments, 16 Fragments technique also performs well. Single fragment and 4 fragments perform poorly.

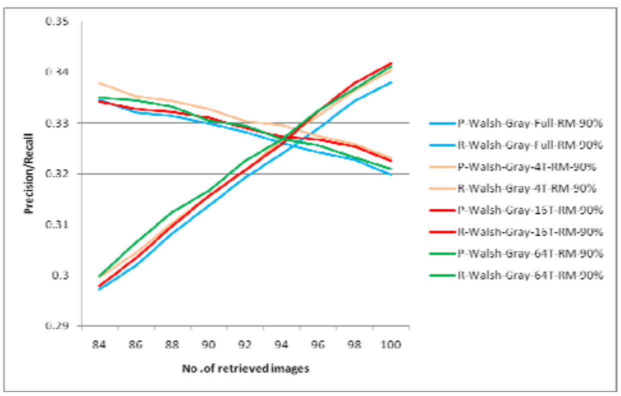


Figure 14. Cross over 90% Walsh transform Row Mean Technique for Full (1 fragment), 4 fragments, 16 fragments, 64 fragments.

Figure 15. Cross over 90% Walsh transform Column Mean Technique for Full (1 fragment), 4 fragments, 16 fragments, 64 fragments.

Figure 16 and figure 17 show the Cross over plots for 95% Walsh transform applied on row mean and column mean vector respectively for image retrieval. The best results for Walsh transform for 95% energy-Row mean are obtained for 16 fragments technique, as shown in figure 16. The highest cross over values obtained here is 0.3315. Next best results are obtained for 16 fragments and Full i.e., single fragment technique gives the poorest result. Figure 17 shows the cross over for 95% column mean. It indicates 64 fragments technique to be best giving highest cross over value 0.3559.

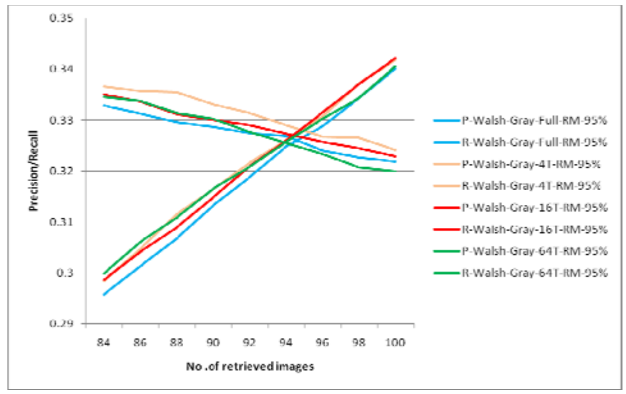


Figure 16. Cross over 95% Walsh transform Row Mean Technique for Full (1 fragment), 4 fragments, 16 fragments, 64 fragments.

Figure 17. Cross over 95% Walsh transform Column Mean Technique for Full (1 fragment), 4 fragments, 16 fragments, 64 fragments.

The observation from cross over plots discussed in section VII can be summarized as follows.

TABLE VII.
BEST FRAGMENTATION TECHNIQUE ACCORDING TO ENERGY PERCENTAGE AND FEATURE VECTOR

Energy Percentage and Feature Vector	Best Fragmentation Technique
85% RM	64 Fragments
85% CM	64 Fragments
90% RM	64 Fragments
90% CM	64 Fragments
95% RM	16 Fragments
95% CM	64 Fragments

IX. CONCLUSION

In this paper a novel technique of energy compaction on Walsh transform is used using Row Mean, Column mean, Image fragmentation. This technique of energy compaction helps in reducing the size of the feature vector drastically. It can also be noted that using less number of coefficients for the transform it increases the computational speed. An added advantage for Walsh transform is that the number of additions required are $2N^2(N-1)$ and absolutely no multiplications. So Walsh transform along with energy compaction reduces the computational time by a considerable amount.

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