Energy Compaction and Image Splitting for Image Retrieval using Kekre Transform over Row and Column Feature Vectors

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Summary
Success of image retrieval depends on performance and speed of the retrieval technique used. Many techniques have already been proposed for content based image retrieval, however, the thrust of better performance and faster retrieval is yet present. The paper proposes novel content based image retrieval techniques using row mean, column mean, energy compaction and image splitting. The 32 versions of proposed methods are tested for 55 queries on generic image database of size 1000images spread across 11 classes. With help of precision and recall the performance evaluation of proposed techniques shows that energy compaction gives better quality of retrieved results at much reduced time complexity. Image splitting also helps in improving the performance, more parts gives better retrieval.

Key words:
CBIR, Image Splitting, Energy Compaction, Kekre Transform, Row feature vector, Column feature vector.

1. Introduction

The requirement to find the relevant images from huge databases created due to recent technological developments in diversity of domains is the important field of research [1,4]. The need to find a desired image from a collection is shared by many professional groups, including journalists, design engineers [8,11,12], forensic experts [15] and art historians [23,24]. While the requirements of image users can vary considerably, it can be useful to characterize image queries into three levels of abstraction: primitive features such as colour or shape, logical features such as the identity of objects shown and abstract attributes such as the texture of image depicted [3,5,14,17,18,20]. Content-based image retrieval (CBIR) is a technique to retrieve images on the basis of image specific features such as colour [1,6,9,19,21], texture [2,10,13,16,18] and shape [4,7,22]. In CBIR, initially, features are computed for both stored and query images, and used to identify images most closely matching the query.

The paper considers methods for image retrieval by the use of feature vectors Row mean and Column mean [2,3,17]. The novel techniques of Image Splitting [1,2,3,21] and Energy Compaction [3] are introduced. By use of image splitting, higher precision and recall can be obtained. Energy compaction technique offers reduction in the feature vector size and hence reduction in computation complexity. The transform used is Kekre Transform [15,18], which is a very computationally light transform.

2. Kekre Transform

Kekre Transform matrix is the generic version of Kekre's LUV colour space [8,26,27,28,29] matrix. Kekre Transform matrix can be of any size NxN, which need not have to be in powers of 2 (as is the case with most of other transforms). All upper diagonal and diagonal values of Kekre's transform matrix are one, while the lower diagonal part except the values just below diagonal is zero. Generalized NxN Kekre Transform matrix can be given as...

$$K_{NxN} = \begin{bmatrix} 1 & 1 & 1 & .. & 1 & 1 \\ -N+1 & 1 & 1 & .. & 1 & 1 \\ 0 & -N+2 & 1 & .. & 1 & 1 \\ \vdots & \vdots & \vdots & \vdots & \vdots & \vdots \\ 0 & 0 & 0 & .. & 1 & 1 \\ 0 & 0 & 0 & .. & -N+(N-1) & 1 \end{bmatrix} \quad (1)$$

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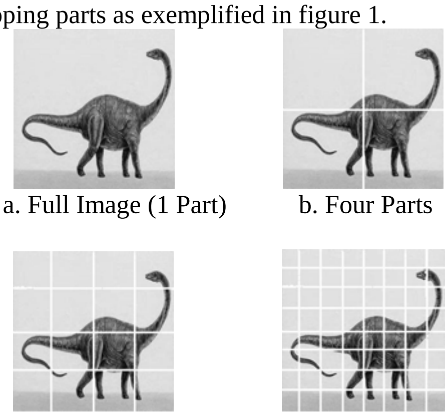
The formula for generating the term K_{xy} of Kekre Transform matrix is

$$K(x,y) = \begin{cases} 1 & ,x \le y \\ -N + (x-1) & ,x = y+1 \\ 0 & ,x > y+1 \end{cases} \qquad (2)$$

For taking Kekre Transform of an NxN image, the number of required multiplications are (N-1) and number of additions required are 2N(N-1).

3. Image Splitting

The image Splitting is the method of dividing the image into non overlapping parts. Then row mean and column mean of each part are obtained. After applying transform on these, feature sets can be obtained to be used in image retrieval. The paper considers 1, 4, 16 and 64 non overlapping parts as exemplified in figure 1.



a. Full Image (1 Part) b. Four Parts

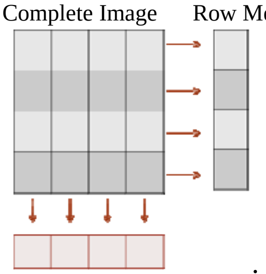
c. Sixteen Parts d. Sixty Four Parts

Figure. 1 Splitting of an image into 4 parts, 16 parts and 64 parts respectively

4. Feature Vectors

The row mean vector is the set of averages of the intensity values of the respective rows. The column mean vector is the set of averages of the intensity values of the respective columns. If figure 2 is representing the sample image with 4 rows and 4 columns, the row and column mean vectors for this image will be as given below.

Complete Image Row Mean



Column Mean

Figure. 2 Sample Image Template describing Row mean and Column Mean Feature Vector.

Kekre Transform can be applied to the row mean and column mean vectors of image to get Kekre Transform row mean and Kekre Transform column mean feature vectors respectively. The generated Kekre coefficients will be used as feature vectors of the image which can further be used for image retrieval. Thus, features of all images in the database are obtained and stored in feature vector tables for Kekre Transform row mean, Kekre Transform column mean.

I. Kekre Transform Row Mean Image Retrieval

Here, first the row mean of query image is obtained. Then, the Kekre Transform row mean feature vector of query image is obtained by applying Kekre Transform on row mean. For image retrieval using Kekre Transform row mean, these query image features are compared with Kekre Transform row mean features of image database by finding Euclidian distances using the formula given as equation 3.

$$ED = \sqrt{\sum_{i=1}^{n} (Vpi - Vqi)^2} \qquad (3)$$

These Euclidian distances are sorted in ascending order and result images are grouped together to get the precision and recall using the formulae as given below in equation 4 and equation 5.

$$\text{Precision} = \frac{Number\_of\_relevant\_images\_retrieved}{Total\_number\_of\_images\_retrieved} \qquad (4)$$

$$\text{Recall} = \frac{Number\_of\_relevant\_images\_retrieved}{Total\_number\_of\_relevent\_images\_in\_database} \qquad (5)$$

II. Kekre Transform Transform Column Mean Image Retrieval

Here first the column mean of query image is obtained. Then the Kekre Transform column mean feature vector of query image is obtained by applying Kekre Transform on column mean. For image retrieval using Kekre Transform column mean, these query image features are compared with Kekre Transform column mean features of image database by finding Euclidian distances using the formula given as equation 3. These Euclidian distances are sorted in ascending order and result images are grouped together to get the precision and recall using the formulae as mentioned above in equation 4 and equation 5.

5. Energy Compaction

Kekre Transform applied on an image transfers the high frequency components at the higher end and low frequency components towards lower side. This can be used as an advantage in image retrieval by eliminating the coefficients which do not contribute significantly. The energy compaction method therefore aids in reducing the feature vector size, which gives faster retrieval.

A. Average Energy Plot

Average Energy plot depicts the average energy compaction done by Kekre Transform on all the database images. The average energy plot can be obtained for each of the above specified feature vector techniques, i.e., row mean and column mean. Firstly, all the feature vectors are arranged 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 splitting technique used as explained in section 3. The database considered consists of 1000 generic images. Hence if single part technique is used, 1000 feature vectors, either row mean or column as per selection, are obtained. For 4 parts technique four features, one for each part, are obtained. Therefore, the two dimensional feature vector array will consist of 4000 vectors. Once the average vector is obtained, Kekre Transform is applied on it. By application of Kekre Transform, the high frequency components are obtained at the higher side of the vector. Further, its terms are squared to obtain positive values of energy. In the following subsections calculation of average value feature vector for row mean and column mean is discussed.

i. Row mean feature vector

Here, row mean is considered as the feature vector. Hence, the row means of all the parts of all the images in the database are arranged in a two dimensional array and average row mean is calculated. The size of row mean depends on the splitting technique used. For an image if size of row mean is N when 1 part method is used, the size of row mean is N/2 when 4 parts method is used and four such row mean vectors can be obtained per image. Now, Kekre Transform is applied to obtain transformed row mean vector.

ii. Column mean feature vector

In this method, column mean is considered as the feature vector. Hence, the column means of all the parts of all the images in the database are arranged in a two dimensional array and average column mean is calculated. The size and number of column means depends on the splitting technique as in case of row means. Now, Kekre Transform is applied to obtain transformed column mean vector. This vector depicts the values of the average energy plot for all images in the database considered together. Further, after calculation of the transformed average feature vector, the values are added to get a cumulative vector. The average energy plots for row mean and column mean on the splitting technique are shown in figure 3 to 8.

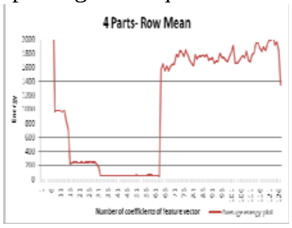


Fig. 3 Average Energy Plot for 4 Parts Row Mean Technique

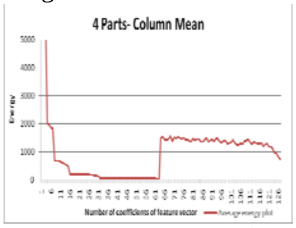


Fig. 4 Average Energy Plot for 4 Parts Column Mean Technique

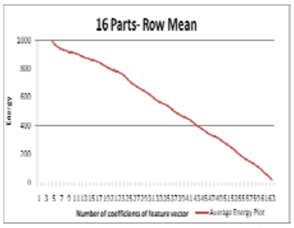


Fig. 5 Average Energy Plot for 16 Parts Row Mean Technique

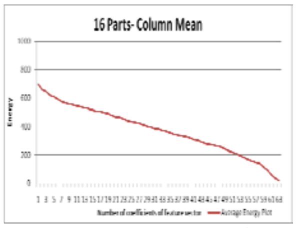


Fig. 6 Average Energy Plot for 16 Parts Column Mean Technique

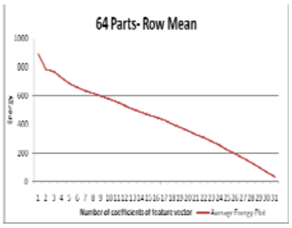


Fig. 7 Average Energy Plot for 64 Parts Row Mean Technique

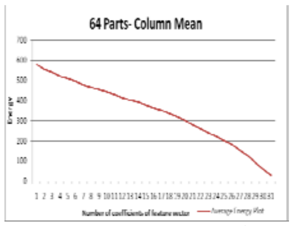


Fig. 8 Average Energy Plot for 64 Parts Column Mean Technique

The cumulative vector signifies the cumulative energy up to the considered feature vector coefficient. After obtaining the average energy vector, the energies are added cumulatively from first coefficient to the last coefficient of the feature vector. Therefore cumulative energy at the last coefficient denotes the total energy of the image. It is found that energy at the lower coefficients is very less and hence they do not add significantly to the cumulative energy vector. Therefore, as a result, the cumulative energy plot tends to become parallel to the X axis which denotes the number of coefficients of the feature vector, as shown in figure 9 to figure 14.

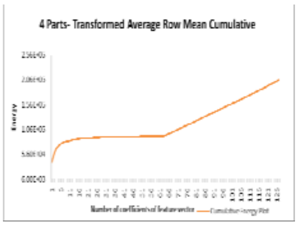


Fig. 9 Average Cumulative Energy Plot for 4 Parts Row Mean Technique

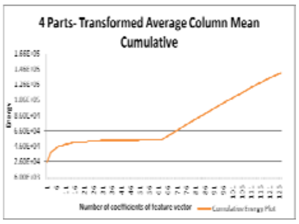


Fig. 10 Average Cumulative Energy Plot for 4 Parts Column Mean Technique

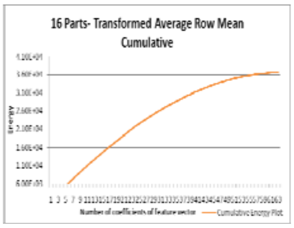


Fig. 11 Average Cumulative Energy Plot for 16 Parts Row Mean Technique

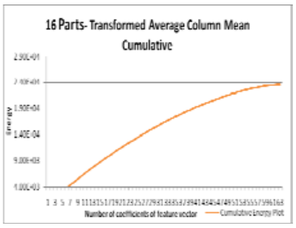


Fig. 12 Average Cumulative Energy Plot for 16 Parts Column Mean Technique

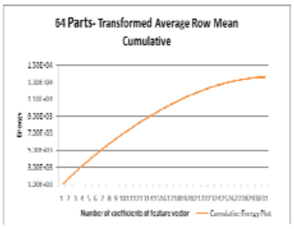


Fig. 13 Average Cumulative Energy Plot for 64 Parts Row Mean Technique

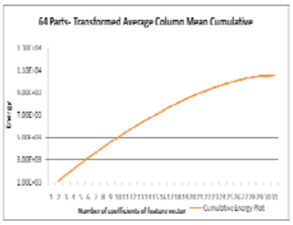


Fig. 14 Average Cumulative Energy Plot for 64 Parts Column Mean Technique

B. Compaction by use of Energy Percentage

The compaction of energy is done by considering percentages of total energy which is obtained from cumulative vector. The proposed method considers 100% energy, 95% energy, 90% energy, 85% energy. From the average energy plots a particular amount of energy is selected to determine the number of coefficients of the feature vector to be considered for image retrieval. As the percentage of energy considered is reduced, the number of coefficients required also drastically reduces, reducing the candidate feature vector size for image retrieval. Table II shows the number of coefficients required in each case.

6. Technique of Implementation

The implementation of the CBIR techniques is done in MATLAB 7.0. The CBIR techniques are tested on the image database of 1000 variable size gray scale images spread across 11 categories of human being, animals, natural scenery and manmade things. Sample images from each category are shown in figure 15.

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 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. 15 Sample Image Database of Grayscale Images

7. Results and Discussion

The crossover points of precision and recall of these CBIR techniques act as an important parameters to judge their performance [1,5,25]. Table I shows the number of coefficients of the feature vector in each case. To determine which splitting method is best suited for gray scale images CBIR cross over points for each of the splitting method are plotted. For each splitting technique and row mean or column mean the precision and recall values are obtained for energy 100%, 95%, 90% and 85%.

TABLE I
SIZE OF FEATURE VECTORS ACCORDING TO SPLITTING TECHNIQUE AND ENERGY PERCENTAGE

Splitting Method and Feature Vector Technique	Energy Percentage			
	100	**95**	**90**	**85**
Full Image Row mean	**256x1**	**249x1**	**244x1**	**241x1**
Full Image Column mean	**256x1**	**251x1**	**247x1**	**244x1**
4 Parts Row mean	**128x4**	**121x4**	**115x4**	**110x4**
4 Parts Column mean	**128x4**	**122x4**	**117x4**	**112x4**
16 Parts Row mean	**64x16**	**51x16**	**46x16**	**41x16**
16 Parts Column mean	**64x16**	**54x16**	**49x16**	**44x16**
64 Parts Row mean	**32x64**	**26x64**	**23x64**	**22x64**
64 Parts Column mean	**32x64**	**27x64**	**24x64**	**21x64**

To determine which energy compaction method is better, crossover plots for each splitting method are plotted. Figure 16 shows the crossover of precision and recall values of Full image-Row mean considered for different energy compactions. Highest cross over denotes best image retrieval performance, hence it could be concluded that, for Full image (1 Part) – Row mean technique 90% energy compaction method outperforms other compaction techniques, even 100%. This indicates that precision and recall obtained by using a size of row mean feature vector of 7 performs better than using feature vector size of 256. Thus the highest cross over for 1 part technique is 0.32576, when 90% energy is used for row mean.

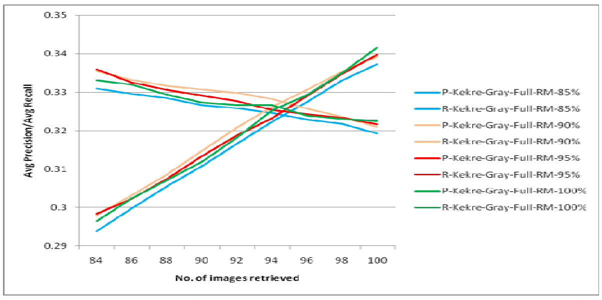


Figure. 16 Cross over for Full image (1 Part) Row Mean Technique for 85%, 90%, 95%, 100%.

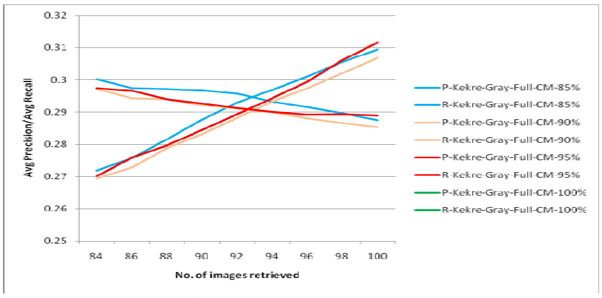


Figure. 17 Cross over for Full image (1 Part) Column Mean Technique for 85%, 90%, 95%, 100%.

However, the observation for Full image-Column Mean is different. As shown in figure 17, best performance is obtained by 85% energy. Hence column mean of 6 can be used for 1 part method to obtain highest cross over value of 0.29687. Cross over for 4 Parts method are shown in figure 18 and figure 19. As seen from the cross overs shown in figure 18, for 4 Parts Row mean technnique, 100% energy method proves to be best. Hence, highest cross over of 0.33238 is obtained. For 4 Parts column mean technique, as shown in figure 19, all energy compaction methods perform similarly and there is no significant difference in the higest cross over values.

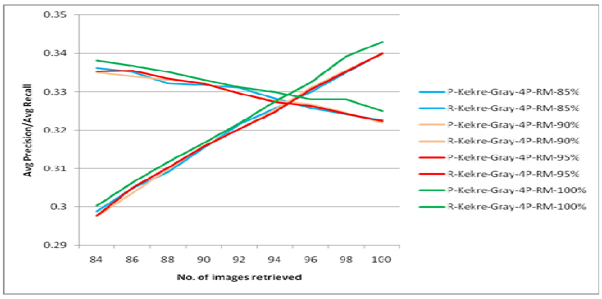


Figure. 18 Cross over for 4 Parts Row Mean Technique for 85%, 90%, 95%, 100%.

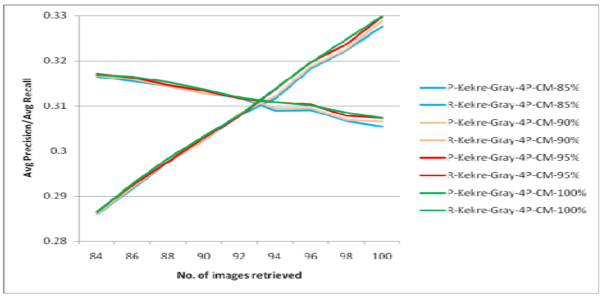


Figure. 19 Cross over for 4 Parts Column Mean Technique for 85%, 90%, 95%, 100%.

Cross over for 16 Parts method are shown in figure 20 and figure 21. From the cross over points shown in figure 20, it is observed that for 16 Parts Row mean technnique, 85% energy method performs marginally better than other energy compaction methods. From table II it is seen that only 5 coefficients are required for 16 parts-Row mean 85% energy method. Hence, highest cross over of 0.3338 by use of 44 coefficients instead of 64.

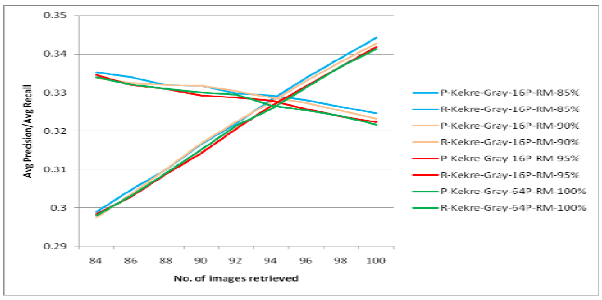


Figure. 20 Cross over for 16 Parts Row Mean Technique for 85%, 90%, 95%, 100%.

As shown in figure 21, for 16 Parts column mean technique 100% technique performs best. Cross over for 64 Parts method are shown in figure 22 and figure 23.

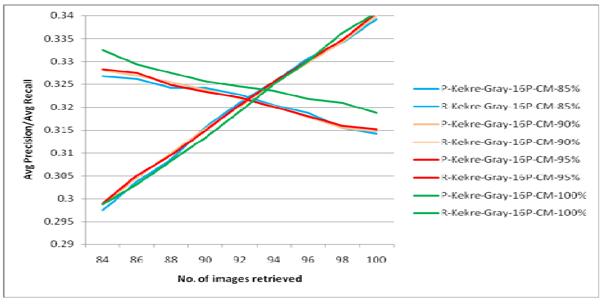


Figure. 21 Cross over 16 Parts Column Mean Technique for 85%, 90%, 95%, 100%.

For 64 Parts Row mean technique, figure 22, 85% energy method performs marginally better than other energy compaction methods. From table II it is seen that 22 coefficients are required for 64 parts-Row mean 85% energy method. Hence, highest cross over of 0.32867 by use of 22 coefficients instead of 32.

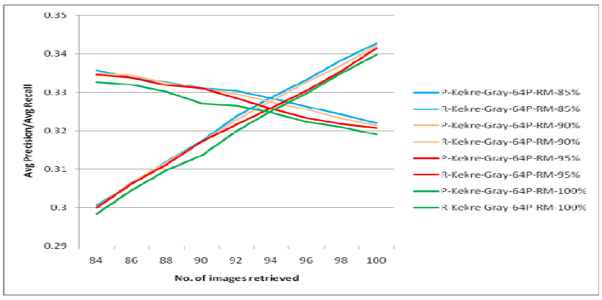


Figure. 22 Cross over for 64 Parts Row Mean Technique for 85%, 90%, 95%, 100%.

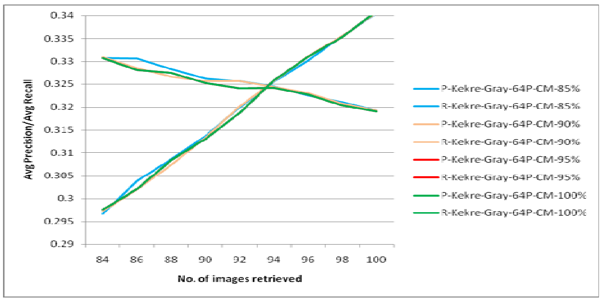


Figure. 23 Cross over 64 Parts Column Mean Technique for 85%, 90%, 95%, 100%.

It is seen in figure. 23 that similar to case in 4 Parts column mean technique, again for 64 Parts column mean technique all energy compaction methods perform similarly and there is no significant difference in the higest precision-recall values.

For determining which splitting method is better, crossover plots for each energy compaction method are drawn. The precision and recall cross over plots for 85% energy shown in figure 24 and figure 25.

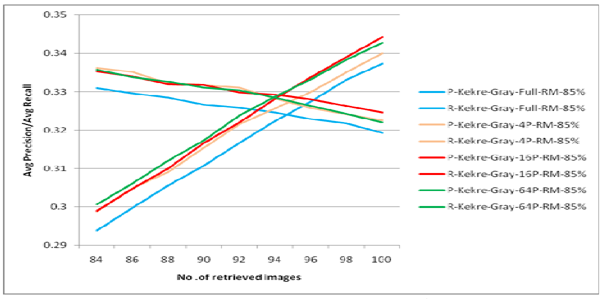


Figure. 24 Cross over 85% Row Mean Technique for Full (1 Part), 4 Parts, 16 Parts, 64 Parts.

It is observed from figure 24 that if 85% energy is used for row mean, 16 Parts technique performs best. The highest cross over is 0.33325. The next best performance is of 64 Parts technique and Full i.e., 1 Part technique gives least performance for 85% energy. As seen from Figure. 25, for 85% Column Mean, 64 Parts technique gives best performance. Closest to 64 Parts technique is 16 Parts technique. Performance of 1 Part and 4 Parts is quite low.

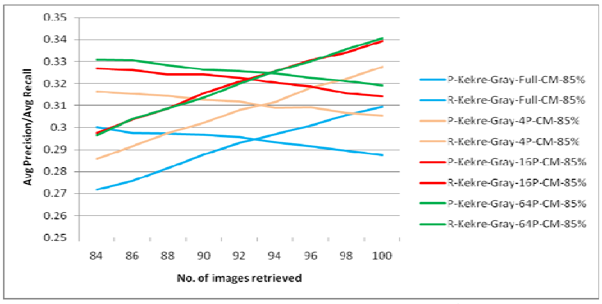


Figure. 25 Cross over 85% Column Mean Technique for Full (1 Part), 4 Parts, 16 Parts, 64 Parts.

Cross over points of precision and recall curves for 90% energy are shown in following figure 26 and figure 27.

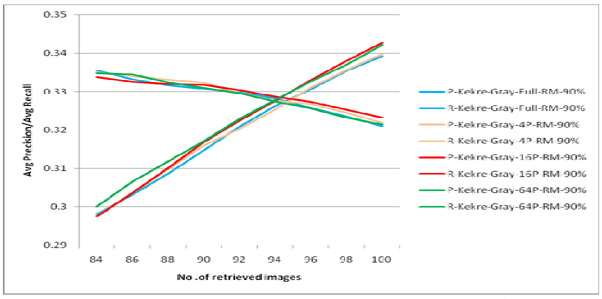


Figure. 26 Cross over 90% Row Mean Technique for Full (1 Part), 4 Parts, 16 Parts, 64 Parts.

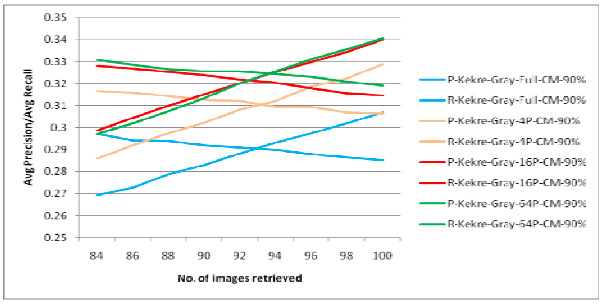


Figure. 27 Cross over 90% Column Mean Technique for Full (1 Part), 4 Parts, 16 Parts, 64 Parts.

Cross over for 90% Row mean in figure. 26 clearly indicates 16 parts technique performs well for 90% energy. The cross over for 90% column mean indicates 64 Parts technique to be best. This is similar to performance of 64 Parts technique in 85% energy method. Close to 64 Parts, 16 Parts technique also performs well. Again, 1 Part and 4 Parts perform poorly.

Figure 28 and figure 29 show the cross over point plots for 95% energy. The best results for 95% energy-Row mean are obtained for 16 Parts technique, as shown in figure 28. The highest crossover value obtained here is 0.33162. Figure 29 shows the cross over for 95% column mean. It indicates 64 Parts technique to be best giving highest cross over value 0.32582. This is similar to performance of 64 Parts technique in 85% and 90% energy methods. Again, 1 Part and 4 Parts perform poorly and along with 64 Parts, 16 Parts technique also gives good results.

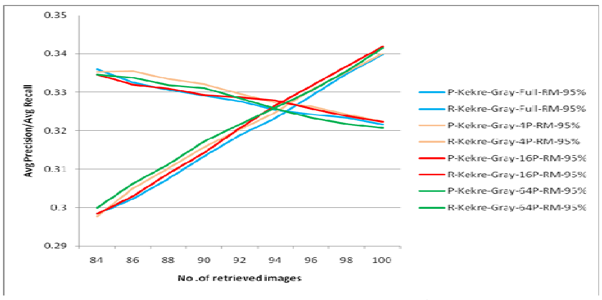


Figure. 28 Cross over 95% Row Mean Technique for Full (1 Part), 4 Parts, 16 Parts, 64 Parts.

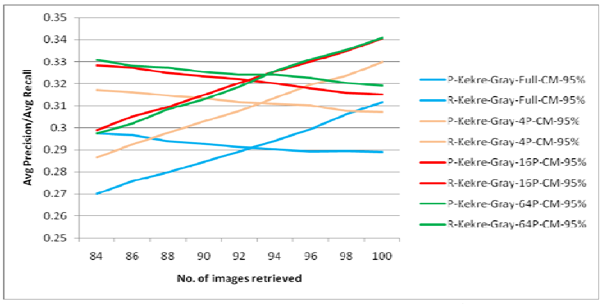


Figure. 29 Cross over 95% Column Mean Technique for Full (1 Part), 4 Parts, 16 Parts, 64 Parts.

The observation from cross over plots discussed in this section can be summarized as table II and table III.

TABLE II
BEST ENERGY PERCENTAGE ACCORDING TO SPLITTING METHOD AND FEATURE VECTOR TECHNIQUE

Splitting Method and Feature Vector Technique	**Best Energy Percentage**
Full Image Row mean	90%
Full Image Column mean	85%
4 Parts Row mean	100%
4 Parts Column mean	Any
16 Parts Row mean	85%
16 Parts Column mean	100%
64 Parts Row mean	85%
64 Parts Column mean	Any

TABLE I
BEST SPLITTING TECHNIQUE ACCORDING TO ENERGY PERCENTAGE AND FEATURE VECTOR

Energy Percentage and Feature Vector	Best Splitting Technique
85% RM	16 Part
85% CM	64 Parts
90% RM	16 Parts
90% CM	64 Parts
95% RM	16 Parts
95% CM	64 Parts

8. Conclusion

In the paper thirty two novel techniques of CBIR using Row Mean, Column mean, Image Splitting and Energy compaction are proposed. The proposed techniques aim to increase the precision and recall for image retrieval using feature vectors row mean and column mean along with image splitting and also reduce the computation complexity by reducing feature vector size by use of energy compaction. The splitting technique proves worth full, since, as the numbers of parts are increased higher precision and recall values are obtained at the cost of increased feature vector size. Further, by the use of energy compaction technique, unnecessary coefficients, which do not contribute to image retrieval, can be eliminated.

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