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Kekre Transform over Row Mean, Column Mean and Both Using Image Tiling for Image Retrieval

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***Abstract*—In this paper novel image retrieval techniques based on features extracted from Kekre transform applied on row mean, column mean and combination are presented. Further the concept of image tiling is added to these to get total of 26 novel CBIR techniques. Proposed image retrieval techniques are applied to image database of 1000 images spread across 11 categories. Experimentation shows that taking row mean, column mean and combination improves the performance of image retrieval as compared to taking Kekre Transform of full image. Also image tiling slightly helps in improving the image retrieval techniques.**

***Index Terms*—CBIR, Kekre Transform, Row Mean, Column Mean, Image Tiling.**

I. Introduction

The increasing popularity of image related applications and advancements in storage techniques have posed increasing technical challenges to computer systems to store/transmit and index/manage image data effectively to make such collections easily available. Most of the existing techniques are based on textual annotations which limit the searching capabilities and they hardly captured the intricate details of an image. Further these annotations are subjective, cumbersome and they do not give satisfactory results. So research on efficient image retrieval techniques has amassed prime importance in this exploding age[1].

This led to research on the lines of automatically extracting features of images for the purpose of efficient retrieval and sequencing of images which is referred as Content Based Image Retrieval (CBIR) [3],[4],[14]. Image retrieval is performed based on feature representations of the image, most commonly considered features being color, shape and texture[7],[18],[19].

CBIR technology is implemented in a host of different applications which include art galleries, museums, archaeology [4],[5], architecture/engineering design [6],[13], geographic information systems [2], weather forecast [7], medical imaging [7], trademark databases [8], criminal records [9], World Wide Web like photo sharing and video streaming sites[10].For pure statistics, PhotoBucket , a popular photo sharing website has 25 Million unique site visitors/month in the US, and over 46 Million unique site visitors/month worldwide[22].The application potential of CBIR for fast and effective image retrieval is enormous, expanding the use of computer technology to a management tool.

The goal of Content-Based Image Retrieval (CBIR) systems is to operate on collections of images and, in response to visual queries, extract relevant image. The typical CBIR system performs two major tasks [3],[12]. The first one is feature extraction (FE), where a set of features, called image signature or feature vector, is generated which describes the image stored in the library extensively. A feature vector is much smaller in size than the original image, typically of the order of hundreds of elements (rather than millions)[18],[19]. The second task is similarity measurement (SM), where a distance between the query image and each image in the database using their signatures is computed so that the most relevant images can be retrieved [3],[12].

In the paper four methods of image retrieval explored are as follows full Kekre Transform [14], Kekre Transform Row Mean, Kekre Transform Column Mean and Kekre Transform Row Mean Column Mean CBIR. Section II describes Kekre transform. Section III explains proposed CBIR techniques. Section IV gives implementation and section V elucidates results with discussion.

II. Kekre Transform

Kekre Transform[14] matrix is the generic version of Kekre's LUV color space matrix [6],[7],[10],[11]. 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...

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

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

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

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).

III. Proposed CBIR Techniques

Image retrieval mainly has two steps Feature Extraction and Query Execution. Mainly three different techniques are used here for image retrieval, which are listed below.

- Kekre Transform Row Mean,
- Kekre Transform Column Mean and
- Kekre Transform Combination.

Here first the row mean and column mean of an image are found and then discrete cosine transform is applied on them to get feature vectors of image for respective technique of image retrieval

Row Mean and Column Mean Extraction[21]

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 [5]. Figure 1 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.

Row Mean Vector =
[Avg(Row 1), Avg(Row 2), …., Avg(Row n)] (3)

Column Mean Vector =
[Avg(Col. 1), Avg(Col. 2), …., Avg(Col. n)] (4)

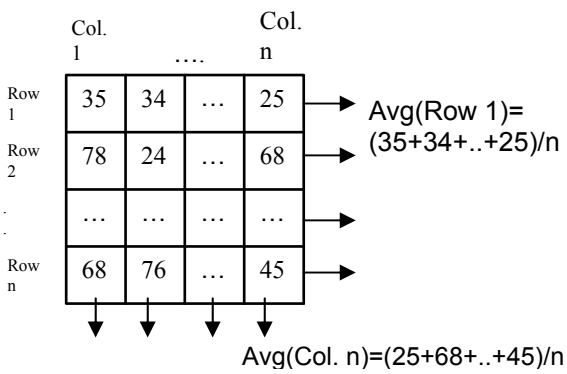


Fig. 1 Sample Image Template (with size nxn)

Feature Vector Extraction

The 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. For Kekre Transform combination, the Kekre Transform row mean and Kekre Transform column mean feature vectors are considered together. The generated Kekre Transform coefficients will be playing the role of 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 all three different image retrieval techniques, Kekre Transform row mean, Kekre Transform column mean and Kekre Transform combination.

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 5.

$$ED = \sqrt{\sum_{i=1}^{n} (Vpi - Vqi)^2} \quad (5)$$

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 6 and equation 7.

$$\Pr ecision = \frac{Number\_of\_relevant\_images\_retrieved}{Total\_number\_of\_images\_retrieved} \quad (6)$$

$$\operatorname{Re} call = \frac{Number\_of\_relevant\_images\_retrieved}{Total\_number\_of\_relevent\_images\_in\_database} \quad (7)$$

Kekre 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 5.

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 6 and equation 7.

Kekre Transform Combination Image Retrieval

Here both row mean and column mean of query image are obtained. Then the Kekre Transform row mean feature vector of query image is obtained by applying Kekre Transform on row mean and Kekre Transform column mean feature vector is obtained by applying Kekre Transform on column mean.

For image retrieval using Kekre Transform combination, both feature vectors are considered together for comparison

with database image features. The Euclidian distances are computed and precision and recall are found.

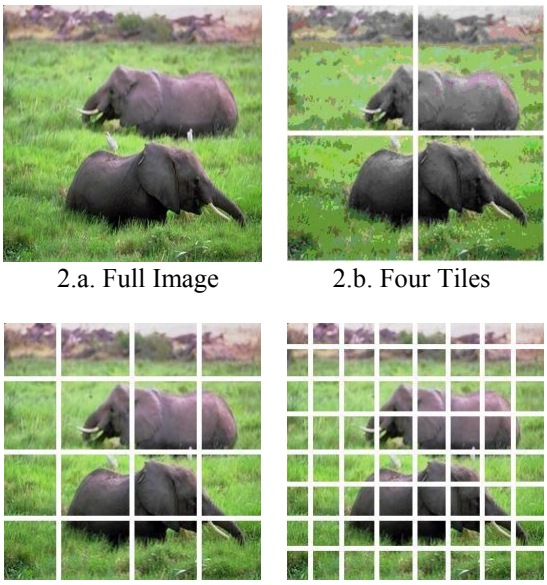
Image Tiling in CBIR

The image tiling deals with dividing the image into non overlapping parts. Then row mean and column mean of each tile is obtained. After applying transform on these, feature sets can be obtained to be used in image retrieval.

Here we have considered four, sixteen and sixty four non overlapping tiles as shown in figure 2. The size of feature vectors for respective number of tiles is shown in table I. In further discussion, we will also refer to tiles as quadrants.

TABLE I
SIZE OF FEATURE VECTORS ACCORDING TO NUMBER OF TILES

Tiles(size)→ Feature↓	**1x1**	**2x2**	**4x4**	**8x8**	**nxn**
Row Mean	1	4	16	64	n^2
Column Mean	1	4	16	64	n^2
Row-Column Combined	2	8	32	128	$2n^2$



2.a. Full Image 2.b. Four Tiles

2.c. Sixteen Tiles 2.d. Sixty Four Tiles

Fig. 2 Tiling of an image into 4, 16 and 64 tiles respectively

Proposed CBIR Techniques

After combining the row mean, column mean, combination and tiling concepts we can get total of 26 CBIR techniques, 13 for grayscale and 13 for color images. So the list of proposed CBIR techniques will be as follows..

i. Kekre Transform Complete Image CBIR
ii. Kekre Transform Row Mean CBIR
iii. Kekre Transform Column Mean CBIR
iv. Kekre Transform Combination (RMCM) CBIR
v. Kekre Transform Row Mean 4 tiles CBIR
vi. Kekre Transform Column Mean 4 tiles CBIR
vii. Kekre Transform Combination (RMCM) 4 tiles CBIR
viii. Kekre Transform Row Mean 16 tiles CBIR
ix. Kekre Transform Column Mean 16 tiles CBIR
x. Kekre Transform Combination (RMCM) 16 tiles CBIR
xi. Kekre Transform Row Mean 64 tiles CBIR
xii. Kekre Transform Column Mean 64 tiles CBIR
xiii. Kekre Transform Combination (RMCM) 64 tiles CBIR

IV. IMPLEMENTATION

The implementation of the three CBIR techniques is done in MATLAB 7.0. The CBIR techniques are tested on the image database [20] 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.

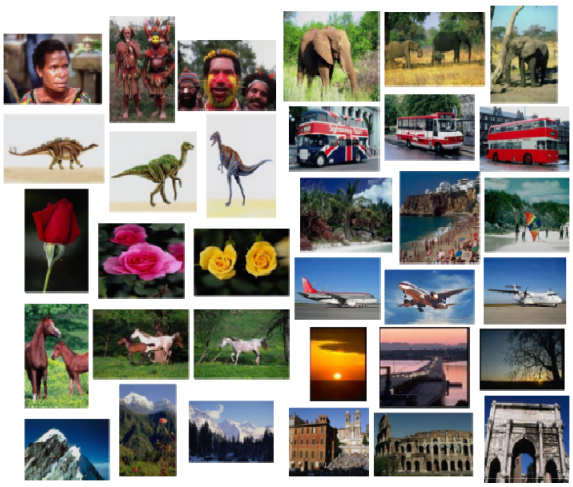


Fig. 3. Sample images from the database having 11 categories, for a total of 1,000 images.

V. RESULTS AND DISCUSSION

For testing the performance of each proposed CBIR technique, 55 queries (5 from each category) are fired on the database of 1000 variable size generic images spread across 11 categories for every proposed technique. 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. The crossover point of precision and recall of these CBIR techniques act as one of the important parameters to judge their performance [15],[17]. The tables given below show the values of crossover points for different CBIR techniques and the various tiling methods used to determine which tiling method is best suited for gray as well as color based CBIR.

TABLE II PRECISION RECALL CROSSOVER FOR GRAY BASED CBIR ACCORDING TO TILING DONE IN A CBIR TECHNIQUE

Precision-Recall Crossover Points Gray Based CBIR					
Row Mean (RM)		Column Mean (CM)		Combination (RMCM)	
Full	0.327	Full	0.301	Full	0.334
4 Tiles	0.329	4 Tiles	0.310	4 Tiles	0.327
16 Tiles	0.328	16 Tiles	0.323	16 Tiles	0.328
64 Tiles	0.324	64 Tiles	0.324	64 Tiles	0.321

TABLE III PRECISION RECALL CROSSOVER FOR COLOR BASED CBIR ACCORDING TO TILING DONE IN A CBIR TECHNIQUE

Precision-Recall Crossover Points Color Based CBIR					
Row Mean (RM)		Column Mean (CM)		Combination (RMCM)	
Full	0.401	Full	0.396	Full	0.403
4 Tiles	0.399	4 Tiles	0.402	4 Tiles	0.407
16 Tiles	0.401	16 Tiles	0.404	16 Tiles	0.409
64 Tiles	0.400	64 Tiles	0.399	64 Tiles	0.401

TABLE IV PRECISION RECALL CROSSOVER FOR GRAY BASED CBIR ACCORDING TO CBIR TECHNIQUE APPLIED IN TILED IMAGE

Precision-Recall Crossover Points Gray Based CBIR							
Full Image		4 Tiles		16 Tiles		64 Tiles	
Complete image	0.313	Complete image	0.316	Complete image	0.313	Complete image	0.313
RM	0.326	RM	0.328	RM	0.326	RM	0.325
CM	0.301	CM	0.310	CM	0.322	CM	0.324
RMCM	0.333	RMCM	0.313	RMCM	0.328	RMCM	0.321

TABLE V PRECISION RECALL CROSSOVER FOR COLOR BASED CBIR ACCORDING TO CBIR TECHNIQUE APPLIED IN TILED IMAGE

Precision-Recall Crossover Points Color Based CBIR							
Full Image		4 Tiles		16 Tiles		64 Tiles	
Complete image	0.384	Complete image	0.385	Complete image	0.385	Complete image	0.386
RM	0.402	RM	0.399	RM	0.400	RM	0.400
CM	0.396	CM	0.404	CM	0.403	CM	0.399
RMCM	0.402	RMCM	0.412	RMCM	0.409	RMCM	0.397

From table III, it can be inferred that dividing an image into 16 tiles gives a higher crossover value for Row Mean, Column Mean and Row Mean Column Mean Combined Color based CBIR techniques compared to others while from Table V we can state that Row Mean Column Mean Combined CBIR technique gives a higher value of crossover for any selected tiling method.

Figure 4 gives the crossover points of average precision and average recall values plotted against number of retrieved images for all Kekre Transform-Gray Row Mean based image retrieval techniques as Kekre Transform-Gray Row Mean Complete Image CBIR, Kekre Transform-Gray Row Mean 4 tiles CBIR, Kekre Transform-Gray Row Mean 16 tiles CBIR and Kekre Transform-Gray Row Mean 64 tiles CBIR. Here the 4 tiling technique gives the highest crossover point for precision and recall indicating best performance. Value of crossover for 16 tiles based CBIR and complete Row Mean based method overlaps but is below the crossover for four tiling method.

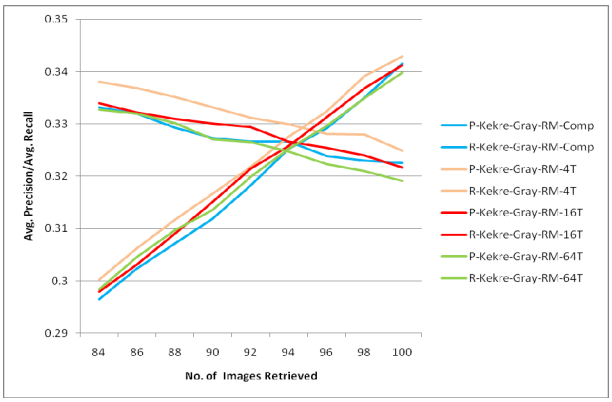


Fig. 4. Crossover Point of Precision and Recall Vs Number of Retrieved Images for Kekre Transform-Gray Row Mean based CBIR

Figure 5 shows the crossover points of average precision and average recall values plotted against number of retrieved images for all Kekre Transform-Gray Column Mean based image retrieval techniques as Kekre Transform-Gray Column Mean Complete Image CBIR, Kekre Transform-Gray Column Mean 4 tiles CBIR, Kekre Transform-Gray Column Mean 16 tiles CBIR and Kekre Transform-Gray Column Mean 64 tiles CBIR. Here the method with 64 tiles and 16 tiles gives the highest crossover point of precision and recall indicating best performance while 4 tiles based CBIR technique performs better than complete Column Mean based method.

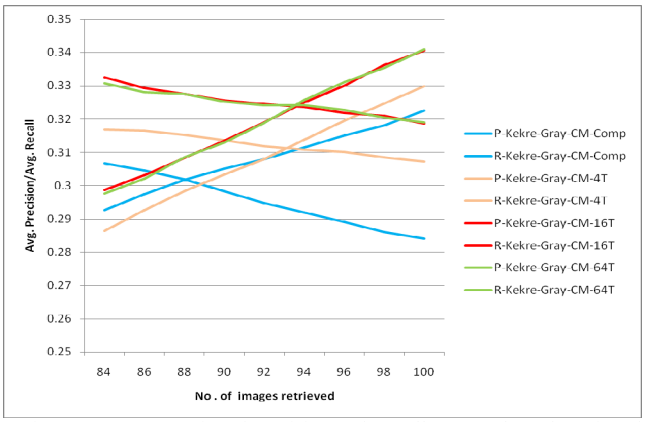


Fig. 5. Crossover Point of Precision and Recall Vs Number of Retrieved Images for Kekre Transform-Gray Column Mean based CBIR

Figure 6 gives the crossover points of average precision and average recall values plotted against number of retrieved images for all Kekre Transform-Gray Combined RMCM based image retrieval techniques as Kekre Transform-Gray Combined RMCM Complete Image,4 tiles,16 tiles and 64 tiles CBIR. Here the method with RMCM of complete image performs the best while the 4 tiling method gives the worst performance.

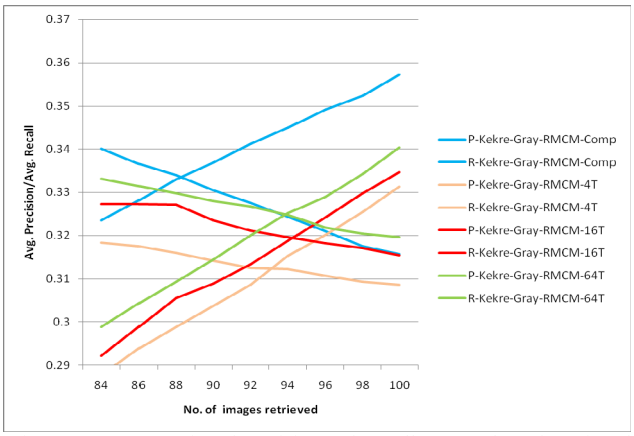


Fig. 6. Crossover Point of Precision and Recall Vs Number of Retrieved Images for Kekre Transform Combined Row Mean-Column Mean based CBIR

The crossover points of average precision and average recall values plotted against number of retrieved images for all Kekre Transform-Gray CBIR techniques applied on complete image are shown in figure 7. Here combination of row mean and column mean is performing better than row mean, column mean of Kekre Transform on full image based CBIR. The Row mean and Combination (RMCM) are outperforming the full image Kekre Transform based techniques, signifying the importance of taking Row mean and Column mean over direct Kekre Transform of complete image as feature vector in CBIR.

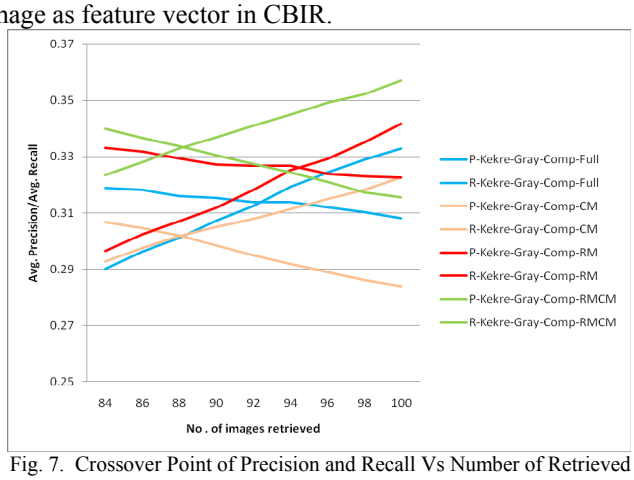


Fig. 7. Crossover Point of Precision and Recall Vs Number of Retrieved Images for Kekre Transform-Gray Complete Image based CBIR

The crossover points of average precision and average recall values plotted against number of retrieved images for all Kekre Transform-Gray CBIR techniques applied on 4 tiles of image are shown in figure 8. Here the row mean based CBIR is giving the best performance.

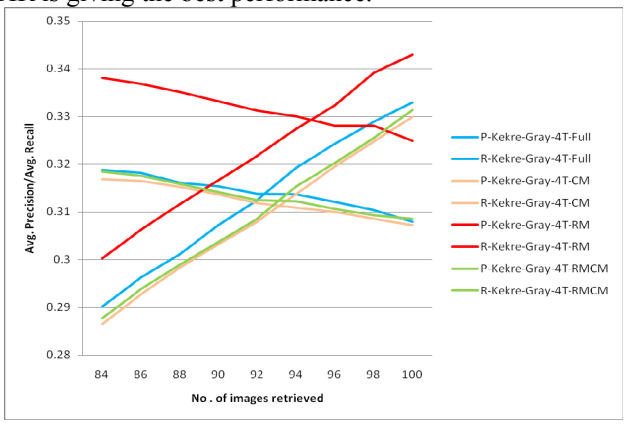


Fig. 8. Crossover Point of Precision and Recall Vs Number of Retrieved Images for Kekre Transform-4-tile based CBIR

Figure 9 shows, the crossover points of average precision and average recall values plotted against number of retrieved images for all Kekre Transform-Gray CBIR techniques applied on 16 tiles of image. Here the row mean CBIR is giving the best performance. The technique of Kekre Transform on all image data (Kekre Transform-Gray-16T-Full) is giving the worst performance, justifying the row mean based feature sets over full transform based in CBIR.

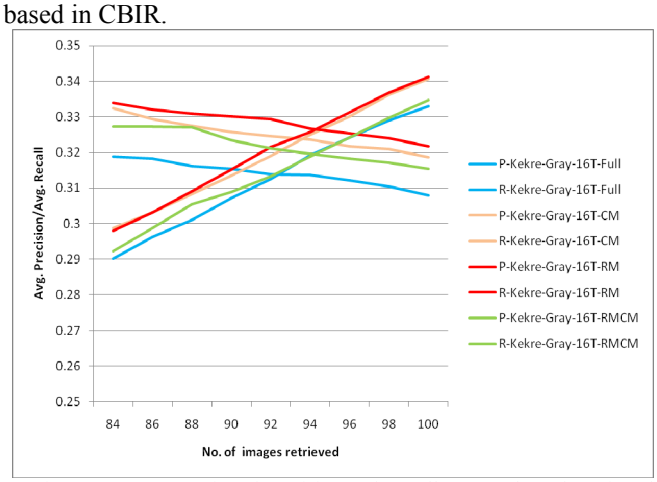


Fig. 9. Crossover Point of Precision and Recall Vs Number of Retrieved Images for Kekre Transform-16-tiles based CBIR

The crossover points of average precision and average recall values plotted against number of retrieved images for all Kekre Transform-Gray CBIR techniques applied on 64 tiles of image are shown in figure 10. Here the Row mean based CBIR and Row Mean Column Mean based CBIR give the best performance and have a negligible difference between their crossover values but is well above the value for the full technique.

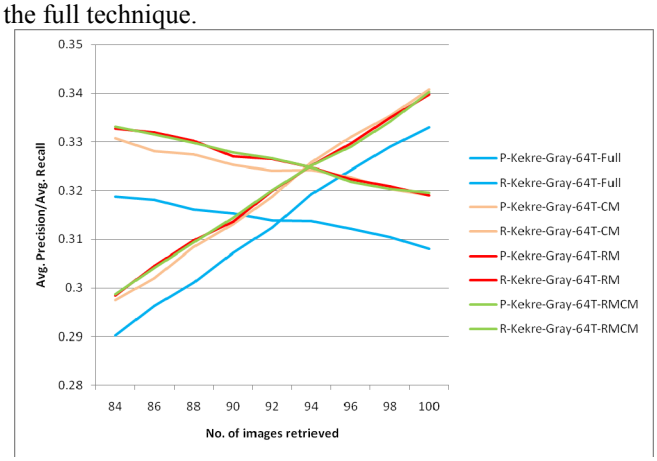


Fig. 10. Crossover Point of Precision and Recall Vs Number of Retrieved Images for Kekre Transform-64-tiles based CBIR

Figure 11 gives the crossover points of average precision and average recall values plotted against number of retrieved images for all Kekre Transform-Color Row Mean based image retrieval techniques as Kekre Transform-Color Row Mean Complete Image CBIR, Kekre Transform-Color Row Mean 4 tiles CBIR, Kekre Transform-Color Row Mean 16 tiles CBIR and Kekre Transform-Color Row Mean 64 tiles CBIR. Here complete image CBIR technique performs slightly better than 64 tiling and 16 tiling method both.

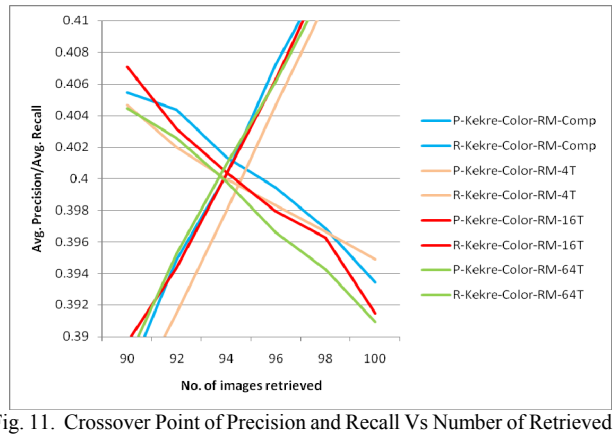


Fig. 11. Crossover Point of Precision and Recall Vs Number of Retrieved Images for Kekre Transform-Color Row Mean based CBIR

Figure 12 shows the crossover points of average precision and average recall values plotted against number of retrieved images for all Kekre Transform-Color Column Mean based image retrieval techniques as Kekre Transform-Color Column Mean Complete Image CBIR, Kekre Transform-Color Column Mean 4 tiles CBIR, Kekre Transform-Color Column Mean 16 tiles CBIR and Kekre Transform-Color Column Mean 64 tiles CBIR. Here the method with 16 tiles gives the highest crossover point of precision and recall showing best performance. Even 4 tiles based CBIR technique perform better than Complete Column Mean based method.

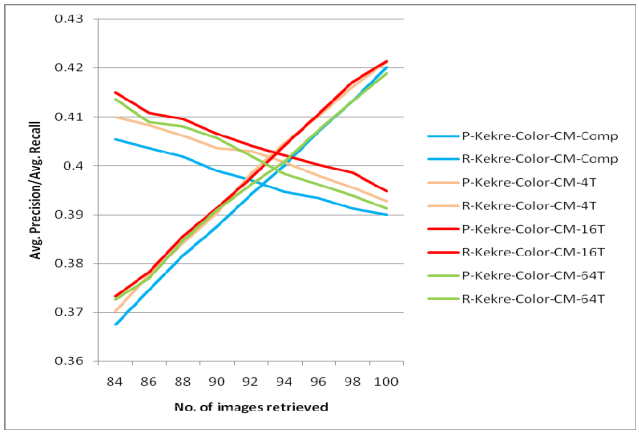


Fig. 12. Crossover Point of Precision and Recall Vs Number of Retrieved Images for Kekre Transform-Color Column Mean based CBIR

Figure 13 gives the crossover points of average precision and average recall values plotted against number of retrieved images for all Kekre Transform-Color Combined RMCM based image retrieval techniques as Kekre Transform-Color Combined RMCM Complete Image , 4 tiles , 16 tiles and 64 tiles CBIR. Here the method with RMCM of 16 tiles based CBIR is performing better than other proposed CBIR techniques.

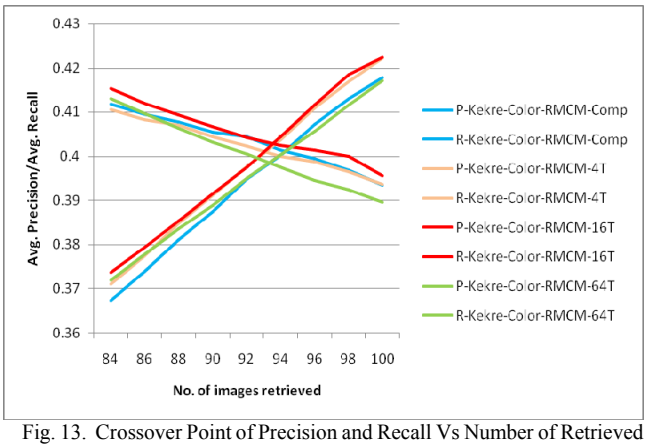


Fig. 13. Crossover Point of Precision and Recall Vs Number of Retrieved Images for Kekre Transform-Color Combined Row Mean-Column Mean based CBIR

The crossover points of average precision and average recall values plotted against number of retrieved images for all Kekre Transform-Color CBIR techniques applied on complete image are shown in figure 14. Here combination of row mean and column mean method and only row mean method are performing better than column mean method of Kekre Transform on full image based CBIR. The Row mean and Combination (RMCM) are outperforming the full image Kekre Transform based techniques, proving the worth of taking Row mean and Column mean over taking direct Kekre Transform of complete image as feature vector in CBIR.

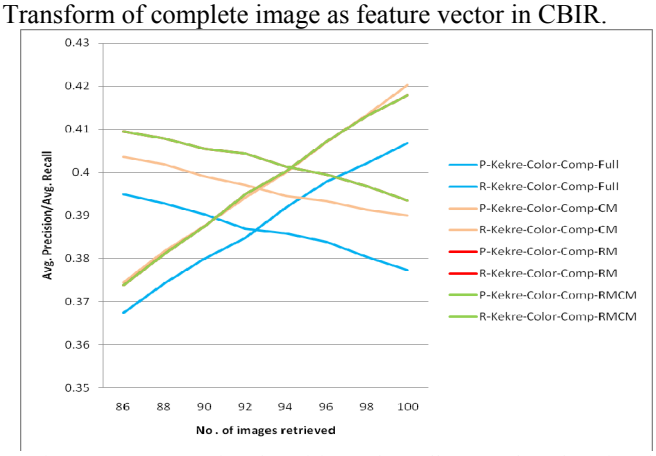


Fig. 14. Crossover Point of Precision and Recall Vs Number of Retrieved Images for Kekre Transform-Color-Complete Image based CBIR

The crossover points of average precision and average recall values plotted against number of retrieved images for all Kekre Transform-Color CBIR techniques applied on 4 tiles of image are shown in figure 15. Here the crossover for combination of row mean and column mean nearly overlaps with that of column mean method giving the best performance.

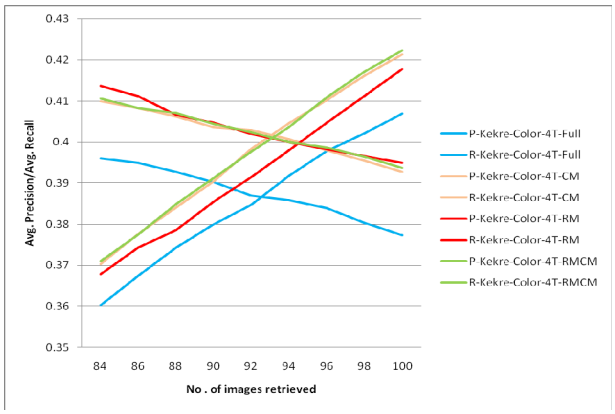


Fig. 15. Crossover Point of Precision and Recall Vs Number of Retrieved Images for Kekre Transform-Color-4-tiles based CBIR

Figure 16 shows, the crossover points of average precision and average recall values plotted against number of retrieved images for all Kekre Transform-Color CBIR techniques applied on 16 tiles of image. Here the combination of row mean and column mean based CBIR is giving the best performance but column mean and row mean methods perform reasonably well. The technique of Kekre Transform on all image data (Kekre Transform-Gray-16T-Full) is giving the worst performance, justifying the row mean and column mean based feature sets over full transform based in CBIR.

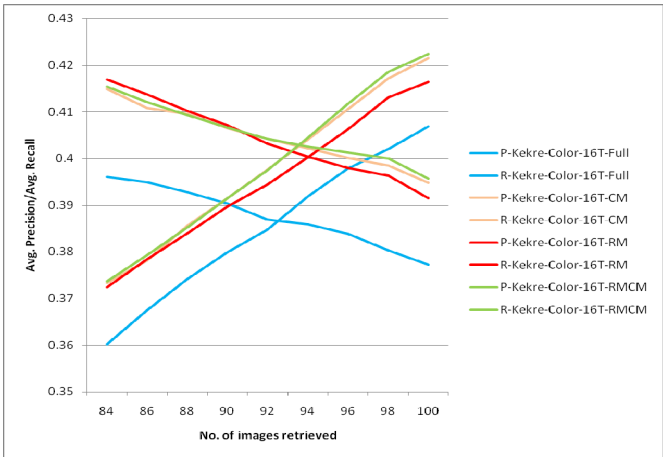


Fig. 16. Crossover Point of Precision and Recall Vs Number of Retrieved Images for Kekre Transform-Color-16-tiles based CBIR

Figure 17 shows the crossover points of average precision and average recall values plotted against number of retrieved images for all Kekre Transform-Color CBIR techniques applied on 64 tiles of image .We can deduce that row mean based CBIR technique is performing better. The other observation could be that the Kekre Transform-Color technique considering Full image is giving the worst performance, signifying that the row mean and column mean based techniques are better than considering full Kekre Transform coefficients as feature vector for CBIR.

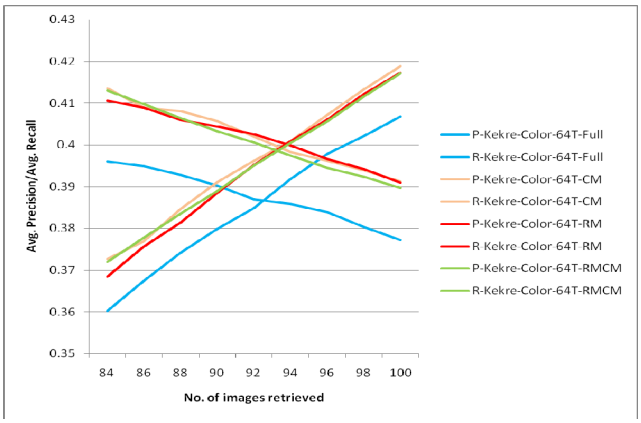


Fig. 17. Crossover Point of Precision and Recall Vs Number of Retrieved Images for Kekre Transform-Color-64-tiles based CBIR

VI. Conclusion

Content based image retrieval techniques based on row mean, column mean and combination of both have been proposed in the paper. The techniques were implemented and tested for 55 queries on image database with 1000 images spread across 11 categories. Experimental results have shown that forming feature vectors by applying Kekre Transform on row mean, column mean or combination improves the performance of image retrieval at less number of elements in feature set compared to taking Kekre Transform of full image. Among the proposed methods, row mean and column mean combination gives the best performance. Further the tiling concept is introduced to divide images in 4, 16 and 64 non overlapping parts. The extensive combinations of means of row-column and tiling are tested and it is observed that tiling marginally improves the performance of image retrieval but at the cost of increased feature set size. In general color based retrieval techniques are performing better than the gray image based image retrieval methods.

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