

Supervised Machine Learning of KFCG Algorithm and MBTC features for efficient classification of Image Database and CBIR Systems

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Abstract

A Content Based Image Retrieval System (CBIR) is proposed using features representing the images quite uniquely. Two algorithms have been used to extract two types of features from each of the images stored in the database. They are Modified Block Truncation Coding (MBTC) and Keri's Fast Codebook Generation (KFCG) algorithm. The features obtained from the images using the two algorithms represent each of them with unique and different values. KFCG algorithm forms a codebook containing codebook vectors. Codebook vectors are a set of code words used to encode the images. KFCG algorithm requires lesser time for vector quantization process. MBTC features can only represent images and hence useful for retrieval of images from database. MBTC features consist of upper and lower mean values of three colour components of colour space of pixels in the colour images. These features yield high performance for the CBIR system proposed in this paper. The images are analysed, compared and retrieved from the database using one of the two types of features. The analysis and comparison is also done using two different methods. Euclidean Distance is used to identify the image being enquired using two different types of features. Similarly, Support Vector Machine (SVM) is also used to obtain the result using two different types of features. SVM is implemented in two stages. First, the features are used to train the SVM variables. During training, some of the image features of different categories being utilized for training purpose are marked by users according to their categories. In the next stage, the SVM variables obtained during training are used to classify the images. A database of 1000 images of 10 different categories are used to perform assessment of the system. The system is implemented using MATLAB.

Keywords: CBIR; KFCG; MBTC; SVM; MATLAB.

INTRODUCTION

In the proposed system, images present in huge databases are retrieved on the basis of features such as color, texture and shape. The two types of features are obtained by using MBTC and KFCG algorithm. Supervised machine learning is involved with the features as obtained through algorithms mentioned above. Support Vector Machine (SVM) classifier is trained using these features, and then SVM classification is done based on variables obtained through training. The system is implemented using MATLAB. The implementation is performed in two stages – SVM Training and SVM

classification. During training, the feature vectors are marked by users as relevant or irrelevant images. Feature vectors corresponding to relevant images are determined by the category (class) of images to be trained and all others are marked as irrelevant. Once trained, training variables generated are used for classification of vectors. The vectors classified point to their respective images and hence classification is done. The images pointed by the classified feature vectors are sorted out in an output folder. The SVM using the features formed by the KFCG and MBTC features has yielded high precision and recall values. CBIR techniques involving MBTC features have resulted to highly efficient retrieval systems when used as stand-alone without SVM which generated the idea that if MBTC and KFCG features are used along with machine learning methods it can be a great potential and produces a highly efficient CBIR system and image database classification. This system gives higher crossover point as compared to other methods using features such as Gabor, MBTC or KFCG features alone without SVM classifiers.

It has been found that the methodology and algorithms used have proved to be much superior in results than the results shown by some existing works as mentioned in [43], [3].

Section III mentions about algorithms used to extract features and classification of features; Similarity measures used to rank the resulting images is mentioned in section in IV while formulae used to evaluation of results are discussed in section V; Section VI deals with the proposed CBIR system; Database used and obtained results are analyzed in detail in the section VII; Problems and challenges, conclusion, future scope and acknowledgement are mentioned in the sections VIII to XI respectively.

LITERATURE REVIEW AND RELATED WORK

Classification of Image Database and Content Based Image Retrieval (CBIR) has been utilized in the image libraries and search engines for correct and precise discrimination of images so that retrieval of exactly the same image can be done as enquired. Conventional methods employ manual indexing of image which is not time and cost efficient [11]. An active research is in progress in the field of machine learning and pattern recognition for automatic approach to these processes. Content based image retrieval systems based on information content of the images have shown good results and are able to retrieve the result closer to exactly the same image as enquired. Improvement in the performance became possible due to

utilization of content features of the images stored in the database. Many types of content based retrieval systems based on various techniques have been employed to perform indexing or retrieving images or videos from large databases but researchers' expectations are yet to be fulfilled [6]. Different methods have been tried too but still searches based on text content of the images or videos are being used [5]. A system using face detection method was developed for commercial use [15]. Even that performed badly in the video retrieval track [8], [16]. Retrieval systems based on comparison of low level features provided a big hope in the field of content based image retrieval systems. Low level features are obtained from image being searched from the database to get better results [6]. Additional information from the images can improve the results to obtain remarkable achievement which is evident from the system utilizing the color content to retrieve the enquired images [12].

The most widely used low level image features are the features obtained from the images using Gabor filters. They have already proved to be useful for image retrieval methods. MBTC features are used to represent color space of pixels in the color images [25], [33], [26]. Color features are obtained by calculating the Upper Mean and Lower Mean values. Another type of feature, Kekre's Fast Codebook Generation (KFCG) algorithm provides features from images using a unique method. KFCG features can also be used for distinguishing information efficiently from a large database of images. In fact, these features can become useful for very powerful tools to distinguish, identify and obtain the desired information from the huge databases. A set of code-words represents codebook vectors through a codebook which is used to encode as well as decode the images [42]. This algorithm is used for image compression. This algorithm takes lesser time to make codebook for vector quantization process.

Supervised machine learning can also be used with the features obtained through above mentioned algorithms. Support Vector Machine (SVM) classifier is trained using these features, and then SVM classifies the images based on variables obtained through training.

In supervised classification, collection of training images (labelled images) is given, and the problem is to label a newly encountered, yet unlabeled image. Each instance in the training set contains category or class specific labels and several image feature descriptors in the form of a feature vector extracted from images of the training set.

In supervised learning process, first step is to train the machine. While training, the images are labelled for the known categories of images [7]. During training, a semantic feature space is constructed, and a query semantic feature vector is constructed for each semantic category. Next step is to classify images using the support vector machine. The results are obtained by using the support vector machine with different kernels [7], [22]. An observation is made by the comparison of the results obtained through different kernels. However, linear kernel is suitable when number of features are large. Hence linear kernel has been used in the implementation of our CBIR system.

Since image features obtained through Gabor filters have been widely used in CBIR, they have also proved to be useful in the classification of images using SVM classifiers [11]. The features obtained through Gabor filters are used to train SVM for labeled images. Once the SVM classifier is trained, the features of unlabeled Images are applied to SVM classifier to classify images. Gabor filters have yielded acceptable results but when they are applied in SVM the results are better in the applications of face recognition [34], [39], analysis of facial expressions [35], object recognition [36], face detection [37], [38], finger print classification [40], texture classification[41] and classification of image database [11]. It has been observed that fusion of Gabor filters and MBTC based features have yielded better results in CBIR than Gabor filters alone [25]. This improvement [25] is mainly due to exploitation of color spaces in MBTC. If we obtain features of images based on MBTC and apply these features to train SVM classifiers and then use the trained SVM to classify images, the result thus obtained will be much better than that obtained using Gabor filters without SVM [43]. Modified Block Truncation Coding (MBTC) alone can also be used to extract features and then use these features for information search and retrieval.

EXTRATION OF IMAGE FEATURES AND CLASSIFICATION OF IMAGES

Texture features and color content of the images are most effective in the identification and classification of images from the database. Gabor features are largely used as texture features while color information of the image is represented by the color histogram [4].

Features representing color content of the images are generated using MBTC algorithm. MBTC is a modified BTC algorithm. The other feature that is exploited to represent the images uniquely is obtained using KFCG algorithm.

a. Extraction of features using BTC Algorithm

One of the image compression method is block truncation coding (BTC) [14]. The image is partitioned into smaller sub-images and BTC features are calculated for each block [17], [18]. BTC features represent the image very distinctively and therefore it provides better results for image retrieval purpose. If the three color components (red, green and blue) are considered as three different planes and each one of them is treated with BTC algorithm we get color content representation in the BTC algorithm [14]. The features thus obtained represent the color image distinctively and provides high retrievability. Following equations describe about the method to obtain the MBTC features.

- The average image is formed from the three different color components of red, green and blue as shown in (1)

$$I_{avg}(x, y) = I_R(x, y) + I_G(x, y) + I_B(x, y) \quad (1)$$

- A threshold value is calculated for each color component. The expression for red component is as shown in (2)

$$R_{threshold} = \frac{\sum_{r=0}^x \sum_{c=0}^y I_R(r, c)}{x * y} \quad (2)$$

- Based on the threshold value calculated in (2), a binary bitmap is created for all the three components. The expression for red component is as shown in (3)

$$R_{bm}(r, c) = \begin{cases} 1, & I_R(r, c) \geq R_{threshold} \\ 0, & otherwise \end{cases} \quad (3)$$

- A mean value m_1 and m_2 are calculated for each color component. Expression for the red component is as shown in (4) and (5).

$$m_{R1} = \frac{\sum_{r=0}^x \sum_{c=0}^y R_{bm}(r,c) I_R(r,c)}{\sum_{r=0}^x \sum_{c=0}^y R_{bm}(r,c)} \quad (4)$$

$$m_{R2} = \frac{\sum_{r=0}^x \sum_{c=0}^y (1-R_{bm}(r,c)) I_R(r,c)}{x * y - \sum_{r=0}^x \sum_{c=0}^y R_{bm}(r,c)} \quad (5)$$

$$m_1 = \{m_{R1}, m_{G1}, m_{B1}\} \text{ and } m_2 = \{m_{R2}, m_{G2}, m_{B2}\}$$

$M1$ and m_2 represent the entire block. Mean values of all the blocks considered together represent the entire image.

b. Features Extraction of KFCG

In vector quantization an image is divided into small blocks. Each smaller block is represented by the closest codeword formed by some bits [27]. The algorithm Linde-Buzo-Gray (LBG) is largely used to generate codebook [28]. In this algorithm, separated clusters are formed by training vectors found in the blocks. The codebook vector found closest to a training vector represents that vector [30]. Smaller blocks are formed by dividing them again and again. Each smaller block is associated to a cluster represented by their codebook vectors. Centroid of a cluster is its codebook vector [29]. The images are encoded and decoded by a collection of codewords known as codebook vectors [31]. KFCG algorithm is used for image compression [32] [23]. It is faster to generate the codebook by vector quantization method. The proposed system mentioned in this paper utilizes the codebook vector generated by KFCG algorithm as the feature vector for CBIR [20].

c. Features Classification using Support Vector Machine

An enhanced result is achieved by using the support vector machine (SVM) [11]. SVM can utilize the feature vectors representing images very efficiently for CBIR. Training of SVM is done by marking feature vectors from known classes of images. Unknown images from the database having features matching with features from images belonging to known classes are classified by the SVM.

SIMILARITY MEASURE

Using features representing the images to evaluate similarity among them has been proved to be most reliable and convenient [1]. The images from the database are ranked as per the similarity found between the features extracted from the query image and features extracted from images of the database [9] [10]. Since the features determine the ranking of the similarity, selection of the features is of utmost importance for similarity.

The most similar images are obtained by finding Euclidean distance between the query image and the images stored in the database. The Euclidean distance is measured between the feature vectors of the query image and the images from the database. The Euclidean distances obtained are sorted to find minimum distance among all leading to most similar image. Another way to obtain similar images is to use SVM. Images classified into one category by the SVM contain most similar images among them.

The expression to find Euclidean Distance between an enquired image q and an image d from database is given in (12)

$$\text{Euclidean Distance} = \sqrt{\sum_{n=1}^N (V_{dn} - V_{qn}) \cdot (V_{dn} - V_{qn})} \quad (12)$$

Where V_{dn} and V_{qn} are features representing images d from database and query image q respectively each of the size of N [20].

RESULT PARAMETERS

The evaluation of the CBIR system is done with two popular parameters [11]. Precision and Recall values are obtained as given in (13) and (14) [2].

$$\text{Recall} = \frac{DC}{DB} \quad (13)$$

$$\text{Precision} = \frac{DC}{DT} \quad (14)$$

DC = number of similar images detected correctly

DB = number of similar images in the database

DT = total number of detected images

CBIR SYSTEM PROPOSED

MBTC and KFCG features are used in the proposed CBIR system instead of more popular Gabor features [2]. The system is implemented and result is obtained using two different methods.

a) Without using SVM

Two types of features are obtained for all the images in the database using two different algorithms as mentioned in the

features extraction section. A feature vector, thus obtained represents a single image. A set of Feature vectors obtained using MBTC algorithm representing the image database is stored in a feature vectors directory. Similarly, another directory is also formed by the feature vectors generated using KFCG algorithm. This is offline processing of the database. Process flow of the proposed CBIR system is shown in Fig. 1 [20]. Segmentation of images is done by the algorithm itself to generate the features. For a query image, segmentation and feature extraction is done by using two different algorithms. The feature vectors, thus obtained are compared with the feature vectors representing the images stored in the database. The closest matching images are obtained according to the ranks sorted out from the minimum distance obtained between feature vectors representing the images of the database and the feature vector of the query image.

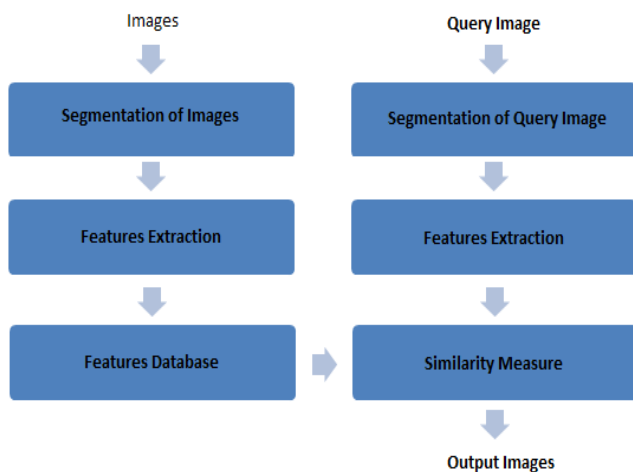


Figure 1. Proposed CBIR system

b) With SVM

As similar to the CBIR system without using SVM mentioned above each image is represented by two types of feature vectors obtained by two different algorithms. Feature vectors of the images of known category are marked manually to register them for those categories. The SVM is trained using feature vectors from images of the known categories. The SVM variables for different known categories generated by training the SVM are used for SVM classification of different categories of images. Feature vectors of the images from the unknown categories are used to classify the images using variables obtained by training of SVM. After classification, images of the unknown category are found in the output folder of the desired category.

The query image and all the other images of the same category is found in the output folder. This is a novel approach to retrieve an image. The query image is obtained from the output folder of that category after classification is done by the SVM. Fig. 2 shows the proposed CBIR system using SVM. During segmentation stage, the images are divided into sub-images of smaller size so that features can be obtained from those smaller sub-images. The features obtained are labelled for the known categories and then stored in the feature vectors database.

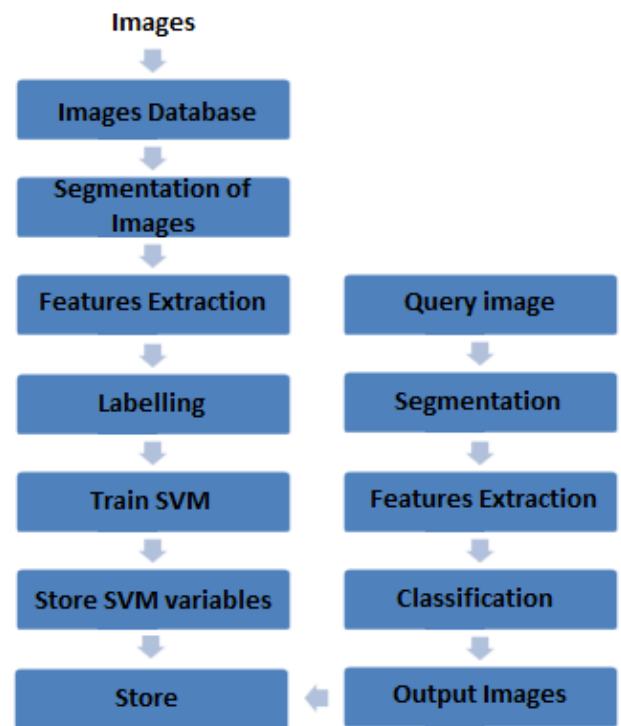


Figure 2. CBIR system using SVM

RESULTS

1) Database

The two techniques mentioned in the proposed system are applied to the database of 1000 images. The database consists of 10 different categories of 100 images each as shown in Fig. 3.

The output folder consists of images matching with the query image and sorted as per the rank assigned according to the Euclidean distance. The minimum Euclidean distance will represent image closest to the query image.

In the system using SVM, classification of images is done using SVM and the images closest to the query images are classified to the category of the image enquired.

2) Result Analysis

The result generated by the system is shown in the Fig. 4 to Fig. 9. They represent the best image retrieval results found for the shown categories from the 10 categories comprising the database. Though the result for other categories are also highly appreciable, the result is shown only for the four categories as mentioned in the charts for the best analysis. The results are obtained by the proposed CBIR system using the two methods as mentioned in section VI. Each method is implemented by using the two types of features mentioned in the section III.

The results shown in the charts are obtained by the system without using SVM based on MBTC and KFCG algorithm [24]. The comparison can be drawn among results obtained by using different categories, among results obtained through different

types of features and among the results obtained by the CBIR system being used with SVM and without SVM [21].



Figure 3. Sample image database of 1000 images with 10 categories

a) Result analysis of the CBIR system without using SVM

The results obtained by the system using different features and their comparison with respect to precision and recall values have been demonstrated in this section.

i) Results for images using MBTC features

Result in Fig. 4 shows comparison of precision values for given categories of images without using SVM with MBTC features whereas result in Fig. 5 shows comparison of recall values for given categories of images without using SVM with MBTC features.

ii) Results for images using KFCG features

Fig. 6 shows comparison of precision values for given categories of images without using SVM with KFCG features whereas result in Fig. 7 shows comparison of recall values for given categories of images without using SVM with KFCG features.

ii) Comparison of results using two different types of features

Result of Fig. 8 shows comparison of precision values for given categories of images without using SVM with two different features where Fig. 9 shows comparison of recall values for given categories of images without using SVM with different features.

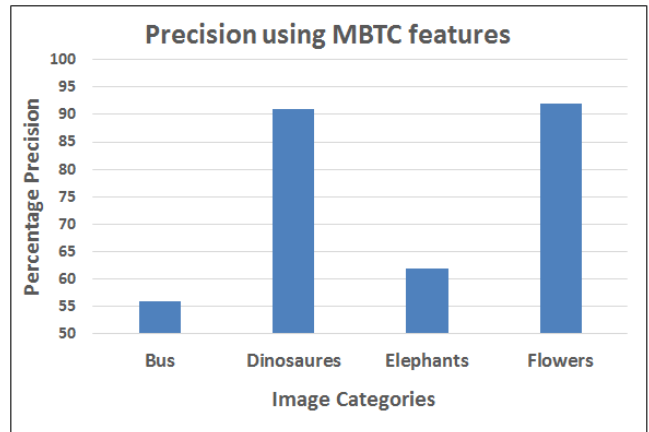


Figure 4. Precision values using MBTC features without SVM

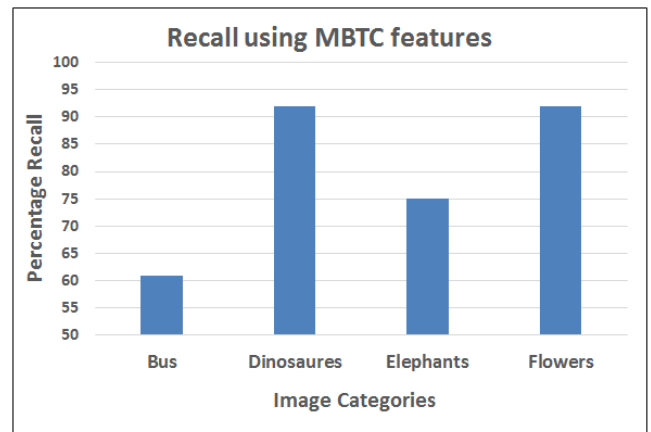


Figure 5. Recall values using MBTC features without SVM

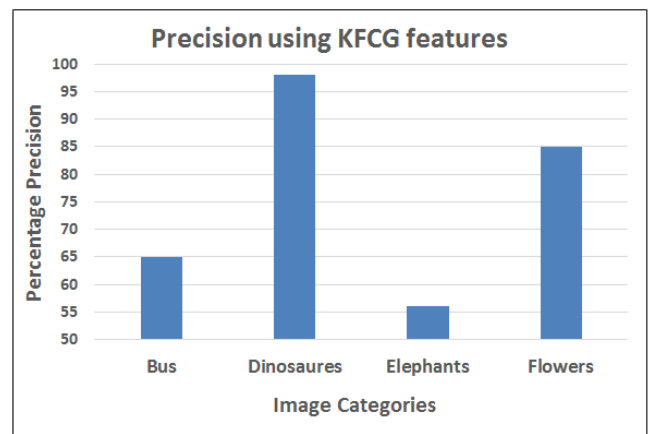


Figure 6. Precision values using KFCG features without SVM

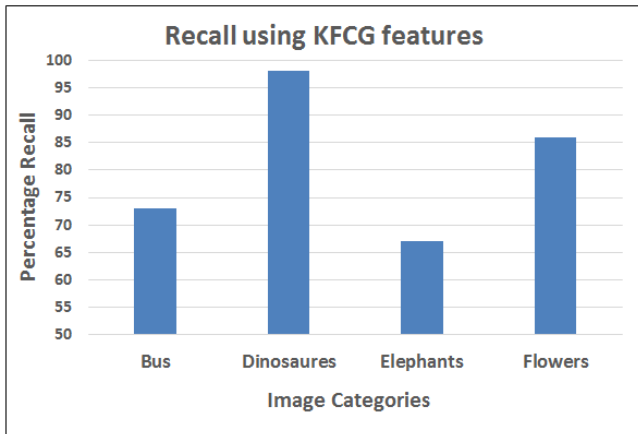


Figure 7. Recall values using KFCG features without SVM

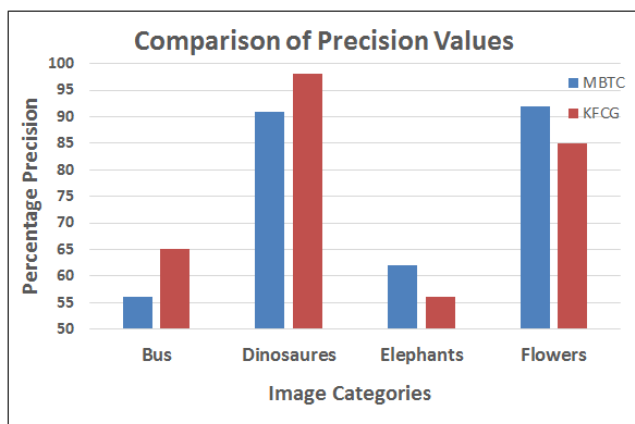


Figure 8. Comparison of Precision values using two features

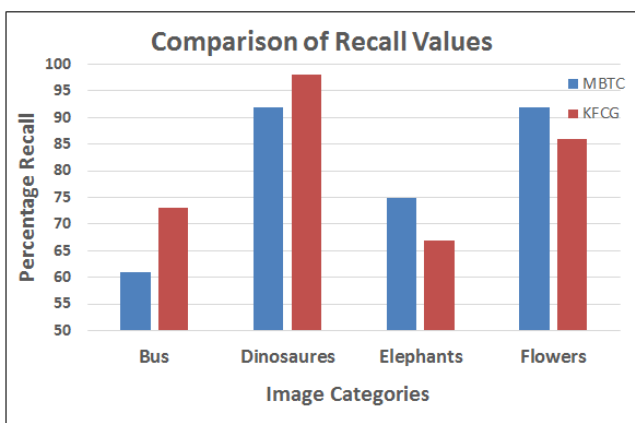


Figure 9. Comparison of Recall values using two features

It is clear from the above results shown in this section (a) that result is ranging from as low as 56% to as high as 98%. It can be understood that results are better for some categories and comparatively poorer for some categories. This variation is consistent for both the types of features.

For comparison among the two types of features, MBTC performs better for some types of categories of images while the other type of feature KFCG performs better for other two types of categories. This comparison is consistent for precision and recall results.

b) *Result analysis of the CBIR system using SVM*

Figures below shows precision values and recall values obtained by the system using SVM and comparisons of results among different categories and among two types of features.

i) *Results for images using features from MBTC algorithm*

Results in Fig. 10 show precision values for images using SVM with MBTC features whereas result in Fig 11 show recall values for images using SVM with MBTC features.

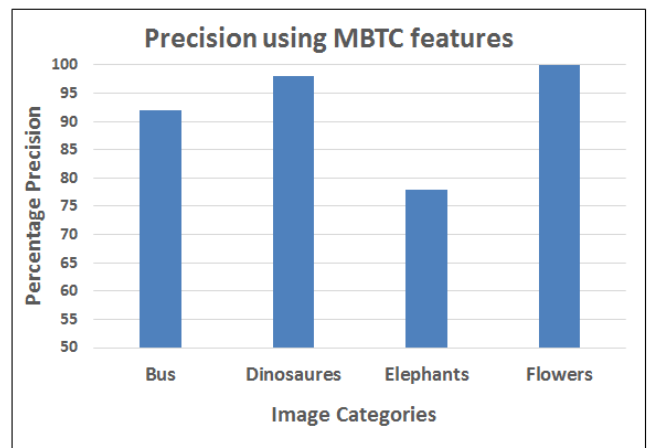


Figure 10. Precision values using MBTC features with SVM

ii) *Results for images using KFCG features*

Results in Fig. 12 show precision values for images using SVM with KFCG features whereas result in Fig. 13 show recall values for images using SVM with KFCG features.

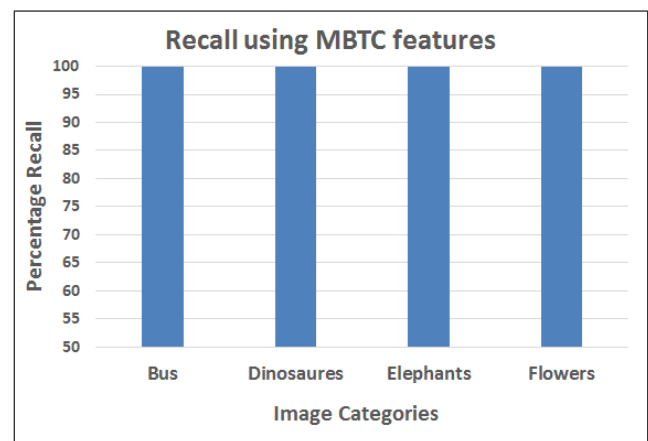


Figure 11. Recall values using MBTC features with SVM

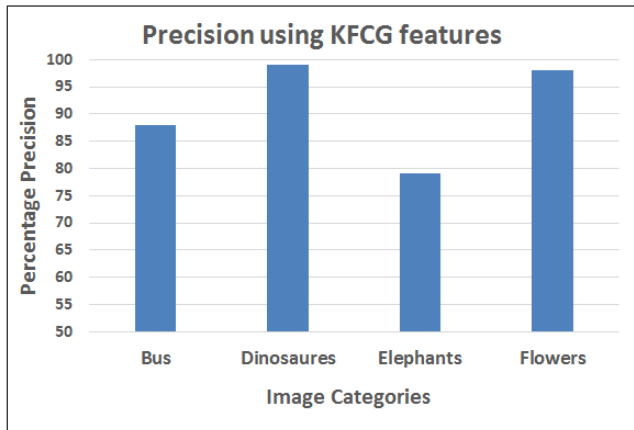


Figure 12. Precision values using KFCG features with SVM

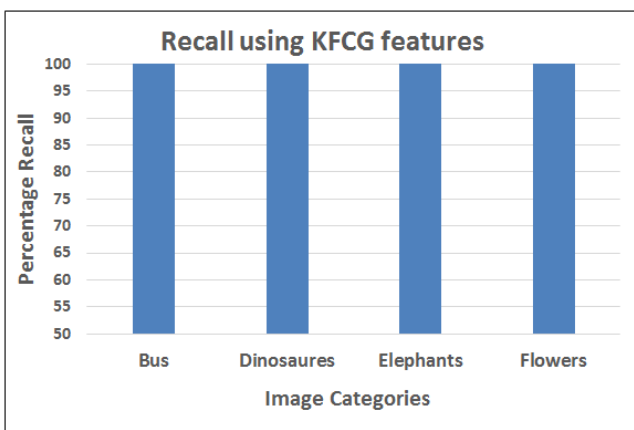


Figure 13. Recall values using KFCG features with SVM

iii) *Comparison of results using two types of features*

Fig. 14 shows comparison of precision values obtained by using two different features generated from the images by the CBIR system using SVM.

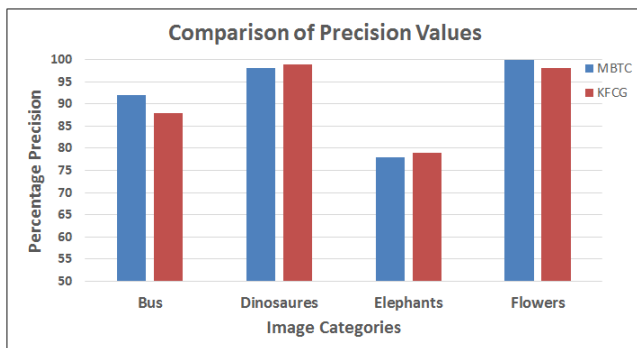


Figure 14. Comparison of Precision values using two features

Fig. 15 shows comparison of recall values obtained by using two different features generated from the images by the CBIR system using SVM.

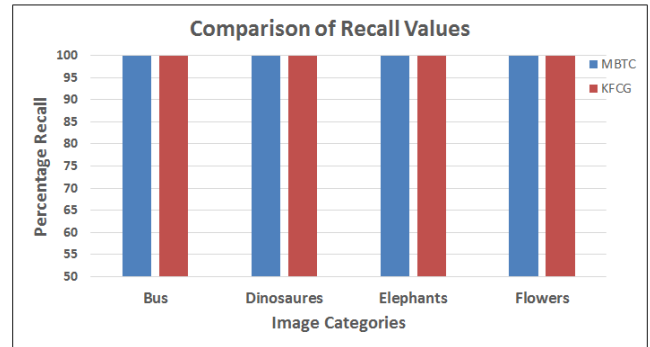


Figure 15. Comparison of Recall values using two features

The result analysis done in the section (b) for different categories is relevant for the system using SVM also. But, as we do the comparison of results found from different features, the analysis is different. Though it is clear that results are higher for SVM based system but the two types of features perform similarly with slight differences.

c) *Comparison of the CBIR system with and without using SVM*

The charts shown below demonstrate the comparison between results obtained by the CBIR system obtained by SVM and without SVM.

i) *Comparison of precision values obtained by MBTC features by SVM and without SVM*

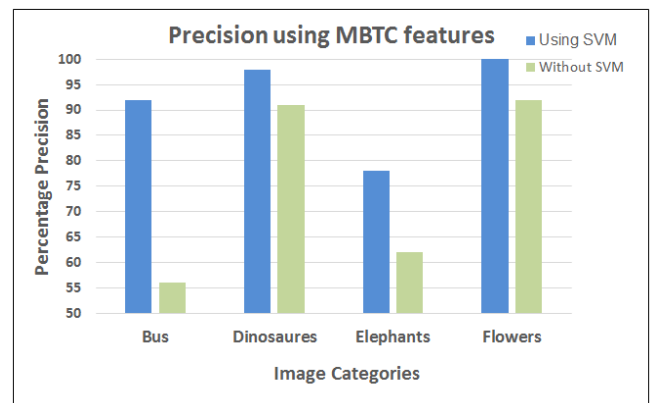


Figure 16. Comparison of precision values using MBTC features with and without SVM

ii) *Comparison of recall values obtained by MBTC features by using SVM and without SVM*

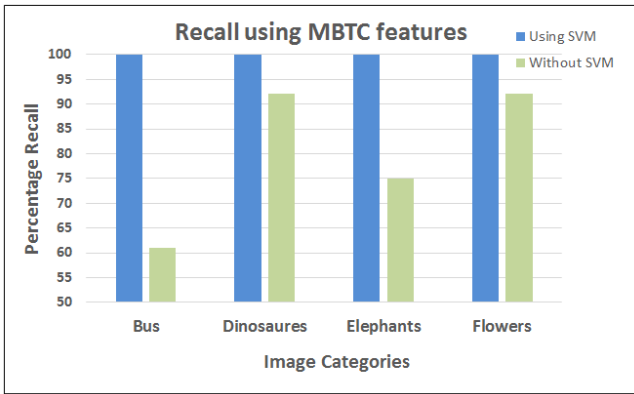


Figure 17. Comparison of recall values using MBTC features with and without SVM

iii) Comparison of precision values obtained by KFCG features by SVM and without using SVM

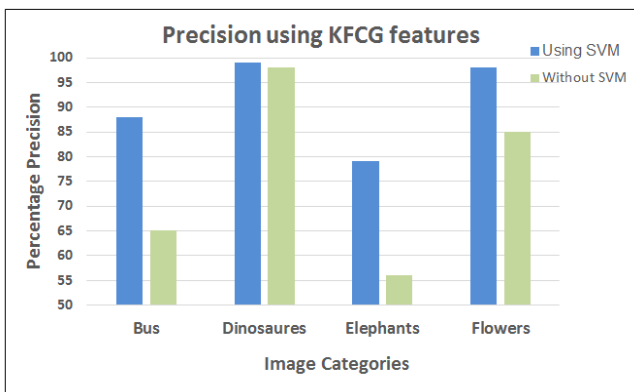


Figure 18. Comparison of precision values using KFCG features with and without SVM

iv) Comparison of recall values obtained by KFCG features by SVM and without using SVM

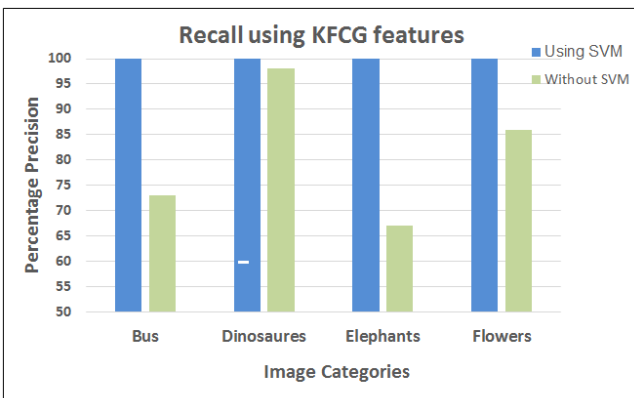


Figure 19. Comparison of recall values using KFCG features with and without SVM

Charts shown in this section clearly identifies the huge difference between results obtained through system using SVM with that of the system without using SVM. The system using SVM shows quite higher results ranging from minimum value of 78% up to 100%. It is clear from this fact that SVM based system is far superior than without using SVM.

PROBLEMS AND CHALLENGES

Features are used to represent the images for the implementation of retrieval system proposed. These features are expected to be unique for all images but due to the identical background in the images false retrievals may also result. So the performance is below expectation for the categories of images whose foreground objects may be distinct but their background have similarity in terms of features or colour content. For example, categories of bus and elephants show relatively poorer results as compared to other categories because of too many information in the background.

CONCLUSION

The CBIR system proposed show higher level of retrieval performance as compared to the conventional CBIR systems. Use of MBTC algorithm to extract colour information distributed over the entire image and KFCG algorithm to obtain codeword vectors representing sub-blocks in relation to clusters provide a unique and distinct representation of an image that ensures high precision and high recall values. The performance is boosted further due to classification of images done by the SVM.

FUTURE SCOPE

An effort is need for images having distinct foreground information but similar background lead to false retrievals and hence reduce result values for some categories. In contrast, for images having similar foreground but having different background may also cause false retrievals. Both the concerns require a considerable effort and provide a scope of future research.

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REFERENCES

- [1] Weiming Hu, Nianhua Xie, Li Li, Xianglin Zeng, Maybank S., "A Survey on Visual Content-Based Video Indexing and Retrieval", IEEE Transactions on Systems, Man, and Cybernetics, Part C (Applications and Reviews), 41-6,797-819, 11/2011
- [2] Liang-Hua Chen, Kuo-Hao Chin, Hong-Yuan Liao, "An integrated approach to video retrieval",

- Proceedings of the nineteenth conference on Australasian database-Volume 75, 49–55, 2008
- [3] Dhanraj R. Dhotre, G.R. Bamnote, "Multilevel Haar Wavelet Transform and Histogram Usage in Content Based Image Retrieval System", IEEE Xplore, 22-24 Sept. 2017
- [4] Yining Deng, B.S. Manjunath, "Content-based Search of Video Using Color, Texture, and Motion", IEEE, pg 534-537, 1997
- [5] Ja-Hwung Su, Yu-Ting Huang, Hsin-Ho Yeh, Vincent S. Tseng, "Expert Systems with Applications", 37, pg 5068-5085, 2010
- [6] Nicu Sebe, Michael S. Lew, Arnold W.M. Smeulders, "Video retrieval and summarization", Computer Vision and Image Understanding, vol. 92, no. 2-3, pg 141-146, 2003
- [7] C.-C. Chang and C.-J. Lin. Training nu-support vector classifiers: Thoery and algorithms. Neural Computation, 13:2119–2147, 2001.
- [8] Alexander G. Hauptmann, Rong Jin, and Tobun D. Ng, "Video Retrieval using Speech and Image Information", Electronic Imaging Conference (EI'03), Storage Retrieval forMultimedia Databases, Santa Clara, CA, January 20-24, 2003.
- [9] Swain M.J. and Ballard, B.H. "Color Indexing," Int'l J. Computer Vision, vol. 7, no. 1, pp. 11-32, 1991.
- [10] Hafner, J. Sawhney, H.S. Equitz, W. Flickner, M. and Niblack, W. "Efficient Color Histogram Indexing for Quadratic Form Distance," IEEE Trans. Pattern Analysis and Machine Intelligence, 17(7), pp. 729-736, July, 1995.
- [11] Aljhdali, S., Ansari, A., Hundewale, N., "Classification of Image Database Using SVM With Gabor Magnitude", International Conference on Multimedia Computing and Systems (ICMCS), Tangier, Morocco, 2012 , vol., no., pp.126,132, 10-12 May 2012
- [12] Mohd. Aasif Ansari, Hemlata Vasishtha, "CBVR and Classification of Video Database–Latest Trends, Methods, Effective Techniques, Problems and Challenges", International Journal of Computer Applications (ISSN : 0975 – 8887), Volume 125 – No. 6, September 2015
- [13] H. Yu, J. Han, and K. C. Chang. PEBL: Positive-example based learning for Web page classification using SVM. In Proc. 8th Int. Conf. Knowledge Discovery and Data Mining (KDD'02), pages 239–248, Edmonton, Canada, 2002.
- [14] Guoping Qiu, "Colour Image Indexing Using BTC", IEEE Transaction on Image Processing, Vol. 12, January 2003.
- [15] Visionics Corporate Web Site, FaceIt Developer Kit Software, <http://www.visionics.com>, 2002.
- [16] The TREC Video Retrieval Track Home Page, <http://www-nlpir.nist.gov/projects/trecvid/>
- [17] Edward J. Delp, Martha Saenz, and Paul Salama, "BLOCK TRUNCATION CODING (BTC)", Handbook of Image and Video Processing: BTC, Video and Image Processing Laboratory, School of Electrical and Computer Engineering, Purdue University, West Lafayette, Indiana.
- [18] Delp, E.J., "Image Compression Using Block Truncation Coding", IEEE Transactions on Communication, ISSN : 0090-6778, Volume:27, Issue:9, pg 1335-1342, Sep 1979,.
- [19] Wikipedia Online. <Http://en.wikipedia.org/wiki>.
- [20] Mohd. Aasif Ansari, Hemlata Vasishtha, "Enhanced Video Retrieval and Classification of Video Database Using Multiple Frames Based on Texture Information", International Journal of Computer Science and Information Technologies (ISSN : 0975 – 9646), Volume 6 (2), pg 1740 - 1745, April 2015
- [21] Mohd. Aasif Ansari, Hemlata Vasishtha, "Enhanced Video Retrieval and Classification of Video Database Using Multiple Frames Based on MBTC features", International Journal of Advances in Electronics and Computer Science (ISSN : 2393 – 2835), Volume 2 (12), pg 32 - 39, Dec 2015
- [22] Nello Cristianini and John Shawe-Taylor, "An Introduction to Support Vector Machines and Other Kernel-based Learning Methods", Cambridge University Press, 2000.
- [23] H. B. Kekre, Tanuja K. Sarode, "Fast Codebook Generation Algorithm for Color Images using Vector Quantization," International Journal of Computer Science and Information Technology, Vol. 1, No. 1, pp.: 7-12, Jan 2009.
- [24] Mohd. Aasif Ansari, Hemlata Vasishtha, "CBVR and Classification of Videos based on BTC Color Features using SVM", Proceedings of the International Conference on Emerging Research Trends in Applied Engineering and Technology, KGCE, Karjat, ISBN: 978-93-5258-409-3, 1-2 April, 2016.
- [25] H.B. Kekre, V.A. Bharadi, S.D. Thepade, B.K. Mishra, S.E. Ghosalkar, S.M. Sawant, "Content Based Image Retrieval Using Fusion of Gabor Magnitude and Modified Block Truncation Coding," icetet, pp.140-145, 2010 3rd International Conference on Emerging Trends in Engineering and Technology, 2010.
- [26] X. Fu, Y. Li, R. Harrison, S. Belkasim, "Content-based Image Retrieval Using Gabor-Zernike Features", The 18th International Conference on Pattern Recognition (ICPR'06).
- [27] Mukesh Mittal, Ruchika Lamba, "Image Compression Using Vector Quantization Algorithms: A Review", International Journal of Advanced Research in

Computer Science and Software Engineering (ISSN: 2277 128X), Volume 3, Issue 6, June 2013.

- [28] Manoj Kumar, Poonam Saini, "Image Compression With Efficient Codebook Initialization Using LBG algorithm", International Journal of Advanced Computer Technology (IJACT), ISSN:2319-7900, vol. 2, no. 2
- [29] JariKangas, "Increasing the Error Tolerance in Transmission of Vector Quantized Images by Self-Organizing Map", Helsinki University of Technology, Finland.
- [30] Yu-chen, Hu, Bing-Hwang, Su Chih-Chiang Tsou. "Fast VQ codebook search algorithm for grayscale image coding", Science Direct Image and vision computing 26(2008) 657-666.
- [31] Asmita A. Bardekar, Mr. P.A. Tijare, (IJCSIT) International Journal of Computer Science and Information Technologies, Vol. 2 (6) , 2011, 2584-2589. ISSN:0975-9646
- [32] H. B. Kekre, Tanuja K. Sarode, "New Fast Improved Codebook Generation Algorithm for Color Images using Vector Quantization," International Journal of Engineering and Technology, vol.1, No.1, pp.: 67-77, September 2008.
- [33] Dengsheng Zhang, Aylwin Wong, Maria Indrawan, Guojun Lu, "Content-based Image Retrieval Using Gabor Texture Features" Gippsland School of Computing and Information Technology.
- [34] J. Wang, X. Liao, and Z. Yi (Eds.), "Gabor features-based classification using SVM for face recognition" ISSN 2005, LNCS 3497, pp. 118-123, 2005. Springer-Verlag Berlin Heidelberg 2005
- [35] Praseeda Lekshmi.V, Dr.M.Sasikumar, "Analysis of Facial Expression using Gabor and SVM" , International Journal of Recent Trends in Engineering, Vol. 1, No. 2, May 2009
- [36] Lin-Lin SHEN, Zhen JI, "Gabor Wavelet Selection and SVM Classification for Object Recognition", Volume 35, Issue 4, April 2009, Pages 350-355 Elsevier
- [37] Zhang Guo-yun, Guo Long-yuan ; Wu Jian-hui ; Li Hong-min ; Guo Guan-qi, "Face detection using Gabor wavelet and SVM" Computer Application and System Modeling (ICCA SM), 2010 International Conference on (Volume:2)
- [38] Djamel Eddine Benrachou, Brahim Boulebtateche, and Salah Bensaoula, "Gabor/PCA/SVM-Based Face Detection for Driver's Monitoring", Journal of Automation and Control Engineering, Vol. 1, No. 2, March 2013
- [39] Linlin Shen, Li Bai, Zhen Ji, "A SVM Face Recognition Method Based on Optimized Gabor Features", 9th International Conference, VISUAL 2007 Shanghai, China, June 28-29, 2007 Revised Selected Papers Springer Berlin Heidelberg
- [40] Batra, D. Singhal, Girish ; Chaudhury, S. "First Gabor Filter based Fingerprint Classification using Support Vector Machines", India Annual Conference, 2004. Proceedings of the IEEE INDICON 2004.
- [41] H.B.Kekre, Sudeep D. Thepade, "Using YUV Color Space to Hoist the Performance of Block Truncation Coding for Image Retrieval", IEEE International Advanced Computing Conference 2009 (IACC'09), Thapar University, Patiala, INDIA, 6-7 March 2009.
- [42] Mohd. Aasif Ansari, Dr. Hemlata Vasishtha, "Enhanced Video Retrieval and Classification of Video Database Using Multiple Frames Based on Texture Information", (IJCSIT) International Journal of Computer Science and Information Technologies, Vol. 6 (2) , 2015, 1740-1745
- [43] Anusha Yalavarthi, K. Veeraswamy, K. Anitha Sheela, "Content Based Image Retrieval using enhanced Gabor Wavelet transform", IEEE Xplore, 1-2 July 2017.