Image Retrieval using Texture Features extracted from GLCM, LBG and KPE

Dr. H.B.Kekre, Sudeep D. Thepade, Tanuja K. Sarode and Vashali Suryawanshi

***Abstract*—In this paper a novel method for image retrieval based on texture feature extraction using Vector Quantization (VQ) is proposed. We have used Linde-Buzo-Gray (LBG) and Kekre's Proportionate Error (KPE) algorithms for texture feature extraction. The image is first divided into pixel blocks of size 2X2, each pixel with red, green and blue component. A training vector of dimensions 12 is created using this block. Collection of such training vectors is a training set. To generate the texture feature vector (size of codebook 16X12) of the image, popular LBG and KPE algorithms are applied on the initial training set. Results are compared with the Gray Level Co-occurance Matrix (GLCM) method. The proposed method requires 89.10% less computations compared to the GLCM method. The LBG and KPE based image retrieval techniques give higher precision and recall values than GLCM based method, which concludes that the proposed techniques give better texture feature discrimination capability than GLCM.**

***Index Terms*—CBIR, Vector Quantization, GLCM, LBG, KPE.**

I. Introduction

More and more images are being readily available to professional and amateur users because of astonishing advancements in color imaging technologies. The large numbers of image collections, available from a variety of sources (digital camera, digital video, scanner, the internet etc.) have posed increasing technical challenges to computer systems to store/transmit and index/manage image data effectively to make such collections easily available. The storage and transmission challenge is tackled by image compressions which have been studied for more than 30 years and significantly advancements have been made [1]. The challenge to image indexing/management is studied in the context of image database [2, 3], which has also been actively researched by researchers from a wide range of disciplines including those from computer vision, image processing and traditional database areas for over a decade.

A wide range of possible applications for CBIR technology has been identified. Some of these are art galleries, museums, archaeology [4,5], architecture/engineering design [6], geographic information systems [2], weather forecast [7], medical imaging [7], trademark databases [8], criminal investigations [9], image search on the Internet (very general image content) [10].

The earliest use of the term content-based image retrieval in the literature seems to have been by Kato et.al.[11], to describe his experiments into automatic retrieval of images from a database by color and shape feature. The term has since been widely used to describe the process of retrieving desired images from a large collection on the basis of features (such as colors, texture and shape) that can be automatically extracted from the images themselves. 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 to accurately represent the content of each image in the database. A feature vector is much smaller in size than the original image, typically of the order of hundreds of elements (rather than millions). 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 top "closest" images can be retrieved [3,12].

For feature extraction in content based image retrieval there are mainly two approaches [5] feature extraction in spatial domain and feature extraction in transform domain [47]. The feature extraction in spatial domain includes the CBIR techniques based on histograms [5], BTC [2, 3, 14], VQ [13,15,43]. The transform domain methods are widely used in image compression, as they give high energy compaction in transformed image. So it is obvious to use images in transformed domain for feature extraction in CBIR [16, 17]. Transform domain results in energy compaction in few elements, so large number of the coefficients of transformed image can be neglected to reduce the size of feature vector.

In section II texture feature extraction using GLCM is explained. Section III deals with feature extraction using VQ algorithms. Results and discussion are given in section IV and conclusions are presented in section V.

II. Texture Feature Extraction

A variety of techniques have been used for measuring texture such as co-occurance matrix, Fractals, Gabor filters, variations of wavelet transform [21]. Further techniques have also been developed for describing the local patterns using

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Dr.H.B.Kekre is Sr.Professor with Mukesh Patel School of Technology Management and Engineering, SVKM's NMIMS University, Mumbai-56, INDIA (phone: 91-9323557897; fax: 91-022-26717779; e-mail: hbkekre@yahoo.com).

Sudeep D. Thepade. is Ph.D. Research Scholar and Assistant Professor, with Mukesh Patel School of Technology Management and Engineering, SVKM's NMIMS University, Mumbai-56, INDIA. (phone:91-9766258833; fax: 91-022-26717779; e-mail:sudeepthepade@gmail.com)

Tanuja K.Sarode is Ph.D. Research Scholar with Mukesh Patel School of Technology Management and Engineering, SVKM's NMIMS University, Mumbai-56, INDIA. Assistant Professor, Thadomal Shahani Engineering College, Bandra(w), Mumbai, INDIA. (phone: 91-9820122805; e-mail: tanuja_0123@yahoo.com).

Vaishali Suryawanshi is Lecturer with Thadomal Shahani Engineering College, Bandra(w), Mumbai, INDIA. (phone: 91-9869207848; e-mail: vaishali.surya@gmail.com).

texture spectrum [20], for characterization of texture using a composition of edge information and co-occurance matrix properties [19]. The identification of specific textures in an image is achieved primarily by modeling texture as a two-dimensional gray level variation [21]. This two dimensional array is called as Gray Level Co-occurance Matrix (GLCM).

Normalized probability density $P_\delta(i,j)$ of the co-occurance matrices can be defined as follows.

$$P_\delta(i,j) = \frac{\#\{|(x,y),(x+d,y+d)| \in S \mid f(x,y)=i, f(x+d,y+d)=j\}}{\#S} \quad (1)$$

Where,

x, y = 0,1,…..N-1 are co-ordinates of the pixel

i, j = 0,1,…..L-1 are the gray levels

S is set of pixel pairs which have certain relationship in the image.

#S is the number of elements in S.

$P_\delta(i,j)$ is the probability density that the first pixel has intensity value i and the second j, which seperated by distance δ=(dx, dy).

The GLCM is computed in four directions for $\delta=0^0$, $\delta=45^0$, $\delta=90^0$, $\delta=135^0$. Based on the GLCM four statistical parameters energy, contrast, entropy and correlation are computed. Finally a feature vector is computed using the means and variances of all the parameters [18].

The steps for extracting texture features of image using GLCM can be given as below.

1) Separate the R,G,B planes of image.
2) Repeat steps 3-6 for each plane.
3) Compute four GLCM matrices (directions for δ=00, δ=450, δ=900, δ= 1350) as given by eq. (1)
4) For each GLCM matrix compute the statistical features Energy(Angular second moment), Entropy(ENT), Correlation(COR), Contrast(CON) [18,22] as follows whre P(i,j) is probability density.

Energy: (Angular Second Moment (ASM))

$$ASM = \sum\sum P^2(i,j) \quad (2)$$

Energy measures textural uniformity (i.e. pixel pairs repetitions).

Contrast (CON):

$$CON = \sum\sum (i-j)^2 P(i,j) \quad (3)$$

Contrast indicates the variance of the gray level .

Entropy (ENT)

$$ENT = -\sum\sum P(i,j)\log[P(i,j)] \quad (4)$$

This parameter measures the disorder of the image. For texturally uniform image, entropy is small.

Correlation: (COR)

$$COR = \frac{\sum\sum ijP(i-j) - \mu_x\mu_y}{\sigma_x\sigma_y} \quad (5)$$

Where μ_x, μ_y, σ_x, σ_y are the means and standard deviations of Px and Py respectively.

Px is the sum of each row in co-occurance matrix

Py is the sum of each column in the co-occurance matrix. Thus we obtained

ASM0	ENT0	COR0	CON0
ASM 45	ENT 45	COR45	CON45
ASM 90	ENT 90	COR90	CON90
ASM 135	ENT 135	COR135	CON135

5) Compute the feature vector using the means and variances of all the parameters.

Thus, the feature vector f={μASM, μENT, μCOR, μCON, σASM, σENT, σCOR, σCON } Where μ is mean and σ is variance of the parameters.

III. Vector Quantization

Vector Quantization (VQ) [23-31] is an efficient technique for data compression and has been successfully used in various applications such as index compression [32, 33]. VQ has been very popular in a variety of research fields such as speech recognition and face detection [34, 35]. VQ is also used in real time applications such as real time video-based event detection [36] and anomaly intrusion detection systems [37], image segmentation [38-41], speech data compression [42], content based image retrieval CBIR [43] and face recognition [44].

Vector Quantization (VQ) techniques employ the process of clustering. Various VQ algorithms differ from one another on the basis of the approach employed for cluster formations. VQ is a technique in which a codebook is generated for each image. A codebook is a representation of the entire image containing a definite pixel pattern [23] which is computed according to a specific VQ algorithm. The image is divided into fixed sized blocks [23] that form the training vector. The generation of the training vector is the first step to cluster formation. Vector Quantization VQ can be defined as a mapping function that maps k-dimensional vector space to a finite set CB = $\{C_1, C_2, C_3, \ldots, C_N\}$. The set CB is called codebook consisting of N number of code vectors and each code vector $C_i = \{c_{i1}, c_{i2}, c_{i3}, \ldots, c_{ik}\}$ is of dimension k. The key to VQ is the good codebook. Codebook can be generated in spatial/transform domain by clustering algorithms [23-31]. The method most commonly used to generate codebook is the Linde-Buzo-Gray (LBG) algorithm which is also called as Generalized Lloyd Algorithm (GLA) [15, 16].

In this paper, we carry out CBIR using LBG and KPE.

A. LBG Clustering Algorithm

For the purpose of explaining this algorithm, we are considering two dimensional vector space as shown in Figure.3. In this figure each point represents two consecutive pixels dividing image into blocks of dimension 1x2. In this algorithm centroid is computed as the first codevector C_1 for the training set. In Fig. 3 two vectors v_1 & v_2 are generated by adding constant error to the codevector. Euclidean distances of all the training vectors are computed with vectors v_1 & v_2

and two clusters are formed based on nearest of v_1 or v_2. Procedure is repeated for these two clusters to generate four new clusters. This procedure is repeated for every new cluster until the required size of codebook is reached or specified MSE is reached. The drawback of this algorithm is that the cluster elongation is $+135^o$ to horizontal axis in two dimensional case. This results in inefficient clustering. This drawback is addressed by KPE Algorithm [25].

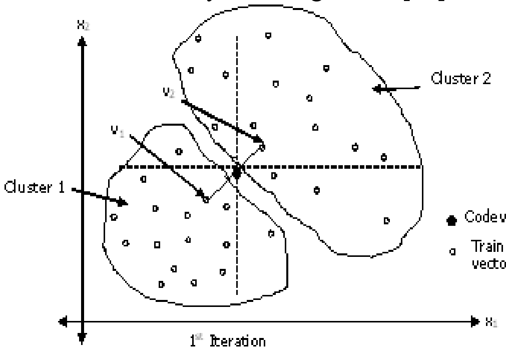


Figure 1. LBG for 2 dimensional case

B. *Kekre's Proportionate Error Algorithm (KPE)*

In this algorithm a proportionate error is added to the centroid to generate two vectors v_1 & v_2. The error ratio is decided by magnitude of coordinates of the centroid. Hereafter the procedure is same as that of LBG. In this algorithm while adding proportionate error a safe guard is introduced so that neither v_1 nor v_2 go beyond the training vector space. This overcomes the disadvantage of the LBG of inefficient clustering. Next we discuss proposed CBIR technique for feature extraction.

C. *Proposed CBIR Technique for Feature Extraction*

Here the feature vector space has 16x12 number of elements. This is obtained using following steps of Kekre's Proportionate error (KPE) algorithm

1) Image is divided into the non-overlapping windows of size 2x2 pixels (each pixel consisting of red, green and blue components).
2) These are put in a row to get 12 coordinates per vector. Collection of these vectors is a training set (initial cluster).
3) Compute centroid (codevector) of the cluster
4) Split the cluster using LBG/KPE.
5) Repeat the 3, 4 till we obtain codebook of size 16.

The codebook is stored as the feature vector for the image. Thus the feature vector database is generated. Sqaured Euclidian distance (ED) is used as similarity measure as given in eq. (6)

$$SED=\sum_{i=1}^{n}\left(v_{pi}-v_{qi}\right)^2 \quad (6)$$

where, Vpi and Vqi are the feature vectors of the image P and Query image Q respectively with size n.

IV. Results

Vector quantization is used for CBIR, as texture is one of the important aspects to represent image contents. A block of 2x2 color pixels is considered for vector thereby making the training vector dimension equal to 12. The method is implemented in Matlab 7.0 on Intel Core 2 Duo Processor T8100, 2.1 GHz, 2 GB RAM machine to obtain results. Our database consists of total 7200 images of size 128x128x3. There are 100 different categories consisting of 72 images in each categories To test the proposed method, from every class five query images are selected randomly. So in all 500 query images are used.

To check the performance of proposed technique we have used precision and recall. The standard definitions of these two measures are given by following equations.

$$\text{Precision}=\frac{\text{Number\_of\_relevant\_images\_retrieved}}{\text{Total\_number\_of\_images\_retrieved}} \quad (7)$$

$$\text{Recall}=\frac{\text{Number\_of\_relevant\_images\_retrieved}}{\text{Total\_number\_of\_relevent\_images\_in\_database}} \quad (8)$$

Fig.2. Shows a sample database of 100 images by randomly selecting one image from each category. The database has 100 categories, for a total of 7200 images. The image database used in the experiments is the subset of Columbia Object Image Library (COIL-100) [45]. Each object was rotated in 72 different poses with variation of 5 degrees, resulting in 72 images per object in the database.

Fig.3. Shows Results of object category 52. Note that the database contains total 72 mages. For the query image as shown in Fig. 3 for 72 retrieved images the total relevant images obtained are all 72.

Fig. 2. Sample database consisting of 7200 Images, the database has 100 categories, 72 images in each category.

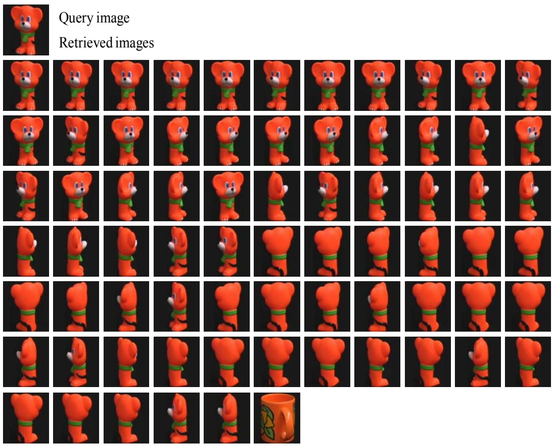
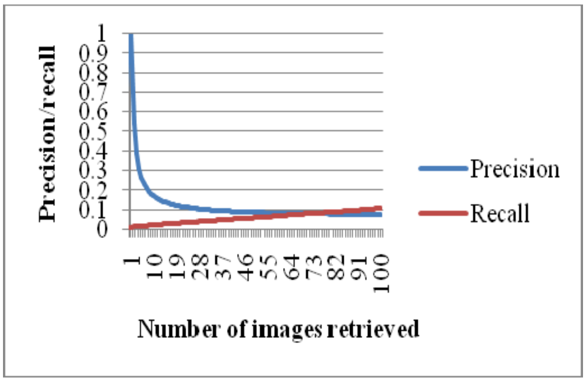
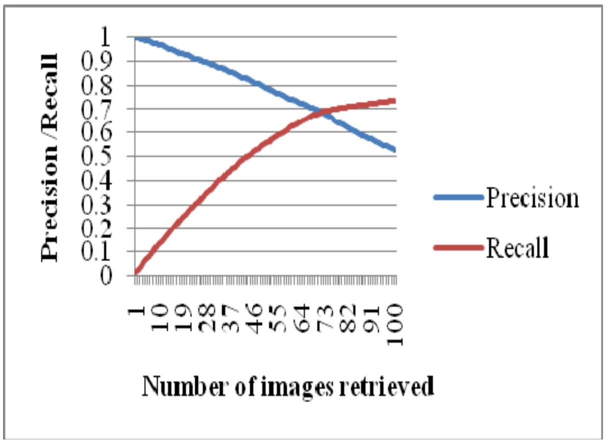


Fig.3. Results of Object category 52 query image.

Fig 4. Shows net Average Precision/Recall Vs Number of retrieved images for all categories obtained using GLCM on color images with ED as similarity measure, GLCM on color images with MD as similarity measure, LBG and KPE.



4.a. Plot of Precision/Recall Vs Number of images retrieved using GLCM on color images with ED as similarity measure crossover point obtained is 8.16%



4.b. Plot of Precision/Recall Vs Number of images retrieved using LBG on color images Cross crossover point obtained is 69.07%

4.c. Plot of Precision/Recall Vs Number of images retrieved using KPE on color images Cross crossover point obtained is 69.36%

Fig 4. Net Average Precision/Recall Vs Number of retrieved images for all categories obtained using GLCM on color images, LBG and KPE.

Fig. 4.a shows net average precision/ recall for GLCM on color images with ED as similarity measure, while Fig. 4.b-c gives the same for the proposed method using LBG and KPE respectively. The precision and recall values of proposed CBIR technique are higher than that of applying GLCM. The crossover point of precision and recall obtained for proposed technique is 69.36% for KPE, 69.07 for LBG which is much greater than the 8.16% for GLCM. Note that the database contains total 72 images. For the query image as shown in Fig. 3 for 72 retrieved images the total relevant images are 55.

A. *Complexity Analysis*

Let M be the total number of training vectors, k be the vector dimension, N be the codebook size, 1 CPU unit is required for addition of 8 bit numbers, 1 CPU unit for comparison. For multiplication of two 8 bits number 8 CPU units are required. To compute one squared Euclidian distance (ED) of k dimensional vector we require k multiplications and 2k-1 additions hence 8k + 2k -1 CPU units.

TABLE I. COMPARISON OF LBG, AND KPE ALGORITHM WITH RESPECT TO TOTAL NUMBER OF COMPARISONS, TOTAL NUMBER OF ED COMPUTATIONS AND TOTAL CPU UNITS REQUIRED.

Complexity Parameters	LBG	KPE
Total Comparisons	$2M\log_2 N$	$2M\log_2 N$
Total No. of ED	$2M\log_2 N$	$2M\log_2 N$
Total CPU units	$4M\log_2 N$ (10k-1)	$4M\log_2 N$ (10k-1)

Computational Complexity for one GLCM.
Let L number of gray levels.
Number of Multiplications for ASM = L^2
Number of Additions for ASM = L(L-1)

Number of Multiplications for CON = $2L^2$
Number of Additions for CON = 2L(L-1)

Number of Multiplications for ENT = L^2
Number of Additions for ENT = L(L-1)

Number of Multiplications for COR = $6L^2$
Number of Additions for COR = 7L(L-1)

Total No.of Multiplications for all 3color planes= $3*10L^2$

Total Number of Additions for all 3 color planes $=3*11L(L-1)$

Total CPU units = $8*3*10L^2 + 3*11L(L-1)$

Hence Total CPU units for all four GLCM =

$$4*[8*3*10L^2 + 3*11L(L-1)]$$

TABLE II. TOTAL CPU UNITS REQUIRED FOR LBG, KPE, KFCG AND DCT FOR P, Q =128, M=4096, N=16 AND K = 12

Complexity Parameters	LBG	KPE	GLCM
Total CPU Units	7798784	7798784	71531520

From the Table II it is observed that GLCM method requires 9.17 times more computations as that of LBG/ KPE.

V. CONCLUSION

Despite technological advances in image generation and storage, the expertise and techniques for effective image retrieval still lack maturity. In this paper a novel method for image retrieval based on VQ for texture feature extraction is proposed. We have used LBG and KPE algorithms for texture feature extraction. Proposed CBIR method is 9 times faster than the GLCM method and requires 89.10% less computations as compared to that of GLCM method. The precision and recall values in proposed image retrieval techniques are much higher as compared to conventional GLCM based CBIR. In LBG and KPE, KPE performs marginally better than LBG in terms of slightly higher precision and recall values.

So the Image retrieval using texture features extracted from VQ using LBG and VQ using KPE are better and faster than CBIR using texture features of GLCM.

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Dr. H. B. Kekre has received B.E. (Hons.) in Telecomm. Engg. from Jabalpur University in 1958, M.Tech (Industrial Electronics) from IIT Bombay in 1960, M.S.Engg. (Electrical Engg.) from University of Ottawa in 1965 and Ph.D. (System Identification) from IIT Bombay in 1970. He has worked Over 35 years as Faculty of Electrical Engineering and then HOD Computer Science and Engg. at IIT Bombay. For last 13 years worked as a Professor in Department of Computer Engg. at Thadomal Shahani Engineering College, Mumbai. He is currently Senior Professor working with Mukesh Patel School of Technology Management and Engineering, SVKM's NMIMS University, Vile Parle(w), Mumbai, INDIA. He ha guided 17 Ph.D.s, 150 M.E./M.Tech Projects and several B.E./B.Tech Projects. His areas of interest are Digital Signal processing, Image Processing and Computer Networks. He has more than 300 papers in National / International Conferences / Journals to his credit. Recently six students working under his guidance have received best paper awards. Currently he is guiding ten Ph.D. students.

Tanuja K. Sarode has received M.E.(Computer Engineering) degree from Mumbai University in 2004, currently Pursuing Ph.D. from Mukesh Patel School of Technology, Management and Engg., SVKM's NMIMS University, Vile-Parle (W), Mumbai, INDIA. She has more than 10 years of experience in teaching. Currently working as Assistant Professor in Dept. of Computer Engineering at Thadomal Shahani Engineering College, Mumbai. She is member of International Association of Engineers (IAENG) and International Association of Computer Science and Information Technology (IACSIT). Her areas of interest are Image Processing, Signal Processing and Computer Graphics. She has 56 papers in National /International Conferences/journal to her credit.

Sudeep D. Thepade has Received B.E.(Computer) degree from North Maharashtra University with Distinction in 2003. M.E. in Computer Engineering from University of Mumbai in 2008 with Distinction, currently Perusing Ph.D. from SVKM's NMIMS University, Mumbai. He has more than 07 years of experience in teaching and industry. He was Lecturer in Dept. of Information Technology at Thadomal Shahani Engineering College, Bandra(w), Mumbai for nearly 04 years. Currently working as Assistant Professor in Computer Engineering at Mukesh Patel School of Technology Management and Engineering, SVKM's NMIMS University, Vile Parle(w), Mumbai, INDIA. He is member of International Association of Engineers (IAENG) and International Association of Computer Science and Information Technology (IACSIT), Singapore. His areas of interest are Image Processing and Computer Networks. He has about 65 papers in National/International Conferences/Journals to his credit with a Best Paper Award at International Conference SSPCCIN-2008 and Second Best Paper Award at ThinkQuest-2009 National Level paper presentation competition for faculty.

Vaishali Suryawanshi has received B.E (Computer Engineering) degree from North Maharashtra University in 2000. Currently she is pursuing her M.E. (Computer Engineering) from Thadomal Shahani Engineering College Mumbai. She is working as a lecturer in Thodomal Shahani Enginnering college and has 7 years of teaching experience.