7. Conclusions and Further work

7.1 Conclusions

• Codebook Generation

In this thesis three new proposed codebook generation algorithms are given

Kekre’s Proportionate Error Algorithm (KPE),
Kekre’s Median Codebook Generation Algorithm (KMCG) and
Kekre’s Fast Codebook Generation algorithm (KFCG).

All these codebook generation methods are compared with LBG since it is well recognized algorithm. It is observed that KMCG is faster than all of them. From the results it is observed that KFCG algorithm gives less MSE compared to LBG, KPE and KMCG. Figure 7.1 shows the total CPU units required for LBG, KPE and KFCG relative to KMCG for the codebook sizes 128 to 1024 respectively.

![Figure 7.1 Total CPU units required for LBG, KPE and KFCG relative to KMCG for different codebook sizes.](image)

Figure 7.2 Shows percentage MSE reduction of KPE, KMCG and KFCG with respect to LBG for the codebook sizes 128 to 1024 respectively.
Search algorithms

Two new codebook search algorithms are introduced in chapter 4.

Kekre’s Centroid Search Algorithm (KCS),
Kekre’s Median Search Algorithm (KMS)

The performance of these algorithms is compared with exhaustive search (ES) method. It is observed that KMS is faster than all of them. KMS requires approximately 67 to 36 times less computations as compared to KCS and approximately 2127 to 9144 times less computations as compared to ES. These search algorithms are tried on various codebooks generated from LBG, KPE, KFCG and KMCG. From the results it is observed that KFCG codebook gives less MSE compared to LBG, KPE and KMCG codebooks when different search algorithms are used for encoding. The MSE obtained from KMS is slightly higher than that of ES but the distortion is imperceptible.

Error minimization algorithms

Further following error minimization techniques are presented

- Genetic
- K-Means
- Multilevel

In these genetic algorithm is modified to reduce the convergence time. Multilevel error minimization technique is a novel method that is proposed here. From the error minimization techniques discussed
it is observed that K-Means method gives the minimum MSE but require huge amount of time for convergence and the multilevel method gives imperceptibly more MSE as compared to the K-Means and Genetic and is faster. However it is observed that in all the three error minimization techniques KFCG has given always less MSE as compared to LBG, KPE and KMCG.

• **Applications**

Some new applications have been introduced in chapter 6 as applications of VQ they are as follows:

- **Image Segmentation:**
  - Mammography images
  - Low altitude aerial images
- Speech Data compression
- Content Based Image Retrieval (CBIR)
- Face Recognition
- Iris Recognition
- Colorization

In case of image segmentation of Mammography images Gray Level Co-occurrence Matrix, watershed algorithm and KFCG algorithm are used for tumor detection for mammography images. From the results it is observed that GLCM and watershed give over segmentation while KFCG shows far better results for the same. This approach does not lead to over segmentation or under segmentation. Further KFCG gives more accurate center point location of the tumor as against GLCM and watershed.

In case of image segmentation on low altitude aerial images Kekre’s Fast codebook generation algorithm is used for segmenting architectural elements in low-altitude aerial images of urban scenes. The evaluation function ‘Q’ correctly retrieves the best segmentation
result. It has been found that when the training vector size is 12 i.e. when a block of 4 pixels is taken into a training vector, a zigzag effect appears over the contours. When the training vector size is 3, the zigzag effect over the contours is not seen. Performance of this algorithm is far better than on-the-fly watershed algorithm which generates over segmented image.

In speech signal compression three different vector dimensions 8, 16 and 32 for codebook size 256 resulting in compression ratios 16:1, 32:1 and 64:1 respectively are considered. Three VQ algorithms LBG, KPE, and KFCG for speech coding are used. Among these three VQ algorithms performance of KFCG is better than LBG and KPE.

In chapter 6 a novel method for CBIR using vector quantization technique for data compression is proposed. For VQ technique KMCG algorithm to generate codebook is used which is very fast as it does not involve any Euclidean distance computation. This technique for CBIR has far less complexity as compared to using commonly used full DCT. The net precision/recall values of proposed CBIR technique are higher than those obtained using full DCT, which proves that the proposed method has better discrimination capability. For applying full DCT on all images in database it is necessary to resize them and query image for proper comparison. The images are resized to 128x128 for using full DCT and it is seen that the computation complexity of proposed method is 25% less. The proposed technique avoids resizing of images for feature extraction and still gives better discrimination capability.

In face recognition application KMCG is used and its results are compared with full 2 dimensional DCT. These methods are implemented on face database without any pre-processing. It is
observed that high accuracy of 86% is obtained using KMCG as against DCT where accuracy obtained is 75.43% on a database of 400 training images (8 per person) and 92.67% in KMCG against 90.33% of DCT on a database of 450 training images (9 images per person). Further it is observed that even in the worst case KMCG requires 169 times less computations than DCT.

In Iris Recognition system VQ based LBG, KPE & KFCG Algorithms are used and results are compared with full 2 dimensional DCT. These algorithms are implemented on iris image without any pre-processing or segmentation including iris localization in spite of which it has been possible to obtain such a high accuracy. KFCG has the best performance with the accuracy of 89.10%. DCT has low accuracy around 66.10%. Further LBG and KPE methods require 72.6% less and KFCG requires 99.94% less computations as that of full 2-D DCT.

For colorization application a novel technique of coloring gray scale digital images using the vector quantization approach is proposed. To obtain codebook Kekre’s Fast code book generation (KFCG) Algorithm is used. In general the original color image may not be available. However to test the performance of the algorithm color image is selected and converted it to gray scale image. This grayscale image is colored using similar reference image of the same class. The result of the algorithm presented gives good performance after selecting appropriated reference image.

In short two newly proposed algorithms for VQ i.e KFCG and KMCG give better results and require less number of computations for all these applications when compared with existing algorithms.
7.2 Further Work

Further work includes the standard/Global codebook generation methods for class of images. The clustering algorithms discussed above could be used for global codebook generation. The codebooks could be generated using any clustering algorithm LBG/KPE/KFCG/KMCG for a particular class of images these are local codebooks. These local codebooks can be combined together and training vector space could be generated. On this training vector set same codebook generation algorithm can be applied and global codebook can be prepared. Further Vector quantization technique could be used for Steganography and signature recognition applications.

The applications of VQ in various areas are indicated in chapter 6. Here newly introduced VQ methods are used and compared with the well known existing methods. It has been found that they perform far better than the existing techniques. However these applications need to be investigated in great details.