CHAPTER VI

CONCLUSIONS FROM RESULTS AND FUTURE PERSPECTIVES

This chapter presents significant conclusions from the results and discussions obtained after the experimentation done for the verification of the proposals (objectives) geared up in order to improve the performance of compression achieved by the Vector Quantizers designed with various techniques presented in chapter IV and V. The conclusion section is mainly divided into two parts. The conclusions from the experimentation on gray scale images and secondly, conclusions from experimentation of color images are presented. Major concluding remark that is derived form entire experimentation is as follows,

- **The concept of designing codebook using block vectors is different from the methods described in the reviewed literature.**
- Prior to this research, only quality measures such as MSE, SNR and PSNR were used by other researchers for evaluation of VQ based compression technique. It may be the first attempt to use other quality measures for the evaluation of performance of compression using VQ. Since no bench marking results are available, the quality analysis using these measures is done by comparing with the figures published earlier and used in other compression schemes such as JPEG and SPIHT [49][50][51] .The analysis of compression performance with these quality measures is based on the closeness of it with its ideal values.
- The images with 256x256 pixel size and 8 bpp with 4x4 block size is best for testing. Even though many researchers used 512x512 size images with 4x4 block size, it is not considered here, since it is bound to give better results. Higher the image size, higher must be the block size in order to get more compression.

At the end, the proposals and thoughts through which the same work may be continued for obtaining much better results are presented.

6.1 Conclusions from the results obtained by performance evaluation of compression of gray scale images.

The procedure, results, discussions and brief conclusions related to the compression of gray images using different VQ's designed with the proposed ideas are presented in

chapter IV. The significant conclusions derived from seven major experiments are as follows

- From the results and discussions of first experiment, it has been observed that the training of SOFM based codebook with single image having many features works better than the techniques described in section 2.1 and 2.2. The quality analysis of the codebook designed with Lena image (referred as Lena codebook) shows that the average PSNR is increased by about 1.5 dB in comparison with the results summarized in Table 2.2. Using codebook designed with Lena image ,the images with human face , less details , less variation in gray levels and less number of edges (low frequency) are compressed with good quality .This codebook does not perform well for texture rich, synthetic, natural scene and medical images. For all medical images, quality is low on objective and subjective grounds. The Lena based codebook is unable to produce perfect white patch in decompressed images. The image fidelity, structural contains and normalized correlation, which indicates the similarity and many times called as similarity factor indicates that the reproduced images are, very well correlated .***This confirms the success of procedure adopted for the codebook design.***

The results though are not encouraging definitely has given a direction for further experimentation and guidelines for improvement of codebook performance. From other experiments, there being a marginal difference in quality and compression ratio between 256, 512 and 1024 size codebook, we have decided to use codebook of 1024 or 1K size for further experiments.

- Form the conclusion of experiment no 1, it is very much clear, that the samples used for training in SOFM plays a vital role in achieving quality and a samples sequentially taken from Lena images provides high matching probability for specific images and are not the best match for images mentioned earlier. The idea of using other images, that are shown in fig 4.4 along with Lena (being a good contributor) in a single image propelled to design a new codebook called **"Enhanced VQ."** This Vector quantizer indicated an improved quality and compression performance. There is a significant boost in all the quality measures and the quality of all images especially medical images has been improved. The mean opinion score is in the range of 8 to 8.5. Even though the white patch is reproduced well, still some black dots are present, this is drawback of SOFM

algorithm. This is due to the neighborhood problem and needs to be investigated for much better quality. To minimize the blockiness that is present, edge-preserving codevectors must be present in the codebook.

- Striving hard to boost quality, efforts are put on other side, i.e. the SOFM neural network is trained with different learning rates, epochs and with three weight initializations viz, midpoint, random and zero. Different codebooks are designed by varying the parameters .Testing is done with the same test images and quality analysis is carried out. The analysis indicates that the number of epochs should be fixed at 100, which gives better performance. The weight initializations may be changed depending upon the magnitude, mean or standard deviation of the pixel values in the training block. The learning rate can be changed depending upon the edge contents in order to preserve the exact topology. Edges can be found out by calculating standard deviation or using Canny edge operator. Thus, experiment 3 showed a way to achieve best quality.
- One more fantastic approach is to use DCT [43] [44] based codevectors in the codebook. Since DCT is energy compaction technique, it gives very good results for low frequency content in images and edges are preserved to some extent. The performance of DCT-VQ is directly comparable to JPEG. In experiment no.4 the codebooks are designed using DCT along with SOFM ,with the same training image that is used for the design of enhanced VQ. Similarly , the codebook is also generated by applying Canny edge operator to the training image and selecting prominent edge patterns along with some regularly used training samples. The comparison of the DCT based VQ, Canny VQ and the enhanced VQ is compared. DCT and Canny works slightly better than "Enhanced" codebook. More refinements in the "Enhanced" will be preferable because "Enhanced" codebook based encoder and decoder is very simple to implement in FPGA using VLSI technology. The DCT based codebook will involve some complexities.
- Experiment no.5 deals with development of codebook, which is based on the selection of samples depending upon their contributions in image reconstruction. During the testing of the earlier VQ's ,the contribution of individual images used in the training image for matching is calculated. Few more samples from images, which have higher probability of matching, are selected. This is done by applying

different mathematical operations such as mean, standard deviation, Canny operations and adjusting SOFM parameters accordingly .Different samples are chosen from different images individually, and not by using training image which is used during design of "Enhanced VQ". The designed VQ is named as **"Generic VQ".** This codebook uses the combination of different approaches like classified VQ, mean shaped VQ etc, presented in literature survey. **"Generic VQ"** exhibits very good performance. **The PSNR, SC, IF, MSSIM and UQI are improved to a large extend and visual quality is well acceptable. As indicated in section 3.4 the MOS is in the range of 8 to 9.3 which is very good.**

- There are still some codevectors which are rarely selected during the encoding process, such codevectors are discarded and the error information, which is generated during the training and samples with higher error are included thus making the VQ as **"Generic VQ with error."** More search time is required. This increases the bit rate. This can be reduced by applying entropy-coding techniques for indices. The quality of the decompressed images is very high and comparable to JPEG of 70% quality. The file size is also comparable. The encoding and decoding of images with "Generic" and "Generic with error" is very simple in comparison with JPEG encoding and decoding process. The average PSNR is around 34 dB and average image fidelity if around 0.85, which is supposed to be very good. The MSSIM is approached to "1", which indicates the similarity with respect to the contrast and brightness. **"Generic with error" happens to be a novel contribution in this research.**
- In "Generic" and "Generic with error", still there is some distortion in many blocks. The distortion is predicted and image is reconstructed after prediction, the quality is improved to some extent. Back propagation neural network is trained with more than 4000 samples with some distortion. **This is novel contribution in quality improvement perspective**. Variety of training and learning rules are tried, but Levenberg-Marquardt (LM) algorithm for training and conjugate gradient as learning rule sounds to be good performer. The improvement in quality is around 25%-30%. Neural network is successful in recovering few edges. If back propagation network is trained with large variety of samples, then the performance may be elevated further. There is room for research in quality

improvement with supervised neural networks like adaptive resonance theory (ART) models, radial basis function (RBF) models or even learning vector quantization (LVQ). The hardware implementation of well-trained back propagation neural network is quite possible with VLSI technology.

- "Generic", "Generic with error" exhibits very good qualitative performance for medical images. The texture in medical images such as CT or MRI is many times important for diagnosis. A lossy compression technique often degrades the texture. The separate textural analysis shows that, the texture is recovered up to 70 % with generic with error and back propagation. Still more efforts are needed to design the codebooks and use of proper post processing techniques to prevent the loss of texture.

6.2 Conclusions from the results obtained by performance evaluation of compression of Color images.

The same concepts of VQ design, but with different training images are used in codebook generation for color image compression. Five major experiments were worked out and quality analysis is performed. The training and testing criteria discussed in chapter IV and in section 6.1 are used for color image compression. Three codebooks for three color spaces are designed.

- The enhanced, generic called as "**Generic 1**" and generic with error called as "**Generic 2**" codebooks are designed for RGB color space and tested with different color images. "Generic 2" out performs and the performance is comparable with JPEG of 70 % quality in quality and compression /bit rate perspective. **Design of "Generic 1" and "Generic 2" codebook serves to be major contribution.** The colors of the images compressed using generic codebook matches very closely to the original images, where as in JPEG the colors are not reproduced faithfully.
- **Another important contribution** is to design VQ over different color spaces. The color spaces used are HSI, HSV,YIQ (NTSC) and YCbCr. The images used for training of the codebooks are the same that are used for "Generic" codebooks. The YCbCr based codebook does not perform well. This may be due to the improper training of the difference components. It has also been found that the YIQ based "Generic VQ" performs well, especially with low frequency images and quality degrades for high frequency and synthetic images. The HSI and HSV based

"Generic" codebooks with and without error provides better statistical and subjective quality.

- The complexity in encoding and decoding of images increases because of the conversion involved. As discussed in chapter V, **HSI and HSV have advantage, that the three planes are highly correlated. It is possible to have only one or two codebooks at encoder which corresponds to intensity or value and hue and three codebooks at decoder side .This reduces the file size and codevector search time, since only one or two codebooks are to be searched.** The file size of the compressed images will be one third or two third of the JPEG file size. The similar approach is experimented using YIQ color space also.
- The back propagation can be used for the color image compression using VQ.
- The effectiveness of the design lies in its ***simplicity,*** **lower storage space, and transmission rate** when a design of low cost, high performance , real time dedicated imaging device using VLSI is envisioned. This also accomplishes the tradeoff between quality and bit rate in very good manner. *The bit rate can be reduced by maintaining the same quality.* This may not be true with other compression schemes.
- All the decompressed images except back propagation technique are analyzed without any post processing. **This is a major strength of the present research work.**

6.3 Future directions

Optimization of the codebook was the past, is present will remain the future of the VQ techniques. The quality lies in perfect matching of the code words with input. This depends upon selection of samples on based on variety of criteria. The work has been started and lot of room is available in the areas of soft computing. Following are the directions towards the further research in the same area.

- Genetic algorithms (GAs) are a part of evolutionary computing, exploit the ideas of the survival of the fittest used to solve optimization problems. The goal of GA is to built an artificial genetic system with natural characteristic and if higher level of adaptation can be achieved, existing systems can perform their functions longer and better. Features for self-repair, self-guidance, and reproduction are the rule in biological systems, whereas they barely exist in most sophisticated artificial systems. The use of genetic algorithms has been experimented and VQ is designed with Lena image . PSNR is used as a fitness function. The quality of decompressed image is

good. The different facets of Genetic algorithm can used to design the codebook. Already few researchers have published papers, but it is still in an infant state.

- The wavelet transform is also a powerful and its combination with SOFM can be used, but the hardware implementation of wavelet-based codebooks seems to be difficult.
- Although literature survey shows that Fuzzy k means based VQ do not perform well ,still improvement in algorithms and also using Fuzzy c means may improve the compression performance. The Fuzzy approaches have advantage that they will reduce the width of the codebook, thus reducing the memory requirements.
- The proposed research emphasizes use of generic VQ in medical image compression for better compression with quality.In medical images, in fact in all images, preservation of texture is vital. In proposed work, the texture analysis is done and achieved average success, but VQ designs can be done which will preserve edges and texture. The generic VQ must have certain codevectors, which will go for document, facsimile document , letters compression.
- Even though lot of work has been done on search techniques for faster encoding, still use of genetic algorithms or predictive neural nets like radial basis functions or ART's can be used for fast search.
- The optimization in no reference quality measures will bring revolution in the decoding process. Use of Support vector machines (SVM) can be though off.
- Similar kind of techniques may be used in video compression.
- Few more experimentation can be carried out by using other color spaces such as YUV, L*a*b, xyz etc.