CHAPTER I

INTRODUCTION

1.0 Background

There has been an explosive growth in multimedia technology and applications in the past several years. Efficient representation for storage, transmission, retrieval and security are some of the biggest software and hardware related challenges.

Image information is one of the richest, but also most bandwidth consuming modes of communication. There is an ever-ending demand of speed for transmission of images / videos over internet and mobile for education, business, entertainment, and telemedicine applications. Thus, compression of image data is essential. Compression is crucial when images are stored in a database, such as archiving of personal images, medical images in hospitals, multispectral satellite images, and fingerprint images.

Images contain statistical redundancy and perceptual irrelevancy, which contribute to the total number of bits required to represent them. The science of obtaining a compact representation of an image while maintaining all the necessary information is referred as ***image compression.***

A fundamental goal of data compression is to reduce the bit rate, i.e. increase compression ratio for transmission or data storage while maintaining an acceptable fidelity or image quality. Guaranteeing a certain level of quality after compression has become a prime concern for content providers. **Designing an efficient compression scheme, which provides good quality of reconstruction, is major concern of this research work.**

Second important proposal in this research is the use of **"image quality metrics."** Compression and transmission lead to artifacts and distortions affecting image quality. Identifying the image quality measures that have highest sensitivity to these, distortions would help in systematic design of coding, and improving or optimizing the picture quality.

Numerous compression techniques have been developed, mainly categorized into lossless and lossy [3] [56]. Lossless compression is also referred to as reversible, entropy or noiseless coding as it enables complete recovery of the original image from the compressed data. The main draw back of this method is low compression ratio, especially in the case of some images having high frequency content .The compression ratio could be as low as 2:1. Lossless approach includes run length encoding (RLE),

statistical methods such as arithmetic, Huffman, Shannon Fano, dictionary coding like LZW and differential pulse code modulation.

Lossy compression is also referred to as irreversible compression. Its main advantage is higher compression ratio. However, it introduces some error in the data by eliminating some information and the original data cannot be recovered completely. **Quantization** forms the heart of any lossy compression scheme. Quantization involves representation of a set of fine resolution data by a coarse resolution approximation.

Lossy taxonomy includes transform coding, such as DCT, wavelets, fractals etc, and quantization techniques like scalars (SQ) and vector (VQ). SQ involves processing the input samples individually whereas VQ involves processing the input samples in groups. An SQ involves mapping of each individual input to an output using some distortion measures. VQ involves mapping a group of inputs into a set of well-defined vectors using some distortion measures. VQ can be considered as a pattern recognizer where an input pattern is approximated by a predetermined set of standard patterns. VQ exploits the linear and nonlinear dependence among vectors. It also provides flexibility in choosing multi dimensional quantizer cell shapes and in choosing a desired codebook size. Another advantage of VQ over SQ is the fractional value of resolution that is achievable. This is very important for low bit rate applications where low resolution is sufficient. According to Shannon's Rate Distortion Theory [1] [3] [4] [23], it has been proved that better results would be obtained by processing a block of data as vectors instead of processing the data individually as scalars because vectors makes good use of the statistics of the signal.

Vector Quantization (VQ) is successful, effective, efficient, secure, and widely used compression technique over two decades. The strength of it lies in higher compression ratio and simplicity in implementation, especially in decoder. A vector quantizer (VQ) can be defined as mapping Q of L dimensional Euclidean space R^L into a finite subset Y of R^L,thus

$$Q : R^L \rightarrow Y$$

Where $Y = \{Xi; i = 1,2,3.....M\}$ the set of reproduction vectors (code vectors) and M is is number of vectors in Y (codebook). Thus the VQ compression process comprises of two functions, an encoder, which views the input vector x and generate the address of reproduction vector Xi from the codebook such that the distance (distortion) between

them is minimum. Second function is decoder, which has the same codebook as in encoder and it uses the address (index), reproduces the code vectors, for mapping of the image. [3]

VQ suffers through a drawback of having blockiness in decoded image; this is because of the edges in images that are lost due to the quantization of vectors. The qualitative performance of the decompressed image solely depends upon the design of codebook.

Even though many researchers [3] [4] [9] [11] [23] [26] [43] [44] [87] devised codebook design algorithms, still more techniques can be developed for the optimization of the codebook in order to bridge the gap between bit rate and quality. **The proposed research work involves constructing various novel techniques for codebook design in order to optimize compression performance and analysis of reconstructed images using different subjective and objective quality measures. In addition, being VQ is lossy compression technique, the novel neural network based method for prediction of loss is proposed.**

1.1 Motivation and Objectives

The famous Moore's law, which states that every 18 months the speed of computer doubles has an evil twin, every 18 months software becomes twice as slow. Due to an information explosion and enormous use of multimedia contents, a similar relationship can be formulated for images: no matter how big the memory budget of the images may seem to be, memory could be filled up much faster than expected. The appetite for bytes grows faster than the rate at which the memory budget grows.

Steward Brand in his famous book "The media Lab, Inventing future at MIT" (Published in 1989),focused on Telemedicine ,i.e. "image transfers over network" and image understanding using artificial intelligence, which is a reality today. The success of telemedicine applications solely depends upon the speed of the network and the quality of images transmitted and recovered. Losses in images may lead to the wrong diagnostics. Smaller bandwidth conditions, is still a reality in many countries in the globe. High compression with good quality is vital in such applications.

As discussed in the above paragraphs image storage and transfer requirements, the early work done by many researchers in attempt to meet compression and quality requirements and work done by M.A.Joshi [63][64][68] in area of image compression using vector quantization motivated to start work in image compression using neural

networks. Theme of implementing ***simple real time compression scheme for dedicated imaging devices*** also propelled to work in this area.

Following global and detailed objectives are geared up,

1.1.2 Global objectives of the proposed research

- To design a generic codebook, which will provide minimal distortion and maximize the compression ratio, when used for compression of gray and color images. This is achieved using the proper samples selected after observing their matching probabilities and training them using SOFM algorithm whose parameters are changed according to the mathematical characteristics of the input samples. These samples will preserve the edges in reconstructed images.
- Applying quality measures to the decompressed images in order to analyze the compression performance and use the analysis for the optimization of the codebook.
- Design codebooks using different color spaces and compare the performance in terms of quality and compression ratio with other VQ's and widely used JPEG compression scheme.
- Make use of suitable artificial neural network for predicting the loss (distortion) ,so that the quality of the decompressed image can be brought up to the mark.

1.1.3 Detailed objectives of the proposed research

- Still there is a need of a *single* generic codebook, which includes samples, which have highest probability density function of matching. It should contain error samples also, so that during decoding the respective errors are added in order to reproduce a sample close to original one. The codebook must encode (compress) all kinds of images i.e images with different characteristics, frequency components etc. In majority papers that are surveyed, testing is done on specific images only, especially facial or close object.
- SOFM neural network is found to be an efficient algorithm in image coding. There are some drawbacks of SOFM, which can be investigated and relative changes in algorithm or training mechanism is required instead of using SOFM algorithm directly.
- The training of the codebook should be done in such a manner that it will contain variety of samples from different images. The samples will be selected based on rigorous experimentation, applying mathematical procedures and operators used in

image processing such as sobel, canny edge operators to select edge-based samples. **This will serve as novel contribution.**

- The trade off between size of codebook, the block size used during training of codebook and testing of images for compression and decompression, *compression ratio (bit rate) and the quality of reconstructed image should be wisely balanced.*
- Until now, the quality of images compressed with VQ is evaluated by calculating its SNR or PSNR .The PSNR cannot be only measure of quality and many times psycho visual quality of image is bad and PSNR is good and vice versa. There is higher degree of need to evaluate quality with few more quality measures available in literature. Psycho visual quality measure such as mean opinion score can also be included as subjective quality measure.
- Very few papers [69] [70] [71] used VQ with SOFM for medical images. VQ being is strong in providing enormous compression, it will be powerful in Telemedicine based applications, however it is little lower in quality due to loss, which many times not accepted by radiologist. The texture of image is degraded, which is also used as basis of diagnosis in some cases. Some more work is required to get better quality and compression for medical images, which in turn will be used for diagnostic purposes.
- Supervised Neural networks are used as predictors in random process and found to be successful in many engineering applications in which predictions are done based on the statistics. *The loss can predicted out to certain extent by using a proper back propagation network and image quality can be improved further.* **This will be a novel contribution.**
- The similar kind of codebook can be designed for color images also. The experimentation is done mainly on RGB color space, ***an attempt can be made on other color spaces like HSI, HSV, YCbCr and YIQ and see the effect on performance of compression on quality grounds.*** The same quality measures can be applied to JPEG images compressed with different quality and can be compared with the VQ compression with respect to quality, and bit rate. **This will serve as another important contribution.**
- Finally, but important, the entire design methodology proposed must be such that it can be implemented with least complexity and cost in dedicated real time imaging systems using VLSI technology.

1.2 Problem Definition

The normal trend was to use random codebook. The thrust was on getting more and more compression at the cost of quality .Post processing can be done in order to improve the quality. An integrated approach of good compression ratio along with good quality is to be addressed. As discussed in previous section, the proposed research aims towards compression and decompression of gray level and color images using vector quantizer designed with selective training of SOFM neural network. The novelty will be selective training, which is based on selected features including frequency sensitive, and difference between input and codevector for variety of input samples of image sub blocks. The proposed *single stage* VQ will bridge the gap between compression ratio and quality very well. The quality analysis is carried out by applying variety of quality measures in order to evaluate the performance of the proposed process and compare it with existing and widely used techniques devised by peer researchers.

Further, novelty was brought in by use of well-trained backpropagation neural network algorithm for prediction of loss occurred due to the distortion. The major objective is that the entire process must be successfully applied to color images and observe the effect of self-organization on different color spaces. The entire problem is broadly formulated as

"The Compression and Decompression of images using Vector Quantization by Self Organizing Kohonen Artificial Neural Networks."

1.3 Organization of the thesis

The thesis is organized into six chapters.

Chapter I – Introduction, briefly discusses the need of an image compression and choice of Vector Quantization (VQ) as compression scheme. It includes a brief theory of VQ for bringing the clarity in presenting the motivation and the global and detailed objectives for carrying out the proposed study. It concludes with organizational aspects of the thesis report.

Chapter II – Review of literature survey describes the comprehensive literature survey that was undertaken to review the different techniques of Vector quantizer design, quality measures for the objective and subjective analysis of quality of decompressed images. In this regard, work done and presented by researchers round the globe in International journals like IEEE transactions on Image processing , IEEE transactions on Neural networks, IEEE transactions on Communications, IEEE transactions on Circuit

and Systems for video technology, Journal of Electronic Imaging (EURASIP), Journal of Information Science, GVIP journals , Journal of Engineering Applications of Artificial Intelligence etc, are deeply studied. The IEEE conference Proceedings in relevant areas, have been reviewed. More than 100 papers from year 1984 to year 2007 are reviewed. Finally, the significant conclusions derived from literature survey are summarized and the need for proposal is defined.

Chapter III Design techniques for Vector Quantizers describes the theoretical aspects of Vector Quantizer design, Kohonen's Self Organizing neural networks algorithm and the quality measures used in quality analysis of compression scheme. The comparison of earlier VQ design and VQ with SOFM is also exposited. Finally, the theoretical aspects of color spaces/colors models and their conversions is presented.

Chapter IV Implementation of Vector Quantization based Image Compression for gray Scale images: The Quality Improvement approach deals with the experimentation procedures, design procedures for Enhanced VQ, Generic VQ and Generic with error VQ along with actual training and testing aspects for gray image compression. Procedure for application of back propagation VQ to enhanced and generic is also presented. The results, discussions and brief conclusions of 16 experiments, which are divided into 7 main experiments, are presented along with few images .The results of entire experiments are summarized at the end.

Chapter V Compression of Color Images Using Vector Quantizers Designed with Different Color Spaces: the Quality Perspective deals with experimentation with color images and VQ designs with different color spaces. Total 14 experiments, which are divided into 5 main experiments, are presented along with results, comparisons, discussions and brief conclusions of the proposals.

Chapter VI Conclusions from results and Future Directions describes the significant conclusions obtained from the present experimental verifications and suggests future direction for continuation of research in the same area.