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An Intelligent Method Based Medical Image Compression

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Abstract: Compression methods are important in many medical applications to ensure fast interactivity through large sets of images (e.g. volumetric data sets, image databases), for searching context dependant images and for quantitative analysis of measured data. Medical data are increasingly represented in digital form. The limitations in transmission bandwidth and storage space on one side and the growing size of image datasets on the other side has necessitated the need for efficient methods and tools for implementation. Many techniques for achieving data compression have been introduced. Wavelet transform techniques currently provide the most promising approach to high-quality image compression, which is essential for Teleradiology. This paper presents an approach of intelligent method to design a vector quantizer for image compression. The image is compressed without any loss of information. It also provides a comparative study in the view of simplicity, storage space, robustness and transfer time of various vector quantization methods. The proposed approach presents an efficient method of vector quantization for image compression and application of SOFM.

Keywords: Medical Imaging, Neural Networks (NN), Vector Quantization, Wavelet Transformt, SOFM.

1. INTRODUCTION

Medical image compression plays a key role as hospitals move towards filmless imaging and go completely digital. Image compression will allow Picture Archiving and Communication Systems (PACS) to reduce the file sizes on their storage requirements while maintaining relevant diagnostic information. Teleradiology sites benefit since reduced image file sizes yield reduced transmission times. Even as the capacity of storage media continues to increase, it is expected that the volume of uncompressed data produced by hospitals will exceed capacity and drive up costs. This paper will propose an approach to improve the performance of medical image compression while satisfying both the medical team who need to use it, and the legal team who need to defend the hospital against any malpractice resulting from misdiagnosis owing to faulty compression of medical images. The improved compression performance will be accomplished by making use of clinically relevant regions as defined by physicians.

In medical imaging, lossy compression schemes are not used due to possible loss of useful clinical information and as operations like enhancement may lead to further degradations in the lossy compression.

Hence there is a need for efficient lossless schemes for medical image data.

Need for Coding

Need for coding algorithms: A common characteristic of most images is that the neighboring pixels are correlated and therefore contain redundant information. The foremost task then is to find less correlated representation of the image. Two fundamental components of compression are redundancy and irrelevancy reduction. Redundancy reduction aims at removing duplication from the signal source (image/video). Irrelevancy reduction omits parts of the signal that will not be noticed by the signal receiver, namely the Human Visual System. In general, three types of redundancy can be identified

- Spatial Redundancy or correlation between neighboring pixel values.
- Spectral Redundancy or correlation between different color planes or spectral bands.
- Temporal Redundancy or correlation between adjacent frames in a sequence of images.

The compact representation of an image while maintaining all the necessary information without much loss of data is referred to as Image compression. It can be classified into two types:

(i) Lossless and

(ii) Lossy compression.

Again lossy compression can be broadly classified into two types, namely Scalar Quantization (SQ) and Vector Quantization (VQ)[1]. A popular technique for source coding of image and speech data, since 1980 is VQ. VQ involves processing the input samples in groups into a set of well-defined vectors using some distortion measure.

Most of the benefits of image compression include less required storage space, quicker sending and receiving of images i.e., the transfer rate is high, and less time lost on image viewing and loading. One of the example to illustrate this, is in medical application. The constant scanning and/or storage of medical images and documents take place. Image compression offers many other benefits, as information can be stored without placing large loads on system servers . Depending on the type of compression applied, images can be compressed to save storage space, or to send to multiple places for particular application. At the destination, these images can uncompress when they are ready to be viewed, retaining the original high quality.

Image compression also plays an important role to any organization that requires the viewing and storing of images to be standardized, such as a chain of retail stores or a federal government agency. In the retail store example, the introduction and placement of new products or the removal of discontinued items can be much more easily completed when all employees receive, view and process images in the same way. Federal government agencies that standardize their image viewing, storage and transmitting processes can eliminate large amounts of time spent in explanation and problem solving. The time they save can then be applied to issues within the organization, such as the improvement of government and employee programs.

2. MEDICAL IMAGE & COMPRESSION

The compression of medical images has a great demand. The image for compression can be a single image or sequence of images. The medical community has been very reluctant to adopt lossy algorithms in clinical practice. However, the diagnostic data produced by hospitals has geometrically increased and a compression technique is needed that results with greater data reductions and hence transmission speed. In these cases, a lossy compression method that preserves the diagnostic information is needed.

Medical image sequences called Volumetric Medical Image (VMI) or 3-D medical data needs efficient image compression solving storage and transmission problems and also preserving diagnostic information. In these cases, a lossy compression method that can preserve the diagnostic information is needed. Visually indistinguishable resultant images at high quality can be obtained using lossy compression techniques, for compression rates much greater than those obtained by lossless compression techniques. That is, human eye cannot detect a difference between the original image and the compressed then decompressed image with the lossy compression method.

Compression is not just about the storage costs, it is also about transmission time, imaging apparatus utilisation and convenience/comfort of the patient. Compression techniques can reduce file size and transmission time, thus improving overall care. Image compression techniques take advantage of redundancy that occurs. There are different types of redundancy. Each compression methodology will exploit one of these redundancies. The different types of redundancies are spatial, temporal and spectral.

The research presented here will focus on the first of these three types of redundancies although the techniques can be used in the others also. It will make use of spatial redundancies since static spatial X-rays will be used.

3. IMAGE COMPRESSION USING VQ

In Vector Quantization **[3][4]** an input image is divided into small blocks called Training Vector (x_j (k).)This Training Vectors can be closely reconstructed from applying a transfer function (Q) to a specific region of an input image itself, which is called Codebook $(\hat{y}_i(k))$.Thus, only the set of transfer functions, which have fewer data than an image, were required for reconstruct the input image back. A transfer function (Q) is defined as follows.

$$Q \;:\; R^k \rightarrow \boldsymbol{Y},$$

Where Y = {x_i: i = 1, 2, ..., N} that recreate and N is the number of vectors in Y. VQ consists of 2 parts.
i) Encoder
ii) Decoder
The encoder takes an input vector and outputs the index of the codeword that offers the lowest distortion .In this case the lowest distortion is obtained by evaluating the Euclidean distance between the input vector and each codeword in the codebook, once the closest codeword is found, the index of that codeword is sent through a channel .When the decoder receives the index of the codeword, it replaces the index with the associated codeword. In this method a problem arises, i.e, the image quality is not better but as the index is transmitted less channel bandwidth is required.
But image quality can be improved by application of wavelet transform and more it can be efficient by using SOFM for vector quantization. These are described in section

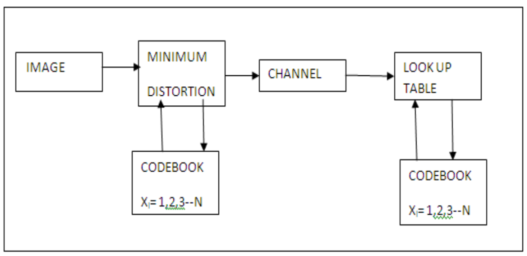


FIG1. Image Compression Using VQ

METHOD 1: Algorithm for selection of codebook from wavelet coefficient.

1) The input image is subdivided into blocks and from that training vector is obtained in form a column vector(N*1).

2)Then wavelet transform is applied to the image for 2 level decomposition .From the approximation coefficient the codebook of size (1*16) is selected .

3)The minimum distortion(Euclidean distance) between the training vector and the codebook is calculated .

4) Then the index which has minimum distortion is transmitted.

5) At the decoder the codebook is recovered from the transmitted index .A matrix which has the dimension equal to the wavelet coefficient is generated.

6) Then IDWT is applied to this new matrix

METHOD 2: Algorithm for selection of codebook from image.

1) The input image is subdivided into blocks and from that a codebook is randomly selected of size(1*N)

2)Then wavelet transform is applied to the image for 2 level decomposition .From the approximation coefficient the Training vector is found and converted to a column matrix of size(N*1)

3) The minimum distortion(Euclidean distance) between the training vector and the codebook is calculated .

4) Then the index which has minimum distortion is transmitted.

5) At the decoder the codebook is recovered from the transmitted index .A matrix which has the dimension equal to the wavelet coefficient is generated.

6) Then IDWT is applied to this new matrix.

The result is better in case of TYPE 1

As the result obtained from all the methods related to VQ for image compression in the previous section a has proved not to be optimal because of random selection of codebook and not updating it which generates an image not 100% approximate the original image.

Vector quantization an effective algorithm for updating the codebook and is applied i.e, SOFM (Self Organization Feature Map) [9],[10].
In the following section application of SOFM is combined with wavelet to increase the quality of the reconstructed image.

4. DESIGN OF CODEBOOK

The code vectors **[5]** are generated by evaluating the characteristics of the specific image sub samples, which are determined through rigorous mathematical operations and training the selected samples by

Kohonen's SOFM artificial neural network with adjustable learning rate and initializations conditions followed by application of discrete wavelet transform (DWT). The testing of the codebook is done with variety of images and the compression performance is evaluated by using objective and subjective quality measures. Unlike many researcher's who use only Peak Signal to Noise Ratio (PSNR) for determining the quality which is deceptive many times, we have employed other quality measures such as Image fidelity, structural content, mean structural similarity index, universal quality index, spatial frequency measure and spectral activity measure along with PSNR.

4.1 PROPOSED ALGORITHM

1) The 256x256 pixel image in 4x4 pixel blocks inorder to generate a 16-element vector, which acts as input to SOFM neural network

2) Statistical operations on pixel blocks such as calculation of mean, standard deviation, variance is performed

3) Depending upon the standard deviation change the initialization of weights, since weights of SOFM neural net serves as code-vectors in codebook, learning rate and possibly number of epochs are changed in order to prevent over training of certain input vectors

4) The generated code-vectors are transformed using 'haar' or 'db1' mother wavelet up to one decomposition level. Thus every code-vector is transformed into LL, LH, HL and HH i.e. into low frequency approximation coefficients, horizontal, vertical and diagonal coefficients. The size of code-vector is reduced to 4 elements from 16elements due to down sampling.

5) The approximation coefficients and horizontal coefficients are combined together to form 16 element vector, similarly the vertical and diagonal coefficients are combined to form another16 element code-vectors. Thus due to such combination, two code vectors corresponding to one SOFM-generated code-vector are generated. So two codebooks are generated. The size of the codebooks is 1K each

6) In this method compression is more and the result is better than other VQ method and effect of artifact is very less.

4.2. QUALITY MEASURES

We have employed few quality measures that are normally used for the quality analysis of decompressed images.

1. **Mean Square Error (MSE):**

   MSE $=\sum_{j=1}^{M}\sum_{k=1}^{N}[X(j,k)-\hat{X}(j,k)]^2/MN$

   Where X is the input vector and $\hat{X}$ is a codebook vector. M*N is the image size in pixels. MSE should be low for less distortion which means better quality images

2. **Peak Signal To Noise ratio (PSNR):**

   PSNR = $10\log\left(\frac{255\times255}{MSE}\right)\,dB$

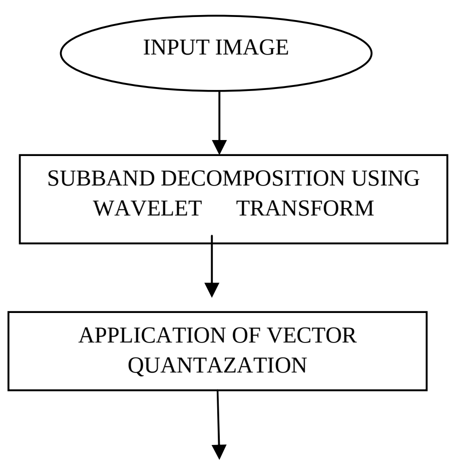
For perfect reconstruction it should approach to infinity. Normally it is in the range of 35 to 55 dB.

3. Normalized-Correlation-Coefficient

NK = $\sum_{j=1}^{M}\sum_{k=1}^{N}\left[\frac{X(j,k)\cdot\hat{X}(j,k)}{\sum_{j=1}^{M}\sum_{k=1}^{N}[X(j,k)]^2}\right]$

Normally SC, IF and NK are in the range of 0 to 1. A value very near to or equal to one is the best.

5. FLOW CHART OF IMAGE COMPRESSION TECHNIQUE BY VECTOR QUANTIZATION USING SOFM,WAVELET



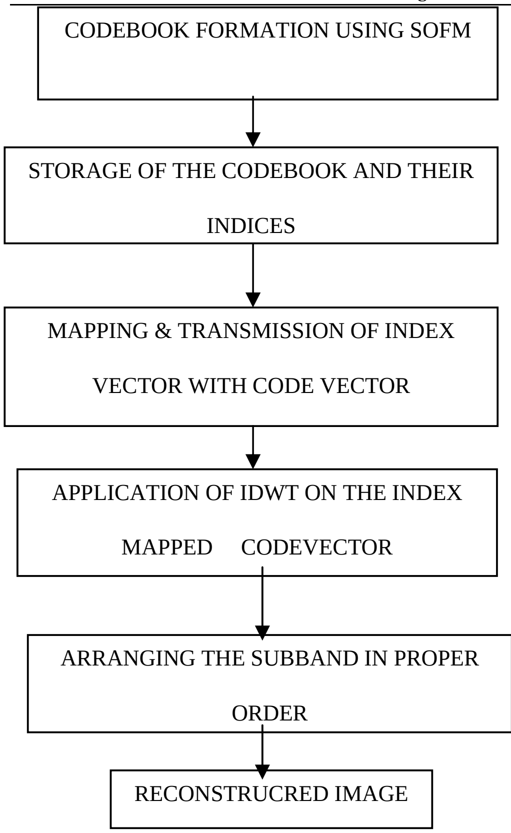
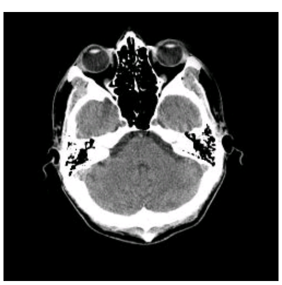
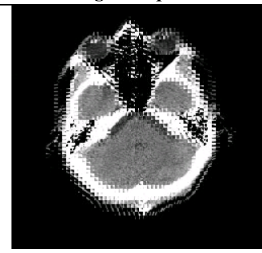
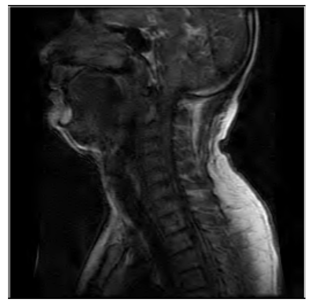


Fig.2. Flow Chart for Image Compression

6. RESULT & CONCLUSION







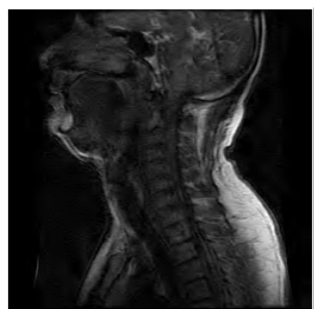


Fig 3. Original image(top) and Reconstructed image (bottom) with VQ using Proposed Method .

The figure shows the result of original as well as the compressed images. The compression algorithm is not only provide good compression results, but it also should be robust enough to withstand transmission errors to a certain degree. As a result of the collective benefits that JPEG 2000 has to offer, despite its computational complexity, it is the lossless compression of choice for medical images. It can help to healthcare facilitators in an effective, rapid manor, efficient database access and remote access to digital libraries, all aiding to reduce the waiting times for diagnosis. Actual studies are conducted in order to extend the proposed approach to higher block dimensions (4x4) and to the VQ video images. There is no single algorithm or methodology that satisfies all the requirements that use the vector quantization for image compression as every algorithm has its own merits and demerits.

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