SUBBAND CODING OF 3D MRI IMAGES USING OCTTREES

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ABSTRACT

In this paper we discuss a method of compression of 3-D MRI images. A subband coding scheme with an octave splitting is proposed. The higher frequency subbands are encoded using an octtree structure. Octtrees provide a convenient data structure to store the sparse information present in the higher frequency subbands. Each unit block of the octtree is coded using a hybrid vector and scalar quantization scheme. The baseband is encoded using a DPCM based method using a nonlinear neural network predictor. This scheme provides an elegant way of compression of MRI images with minimum error.

1. INTRODUCTION

In this paper we discuss a method of compression of Magnetic Resonance Images (MRI) which are three dimensional signals with high correlation between the pixels along all the three axes. We propose a 3-D subband coding [1] method to compress these images. The signal to be coded is split into a number of frequency bands and each band is encoded separately. The signal is then reconstructed from these bands. It has been seen that this method gives a higher compression, than coding the entire signal as a whole. A number of techniques have been proposed for the compression of the subbands. These techniques use both the intraband correlation of the pixels as well as the interband correlation. Recently subband coding has been used for three dimensional sources like a sequence of frames (video). Coding of these images are slightly different, as the interframe correlation in a video is more motion and less deformation and in medical images it is more of deformation.

The higher frequency subbands in the decomposition have sparse data and their encoding offers a challenging task. Octtrees structures, a three dimensional generalization of binary and quad-tree structures [3] can be used to isolate the sparse points with very little overhead for the tree structure. The occurrence of small groups of points rather than isolated single points makes more suitable the use of vector quantization [5]. The baseband has to be encoded carefully as it contains the most useful information, use of DPCM based schemes is ideal for this band. Use of a nonlinear predictor [2] has been shown to provide better compression and hence is used to code the baseband.

2. SUBBAND CODING

A subband coding system consists of an analysis filterbank, an encoder, a decoder and a synthesis filterbank. The analysis filterbank splits the signal into different frequency bands. Each of these bands is then coded by the encoder using different techniques with different bit allocations depending upon the characteristics of the band. To recover the signal, the decoder decodes the corresponding bands and the synthesis filterbank reconstructs the signal.

For subband coding, it is required that the analysis/synthesis filter banks have a perfect or nearperfect reconstruction capability in the absence of any coding. It is also required that the overlap of adjacent frequency bands is minimum to avoid aliasing. Quadrature mirror filters have these properties and hence are suitable for subband coding.

The simplest form of the filterbank is a two channel filter bank. These filterbanks can be used recursively to form a tree structured filterbank. The tree structure can be either a complete tree or an octave splitting where only the lowest frequency band is split recursively. Recently nonuniform splitting based on entropy/rate-distortion characteristics has been used in the wavepacket algorithm. For two (three) dimensional signals, separable filter can be conveniently used for the subband splitting. The signal is first split along one axis and then using the same filterbank, is split along the other axis.

In the proposed method, we use an octave splitting of the signal. The signal is first split using a two channel filterbank to give the level 1 subbands, the lower

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level 1 band is then again split into two bands called the level 2 subband. For three dimensional signals this gives us 15 bands as shown in the Fig. 7.

3. QUANTIZATION OF THE SUBBANDS

3.1. Coding of the baseband

The baseband contains the most important information in the subband decomposition. It has also been seen that this band generally has a autocovariance matrix with high values and hence can be encoded using DPCM based techniques. For causal prediction using only the first neighbor, three dimensional signals require 13 pixels for prediction as shown in Fig. 2. We use a nonlinear neural network based predictor for this band. The predictor is a three layer perceptron which is trained using the back-propagation algorithm [2]. It has been shown that this predictor performs better than a linear predictor. The error between the prediction and the original pixel value is entropy coded [6] to give a lossless coding scheme for this subband.

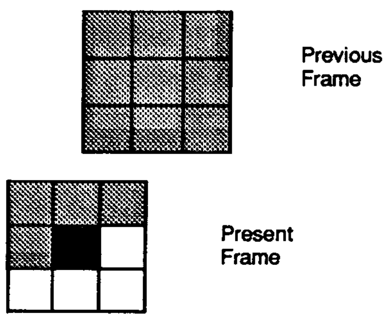

Figure 1: Three dimensional prediction, using 9 pixels from the previous frame and 4 pixels from the present frame

3.2. Coding of higher frequency subbands

It is generally true that the higher frequency subbands contain much lesser information than the baseband. One can also find large regions with no or very less amount of information. Coding of these higher frequency subbands presents a very interesting problem. A number of methods have been proposed including the zerotree algorithm to code the higher frequency subbands. In this paper we explore a method of coding the higher frequency subbands using Octtrees. A hybrid scheme using both scalar and vector quantization is used to code the non-zero pixels.

Octtrees : A one dimensional signal can be encoded using binary trees as follows. Based on some criterion, it is determined if the signal contains significant information. If it contains significant information, it is split into equal parts. Each part is then checked to see if it contains significant information, if it does, it is further split. This process is repeated untill the smallest codeable unit is reached. This method of spiting gives an unbalanced tree structure. The tree is encoded by giving each node a value 0 if is not split and a value 1 it contains useful information (and hence is split). It is then necessary only to code the information containing segments, with the binary tree structure as the overhead.

An octtree is a three dimensional generalization of a binary tree. We use a bottom-up approach to construct the octtree, variance of the block is used as the criterion which determines if a block contains significant information. We start with a minimum codable block called the unit block A group of 8 adjacent blocks (2x2x2) is created and the variance of each one of them is determined. If the variance of all the blocks is less than some threshold, the blocks are grouped together into a bigger block, which forms a node in the previous layer of the octtree. This process is repeated untill the largest possible block is reached. Basically we start with a complete tree and prune it from the bottom based on the variance. This pruning can also be based on rate-distortion criterion

The unit block size used was 2x2x2 pixels for the level 2 subband and 4x4x4 pixels for the level 1 subband. (The base band is level 2 subband Fig. 7)

Hybrid quantization We use a combination of both scalar and vector quantizers to quantize the information containing blocks of size 2x2x2 pixels. We have chosen a VQ scheme here because it was found that even though there was sparse information in the higher frequency subbands, they were not isolated points but a group of points bunched together. But due to the octtree decomposition, the blocks sometimes contain isolated single points and hence need to be scalar quantized. An overhead of 1 pixel per block is required to determine if it is going to be scalar or vector quantized. The decision on which block has to be VQ and which has to be SQ is made by fixing a threshold on the VQ error, if the error is greater than the threshold, each pixel of the block is scalar quantized. A single stage VQ is employed and the codebook is obtained using the Generalized Lloyd's Algorithm.

The unit blocks of the level 2 subbands are encoded directly by the above scheme. The unit blocks of the level 1 subbands are further subdivided into eight blocks and each subblock is encoded using the hybrid quantization scheme.

The choice of using 4x4x4 blocks in the higher frequency subband instead one more level of octtree splitting was made because it was seen that a high percentage of the 4x4x4 blocks which contained information had information in majority of the subblocks and hence the octtree structure gave little gain.

4. SIMULATION AND RESULTS

The proposed technique was used to compress a 8-bit MRI brain image with dimensions of 256x256x64. A 16-tap QMF filter of the Johnston family [4] was used for the subband decomposition. A nonlinear neural network predictor was trained and used to encode the base band, The prediction error was entropy coded using huffman codes.

The octtree structures for the higher frequency subbands were constructed using the variance criterion with a threshold of 10 for the level 1 and level 2 subbands. Further investigation is needed to find the optimal thresholds.

Blocks containing significant information were encoded using the hybrid scheme, a VQ with a codebook size of 1024 was used. The same codebook was used for all the subbands. A MSE threshold of τ_{mse} was used to determine if scalar quantization was required. A step size α was used for the scalar quantization.

Different bit-rates can be achieved by varying τ_{mse} and α. The graph in Fig. 2 shows the PSNR for different values of τ_{mse} and α. The graph in Fig. 3 shows the PSNR for different bitrates, the optimal value of τ_{mse} and α needs to be chosen for the required bitrates. It was seen that good quality reconstructions were obtained for bitrates between 1 and 2 bits per pixel. We use the PSNR as a quantitative measure of the performance. The Figs. 5 and 8 show a original and compressed image slice, it is seen that the images have very little visual degradation.

5. CONCLUSION

We have shown a method of compression of 3-D MRI images using octtrees to encode the higher frequency subbands, with good rate-distortion performance. Use of octtrees is ideal for encoding the bands with sparse information. Furthermore it is seen that use of vector quantization to code the higher frequency subbands is desirable as the information bearing pixels are seldom isolated single points.

6. REFERENCES

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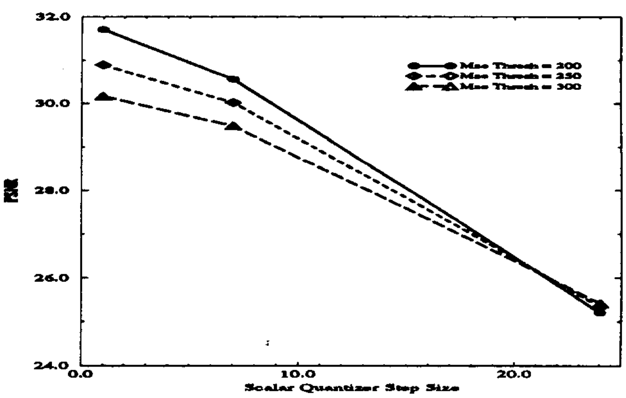

Figure 2: PSNR for different values of stepsize and thresholds

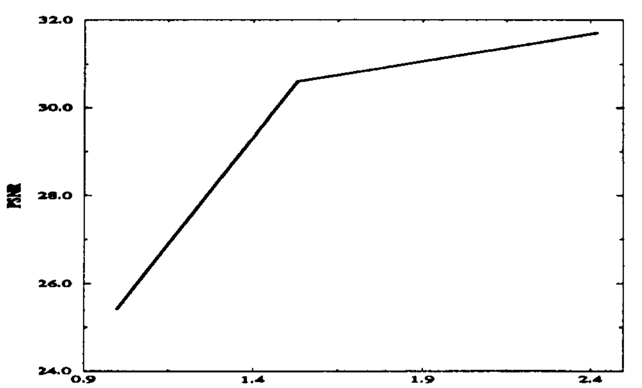

Figure 3: PSNR performance for different bitrates

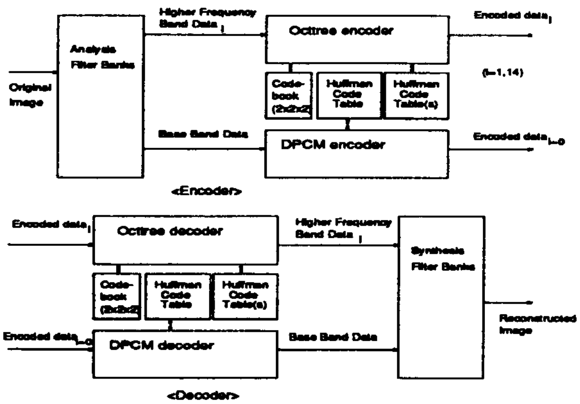

Figure 4: Schematic Diagram of the Codec

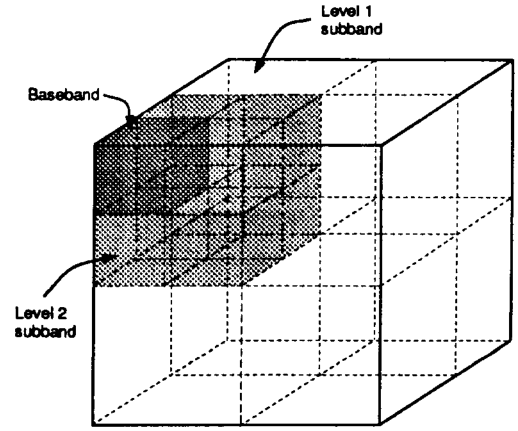

Figure 7: Configuration of the subband splitting

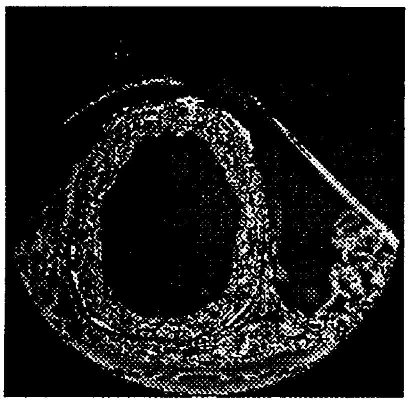

Figure 5: Original image slice

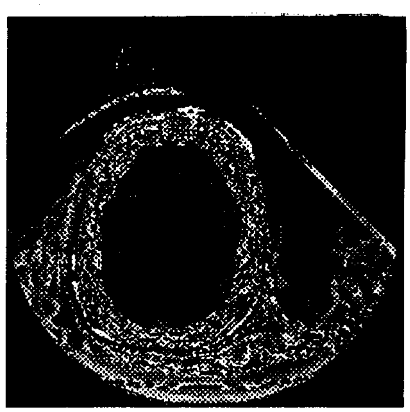

Figure 8: Compressed slice at 1.5bpp

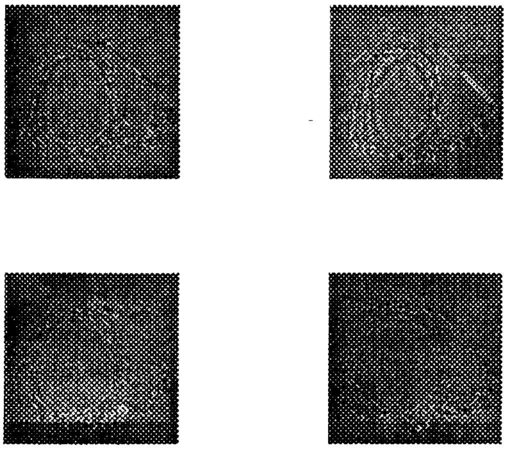

Figure 6: Four slices of a level 2 subband

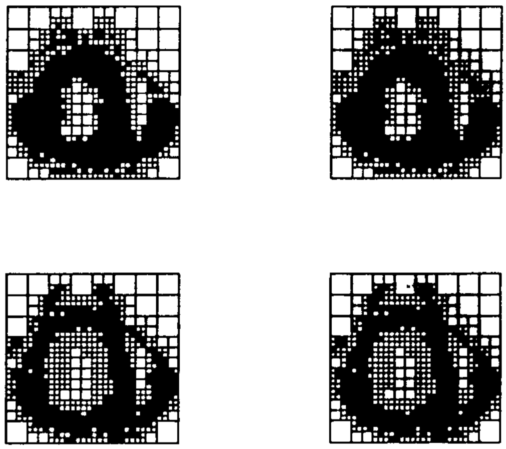

Figure 9: Octtrees for the slices shown in Fig. 4