International Journal of Soft Computing 3 (1): 33-37, 2008
ISSN: 1816-9503

Region Based Compression of MRI Sequence Using Shape Adaptive Wavelet Transform Coding

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Abstract: Region-based coding is an important feature provided in today's image coding schemes including SPIHT and JPEG2000 as it allows different regions of interest in an image to be encoded at different bit rates and hence at different qualities rather than encoding the entire image with a single quality constraint. This study proposes an algorithm for three-dimensional region-based coding of volumetric medical datasets like MRI sequence. A 3D SA-DWT is used to decompose the data with multiple, arbitrarily shaped regions to obtain the representation of the regions in the transform domain. Then, a modified 3D SPIHT coding algorithm based on an unbalanced 3 structure is adopted in 3D region-based coding. This coding scheme offers good rate-distortion performance with additional features such as distortion scalability and flexibility in precise rate control. Experimental results show that the proposed algorithm outperforms the other coding schemes based on SPIHT algorithm in terms of R-D performance and quality of the image.

Key words: Medical image compression, shape adaptive wavelet transform coding, SPIHT algorithm

INTRODUCTION

Medical imaging modalities, such as Magnetic Resonance Imaging, Computed Tomography, Ultrasound, Single Photon Emission Computed Tomography and Positron Emission Tomography produce multiple slices of images with each slice providing information of a different cross section of the part of the body under examination Multispectral-imaging techniques generate multiple images of the same scene at different spectral wavelengths. The applications, such as image database, retrieval and image transmission require an efficient image compression scheme to reduce the cost of image storage and transmission time. For accurate diagnosis, lossless compression of medical image data is required to preserve all the information. However, lossless compression algorithms have a moderate compression ratio, typically in the range of 3:1. For medical applications, only specific regions in the volumetric data are of interest. For example, in MR imaging of the skull, the physician is mostly concerned about the features inherent in the brain region. High compression ratios can be achieved by allocating more bit rate for Region of Interest (ROI) and less bit rate for the remaining regions, i.e., the background. Region-based image coding schemes using heterogeneous (multiple) quality constraints are especially attractive because they not only can well preserve the diagnostic features in region(s) of interest, but also meet the requirements of less storage and shorter transmission time for medical imaging applications.

The main advantage of the proposed technique is that it supports Multiple-Region Multiple-Quality (MRMQ) coding using unbalanced orientation trees. By this method, total bit rate can be allocated among multiple ROIs and background accurately, depending on the quality constraints. We implemented 3D MRMQ coding algorithm and proposed a bitstream structure for multiple ROIs. Experimental results show that this technique offers reasonably well rate-distortion performance for coding multiple ROIs.

MATERIALS AND METHODS

Shape adaptive DWT for ROI: Region-of-Interest (ROI) coding is an important feature in current image compression codecs, which allows different regions of an image to be compressed at different qualities. Especially in medical imaging, ROI coding can help compression methods to focus on those regions that are important for diagnostic purposes. SPIHT (Said and Pearlman, 1996) and JPEG2000 (Taubman and Marcellin, 2002) both support ROI coding but they use different techniques to incorporate this feature. In JPEG2000 exploits intra-band dependency and adopts EBCOT algorithm for coding bit

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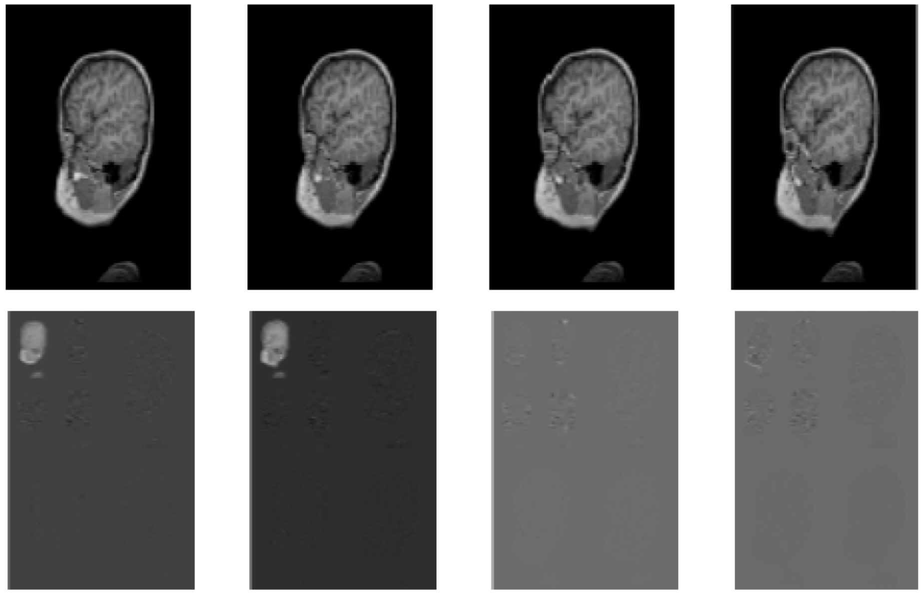

Fig. 1: Sample slices of brain MR Images with 1mm thickness and 3-D shape adaptive wavelet decomposition with 2 levels in spatial and 2 levels in temporal domain

planes of wavelet coefficients. In this, Taubman (2000) partitioned each subband into (fixed size) code blocks, which are numbered in raster scan order. Each code block is coded independently by employing fractional bit plane coding method and context based arithmetic coding. So a separate embedded bit stream is generated for each code block. R-D optimization over all code blocks is achieved by Post-Compression Rate-Distortion (PCRD) operation, which truncates each of the embedded bit streams of the code block to minimize the overall distortion subject to a given bitrate.

In contrast to JPEG2000, Park and Park (2002) employs shape-adaptive discrete wavelet transform, for wavelet decomposition of an image containing the ROI. Once the ROI coefficients are identified, SPIHT coding algorithm will be applied on these coefficients to create the embedded bit stream. Schwarz and Muller (2000) use an object-based extension of SPIHT algorithm in order to code the ROI coefficients efficiently by taking advantage of the ROI information in the transform domain. When the spatial orientation trees are established in the initialization step of SPIHT, Tasdoken and Cuhadar (2002) use the ROI information obtained from decomposition of the ROI mask to mark the spatial orientation tree. If all coefficients or some coefficients in a spatial orientation tree belong to the ROI, the corresponding tree is marked as an ROI tree. If all coefficients in a tree are outside the ROI, this tree is identified as a background tree. The background tree is skipped at the initialization stage. Also when a node and all its descendants in a spatial orientation tree are outside the ROI, the tree is pruned from that node. By doing so, no information about coefficients outside the ROI needs to be coded.

To support Region of Interest (ROI) coding, it is necessary to identify the wavelet transform coefficients associated with the ROI. Commonly, the number of transform coefficients that are related to the reconstruction of ROI is different to that of the ROI in image domain. We have to keep track of the coefficients that are involved in the reconstruction of ROI through each stage of decomposition. Shape adaptive Discrete Wavelet Transform (SA-DWT) proposed by Li and Lei (2000) provides a simple solution to this problem. SA-DWT has two significant features. One is that the number of coefficients after SA-DWT is identical to the number of pixels in the ROI of the original image; the other is that spatial correlation and locality properties of wavelet transform and self-similarity across subbands are well preserved after SA-DWT. These features make bit-plane coding, such as the one used in SPIHT, still applicable for encoding ROIs in an image. It is shown that SA-DWT is capable of achieving high coding efficiency for arbitrary shape region-based coding.

An important feature of SA-DWT is that the spatial correlation, locality and shape of the ROI are all well preserved. SA-DWT retains the multi-resolution property of wavelet transform, which is decomposition of an image into different resolution levels. A low-resolution reconstruction of an arbitrary shape ROI can be obtained using lowest frequency subband coefficients; incorporating higher frequency subband coefficients progressively, higher resolution reconstruction can be obtained. State-of-the-art coding schemes, SPIHT and JPEG2000, both use wavelet transform prior to coding and produce embedded bit streams that provide the features of resolution and distortion scalability. Thus, we can reconstruct the source image at low spatial resolution and low quality from part of the embedded bit stream. By progressively decoding more bits, higher spatial resolution and better quality image will be obtained. SPIHT exploits inter-scale dependencies between wavelet coefficients based on set partitioning sorting and spatial orientation tree.

3D MRMQ-SPIHT algorithm with unbalanced tree: The main objective in applying three-dimensional coding schemes is to exploit the correlations between image pixels across the third dimension (inter-slice or temporal direction) to achieve better compression ratio. A new method based on optimal 3D coefficient tree structure proposed by Tasdoken and Cuhadar (2003) for video coding, establishes 3D coefficient trees according to the relationships of coefficients in the spatial and temporal dimensions. 3D SPIHT coding scheme is extended from 2D SPIHT algorithm. Figure 2 shows a general scheme for the 3D SPIHT coder.

An image sequence is a group of slices called GOS. The length of the GOS size has an immediate effect on the compression algorithm. Large GOS sizes results in better compression ratios but require more memory both at the encoder and the decoder and causes coding delays. If the size of GOS is small, the boundary effect becomes significant, that is the PSNR drops severely at the GOS boundaries. This can degrade the overall coding performance. Typically, every 64 or 128 frames are put together for compression of volumetric data since decoding speed is not a major concern. 3D dataset is decomposed using three-dimensional wavelet transform into threedimensional sub bands, then modified SPIHT coding algorithm is used to create compressed bit stream using bit plane coding. 3D SPIHT decoder extracts information from the bit stream to create the reconstructed image sequence. Wavelet transform on three-dimensional data can be carried out by calculating one-dimensional transform along the temporal dimension and then applying the two-dimensional spatial transform on each resulting frame. At the next decomposition level, wavelet transform is applied on the lowest sub band and this process repeated in a cascaded manner, until desired

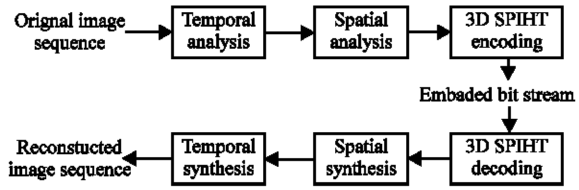

Fig. 2: 3D SPIHT coding scheme

number of levels is achieved. Alternatively 3D wavelet transform can be calculated by first performing one-dimensional transform along the temporal dimension until the required number of temporal decomposition levels is obtained and then carrying out the two dimensional transform on each temporal-transformed frame up to the desired number of spatial decomposition levels.

The representations for multiple volumetric regions constitute the conventional wavelet coefficient volume. The spatio-temporal orientation trees can be constructed by using the conventional SPIHT coding algorithm. However, when coefficients are to be encoded, an important issue is that there exist coefficients from different volumetric regions within the same spatio-temporal orientation tree. This problem can be solved by using different labels, which help to distinguish the coefficients from different volumetric regions. For encoding of the transform coefficients pertaining to a region, we partition all the spatio-temporal orientation trees using the conventional method and encode the information about wavelet coefficients in a particular volumetric region. This scheme directly extends the original algorithm to encode multiple regions at multiple quality constraints or at a specified quality constraint. Thus, independent bitstreams for each volumetric region are produced and a context-based arithmetic coding algorithm can then be used to improve coding efficiency by exploiting the dependencies between significant information of wavelet coefficients.

To further improve the performance of multiple volumetric regions coding, we will adopt unbalanced spatio-temporal orientation tree structure, to construct homogeneous trees where all transformed coefficients in a particular tree belong to the same volumetric region. In case of a single volumetric ROI, the transform coefficients are classified into three categories. By reorganizing the parent-children relations of coefficients in heterogeneous trees, an unbalanced tree structure with coefficients belonging only to the ROIs is created. In case of multiple volumetric regions, we modify the method to construct spatio-temporal orientation tree with the coefficients having same region label.

RESULTS AND DISCUSSION

For experimental verification on the performance of the proposed scheme, we use MR brain volumetric dataset (256×192×60 at 8bits) collected from the MRI scan centre. Some of the slices from the original sequence are shown in Fig. 3, which illustrates the ROI masks for slice number 10 and slice number 20 of the image sequence. For all experiments, rate is computed from actual (compressed) file sizes.

The rate-distortion performance of the Unbalanced Tree algorithm (UT-SPIHT) based on 3D SPIHT is evaluated and performed comparisons with other methods including Dyadic-wavelet SPIHT (DY-SPIHT), Packet-wavelet SPIHT (PK-SPIHT) and Optimal Tree SPIHT algorithms (OT-SPIHT) for the compression of MRI volumetric datasets.

The experiment is first performed with different interslice transform levels and fixing the GOS size at 64. In Table 1, the PSNR results by biorthogonal 9/7 and biorthogonal 5/3 at rate 0.1 and 0.4bpp are compared.

The results show that 9/7 wavelet transform has better R-D performance than 5/3 wavelet. However, increasing the number of interslice decomposition levels has little effect on compression performance. Moreover, we investigated the effects of different GOS sizes on compression performance. The number of spatial decomposition levels is chosen as 5 and interslice decomposition level is chosen as 2. Here, to form a 3D dataset, the whole image sequence is divided into groups of 8, 16, 32 and 64 slices to form different GOS sizes. ROI PSNRs are averaged over 64 slices. Table 2 provides the PSNR results for different GOS sizes at rates of 0.1 and 0.4bpp, respectively.

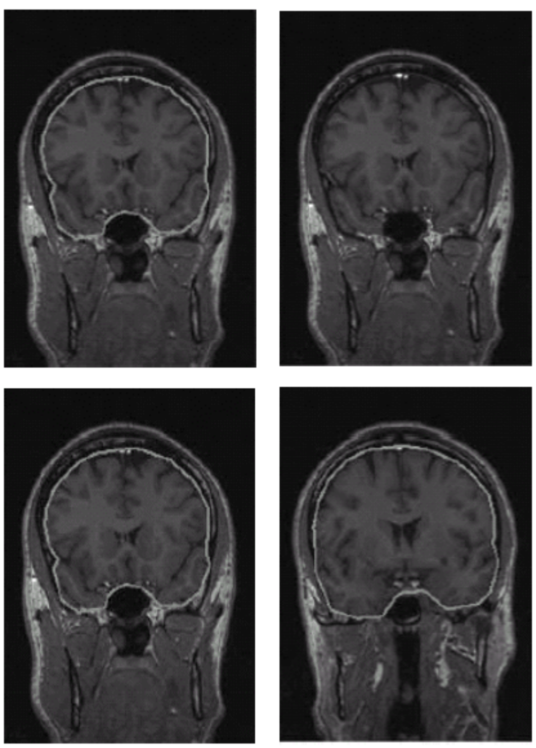

Fig. 3: Original slices 10 and 20 (left) and pre-segmented slices (right) of the image sequence

Table 1: Average ROI PSNR (dB) at rate 0.1bpp with different interslice transform levels (GOS size is 64)

Inter slice level	Average ROI PSNR (dB) using 9/7 wavelet transform 0.1 bpp	0.4 bpp	Average ROI PSNR (dB) using 5/3 wavelet transform 0.1 bpp	0.4 bpp
2	36.39	43.65	35.93	43.21
3	36.24	43.47	35.70	42.89
4	36.11	43.36	35.47	42.72
5	36.04	43.29	35.33	42.60

Table 2: Average ROI PSNR (dB) at 0.1bpp for different GOS sizes

Size of the group of slices	Average ROI PSNR (dB) using 9/7 wavelet transform 0.1 bpp	0.4 bpp	Average ROI PSNR (dB) using 5/3 wavelet transform 0.1 bpp	0.4 bpp
8	36.01	43.24	35.53	42.95
16	36.20	43.47	35.73	43.14
32	36.32	43.59	35.88	43.11
64	36.39	43.65	35.93	43.21

Table 3: Comparison of average ROIs' PSNR (dB) with different 3D coding methods at 0.4bpp

Size of the group of slices	PSNR in dB: Proposed scheme UT-SPIHT	OT-SPIHT	PK-SPIHT	DY-SPIHT
8	43.24	42.46	41.27	41.34
16	43.25	42.39	41.99	42.20
32	43.21	42.46	41.93	42.26
64	43.29	42.38	41.97	42.30

The results in Table 2 shows that average PSNR of the ROI increase with larger GOS size. However, one must note that increasing GOS size increases the memory requirements of the algorithm. If we assume that 8 bytes are required to store the wavelet coefficients, an 8-slice 256×192 pixel GOS requires about 3MB of memory, while a 64-slice GOS requires 24MBs. Once again, the R-D performance using 9/7 wavelet is slightly better than that of 5/3 wavelet for different GOS sizes.

To compare the proposed UT-SPIHT coding algorithm with DY-SPIHT, PK-SPIHT and OT-SPIHT algorithms, we perform experiments by setting the number of decomposition levels in the spatial domain to 5 except for DY-SPIHT, in which spatial transform levels are equal to interslice transform levels. The number of decomposition levels between the slices is set to 2, 3, 4 and 5 according to the GOS size of the image sequence, i.e. 8, 16, 32 and 64 respectively. Results of average PSNRs for the ROI at bit rate of 0.4bpp are given in Table 3.

As can be seen from Table 3, the proposed UT-SPIHT algorithm performs better than the other 3 algorithms for different GOS sizes. For GOS size of 16, it performs on average 0.6 dB better than the OT-SPIHT algorithm.

CONCLUSION

In this study, a novel algorithm is presented to encode the medical volumetric data based on the region of interest. The unbalanced tree structure is used in this scheme along with the 3D SPIHT to support the compression of multiple ROIs at different qualities for effective compression. In this scheme, 90% of the bit budget is used to code the ROI, which can reconstruct the images with high quality. Since other 3D coding algorithms do not support encoding of multiple ROIs, we compare the R-D performance of the scheme with the existing conventional SPIHT. The experimental results show that the proposed scheme provides a better PSNR while comparing with other ROI coding techniques.

REFERENCES

Li, S. and W. Lei, 2000. Shape-adaptive discrete wavelet transforms for arbitrarily shaped visual object coding. IEEE. Trans. Circuits Sys. Video Tech., 10: 725-743.

Park, K. and H.W. Park, 2002. Region-of-interest coding based on set partitioning in hierarchical trees. IEEE. Trans. Circuits Sys. Video Tech., 12: 106-113.

Said, A. and W.A. Pearlman, 1996. A new, fast and efficient image codec based on set partitioning in hierarchical trees. IEEE. Trans. Circuits Sys. Video Tech., 6: 243-249.

Schwarz, H. and E. Muller, 2000. Object-based 3-D wavelet coding using layered object representatio. IEEE Int. Conf. Image Processing, 1: 1000-1003.

Tasdoken, Y. and A. Cuhadar, 2003. ROI coding with region-based integer wavelet transforms and unbalanced spatial orientation trees. Proc. SPIE Conference on Image and Video Communications and Processing.

Tasdoken, S. and A. Cuhadar, 2002. Quadtree-based multi-region multi quality image coding. IEEE. Signal Processing Letters.

Tasdoken, S. and A. Cuhadar, 2003. Multiple, arbitrary shape ROI coding with zerotree based wavelet coders. Proceeedings of the International Conference on Acoustics, Speech and Signal Processing, ICASSP.

Taubman, D., 2000. High performance scalable image compression with EBCOT. IEEE. Trans. Image Processing, 9: 1058-1070.

Taubman, D.S. and M.W. Marcellin, 2002. JPEG2000: Standard for interactive imaging. Proc. IEEE, 90: 1336-1357.