

Positron Emission Tomograph Compression by Using Wavelet Transform

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Abstract - The use of digitized information is rapidly gaining acceptance in radiological applications. Image compression plays an important role in the archiving and transmission of different digital diagnostic modalities. Currently block DCT based compression schemes (i.e. JPEG, MPEG) are usually used for telephone conferencing, cable video transmission and other non-medical applications. This scheme is not suitable for medical tomographic imaging (like PET) because of block artifacts resulting from the block based DCT coefficient quantization. For PET data, it is usually stored in two byte integer format per pixel for the precision preservation which makes the DCT based compression coding procedure difficult without specially designed and trained codebooks. A full frame wavelet image coding approach has been investigated in this study. It adopts the zerotree data structure, bit-plane coding and adaptive arithmetic coding to improve the coding efficiency. This lossy image compression increases the data size reduction and keeps the reconstructed images visually indifferent to the original images at compression ratio up to 10:1 in clinical image quality evaluation. Our algorithm not only achieves a higher compression ratio but also maintains high fidelity for the reconstructed image which could be used in the PACS system and telediagnosis environment.

I. INTRODUCTION

Among medical imaging modalities, Positron Emission Tomograph (PET) images has been served as the quantitative measurement of physiological function. The data are comprised of positron emission decay detection by annihilation radiation coincidence measurement. Due to limited radiopharmaceutical dosage, a low number of photons are detected and the statistic noise is high. In order to maintain the PET data precision, it is usually stored in two byte integer format per pixel. The data has wider range of pixel values than other tomographic modalities.

Most of the clinic diagnosis for PET images are examined in WholeBody-PET (WB-PET) format. It usually consists of at least 500 transaxial slices and require over 35 Mbyte of data to store in uncompressed form. Lossless compression gives very little gain for WB-PET because of the high noise level in the images. In order to efficiently transmit image data over band-limited communications networks and serve the archival purpose to reduce the storage size, a lossless compression algorithm has been investigated in this study.

There are two types of transform used in image compression: block based and full frame based transform. Discrete

Cosine Transform (DCT)-based image compression methods such as Joint Photographic Experts Group (JPEG) are experienced widespread use in nonmedical application like network browser system, CD-ROM image retrieval database. Although the block DCT is quite suitable for these applications, it has the disadvantage of producing block-like image artifacts that could mask or be mistaken for pathology in medical images. In addition, PET image has 16 bit depth per pixel which makes the encoding procedure difficult without specially designed and trained codebooks.

The approach that we have taken is to design an algorithm that in contrast with the block DCT does not partition the image into blocks for coding, thereby significantly reducing artifact generation in the reconstructed image. A full frame wavelet compression has been studied in compressing PET images. By utilizing wavelet spatial-frequency localization property, a zerotree context modeling and bit-plane coding with adaptive arithmetic coding is developed. The results show full frame wavelet compression approach has better coding efficiency and is suitable for deep pixel image compression like PET.

This paper is organized as follows: section II describes the work performed, section III presents the discussion and section IV is the conclusion.

II. DESCRIPTION OF WORK PERFORMED

Hierarchical wavelet transform was used to obtain a multi-resolution representation of the PET image. By using a biorthogonal basis[1,2,3], an example of the decomposition is shown in Figure 1(b); the original image from which this example was generated is shown in Figure 1(a). The wavelet domain representation itself illustrated in Figure 1(b) does not introduce any compression. Compression is obtained by quantizing the transformed data thereafter.

Zerotree coding which embeds successive approximation quantization was introduced by Dr. Shapiro [4]. The zerotree data structure offers an efficient context representation in wavelet transform domain. The basic assumption for coding wavelet coefficients is based on its magnitude. The wavelet coefficients with the same magnitude are assumed to have equal importance and should be transmitted before coefficients with smaller magnitudes. A wavelet coefficient is said to be *insignificant* if the magnitude is smaller than a given threshold T . The zero tree data structure is based on the

hypothesis that if a wavelet coefficient at a coarse scale is insignificant with respect to a given threshold T , then all wavelet coefficients of the same orientation in the same spatial location at finer scales are highly likely to be insignificant with respect to T .

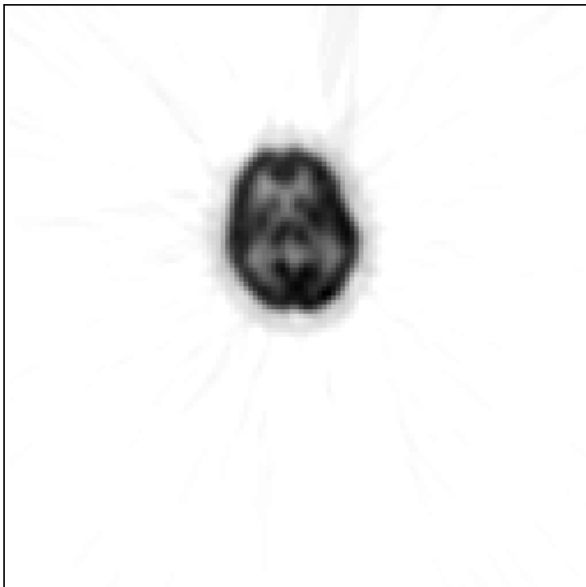


Fig. 1(a) Original PET Brain Image

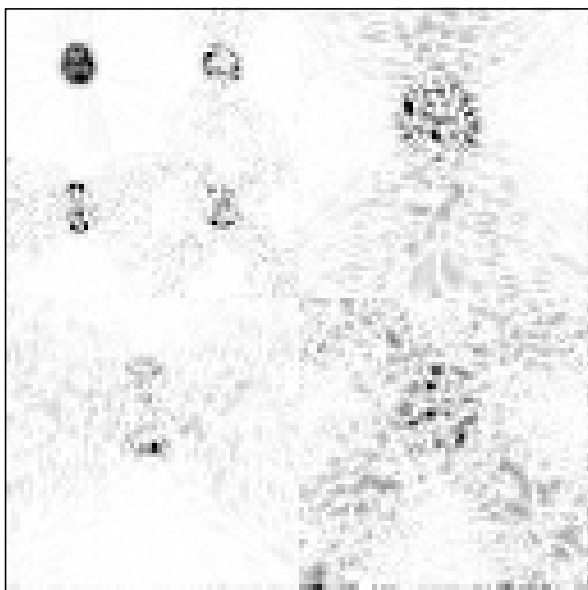


Fig. 1(b) Two level wavelet decomposition of Figure 1 (a).

The Parent-child dependencies of zerotree data structure are illustrated in three level decomposition of wavelet subbands (Fig. 2). The arrows point from the subbands of parents to the subbands of the children. Except the lowest level, each parent has four children at higher level subband. The parent in the lowest level has only three children. Through the relationship across the subbands of the parent-child relationship, the ancestors-descendents dependencies is also developed.

Four symbols are used for the corresponding significance map with respect to the threshold level T :

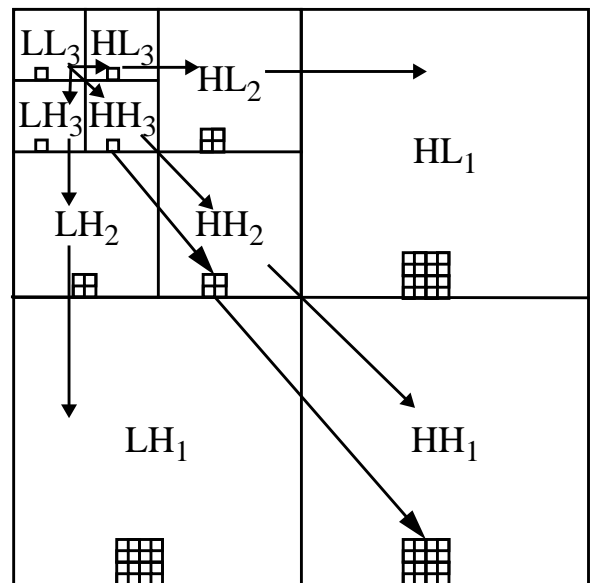


Fig. 2 Parent-child dependencies illustration for three level decomposition of wavelet subbands.

- 1) **Zerotree root**: the coefficient itself and all its descendents are all insignificant.
- 2) **Isolated zero**: the coefficient itself is not significant but has some significant descendent.
- 3) **Positive significant**: the coefficient itself is significant with positive sign.
- 4) **Negative significant**: the coefficient itself is significant with negative sign.

A scanning of the coefficients is in such a way that no child node is scanned before its parents. So, each coefficient within a given subband is scanned before any coefficient in the next subband.

While constructing zerotree data structure, two separate lists: dominant list and subordinate list, are maintained during the encoding (and decoding) process. The dominant list contains the locations of those coefficients that have not yet been found to be significant. The subordinate list contains the magnitudes of those coefficients that have been found to be significant.

Successive approximation quantization is performed while keeping the threshold in a decreasing order. For each threshold, each list is scanned once and called dominant pass and subordinate pass respectively. During the dominant pass, the dominant list is scanned and the locations of all pixels whose magnitude exceeds the threshold with the sign information are encoded using zerotree data structure. Those pixels are therefore appended to the subordinate list, and the corresponding coefficients in the wavelet transform image are set to zero so that their location won't be encoded on the future passes and prevent the finding of zerotree roots for lower threshold values. In the subordinate pass, the next refinement bit in the representation of each pixel on the subordinate list is encoded. Using only the information that is known at the decoder, the subordinate list is then sorted, and the process continues to

alternate between the two passes for each threshold until a bitrate target is met, minimum value of threshold is reached or a given distortion criteria is maintained.

The entire bitstream is arithmetically encoded with an adaptive model. The encoder fully adapts to the statistics of each pass' data and requires no training, no code-book, or pre specified probability tables.

III. DISCUSSION

To evaluate the performance of the compression algorithm, we compressed eight WB-PET studies, each containing more than 300 transaxial planes at different compression levels by adjusting the quantization stepsizes of the transformed coefficients. After reconstructing the studies, coronal cross sec-

tional images were produced [5] and the images were read by a group of trained radiologists. It was found that there are no appreciable difference between the original, uncompressed images and reconstructed images that had been compressed up to 10:1. In reconstructed images at higher compression ratios, a small but noticeable, difference was seen. This is also consistent with the more structured "noise" seen in the difference images (Fig 3(b)). Although these images were visible different, all lesions were still visible (Fig 3(a), the areas where the arrows point to). In order to fully determine what the upper compression limit is, a larger ROC study needs to be performed.

Currently, there are few compression software which are capable of processing two bytes per pixel images like PET. We compare our approach with "CREW" [6] from Ricoh Cal-

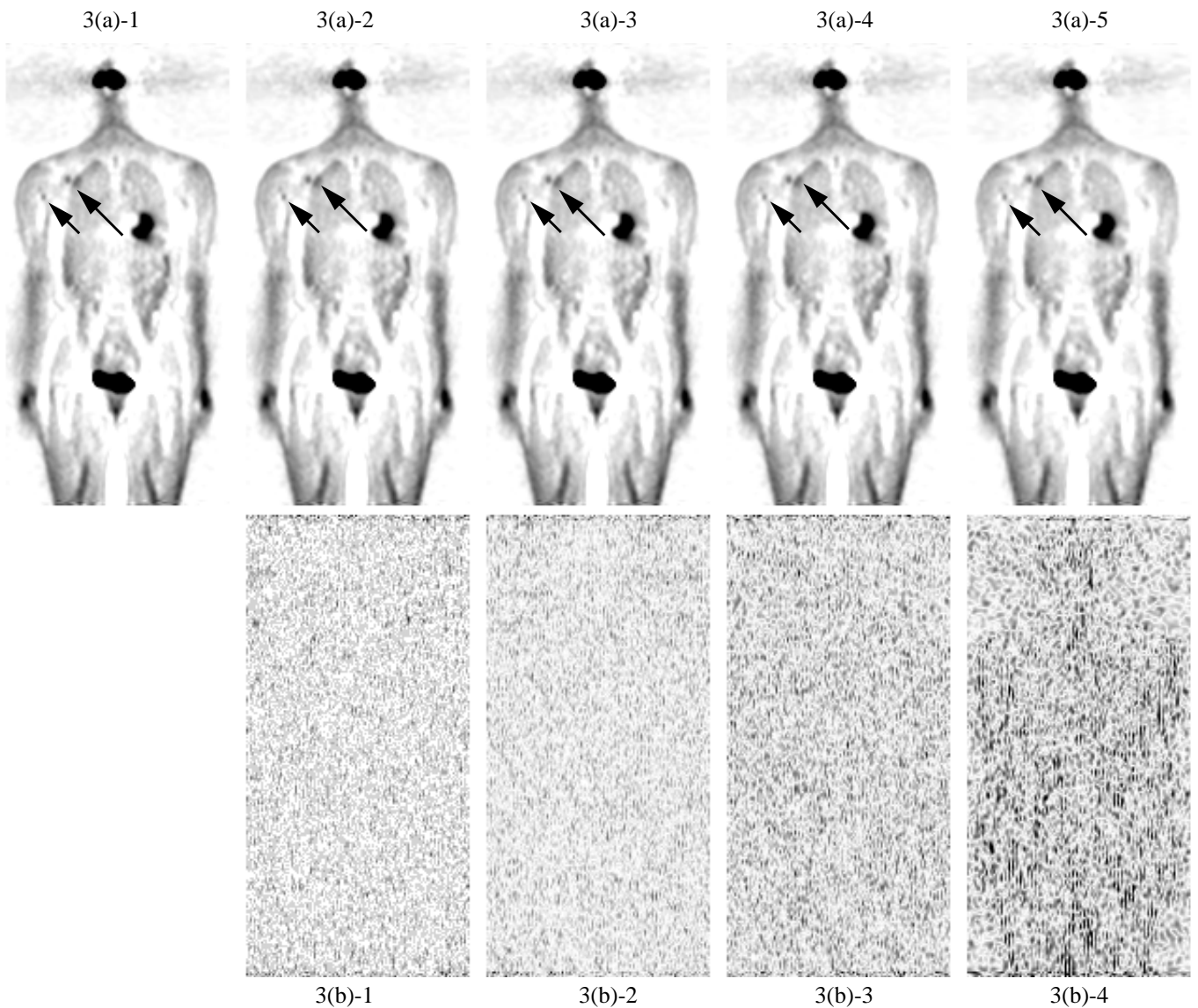


Fig. 3: 3(a)-1, Original coronal cross sectional image. 3(a)-2, 3(a)-3, 3(a)-4, 3(a)-5 are reconstructed images at compression ratio 2.5:1, 4.2:1, 9.3:1, 37.5:1 respectively. 3(b)s are difference images between 3(a)-1 to 3(a)-2, 3(a)-3, 3(a)-4, 3(a)-5. The difference images are scaled at a factor 900 (3(b)-1), 180 (3(b)-2), 54 (3(b)-3) and 18 (3(b)-4) for display purpose.

ifornia Research Center. The results show our method performs comparably with “CREW”. An comparison is shown in Fig. (4) for compressing Fig. (1) PET brain image.

- [6] Zandi A, Allen J, Schwartz E, Boliek M, “CREW: Compression with Reversible Embedded Wavelets”, Proc. *IEEE Data Compression Conference* 212-221, 1995.

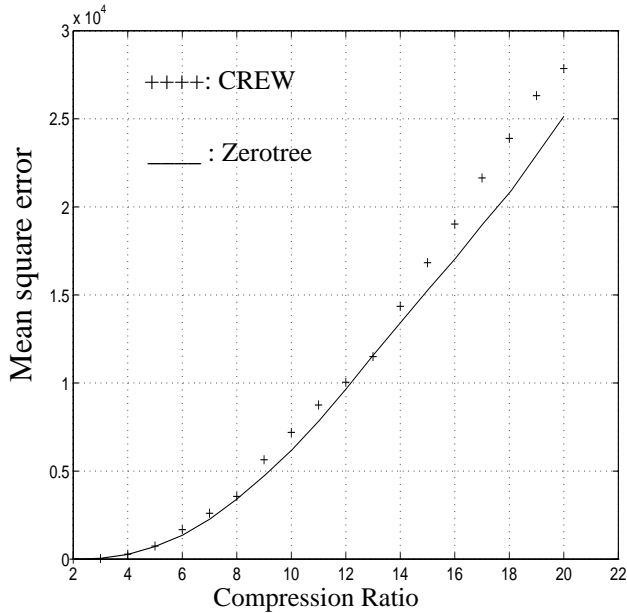


Fig. 4 Plot of compression ratio vs. mean square error for Fig (1) image using zerotree and CREW methods.

IV. CONCLUSION

WB-PET images can be compressed with high efficiency by full frame wavelet transform approach. The reconstructed image are visually identical to the original images. The difference images show no structured error patterns. High image fidelity is achieved by our approach. While it is premature to make conclusions regarding acceptable compression ratios in the absence of ROC studies, these results suggest that approaches based on the full-frame wavelet transform with zerotree data structure coding scheme have strong promise to provide both high image quality and high compression efficiency when applied to deep pixel medical imaging like WB-PET.

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