

Compression of Echocardiographic Scan Line Data Using Wavelet Packet Transform

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Abstract

An efficient compression strategy is indispensable for digital echocardiography. Previous work has suggested improved results utilizing wavelet transforms in the compression of 2D echocardiographic images.

Set partitioning in hierarchical trees (SPIHT) was modified to compress echocardiographic scanline data based on the wavelet packet transform. A compression ratio of at least 94:1 resulted in preserved image quality.

1. Introduction

Digital echocardiography has important applications in clinical cardiology beyond simplifying review, including advanced image analysis and remote diagnosis. Because of the huge storage requirement and limited networking bandwidth, an efficient compression strategy is indispensable. Successful algorithms for image compression, such as JPEG, set partitioning in hierarchical trees (SPIHT) based on wavelet transform [7], can be applied directly to the compression of echocardiographic images.

Echocardiographic scanline data, precursor of the echocardiographic image, is of polar structure and can be expressed as $f(r, \theta)$, where r is scanline depth and θ is the angle within the sector. Scan conversion methodology is used to interpolate polar scanline data into a raster format image.[4] As a consequence, echocardiographic scanline data contains much less spatial redundancy than echocardiographic image. For example, the size of an echocardiographic image in DICOM output is 640x480, while that of the corresponding scan line data is 512x128.

In this study, we investigated the compression of echocardiographic scan line data using a modified SPIHT algorithm based on wavelet packet transform to achieve higher compression ratio while still attaining good image quality for diagnosis.

2. Wavelet packet transform

The wavelet packet transform allows a finer resolution of higher frequency information as compared to the standard wavelet transform.[3] Given that echocardiographic scanline data has much less spatial

redundancy than an echocardiographic image, the wavelet packet transform was selected.

The wavelet packet transform is realized by the iteration of both a high pass wavelet branch and a low pass scaling branch of the Mallat algorithm tree.[6] Figures 1 and 2 show the 2-level 1D wavelet packet transform (WPT) and inverse wavelet packet transform (IWPT) by means of analysis filter banks and synthesis filter banks, respectively,

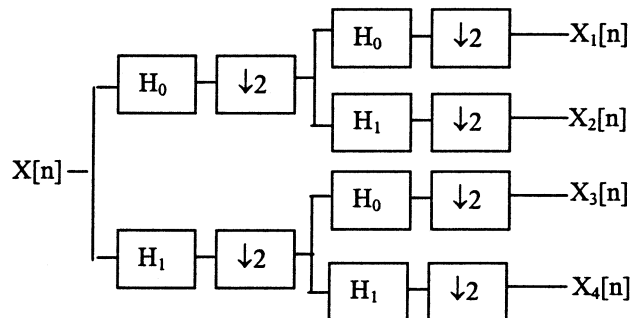


Figure 1. 2-level 1D wavelet packet transform

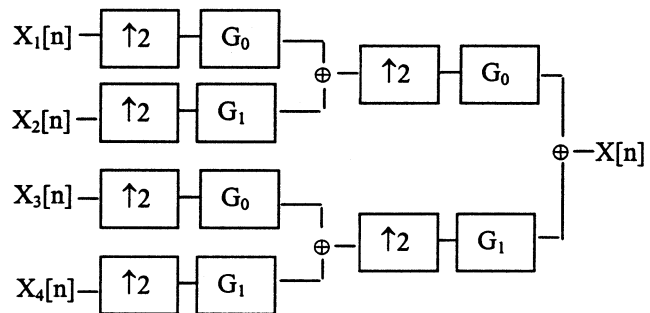


Figure 2. 2-level 1D inverse wavelet packet transform

H_0 and G_0 are scaling filters for WPT and IWPT, respectively, and H_1 and G_1 wavelet filters for WPT and IWPT, respectively. In order to handle boundary problem during convolution, symmetric extension method was used, which has been shown superior to other methods as zero padding and periodic extension for subband image coding.[1] If signal length is L_x , and filter length is L_f , after filtering and decimating once, subband length would equate to the nearest integer of $(L_x + L_f - 1)/2$.

The echocardiographic scanline data $f(r, \theta)$ was modeled as a separable system, and the 2D wavelet packet transform was realized using 1D wavelet packet transforms along r and θ .

3. Modified SPIHT

Set partitioning in hierarchical trees (SPIHT) is a zero tree-coding algorithm, and a very efficient image compression algorithm based on wavelet transform. The key data structure in SPIHT is called spatial orientation tree (SOT) among wavelet coefficients. [7]

In this study, we modify SPIHT to work in conjunction with the wavelet packet transform. Similarly, a tree structure among wavelet packet transform coefficients should be defined. Suppose an L -level wavelet packet transform was performed. After first decomposition the four obtained subbands were arranged in the order of LL->HL->LH->HH, then the arrangement was done in the same way for every subband during the left $L-1$ decompositions. Hence 4^L ordered subbands with same size were obtained at last. Let (I, J, B) be the coordinates of a wavelet packet transform coefficients, where I and J are spatial coordinates and B is the order index of the subband sequence. The tree structure is recursively defined as following:

- (1) If $B=1$, there are three offspring: $(I, J, K, 2)$, $(I, J, K, 3)$, $(I, J, K, 4)$.
- (2) Else if $B \leq 2^{(L-1)}$, it has four offspring: $(I, J, K, 4*B-4)$, $(I, J, K, 4*B-3)$, $(I, J, K, 4*B-2)$, $(I, J, K, 4*B-1)$.
- (3) Else no offspring.

4. Coding results and discussion

Two dimensional echocardiographic scanline data with size 512×128 was extracted from the ResearchLink file format of the ATL HDI5000 system. A 4-level 2D wavelet packet transform using Harr wavelet base was applied. The coefficients were quantized at different compression ratios by modified SPIHT. The compression ratio was calculated based on the size of the scan converted echocardiographic image: 640×480 . The peak signal-to-noise ratio (PSNR) was calculated at different compression ratios and compared with the result of JPEG compression.

Table 1 shows the PSNR values of the proposed algorithm applied to the scanline data at the compression ratios of 94:1, 117:1, 141:1, 164:1, and 188:1; while Table 2 shows the PSNR value of JPEG applied to the scan converted image at compression ratios of 20:1, 25:1, 30:1, and 40:1. The proposed algorithm applied directly to the scanline data can achieve much higher compression ratio while still retaining better image quality as JPEG at much lower compression ratio.

94:1	117:1	141:1	164:1	188:1
32.6	31.9	30.4	30.1	29.7

Table 1. PSNRs (dB) for the modified SPIHT algorithm applied to echocardiographic scanline data at different compression ratios

20:1	25:1	30:1	35:1	40:1
32.2	30.9	29.8	28.8	28.1

Table 2. PSNRs for JPEG compression applied to echocardiographic image at different compression ratios

Figures 3-6 show the original image, the compressed image by the proposed algorithm at 94:1 and 117:1, and the compressed image by JPEG at 20:1.

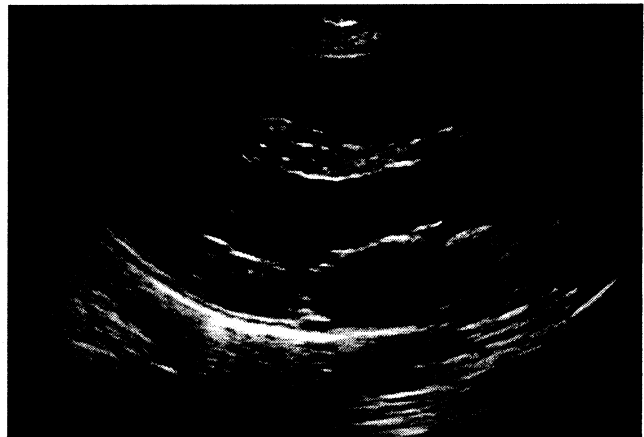


Figure 3. Original image



Figure 4. Image compressed by the Modified SPIHT at 94:1

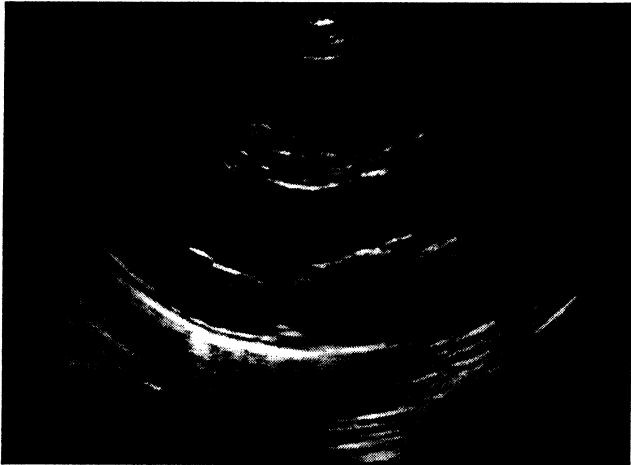


Figure 5. Image compressed by Modified SPIHT at 117:1



Figure 6. Image compressed by JPRG at 20:1

JPEG has been studied extensively in [5] for the compression of echocardiographic images, which shows that at compression ratio of 20:1 diagnostic information still can be obtained.

Thinking of the fact that there exists more discontinuity in scan line data than scan converted image we chose Harr wavelet instead of other kinds of more smoothing wavelet. Furthermore, because the corresponding wavelet filters and scaling filters of Harr wavelet are just 2-tap filters, it improved computing efficiency.

5. Conclusion

Modified SPIHT based on wavelet packet transform was used to compress echocardiographic scan line data. At compression ratio of at least 94:1 the quality of the scan converted image was still preserved. In the future study, we will extend the algorithm to compress echocardiographic scan line data video to further compression ratio. A lossless compression strategy based on integer wavelet transform [2] will also be studied to compression scan line color Doppler data.

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