MR Image Compression and De-Noising by Wavelet Transform with Soft-Thresholding

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Introduction

Wavelet Transform (WT) not only has outstanding advantages in coding efficiency, progressive network transmission and subjective visual quality over Discrete Cosine Transform (DCT) in noise free image compression [1], but also provides a very convenient way to analyze and reduce noise from noisy data. This paper studies MR image compression by wavelet transform with emphasis on de-noising in wavelet domain by soft-thresholding. Some results and discussions are also presented.

Method

Consider a series of noisy data and further assume the noise is Gaussian white noise. The method for de-noising by soft-thresholding is to translate all the wavelet coefficients toward 0 by a threshold. Refer to [2] for the mathematical proof. When the noise level is unknown, one estimator must be used.

Since the assumption of Gaussian white noise holds true for MR images, it should not be too difficult to extend the above de-noising idea to two-dimensional case. However, some special attentions are needed, which will be stated next.

To estimate the noise level from two-dimensional WT coefficients, we observe the fact that most of high frequency energy comes from noise rather than from the image itself. Thus, in this paper, we simply use the following formula to estimate the noise level.

$$\sigma = MAD/C_1$$

where C_1 is a constant less than 1 and *MAD* denotes the median absolute value of coefficients in the sub-band obtained by high-pass filtering the image in both row and column directions in the first level WT.

Subsequently, the threshold for the first level of WT can be calculated by multiplying the above noise level with a constant C_2.

However, the noise has different contribution to different scale in WT. The bigger the scale, the higher the noise level. So, the threshold should change with the scale. Denote σ_k as the noise level of k*th* scale of WT. Then the noise level of (k+1)*th* scale is given as σ_k/C_3 , where C_3 is a constant greater than 1.

In addition, even at the same scale, the threshold should not be the same in different sub-bands. To reflect this difference, we take the threshold of sub-bands in anti-diagonal direction as 1.5 times large as that of sub-bands in main-diagonal direction.

Once the thresholds are calculated for different scales and sub-bands, it is easy to shrink the WT coefficients for de-noising as in one-dimensional case before compression.

Result and Discussion

The SPIHT algorithm [1] is used as normal WT compression in this paper. One MR image with Gaussian white noise (0 mean and 15 variance) is tested for WT only and WT with de-noising scheme, respectively. The constants C_1, C_2 and C_3 equal 0.8, 2.0 and 1.1 in our experiment. The original and decoded images (compression ratio=10) are shown from Fig. 1 to Fig.4 respectively. Although the peak signal to noise ratio of WT with de-noising is slightly lower than that of normal WT (from 27.87dB to 27.05dB), it is very clear that the WT with de-noising consideration can achieve better subjective visual quality than the normal WT at the same compression ratio.

Acknowledgements

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References

[1] A. Said and W.A. Pearlman, "A new fast and efficient image codec based on set partitioning in hierachical trees," IEEE Trans. On Circuits and Systems for Video Technology, 6(3), 243-250, June 1996.

[2] David L. Donoho, "De-Noising by Soft-Thresholding," IEEE Trans. On Information Theory, 41(3), 613-627, May 1995.

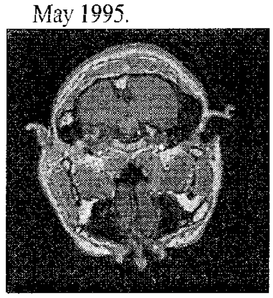

Fig. 1 Original MR image

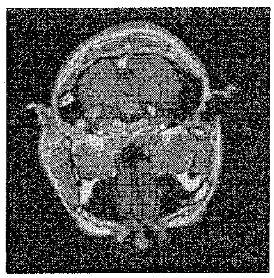

Fig.2 Noisy MR image

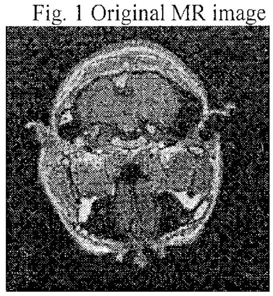

Fig.3 WT without de-noising

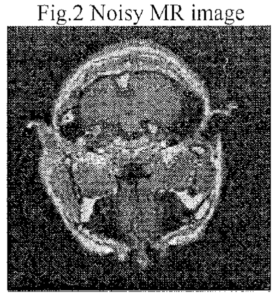

Fig.4 WT with de-noising