Acoustic image compression with the wavelet transform.

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Introduction

This investigation was motivated by acoustic images collected by a portable, autonomous, echosounding device and a Furuno echosounder. Marine and freshwater data were used to examine the feasibility of improving standard compression with the wavelet transform. A feature of these acoustic images is that they consist of reflected signals from both point and volume scatterers. The point scatterers appear as transient signals in the image, typically large, rapidly decaying spikes. The wavelet transform has generated much interest due to its ability to represent transient signals sparsely in the wavelet domain.

Discrete wavelet transform

The discrete wavelet transform is analogous to the fast Fourier transform although there are a few major differences. For example, the wavelet transform provides the optimal time-frequency window at all frequency scales. As well, the basis functions are not limited to the familiar sine and cosine functions of the Fourier transform. A number of wavelets have been derived which are efficient at representing all square-integrable functions [1]-[2]. Of these, two were chosen for this study: the DAUB4 and DAUB12 wavelets. The DAUB4 wavelet models linear, piecewise-continuous functions and DAUB12 provides continuity in higher derivatives.

Compression

The compression ratio is the size, in bytes, of the compressed image divided by the size of the original. Standard compression schemes fall into two categories. Lossless compression, a reversible process, is defined by the ability to recover the original image intact. Lossy compression sacrifices this requirement to provide a lower compression ratio. The choice of scheme is dependent on the intended use of the acoustic data.

Investigation

The pixels of the digital acoustic images were described by 16-bit integers. However, in each image, less than 16 bits of information was present. This implied an inherent compressibility. To allow a standard comparison, the amplitude range of each image was first shifted and scaled to cover the entire 16-bit range (0-65535). Each image was transformed into the wavelet domain with the DAUB4 and DAUB12 wavelets. The results were subsequently rescaled to cover the full 16-bit range, then compressed with a standard compression program. A greater degree of compression was also achieved through the removal of the least significant coefficients after the transform. These values were chosen arbitrarily at a factor below the peak value and ranged from 0.0 to 0.1, with the former corresponding to lossless compression (see sample, Figure 1). The value 10^{-5} is approximately the resolution of the 16-bit image.

The mean square error (MSE),

$$\bar{e} = \sum_{i,j}\left(f_{i,j} - o_{i,j}\right)^2 \Big/ \sum_{i,j} o_{i,j}^2 ,$$

where $f_{i,j}$ and $o_{i,j}$ are the pixel values in the uncompressed and original images, respectively, was calculated to provide a crude estimate of the amount of information loss. Compression ratios and MSE's for the different schemes are summarised in Table 1, below. The MSE for the original image is the round-off error associated with shifting and scaling.

Summary

The wavelet transform appears to be effective at compressing the acoustic images in this study for the reason that the signal is made "sparse" by the wavelet transform. This stems from the fact that these acoustic images consist of dominant information returned from point reflectors in the acoustic domain. These signals are "wavelet-like" and therefore may be amenable to modelling by wavelets.

References

[1] Chui, C., Wavelet Analysis and Its Applications: Volume I. Academic Press, Inc. Toronto, 1992.

[2] Daubechies, I., The wavelet transform, time-frequency localization and signal analysis, IEEE Trans. Inform. Theory **36** (1990), 961-1005.

Table 1--Compression ratio and mean square error.

	DAUB4		DAUB12	
Image	Ratio	MSE	Ratio	MSE
Original	69.2%	6.39E-05	69.2%	6.39E-05
0.0	56.7%	2.79E-04	57.6%	2.69E-04
0.00001	56.6%	2.78E-04	57.6%	2.72E-04
0.0001	43.7%	7.66E-04	46.9%	6.59E-04
0.001	22.5%	5.25E-03	25.1%	4.47E-03
0.01	9.0%	3.46E-02	10.5%	3.05E-02
0.1	2.9%	1.98E-01	3.5%	1.75E-01

Figure 1--Original and lossy (0.01) compressed image.