Global and Local Distortion Inference During Embedded Zerotree Wavelet Decompression

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Abstract
Local distortion inference is proposed as an alternative to assuming a spatially uniform error for image compression applications requiring careful error analysis. This paper presents an algorithm for inferring estimates of the $L_2$-norm distortion (root-mean-square or RMS error) for the Embedded Zerotree Wavelet (EZW) algorithm while maintaining its good rate-distortion performance. A small amount of both rate and computational burden is required of the encoder to calculate and transmit sums of wavelet coefficient energies. A greater computational burden is added to the decoder, mainly by an "error-propagation transform" of equal complexity to the inverse hierarchical wavelet transform. The asymmetry of the compression system with distortion inference is ideal for space-based data gathering applications where computation capacity may be limited in the encoder but virtually unlimited in the decoder.

Global distortion inference is accomplished by maintaining error energy estimates of the wavelet coefficients separately for the subordinate and dominant lists. An equal reduction of error energy per significant bit is found to accurately interpolate the operational rate-distortion curve, which is explicitly transmitted prior to each dominant pass. Because of the orthogonality of the wavelet transform, the rate-distortion curve also applies to reconstructed images in the spatial domain. No additional rate overhead is needed to obtain a local distortion estimate. Individual estimates of wavelet coefficient error energies may be transformed to the spatial domain by applying the statistical propagation of errors formula for weighted sums of random variables. The resulting local distortion information is a "noise image" which gives an estimate of the RMS error for each pixel of the decompressed image. This local information is analogous to the error-bars often plotted on graphs of 1-dimensional data. It can be used during an analysis to more appropriately weight the value of each pixel, rather than weighting them all equally.

This local distortion estimate is most useful at low bit rates, when compression error dominates. Large errors, however, can occur that are significantly underestimated by the noise image. This is probably caused by correlation of the error with the input image and/or nearby errors. The error propagation transform, as implemented, assumes errors are uncorrelated since no correlation information is available at the decoder. In spite of this defect, the local estimate is usually a better estimate than the global RMS error for low bit rates, even for the outliers. At higher bit rates the EZW compression error becomes very Gaussian and quite spatially uniform. In this case the local distortion estimate gives little or no improvement over the global estimate.