ENTROPY-CONSTRAINED SUBBAND CODING OF IMAGES USING A PERCEPTUAL DISTORTION CRITERIA

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Abstract

A new perceptually relevant entropy-constrained coding scheme based on the just-noticable-distortion (JND) level of the human observer is described and its properties demonstrated. The JND at each pixel location is defined as the threshold of detectability of the human visual system (HVS) to errors in reproducing that pixel. Because of the masking effect of the HVS, errors below the JND are rendered imperceptible. The JND is determined empirically as a function of spatial frequency, local texture and local contrast. A distortion measure is developed, making essential use of the JND, for a subband coding environment which attempts to mimic the subjective evaluation effects of the HVS. This distortion measure employs a weighted squared-error metric, where the weighting depends upon the JND value at each pixel position. It essentially assigns near-zero distortion to subthreshold errors and approximately squared-error distortion to superthreshold errors. This perceptual distortion measure was incorporated into a previously developed design procedure for entropy-constrained subband coding (ECSBC) schemes based upon training data. We demonstrate that, compared to use of the conventional squared-error distortion, significant improvements in subjective image reconstruction quality can be achieved at low average bit rates using this perceptual distortion measure.

Summary

Image compression is a very important area of research today, especially for use in bandwidth intensive applications such as high-definition television (HDTV) and multimedia systems. The aim of image compression, or coding, is to minimize the average distortion, as indicated by a specified fidelity or distortion measure, for a fixed transmission rate. This can be accomplished by exploiting any redundancy present in the image, together with use of an appropriate quantization strategy.

While there has been extensive research directed toward characterizing the rate-distortion performance of various image compression schemes, almost all of these studies have been based on use of the mean-squared error fidelity criterion. For example, previously reported results for entropy-constrained subband coding (ECSBC) have shown good quality image reconstructions, as well as excellent rate-distortion performance, using a minimum mean-squared error distortion criterion [1]. Minimum mean-square error (MMSE), however, is not the best measure of human psychophysical evaluation because it does not take into consideration the relative *visibility* of coding artifacts. It is becoming increasingly necessary to define distortion measures based on subjective evaluation criteria [2], which will allow minimization of the perceived distortion, rather than mean-square error, for a desired transmission rate. Determination of a perceptually based distortion metric has therefore been a subject of renewed interest in the image coding literature with early work described in [3].

In this paper we focus on the development and use of a perceptually relevant distortion measure for use in a subband coding environment which better mimics the subjective evaluation properties of the HVS than the squared-error metric. This distortion measure is then incorporated in a straightforward manner into previously developed design procedures for ECSBC schemes based upon training data, as described in [1] for the specific case of mean-square distortion.

The perceptual distortion measure is based upon the concept of a just-noticable-distortion (JND) level at a given pixel location in the reconstructed fullband image when errors occur in different subbands. This results in a spatially varying perceptual threshold $T_i(\mathbf{x})$ indicating the JND due to errors at pixel site $\mathbf{x}$ in the i'th subband. The evaluation of $T_i(\mathbf{x})$ is determined empirically similar to the procedure described in [4] and depends upon spatial frequency (subband), local texture and local contrast. However, unlike the coding approach in [4], where the perceptual threshold was used to simply set the stepsize of a uniform threshold scalar quantizer, in this work the perceptual threshold is used to describe a distortion measure which is then used in the design of ECSBC schemes. By making use of the appropriately adapted ECSBC design procedure reported in [1], a variety of scalar and vector quantization schemes can be investigated for encoding the subband components. This includes entropy-constrained vector quantization (ECVQ) [5] as well as entropy-constrained predictive vector quantization (ECPVQ) schemes [6]. Optimum bit allocation is provided as an integral part of this design approach.

A number of results are presented illustrating the superior subjective performance associated with the use of this perceptual distortion measure compared to the conventional squared-error distortion criterion. Suggestions for further extension of this approach are provided.

References

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