COMBINING CONTRAST ENHANCEMENT BY REVERSE MAPPING WITH MULTIRESOLUTION VQ FOR BROWSING

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ABSTRACT

We form a multiresolution vector quantization (MVQ) codebook for progressive transmission using principal components partitioning of a full search VQ codebook [8, 4]. Downsized intermediate codewords provide fast reconstruction of coarse images appropriate for browsing satellite image databases in an X-Window environment. Browse images can be expanded in size and improved in quality progressively.

Any single band of a Landsat image has very low contrast, but contrast enhancement by global histogram equalization produces a visually informative image. When VQ codebook design incorporates contrast enhancement of the codebook to produce the decoder, the VQ requires no additional operations to produce a contrast enhanced final image [2]. We adapt this technique for better performance in our multiresolution scheme by first designing the decoder codebook from a contrast enhanced training set. Using our inverse technique, reverse mapping, we then derive the encoder from the decoder. Thus the decoder is optimized for the contrast enhanced image, a necessity for expansion into our multiresolution decoder.

1. MULTIRESOLUTION VQ

A large image, such as a satellite image, consumes huge amounts of memory in its original format, requires a long transmission time to send, and does not fit on a computer monitor. For example, the test image reproduced in this paper is one quarter of one band of a seven band Landsat image and measures 2960 pixels by 3064 pixels at 8 bpp. Our multiresolution vector quantization algorithm compresses the image on the order of 50:1, and produces a range of image sizes in varying resolution which will fit on a computer monitor [4]. We design the top level codebook consisting of 1024 8×8 codewords as the decoder of a full search vector quantizer. We discuss the design of the encoder in section 4. Codeword reorganization along the principal components of the training set [8] imposes a tree structure on the codebook suitable for a hierarchical decoding codebook. We compute increasingly smaller codebooks with smaller codewords computed as pixel averaged, weighted centroids of the larger codewords at 3 intermediate levels of the tree: 6 bits per codeword (64 4×4 codewords), 3 bits per codeword (8 2×2 codewords), and 1 bit per codeword (2 single pixel codewords) as illustrated in figure 1. The smallest codebook yields a binary image suitable for display or printing on monochrome devices. The encoded image is then suitable for progressive transmission to produce images of increasing size and quality. Decoding is a simple lookup operation requiring one bit per codeword to produce the smallest, coarsest image, an additional two bits per codeword for the next largest, three additional bits for the second largest, and four additional bits for a full sized image.

This bottom up method was developed in [4]. Work by Perlmutter and Gray [7] employs a top down approach to produce multiresolution codebooks from a pruned TSVQ codebook with impressive results. It has the advantage of low search complexity at the encoder and offers the improvement of variable rate codes.

2. CONTRAST ENHANCEMENT

The human eye will not perceive the difference between one grayscale level and the next because of insufficient contrast. Contrast enhancement increases the visible information in regions where the differences in gray scale levels are small, at the expense of moving the values at other levels closer together [6]. If, for example, an image is mostly dark, then there are relatively few pixels with values at the lighter end of the scale. Contrast enhancement maps pixels with values at the lighter end of the scale to a smaller range of values and

This work was supported by the Washington Technology Center, the Statistical Sciences Division of MathSoft, Inc., an NSF Young Investigator award, a Hewlett-Packard equipment grant, and a Sloan Research Fellowship.

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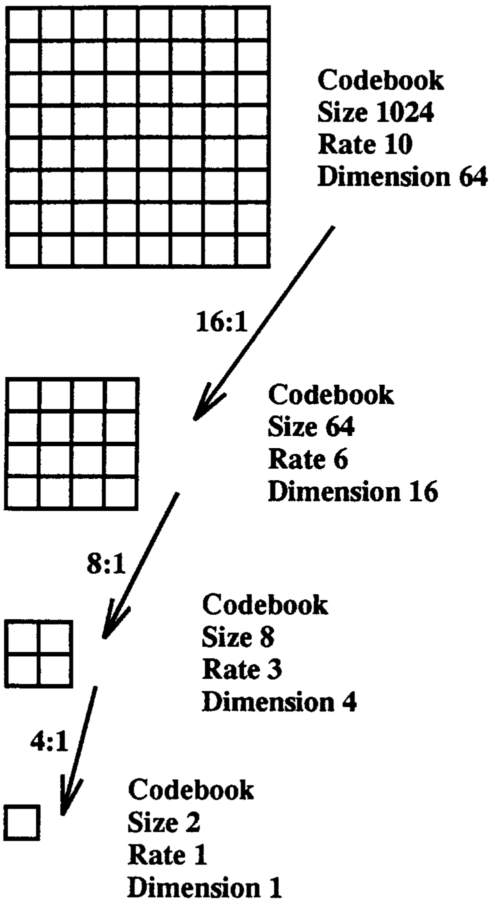

Figure 1: Multiresolution Codebook.

the pixels at the darker end of the scale to a wider range of values. The differences between the darker pixels become larger and thus more visible to the eye.

In our application, any single Landsat image band has very low contrast, but contrast enhancement by global histogram equalization produces a visually informative image.

3. COMBINING CONTRAST ENHANCEMENT WITH VECTOR QUANTIZATION

Image contrast enhancement can be combined with vector quantization by performing histogram equalization on the decoder codebook [2] using statistics from the training set. The unenhanced image is encoded using the original codebook, but decoded using the contrast enhanced codebook to produce a contrast enhanced image. The contrast enhancement then requires no additional operations over decoding an image. As suggested by Cosman in [3], the design of the VQ encoder used to implement image processing such as contrast enhancement can be modified to improve the final processed image.

4. REVERSE MAPPING

Our training set consists of 289,166 8×8 vectors taken from two Landsat images (8 bpp) of a geographic area in the Manaus Basin of the Amazon River. Our test image is a Landsat image from an adjacent, nonoverlapping area. In the original, low contrast training set, pixel values are concentrated in a narrow range. Figure 2a shows the counts of all the 8×8 vectors from our training set. The generalized Lloyd algorithm (GLA) vector quantizer codebook design algorithm [5], in minimizing mean squared error, tends to place codewords at outliers, assigning fewer codewords in the narrow region where most input vectors are concentrated. Contrast enhancing this codebook to produce the decoder codebook produces a codebook which is structured to best represent the unenhanced training set. We can enhance the results by producing a codebook which is designed to best represent the desired *output*.

Our inverse technique, *reverse mapping*, allows us to design the decoder codebook on the contrast enhanced training set and *reverse map* the decoder to produce the encoder codebook.

We first contrast enhance the training set, which is used to design the decoder codebook. We derive the encoder codebook from this decoder codebook, placing it in the domain of the unenhanced training set by reverse mapping the pixel values in much the same way that we would do contrast enhancement. When performing the original contrast enhancement, we constructed a mapping from each pixel value to a new value. We now construct a *reverse mapping* from each new pixel value back to the centroid of the unenhanced pixel values which mapped into it. We apply this reverse mapping to each pixel value in the decoder codebook to derive the encoder codebook. Thus, the decoder codebook is optimized to give the best possible contrast enhanced image.

Figures 2a, 2b, and 2c help illustrate the advantages of reverse mapping by displaying the norms of the training vectors and the norms of codewords from codebooks of increasing size. In figure 2a, the norm values are heavily concentrated in a small region around value 250. Thus we would like to concentrate our codewords in this regions to better represent the bulk of the input data. We plot the norms of the 64-dimensional codewords in a series of encoder codebooks from size 1 to size 1024 for our Landsat data in Figures 2b and 2c. The encoder codebook designed with the GLA (figure 2b) has assigned more codewords to outlying vectors than the encoder codebook designed with reverse mapping (figure 2c). In the contrast enhanced domain these outlying vectors will be compacted into a small range of pixel values. Thus these codewords will play a smaller role in reducing the distortion of the final contrast enhanced image.

Reverse mapping could also be applied with some modification to the PTSVQ multiresolution approach of Perlmutter and Gray by building their tree in from a contrast enhanced training set and reverse mapping the tree to create an encoder. The table lookup decoder would remain the same. Wavelet multiresolution coefficients, however, would not reverse map conveniently[1].

5. RESULTS

We compared the results of reverse mapping with MVQ to the original, contrast enhanced image and to images produced using the contrast enhanced GLA MVQ codebook. The effects of allocating fewer codewords to the outlying vectors are most pronounced in the small codebooks where each codeword is more important to reducing overall distortion. While we use a very large codebook at the top level, the lower levels have very small codebooks and can be skewed by the outlying codewords.

When compared with contrast enhancement of the decoder codebook [2], the reverse mapping technique shows a clear improvement in the ability of the VQ to produce a visually informative image for the smaller codebooks. At the larger codebook sizes, the results are similar. MVQ with contrast enhancement produces images of good quality at low bit rates. Figure 3, our test image, is an original, contrast enhanced, band two Landsat image which has been reduced in size by a factor of 16 for publication. Figure 4 is the GLA MVQ image created from the unenhanced Landsat image decoded using 2×2 codewords. It shows a reasonably good browse image of the original, but has noticeable distortion. Figure 5 is the Reverse-Mapped MVQ image created from the unenhanced Landsat image using 2×2 codewords. Figure 5 shows that this reverse mapping technique obtains closer results to contrast enhancement of the original image and is virtually identical to the image obtained from MVQ of the original contrast enhanced image (not shown).

6. CONCLUSIONS

Multiresolution Vector Quantization produces a range of image sizes suitable for progressive transmission starting with a small binary image after receipt of one bit per codeword. The decoding operation is a simple table lookup. Reverse mapping enables the integration of contrast enhancement into this and other algorithms to produce contrast enhanced images of similar quality to original contrast enhanced images.

7. ACKNOWLEDGEMENTS

The authors would like to thank Dr. Andrew Bruce of the Statistical Sciences Division of Mathsoft, Inc., for suggesting the multiresolution application.

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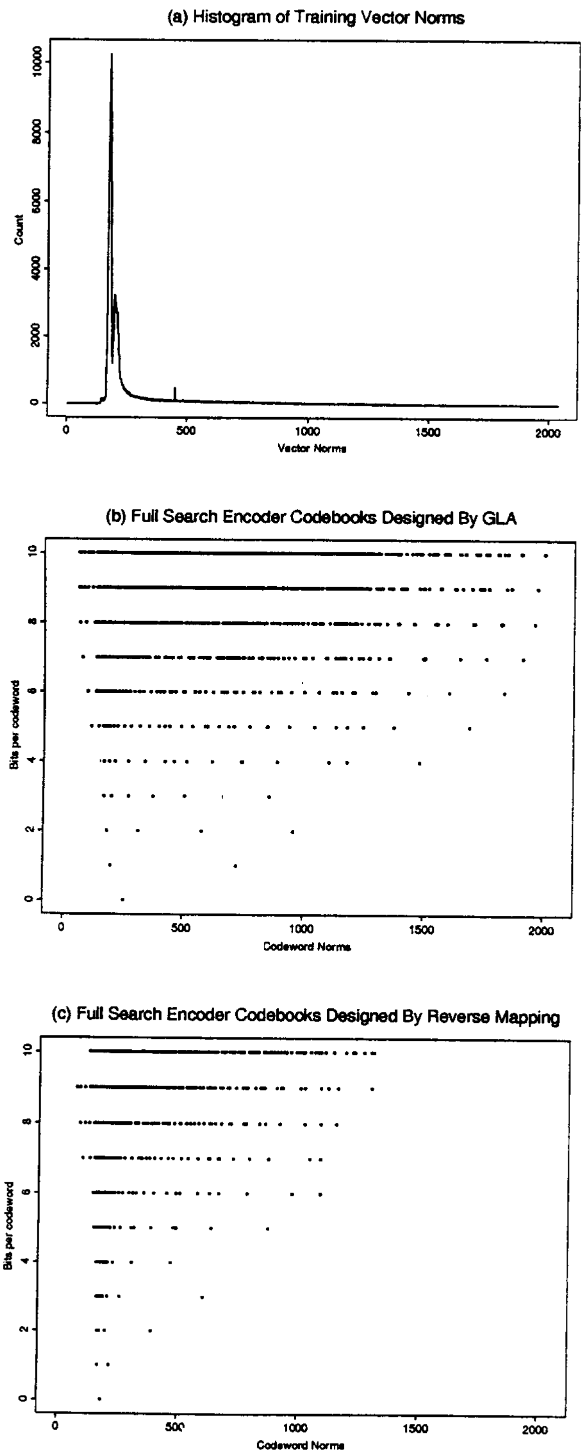

Figure 2: Comparison of Training Vector Norms and Encoder Codeword Norms for Standard VQ and Reverse Mapping.

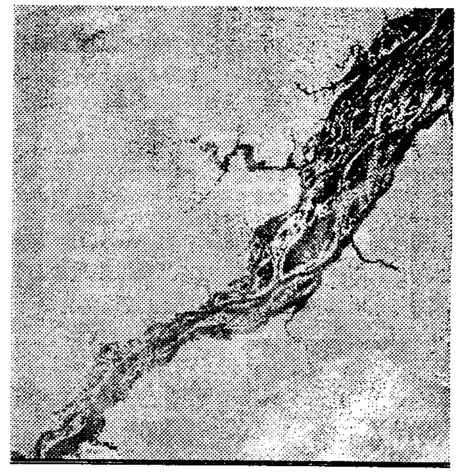

Figure 3: Original Contrast Enhanced Image. : 2960 × 3064 pixels, 8bpp.

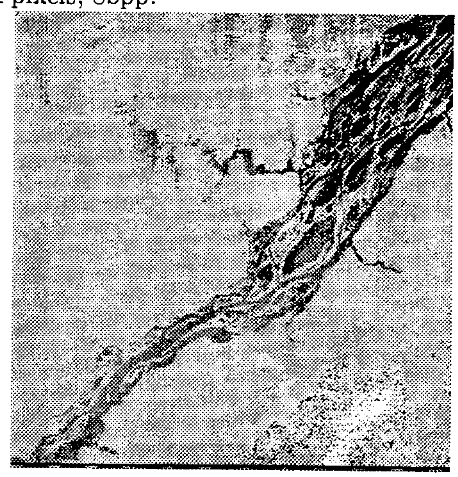

Figure 4: Reconstructed GLA MVQ Image of 2 × 2 codewords : 740 × 766 pixels, .75bpp.

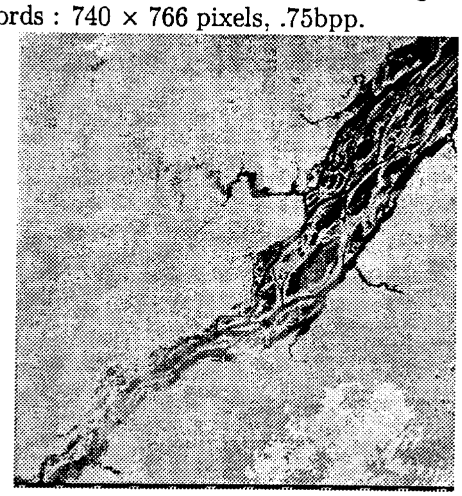

Figure 5: Reconstructed Reverse Mapped MVQ Image of 2 × 2 codewords : 740 × 766 pixels, .75bpp.