POST PROCESSING TRANSFORM CODED IMAGES USING EDGES

William E. Lynch
ECE Dept.
Concordia University
Montréal, Québec H3G 1M8

Amy R. Reibman
AT&T Bell Laboratories
Holmdel, NJ 07733

Bede Liu
EE Dept.
Princeton University
Princeton, NJ 08544

ABSTRACT

Transform coding, a popular image compression strategy, results in two visible artifacts: blocking and ringing. These are both high frequency artifacts. Since images contain high frequency information the artifacts are removed using a space varying low pass filter as a post processor. Low frequency blocks and flat regions of blocks containng a strong edge are filtered. Low frequency blocks are identified in the transform coefficient domain; edge blocks are identified in the spatial domain. This does not require any alterations in the compressed bit stream. Improvement is demonstrated both subjectively and objectively.

1. INTRODUCTION

Post processing schemes aimed at popular image compression strategies are particularly interesting because they do not require that the bit stream be altered. Thus, they allow a decoder to gain a competitive advantage while remaining compatible with the existing encoders.

Discrete Cosine Transform (DCT) coding results in two types of artifacts: 1) Blocking: the attenuation of high frequency terms in compression can turn the slowly varying regions into a series of visible step changes; and 2) Ringing: At object boundaries the sharp transition or edge can cause ringing artifacts in the non-transition or non-edge regions as higher frequencies are attenuated in compression. Both are high frequency artifacts. Recognizing the high frequency nature of the artifacts, a straightforward solution is Low Pass (LP) filtering, but this leads to a trade-off between noise attenuation and the loss of high frequency detail, like edges.

Schemes have been proposed in which a filter is switched on or off depending on the behaviour of the signal [1, 2]. While this technique is aimed at Vector Quantization artifacts, it is also applicable to other block based schemes like Transform Coding. This generality means that it does not take advantage of the specifics of the DCT codec.

Of postprocessing schemes that are aimed at specific CODECS's, Gonzales et al. have proposed a scheme for the DCT that operates in the frequency domain[3]. It estimates low order AC coefficients from the DC coefficients of the surrounding data blocks. It limits the correction on the reconstructed AC coefficient to the range of possible inputs to the uniform quantizer. Thus the corrected coefficient is consistent with the information in the data stream. Also working in the transform domain and providing consistent

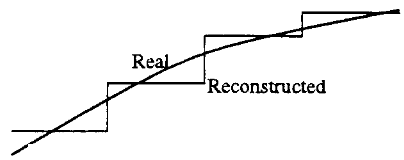

Figure 1: Effect of Compression on Smooth Areas

estimates of coefficients is an iterative scheme proposed by Badique et al. [4].

Wu and Gersho point out that since the decoder must reconstruct the image with quantized DCT coefficients, the DCT basis vectors are not the optimum tools to reconstruct the image [5]. In order to realize an implementable system they impose an additive constraint and calculate the best basis vectors in a mean square sense using a set of training blocks.

In this paper a simple switched linear filter scheme designed specifically for post processing transform coded images is proposed. The strategy for determining when to apply space varying filtering is:

- Classify blocks as either high frequency or low frequency.
- Find blocks whose high frequency content is due to edges. Attach the flat regions of these blocks to low frequency blocks.

The low frequency blocks and the flat parts of the edge blocks are then filtered with one or more appropriate filters.

In Section 2 the post processing scheme proposed in this paper is described. Section 3 gives objective and subjective results while Section 4 draws conclusions.

2. EDGE BASED POST PROCESSING

The standard still image compression scheme used as a benchmark is the JPEG compression scheme [6]. It is a transform coding scheme based on the DCT.

Figure 1 illustrates the effect of transform coding compression on a smoothly varying region. In this one dimensional picture, the smooth original image is shown along with a possible reconstructed image. Here the compression has wiped out all but the DC terms. Note that the flat DC terms have been quantized so that the flat areas of the reconstructed block are not necessarily at the true DC value of the corresponding region.

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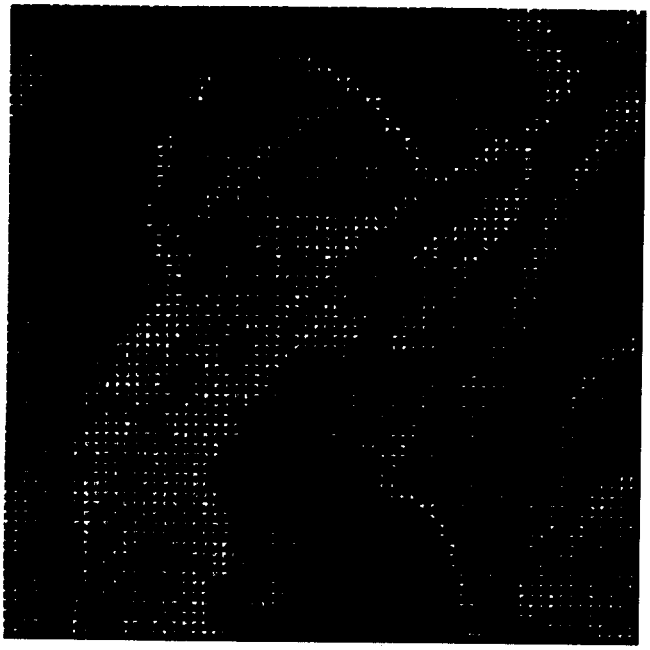

Figure 2: Lena DCT

Figure 3: Original Lena

When only the DC value is sent for an $8*8$ block, the image is effectively subsampled by a factor of 64. Subsampling at this rate means that the frequency content of the reconstructed image should fall inside a band that is 1/64th of the possible bandwidth. This is true not only inside the transform blocks but also between transform blocks. Dramatic steps in the reconstructed image like those shown in Figure 1 are thus undesirable.

Contiguous blocks that have only a DC term should be filtered to remove these steps. While a similar argument would hold for any one of the 64 coefficients, or group of coefficients, and their respective frequency bands, the low frequency coefficients are of particular interest. There are three interrelated reasons for this:

1. Images tend to have more energy at low frequencies. ([7], page 40).
2. The compression process quantizes higher frequency terms more coarsely than low frequency terms.
3. Humans are more sensitive to low frequency errors than high frequency errors.

The first two reasons mean that most of the image information is in the low frequency bands; the third means that the errors in the low frequency band are more important.

As an example consider, Figure 2, which shows the DCT coefficients for Lena compressed to about 0.34bpp. The original Lena is shown in Figure 3. In Figure 2 the coefficients with value zero have been set to black and the non-zero coefficients are white. In the smooth areas of the arm and face, and in the background most of the blocks have just a few low frequency terms. In these areas there should be no dramatic steps as the data indicates that the original had no high frequencies. Since the blocks have 128 subtracted from them before taking the DCT, blocks that are completely black indicate a block with 128 DC value and no high frequency terms. Figure 4 shows the reconstructed Lena image. Note that the blocks in the DCT image which have only a few low frequency terms correspond to the areas in the reconstructed image that suffer from blocking.

2.1. Selection of Pixels to be Filtered and Filtering

A block is declared low frequency if:

$$C_{\mathrm{DCT}}(i,j) * K_{low} = \hat{0}$$

Here $C_{\mathrm{DCT}}(i,j)$ is the $8*8$ block of quantized DCT coefficients of block (i,j), $*$ is element by element multiplication, K_{low} is the test matrix, and $\hat{0}$ is the $8*8$ 0 matrix. The test matrix used is zero everywhere except in a $2*2$ square in the top left corner, where it is one.

The low pass filter used will not attenuate the frequencies in the bands allowed by the test matrix. Improved performance can be achieved if different filters are used on blocks that contain just DC terms and blocks that contain the first AC frequency term. This would entail two filter requirements (pass DC only/ pass DC plus first AC frequency). Since there are two spatial directions this would give a total of four different block types. The method that makes the distinction between these four block types is called 4T. This method is used in the results presented here.

Flat regions in blocks containing strong edges should also be filtered. Edge blocks are detected as in [8]. (Slightly different parameter than those given in the reference are used for the present simulations, specifically $T_{adj} = 1.5$ and a minimum threshold of 100.)

This detector selects blocks that contain strong edges. These are marked along with the edge and non edge regions within them. After edge blocks are selected, the non-edge

Figure 4: Lena - Standard Compression - 0.34bpp

Figure 6: Lena - 4T Post Processing - 0.34bpp

Q Factor	Bits/Pixel	No PP	4T
Lena			
2	0.44	32.52	32.65
3	0.34	31.30	31.52
4	0.29	30.33	30.64
5	0.25	29.56	29.93
6	0.23	28.90	29.33
Pepper			
2	0.44	31.89	32.04
3	0.35	30.85	31.12
4	0.30	29.95	30.31
5	0.26	29.16	29.59
6	0.24	28.54	29.03

Table 1: Post Processing SNR (dB)

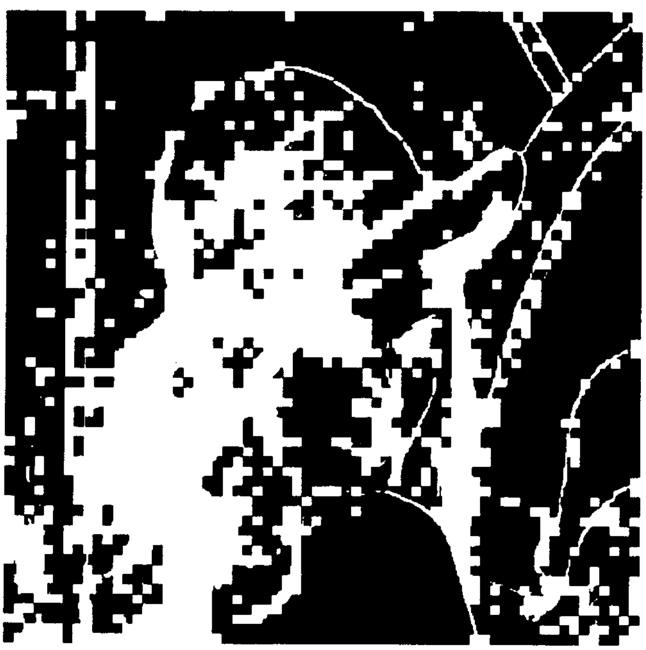

Figure 5: Lena - Points to be Filtered - 0.34bpp

regions of each edge block are examined to see if they are adjacent to a Low Frequency Block. When this is so, the pixels in that region are marked for low pass filtering. In this way, edge regions and texture regions will not be filtered, but non-edge, non-texture regions will. Figure 5 shows the points selected to be filtered for Lena at 0.34 bpp.

Separable filters will be used for the required two dimensional filtering. In this way only one dimensional filters will be designed.

To avoid using pixels from different objects or edge pixels when filtering four square separable filters are designed for each bandwidth requirement. The sizes are $3*3$, $5*5$, $7*7$ and $9*9$. For each pixel to be filtered the largest size is used such that all of the pixels inside the window are also pixels marked for low pass filtering, with the exception that always at least a $3*3$ window is used. Thus four distinct filters are necessary: each one selected depending on how close the pixel is to an edge.

Figure 7: Lena - Before Post Processing Zoomed - 0.34bpp

Figure 8: Lena - 4T Post Processing Zoomed - 0.34bpp

3. RESULTS

In this section the above described post processing scheme is tested on images compressed with the standard algorithm. Lena (shown in Figure 3) and Pepper are tested at five different bit rates.

3.1. Objective Results

The SNR before and after post processing is shown Table 1. "No PP" means no post processing is done.

The final three columns of the table give SNR results for three different post-processing schemes. The objective performance of the three schemes is very close, yielding about 0.1 dB improvement at the highest bit rate and up to 0.4 dB improvement at the lowest. Results are shown for Lena as well as Pepper.

3.2. Subjective Results

While the objective performance of this post processing scheme is encouraging, it is in subjective results that the most dramatic improvements are found. Figure 4 shows Lena compressed at 0.34bpp, and Figure 6 shows the same image after 4T post processing. Blocking in smooth areas has been removed as well as ringing along edges. Figures 7 and 8 are the same figures zoomed. Note that the ringing along the edge of the arm has been removed by the post processing. Similar results are seen at other bit rates.

4. CONCLUSIONS

In this paper a new post-processing strategy was introduced aimed at improving the performance of transform coding still image compression schemes. The scheme addressed both the ringing artifact and the blocking artifact. Improvements were demonstrated both subjectively and objectively.

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