Lapped Transforms in a JPEG 2000 Coder

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Abstract—JPEG-2000 is the latest image coding standard and is based on wavelet transforms and dyadic spectral decompositions. We have adapted the JPEG-2000 image coder for use with uniform transforms, by replacing the wavelet stage by lapped transforms. We set code-blocks that do not cross subband boundaries and encode the lapped transform coefficients directly as if they were wavelet ones. Results indicate a sizeable gain in PSNR for a number of images and corroborate previous results that may cause some small loss in the performance when the distortion of each code-block can be calculated as

$$D = \sum_i D_i,$$

where the distortion of each code-block can be calculated as

$$D_i = G_b \sum_j (\hat{y}_i[j] - y_i[j])^2,$$

and where $G_b$ depends on the filter used to generate the subband that the block belongs and $y_i[j]$ is the $j$-th coefficient of the $i$-th code block. In order to make the coder independent of the transform used, $G_b$ was made equal for all subbands. That may cause some small loss in the performance when using non orthogonal transformations, like the wavelet used in JPEG-2000 or the GLBT.

In order to use EBCOT to efficiently encode the coefficients, the subbands are encoded separately. For that to work, regardless of whether transform is uniform or hierarchical, code-blocks should not cross the subband boundaries. In other words, each code-block only contains coefficients of one subband. It is preferable to define the code-blocks as a subband such that the entire subband belongs to one code-block. Examples of code-block partitions are shown in Fig. 1 for the wavelet scheme and in Fig. 2. Note that JPEG-2000’s desirable features, such as regions of interest, quality progression, etc., are maintained regardless of the transform used.

The rate distortion curves for the popular 512×512-pixel image Barbara are shown in Fig. 3, where the typical PSNR (in dB) and bit-rate (in bits per pixel, or bpp) parameters were used. In the tests, the code-block size was 64×64. Since...
it is difficult to compare the different curves in Fig. 3, we used the standard 9/7-tap wavelet transform as a reference and plotted the differential PSNR relative to it. The comparative results for image Barbara in Fig. 3 are shown again in Fig. 4. The flat line (zero level) represents the performance of the wavelet and each curve is compared differentially. The results for three other popular images, Lena, Baboon and Goldhill, of the same dimensions (512×512 pixels) are shown in Figs. 5, 6, and 7, respectively. The transforms in our comparison are the 8x8 DCT, the 8x48 GenLot, the 8x16 GLBT and the 9/7-tap wavelet, five level decomposition. The most impressive result is presented in Fig. 4, where the GenLot has its best results, about 1.8dB above the wavelet curves. As expected, because of its elegant simplicity, the DCT had the worst performance.

III. CONCLUSIONS

This short paper introduces the use of lapped transforms in a JPEG-2000 coder and reports its performance. The results point to the superior performance of lapped transforms such as the GenLOT compared to the 9/7-tap wavelet transform traditionally used with JPEG 2000 coders. For images like Lena, the GenLOT is superior in some rates and worse for

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**Fig. 1.** Original codeblock and subband partition of coefficients for a three-level wavelet decomposition.

**Fig. 2.** Codeblock partitioning for a uniform transform, where each codeblock contains one subband, $S_{i,j}$.

**Fig. 3.** PSNR curves for image Barbara and different transforms. Rate is given in bits per pixel (bpp).

**Fig. 4.** Differential PSNR curves for image Barbara relative to the performance of the 9/7-tap wavelet.

**Fig. 5.** Differential PSNR curves for image Lena relative to the performance of the 9/7-tap wavelet.

The details of the compressed image Barbara at 0.3 bpp are shown in Fig. 8 for different transforms.

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Fig. 6. Differential PSNR curves for image Baboon relative to the performance of the 9/7-tap wavelet.

Fig. 7. Differential PSNR curves for image Goldhill relative to the performance of the 9/7-tap wavelet.

others. For other images the GenLOT consistently outperforms the wavelet decomposition. Actually, for image Barbara, gains are in the order of 1.5 dB, which is a staggering margin. This result is one more evidence of the competitive performance of uniform lapped transforms in image compression.

REFERENCES

Fig. 8. Detail of image Barbara compressed at 0.3 bits/pel. (a) DCT, (b) wavelets, (c) $8 \times 16$ GLBT, (d) $8 \times 48$ GenLOT.