Express Letter

A DCT-Based Aliasing Cancellation Method in Subband Coding

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Abstract—**Aliasing artifacts of subband coded pictures at low bitrates can be eliminated by adding the information from the higher bands that cancel aliasing at the lower band. This is done by DCT coding the high-frequency bands and selecting the coefficients with the highest energy. The optimum scanning directions of these coefficients for each band are given. As an application of these ideas, a method for the transmission of high-resolution still pictures at 64 kb / s based in a combination of subband analysis / synthesis and a modified H261 video codec is proposed. The progressive buildup obtained with this method is pleasant to the human observer, and is four times faster than if the DCT alone were used.**

I. Introduction

Subband coding [1] has been increasingly used in image coding. It consists of dividing a frame of a picture into several frequency bands, called subbands, and coding each band separately. Each band is subsampled such that the subbands altogether have the same number of samples as the original image. The original image is restored by upsampling, filtering, and adding the subbands.

One of the main advantages of subband coding is the absence of blocking artifacts in the coded image, an inherent degradation in DCT-based codecs at low bitrates. However, the efficient coding of the bands is still as open challenge. Despite their entropy being quite low, the subbands are difficult to code. This is because the data in the high-frequency bands is scattered spatially, requiring a great amount of overhead addressing to be transmitted alongside the pixel values. Besides, it is not easy to identify the information from the subbands that is important enough to improve the reconstructed image quality, especially at low bitrates.

In this letter, it is shown that DCT coding of high-frequency bands clusters the required antialiasing components in certain regions, making them easily identifiable and efficiently coded. As a practical application of subband DCT-based coders, progressive transmission of high-resolution still pictures using a modified H261 coder is discussed.

Manuscript received August 5, 1992; revised February 1, 1993 and May 6, 1993. This work was supported in part by the Universidade Federal do Rio de Janeiro and the Conselho Nacional de Desenvolvimento Cientifico e Tecnologico, Brazil, under Grant 200885/910. Paper was recommended by Associate Editor Takao Nishitani.

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IEEE Log Number 9211405.

II. Aliasing Cancellation and DCT Coding

The lowest band of a subband coded picture is similar to the original picture. However, due to subsampling, aliasing is introduced, causing some disturbances. If the components from the high bands that cancel the aliasing in the lowest band could be added to this band, a smooth low-pass version of the image would be obtained. Thus, when the subband decomposition is employed as part of an image coding scheme, it is desirable to identify those components from the high bands that cancel the aliasing components from the lowest band.

It can be shown that DCT-based subband coding has this property. Consider the one-dimensional spectrum of a natural image, either in the horizontal or vertical direction, as shown in Fig. 1(a). The spectra of the low and high subbands of the image after decimation, along with their aliasing components, are shown in Fig. 1(c) and 1(d). The low band has a spectrum similar to the original signal plus the aliased component from the high band. Due to decimation, the spectrum of the high band is reversed from Fig. 1(b) to 1(d) with the aliased components appearing in the higher frequencies [2]. Since natural images have a decaying power spectral density, as in Fig. 1(a), this spectral inversion causes most of the energy of the high band to be concentrated at higher frequencies, as in Fig. 1(d). This is confirmed by the data in Table I, showing correlation coefficients for horizontal and vertical directions of a four-band decomposition (as in Fig. 2) of single frames of some well-known test image sequences. These data show that if a band is high pass filtered in one direction the correlation coefficient is negative in that direction, indicating its prevailing high-frequency content.

Fig. 1(c) and (d) also shows that the information from the high band required to cancel the aliased components of the low band is located at the higher frequencies of the high band, which correspond to the frequency components with larger energy. Since DCT does essentially a spectrum analysis of the signal, these components will be represented by the high-frequency DCT coefficients. As these coefficients will have the larger energies, they will be the ones retained after the quantization. Thus, DCT coding of the high band will lead naturally to the selection of those coefficients that are required to cancel aliasing in the low band.

A. Scanning Directions

In the case of the four-band subband decomposition shown in Fig. 2, the same reasoning can be extended to two dimensions, yielding the diagrams depicted in Fig. 3. In this figure, the label i–j indicates the information from band j that will cancel the aliasing in band i. Only 1–2 and 1–3 parts of bands 2 and 3 are required to cancel aliasing in band 1. However, in order that parts 1–2 and 1–3 be alias free, the intersection of parts 2–4 and 3–4 is also needed. Thus, a smooth low-pass version of the image can be reconstructed with the dense shaded parts shown

TABLE I
FOUR-BAND DECOMPOSITION: CORRELATION COEFFICIENTS

Band	Trevor		S. Screen		J. in the Box		Miss America		T. Tennis	
	ρ_h	ρ_v	ρ_h	ρ_v	ρ_h	ρ_v	ρ_h	ρ_v	ρ_h	ρ_v
1	0.920	0.947	0.882	0.881	0.891	0.917	0.980	0.935	0.880	0.777
2	−0.207	0.760	−0.346	0.450	−0.210	0.592	−0.312	0.410	−0.352	0.404
3	0.419	−0.455	0.464	−0.433	0.489	−0.294	0.812	−0.882	0.556	−0.360
4	−0.338	−0.300	−0.302	−0.407	−0.296	−0.388	−0.295	−0.037	−0.163	−0.061

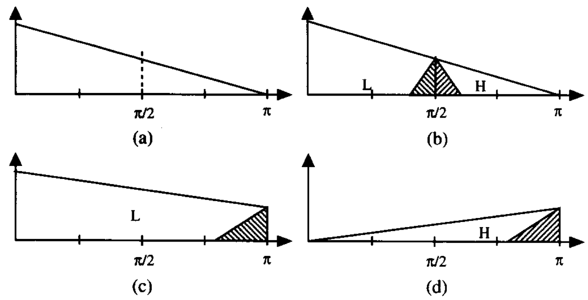

Fig. 1. (a) Original signal spectrum; (b) high- and low-pass components of the signal, along with the alias components; (c) decimated lower band; (d) decimated higher band.

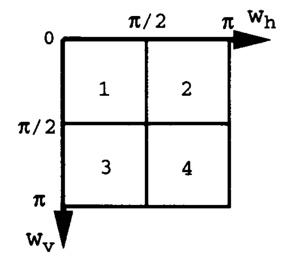

Fig. 2. Frequency partition used in the subband analysis.

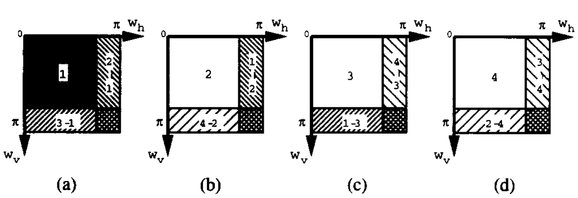

Fig. 3. Alias components of the subsampled bands: (a) band 1; (b) band 2; (c) band 3; (d) band 4.

in Fig. 3, i.e., the whole of band 1, parts 1–2, 1–3, and the intersection of 2–4 and 3–4. In addition, these are the frequencies of each band with the highest energies.

From the above discussion it can be concluded that, if the scanning directions for the 8 × 8 DCT coefficients for each band are the ones shown in Fig. 4, the coefficients with the highest

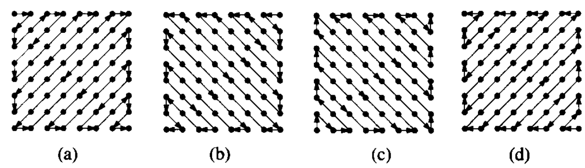

Fig. 4. Scanning directions of each band: (a) band 1; (b) band 2; (c) band 3; (d) band 4.

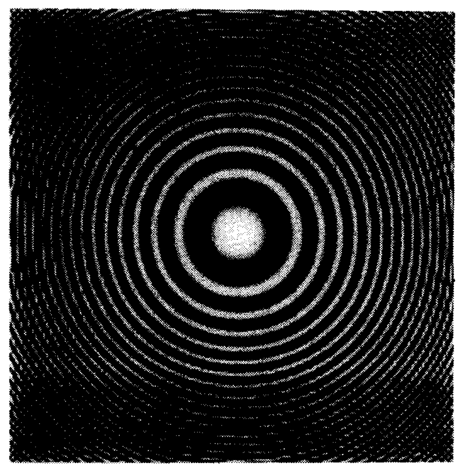

Fig. 5. Zoneplate with high bands entropy coded.

energy values will be, in general, scanned first. This will lead to shorter zero-runs and earlier end of block codes (EOB codes), and, as a consequence, lower bitrates than if the usual zigzag scanning [3] is employed in all the bands.

B. Testing with a Zoneplate

The aliasing cancellation of subband DCT can be verified by coding a zoneplate picture. Fig. 5 shows the reconstructed zoneplate image when the high-frequency bands of a four-band decomposition are linearly quantised and have an average entropy of 0.08 b/pel. The low-frequency band is not coded. Fig. 6 shows the same image, with the difference that the high-

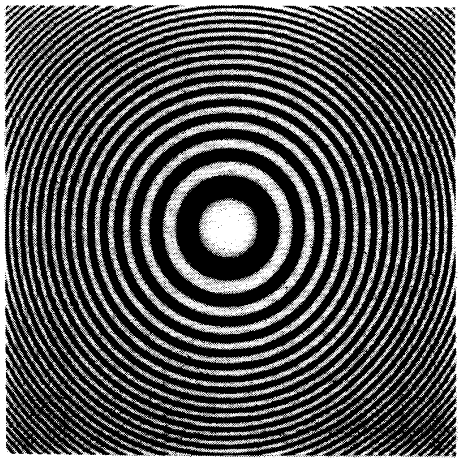

Fig. 6. Zoneplate with high bands DCT coded.

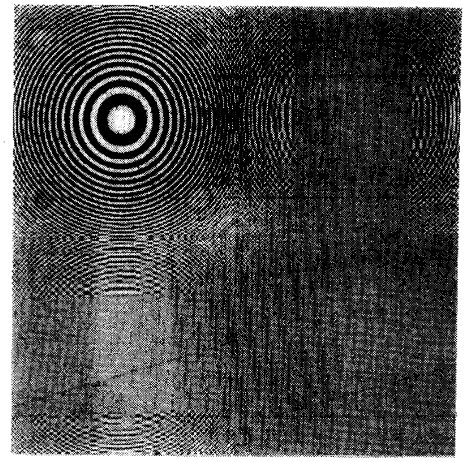

Fig. 8. Higher bands of zoneplate DCT coded.

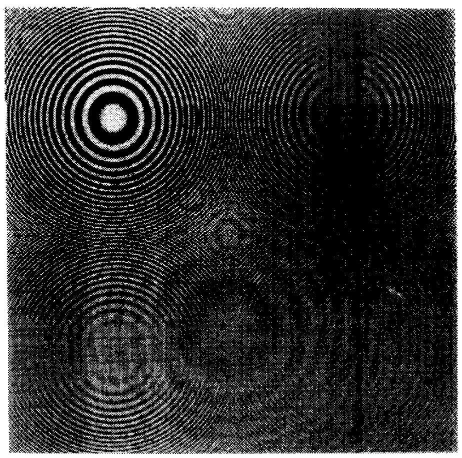

Fig. 7. Higher bands of zoneplate entropy coded.

frequency bands are coded with an 8×8 DCT at the same bitrate, using the scanning directions indicated in Fig. 4. These figures show that at such low bitrates, aliasing is present if the bands are just linearly quantised and appear as low-frequency circles superimposed on the image near its borders. With the DCT, no aliasing is introduced, implying that the DCT coding of the bands retains enough information to cancel the aliasing in the low-frequency band. Figs. 7 and 8 show the coded subbands themselves. Although the linearly quantised bands do appear to retain most of their original values, they fail to cancel the aliasing in the reconstructed picture. The heavily filtered DCT subbands retain enough high-frequency components to reduce aliasing in the final picture.

III. Application Example

As an application of a subband DCT-based codec, a hybrid combination of the subband and a modified H261 codec (SUB/H261) for progressive transmission of high-resolution still pictures was implemented. The subband employs a four-band analysis to decompose high-resolution 704×576 images into four CIF subimages, where each one is sequentially transmitted with a modified H261 codec, starting from band 1. In the receiver, a subband synthesis recovers the progressively received subimages. Since the high-frequency bands carry little information, an acceptable level of signal-to-noise ratio is achieved for each of them after only a few transmitted frames, which makes the overall buildup quite fast.

Some modifications to the standard H261 were made to adapt it for the subband data. In particular, the scanning directions were set according to Fig. 4, which results in shorter runs of zeros, making coding more efficient.

In order to assess the performance of the SUB/H261 coder, a progressive transmission scheme that uses only the H261 coder was also simulated. In this scheme, the high-resolution image is divided spatially into four CIF subimages, each subimage being transmitted through H261. The subband filters used were of the type proposed in [4]. With the MIT test image, SUB/H261 gives an almost four times faster buildup than the H261. Figs. 9 and 10 show the MIT image coded with the SUB/H261 and H261 only, after 48 and 50 CIF frames, respectively, were received. The SUB/H261 is subjectively superior to the H261-only scheme in terms of both smoothness and preservation of high-frequency detail, as can be seen in the patterns on the girl's blouse and hair. In addition, the extra filtering provided in the subband synthesis process alleviates the blockiness caused by the DCT coding of the subbands.

IV. Conclusion

The DCT was shown to be very efficient for the coding of the high-frequency bands of a four-band subband decomposition. Besides its efficiency, it favours the aliasing cancellation in the low-frequency band, providing a smooth low-pass version of the image with minimum information from the high-frequency bands. The progressive transmission of high-resolution still pictures using a modified H261 codec shows very good performance. These indicate that subband DCT-based codecs are very promising for image coding applications.

Fig. 9. MIT image transmitted with SUB/H261 after 48 frames were received.

Fig. 10. MIT image transmitted with H261 only after 50 frames.

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