EMBEDDED VECTOR QUANTIZATION OF WAVELET COEFFICIENTS FOR IMAGE CODING

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Abstract: In this paper embedded vector quantization of wavelet coefficients is presented. The codification method is an extension of the one described in [1], where an image is transformed using the scheme proposed by Mallat with symmetric extension. Results have been improved significantly with the introduction of the embedded vector quantization, getting results very close, even better, to those obtained using the best published algorithms for different bit per pixel rates and for different images.

The main characteristics of this new coder are: totally embedded code and codification without keeping in mind any relation between the subbands. On the other hand the main differences with the algorithm proposed in [1] are: The use of bidimensional vectors, coefficients are not grouped into positives and negatives and a bit which indicates if there are significant coefficients has been used.

Key-Words: Image compression, Wavelet transform, Embedded, Vector quantization CSCC'99 Proc.pp.2111-2114

1 Introduction

The steps of the developed coder can be summed up in three stages: transformation, quantization and codification. In the first stage, a wavelet decomposition is done using Mallat scheme with the whole-point symmetric extension. This decomposition, as has been widely probed, becomes very useful for image compression, since it provides not very correlated coefficients representing the image and in most of the natural images the energy is concentrated into a few coefficients which belong to the low frequency subbands. Since the whole-point symmetric has to be used to avoid first order discontinuities biorthogonal filters are needed.

In the second stage, in the coder under study, an embedded vector quantization (EVQ) based on successive approximations is proposed. Vector quantization (VQ) has been found to offer advantages over scalar quantization, specially when some kind of dependencies exist between coefficients. If the pretended scheme is an embedded one a change of philosophy in the regions design and reconstruction values must be done, which will be described in section 2. The EVQ brings forward better results in objective quality measurements and furthermore an increment in the speed coding is achieved since compares fall down to half of the scalar case.

The third stage is carried out with [1] as start point. Some modifications has been introduced such as: no difference between positives and negatives coefficients has been considered and a bit indicating if the subband has significant elements has been used in every successive approximation.
Results obtained verifies the EVQ efficiency with regard to scalar quantization behaviour, and as good, even better, as the ones published with the best embedded algorithms published.

2 Embedded Vector Quantization

As mentioned before, vector quantization may improve scalar quantization if the coefficients are related. The result of the wavelet decomposition is merely correlated coefficients. However, the correlation of the coefficient magnitudes is high enough to try to use the called EVQ. The correlation coefficients for the different groups of wavelet coefficients are presented in table 1 for Lena image.

	ρ[1,0]	ρ[0,1]
D1	0.636	0.630
V1	0.667	0.642
H1	0.693	0.648
D2	0.654	0.609
V2	0.639	0.636
H2	0.711	0.602
D3	0.597	0.567
V3	0.608	0.550
H3	0.740	0.577

Table 1. Correlation coefficients of the wavelet coefficients.

In the proposed quantization the start point will be the transformed image. A pair of consecutive coefficients can be defined as the projection of a bidimensional vector, so these components can be transformed into a magnitude and an argument like it is done with a complex number. Now a Voronoi regions design must take place, but if an EVQ scheme is pretended the Voronoi regions must be selected in a successive approximation way. Figure 1, presents the distribution of the vectors in an image, where every two consecutive coefficients form a vector.

In order to achieve better results it is necessary to send in first place those vectors that introduce biggest error, that is to say in the orthogonal case, those with high magnitude. In the biorthogonal case is nearly impossible to prevent the effect of every vector candidate to be sent. So although the error is not only a function of the magnitude of the coefficients, for the proposed coder the orthogonal optimum solution, based on attaching more importance to those with high magnitude, has been chosen.

So now all coefficients are building vectors, whose argument is between zero and $\pi/2$ since only absolute value is considered to form the vector. In figure 2, the evolution of the EVQ of a vector is illustrated. At the begin of the EVQ process, in order to get successive approximations a threshold 2^N is taken, in such a way that the maximum of the vectors magnitudes belong to the interval $[2^N, 2^{N+1})$. The threshold divides the vectors in two groups; those whose magnitude is larger than the threshold, significant vectors and those smaller. Let the first threshold 2^8 and the vector (257,125) the first vector to quantize. The vector is transformed to (285.78,0.45) in a magnitude and argument form. Some information has to be sent to locate the significant vector in the recovered matrix, since no all coefficients are considered. Until the moment in which the vector is point out as significant, the vector is reconstructed as a null vector. When a vector results significant, two bits indicating the sign of the coefficients and a bit to refine the argument must be sent to the decoder. So in the example, after transmit the associated information to the significant vector, the vector is reconstructed with $(384,\pi/8)$. The shadowed area in figure 2(b) is the associated area to the reconstruction value $(384,\pi/8)$. This coding step is called dominant pass and is done with all the vectors whose magnitude is greater or equal than the threshold.

After the dominant pass, the threshold is update, (2^7 in the example) and the information of the subordinate pass is sent. This information is two refinement bits for each coefficient that previously resulted significant. One bit for the magnitude and one bit for the argument.

From the subordinate pass, the vector of the example is reconstructed with $(320,3\pi/16)$ and the shadowed area in figure 2(c) corresponds to this reconstruction value. If the coding process is stopped at this moment, the reconstruction of the two coefficients is (266,177).

As can be deduced from the previous, uniform distributions in the magnitude and in the argument have been supposed.

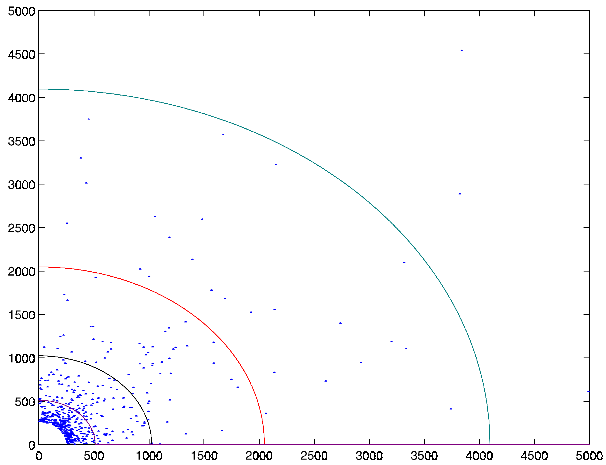

Figure 1.Coefficient distribution

3 Results

Results for four test images and also those obtained with Said & Pearlman algorithm are presented in tables 2, 3, 4 and 5. The four cases are black and white images with dimensions 512x512 and 8 bpp. Bits per pixels rates obtained in every case have been calculated from the length of the file where they are stored. It has never been considered entropy coding which implies greater reduction of bit per pixel rate. Arithmetic coding in [3] may produce an improvement of 0.3 to 0.6 dB for the same bit per pixel rate and similar increments will be expected in the proposed coder.

The measure of distortion is the peak signal to noise ratio (PSNR) which is derived from the mean squared error.

$$PSNR = 10\log_{10}\frac{255^2}{mse}$$

4 Conclusions

Results obtained show, for several rates in the FINGPRINT image and in the GOLDHILL image a slightly better behaviour of the coder developed in this work with regard to SPITH. Results obtained in the LENA image and in BARBARA image are also very similar to those obtained with SPITH. In all cases can be said that EQV gives better results than scalar quantization. These results lead us to assign a relative relevance to the relation between the coefficients of different frequency bands.

This article`s main contribution is that it is more important to exploit the intra-band relations of wavelet coefficients than the inter-band. So new coders can be developed in order to achieve faster speed coding or select different schemes for the wavelet transformation, like the best-basis wavelet packet transform.

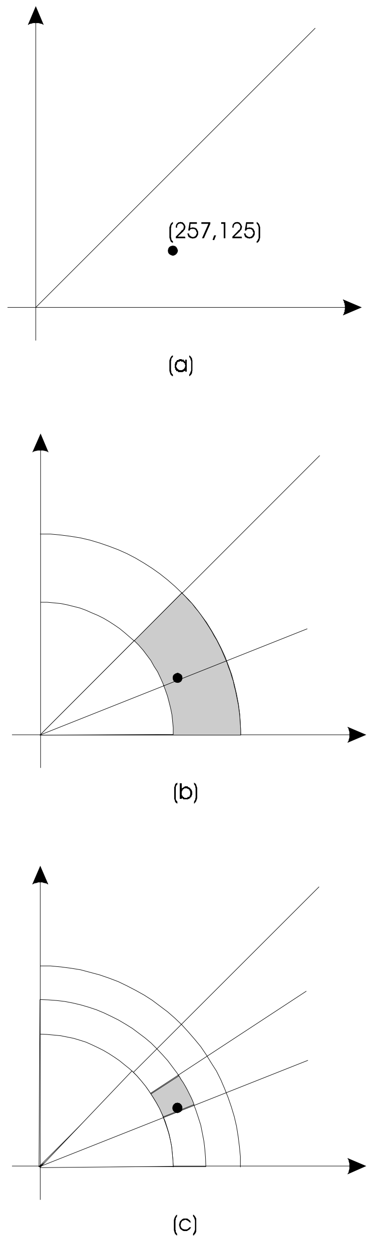

Figure 2. Evolution of the EVQ

	sc. cod.	vec. cod.	SPIHT
0.1 bpp	28.22	28.46	28.48
0.2 bpp	30.60	30.90	31.12
0.3 bpp	32.06	32.54	32.81
0.4 bpp	33.23	33.59	33.92
0.5 bpp	34.37	34.65	34.90

Table 2. Results for Lenna (512 x 512 pixels)

	sc. cod.	vec. cod.	SPIHT
0.1 bpp	24.15	24.34	24.37
0.2 bpp	26.21	26.49	26.68
0.3 bpp	27.46	28.17	28.66
0.4 bpp	29.34	29.56	30.32
0.5 bpp	30.49	31.37	31.62

Table 3. Results for Barbara (512 x 512 pixels)

	sc. cod.	vec. cod.	SPIHT
0.1 bpp	26.03	26.14	26.00
0.2 bpp	27.89	28.16	28.19
0.3 bpp	29.81	30.03	29.69
0.4 bpp	30.62	31.00	30.97
0.5 bpp	31.76	31.92	31.94

Table 4. Results for Fingprint (512 x 512 pixels)

	sc. cod.	vec. cod.	SPIHT
0.1 bpp	27.43	27.77	27.64
0.2 bpp	29.27	29.48	29.50
0.3 bpp	30.32	30.86	30.81
0.4 bpp	31.30	31.67	31.79
0.5 bpp	32.22	32.52	32.68

Table 5. Results for Goldhill (512 x 512 pixels)

References:

[1] Maldonado-Bascón, S.; López-Ferreras, F.; Amo-López, P. “Unhierarchical coding of image wavelet coefficients without sending the sign” *Proc.of the IEEE-SP Int. Symposium on TFTS Analysis. Pittsburgh*, U.S.A. Oct. 1998.

[2] Mallat, S. “A theory for multiresolution signal decomposition: The wavelet representation” *IEEE trans. on pattern analysis and machine intelligence.* Vol. II N. 7 July 1989

[3] Said, A., Pearlman W. A. “A new fast and efficient image codec based on set partitioning in hierarchical trees.” *IEEE trans. on ciruits and systems for video technology*, Vol. 6 June 1996

[4] Strang, G.; Nguyen, Truong. “Wavelets and filters banks” *Wellesly-Cambridge Press* 1996

[5] Shapiro, Jerome M. “Embedded image coding using Zerotrees of wavelet coefficients” *IEEE trans. on signal processing*, Vol. 41 n.12, Dec 1993.