IMAGE CODING BASED ON EDGES AND TEXTURES VIA WAVELET TRANSFORM

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ABSTRACT

The increasing interest on image compression is due to the increasing necessity of transmission velocity and memory to keep digital images, on many kind of midia. In order to reduce the quantity of bits needed to store images and, consequently, increase their transmission velocity, many coding methods have been studied, especially those which utilize transforms.

This paper presents an image compression technique that codifies edges and textures separately using the wavelet transform. Several test images have been coded with the proposed method and the results show that the reconstructed images have good performance in relation to their PSNR and, especially, in terms of visual perception.

1. INTRODUCTION

Our ability to interpret a line drawing as being similar to the image from which it was derived is a fact that has obvious importance for image compression, since line drawings, in general, can be represented with a smaller number of bits, if compared with gray level images. Edges and textures represent structural properties of an image, and a coding method that dismembers an image in these two categories and codes this information separately, can be considered a second generation image coding method as it takes advantage of the structural properties of such image.

The wavelet transform has been studied with growing interest, specially by image processing community due to its similarity with the human visual system[1].

In the present paper two different definitions of wavelet transform are employed. The dyadic wavelet transform [2] [3] [4] is used to extract and code the edge information. Another coding scheme, a wavelet transform subband based coding [5] [6] is utilized to code the texture information.

This paper is organized as follows. In Section 2 we discuss the edge detection performed by wavelet transform. In Section 3 the coding process suggested is described. Finally in Section 4 we summarize our results and our conclusions.

2. DETECTING EDGES WITH WAVELET TRANSFORM

It has been shown [2] [3], that multiscale edges can be detected and characterized with a wavelet transform. For a particular class of wavelets, called dyadic wavelet transform, the local maxima of this wavelet transform provide the locations of edges in images.

If an image is represented as f its dyadic wavelet transform [2] [3] is defined as:

$\left\{S_{2^J}^d f, \left(W_{2^j}^{1,d} f\right)_{1\le j\le J}, \left(W_{2^j}^{2,d} f\right)_{1\le j\le J}\right\}$ over the 2^j scales.

From a practical viewpoint these components can be obtained by filtering the low frequency image ($S_{2^j}^d f$; for $j=0$, $S_1^d f = f$) using the filters coefficients as described in [2].

The modulus of the dyadic wavelet transform can be calculated on each point *(x,y)* as

$M_{2^j} f(x,y) = \sqrt{\left|W_{2^j}^1 f(x,y)\right|^2 + \left|W_{2^j}^2 f(x,y)\right|^2}$ and the phase as $A_{2^j} f(x,y) = \arctan(W_{2^j}^2 f(x,y) / W_{2^j}^1 f(x,y))$.

For each scale 2^j a point *(x,y)* is considered as a wavelet transform modulus maximum if its modulus is bigger than its left and right adjacent points moduli. These set of points form, at each scale, another image containing several edges of the original image.

A close approximation to the original image can be acquired from these multiscale edges if we keep all the information produced by the wavelet transform and by the edge detection process, that is: edges on each wavelet transform scale, module and phase information on these maxima positions and, a low frequency image that is obtained by the wavelet transformation. The method for image reconstruction is based on an alternating orthogonal projections algorithm which recovers the wavelet components of all scales and the reconstructed image is obtained by executing the inverse transformation[2].

3. THE SUGGESTED CODING PROCESS

As described before, the application of the dyadic wavelet transform leads to a map containing the edges of the image. By applying the transformation process successively we get a different edge map for each scale. The amount of the details in each scale decreases as we go to higher scales in the dyadic wavelet transform process.

In order to reach a good compression ratio, some information should be abandoned in the edge coding process, like contours that seem to be not "important" to the image understanding, or edge maps on some scales. In the proposed method only three scales of the transform are used. All the three edge maps of these scales are necessary for the image reconstruction. As a way of reducing the amount of data stored only the edge map of the second scale is kept and used as an approximation of the two others. Also the length of each edge line is measured in order to discard those smaller than a given line size.

In order not to lose all the information that has been discarded, which can impose severe image distortions, an error image can be obtained by subtracting the reconstructed image by the edge coding method from the original one. This error image has most of its energy concentrated in texture regions and has to be coded separately by using another coding scheme, like the well known wavelet transform subband coding method.

This kind of approach, that is, to code edges using multiresolution decomposition by means of wavelet transform and, textures separately by employing another coding method, was first proposed by Mallat and Froment [4]. The proposed coding scheme represents a step towards an improvement of their method [7].

In the present work, the approach used for the edge coding is that, the edge selection is based on the length of the contour line and only one reference edge map is kept as if the edge locations would not move across scales. This edge map is preserved by keeping the origin point of each contour line and its directions across the map.

The wavelet transform moduli of the selected edge points must be kept too. This is done by preserving only one line module average and after, a predictive coding is applied by using the DPCM (differential pulse code modulation) and arithmetic coding. Doing this, it is possible to take advantage of having a short alphabet of symbols, what increases the arithmetic coding efficiency.

For the low frequency image produced by the dyadic wavelet transform, the embedded zerotree wavelet coder (EZW), defined by Shapiro [5] [6], is used. This procedure allows an entire edge reconstructed image which has better quality than sub-sampling and interpolation as used in [4].

The phase values of each selected edge points are necessary for the use of the alternating orthogonal projections algorithm [2] as part of the image reconstruction process. They are not retained in the compression process and can be recovered by using the low frequency image produced by the dyadic wavelet transform process.

The error image, that has most of its energy concentrated in texture regions is low frequency bound, and so, it is also coded by the Shapiro's EZW method. In addition to the satisfactory coding ratio and reconstruction image quality, the EZW algorithm allows a bit rate control by means of its characteristics of stopping whenever a desired bit rate is met.

4. SUMMARY

Many test images were coded using the proposed method. Table 1 presents some of these results. As can be seen, the proposed scheme reach better peak signal to noise ratios (PSNR) than the JPEG (Joint Photographic Expert Group) method in most of the case.

Table 1 Peak signal to noise ratio (PSNR) in dB obtained for some test images

IMAGE	LENGTH	COMPRESSION RATIO	PSNR	PSNR (JPEG)
BOAT	(256X256)	1 bit/pixel	27.68	23.26
LADY	(256X256)	1 bit/pixel	33.84	32.94
LENA	(256X256)	1 bit/pixel	34.51	33.52
SOLIDS	(256X256)	1 bit/pixel	43.00	42.93
SOLIDS	(256X256)	0.5 bit/pixel	36.67	37.03
LENA	(512X512)	1 bit/pixel	38.50	37.05
LENA	(512X512)	0.5 bit/pixel	34.93	35.01

Also the reconstructed images have peak signal to noise ratios (PSNR) greater than many methods based on wavelet transform. Furthermore, one of the principal advantages of this method is that the contours of the image are well defined and are not destroyed by the compression process, what usually happens. Visually, this characteristic is welcome to the human observer, and can be better observed if we compare the suggested method with JPEG as we can see in Figure 1 and Figure 2.

The suggested method improves the second generation coding method proposed in [4]. In addition, it presents simulation results that have PSNR comparable with those of the most efficient image coding procedures, with superior performance in terms of visual perception.

5. REFERENCES

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(a)

(b)

Figure 1: Lena (512x512) recovered by (a) JPEG and (b) the coding method based on edges and textures, both at a compression ratio of 0.5 bit/pixel.

(a)

(b)

Figure 2: Lady (256x256) recovered by (a) JPEG and (b) the coding method based on edges and textures, both at a compression ratio of 1bit/pixel.