LOSSY IMAGE COMPRESSION USING A THREE STEP NONLINEAR WAVELET

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ABSTRACT

The wavelet transform is a powerful and complex tool in the context of data compression. The discovery of the lifting schemes structure make à wavelet filters simple, rapid and reversible. The compression field is an open research area. In recent years, a significant development has experienced leading to the emergence of a large number of applications. This work aims to study some adaptive nonlinear wavelet -developed recently- based on three nonlinear steps. These transforms are applied in lossy image compression; in our work, we used a bit allocation algorithm and scalar quantization.

KEYWORDS: Nonlinear wavelet, lifting schemes, lossy image compression, bit allocation algorithm, uniform quantization

1 INTRODUCTION

The image is à strong media has semantic content, it became a means of communication to full increasingly present in our daily lives. It is also an essential tool in satellite and astronomical fields, film production, and industrial computing.

Today, the wavelets have proven their usefulness in many application areas of signal and image processing, especially in image analysis and coding.

A disadvantage of linear wavelet is their inability to adapt to the data regularity. Indeed, in areas where the signal is very regular, we would use high-order wavelets, whereas in areas where it is irregular, we would prefer to use wavelets to lowest order.

The discovery of the lifting structure [1] has a multiresolution wavelet transforms, with a simple construction, always invertible and authorizing the implementation of nonlinear operators able to capture the singularities of a signal. The adaptive lifting scheme is a modified version of the classical one; the adaptation consists in choosing between different filters, according to local information signal, there are two adaptive lifting forms: either we begin by predicting then updating or by applying the update operator after the prediction one [1].

In this context, the researchers [3],[5].[6] have identified a new class of adaptive wavelets. Our work consists first, to study those wavelet filters, then, to realize the lossy image compression with this nonlinear transform.

This paper is organized as follows. Sections 2 represent the image compression system based on adaptive wavelet transform and a detailed description of each block.

An overview of the performance criteria used in compression in section 3. Simulation results and concluding remarks are presented in sections 4 and 5, respectively.

2 PRINCIPLE OF METHOD

The main principle of our compression scheme, is illustrated in Figure 1,

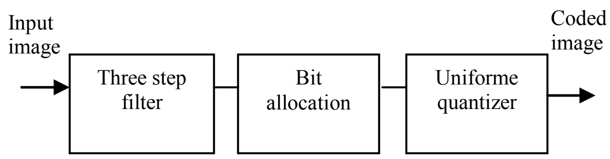

Figure 1: Principle of the compression scheme

2.1 Three step filter

2.1.1 2D nonlinear filter with three steps

Analysis

The principle of analysis of 2D is the 1D transforms applied to the lines then to the clowns. In the analysis operation, the original image is decomposed in to two polyphases images of size (N/2xN), one is the even lines and the other is odd ones, these images are filtered with 1D nonlinear three step lifting schemes. Then, the results will be filtered by column and the final output will be four images of the same size (N/2xN/2) Presents approximated, and three images of detail (horizontal, vertical and diagonal). Figure 4 shows the analysis operation to 2D (three stage of lifting scheme)

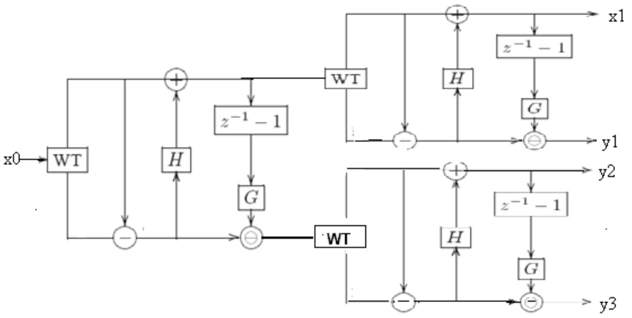

Figure 2: The analysis operation in 2D (three stage lifting scheme)

Where WT is the lazy wavelet transform $x(n) = x_0(2n)$, $y(n) = x_0(2n-1)$ and H, G are threholding operators defined for all u □ IR as:

$$H(u) = \begin{cases} 1/2\ u & \text{if } |u| \langle T \\ \alpha\ T\ /\ 2\,sign\,(u) & \text{otherwise} \end{cases}$$

$$G(u) = \begin{cases} u & \text{if } |u| \succ T' \\ \alpha' T' & \text{otherwise} \end{cases}$$

Where T, T' are positive threshold values and $\alpha, \alpha' \in \{0,1\}$ constants which determine the kind of thresholding (hard or soft) .

Synthesis

The synthesis operation is the opposite of the analysis, where the input is the approximated image and three details, the first filtering will be on column then both witches resultant will be filtered by line we shall obtain on one embellish with images synthesized has the same size as the original image as shown in Figure 3.

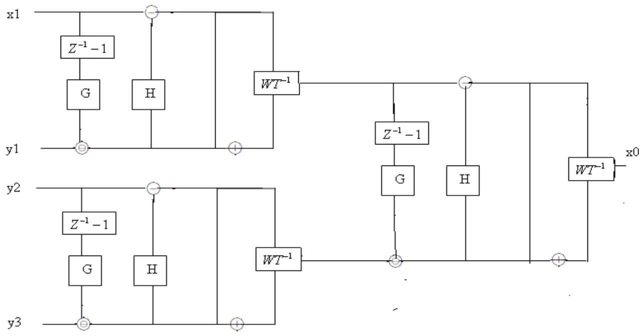

Figure 3: The synthesis operation in 2D (three stage lifting scheme)

2.1.2 Parameters filters sélection

These filters are not with a perfect reconstruction, where, the division on real numbers makes an error between the original image and the reconstructed one. These error depend to the filter coefficients $(T, \alpha, B, T', \alpha')$levels of decomposition and the nature of the image.

We have tested many images to select the efficient filter coefficients at many level of decomposition. As example, for the synthetic image SLOPE, the figures (4,5,6,7,8) presents the variation of the PSNR at different level of decomposition (psnr1 for one level of decomposition, psnr2 for two level, psnr3 for three level and psnr4 for four level) according the five coefficients $(T, \alpha, B, T', \alpha')$.

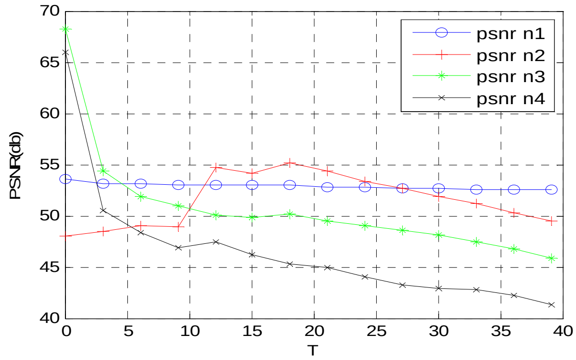

Figure 4: changes PSNR according to T

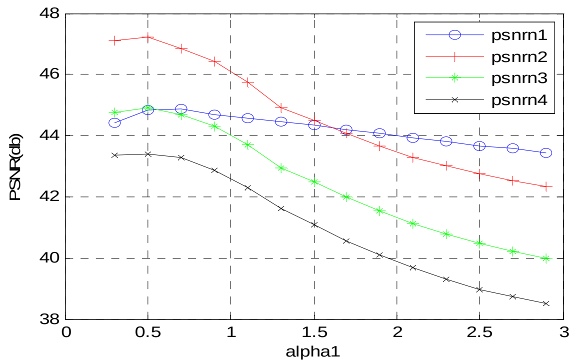

Figure 5: changes PSNR according to α

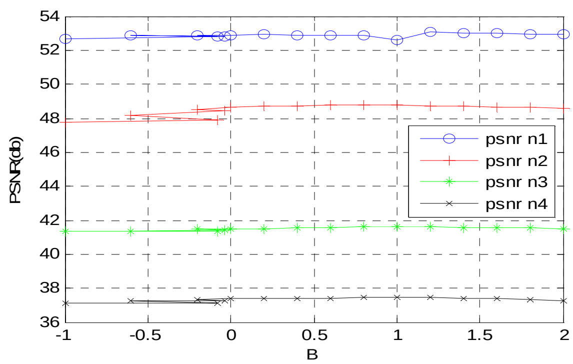

Figure 6: changes PSNR according to B

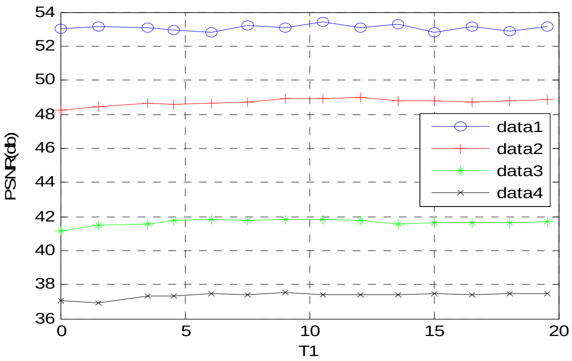

Figure7: changes PSNR according to T'

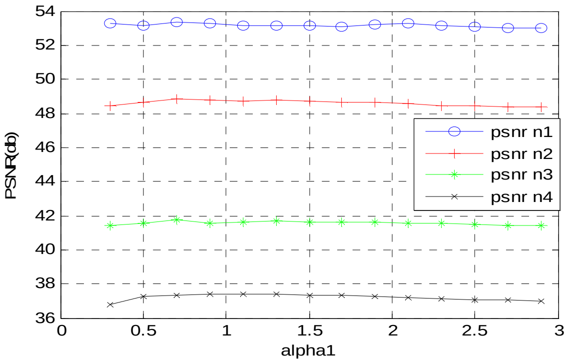

Figure 8: changes PSNR according to α'

This filter is adapted to the image nature; therefore, the filter coefficients change for every image, our choice is based on the maximum of PSNR between the original and reconstructed images.

The selected coefficients for the image slope and montage are resumed in table1 and table2.

Table1: PSNR results for different values of cœfficients at each level

Selected	*cœf*	T	α	α'	B	T'
Level (Slope Image)	1	53.634	52.873	53.328	53.058	53.416
	2	55.163	48.912	48.862	48.771	48.929
	3	68.193	41.890	41.746	41.609	41.863
	4	65.961	37.501	37.430	37.446	37.487
Level (Montage image)	1	52.013	52.014	53.511	52.772	53.933
	2	49.068	49.072	49.637	49.185	49.625
	3	47.207	47.208	47.791	47.219	47.712
	4	46.583	46.588	47.339	46.653	47.226

Table2: selected cœfficients at each level

Selected	*cœfficients*	T	α	α'	B	T'
Level (Slope Image)	1	0.1	0.3	0.7	1.2	10.55
	2	18.1	0.3	0.7	0.8	9.05
	3	0.1	2.7	1.3	0.8	9.05
	4	0.1	0.7	1.3	0.8	6.05
Level (Montage Image)	1	24.1	0.9	0.3	1.6	1.55
	2	30.1	1.1	0.3	1.6	4.55
	3	30.1	0.9	0.3	1.6	7.55
	4	36.1	1.3	0.5	1.6	7.55

LENA Image: Decomposition levels: level 1			
A THREE STEP NONLINEAR FILTER		9/7FILTER	
approximated image and details	Histogram	approximated image and details	Histogram

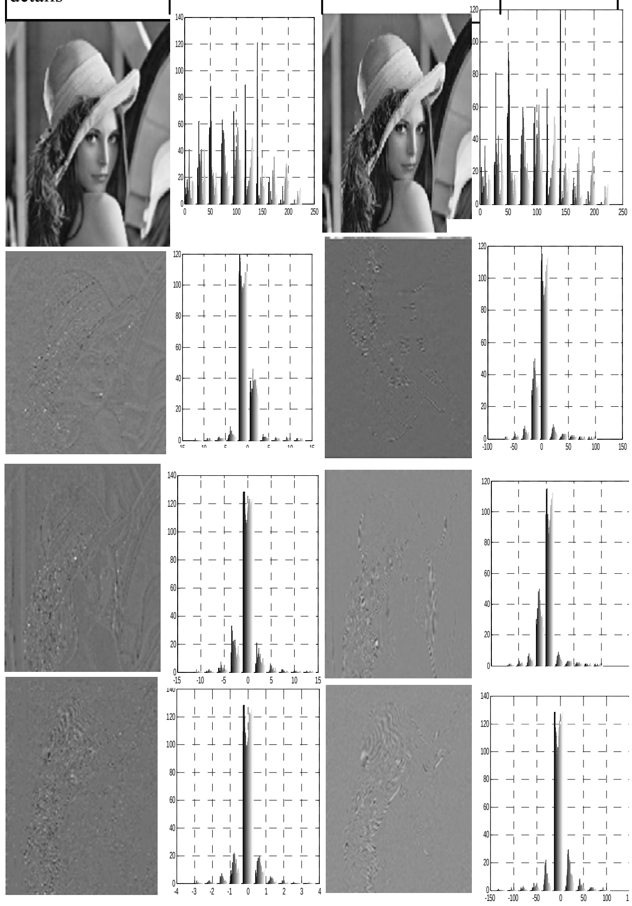

Figure 9: The changes of histograms by NL and 9/ 7 filters

Discussion

The filter efficiency is function of the image nature, for that we tested several pictures of different types:

- Portrait image (Lena): behave a variety of information, where the division in the filter stage can cause remarkable loss of information. This is clear in the result obtained. PSNR or has not exceeded (48 dB).
- The synthetic images: these images are simple, and there is some similarity between the pixels of the image. This feature has favorite the filtering operation of this kind of pictures, where the PSNR reach (66dB) for the images Slope.
- The image montage Decomposed of some images with different characteristics. This hybridization has contributed the synthetic images character and the PSNR is better than those of portrait images (54dB).

For all the images, we found that every time we increase the level of decomposition PSNR decreases, it is justified by the increase of the filtering operation that is to say the division causing more losses in information

2.2 Bit allocation

The type of quantizer to be used as well as its image coding performances can be determined from statistical analysis of sub–images obtained after nonlinear wavelet transform.

The normalized histogram of sub-images provides us with information on the distribution of the coefficient values in the sub-image [7]. The objective of such a bit allocation method is to optimize the overall coder performance and minimize the quantization error.

For this study, the bit allocation algorithm used is taken from [6].

Figure 9 shows the effect of changes in amplitudes approximated and details images. The sub-images resulting from the comparison between the histograms of two images (Lena and Slope) filtered by the adaptive nonlinear three-step filter and the biorthogonal 9/7. Note that the histogram of the approximate image from the adaptive nonlinear wavelet is similar to that of image processed by the bi-orthogonal one and the approximate image contains more information on filters NL.

For the images (vertical, horizontal and diagonal details) processed by the adaptive non-linear filter we see that the distribution of information is in a very small interval, compared to the biorthogonal 9/7, for the image Lena at one level of decomposition. For example, the interval of horizontal detail histogram is [-5, 5] with σ = .7054, and by the biorthogonal filter the interval is [-40.40] with σ = 466.3116.

2.3 uniform quantization

The purpose of quantization is to select, for a value of entrance given, the closest neighbor belonging to a finished set predetermined by numerical values.

The wavelet transform is followed by a bit allocation algorithm, then a uniform scalar quantization. Effects of quantization on the three-step non linear filter and the biorthogonal 9/7 are illustrated in Figures (10, 11, 12 and 13).

3 PERFORMANCE CRITERIA

3.1 Compression ratio and binary debit

It is the fundamental purpose of the compression, it gives a measure of performance of the methods of compression of the fixed images, and in other words it gives a measure of reduction of the quantity of information to pass on.

The compression ratio defines itself by**:**

$$rate = \frac{\text{Number of bits in the original image}}{\text{Number of bits in the compressed image}}$$

This compression ratio can be connected with the binary debit expressed in bits by pixel (bpp**).**

The debit constitutes an often used alternative measure which gives the necessary average number of bits to describe a pixel of the compressed image or still the digital resolution of the image divided by the compression ratio**.**

3.2 Peak Signal to Noise Ratio

For the quality measures: we shall use the "report signal on noise" RSB or SNR (signal to noise Ratio). An active variant of this measure is "the report signal on noise of crest with crest" PSNR (Peak Signal to Noise Ratio) [8] it confronts in decibels and defined from the EQM by the equation:

$$PSNR(db) = 10\log_{10}\left(\frac{255^2}{EQM}\right)$$

With $$EQM = \frac{1}{MN\sum_{i=1}^{M}\sum_{j=1}^{N}(I_0(i,j) - I_c(i,j))^2}$$

I_0 :The original image.

I_c :Compressed image.

N, M: length and width of the image respect

4 COMPRESSION RESULTS

For adaptive nonlinear filters with three stages:-Every time the value of TC increases, the PSNR value increases as well.

The change of these parameters de lays level of decomposition; it was found that every time these two values decrease the decomposition level increases. And they change with the type of image such as synthetic image the adaptive wavelets provide good resultsthen the biorthogonal 9/7. Whereas, for natural images, they give less accurate results.

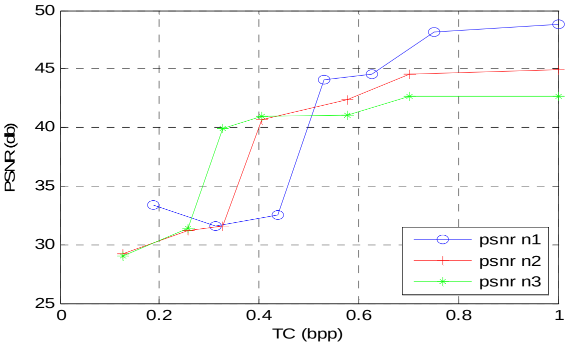

Figure 10: Effect of quantization on the filters nonlinear three steps for Montage Image

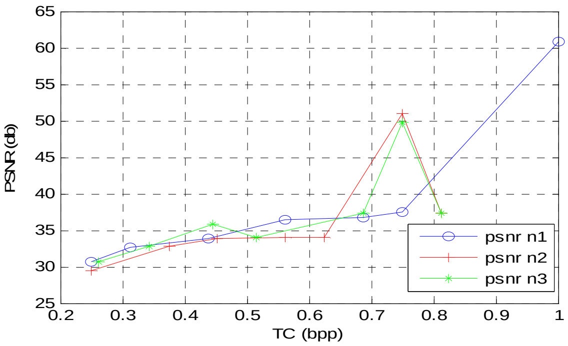

Figure 11: Effect of quantization on the 9/7 filters for Montage Image

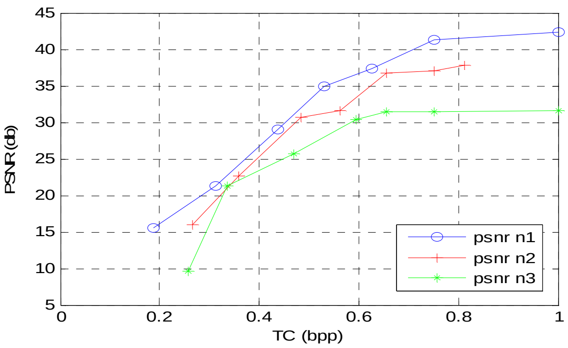

Figure12: Effect of quantization on the filters nonlinear three steps for Slope Image

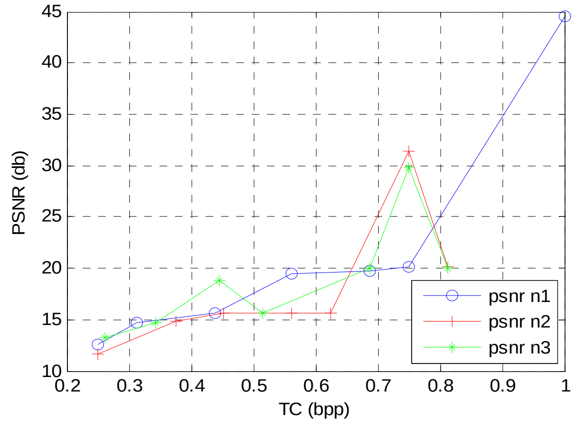

Figure13: Effect of quantization on the 9/7 filters for Slope Image

5 CONCLUSIONS

In this paper, we studied the application of new wavelet in the lossy image compression. This transform based on three lifting schemes is nonlinear. The selections of filter parameters depend on the image and decomposition level. The filters with selected parameter are used in our compression system. Where each filtered image is quantized with a number of bits. The number of bits is calculated by an algorithm off allocation. The work presented in this paper can be extended in various directions. We will try to implement these wavelets in video compression, and also to the field of image classification, pattern recognition and segmentation.

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