Adaptive compression of images based on wavelets

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Abstract

In most applications of image processing, the user is interested generally only in certain regions of the image. In these cases, it is reasonable to consider adaptive processing of different regions in the image.

In this work, we propose an adaptive image compression technique for still images using irreversible methods. After the selection of regions of interest, the approach consists in applying wavelet compression to these regions and classical JPEG image compression with losses to the context of the image. Testing this approach on images with regions of interest produced good results. Preliminary results revealed the superiority of adaptive compression in terms of compression ratio for comparable visual image quality. Moreover, when the context is compressed using JPEG, the wavelet method on regions of interest always outperforms the reversible LZ77 method in terms of compression ratio and visual image quality.

Keywords*: Image processing, adaptive compression, regions of interest, wavelets, JPEG, LZ77.*

1.Introduction

The image is the tool of choice in several fields such as medicine, multi-media and cartography. Its digitalization makes its transmission and storage reliable. Still, it is required that both transmission and storage devices have respectively high capacities and broad bandwidth [Mercier 2003]. The user is often only interested in a specific piece of information conveyed through the image, and it is this particular information which will be qualified as pertinent [Colinet 2001]. Moreover, an interesting compression approach consists of not degrading certain regions of interest while degrading other regions in the context in a controlled way. This suggests the use of an adaptive compression approach.

The adaptive approach is based on coding the scene by degree of importance with the help of various methods. The zones of interest can be detected manually or in a semi-automatic or automatic way. During the last decade, the adaptive compression has been used by many studies. In this context, Guisto and al. in 1990 [Guisto and al. 90] suggested a "smart" compression based on the use of a system which first locates the zones of interest. The compression phase consists of applying some techniques such as the vectorial quantification or polynomial approximation on these zones without worrying about losses. Nguyen [Nguyen 95] introduced an original method of selective compression of sequences of images classified by zones for transmission with very low flow. This method is based on the idea of level of interest affected at each zone of the scene in which the coder, which is of a hybrid structure, uses a global sub-band representation. The author gives a great emphasis on coding while the method does not allow control of the resolution of the filtered context. To overcome this problem, Benharrosh used an adaptive approach based on traditional reversible compression techniques associated with multi-resolution analysis. The objective is to transmit in an optimal way through a network of limited flow an image containing items preserved to full resolution in a low resolution context, while making it possible to avoid any potential loss of the zones of interest [Benharrosh 98]. More recently, Albanesi used a model of human visual system, that takes advantage of the space and the properties of frequency-localization of decomposition by wavelets to permit a quantification stage for each wavelet coefficient. In order to maintain the visual quality of the target image, his approach allows to the user to define arbitrarily formed zones of interest and allocate for each one a different quality factor [Albanesi 03].

The results obtained in these various works have incited us to test the performance of an adaptive method on the basis of irreversible compression techniques applied on the different zones of the image.

In this work, we are mainly concerned with the image quality in the zones of interest, the reconstructed image as a whole, and the compression ratio. Identification of the zones of interest will be done manually. Considering great success of wavelets in compression, we suggest applying a method based on wavelets to the zones of interest. We applied the JPEG method with losses on the context. We tested this approach on different images with one or many zones of interest. We compared the performance in terms of visual quality and compression ratio with those obtained by applying LZ77 method on the zones of interest. Further, we compared the results with those obtained with carrying out compression by wavelets then by JPEG method with losses on the whole image.

2.Methods

2.1. Adaptive compression concept

The proposed adaptive compression is directly concerned with the process of data exchange. This process consists of:

- A preliminary analysis of the data by the transmitter, who determines the qualified regions of interest;
- A manual or semi-automatic selection of the zones of interest;
- An adaptive compression of data to be transmitted or stored in such a way that the zones of interest are not degraded significantly.

After transmission or storage, synthesis or data reconstruction and analysis are performed. The first consists of reconstructing the transmitted data, which corresponds to data decompression stage [TEMICS 01]. The analysis consists of examining the transmitted data (zones of interest in a degraded context).

In an image with zones of interest, the image context must allow the user to comprehend the scene as a whole. Therefore, it is not necessary for the image to be represented with full resolution [Vasndev 96]. Morever, it is possible for the user to choose to compress it strongly according to his/her own interest. The JPEG method with losses allows the user to have high compression ratios after carrying out smoothing and decimation [Weidong 95].

2.2.Compression of the zones of interest

2.2.1.Extraction of the zones of interest

The objective is to introduce a method that can generate a low resolution image while keeping the user’s zone of interest intact. To achieve this, the preliminary stage consists of detecting then extracting it. Algorithms for extraction are not yet very reliable and need to be implemented and tested. On the other hand, the zones of interest in an image can differ greatly, requiring a study and implementation of various algorithms for extraction [Eglin 01].

In this study, we chose to manually extract the zones of interest based on surface selection This consists of selecting some squares, which are represented by three parameters for each zone: the first two locate it in the initial image (coordinates of the center (xi, yi) and the side ai), the third parameter corresponds to its intrinsic value in the image. That is to say, the radiometry of the pixels constitute the zone of interest (Fig.1).

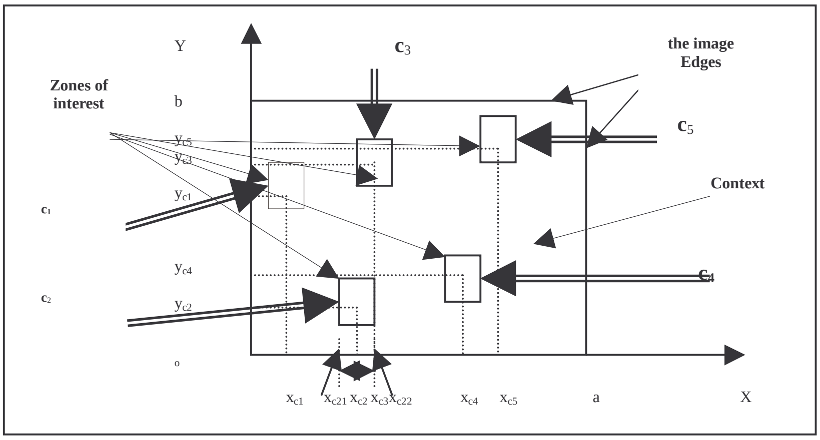


Figure1. Selection of the Zones of interest (**a**= the image width, **b**= the image length, **(x_{ci} ,y_{ci})**= the coordinates of the center of the square **C_i** which represents a zone of interest, **O_i**= the square center **C_i**, **a_i**= x_{ci2}-x_{ci1} = the square side **C_i**).

2.3.2.Compression by wavelet method

The following figure shows the principle of compression by wavelet method :

Figure2. Principle of the image compression by wavelet.

The transformed image corresponds to multi-resolution analysis of the image, used in several layers. In each one, the geometrical dimensions are reduced at a rate of 2 per whole of the orthogonal filters (where the characteristics are determined by the wavelet family used). Thus, the result consists of 4 small images. One of them represents the source image (henceforth “smooth” image) while the 3 others contain information of high frequencies lost during the reduction stage (henceforth “detail” image). The passage from one layer to another is done through the reduced image (smooth), there are then, 4 times fewer points to treat: see Fig.3 [DeVore92].

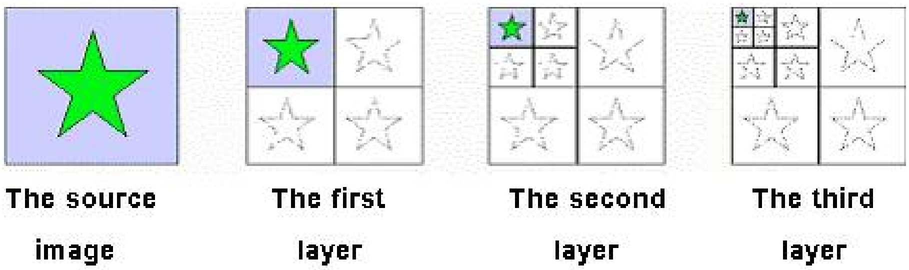


Figure3. multi resolution Analyzis of the image on 3 layers

The treatment is done by successive filterings on each image axis followed by a decimation (keeping one point out of two) Fig.4 [Feaureau 90].

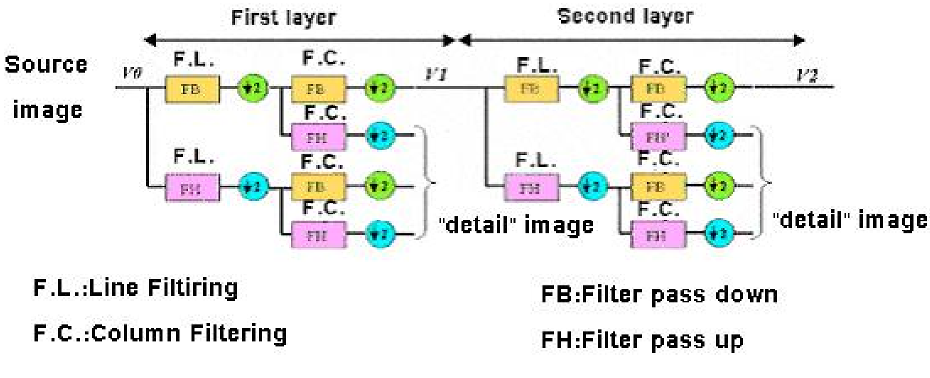


Figure4. Treatment of 2 layers of the wavelet

The objective of the treatment resides in "detail" image characteristics which allow us to make use of efficient algorithm quantification. The analysis of these images reveals that they consist of a many points of low value, which once forced to zero in quantification, will permit a strong compression ratio. However, the "smooth" image does not change (there is no quantification). Therefore, it is necessary to limit its size to reduce the data volume; a 5 layer treatment produces a "smooth" image that is 1024 times smaller than the original image [Eom 95].

2.3. Generale description of the method

Figure 5 describes the methodology suggested. The compression ratio using this methodology will depend, first, on the size of the zones of interest as compared to the image size and second, on the reduction factor applied on the support. The suggested method stipulates treating each datum in an optimal way compared to its type.

2.3.1. Diagram of the introduced method

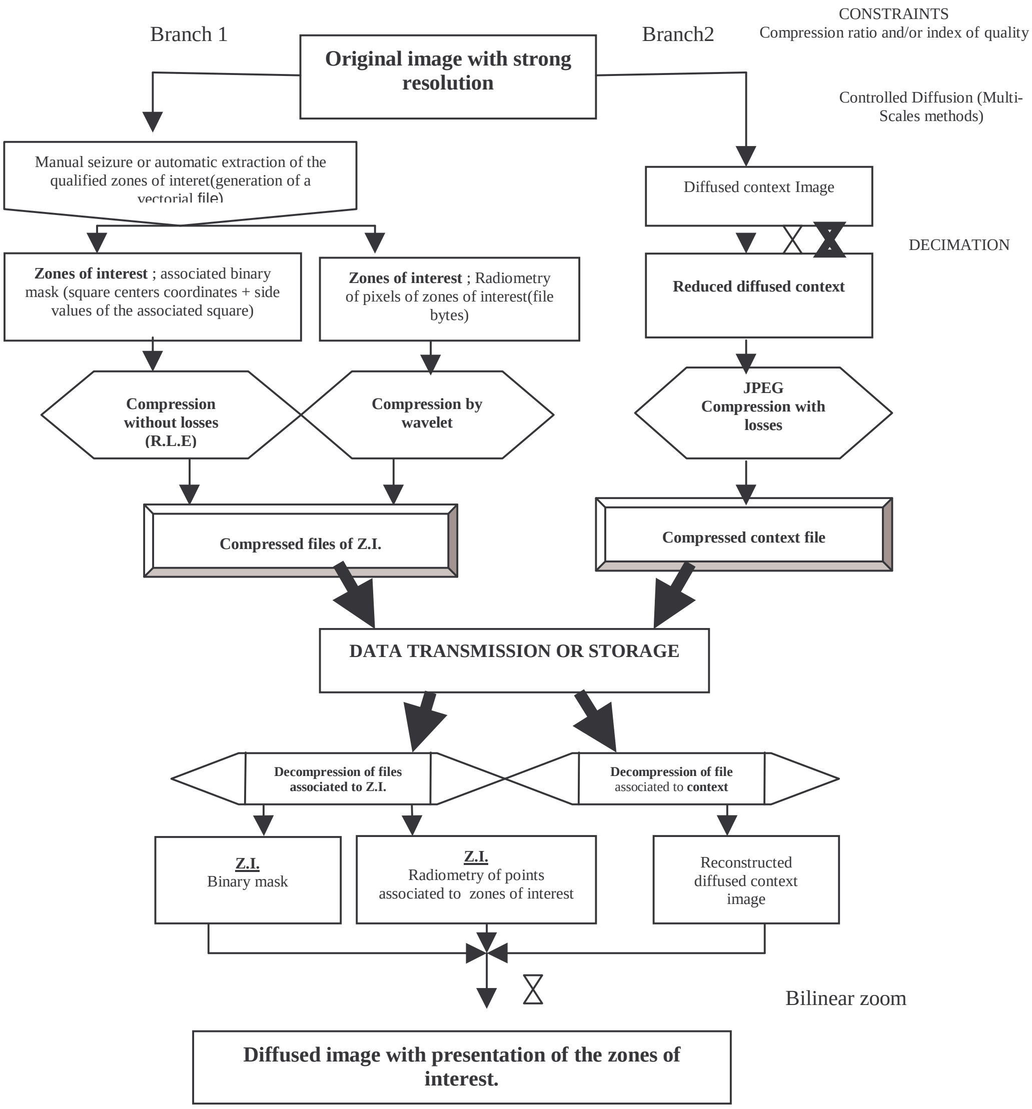


Figure5. Adaptive compression methodology

3.Results

We tested the adaptive method on a cartographic images from the internet with manually selected zones of interest.

3.1.Compression of the zones of interest (branch1, Fig.5)

In all the images, we chose to consider the zones of interest as a binary mask allowing us to locate the centers and sides of the square in the image and an image file containing pixels radiometries constituting these squares.

The mask is compressed by means of Run Length Encoding [Guillois 93] (the compression ratio is on average of order 10). The associated radiometries file is also determined by the method of wavelets (compression ratio higher than 20). We could also consider the zone of interest as a textual file containing the coordinates and radiometries of each element. However, this method is not valid unless the number of elements belonging to the zone of interest is very small as compared to the initial image size (lower than 1%). We notice that when the selection of the zones of interest is manual, it would be preferable to consider the binary mask as a vectorial file rather than an image in order to construct the mask [Pascal 00].

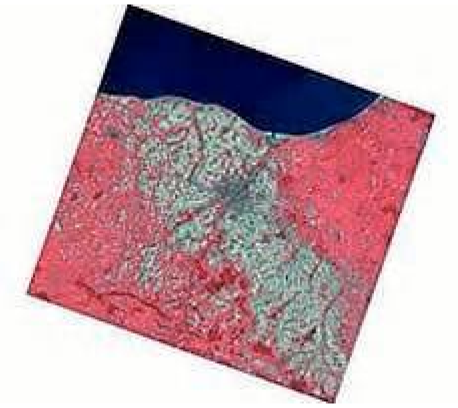
3.2.Compression of the context (branch2, Fig.5)

Smoothing is carried out simply to make the algorithms more effective considering the increase in correlation between close pixels [Vaish 90]. It is followed by context decimation, which leads to a large increase in the compression ratio on the context. However, it is necessary before decimation, to carry out diffusion in such a way to limit the effects due to spectrum folding up. It should be noted that the degradation level applied to the image during the diffusion is a function of the selected decimation factor [Moury 95].

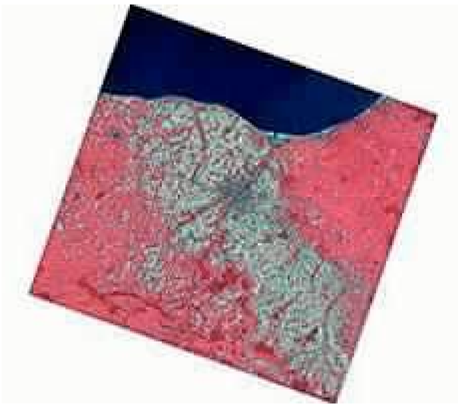
Under-sampling as much as JPEG allows to compress the context in an important way. However, while considering the quality of the reconstructed image, it is better not to under-sample and apply a JPEG very strongly [Rao and al. 90, Wallace 91]. The applied JPEG compression after decimation produces block effects. Nevetheless our method allows us to apply the JPEG method with losses on the context, and consequently obtain a much smoother image and additionally offer, a better compression ratio and a better quality.

3.3. Applications and Comparison of our approach with the JPEG method with losses, the wavelets method and the adaptive method based on LZ77.

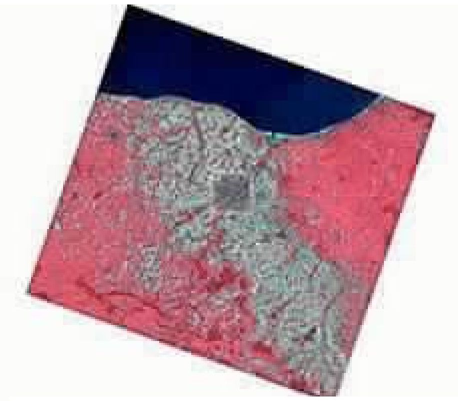
3.3.1. A case of one Zone of interest.



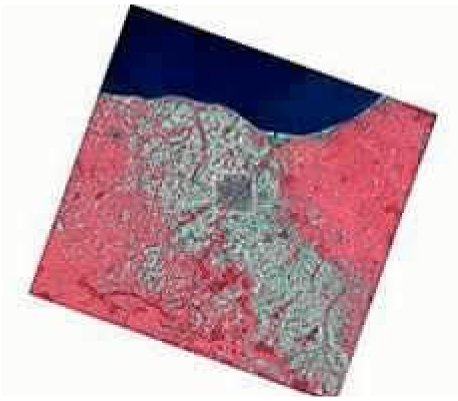
A cartographic image compressed by wavelts
Format : JPG-JFIF
Size of file : 7915 bytes
Quality : 0.80
Definition : 229(H)x199(V) pixels
Bits by Pixels: 24
Resolution : 96(H)x96(V) dpi



A cartographic image compressed by JPEG with losses
Format : JPG-JFIF
Size of file : 6642 bytes
Quality : 0.80
Definition : 229(H)x199(V) pixels
Bits by Pixels : 24
Resolution : 96(H)x96(V) dpi



A cartographic image compressed by the adaptive method based on the LZ77
Format : JPG-JFIF
Size of file : 6582 bytes
Quality : 0.80
Definition : 229(H)x199(V) pixels
Bits by Pixels : 24
Resolution : 96(H)x96(V) dpi

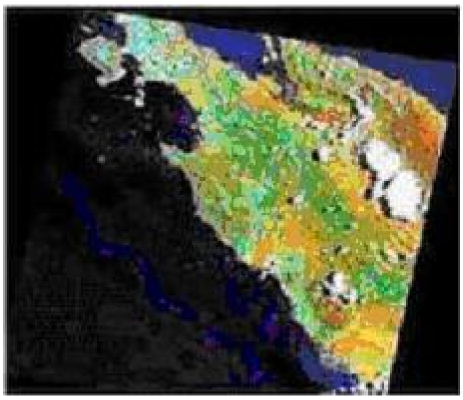


A cartographic image compressed by our approach
Format : JPG-JFIF
Size of file : 6496 bytes
Quality : 0.80
Definition : 229(H)x199(V) pixels
Bits by Pixels : 24
Resolution : 96(H)x96(V) dpi

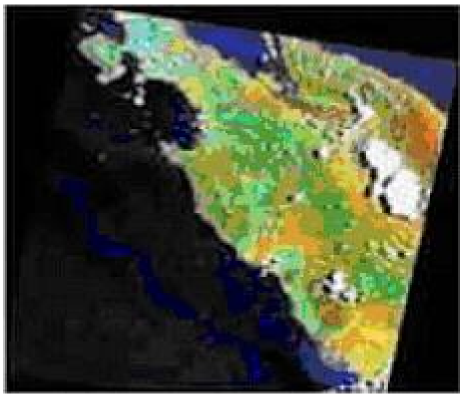
Z.I. compressed by LZ77
Format : JPG-JFIF
Size of file : 479 bytes
Quality : 0.80
Definition : 23(H)x23(V) pixels
Bits by Pixels : 24
Resolution : 96(H)x96(V) dpi

Z.I. compressed by wavelets
Format : JPG-JFIF
Size of file : 407 bytes
Quality : 0.80
Definition : 23(H)x23(V) pixels
Bits by Pixels : 24
Resolution : 96(H)x96(V) dpi

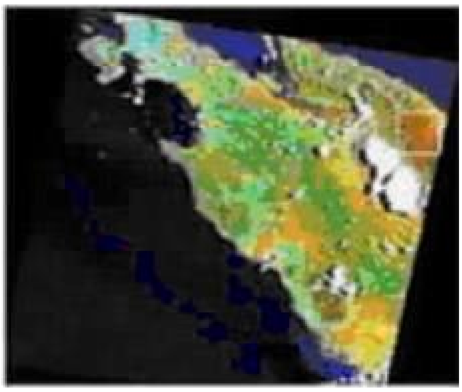
3.3.2. A Case of two Zones of interest.



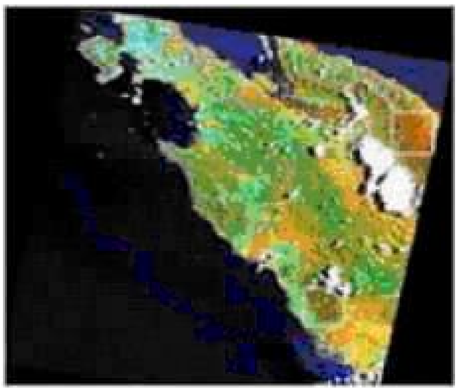
A cartographic image compressed by wavelet
Format : JPG-JFIF
Size of file : 7593 bytes
Quality : 0.80
Definition : 229(H)x199(V) pixels
Bits by Pixel : 24
Resolution : 96(H)x96(V) dpi



A cartographique image compressed by JPEG with losses
Format : JPG-JFIF
Size of file : 7926 bytes
Quality : 0.80
Definition : 229(H)x199(V) pixels
Bits by Pixels : 24
Resolution : 96(H)x96(V) dpi



compression by the adaptative method using LZ77
Format : JPG-JFIF
Size of file : 7401 bytes
Quality : 0.80
Definition : 229(H)x199(V) pixels
Bits by Pixels : 24
Resolution : 96(H)x96(V) dpi

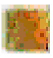


compression by our method
Format : JPG-JFIF
Size of file : 7318 bytes
Quality : 0.80
Definition : 229(H)x199(V) pixels
Bits by Pixels : 24
Resolution : 96(H)x96(V) dpi

Lower Z.I. compressed by LZ77
Format : JPG-JFIF
Size of file: 490 bytes
Quality : 0.80
Definition : 21(H)x21(V) pixels
Bits by Pixels : 24
Resolution : 96(H)x96(V) dpi

Higher Z.I. compressed by LZ77
Format : JPG-JFIF
Size of file: 531 bytes
Quality : 0.80
Definition : 24(H)x24(V) pixels
Bits by Pixels : 24
Resolution : 96(H)x96(V) dpi

Lower Z.I. compressed by wavelet
Format : JPG-JFIF
Size of file: 440 bytes
Quality : 0.80
Definition : 21(H)x21(V) pixels
Bits by Pixels : 24
Resolution : 96(H)x96(V) dpi



Higher Z.I. compressed by wavelet
Format : JPG-JFIF
Size of file: 475 bytes
Quality : 0.80
Definition : 24(H)x24(V) pixels
Bits by Pixels : 24
Resolution : 96(H)x96(V) dpi

3.3.3. A Case of three Zones of interest.

Compression by wavelets
Format : JPG-JFIF
Size of file : 9319 bytes
Quality : 0.83
Definition : 229(H)x199(V) pixels
Bits y Pixels : 24
Resolution : 96(H)x96(V) dpi

Compression by JPEG with losses
Format : JPG-JFIF
Size of file : 9729 bytes
Quality : 0.83
Definition : 229(H)x199(V) pixels
Bits by Pixels : 24
Resolution : 96(H)x96(V) dpi

Compression by the adaptive method using LZ77
Format : JPG-JFIF
Size of file : 9061 bytes
Quality : 0.83
Definition : 229(H)x199(V) pixels
Bits by Pixels : 24
Resolution : 96(H)x96(V) dpi

Compression by our approach
Format : JPG-JFIF
Size of file : 8934 bytes
Quality : 0.83
Definition : 229(H)x199(V) pixels
Bits by Pixels : 24
Resolution : 96(H)x96(V) dpi

Left Z.I. compressed by LZ77
Format : JPG-JFIF
Size of file : 401 bytes
Quality : 0.83
Definition : 19(H)x19(V) pixels
Bits by Pixels : 24
Resolution : 96(H)x96(V) dpi

Itermediate Z.I. compressed by LZ77
Format : JPG-JFIF
Size of file : 498 bytes
Quality : 0.83
Definition : 19(H)x19(V) pixels
Bits by Pixels : 24
Resolution : 96(H)x96(V) dpi

Right Z.I. compressed by LZ77
Format : JPG-JFIF
Size of file : 489 bytes
Quality : 0.83
Definition : 19(H)x19(V) pixels
Bits by Pixels : 24
Resolution : 96(H)x96(V) dpi

Left Z.I. compressed by wavelet
Format : JPG-JFIF
Size of file : 459 bytes
Quality : 0.83
Definition : 19(H)x19(V) pixels
Bits byPixels : 24
Resolution : 96(H)x96(V) dpi

Intermediate Z.I. compressed by wavelet
Format : JPG-JFIF
Siza of file : 457 bytes
Quality : 0.83
Definition : 19(H)x19(V) pixels
Bits by Pixels: 24
Resolution : 96(H)x96(V) dpi

Right Z.I. compressed by wavelet
Format : JPG-JFIF
Size of file : 448 bytes
Quality : 0.83
Definition : 19(H)x19(V) pixels
Bits byPixels : 24
Resolution : 96(H)x96(V) dpi

We summarize the results obtained on the following tables :

Image/Method	Original Size in bytes	Traditional methods				adaptive Méthods			
		JPEG with losses		Wavelet		LZ77 : Z.I JPEG :Context		Wavelet : Z.I JPEG :Context	
		Quality	Size of file	Quality	Size of file	Quality	Size of file	Quality	Size of file
Cartographic image1 (JPG-JFIF)	7953	0.80	6642	0.80	7915	0.80	6582	0.80	6496
Cartographic image2 (JPG-JFIF)	9091	0.80	7926	0.80	7593	0.80	7431	0.80	7318
Cartographic image3 (JPG-JFIF)	11161	0.83	9729	0.83	9319	0.83	9061	0.83	8934

Table1 : A comparison of the introduced method, given by the Quality and the Size of the compressed image, with the adaptive method using LZ77, method JPEG with losses and method based on the wavelet.

	Zone of interest	Original Size in bytes	Compression method			
			LZ77		wavelet	
			Quality	Size of file	Quality	Size of file
Cartographic image1 (JPG-JFIF)	Zone1	494	0.80	479	0.80	407
Cartographic image2 (JPG-JFIF)	Higher Zone	564	0.80	531	0.80	475
	Lower Zone	526	0.80	490	0.80	440
Cartographic image3 (JPG-JFIF)	Left Zone	521	0.83	501	0.83	459
	Intermediate Zone	520	0.83	498	0.83	457
	Right Zone	512	0.83	489	0.83	448

Table 2 : A comparison between the wavelet and LZ77 compression of the zones of interest on the various images tested.

We notice that the application of our adaptive method and that using LZ77 give good quality, but concerning compression ratio our approach is superior to that of each one of these methods.

4.Conclusion

We have suggested the adaptive method concept. It resides on the fact that the user is generally interested only in some parts of the image.

We have come to the conclusion that an interesting approach resides on a degradation of certain zones of interest, which is imperceptible to the naked eye, and a controlled degradation of the context. The selection of the zones of interest can be done either in a supervised way or not. The suggested method of compression can integrate some multi-resolution analysis techniques in a very sophisticated way together with some existing compression techniques (with or without loss). It enables the user to consider each datum in an optimal way according to its type. Consequently, the user obtains relatively high compression ratios and a higher quality image. As we have pointed out, using our method, we obtain a good quality with a compression ratio higher than that of the adaptive method using LZ77, JPEG with losses and the wavelet method.

The automated methods for extracting the zones of interest have the advantage of controlling the resolution of the filtered image. However, their application opens is very heavy (management of a great number of images, "detail" images and resolution images degraded in the same size as the initial image as it is the case of the Wavelet Transform by Holes W.T.H). However, these methods do not allow synthesis to whatever scale.

We are considering extending this research work by applying the wavelets package and the combining fractals and wavelets on the zones of interest.

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