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Image denoising using fractal coding technique in wavelet domain

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Abstract *– There is a considerable amount of literature about image denoising using fractal image coding methods. Some new ideas where also reported using wave late domain. In this paper we propose a mix wavelet-fractal denoising method. Using a non sub-sampled over-complete wavelet transform. We present the image as a collection of translation invariant copies in different frequency sub-bands. Within this multiple representation we do a fractal coding which tries to approximate a noise free image. The inverse wavelet transform of the fractal collage leads to the denoised image. Our results are comparable to some of the most efficient known denoising methods.*

Keywords*: image denoising, fractal image compression, fractal denoising, wavelet image denoising, image restoration*

I. Introduction

Digital images play an important role both in daily life applications such as satellite television, magnetic resonance imaging, computer tomography as well as in areas of research and technology such as Geographical information systems and astronomy. Data sets collected by image sensors are generally contaminated by noise. Imperfect instruments, problems with the data acquisition process, and interfering natural phenomena can all degrade the data of interest. Furthermore, noise can be introduced by transmission errors and compression. By analogy unwanted electrical fluctuations themselves came to be known as "noise". Image noise is, of course, inaudible.

Types of noise

Which is affected to the transmission and receiving of the images

-Amplifier noise (Gaussian noise)

-Salt-and-pepper noise

-Shot noise

-Quantization noise (uniform noise)

The magnitude of image noise can range from almost imperceptible specks on a digital photograph taken in good light, to optical and radio astronomical images

Which are almost entirely noise, from which a small amount of information can be derived by sophisticated processing thus, denoising is often a necessary and the first step to be taken before the images data is analyzed. It is necessary to apply an efficient denoising technique to compensate for such data corruption. Image denoising Still remains a challenge for researchers because noise Removal introduces artifacts and causes blurring of the images. This paper describes different methodologies for noise reduction (or denoising) giving an insight as to which algorithm should be used to find the most reliable estimate of the original image data given its degraded version. Noise modeling in images is greatly affected by capturing instruments, data transmission media, image quantization and discrete sources of radiation. Different algorithms are used depending on the noise model. Most of the natural images are assumed to have additive random noise which is modeled as a Gaussian. Speckle noise is observed in ultrasound Images whereas Rican noise affects MRI images. The scope of the paper is to focus on noise removal techniques for natural images. There are many different types of noise will added during Transmission and receiving of image.

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II. Fractal image coding technique

II.1 what is a fractal?

A fractal is a geometric figure, often characterized as being "self-similar": irregular, fractured, fragmented, or loosely connected in appearance. Benoit Mandelbrot coined the term fractal to describe such figures, deriving the word from the Latin "fractus": broken, fragmented, or irregular.

II.2 Fractal image coding

Fractal image coding can be described as follows: The image to be encoded is partitioned into non-overlapping range blocks ***Y***. The task of the fractal coder is to find a larger block of the same image (a domain block) ***X'*** for every range block such that a transformation of the domain block is a good approximation of the range block (figure 1). The transformation consists of a geometrical transformation and a luminance transformation . The geometrical transformation performs a lowpass filtering and sub-sampling follow by a position shift.

The luminance transformation scales the intensities and changes the mean of the downscaled domain block ***X***. The *collage* is the approximation that is obtained if all fractal transforms are applied to the original image. Fractal coding consists in finding a good collage that is very similar to the original image. Under the condition that these transformations are contractive, this set of transformations can iteratively be applied to any initial image which then will converge to the decoded image (the fractal *attractor*). Fractal encoding of images is lossy. Compression can be achieved if the set of transformations can be described more efficiently than the original pixel data. The error between the original image and the fractal collage will always be exceeded by the error of the decoded fractal attractor.

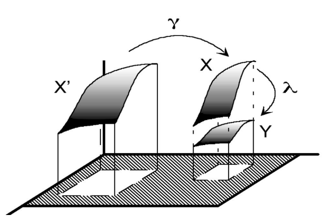

Fig.1. fractal approximations of a range block ***Y*** through a transformed domain block ***X'***

Smooth regions and edges are very self similar and can be coded efficiently by fractal coders. Irregular textures or noisy regions can not be approximated well, as they do not possess similarities across scales. This can be overcome by using a coding scheme with variable block sizes (e.g. quad tree partitioning) or hybrid coding approaches combining fractal coding with other coding techniques. Various optimizations of fractal coding schemes were performed. However as described in the next section, it turned out that fractal coding can be described as a mapping of coefficient-trees in a wavelet decomposition of an image. Fractal coding is nothing else but a wavelet coder with a very restricted mapping rule for coefficient (sub-) trees. This is one reason why other (non "fractal restricted") wavelet coders outperformed pure fractal coding schemes.

II.3 Use of Fractal coding technique for image denoising

Fractal denoising tries to use the fact that fractal coders can describe self similar structures across scales very well but do fail to approximate noisy structures. Consequently if a conventional fractal image coder is applied to a noisy image it will produce a noise reduction. The task of fractal denoising is to construct a fractal code for the noisy image such, that either the collage or the attractor is closer to the original noise-free image than the non encoded noisy image. Opposed to fractal compression no restrictions to the number or complexity of the transformations have to be made. The fractal code for the image to be denoised has to be constructed in such a way that the original image parts have to be preserved (approximated as well as possible) whereas all noisy components should be discarded. In order to achieve this, a careful choice of fractal encoding parameters has to be made. Figure 3 shows the influence of the block size of a fractal coder if applied to a noisy image. If the range block sizes are chosen to be large, then all noisy components will be removed, however the quality of the original image will also be degraded. A smaller range block size will improve the image quality. If the range block size is too small however, all details from the original image can be approximated well but now also the noisy components will be approximated, which brings back the noisy components leading to a lower overall quality. This example demonstrates the importance of a proper choice of the fractal encoding parameters that need to be adapted to the image content and the amount of noise. A simple approach is to use a quadtree partitioning scheme. If some decision criterion (like the approximation error) is exceeded for a range block, then this block is split into four smaller blocks. Figure 3 (lower line, middle) shows the coding result of a

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quadtree partitioning with improved denoising results. However also this result is still far from being acceptable. In addition it should be observed how the image quality is severely affected by blocking artifacts is a fractal coder operating in the spatial domain is used for denoising.


Fig.1(a) fractal attractor, bs = 16 PSNR = 24.3

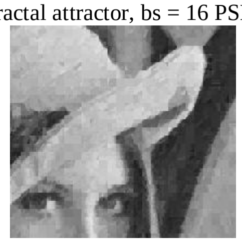
Fig.1 (b) fractal attractor, bs = 8 PSNR = 26.8


Fig.1(c) fractal attractor, bs = 4 PSNR = 25.7

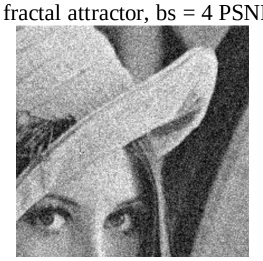
Fig.1 (d) noisy image PSNR = 20.2

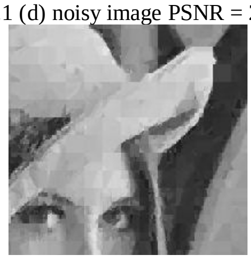
Fig.1 (e) fractal attractor using aquadtree partition
bs = 16/8/4 PSNR = 27.3;

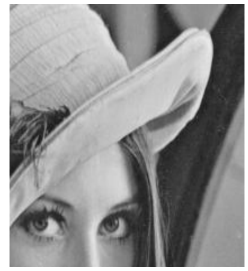
Fig.1 (f) original image

II.3 Fractal coding in the wavelet domain

A wavelet is a wave-like oscillation with an amplitude that starts out at zero, increases, and then decreases back to zero. It can typically be visualized as a "brief oscillation" like one might see recorded by a seismograph or heart monitor . Under the partitioning constraint that every domain block is made up of an even number of range blocks conventional fractal coding can be described in the Haar-wavelet domain. The approximation of a range block through a contracted domain block in the spatial domain then can be described as the prediction (or extrapolation) of fine scale coefficients from coarse scale coefficients in the wavelet domain. The spatial contraction (lowpass average filtering and subsampling) corresponds to moving coefficients to the next higher frequency scale (figure 2). Now the decoding can be performed in a non-iterative way by consecutively extrapolating higher frequency coefficients from lower frequency coefficients. Fractal coding in the wavelet domain is not limited to the Haar-wavelet. The usage of smooth basis wavelets corresponds to fractal coding with overlapping range blocks in the spatial domain, thus avoiding blocking artefacts. A detailed description of the analogy of fractal coding in the spatial and the wavelet domain can be found in 10. The geometrical transformation consists in picking a wavelet coefficient-tree of a domain block ***X'*** and to eliminate the highest frequency coefficients. This corresponds to a lowpass filtering and subsampling. Then this reduced coefficient tree ***X*** is mapped to the position of the coefficient-tree of the range block ***Y*** in the next higher frequency levels. The luminance transformation allows the values of the mapped coefficients to by multiplied by a scaling factor a. The mean of the range block to be changed or set by adjusting or setting one single (root) coefficient in the lowest frequency band.

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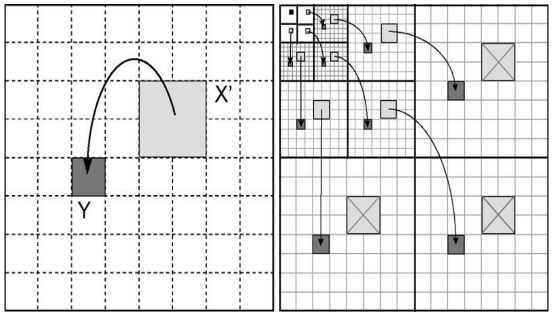

Fig.2. Interpretation of fractal coding in the wavelet domain.

The approximation of a range block ***Y*** through a spatially contracted domain block ***X'*** (left) can be done in the wavelet domain (right).

III. Wavelet based denoising schemes

The idea of wavelet thresholding relies on the assumption that the signal magnitudes dominate the magnitudes of the noise in a wavelet representation, so that wavelet coefficients can be set to zero if their magnitudes are less than a predetermined threshold. Donohue and Johnstone 11 proposed *hard*- and *soft*-thresholding methods for denoising, where the former leaves the magnitudes of coefficients unchanged if they are larger than a given threshold, while the latter just shrinks them to zero by the threshold value. However, the major problem with both methods and most of its variants is the choice of a suitable threshold value. Most signals show a spatially non-uniform energy distribution, which motivates the choice of a non-constant threshold. Since a given noisy signal may consist of some parts where the magnitudes of the signal are below the globally defined threshold and other parts where the noise magnitudes exceed that given threshold, methods relying on a globally defined threshold cut of parts of the signal, on the one hand, and leave some noise untouched, on the other hand. This observation led to the idea of a spatially adaptive threshold choice depending on the relationship of local energy (variance) of the observed signal and the noise variance. Chang et al. 3, 4 were the first to propose this kind of spatially adaptive wavelet thresholding for image denoising. Their method of selecting a spatially adaptive threshold is based on a context model, which involves neighboring coefficients of the wavelet decomposition for the estimation of the local variance. The authors extended this idea by using a more elaborate context model and by iterating the context-based thresholding process in the denoised wavelet representation, which led to significantly improved results (8).

IV. Fractal denoising in the wavelet Domain

Like fractal image coding also fractal image denoising can be performed in the wavelet domain. This is an effective approach to avoid blocking artifacts in the fractal approximation. However if typical octave band wavelet decompositions are used, only a limited set of domain blocks is available leading to reduced coding efficiency. This again can be overcome by employing a non-subsampling overcomplete wavelet decomposition of the image. The usage of an overcomplete wavelet decomposition corresponds to the usage of a set of shifted images. If a fractal approximation is determined not only for one image but for all of these shifted versions, then an additional noise reduction gain is to be expected. If identical signals are superimposed by different statistical independent noise signals, then the addition of these noisy signals will lead to an attenuation of the noise as the wanted signals are correlated whereas the uncorrelated noisy signal attenuate each other.

Fractal denoising suffers from two problems: some parts of the original signal are not approximated well, whereas some noisy parts are approximated by the fractal coder although they are not part of the wanted signal. Under the assumption that these both problems do occur in different regions in the set of the shifted images, the inverse wavelet transform which corresponds to the superposition of the images (shifted back) will reduce the noise and improve the approximation quality of the reconstructed image. To emphasize our approach two aspects shall be mentioned: Using an overcomplete wavelet decomposition even with a Haar-wavelet fractal coder no blocking artifacts will occur. In addition to our best knowledge the best denoising results are obtained using over complete wavelet decompositions, balancing the effects of uncertain thresholding of coefficients.

One further advantage of the wavelet domain is the fact that range blocks need not be restricted to the wavelet coefficient trees which correspond to the range blocks in the spatial domain. Our denoising scheme uses individual separate sub-trees in the three different frequency orientations (horizontal, vertical and diagonal direction).

V. Experimental results

Compares our expected fractal denoising scheme to the fractal wavelet denoising Scheme It should be observed, that the overcomplete non subsampled wavelet decomposition gives greatly improved denoising results, this at the cost of higher computation : Comparisons of fractal denoising techniques

Noise image N = 25
PSNR = 20.17 dB

Fractal denoised Haar-wavelet
(Sub sampled) PSNR = 28.08 dB

18/10 over complete PSNR = 30.94dB
N = 25 (sub sampled)
PSNR = 20.17 dB

VI. Conclusion

We proposed a fractal denoising scheme operating in a non-subsampled overcomplete wavelet decomposition. Denoising results are significantly improved compared to subsampled wavelet decomposition. For some images the denoising results are comparable to other state of the art wavelet denoisers. For other images there is still an importantgap between the results. This is particular true for the Barbara image, which is related to the fact that better splitting criteria are needed in order to properly distinguish important signal components in the high frequency components. Further research will investigate such techniques. In addition instead of a top-down approach, also a bottom-up partitioning scheme could be useful. Further improved approximation results are to be expected if domains from trees from shifted images are possible, which is not yet implemented in our current approach.

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