SIGNAL PROCESSING IV: Theories and Applications
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A BLOCK ADAPTIVE PYRAMID CODING SYSTEM

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In this paper we present a new block adaptive coding scheme which uses non-rectangular Laplacian Pyramid Algorithms. The proposed method is adapted to the local image contents. The original image is broken into subimages according to some previously specified bidimensional activity function defined on the frequency domain. Then, the appropiate algorithm defined on arbitrary sampling lattices is applied and matched to the image contents. The code produces images with notably sharper detail and more pleasing appearance than the Laplacian Pyramid coding, since the method is matched to the local statistical properties of the image. Good visual quality is obtained for low bit rates.

1 INTRODUCTION

Monochrome still images can be modeled as a contour/texture information. Images are made up of objects which have edges forming contours where large changes of brightness ocurr (contour information) and areas of low contrast detail with small changes of brightness (texture information). In summary, images can be viewed as a set of homogeneous regions, with slowly varying picture data.

An optimal adaptive coding scheme can be based upon the local statistics of the image. In this case if the original image is split in subimages, these will have more homogeneous statistical properties. Then for each subimage appropriate algorithms may be applied as a function of local statistical characteristics. The key of this practical system implementation is to achieve a succesful compromise between the shape and the area of the subimages, the overhead information required to describe the subimages and the adaptive coding algorithms.

This paper describes an efficient block adaptive coding scheme using non-rectangular Laplacian Pyramid Coding [1]. An algorithm defined in the frequency domain analizes the shape of the spectrum of the original image and decides whether or not to partition the image into a set of adyacent regions or subimages.

This procedure is iterated for each region and the result is a representation of the image in a set of more homogeneous regions than the original image.

At the same time the algorithm assigns to each subimage an optimum sampling lattice M_i. Finally for each region a non-rectangular Laplacian Pyramid Coding scheme with associatted M_i is applied.

In the second part of the paper we describe the image partition procedure and the frequency algorithm which assigns an optimum sampling lattice to each region.

In the third part of the paper we apply to each region the non-rectangular Piramidal Coding scheme. To minimize the boundary effects between adjacent regions the generalized Laplacian algorithms [2] have been modified. Several images are shown coded with the new block adaptive scheme using the previously introduced generalized Laplacian algorithms and the modified ones.

2 THE PARTITION ALGORITHM

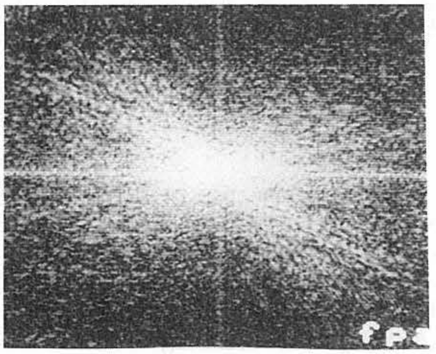
Here a segmentation adaptive procedure is presented. The problem is to obtain a compact representation of the image information. The goal is to approximate the segmented image described by the texture/contour model. In order to accomplish this goal, an algorithm in the frequency domain is introduced.

Before describing the algorithm it will be useful to point out some considerations to fully understand what is presented. These considerations must take into account the following:

- The image should be segmented into a set of adjacent regions corresponding to more homogeneous statistics than the original image. The union of this regions should cover the entire image.

- Certain constrains should be applied to the shape and size of the subregions in order to obtain the minimum overhead information.
- The segmentation process will be controled according to some measure of activity in the transform domain.

Figure 1. shows the power spectrum of "Lena", for an image size of 256x256 pixels. It also shows the power spectrum of the segmented image into sub-blocks of 64x64 pixels.



a)

b)

Figure 1: a) Power spectrum of "Lena". b) Power spectrum of the segmented image.

the partition procedure is as follows:
If the original image of power of two dimensions 2^mx2^m does not satisfy some kind of activity criterion it is split into four disjoint and adjacent sub-squares covering the entire original image.. The size of the sub-squares is 2^{m-1}x2^{m-1}. Then the procedure is iterated within each sub-square. This method leads to the representation of the original image by a set of different squares being their size 2^qx2^q a submultiple of the original size, with $n \leq q \leq m$ where n is the minimum allowable size of the sub-squares.
There is a relationship between the overhead information and the shape and minimum size of the sub-block. The overhead information is the sum of the number of bits used to represent the position and the size of the sub-blocks and the associated geometry M_i. However if compression ratios around 20 : 1 are wanted, the minimum sub-block size must be bigger than 16.
The activity criterion is based on the size and shape of the support region of the power spectrum of each sub-square or sub-block.
In the frequency domain an algorithm applies the activity criterion in seven steps as follows:

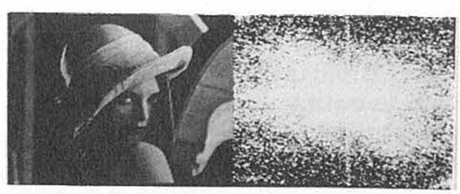
1. The spectrum of the sub-block $b_i(i,j)$ of size 2^qx2^q, $\mathcal{F}\{b_i(i,j)\} = B_i(\omega_1,\omega_2)$ is obtained.
2. The cumulative probability distribution of de A.C. energy of the spectrum is constructed and then total AC energy $\mathcal{E}_i$ of the frequency samples is calculated. The power spectrum is

$$E_i(\omega_1,\omega_2) = \mid B_i(\omega_1,\omega_2) \mid^2 \qquad (1)$$

and the total AC energy is

$$\mathcal{E}_i = \sum_{\omega_1=1}^{2^q} \sum_{\omega_2=1}^{2^q} E_i(\omega_1,\omega_2) - E_i(1,1) \qquad (2)$$

3. The lower terms of the spectrum energy with contribute to the two percent of the total AC energy are discarded and their values are set to zero.



a) b)

c) d)

Figure 2: a) The well known image "Lena" represented with 99% of the power spectrum. b) The binarized image of the power spectrum. c) and d) the same with 97% of the power spectrum.

4. A binarized image of the spectrum energy is constructed, where one level correspond to 98% of the signal energy.
5. A set of binary images $\{P_j\}$ representing the reciprocal sampling lattice shape for the most common sampling geometries M_i is built.
6. The binarized image of the spectrum energy is convolved with the set of binary images $\{P_j\}$. This operation gives the optimum sampling lattice M_i.
7. If the determinant associated to the optimum sampling lattice M_i is lower than eight, the process is stopped. The M_i is the associated geometry assigned to the b_i block.

At the end of the process the original image is split into several sub-blocks whose sizes are submultiples of the original image with each of them having an associated geometry M_i.

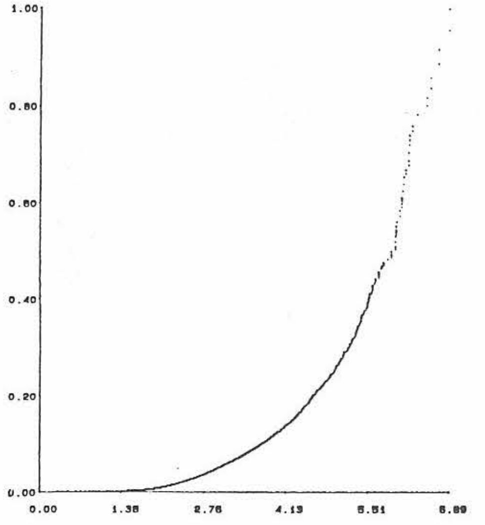


Figure 3: The cumulative probability of the AC energy of "Lena" represented in log scale.

3 MODIFICATED NON RECTANGULAR PYRAMID STRUCTURES

The segmentation technique explained above leads to split the original image in a set of different sub-blocks each of which is associated with a geometry M_i. The next step is to apply the non-rectangular Laplacian Coding with associated sampling lattice defined by a Matrix M_i to each sub-block.

Figure. 4 shows "Photograph" coded using this block adaptive method. The image is divided in sub-blocks of size 64x64 pixels.

Figure 4: "Photograph" coded in sub-blocks of size 64x64 pixels.

When different geometries and different quantization schemes are applied to each sub-block it appears a border effect between neighbouring regions. These impairments degrade the visual quality.

The Gaussian Pyramid is constructed by successively applying an algorithm modeled as a low-pass filtering and bidimensional down-sampling. The Laplacian Pyramid is built from the difference of two Contiguos Gaussian Pyramid levels applying up-sampling and low-pass filtering. These algorithms are based on the Generalized Hierarchical Discrete Correlation (G.H.D.C.) which use images and nucleus of finite support region.

The border effects appear due to the non-circular convolution of the generalized Gaussian and Laplacian algorithms used in the Piramid Coding. These effects are a consecuence of the bad predictions of the boundary pixels.

We shall present here a new pyramid algorithms which can be used to improve the quality of the segmented image.

In this case the Gaussian Pyramid of N levels is a set $\{I_l\}$, $0 \leq l < N$ of N low-pass versions of the original image defined on sampling lattices $\{M_i^l\}$ where the level l is found by circular convolution of the level $l-1$ with a nucleus $\omega(i,j)$ where

$$I_l(i,j) = I_l(N_l(ij)^T) \tag{3}$$

and

$$\left(M_i^{-1}\right)^l \begin{pmatrix} 2^q & 0 \\ 0 & 2^q \end{pmatrix} = \begin{pmatrix} N_{l,11} & N_{l,12} \\ N_{l,21} & N_{l,22} \end{pmatrix} = N_l \quad (4)$$

being K_1 and K_2 arbitrary integers. 2^qx2^q is the size of the sub-block b_i.
The Laplacian Pyramid of N levels is a set $\{E_l\}$ of band-pass images constructed as a suitable difference between two levels of the low-pass structure where

$$E_l(i,j) = E_l(N_l(ij)^T) \quad (5)$$

being K_1 and K_2 arbitrary integers. N_l is the Periodic matrix of the level l for an associated matrix M_i.

4 RESULTS AND CONCLUSIONS

The proposed algorithms improve the block adaptive method and enhance the quality of the coding images. Figure. 5 shows "Lena" coded using these algorithms. The image is divided in sub-blocks of size 64x64 pixels. The signal-to-noise ratio is $21dB$.

In this paper has been presented a block adaptive Coding System which uses a modified non-rectangular Laplacian Pyramid algorithms. The original image is broken into subimages according to an activity function and then the pyramid algorithms defined on arbitrary geometry are applied. These algorithms are adapted to the local characteristics of the image contents.

Figure 5: "Lena" coded in sub-blocks of size 64x64 at 0.8 bits/pixel

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