TREIZIÈME COLLOQUE GRETSI - JUAN-LES-PINS DU 16 AU 20 SEPTEMBRE 1991

HIERARCHICAL PICTURE CODING BASED ON THE HARMONIC ANGULAR DECOMPOSITION

Roberto CUSANI (*), Giovanni JACOVITTI (**)

(*) Electronic Engineering Dpt, University of Rome 'Tor Vergata', Via Orazio Raimondo, 00173 Rome, Italy

(**) Infocom Dpt, University of Rome 'La Sapienza', Via Eudossiana 18, 00184 Rome, Italy

RÉSUMÉ

La dècomposition angulaire harmonique (HA) introduite dans les antécédent travaux, est utilisée pour codage hiérarchique d'image. Les deux premières harmoniques, respectivement correspondent au composant bas frèquence et aux contours, sont séparément quantifiées. Ce codeur à deux composantes bien s'adapte à la transmission hiérarchique, puisque l'information des contours, envoyé dans la première partie de la procédure, donne une très bonne apparence visuelle, meme si très quantifiée.

ABSTRACT

The Harmonic Angular (HA) decomposition, introduced in previous works, is employed for hierarchical picture coding. The first two HA harmonics, corresponding to the low-frequency component and to the edges respectively, are individually quantized, coded and transmitted. This two-ways coder is well adapted to hierarchical transmissions because the edge information transmitted in the first step immediately gives a very good visual appearance, even if roughly quantized.

1.INTRODUCTION

The increasing interest for multimedia communications demands for high efficiency of image compression techniques. In fact, direct pixel-based image representation requires large amounts of data to be accommodated into storage devices and transmission channels.

For this reason, high compression rate coding techniques have been developed.

Fast VLSI devices currently allow real time image coding on low cost computers. Compression rates of 25 for still images and 100 for like images constitute a feasible performance. A world-wide accepted compression technique is the so called block-DCT or adaptive DCT (ADCT) technique, proposed by the JPEG group for the ISO-CCITT standardization activity, and extended to live images by the MPEG group.

On the other hand, the compression rate is not the only parameter to considered for efficient multimedia operations. Some other factors, such as user interface, image database organization and access disciplines, play an important role.

In fact, access to images implies often intensive browsing activities in order to select the wanted documents. If not carefully designed, such activity could imply dramatic cost and channels traffic overhead.

For this reason, image databases are usually organised in such a way that visual information for each document is delivered for stages, following a hierarchical or a progressive strategy based on a detail scale criterion.

When a user access to a given image system, resources immediately supply him with a rough version of this image, characterized by poor resolution. This should allow the user to decide whether the image is the searched one or not. In the first case, the image quality is increased, until a desired level, using additional information batches.

In the JPEG proposal, the hierarchical access mode is based on four quality level, the last one corresponding to an image free of information loss.

In this contribution, the Harmonic Angular (HA) decomposition is employed for hierarchical picture coding. The main difference with the DCT technique is that the HA decomposition is based on spatial features selection.

2.THE HARMONIC ANGULAR DECOMPOSITION

Starting from some early contributions such as in [1], the HA decomposition has been recently applied to some problems of image analysis such as feature extraction and texture classification and recognition [2,3]. It is based on a family of shift-invariant, polar separable, complex LSI operators characterized by the impulse response:

$$f_n(r\cos\theta, r\sin\theta) = g_n(r)\, e^{-jn\theta} \qquad r = \sqrt{x^2+y^2}\,,\ \theta = tg^{-1}(\frac{y}{x})$$

with $n = 0, 1, 2, \ldots$; $x = r\cos\theta$, $y = r\sin\theta$ are cartesian coordinates in the image plane and r, θ are polar coordinates.

These HA filters have the same structure in the frequency domain and present specific properties depending on the radial profile $g_n(r)$.

Arranging the HA filters in a filter bank we define an HA decomposition where the output complex images $R_n(x,y)$ are referred to as n-th order HA harmonics of the input image.

The HA decomposition completely represents the original picture, but it is very redundant because each pixel is replaced by a series of (infinite) complex numbers. On the other hand, every HA harmonic is strictly related to a particular image feature: the zero order corresponds to the low-pass component; the first, second, third and fourth orders are respectively related to edge, line, fork, cross magnitude and orientation; in general, the n-th harmonic is related to n-th fold rotational patterns in the original image.

3. THE CODING TECHNIQUE

Basically, the proposed technique consist of quantising the outputs of a bank of HA filters. The radial profile: $g_n(r) = r^n \exp(-r^2)$, which depends on the order n, has been adopted. Its has been shown to give a good separation of the image features [2].

Since each output image is complex, different quantization strategies could be devised.

Following some previous approaches [4] inspired to some experimental knowledge about the psichophysiology of the human visual system [5], the strategy of separately quantising magnitude (feature strength) and phase (feature direction) has been adopted.

It has been observed that, especially for low cost images (early progression stages), the relevant part of the visual information is carried by the low pass image (zero order HA filter) and by edges (first order HA filter).

So, in the current evaluations, only the zero order and the first order filters have been employed. The size of these filters has been adjusted so as to minimize the quality loss for a given number of information bits.

The whole compression-decompression scheme is shown in Fig. 1.

The focal points of the technique are:

- the selection of the information to be transmitted at each progression level over the HA output planes
- the quantization of this information
- the coding in bit streams.

As far as the first point is concerned, it is clear that the role of the first order HA filter is to provide selected high resolution (wide band) information to be immediately added to the low resolution basic image of the zero order HA filter.

In some images (few edges with smooth surfaces) this technique is very effective, while it becomes inadequate for very textured images.

Regarding to the quantization stage, we have experiences that assigning 4 bits (16 levels) to the magnitude and to the phase 4 bits (16 direction) does not introduce appreciable visual distortion is the reconstructed images.

The compression achievable with this method is

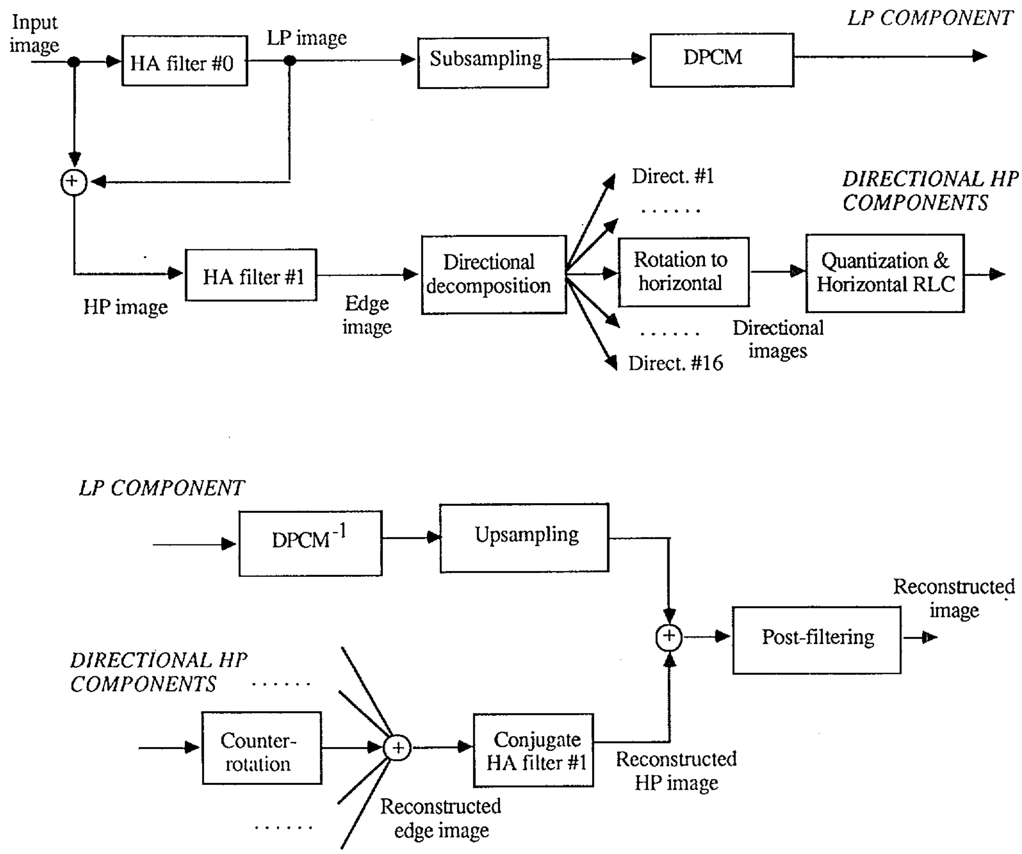
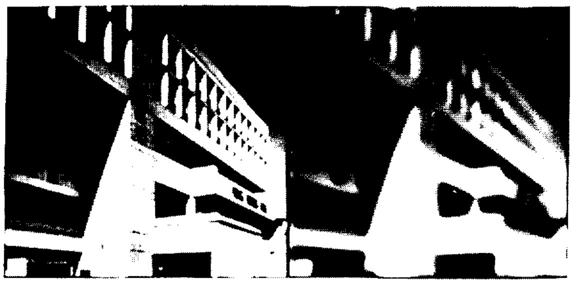


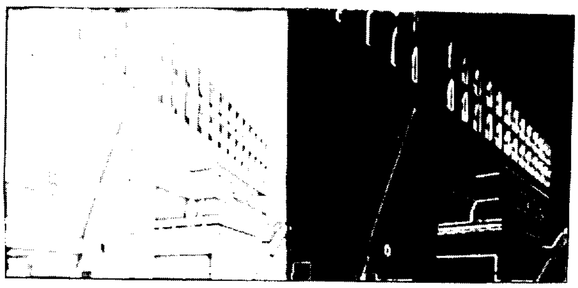
Fig.1 - Block diagram of the compression-decompression procedure.

practically due to the quantization, but essentially depends on the fact that the selected information to be transmitted occupies a small portion of the frames.
More specifically, the zero order output (low pass image) is encoded with usual sub-sampling and DPCM techniques, whereas for the first order output we must take advantage of the fact that they are related to edges.
Many techniques can be employed to code the edge image. In our procedure, 16 directional images are extracted on the basis of the quantized phase. These are rotated such that the contained directional edge patterns become horizontal, and then are coded by PCM of the nonzero values and run-length coding (RLC) of the zero values. Counter-rotations are then performed before recovering the phase information. The edge image is then reconstructed by adding up the directional images.
The conjugate of the first order HA filter restores the edge shape from the reconstructed edge image, giving the reconstructed HP component. This is added to the decoded LP component. The post-filtering equalizes the input-output transfer function and gives, in the absence of any quantization, a lossless reconstruction.
The rotation/counter-rotation procedure was early employed in [4], where the directional decomposition was based on a fixed set of orthogonal filters. The basic advantages of the present procedure are:

- the decomposition is not linear, being based on the phase information, so that an higher directional selectivity is reached
- the number of basic directions can be adaptively decided after the HA filtering; eventually, the directions can be adaptively chosen on the basis of phase histogram



(a) (b)



(c) (d)

Fig.2 - Test picture (a), LP component (b), HP component (c) and edge image (d).

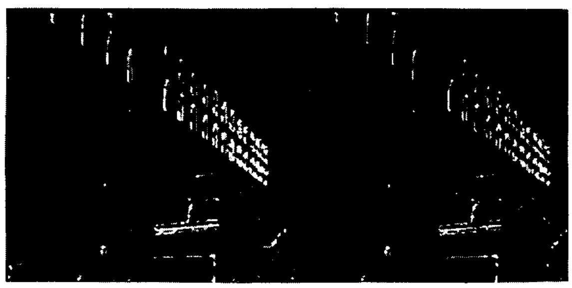
In figs.2-5 the entire procedure is shown with reference to a classic test image. Here, Δ is the quantizing step of the edge image, normalized in the range 0-255.
The images represent the reconstructed versions for increasingly fine quantization steps. It is interesting to observe that the image of fig.5a, obtained with four levels for the edge strength, yet exhibits an evident visual improvements over the LP image of fig.1b. This is obtained with low additional expense.
In general, using a rough RLC technique without taking into account the relationship between consecutive directional edges and between adjacent lines, rates in the range 2-4 bits/pixel have been obtained for the test image. Substantial reductions are expected by eliminating the above redundancy.

4.CONCLUSIONS

The basic feature of the proposed coding technique is that a very good visual quality is obtained with a reduced information by transmitting at first the LP component, followed by a strongly quantized edge information. This is because of the well-known

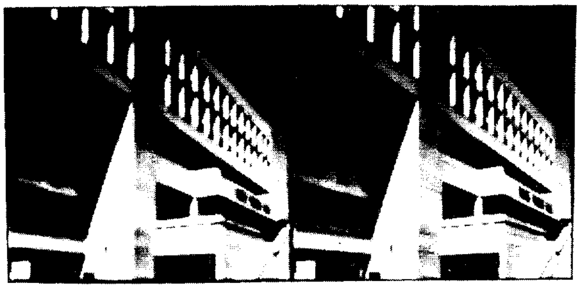
(a) (b)

Fig.3 - Directional image no.4 (a), containing diagonal edges, and its rotated version (b).

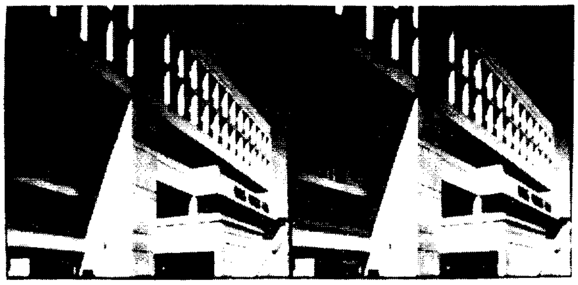


(a) (b)

Fig.4 - Reconstructed edge images at Δ=64 (a) and Δ=32 (b).



(a) (b)



(c) (d)

Fig.5 - Reconstructed images at $\Delta=64$ (a), $\Delta=32$ (b), $\Delta=16$ (c) and $\Delta=8$ (d).

importance of the edges in the visual recognition of shapes, in particular whenever a new image is presented to the human observer.

This means that this method could be employed in early stages of a hierarchical scheme, for browsing purposes. The hierarchical scheme could be completed with successive refinements of the edge information, owing to the invertibility of the employed HA filters response, or with different methods.

Proper selection of the edge information and coding can lead to access cost saving for the class of images essentially characterized by contours.

Furthermore, unlike other coding schemes, the present one is based on spatial feature decomposition and, in particular, on edge extractors. This can be exploited in some applications where image analysis and understanding must be performed at the user side, with reduced overall cost.

REFERENCES

[1] R. Hummel, "Feature Detection using Basis Functions", *Computer Graphics and Image Processing*, vol.9, pp.40-55, 1979.

[2] G. Jacovitti, R. Cusani, "Image Features Extraction by Radial Tomographic Analysis", *Signal Processing V: Theories and Applications*, Elsevier Service publishers B. V. (North Holland), pp.1011-1014, 1990.

[3] G. Jacovitti, R. Cusani, "Local Angular Spectrum Analysis of 2-D Signals", *Proc. IEEE ASSP Workshop on Spectrum Estimation and Modeling*, pp.54-58, Rochester, New York, October 10-12, 1990.

[4] M. Kunt, A. Ikonomopulos, M. Kocher, "Second generation image coding techniques", *Proc. IEEE*, vol.73, no.4, pp.549-575, April 1985.

[5] D. Hubel, T. Wiesel, "Functional architecture of macaque monkey visual cortex", *Proc. Royal Soc. B.*, vol.198, pp.1-59, 1977.