Gabor like wavelet packets versus Gabor like wavelet for the subband decomposition of HDTV image sequences

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Abstract

In this paper, it is proposes to select the most appropriate wavelet and wavelet packet operators for the subband decomposition in the case of HDTV image sequence coding. The coding scheme is based on a subband decomposition, a scalar quantization and an adaptive entropy coding. The proposed comparison is made in term of PSNR for a fixed bitrate.

Résumé

Dans cet article, on propose de sélectionner l'opérateur le plus approprié, entre la transformée en ondelette et la transformée en paquets d'ondelette, pour la décomposition sousbande d'une image dans le cadre de codage de séquences d'images hautes définition. Le shéma de codage est basé sur une décomposition sousbande, une quantification scalaire et un codage entropique adaptatif. La comparaison proposée est réalisée en terme de PSNR pour un débit fixé.

1 Introduction

This paper is concerned with image sequence coding. The goal is to obtain high compression ratios while preserving acceptable restitution quality. The wavelet transform [1, 2] has emerged over the past five years as an interesting tool to analyze and synthesize signals [3]. Such a transform allows to represent the signal with a good accuracy. Concentrating the energy of the signal to a possibly small number of the coefficients, this transform splits an image into different components having statistical characteristics according to the human visual system [4]. When applying a dyadic wavelet transform to an image, the wavelet transform partitions the image into octave bands in the frequency domain. A similar operation seems to be performed in the visual cortex. Some advantages of the octave band partitioning of images in the frequency domain are discussed in [5]. In particular, it allows a multiresolution representation of the data.

From an energy compaction point of view, however, there is no evidence that an octave band partitioning in the frequency domain is the best choice. The theory of wavelet packets introduced by Wickerhauser [6], which is a natural generalization of the wavelet theory, permits to perform the partitioning of the frequency domain in an adaptive way. It is thus possible to build any tiling of the time-frequency space depending on the signal characteristics.

This paper proposes a comparison in term of PSNR for an equivalent bitrate between the coding schemes using a wavelet decomposition and a wavelet packet decomposition. Its structure is as follows. Section 2 introduces the Gabor-like wavelet filter bank. The basic principles of wavelet packets and the criterion used for the selection of the best tree for the decomposition are reported in section 3. The obtained results for each approach are presented in section 4. Finally, section 5 gives conclusions for the two methods.

2 Gabor-like wavelet decomposition

The main interests in the Gabor transform are due to its optimal localization characteristics and its biological properties [7, 8]. The Gabor-like wavelet decomposition allowing the Gabor-like wavelet packets decomposition used in this paper is presented in detail in [5]. The main characteristics of the filter bank are the following :

- The Gabor functions are gaussians modulated by complex exponentials and have an optimal

joint localization in the spatial/spatial-frequency domain according to the Heisenberg uncertainty principle.

- The associated scaling function [6] and wavelet function are quite regular.
- A polyphase implementation is possible for the analysis and the synthesis filters.
- The Gabor-like wavelet transform performs octave bands partitioning of the spatial-frequency domain, in accordance with the human visual system.
- The filters are symmetrical or anti-symmetrical and therefore have a linear phase.
- The use of the proposed filter bank in a tree structure decomposition allows to produce a multiresolution version of the data.

An efficient implementation using filters having coefficients in powers-of-two has been proposed by Ebrahimi [5]. In this way, multiplications are replaced by simple shifts and add operations.

3 Wavelet packets decomposition

The wavelet packets theory has been recently introduced by Meyer and Wickerhauser [2, 6] as a generalization of the orthogonal wavelet transform concept. While a rigid and fixed dyadic partitioning of the time-frequency domain is imposed in the case of the wavelet transform, the idea of wavelet packets is to introduce more flexibility making this partitioning adaptive to the spectral content of the signal. For a lack of place, the mathematical formalism of wavelet is omitted. However, an intuitive introduction which summarizes their main interesting properties is given. Details on the subject can be found in [6, 9].

Let $S(x)$ be the signal of interest. A one stage decomposition consists in filtering $S(x)$ by a low pass filter H_0 and a high pass filter H_1. Those signals are then subsampled by a factor of two as shown in figure 1.

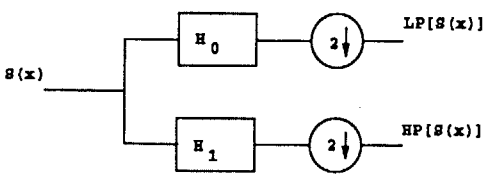

Figure 1: One stage decomposition of the signal (H_0 is the low pass filter and H_1 is the high pass filter).

By repeating recursively this decomposition on each signal, a tree of depth $log(n)$ (where n is the length of the signal being analyzed) can be built. Figure 2 illustrates the full tree.

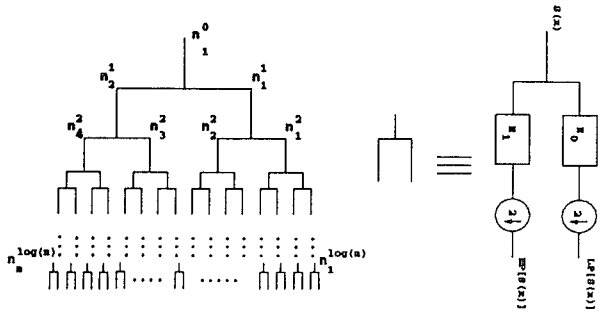

Figure 2: The entire tree obtained by the wavelet packets decomposition.

A finite set of subtrees can be defined by pruning the full tree. The Best Basis Method consists in selecting the optimal subtree with respect to a predefined criterion $M(x)$. The usual criterion used in the context of image compression is the entropy defined such as :

$$Mx = -\sum_i \frac{|x_i|^2}{|X|^2} log_2 \frac{|x_i|^2}{|X|^2} \quad where \quad |X|^2 = \sum_i |x_i|^2 \tag{1}$$

This choice is motivated by the fact that the entropy criterion is computationally simple and permits a good estimation of the bitrate needed for sequence coding. A criterion based on Rate-Distortion theory [10], although yielding better results, is considered too complex for real time implementation. Thus, in contrast with a rigid decomposition of the signal such as wavelet decomposition, the potential of the wavelet packets decomposition is to generate the best tree. Figure 3 illustrates the principles of this selection. Different search methods for the selection of the best tree can be considered. The bottom-up search in the full tree permits to select the optimal tree whereas the top-down search selects a suboptimal one.

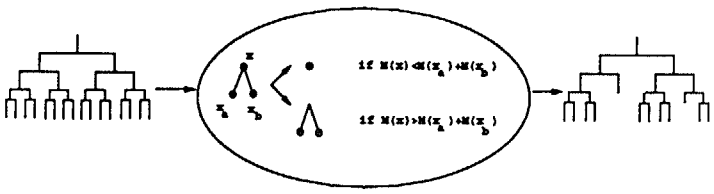

Figure 3: Illustration of the best basis selection principle.

4 Experimental results

For the experiments, HDTV images coming from RAI (1152x1440 pixels) are used for the comparison be-

tween the wavelet decomposition and the wavelet packet decomposition. The filters proposed by Ebrahimi and issue from the Gabor's theory are used. Although the Gabor filters do not form an orthogonal basis, as would be required by the wavelet packets theory, their use did not pose any practical problems. The coding scheme used for experiments is the following : the original image is decomposed by one of the two considered methods and the transformed image is quantized by a scalar operator before to be coded with an adaptive entropy coding. For the wavelet packet decomposition, a bottom-up search is chosen to select the best tree [11].

Figure 4 shows the comparison of the two considered approaches of decomposition. The variation in term of PSNR at same bitrate is about 1dB when using an entropy criterion to select the best tree for the wavelet packet transform. Some criteria such as proposed by Vertterli [10] seem more efficient (2-3dB) but their cost of CPU time increases significantly in case of HDTV images. It should be not realistic to use it.

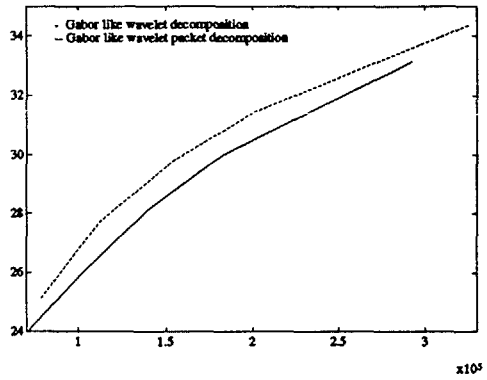

Figure 4: HDTV image (1152x1440 pixels) with 3 levels of decomposition

5 Conclusions

This paper describes two applications in image sequence compression using the wavelet theory and the wavelet packets theory respectively. Brief descriptions of the Gabor-like wavelet filter bank were established. Some advantages of the wavelet packets decomposition and the criterion used to select the best tree were presented. In despite of the increase computational complexity, the wavelet packets theory do not improve sufficiently the quality of the decoded images. Concerning HDTV images and without any coding strategy to reduce the CPU time such as proposed in [11], the wavelet method decomposition is preferred because permitting to analyze and synthesize the 2D signals with a good accuracy.

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