Multilevel Scalable Compression System based on RWT

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Abstract: - Scalable coding is a technology that encodes a bitstream in a scalable way allowing the extraction of different representations to fit best to a diverse range of applications. This paper presents an image codification system based on the wavelet reversible transform with multilevel scalable capacity. Two types of scalability methods are discussed: One spatial and another FGS (Fine Grain Scalability). The proposed codification system permits both lossy and lossless compression by using finite arithmetic reversible transforms. The codification method is based on subcomponents (CFDS) and generates a highly scalable final bit stream which is embedded and adapts to the size of the binary stream by using truncation. The method of segment rearrangement presented in this work permits a substantial improvement over the truncated mechanism. This mechanism allows the possibility of consistent both analytic and perceptual scalability. Moreover, this scalable method allows a direct FGS compression without the necessity of a decoder in the codification section.

Key-Words: - Image compression, reversible wavelet transform, VBLm, CETRO, scalability, FGS

1 Introduction

At present, most compression systems support different approaches for scalability. The necessity of scalability in the transmission of images and video is related to the need to adapt the information transmitted to a variety of available resources, such as the transmission bandwidth. These variations can be motivated by two circumstances, technological variations or channel congestion variations.

Typically, the scalable systems use a multilevel structure. This multilevel structure can be of two types: *self-contained levels*, where each level involves a complete description of the original information and therefore, each level is independent of the others; and *base plus enhancement levels* (Fig. 1), where an elementary level exists (*base level*) from which the decoder is able to reconstruct a first approximation to the original information, and several additional levels to improve its quality.

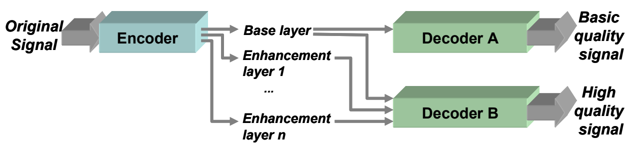

Fig. 1 - Multilevel scalability

In spite of the efficiency of discrete cosine transform (DCT) systems, they are not indicated for the accomplishment of a scalable codification.

Since in 1993 Shapiro [4] proposed the general structure of EZW and later SPIHT [5] was released, the image codification using the discrete wavelet transform (DWT) by means of the decomposition method of Mallat [9] has been applied to the image and video compression field, giving as a result standards such as JPEG2000 [6]. Also, the use of DWT coders [7] [8] have been proposed to perform reversible compression from not lineal transformations (RWT) that represent integers with integers. Some examples may be found in [10], [11] which uses the lifting scheme proposed by Sweldens [12].

The use of the discrete wavelet transform (DWT) in its pyramidal decomposition in subbands allows the distribution of the obtained coefficients into the final bitstream in such a way that it is possible to scale the resolution inherently to the own system with subband decomposition. Nevertheless, most of the coders based on the hierarchical set partitioning do not present an efficient scalable method.

Taubman [1] indicates the scalability characteristics of EBCOT (predecessor of JPEG2000) both in resolution as in quality.

The characteristics of a scalable codification for JPEG2000 are also analyzed by Bilgin and Marcellin [2] extending the use of reversible transforms.

Hsiang [3] uses the EZBC compression system based on wavelet transforms with codeblock codification to present a scalable system both in resolution as in quality.

The compression system used in this paper *(CETRO)* has been proposed in [14] [15]. This work complements previous ones by analysing the scalability of this compression system.

The layout of this work is as follows, section 2 provides brief description of the overall compression system. Sections 3, 4 and 5 discuss respectively Multilevel, Spatial and FGS Scalability. Next section presents some tests and results. Finally, the paper draws some conclusions.

2 General Description of the Compression System

The elements that compose the compression system are those that appear in the following figure (Fig. 2).
The description of the system that we call *CETRO* is described in [14] and [15].
The wavelet transforms applied are reversible. The transformed coefficients are linealiced and quantified (in case a compression takes place with losses). Later on, the transformed coefficients are coded by means of a code system in function of a *subdivision in subcomponents (CFDS)* similar to the code of bit significance. The subcomponents obtained are rearranged by means of an alignment system highly configurable in function of the application that allows the recomposition of the image elements and the obtaining of different importance levels. These importance levels are the beginning from which the bitstream will be generated. The subcomponents of each importance level are coded by means of an entropic *code system of variable longitude (VBLm)* that allows the generation of an embedded bitstream. This bitstream supposes for itself a bitstream that codes a static compressed image.

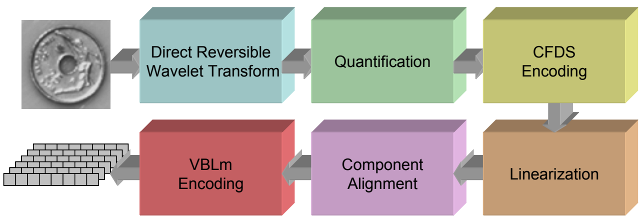

Fig. 2 - General description of the compression system

3 Multilevel Scalability

The bitstream after to use the proposed compression methodology has embedded nature, as long as the distribution of the coefficients assists to a concentration of the levels of energy of the signal in the initial part of the bitstream, always assisting to the used alignment mechanism.

The generated bitstream is structured in importance levels coded by means of the VBLm algorithm.

3.1 Adaptation of the Bitstream to Multilevel Scalability

The longitude of the coded importance levels is variable and also very different in function of the size of the image, the dispersion of energy of the image, the number of levels of decomposition wavelet and the used alignment algorithm. Since it is about an algorithm that generates an embedded bitstream, the one truncated of the bitstream in any point of the same one doesn't impede the complete reconstruction of the image although with more or smaller degradation in function of the quantity of energy that conserves the truncated bitstream.
In the general case, the first generated package corresponds with the basic level of scaled, while the other packages are enhancement levels.
Each one of the generated packages contains one, part or several coded importance levels that use the same VBLm structure; we will call them components. Also, due to the concrete space definition of the information represented by the symbols of the bitstream coming from the code VBLm, it is possible to recompose in a complete way or partly the wavelet coefficients. Also, keeping in mind the high spatial component of the transformation wavelet, it is possible to recompose the original image partly without necessity to have all the coefficients. Therefore, one can say that each generated package is an elementary and consistent unit of image that, by itself, it is able to reconstruct the complete image with more or smaller quality in function of the number and precision of the components that it is able to recompose.
Then, there are two possible ways of adaptation from the bitstream to the multilevel scalability:

a) *Truncate and definition of truncated longitude*: The basic level would correspond with the beginning of the bitstream embedded and the enhancement levels would be the successive ones truncated of the rest of the bitstream.
b) *Segments rearrange*: This mechanism is based on the use of the structure of the VBLm frame (Fig. 3). In this case it is the longitude of the VBLm frame the one that adapts to the size of the package but making that each package begins with the definition of a VBLm frame. It doesn't take place a truncated of the VBLm frame but a division of contents to form two VBLm frames from the original one.

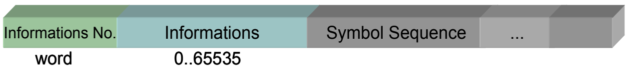

Fig. 3 – VBLM frame structure

We will denominate *CETRO-D (CETRO-Direct)* to the mechanism of truncated simple, while the mechanism of segments rearrange will be for the mechanisms of finer scaling. Anyway, the mechanism of truncate is always available since the lost symbols are supposed as zeros.

3.2 Segments Rearrange Method

The segments rearrange method (Fig. 4) is really a packing process. From VBLm bitstream corresponding to successive importance levels, the segments rearrange method selects the VBLm informations necessary to complete the size of the bitstream of the package.

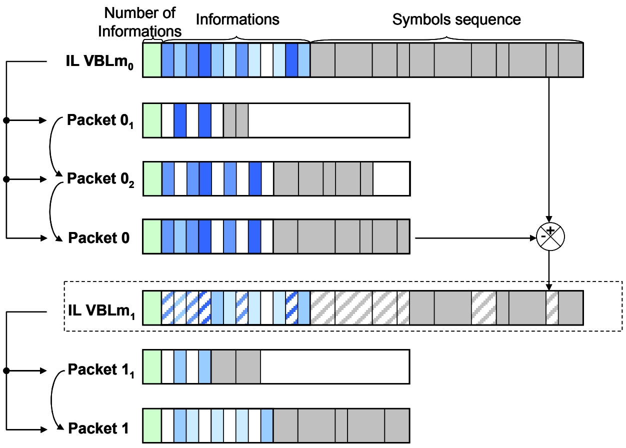

Fig. 4- Packing with segments rearrange.

In the packing process continues staying the order of the importance levels, so that if a package doesn't complete an importance level, that importance level will be completed, if it is possible, in the following package.
The selection of the VBLm informations is carried out in function of its resolution, bigger resolution supposes bigger energy and therefore bigger image information. The informations are selected sequentially starting from their position in the treated importance level.
The underrated informations are treated like they would have null resolution (dummy segments) so that, although it doesn't suppose load of symbols in the final bitstream, they have load of information in the VBLm frame.

3.3 Basic Images and Enhancement Images

The packets generated after the packing process can be treated like images. This is part of the characteristic of consistency of the system. Since it is about components structured as VBLm frames, the space localization of the subcomponents on the matrix of decomposition wavelet is immediate and, therefore, it is possible the application of the inverse wavelet transform in any moment independently of the quantity of available information (analytic consistency). In this way, starting from any packet it is possible the reconstruction of an image with real information on the original image (perceptual consistency).
We can be distinguished two types of reconstruction images:

a) *Basic Images*: They contain, among others, the package of basic level of scaled and they present a zero scaling level.
b) *Enhancement Images*: They only contain enhancement packets and they present a scaling level superior to zero.

An image structurally is composed by several hierarchical levels. In this way, the final bitstream both for basic images and for scaled images presents a structure in several layers (Fig. 5).

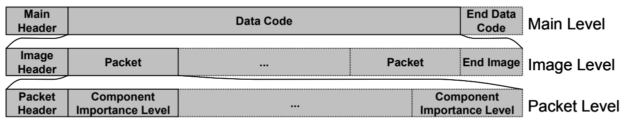

Fig. 5- Multilayer image structure.

4 Spatial Scalability

The systems based on wavelet transforms are systems that are designed in a natural way for the space scalability with resolution increments based in octaves due to their multiresolution nature. In the case of the application over images, this is due to the pyramidal decomposition system of the wavelet transform following the fast transform method of Mallat [9].
However, in most of the compression systems that uses the wavelet transform and, mainly, the systems that use the principle in hierarchical set partitioning with entropic coding on bit planes, the space scalability doesn't show up like an inherent characteristic.
The compression system presented in this paper is not specially designed to support space scalability. However, it is possible to present this scalability type if the system completes a series of conditions:

a) *Use of levels of space scalability in powers of two*: This condition is directly together to the multiresolution nature of the fast wavelet transform.
b) *Election of a suitable system of components alignment*: The main impediment for the use of

space scalability is the alignment mechanism in subcomponents planes. Depending on the type of used alignment mechanism, the energy of the transformed coefficients mixes among the different subbands.

There are mechanisms of subcomponents alignment that adapt perfectly to the scalable space nature, others that could work with space scalability and others that directly discard it.

5 FGS Scalability

The FGS scalability is a scalable method in quality where the enhancement level can be adjusted dynamically to the channel necessities.

In the FGS system each scaling level associates with a package. For the construction of the package, the FGS system is based on the use of the segments rearrange method. With this mechanism it is possible the adaptation of different bitstreams coming from the VBLm code of the importance levels to sizes of certain packages.

The FGS scalability continues maintaining the same structure in packages, packing process and representation of basic and enhanced images, like the indicated in the multilevel scalability.

5.1 Architecture of the FGS System

In traditional realizations of FGS systems (Fig. 6), the enhanced system obtains the source coefficients starting from the obtained residuals of the subtraction of the original signal and the signal reconstructed from the code of the contained coefficients in the information of basic level. This is because the code mechanisms used for the code of the basic level are not designed for the realization of a FGS encoder.

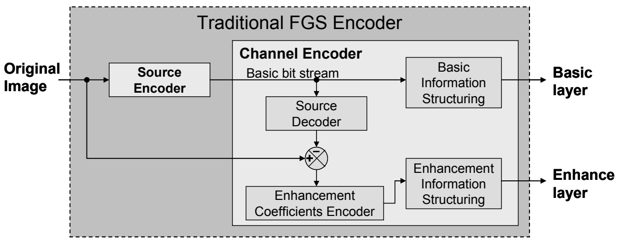

Fig. 6- FGS Traditional Encoder

In our system the code of the transformed coefficients is designed so that it can be carried out a FGS system without necessity of previous reconstruction of the signal of the basic level (Fig. 7). The coefficients used in the levels of improvement are not residuals but elements coming from the general code system. The FGS system understands each other then like a direct extension of the code system and not like an additional element.

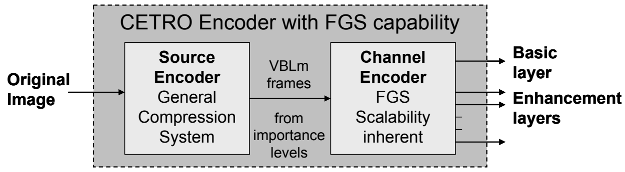

Fig. 7- CETRO-FGS Encoder

5.2 Characteristic of the FGS System

Usually, the FGS systems are based on the use of two channels one basic and another of improvement. In the case of the developed FGS system, the group of combinations among basic and enhancement levels multiplies.

The characteristics that allow the developed FGS scalability system are the following ones:

a) Determination of a concrete basic package size.
b) Determination of a concrete enhancement package size.
c) Determination of an uncertain enhancement package size.
d) Establishment of several enhancement levels:

5.3 FGS Compression with and without Losses

The FGS scalable system developed allows lossy and lossless coding (Fig. 8). Looking for coexistence of both it is necessary begin from a complete bitstream after the application of the basic compression methodology, that is, it should not be applied quantification methods, entry points in alignment or truncated of the bitstream.

In principle, the FGS system presented is totally reversible and therefore it doesn't produce losses in the information.

The use of a basic package of indefinite longitude belongs together with a direct compression without losses in which enhancement levels are not used, that is to say it gets lost the scaling capacity.

The use of a basic finite package and an indefinite enhancement package belongs together to a configuration traditional FGS of two channels, one basic with concrete longitude that fixes a quality of elementary reconstruction and another of improvement that it introduces a refinement of the reconstruction image. If the enhancement package has indefinite longitude, for its adaptation to the capacities of the channel the truncated mechanism is used, being introduced the losses of the signal then.

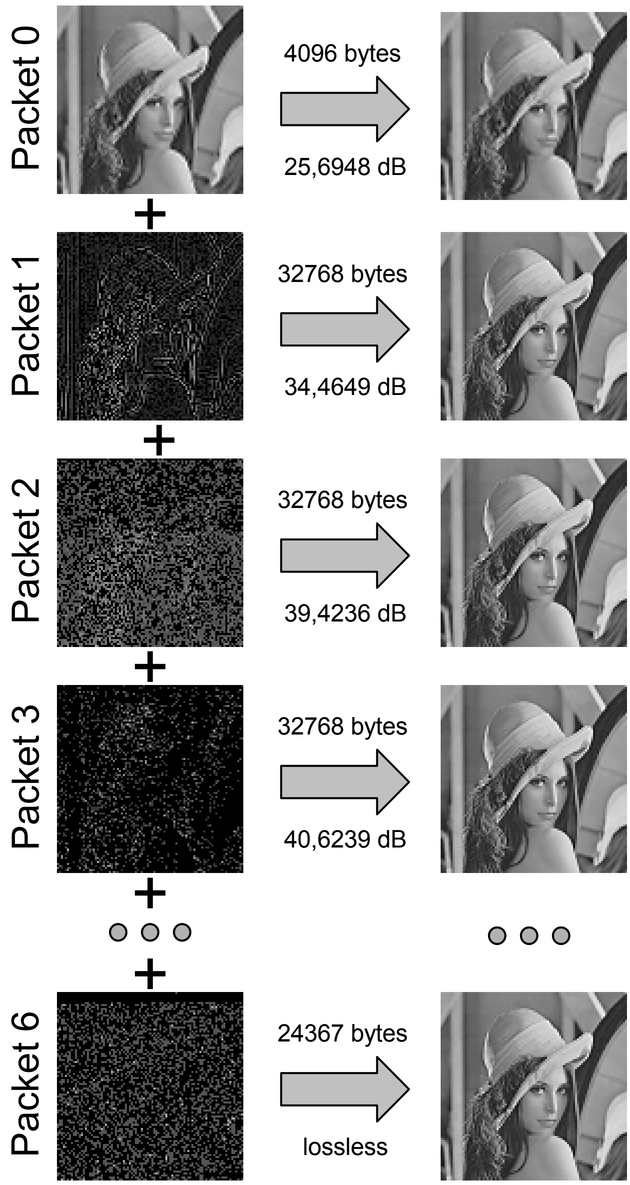

Fig. 8- FGS Scalability for Lena encoding

6 Test and Results

For the accomplishment of the tests diverse images coded in format PNM have been used.

Regarding the denomination of the different code mechanisms, *CETRO-D (CETRO-Direct)* makes reference to the compression system without scalable mechanism. Denomination *CETRO-FGS* indicates the compression system with Fine Grain Scalability mechanism. The transformation method uses RWT SP with 5 levels of decomposition and without previous preprocess. Quantification of components does not exist. A code relationship CFDS of 4:4 is used. The alignment mechanism is in stairway without entry points.

6.1 Adaptation of the Capacity of the Compression System

In this section the capacity of improvement of lossy compression system in the case of the use of the segments rearrange method is valued. A valuation of the lossy compression capacity will be realized comparing the results obtained with those the obtained of the application of traditional and current systems.

In CETRO-D the system of truncated of the bitstream is applied to obtain the wished compression factor. CETRO-FGS obtains the wished compression factor by means of the definition of a longitude of package of basic level.

The figure (Fig. 9) represents of graphic form the general results of the media compression with losses for each one of the compression systems.

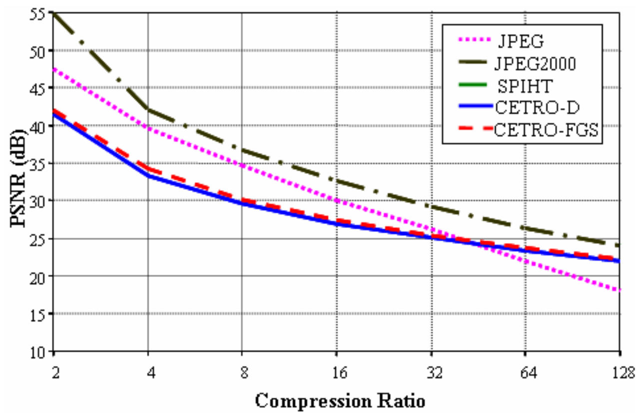

Fig. 9- General results for lossy compression

6.2 Increase of the Reconstruction Quality with FGS

In this section a group of obtained results after the application of the system FGS on a group of images are presented.

The sizes of the packages are fixed in the following way: the package of basic level has a size of 1/128 of the original image size; the packages of enhancement levels have a size of 1/16 of the original image size; the number of enhancement levels is uncertain until arriving to a lossless compression.

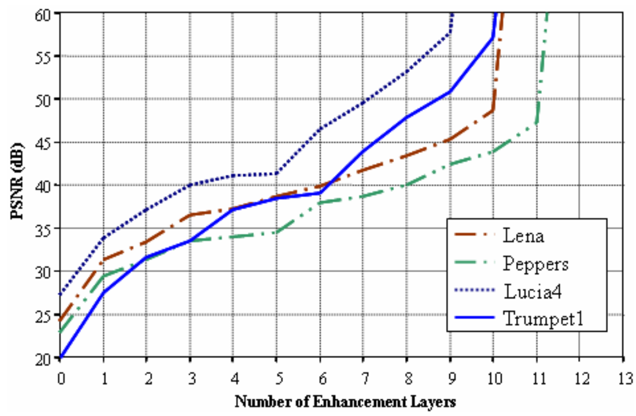

Fig. 10- Increase of the reconstruction quality with FGS

It is possible to be observed like (Fig. 10), for the studied cases according to the established parameters, with less than 13 packages the image can be reconstructed without any type of loss. Each enhancement package introduces greater quality in the reconstruction of the image.

7 Conclusions

This paper presents an image codification system with scalable capacity. It allows both lossy and lossless codification by using the same conceptual structure.

The proposed approach is based on the segments rearrange achieving a substantial improvement in the efficiency of the encoder.

This mechanism brings the creation of a scalable FGS system that eliminates the necessity of decoding in the encoder simplifying its implementation.

The present coding system does not offer large results in rate compression for conventional multimedia systems. However, its high scalable capacity makes it valid to be used in applications of transmission with very small or very variable bandwidth.

One of the main advantages of this codification system is that it allows a lossy and lossless image coding which supposes a scalable codification in which perfect reconstruction can be achieved.

This approach may be used in applications where images must coexist at the same time with different degrees from quality. Also, this compression system may be used in index image systems.

8 Acknowledgment

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