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ISO/IEC JTC1/SC29/WG1
(ITU-T SG8)

Coding of Still Pictures

JBIG

Joint Bi-level Image
Experts Group

JPEG

Joint Photographic
Experts Group

TITLE: Response to Call for AIC evaluation methodologies and compression technologies: LAR Codec

SOURCE: IETR / INSA (France)

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1. Introduction

This document describes the IETR response to the call for contributions of evaluation methodologies and associated test materials and anchors as well as contribution of technologies to be considered for AIC.

In this context, IETR Laboratory proposes the content-based Locally Adaptive Resolution (LAR) codec. The LAR method has been initially introduced for lossy image coding [1]. It is based on the assumption that an image can be represented as layers of basic information and local texture.

The LAR codec tries to combine both efficient compression in a lossy or lossless context and advanced functionalities and services. For this purpose, we defined three different profiles for user-friendly usage (

Figure 1).

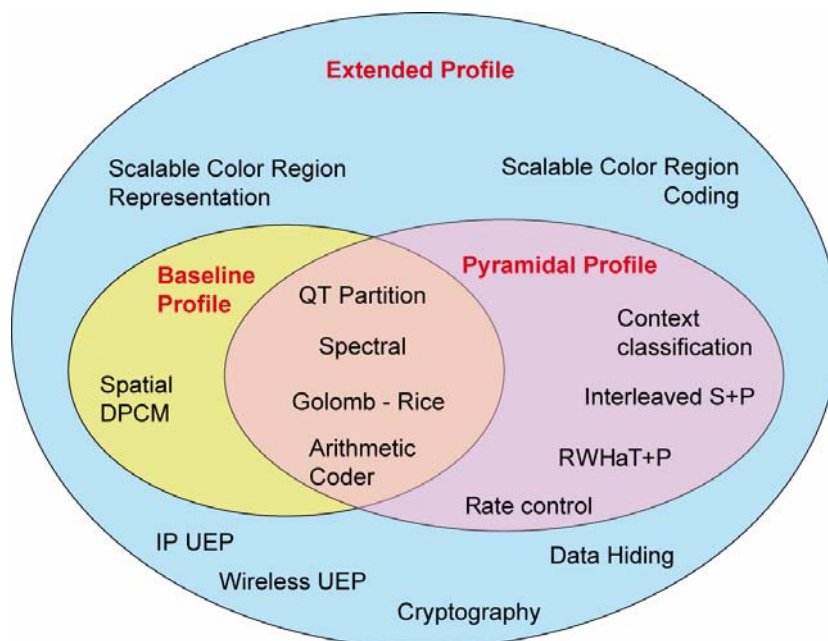


Figure 1: Specific coding parts for LAR profiles

In this contribution, we focus on the following characteristics of our codec:

- functionalities: scalability, hierarchical region representation, adjustable profiles and complexity, lossy and lossless coding,
- services: cryptography, steganography, error resilience, hierarchical securized processes,
- application domains: natural images, medical images, art images.

This LAR method has been previously presented during the JPEG-AIC session of the 2008 San Francisco JPEG meeting: the related document is available on the JPEG site under reference wg1n4692.

2. Technical features

2.1. Characteristics of the LAR encoding method

The LAR (Locally Adaptive Resolution) codec relies on a two-layer system (Figure 2) [1]. The first layer, called Flat coder, leads to construct a low bit-rate version of the image with good visual properties. The second layer deals with the texture that is encoded through a texture coder, aiming at visual quality enhancement at medium/high bit-rates. Therefore, the method offers a natural basic SNR scalability.

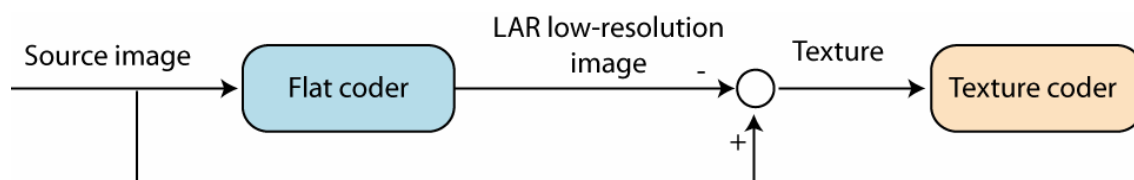


Figure 2 : General scheme of two-layer LAR coder

The basic idea is that local resolution, in other words pixel size, can depend on local activity, estimated through a local morphological gradient. This image decomposition into two sets of data is thus performed conditionally to a specific quadtree data structure, encoded in the Flat coding stage. Thanks to this type of block decomposition, their size implicitly gives the nature of the given block: smallest blocks are located upon edges whereas large blocks map homogeneous areas. Then, the main feature of the FLAT coder consists of preserving contours while smoothing homogeneous parts of the image.

This quadtree partition is the key system of the LAR codec. Consequently, this coding part is required whatever the chosen profile.

2.2. Baseline Profile

The baseline profile is dedicated to low bit-rate encoding [1]. As previously mentioned, the quadtree partition leads to build a variable block size representation of the image: the LAR low-resolution image is obtained when filling each block by its mean luminance value. Moreover, in a lossy context, this semantic information controls a quantization of the luminance: large blocks require fine quantization (in uniform areas, human vision is strongly sensitive to brightness variations) while coarse quantization (low sensitivity) is sufficient for small blocks. Block values are encoding through DPCM scheme, adapted to our block representation.

The flat LAR coder is clearly dedicated to low bit-rate image coding. To obtain higher image quality, the texture (whole error image) can be encoded through the spectral coder (second layer of the LAR coding scheme) which uses a DCT adaptive block size

approach. In this case, both the size and the DC components are provided by the flat coder. The use of adapted block size naturally allows for a semantic scalable encoding process. For example, edge enhancement can be made by only transmitting the AC coefficients of small blocks. Further refinements can be envisaged by progressively sending larger block information.

Considering the entropy coder, we simply adapted the classical Golomb-Rice coder, for low complex application, and the arithmetic coder, for better compression results.

2.3. Pyramidal Profile

To both increase scalability capacity and address lossless compression, we have proposed multiresolution extensions of the basic LAR called Interleaved S+P [2] and RWHaT+P [3]. The overall approach used in these two techniques is identical; the only difference lies in the decomposition step. To fit the Quadtree partition, dyadic decomposition is carried out. The first and second layers of the basic LAR are replaced by two successive pyramidal decomposition processes. However the image representation content is preserved: the first decomposition reconstructs the low-resolution image (block image) while the second one processes local texture information (Figure 2). These methods provide both increasing scalability and an efficient lossy to lossless compression solution.

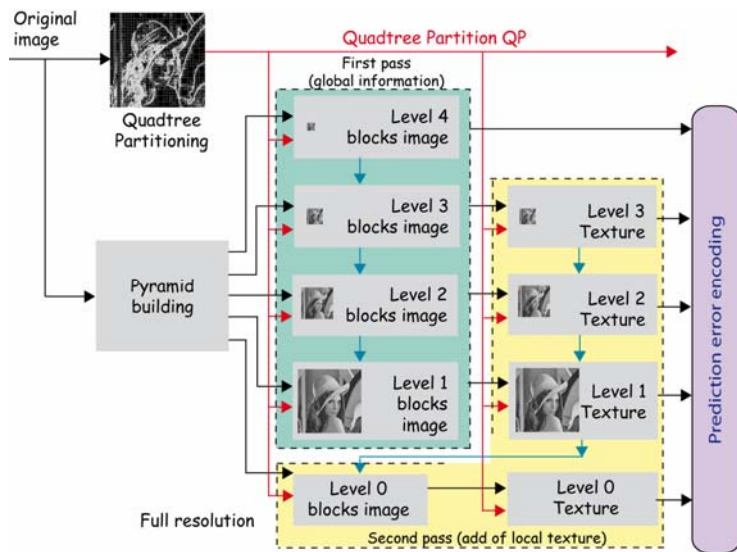


Figure 3: LAR pyramidal decomposition

In the pyramidal profile, we mainly use the arithmetic coding scheme for prediction error encoding. The original structure of the LAR codec leads to automatically producing a context modelling, allowing reduced zeroth order entropy cost. When adding specific inter-classification methods, the compression efficiency can be greatly increased [4][5].

2.4. Hierarchical region representation and coding - Extended Profile

For color images, we have designed an original hierarchical region-based representation technique adapted to the LAR coding method. An initial solution has been proposed in [1]. To avoid the prohibitive cost of region shape descriptions, the most suitable solution consists of performing the segmentation directly, in both the coder and decoder, using only a low bit-rate compressed image resulting from the flat coder (or first partial pyramidal decomposition). Natural extensions of this particular process have also made it possible to address medium and high quality encoding and the region-level encoding of chromatic images. Another direct application for self-extracting region representation is found in a coding scheme with local enhancement in Regions Of Interest (ROI). Actual works aim at providing a fully multiresolution version of our segmentation process: indeed this region representation can be connected to the pyramidal decomposition in order to build a highly scalable compression solution.

The extended profile also proposes the use of dedicated steganography and cryptography processes, which will be presented in next sections.

To sum up, the interoperability of coding and representation operations leads to an interactive coding tool. The main features of the LAR coding parts are depicted on Figure 4.

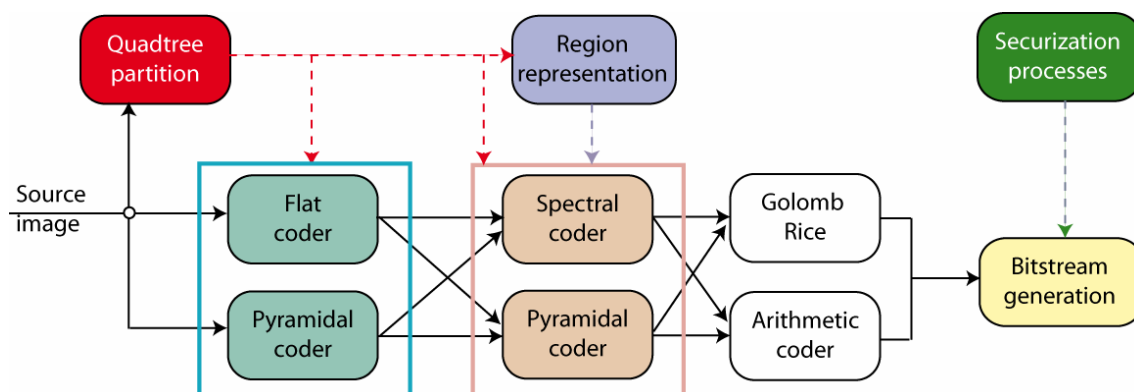


Figure 4: Block diagram of extended profile of the LAR coder

3. Functionalities

3.1. Scalable lossy to lossless compression

The pyramidal description of the images resulting from Interleaved S+P or RWHaT+P encoding provides various scalability levels. The conditional decomposition (the constraint of two successive descent processes by the initial quadtree partition of the image) provides a highly scalable representation in terms of both resolution and quality.

This scalable solution allows compression from lossy up to lossless configuration. The pyramidal profile codec has been tested and has shown its efficiency on natural images, medical images [6] and high resolution art images [7].

3.2. Region level handling

Through the definition of a Region of Interest (ROI), images can be lossily compressed overall and losslessly encoded locally. Combined with a progressive encoding scheme, region scalability allows faster access to significant data. The LAR scheme enables more flexible solutions in terms of ROI shape and size. Indeed, an ROI can be simply described at both the coder and decoder as a set of blocks resulting from the quadtree partition. As the ROI is built from the variable block size representation, its enhancement (texture coding) is straightforward: it merely requires execution of the Interleaved S+P or RWHaT codec for the validated blocks, i.e. ROI internal blocks. Unlike traditional compression techniques, the LAR low resolution image does not introduce strong distortions on the ROI contours. Such distortion usually makes the image too unreliable to be used [7] [8].

3.3. Adjustable complexity

The modularity of our scheme authorizes new level of scalability in terms of complexity, closely related to the chosen profile. The IETR laboratory aims also at providing automatic solutions of fast prototyping onto heterogeneous architecture (DSPs, FPGAs), using Algorithm Architecture Matching methodology. Consequently, if the LAR codec has been developed on PCs, we can easily implement different LAR versions on embedded systems.

Previous works were dedicated to fast development and implementation of distributed LAR image compression framework on multi-components for flat LAR [9], or for extended profile with the proper region description, using cosimulation approaches [10]. For these embedded versions, we used the Golomb-Rice coder as for the entropy coder, because of its lower complexity.

We presented in [11] a dedicated FPGA implementation of the FLAT LAR image coder. This coding technique is particularly well adapted for low bit-rate compressions. From an image quality point of view, the FLAT LAR presents better results than JPEG, while implementation resources requirements are similar. Internal architecture has been designed as a set of parallel and pipelined stages, enabling a full image processing during a unique regular scan. The architecture latency is extremely low as it is determined by the data acquisition for one slice of 8 lines.

4. Services

4.1. Error resilience

Protecting the encoded bit-stream against error transmission is required when using networks with no guaranteed quality of service (QoS). In particular, the availability of the information can be ensured by the Internet protocol (IP). We focused our studies on two topics, namely the loss of entire IP packets and the transmission over wireless channels.

Limited bandwidth and distortions are the main features of a wireless channel. Therefore, both compression and secured transmission of sensitive data are simultaneously required. The pyramidal version of the LAR method and an Unequal

Error Protection strategy are applied respectively to compress and protect the original image. The UEP strategy takes account of the sensitivity of the substreams requiring protection and then optimizes the redundancy rate. In our application, we used the Reed Solomon Error Correcting Code RS-ECC, mixed with symbol block interleaving for simulated transmission over the COST27 TU channel [12]. When comparing to the JPWL system, we show that the proposed layout is better than JPWL system, especially in the case of bad conditions of transmission ($\text{SNR} < 21 \text{ dB}$).

In the other, compensating IP packet loss also requires an UEP process. This later is realized by using an exact and discrete Radon transform, the Mojette transform [6]. The frame-like definition of this transform allows redundancies that can be further used for image description and image communication (Figure 5), for QoS purposes.

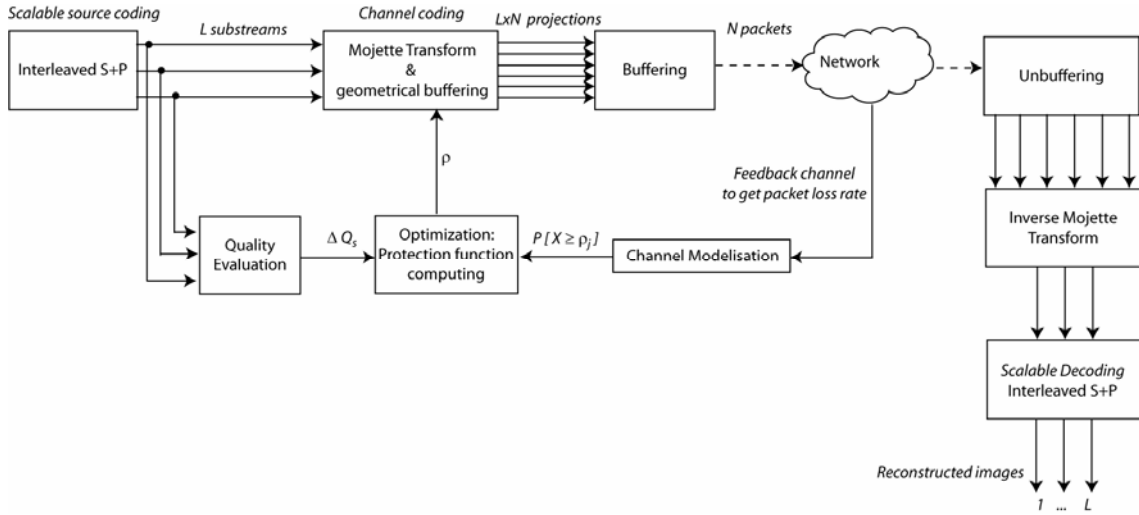


Figure 5: General joint LAR-Mojette coding scheme

4.2. Content securization: cryptography and steganography

Besides watermarking, steganography, and techniques for assessing data integrity and authenticity, providing confidentiality and privacy for visual data is among the most important topics in the area of multimedia security. Our research is focused on fast encryption procedures specifically tailored to the target environment. For that purpose, we use the pyramidal profile with Interleaved S+P configuration.

As the representation relies entirely on knowledge of the quadtree partition, this partition needs to be transmitted without any error. Previous work on error resilience dealt with that aspect and has shown that the decoder was still able to decode erroneous bit-streams. In that case, visual quality was very poor, even when only a few bits of the quadtree were wrongly transmitted. Consequently, we propose to encrypt different levels of the quadtree partition description, as depicted on Figure 6 [13]. This scheme is equivalent to a selective encryption process. Indeed, the encryption of a given level of the partition prevents the recovery of any additional visually-significant data. From a distortion point of view, it appears that encrypting higher level (smaller blocks)

increases the PSNR, and at the same time, the encrypting cost. From a security point of view, as the level increases the search space for a brute force attack increases drastically.

Moreover, we propose a method based on using the quadtree decomposition as a way to protect the content of the image. The main idea is to transmit the data without the quadtree decomposition, using the quadtree as the key to decrypt the image [14]. This system has the following properties: embedded in the original bit-stream at no cost, allowing multilevel access authorization combined with state-of-the-art still picture codec. Multilevel quadtree decomposition provides a way to select the quality of the picture decoded.

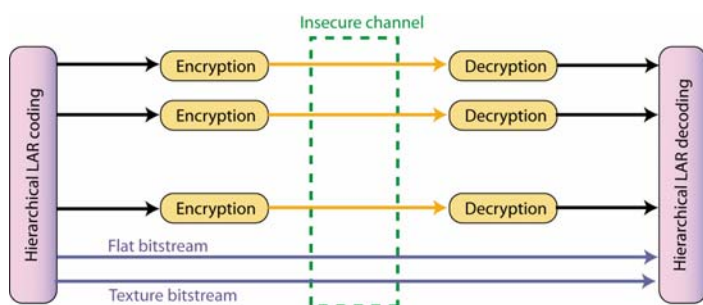


Figure 6: LAR hierarchical selective encryption principle

For the steganography point of view, we have adapted a fast and efficient reversible data embedding algorithm for the LAR-Interleaved S+P compression framework, namely the Difference Expansion, as the two techniques are based on the S-transform. Both this codec and the data embedding algorithm explore the redundancy in the digital picture to achieve respectively either better than state-of-the-art compression rates or reversible data embedding. We obtained resulting capacity-distortion rates of embedded images belong to the best in the literature about lossless data embedding (to be published).

4.3. Client-server application and hierarchical access policy

In France, the C2RMF laboratory, connected to the Louvre museum, has digitized more than 300, 000 documents taken from French museums, in high resolution (up to 20000 × 30000 pixels). The resulting EROS database is for the moment only accessible to researchers whose work is connected with the C2RMF. The TSAR project (Secure Transmission of high-Resolution Art images) is supported by the French National Research Agency. The idea is to integrate another scalable coding solution able to achieve a high lossy and lossless compression ratio. A second area of research concerns the secure access of images. The objective is to design an art image database accessible through a client-server process that includes and combines a hierarchical description of images and a hierarchical secured access.

We are currently working on a corresponding client-server application [7]. Every client

will be authorized to browse the low-resolution image database and the server application will verify the user access level for each image and ROI request. If a client application sends a request that does not match the user access level, the server application will reduce the image resolution according to access policy. The exchange protocol is depicted in Figure 7.

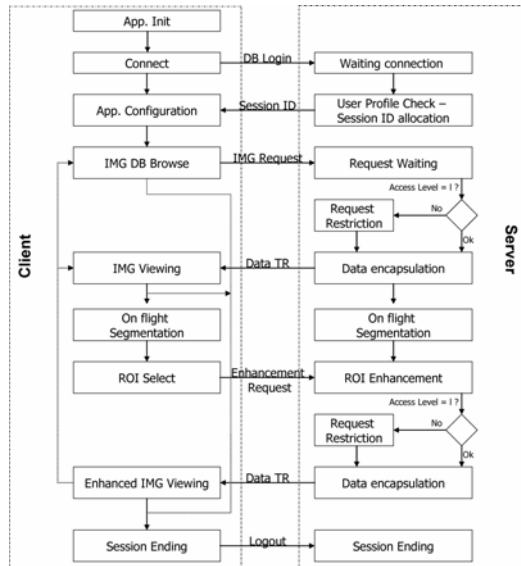


Figure 7: Exchange protocol for client-server application

5. Conclusion

We have presented in this document the LAR codec and its preliminary associated performances. This algorithm also fulfills different functionalities and services, such as scalability, region-level handling, steganography, cryptography, robustness and adjustable complexity. These functionalities have to be evaluated with ad-hoc tools that have to be defined in the JPEG-AIC context.

Consequently, the LAR method appears as a contribution of technologies together with evaluation methodologies for JPEG-AIC.

6. Patent policy

The LAR coding system is not dependant of any patent. The source code is under LGPL license.

7. Bibliography

- [1] O. Déforges, M. Babel, L. Bédat, and J. Ronsin, "Color LAR Codec: A Color Image Representation and Compression Scheme Based on Local Resolution Adjustment and Self-Extracting Region Representation," *Circuits and Systems for Video Technology, IEEE Transactions on*, vol. 17, 2007, pp. 974-987.
- [2] M. Babel, O. Déforges, and J. Ronsin, "Interleaved S+P pyramidal decomposition with refined

- prediction model,” *Image Processing, 2005. ICIP 2005. IEEE International Conference on*, 2005, pp. II-750-3.
- [3] O. Déforges, M. Babel, L. Bédard, and V. Coat, “Scalable lossless and lossy image coding based on the RWHaT+P pyramid and the inter-coefficient classification method,” *Multimedia and Expo, 2008 IEEE International Conference on*, 2008, pp. 185-188.
 - [4] F. Pasteau, M. Babel, O. Déforges, and L. Bédard, “Interleaved S+P Scalable Coding with Inter-Coefficient Classification Methods,” *Proc. of the EUSIPCO'08 European Signal Processing Conference, EUSIPCO* , Lausanne Swiss : 2008, pp. 1-5 .
 - [5] O. Déforges, M. Babel, and J. Motsch, “The RWHT+P for an improved lossless multiresolution coding,” *EUSIPCO proceedings* , 2006, p. nc .
 - [6] M. Babel, B. Parrein, O. Déforges, N. Normand, J. Guédon, and V. Coat, “Joint source-channel coding: Secured and progressive transmission of compressed medical images on the Internet,” *Computerized Medical Imaging and Graphics*, vol. 32, Juin. 2008, pp. 258-269.
 - [7] M. Babel, O. Déforges, L. Bédard, and J. Motsch, “Context-Based Scalable Coding and Representation of High Resolution Art Pictures for Remote Data Access,” *Multimedia and Expo, 2007 IEEE International Conference on*, 2007, pp. 460-463.
 - [8] M. Babel, O. Déforges, and J. Ronsin, “Adaptive Multiresolution Scheme for Efficient Image Compression,” *Proc. of Picture Coding Symposium, April*, 2003, pp. 23-25.
 - [9] M. Raulet, M. Babel, O. Déforges, J. Nezan, and Y. Sorel, “Automatic coarse-grain partitioning and automatic code generation for heterogeneous architectures,” *Signal Processing Systems, 2003. SIPS 2003. IEEE Workshop on*, 2003, pp. 316-321.
 - [10] E. Flécher, M. Raulet, G. Roquier, M. Babel, and O. Déforges, “Framework For Efficient Cosimulation And Fast Prototyping on Multi-Components With AAA Methodology: LAR Codec Study Case,” *15th European Signal Processing Conference (Eusipco 2007) 15th European Signal Processing Conference (Eusipco 2007)* , Poznan; Poland : 2007, pp. ISBN: 978-83-921340-2-2 .
 - [11] O. Déforges and M. Babel, “LAR method: from algorithm to synthesis for an embedded low complexity image coder,” *3rd International Design and Test Workshop 3rd International Design and Test Workshop, IDT'08* , Monastir Tunisia : 2008, pp. 1-4 .
 - [12] W. Hamidouche, M. Babel, C. Perrine, and O. Déforges, “LAR Image Transmission over Fading Channels: a Hierarchical Protection Solution.”
 - [13] C. Fonteneau, J. Motsch, M. Babel, and O. Déforges, “A Hierarchical Selective Encryption Technique in a Scalable Image Codec,” *Proc. of International Conference in Communications International Conference in Communications* , Bucharest Romania : 2008, pp. 1-4 .
 - [14] J. Motsch, O. Déforges, and M. Babel, “Embedding Multilevel Image Encryption in the LAR Codec,” *IEEE Communications International Conference* , 2006, p. 4 .