Progressive Quality JPEG2000 image transmission over noisy channel.

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Abstract

Lossy multimedia transmissions need efficient channel coding schemes. We propose here a specific classification of JPEG2000 data for progressive quality image transmission. We deduce that hierarchical channel coding schemes providing Unequal Error Protection (UEP) can be used. In particular, we focus on the use of RCPC codes.

Keywords

Still image compression, JPEG2000, classification, Unequal Error Protection.

1 Introduction

Among JPEG2000 features, new standard for still image compression [1], we can cite hierarchical coding using quality- or resolution- progressive transmission, region of interest, and error resilience tools.

In lossy multimedia transmission (wireless transmission, IP...), it is useful to evaluate the sensitivity of bitstream in order to classify data into different classes of sensitivity. We propose here a specific classification of JPEG2000 data for progressive quality image transmission. Then we study specific channel coding schemes adapted to JPEG2000 codestream. One way to achieve this goal is the use of RCPC (Rate Compatible Punctured Convolutionnal) codes [4, 5], providing hierarchical channel coding (UEP).

After a brief overview of JPEG200 functionnalities (section 2), we propose a data classification for JPEG2000 bistream (section 3). Then, we present UEP scheme, using RCPC codes, applied to JPEG2000 (section 4). Results for BPSK modulation over gaussian channel are given in section 5.

2 JPEG2000:Overview

2.1 Global compression scheme.

Figure 1 gives the global compression scheme for JPEG2000 [2].

After color components separation, color components are divided into rectangular tiles (Default case: one component=one Tile). The wavelet transform is applied on these tiles.

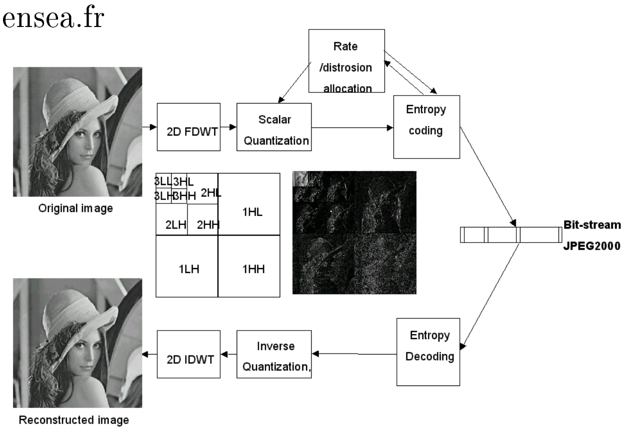

Figure 1: Global compression scheme.

The quantized coefficients of subbands are collected into code-blocks, then into precincts as shown in figure 2. By default, a precinct containts all coefficients of one resolution layer. The coefficients are then entropy coded (arithmetic coding [1]). A Rate-Distorsion allocation procedure allows for a given target bit rate at the output of arithmetic coder to achieve a minimal distorsion.

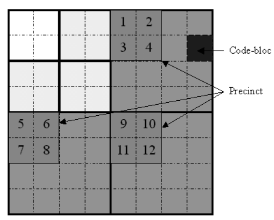

Figure 2: Code-blocks and Precincts for a 3 resolution levels wavelet transform of a tile.

The bitstream is ordered in progressive quality layers. Each quality layer increases the decompressed image quality, measured by means of PSNR (Peak Signal to Noise Ratio).A packet is the elementary component of JPEG2000. It is a spatial, quality and resolution unit for image. All packets of a given tile can be collected into several Tile-parts. The default case is one Tile-part per tile.

2.2 JPEG2000 bitstream syntax

Figure 3 gives bitstream syntaxe for a N_c Quality Layer configuration.

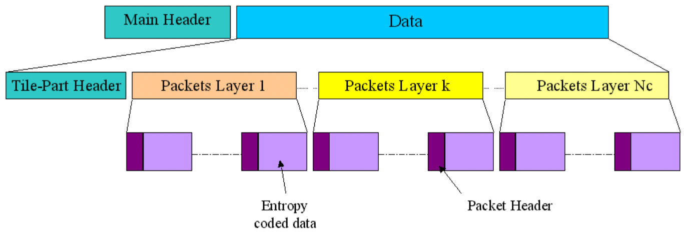

Figure 3: JPEG2000 Syntax for N_c Quality layers configuration.

In both cases, JPEG2000 syntax is divided into: a main header describing global image and compression characteristics, a Tile-part header describing specific characteristics for the associated tile, and data collected into packets (one packet header plus entropy coded data).

2.3 Error resilience tools

Bitstream error sensitivity of JPEG2000 is due to entropy coding. Error resilience tools are provided by JPEG2000 standard to limit error propagation and to allow decoder resynchronisation [6].

3 Encoding options and Classification for progressive quality image transmission

In this section, we give the encoding options useful for progressive quality image transmission. We also propose a data classification.

3.1 Choice of error resilience tools

According to [7] and [8], error resilience tools are useful and can provide up to 4 dB gain in PSNR for a transmission over a binary symmetric channel: Bitstream sensitivity decreases. Joint use of these options can provide an important gain in PSNR for transmission over noisy channels. In the context of progressive quality image transmission, these mechanisms allow to reduce channel coding complexity, because of the lower required performance: for the same PSNR performance, the required BER after channel decoding is lower if error resilience tools are used.

We will use at the encoding stage the following options: SOP (Start Of Packet) markers, Segmentation markers, Termination markers and Partition into Precincts. We will use also the Context values reset which allows parallel encoding [1]. Moreover, we assume that there is just one Tile-part per Tile.

3.2 Proposed classification

The proposed classification is issued from a previous study related in [8]. Here, we focus on a specific classification based on the evaluation of the sensivity of JPEG2000 codestream over noisy channels in a progressive quality image transmission context. The following classification can be proposed.

A JPEG2000 codestream can be divided into two main groups: headers and compressed data.

In the headers class, there are the main header and the Tile-part header. They have to be error free to avoid decoder crash.

The compressed data class is composed by packets. Packets components are packet header and compressed data. It has been shown that errors on packet headers have a very slight influence with the encoding options we use. Hence packet headers can be treated like compressed data. The study of sensitivity of quality layered JPEG2000 codetream allows us to consider one noise sensitive class for each quality layer, because the first quality layers are more influent in terms of error sensivity.

In summary, we propose the following classification for a JPEG2000 bitstream ordered in N_c quality layers in a progressive quality transmission context:

- Class 0: Main header and Tile-part header.
- Class 1: Packets for Quality layer 1.

⋮

- Class N_c: Packets for Quality layer N_c.

4 Achieving UEP through RCPC codes

As seen before, JPEG2000 codestream is not uniformly sensitive to errors: we can classify data according to their error sensitivity. Thus, we define a hierarchical classification of data which need to be differently protected according to their impact in terms of distorsion. The main header and Tile-part headers are supposed to be error free.

One way to achieve Unequal Error Protection (UEP) is the use of RCPC codes introduced by Hagenauer in [4]. With a unique coder (and decoder) based on a "mother convolutionnal" code , we can define unequal error protection through the use of different puncturing tables, constrained by a rate-compatibility condition. Puncturing tables are associated with a class, so that classes in increasing error sensitivity order are associated with codes in decreasing rate order.

To illustrate our work, we compress our images with three Quality layers. The three achievable target bit rates are (0.125 bpp, 0.250 bpp, 0.50 bpp). Figure 4 shows the structure of compressed bitstream in this configuration and the association of data classes with rates for channel coding in general.

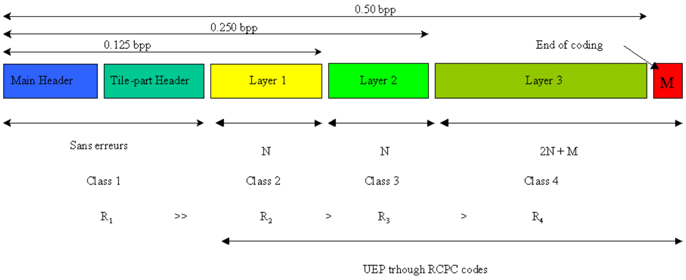

Figure 4: Quality Layers/RCPC codes rates association.

We describe now the simulation chain used (figure 5). The image is compressed with encoding options de-

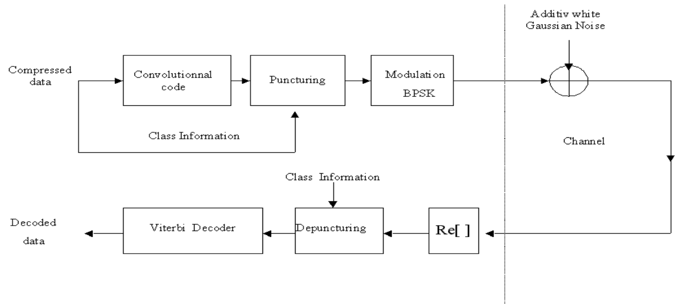

Figure 5: Simulation test chain.

scribed in section 3. The main header and Tile part header are supposed to be transmitted error free.

The coder used is based on a non-recursive convolutionnal mother code of rate $R = \frac{1}{3}$. The polynomial generators, given in octal, are (23,35,27). The puncturing tables are those given by [5]. For each quality layer, we associate a puncturing table. To compare with an Equal Error Protection (EEP) scheme, we impose an identical mean channel coding rate R_m for EEP and UEP schemes.

For example, tables 1 et 2 give for mean rate $R_m = 2/3$ theoretical and practical numbers of bits into each quality layers for the image "Woman" used in our tests compressed with three Quality layers (0.125 bpp, 0.250 bpp, 0.5 bpp). They give also the rate for the channel coding associated with each quality layer.

Mean Rate R_m	Total number coded bits	Rate for class C_2	Rate for class C_3	Rate for class C_4
$\frac{2}{3}$	$6N$	$\frac{2}{5}$	$\frac{2}{3}$	1

Table 1: Theoretical channel coding rates associated with bitstream classes for mean rate $R_m = 2/3$.

To terminate the encoding procedure, we add stuffing bits. This number depends on the delay in the decoding

Mean Rate R_m	Coded bits number class C_2	Coded bits number class C_3	Coded bits number class C_4	Practical mean rate
$\frac{2}{3}$	652640	655328	1312312	$\simeq 0,6672$

Table 2: Practical observed mean rate for image "woman".

stage and on the period of the puncturing tables which is $P = 8$.

After channel coding, the bitstream is mapped into a BPSK modulation and transmitted through a gaussian channel.

On the receiver side, metrics for channel decoding are calculated and soft bits are then decoded with a Viterbi decoder [3]. A decision delay of ten times constraint length is adopted to ensure the convergence of the Viterbi algorithm.

Afterwards, the decompressed image is compared to the initial image. For all tests, the MSE (Mean Square Error) was calculated over 100 independent realizations of noise. The PSNR is finally calculated.

5 Simulation Results

In this section, we present some simulation results.

Figures 6 presents results for image woman over gaussian channel for mean rate $R_m = 2/3$. The Performance

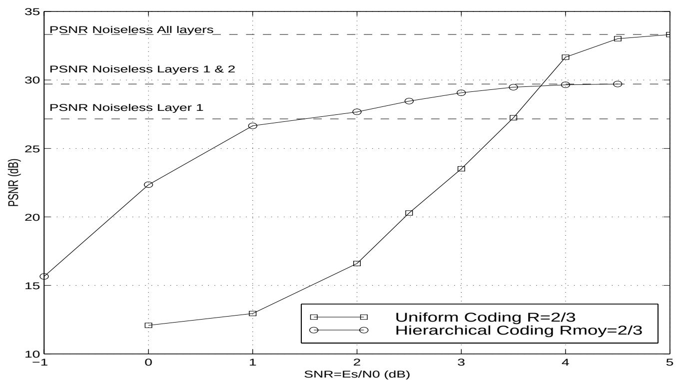

Figure 6: Uniform coding vs. hierarchical coding. $R_m = 2/3$.

of UEP RCPC scheme is compared to the EEP scheme using a non-recursive convolutionnal code (23,35), by means of PSNR for different values E_s/N_0 (SNR).

The gain obtained with the hierarchical channel coding can be very large: for example up to 14 dB for a 2/3 mean rate scheme. For high SNR, gain decreases and uniform channel coding should be preferred.

To understand these results we need the performance of the channel coders over gaussian channel and Rate-Distorsion curves with noise in multi-Quality layers configuration. Performance of the RCPC codes family are given figure 7.

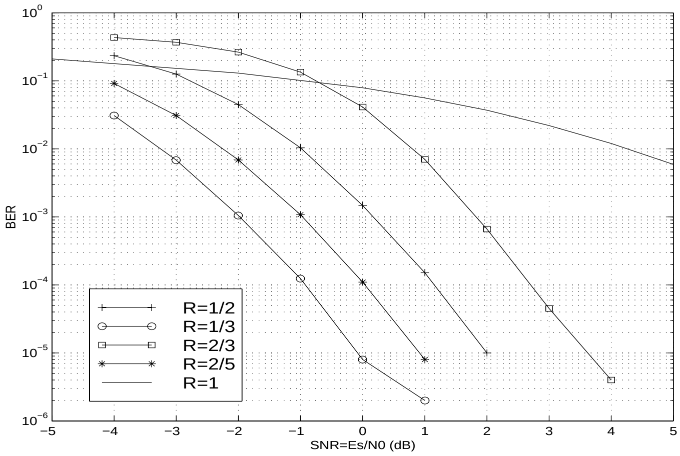

Figure 7: RCPC Codes performance over Gaussian Channel.

Figure 8 gives Rate-Distorsion curves for a binary symmetric channel for a unique Quality layer configuration. In fact, as multi-Quality layer configuration can be viewed as a reorganized single Quality layer configuration, we can study the noise influence for multi-Quality layer configuration with a single Quality layer configuration.

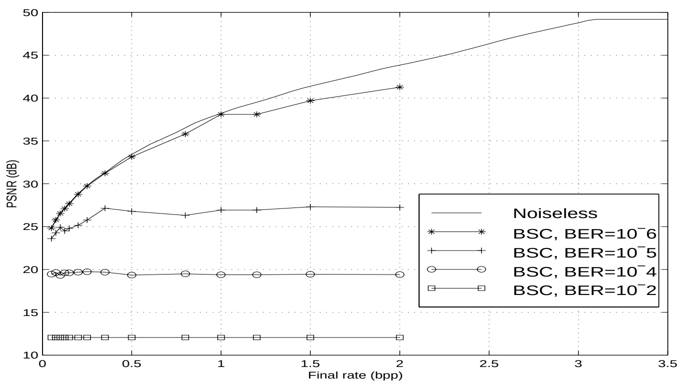

Figure 8: Rate/Distorsion curves over Binary Symmetric Channel (BSC).

We consider therefore the system for a SNR equal to 1 dB. Figure 7 shows that the residual SNR after channel decoding is about 8.10^{-6} for the first Quality layer. If we refer to Rate-Distorsion curves, we obtain the performance for the first Quality layer of about 25 dB. For the hierarchical coder, we obtain about 26.5 dB. Thus, with the hierarchical coding, we obtain performance in the same order than performance imposed by the first Quality layer. For the other classes, the mean residual BER is about 7.10^{-3} and 5.10^{-2}. They also have no influence on PSNR performance. For uniform coding, we can have the same process: at SNR=1 dB, the mean residual BER after channel decoding is about 7.10^{-3}, and we have finally performance of about 14 dB in PSNR.

So hierarchical channel coding through RCPC codes can be very efficient. Performance are good for low and intermediate SNR. For high SNR, uniform channel coding is preferred, as it converges faster to noiseless performance.

6 Conclusion

After a classification of JPEG2000 according to their error sensitivity, hierarchical channel coding was considered. Results show that unequal protection schemes can improve significantly performance over gaussian channels (for example, up to 12 dB gain in PSNR for a channel mean rate $R_m = 1/2$ with RCPC scheme).

This simple approach is the first step before examining the benefit from the use of tandem or joint source-channel decoding techniques.

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