Optimizing the parameters of a progressive image transmission system Using Swarm Intelligence (SI)

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***Abstract*— The compression of image using analyzing techniques give us q high quality in the reconstructed image however in the case of transmission produce a sensitive (to the channel noise) image .In this paper we are going to use combination between error detection , source and channel coding with unequal distribution in the code rate our approach shows a high efficiency and optimization in the use of the code rate using Swarm Intelligence (SI) (minimization in the redundant bits) compared to other approaches.**

Keywords—CRC code, SPIHT, RS code, UEP , SI , BSC

I. INTRODUCTION

The specific choice of transformation type, quantization and entropy coding leads to a wide coder's variety. Numerous compression schemes have been proposed and standardized: for example, conventional compression algorithms, more sophisticated methods have been defined. Thus, in the DWT case, several compression algorithms have been developed such as "Set Partitioning In Hierarchical Trees" (SPIHT) [1], this algorithm makes it possible to progressively transmit images. We will, in what follows, present the principle of this progressive transmission.

We will then propose the unequal protection application of the bit stream with Optimization of the bit rate allocation between source coding and channel coding. Two optimization criteria will be presented: Quadratic Mean Error (MSE), peak signal-to-noise ratio (PSNR). The developed optimization method will be applied to the SPIHT encoder for source image compression.

The use of optimization techniques takes lot of attention in many applications to solve research problems. In case of transmission using channel coding techniques there is no guarantee that makes us sure about the selected parameters if they are adaptive to the channel noise, which make us confused about the technique that can be used to select the parameters. The use of RS code need to determine the code rate value according to the channel conditions with minimum redundancy bits. To achieve this aim we are going to use Swarm Intelligence (SI) Optimization Algorithm to define the input parameter of the RS code with specific conditions to find the global optimum code rate.

II. IMAGES PROGRESSIVE TRANSMISSION

Let's start by introducing some definitions relating to the images progressive transmission [2] [3]. A bit frame at the image encoder output is said to be progressive if it can be decoded at different compression ratios, resulting in an improvement in the obtained image quality, as bits are added additionally. (Fig. 1) illustrates the concept of progressivity by showing a series of decoded images from the same bit frame at increasing rates ranging from 0.01 bpp to 0.2 bpp. It is obvious that higher is the bit rate, better is the visual quality of the rendered image.

In what follows, we will develop more explicitly the progressivity aspect in an image transmission [1] [4] [5]. To do this, let us begin by reminding ourselves that the main objective of a progressive transmission scheme is to transmit first the information generating the greatest reduction in distortion. L et us note the pixels set of the original image where i and j denote the pixel coordinates, and the used transformation. The transformed image is: $Y=\tau(X)$
The matrix Y has the same dimensions as the matrix X representing the source image. Each element is called coefficient of the transform at coordinates (i, j). The coding algorithm applies directly to the transformed image Y.

CR=0.01 bpp.
PSNR = 22.45 dB

CR= 0.02 bpp
PSNR = 24.37 dB

CR=0.1 bpp.
PSNR = 29.99 dB

CR= 0.2 bpp
PSNR = 32.96 dB

Fig. 1. Illustration the concept of progressivity coding of the (Lena) 512 × 512 image using SPIHT algorithm.

In the progressive transmission case, the decoder starts by initializing the reconstruction matrix to zero. Then, it updates the matrix components according to the decoded message. As it determines the values (exact or approximate) of certain coefficients, the decoder is able to obtain a reconstructed image:

$$\hat{X} = \tau^{-1}(\hat{Y}) \qquad (1)$$

Using the mean squared error (MSE) as a distortion measurement, we have

$$D_{MSE}(X,\hat{X}) = \frac{\|X-\hat{X}\|^2}{N} = \frac{1}{N}\sum_{i}\sum_{j}\left(x_{i,j}-\hat{x}_{i,j}\right)^2 \qquad (2)$$

where N is the pixels number in the image. Assuming that the transformation preserves the Euclidean distance, we can write:

$$D_{MSE}(X,\hat{X}) = D_{MSE}(Y,\hat{Y}) = \frac{1}{N}\sum_{i}\sum_{j}\left(y_{i,j}-\hat{y}_{i,j}\right)^2 \qquad (3)$$

Thus, the exact restitution of a transform coefficient leads to the MSE reduction of $\frac{|y_{i,j}|^2}{N}$. As a result, in a progressive transmission scheme, the higher amplitude coefficients must be transmitted first because they generate the greatest decreases in distortion. In the same spirit, the contained information in the amplitude $\left|y_{i,j}\right|$ of a coefficient can be distributed between the different bits constituting the binary $\left|y_{i,j}\right|$ representation of and varies according to the nature of these bits. Indeed, the most significant bits (MSBs) provide more information on the coefficient value than the other bits. They must therefore be transmitted first.

III. SPIHT ALGORITHM

The SPIHT algorithm [1] takes the principles mentioned in EZW [2] while proposing to recursively partition the coefficient trees (Fig. 2). Thus, where EZW coded an isolated insignificant coefficient ('Z')[6], SPIHT performs a recursive partitioning of the tree in order to determine the significant coefficients position in the progeny of the considered coefficient. The significant coefficients are coded in a similar way to EZW: their sign is sent as soon as they are identified as significant and they are added to the coefficients list to be refined. This algorithm also works by bit planes [7]. It offers remarkable performances, reaching those of EZW without entropy coding. Adding entropy coding of the significance information, an additional gain between 0.3 and 0.6 dB is obtained. The bits sent during the significance pass correspond to the program executed at the encoder during the execution of the classification algorithm into significant and insignificant coefficients. By following the same program, the decoder remains synchronous with the decisions of the encoder and finds the same classification [8]. This algorithm is based on the management of three lists, significant coefficients (LSP), insignificant coefficients (LIP) and insignificant sets (LIS). With a significance threshold divided by two at each iterations, and whose initial value is transmitted to the decoder, the algorithm proceeds as follows [9].

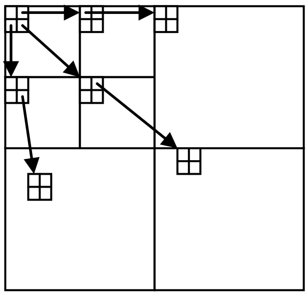

Fig. 2. Tree structure of wavelet coefficients in the case of SPIHT

Direct threads are added to the LIP or LSP according to their significance. If at least one element of all other descendants is significant, this set is separated into four insignificant sets added to the LIS. Processing the coefficients in groups of four allows efficient entropy coding thereafter. As in EZW, the refinement pass consists of progressively coding the least significant bits of the significant coefficients.

A. *Performance RS code*

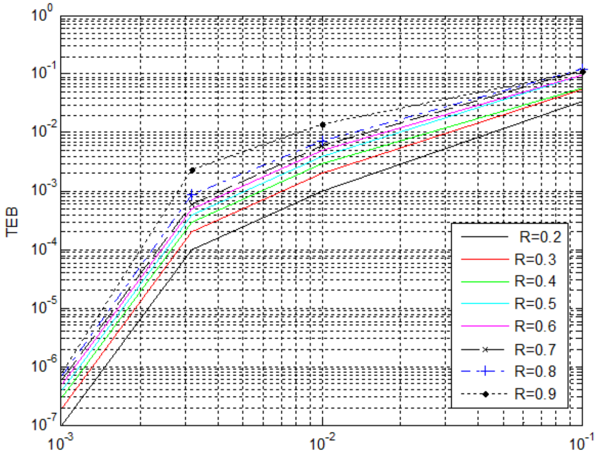

Fig. 3. error Bit rate in function of error probability.

The different encoder performance is represented: the bit error rate as a function of the channel error probability, in Fig.3.

IV. PROTECTION OF SPIHT ENCODED IMAGES BY REED SOLOMON CODE (RS)

A. *Choice of coding performance and results on a BSC*

In what follows, we will discuss the problem of adjusting the channel coding efficiency for a given transmission channel error probability. For this, we consider a set of Code Rates obtained for EEP and UEP protection: {0.2, 0.3, 0.4, 0.5, 0.6, 0.7, 0.8, 0.9}. The manual UEP protection system is tested with RS on "Lena" and "Goldhill" images of size 512x512. A Symmetric Binary Channel (BSC) with two BERs: 10^{-2}, and 10^{-3} is considered. The selection of the reed solomon (RS) code to be applied for each BER of the channel is done experimentally. Indeed, the code (RS) is applied to obtain the highest efficiency, a global bit rate (including source coding and channel coding) of 0.25 to show the (RS) used.

In Fig. 5 and Fig. 6 we provided some results of decoded images with EEP and UEP protection, in order to illustrate the improvement brought by the application of RS at the visual quality level of the images transmitted on a Symmetric binary error rate channel 10^{-2}, or 10^{-3} .

Original image (Lena)

SPIHT
TEB=0, PSNR=34.1186dB

SPIHT+RS (EEP)
TEB=10^{-3}, PSNR=33.32dB

SPIHT+RS (UEP)
TEB=10^{-3}, PSNR=33.97dB

SPIHT+RS (EEP)
TEB=10^{-2}, PSNR=31.34 dB

SPIHT+RS (UEP)
TEB=10^{-2}, PSNR=32.25dB

Fig. 4. Recivied image (Lena) with EEP and UEP protection transmited in BSC channel (CR = 0.25 bpp).

B. *Joint optimization of bit rate allocation between source coding and channel coding*

This first study allowed us to highlight the efficiency of a channel coding scheme, using the reed solomon (RS) code, for the protection of SPIHT coded images transmitted over a symmetric binary channel. In what follows, we will study in more detail the problem of joint optimization of the rate allocation between a nested source encoder and any channel encoder.

C. *Coding and transmission process*

We are interested in encoding and transmitting, on a noisy channel without a given memory, a bit frame delivered by a nested source encoder, coding an HS number of source symbols. It is assumed that the channel coding strategy is done in two steps: error-detection coding followed by error-correcting coding. The role of error detection is to interrupt the decoding of the first detected error and therefore to reject the bits that can contribute to the propagation of errors.

We suppose that we have a set:

$$C = \{c_1(N_{c_1}, K_{c_1}), c_2(N_{c_2}, K_{c_2}), \dots, c_L(N_{c_L}, K_{c_L})\} \qquad (4)$$

Of errors correction codes. The compressed bit frame is formatted into packets of variable length. Each packet of length K_{cl} bits is encoded by a code $c_L \in C$ to generate a coded packet of length N_{cl} bits. We introduce, for each $c_L \in C$, the following ratios, expressed in bits per symbol of the source:

$$r_m(c_l) = \frac{K_{cl}}{H_s}(bpp)\ et\ \ r_c(c_l) = \frac{N_{cl}}{H_s}(bpp) \qquad (5)$$

At the receiver, the decoding is stopped at the first detected erroneous packet, since the following packets are generally unable to improve the quality of the decoded picture.

$$R_{T\pi} = \sum_{i=1}^{M\pi} r_c(c_\pi^i)(bpp) \qquad (6)$$

The constraint flow can therefore be expressed by inequality:

$$R_{T\pi} \leq R_T$$

V. OPTIMIZATION CRITERIA

Several performance measures can be adopted to characterize the performance of a given code allocation policy, and thus serve as criteria to be optimized.

Among these distortion measurements between the original image and the decoded image, there are:

. Quadratic Mean Error (MSE).

. The PSNR.

The bits number correctly decoded and used for the image reconstruction, or else the Useful Reconstruction Rate, which will be designated by DUR (criterion valid in the case of a nested source coding).We give:

$$r_{\pi,i} = \sum_{j=1}^{i} r_m(c_\pi^j)\ \ (bpp) \qquad (7)$$

Describing the useful bit rate of image reconstruction when the (i + 1) th packet is detected false.

We will, in what follows, give, for a policy:

$$\pi = \left\{c_\pi^1(N_{c_\pi^1}, K_{c_\pi^1}), c_\pi^2(N_{c_\pi^2}, K_{c_\pi^2}), \dots, c_\pi^{M\pi}(N_{c_\pi^{M\pi}}, K_{c_\pi^{M\pi}})\right\}$$

Given the respective means (mathematical expectations) of the MSE, noted ($\overline{\text{MQE}\pi}$, of the PSNR, noted $\overline{\text{PSNR}\pi}$ and the Useful Rate of Reconstruction, noted $\overline{\text{DUR}\pi}$:

$$\overline{MSE_\pi} = MSE(r_{\pi,0})P_e(c_\pi^1, P_b) + \sum_{i=2}^{M_\pi+1} MSE(r_{\pi,i-1})P_e(c_\pi^i, P_b)\prod_{j=1}^{i-1}[1 - P_e(c_\pi^j, P_b)] \qquad (8)$$

$$\overline{PSNR_\pi} = PSNR(r_{\pi,0})P_e(c_\pi^1, P_b) + \sum_{i=2}^{M_\pi+1} PSNR(r_{\pi,i-1})P_e(c_\pi^i, P_b)\prod_{j=1}^{i-1}[1 - P_e(c_\pi^j, P_b)] \qquad (9)$$

$$\overline{DUR_\pi} = r_{\pi,O}P_e(c_\pi^1, P_b) + \sum_{i=2}^{M_\pi+1} r_{\pi,i-1}P_e(c_\pi^i, P_b)\prod_{j=1}^{i-1}[1 - P_e(c_\pi^j, P_b)] \qquad (10)$$

MSE (r) designates the function representing (in the absence of noise) the Mean Square Error (MSE) as a function of the rate r (in bpp) for the encoder of source used and in the case of the image to be transmitted.

$$PSNR(r) = 10log_{10}\left(\frac{255^2}{MSE(r)}\right)dB \qquad (11)$$

$P_e(c_\pi^i, P_b)$ is the probability of an error at least at the ith packet (using the code c_π^i) as a function of the probability P_b (probability of error per bit).

In the case of equal error protection EEP:

$c_\pi^i = c_\pi$ is constant. So it can be written:

$$(\overline{MSE_\pi} = P_e(c_\pi, P_b)\sum_{i=1}^{M_\pi+1} MSE\left(r_{\pi,i-1}\right)[1 - P_e(c_\pi, P_b)]^{i-1} \qquad (12)$$

Therefore, it is necessary to determine the code c_π(channel coding) which minimizes the distortion by ensuring a maximum information transmission with the minimum of error.

$R_{c_\pi} = K_{c_\pi}/N_{c_\pi}$is characterized by the probabilities:

P_b: Probability of error per bit characterizing the channel.

And $P_e(c_\pi, P_b)$: Probability of error per packet, for the code c_π and for the probability P_b. One notes that a packet is considered erroneous if one detects at least one error in the packet.

These three performance measures lead to the following three optimization problems:

Problem I: minimization of the average MSE:
$\min_\pi \overline{MSE_\pi}$under the constraint $R_{T\pi} \leq R_T$
Problem II : maximization of average PSNR
$\max_\pi \overline{PSNR_\pi}$under the constraint $R_{T\pi} \leq R_T$
Problem III : maximizing the useful average of reconstruction:
$\max_\pi \overline{\mathrm{DUR}_\pi}$ under the constraint $R_{T\pi} \leq R_T$

It is noted that the performance measures used in Problems I and II (MSE and PSNR) are more representative of the quality of the reconstructed image than that used in Problem III. Nevertheless, the advantage of the latter is that it does not use functions characterizing the performance of the source code in the case of the image in question (MSE (r) or PSNR (r) functions). Therefore, it is not necessary to transmit to the receiver the code allocation policy that has been encoder level. We will, in the following, consider the problem 1.

VI. DETERMINATION OF OPTIMAL SOLUTIONS

In our case it is assumed that the length of the packets at the output of the channel coder is fixed:

$N_{c_\pi^1} = N_\pi = constant$. But the data packets to be coded are of variable length so the number of redundancy bits in each packet is variable. Therefore, to specify the number of source bits $K_{c_\pi^i}$ is equivalent to specifying the number of redundancy bits $N_\pi - K_{c_\pi^i}$in the ith packet.

In the case of the EEP protection, one must find the code $c_\pi$of yield $R_{c_\pi} = K_{c_\pi}/N_{c_\pi}$ which minimizes the expression (12) by ensuring a transmission of maximum information with the minimum of error.

But in the case of the UEP protection, it is necessary to determine for each packet the efficiency $R_{c_\pi^i} = K_{c_\pi^i}/N_\pi$ of the encoder correctors $c_\pi^i\left(N_\pi, K_{c_\pi^i}\right)$which minimizes the expression (8) by ensuring a maximum information transmission with the minimum of error.

The code $c_\pi^i\left(N_\pi, K_{c_\pi^i}\right)$ is chosen from L error correcting codes:

$$C = \left\{c_1\left(N_\pi, K_{c_1}\right), c_2\left(N_\pi, K_{c_2}\right), \dots, c_L\left(N_\pi, K_{c_L}\right)\right\}$$

So we have M^L possible combination of Code Rates, with P is the number of turbochargers different yield and M is the number of packets to transmit.

In our simulation, we adopted a simple optimization method, consists in finding in the EEP protection for the set of packets (TABLE 1) With Ɛ = 10^{-2}.

TABLE I. OPTIMIZATION (RS) CODE STEPS BY THE SWARM INTELLIGENCE (SI) OF EEP PROTECTION

steps	*Step 1: Select Performance R.* *Step 2: Extract the RS (M, t) code input parameters according to the R output.* *Step 3: Apply the RS code (M, t) parameters on the set of packets.* *Step 4: Inject the Channel noise on the set of packets.* *Step 5: Correct the erroneous bits.* *Step 6: If (MSE of the reconstructed image - MSE of the received image) ≤ Ɛ. with* min redundancy bits *End* *Step 7: If not go to step 1.*

For UEP protection by protecting more important packets for image reconstruction. (TABLE 2) With Ɛ = 10^{-2}

This algorithm is more efficient than those used in the literature. And its main advantage is its speed and rapid convergence.

TABLE II. OPTIMIZATION (RS) CODE STEPS BY THE UEP PROTECTION SWARM INTELLIGENCE (SI)

steps	*Step 1: Select the Ri Code Rates.* *Step 2: Extract the encoder input parameters RS (Mi, ti) for each output Ri.* *Step 3: Apply RS encoder parameters (Mi, ti) on each packet.* *Step 4: Inject the Channel noise on each packet to transmit.* *Step 5: Correct the erroneous bits.* *Step 6: Group the packages* *Step 7: rebuild the received image.* *Step 8: If (MSE of the reconstructed image - MSE of the received image) ≤ Ɛ. with* min redundancy bits *End* *Step 9: If not go to step 1.*

A. Application to solomon reed

The flow allocation optimization method presented above is applied to the image transmission system of Fig. 7. The Lena image is taken as a test image. The transmission is done on a symmetrical binary bit error rate channel varying from 10-3, 10-2 and 10-1. For each BER of the channel, optimization is performed for a rate value: CR = 0.25 bpp.

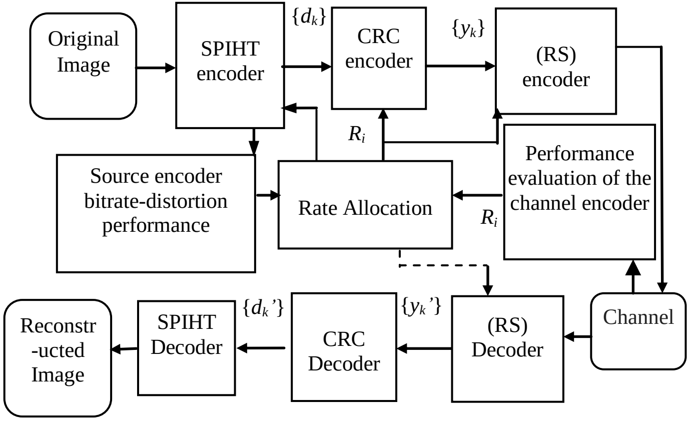

Fig. 7. Applied to the image transmission system

The resulting data is transmitted on a channel without memory. At the receiver, the RS is decoded. The use of these codes makes it possible to have very high coding efficiencies giving rise to a better spectral efficiency of the system. However, for the choice of coding efficiencies, it is often necessary to use Swarm for the automatic selection. For this, we consider a set of 08 different yield codes: {0.2, 0.3, 0.4, 0.5, 0.6, 0.7, 0.8, 0.9}. These codes are derived from an RS. All results are based on a packet length of 16386 bits at the output of the channel encoder.

For each BER of the channel, the optimal code allocation policies according to the minimization criteria of the average MSE (Problem I), are determined by the source coder considered: SPIHT. This problem has been chosen for its effectiveness in optimizing the proposed system.

For BER = 0.001

PSNRrec: reconstructed PSNR

PSNRreç: PSNR received

TABLE III. versus BER of a BSC channel for both Lena and Goldhill images (512 × 512) For BER = 0.001.

Total CR (0.25 bpp)	**BER of channel 0.001**					
	04 packets					
	PSNRrec	***Code Rates***				***PSNRreç***
lena image	*34.1186*	*0.8*	*0.9*	*0.9*	*0.9*	*34.1038*
Godhill image	*30.5609*	*0.7*	*0.7*	*0.8*	*0.8*	*30.5506*
Redundancy bits For image lena	*5353*					
Redundancy bits For image Godhill	*13625*					

TABLE IV. versus BER of a BSC channel for both Lena and Goldhill images (512 × 512) For BER = 0.01.

Total CR (0.25 bpp)	**BER of channel 0.01**					
	04 paquets					
	PSNRrec	***Code Rates***				***PSNRreç***
lena image	*34.1186*	*0.3*	*0.4*	*0.5*	*0.7*	*32.8142*
Godhill image	*30.5609*	*0.3*	*0.6*	*0.6*	*0.7*	*29.6469*
Redundancy bits For image lena	*29557*					
Redundancy bits For image Godhill	*28707*					

TABLE V. versus BER of a BSC channel for both Lena and Goldhill images (512 × 512) For BER = 0.1.

Total CR (0.25 bpp)	**BER of channel 0.1**					
	04 paquets					
	PSNRrec	***Code Rates***				***PSNRreç***
lena image	*34.1186*	*0.2*	*0.2*	*0.2*	*0.3*	*27.8189*
Godhill image	*30.5609*	*0.2*	*0.2*	*0.2*	*0.2*	*26.6171*
Redundancy bits For image lena	*50241*					
Redundancy bits For image Godhill	*52335*					

We have shown in Table 6 the respective variations of the optimal PSNR. The coding system performance introduced by [10], [11] and [12] is presented.

TABLE VI. PSNR VERSUS BER OF A BSC CHANNEL FOR THE LENA 512 × 512 IMAGE USING THE SPIHT ENCODER

Total CR (0.25 bpp)	**BER of channel 0.01**	
	Code Rate	***PSNR***
Sachs et al. (mother rate 1/2) [10]	*0.30*	*27.90*
Thomos et al. "TCS-UEP" [11]	*0.33*	*28.64*
Thomos et al. "TCSD-UEP" [11]	*0.33*	*28.73*
Usama Sayed et Safwat M "UEP" [12]	*0.29*	*30.32*
Système proposé	*0.47*	*32.8142*

Tables.III. IV. V and.VI show, in fact, that the proposed algorithm often allows to find an optimal solution of the problem I.

It is obvious that the performances obtained by applying the UEP protection are better than those obtained by applying the EEP protection.

VII. CONCLUSION

In this paper, we considered the rate allocation optimization the between a nested source encoder and a channel encoder, for a transmission of still images through a BSC channel. We retained the reed solomon (RS) code for data protection because they offer the best performance, in error correction terms, on a binary output channel. We have proposed the unequal protection optimization by different RSs, of the progressive bit stream delivered by the source code. An error detection provided by the CRC codec makes it possible to stop the decoding at the first detected erroneous block and to reconstruct the image from the blocks that are supposed to be correct.

We considered a transmission on a BSC channel two optimization criteria were presented: Quadratic Mean Error (MSE), peak signal-to-noise ratio (PSNR). The optimization method developed will be applied to the SPIHT encoder for compression of the source image. Our simulations have shown that, in the context of coding and transmission considered, the optimal performances obtained with the SPIHT coder are very close. We also noted that the criterion of MSE optimization is the most relevant criterion, as it ensures a better minimum quality of the decoded image at the expense of a slight degradation of the decoded PSNR in the first time with errors absence. Finally, the gain provided by the application of unequal protection (compared to uniform protection) depends both on the source encoder used and the error correction codes considered .

ACKNOWLEDGMENT

The authors would like to be grateful to the Editor and anonymous reviewers for their valuable comments and suggestions, which have improved the quality of the paper.

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