RESEARCH ON UNEQUAL ERROR PROTECTION WITH PUNCTURED TURBO CODES IN JPEG IMAGE TRANSMISSION SYSTEM

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ABSTRACT

An investigation of Unequal Error Protection (UEP) methods applied to JPEG image transmission using turbo codes is presented. The JPEG image is partitioned into two groups, i.e., DC components and AC components according to their respective sensitivity to channel noise.

The highly sensitive DC components are better protected with a lower coding rate, while the less sensitive AC components use a higher coding rate. While we use the s-random interleaver and s-random odd-even interleaver combined with odd-even puncturing, we can fix easily the local rate of turbo-code. We propose to modify the design of s-random interleaver to fix the number of parity bits. A new UEP scheme for the Soft Output Viterbi Algorithm (SOVA) is also proposed to improve the performances in terms of Bit Error Rate (BER) and Peak Signal to Noise Ratio (PSNR). Simulation results are given to demonstrate how the UEP schemes outperforms the equal error protection (EEP) scheme in terms of BER and PSNR.
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Keywords: : JPEG, Turbo-code, puncturing, unequal error protection (UEP), peak signal to noise ratio (PSNR)..

1. INTRODUCTION

Visual signals such as compressed still images are very vulnerable to channel noise. Usually, channel coding is utilized to protect the transmitted visual signals. The Joint Photograph Experts Group (JPEG) standard [l] proposed in 1992 is widely used for still image compression and transmission. Turbo codes [2] are suitable for protecting multimedia signals such as images since these visual signals are characterised by a large amount of data, even after compression. In this paper, we address the special case of JPEG still image transmission over noisy channels in which turbo codes are used for channel coding.

In a JPEG coded image, the coded bits are composed mainly of two types of bits, DC bits and AC bits. There are two justifications in applying UEP to JPEG coded images. First, in the two dimension discrete cosine transform (DCT) adopted by JPEG coding, the DC coefficient is a measure of the average value of the 64 image samples and contains a significant

fraction of total image energy. Thus, the DC coefficients are treated separately from the AC coefficients in various source coding stages of JPEG. Secondly, due to strong correlation in adjacent DC bits, differential coding is applied to DC components. Thus, for DC bits, decoding errors in one block will lead to decoding errors in subsequent blocks. Conversely, for AC bits, decoding errors only affect local blocks.

Observing the output bits from a JPEG image encoder, we found AC bit number is around 6-12 times that of DC.

This gives us a large space for applying UEP turbo coding on the output bits of a JPEG source encoder. We allocate a lower coding rate to highly sensitive DC components and a higher coding rate to less sensitive AC components, while keeping the UEP coding rate the same as that of EEP. In order to improve the performances of the turbo codes in term of the BER, we propose a UEP method adapted to the SOVA algorithm. This method is based on high error protection at the beginning of decoding trellis. We will show how sensitive the BER and PSNR of an image is to different protection levels for DC, AC components and the beginning of decoding trellis. In this case the average BER of the AC component is lower than that of EEP, who is not obtained in [7]. Ideal synchronization is assumed in the simulation results.

2. THE IMAGE TRANSMISSION SYSTEM USED FOR SIMULATIONS

Figure 1 represents the image transmission system for which we evaluate the TEB and PSNR after decoding. An input image is compressed by JPEG. The binary symbols resulting from the JPEG compressing constitute the sequence of data to be transmitted. The coder of channel receiving these data is a standard turbo-coder of rate 1/3 [4]. He is obtained by parallel concatenation of two Recursive systematic convolutional codes (RSC), of rate 1/2, constraint length K=5, and codes 35/23 in octal notation, separated by an interleaver. The code RSC, which has these codes, is powerful in term of the free distance.

The JPEG source encoder used in this study partitions the output bits into two groups of bits, i.e., DC bits and AC bits. Both are sent into a multi-rate turbo encoder. The multi-rate turbo

encoder applies different coding rates to the DC and AC bits according to the particular UEP scheme. We assume that the channel is a binary input channel with Additive White Gaussian Noise (AWGN). QPSK modulation is used. The turbo decoder decodes the UEP coded bits from the noisy channel output. The JPEG image decoder integrates the two groups of DC and AC bits into a standard image coded stream and outputs the reconstructed image.
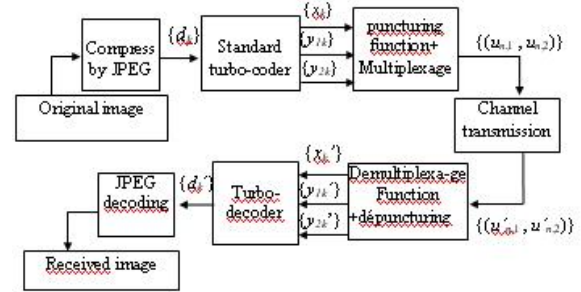

Figure 1. *A block diagram of a communication system*

3. UEP SCHEMES

The multi-rate turbo encoder used for UEP is capable of implementing two different code rates for the DC and AC components. Two different structures were examined. We denote DC bit number and AC bit number in a JPEG image by L_{DC} and L_{AC} respectively. In the first structure, the DC and AC blocks are joined together to form a single block of the same size as that of the EEP scheme. The overall block has its same interleaver. Figure 2 shows the first structure type.

The second structure design is to break the larger stream of size $L_{DC}+ L_{AC}$ into x smaller pieces, each having an identical size of y bits. y is the trellis depth of SOVA decoder. We have

$$x = \left\lfloor \frac{L_{DC}}{l_{DC}} \right\rfloor.$$ l_{DC} is a DC bits number in each

piece. Each piece contains l_{DC} DC bits and l_{AC}=y- l_{DC} AC bits. This x smaller pieces is followed by "$L_{DC}+ L_{AC} -yx$" AC remained bits.

The structure is showed in Figure 3. Using the same inteleaver size for EEP and UEP simplifies the turbo encoder which is desirable from the point of view of hardware implementation. Through varying the number of coded bits

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associated with each information bit, a multi-rate turbo encoder is obtained.
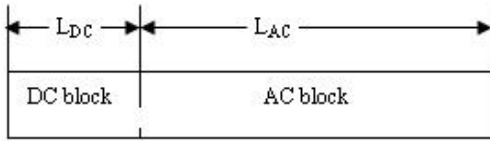
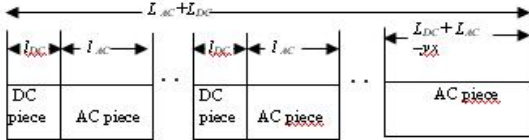

Figure 2. *the first structure type*

Figure 3. *the second structure type*

3.1. First Puncturing Matrix

The puncturing matrix for the first structure has a period $p=L_{DC}+ L_{AC}$ and $N=3$ represented by:

$$P = \begin{bmatrix} g_{11} & \cdots & g_{1 L_{DC}} & \cdots & g_{1 p} \\ g_{21} & \cdots & g_{2 L_{DC}} & \cdots & g_{2 p} \\ g_{31} & \cdots & g_{3 L_{DC}} & \cdots & g_{3 p} \end{bmatrix} \quad (1)$$

.

$$P_1 = g_{11}\cdots g_{1 L_{DC}}\cdots g_{1 p} = [1111111...1111] \quad (2)$$

$$P_3 = g_{31}\cdots g_{3 L_{DC}}\cdots g_{3 p} = [010101...0101] \quad (3)$$

$$P_2^{DC} = g_{21}\cdots g_{2 L_{DC}} \quad (4)$$

$$P_2^{AC} = g_{2 L_{DC}+1}\cdots g_{2 p} \quad (5)$$

And the first parity branch (P_2) depend on the local rate of DC bits and AC bits: R_{DC} and R_{AC} respectively. For example

$$P_2^{DC} = [111110...111110],$$

$$P_2^{AC}=[\underbrace{00101010101010000}_{48bits}\underbrace{00101010101010100}_{48bits}$$

for $R_{DC}= 0.4285$ and $R_{AC}= 0.5055$.

We will use tow type of interleavers:

a- In the case of **S-random odd-even** interleaver: The number of coded bits associated with DC information bit is: $L_{DC}/2$ for the second parity branch. Because only the even positions information bits are interleaved towards even positions. And these positions have no null bits of parity.

b- In the case of **S-random** interleaver: we added in the design of interleaver the following constraint:

The half number of DC bits ($L_{DC}/2$) must interleaved towards even positions. These $L_{DC}/2$ bits are selected randomly. Thus the number of coded bits associated with DC information bit is: $L_{DC}/2$ for the second parity branch.

So in the tow case R_{DC} and R_{AC} depend on the first parity branch: $w(P_2^{DC})$ and $w(P_2^{AC})$ respectively. We have:

$$w(P_3) = \frac{L_{DC} + L_{AC}}{2} \text{ then the local rate}$$

$$R_{DC} = L_{DC}/(L_{DC} + w(P_2^{DC}) + \frac{L_{DC}}{2}) \quad \text{and}$$

$$R_{AC} = L_{AC}/(L_{AC} + w(P_2^{AC}) + \frac{L_{AC}}{2}).$$

3.2. Second Puncturing Matrix

The puncturing matrix for the first structure has a period $p=y$ and $N=3$ represented by:

$$P' = \begin{bmatrix} g_{11} & \cdots & g_{1 l_{DC}} & \cdots & g_{1 p} \\ g_{21} & \cdots & g_{2 l_{DC}} & \cdots & g_{2 p} \\ g_{31} & \cdots & g_{3 l_{DC}} & \cdots & g_{3 p} \end{bmatrix} \quad (6)$$

The same reasoning and interleavers design are applied for this scheme. For $R_{DC}= 0.4$ and $R_{AC}= 0.5086$, we have:

$$P_2'^{DC} = g_{21}\cdots g_{2 l_{DC}} = [111...11] \quad (7)$$

$$P_2'^{AC} = g_{2 l_{DC}+1}\cdots g_{2 l_{AC}} = [101010101000...$$

$$\cdots 101010101000] \quad (8)$$

This puncturing matrix protect the first l_{DC} information bits with a low local rate, so in the SOVA decoding we will minimise the probability of choosing the bad way in the beginning of trellis .Then the BER will be minimum with improving the performances of UEP turbo codes.

4. SIMULATION RESULTS

In this section, we present some simulation results from transmitting JPEG coded "Lena" over the AWGN channel. In JPEG image source coding, quality factor Q is used to control the

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compression ratio and thus the compressed image quality. A 16 state multi-rate systematic turbo codec with codes 35/23 in octal notation is used in the simulations. S-random and S-random odd-even interleaving is used. The PSNR of "Lena" 64 x 64 image are 34.64. He is the highest PNSR the receiver can obtain without any transmission errors. Synchronisation is an issue when variable length coded (VLC) signals such as JPEG images are transmitted through noisy channels. In order to distinguish synchronisation errors from decoding errors, we assume ideal synchronisation within the DCT operational 8x8 subblock in our simulations. In [3], the authors investigated the UEP method applied to header bits and all the other image bits. In this study, we assume all the header bits are transmitted correctly. And in [7], the authors investigated the UEP method witch interleaver structure design is to break the larger interleaver of size $L_{AC}+L_{DC}$ into smaller pieces without changing the order of the image bit stream before coding by the turbo coder, each having an identical size of bits, and the interleaving is applied separately to DC bits then to AC bits. In this study, the interleaving is applied once to all the bits of image $(L_{AC} + L_{DC})$.

UEP schemes using the first structure were simulated for the 64x64 "Lena" image. L_{DC} is 728 and L_{AC} is 11182. Tow different coding rate allocations for DC and AC components were tried while keeping the total turbo coded bits the same as in the EEP case, i.e., overall rate 1/2 coding regardless of the code rate allocation between the DC and AC components. Figures 5 to 6 gives PSNR performances comparisons for tow different interleavers :S-random and S-random odd-even while Figures 7 to 8 give BER performance comparisons.

An UEP scheme using the second structure was also simulated for the 64x64 "Lena" image. L_{DC} is 728 and L_{AC} is 11182. x, y and l_{DC} are 104, 95 and 7, respectively. Figure 8 to 9 gives PSNRs performances comparisons while Figure 10 to 11 gives BER performance comparisons. In this case, the average PSNRs of UEP outperform that of EEP in all interesting Eb/No regions for the S-random interleaver.

For the first structure type, the PSNRs performances of the UEP schemes are worse than that of the EEP scheme for high Eb/No. The underlying justification is that the error protection is condensed at the beginning of the image bit stream in the DC components. Conversely, for the second structure type, the error protection is distributed over the image bit stream. And the UEP scheme is adapted to the SOVA algorithm (section 3.2).

Moreover if the two structures are compared in terms of BER (figure 6, 7, 10 and 11), we see that the UEP BER and AC BER for the first structure are superior that EEP BER, but it is the reverse in the second structure for the S-random interleaver.

For the second structure, the average PSNRs of UEP outperform that of EEP for low Eb/No, but is worse than that of EEP for high Eb/No for the S-random odd-even interleaver and better for the S-random interleaver for high Eb/No. The underlying justification is that the S-random odd-even interleaver is very adapted with the odd-even puncturing (EEP) according to their definition. This is obvious on the graphs of BER in figure 10 and 12: UEP BER is superior than EEP BER for high Eb/N_0 especially for S-random odd-even interleaver.

5. CONCLUSIONS

UEP methods applied to JPEG image transmission using turbo codes are investigated in this paper. The DC and AC components are protected with different coding rates. Different UEP schemes are compared to that of EEP in terms of both BER and PSNR. The simulation results revealed:

1. The BER of highly sensitive DC bits is very sensitive to channel coding rate allocation. For S-random interleaver in second structure: A lower coding rate for DC components will lead to significant DC BER drop while keeping the corresponding AC BER inferior to that of EEP.

2. For very noisy channels, where Eb/No is relatively low, UEP schemes are better than EEP in terms of BER and PSNR. The average BER of the most important DC component is lower than that of EEP and UEP. For high Eb/No, the average PSNR of UEP schemes is worse than that of EEP except for S-random interleaver in second structure which is better. In this case the average BER of the AC component is lower than that of EEP.

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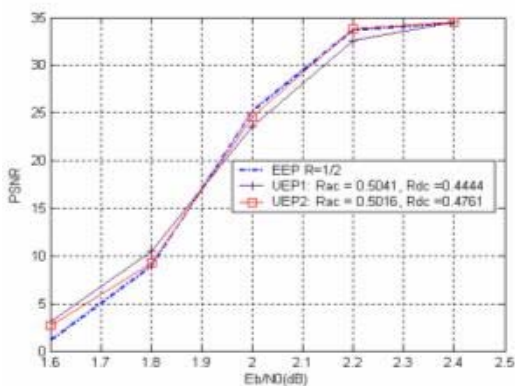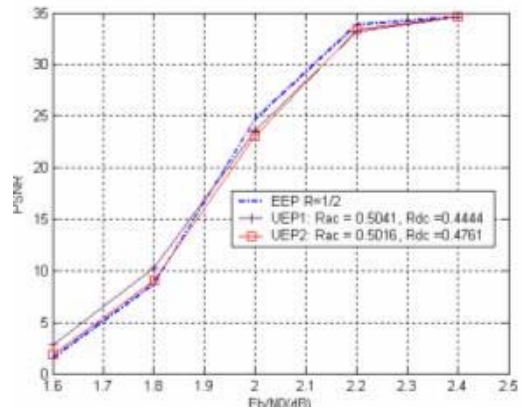
Figure 5. *PSNR performance comparison of EEP and UEP scheme for S-random odd-even interleaver (1st structure type)*
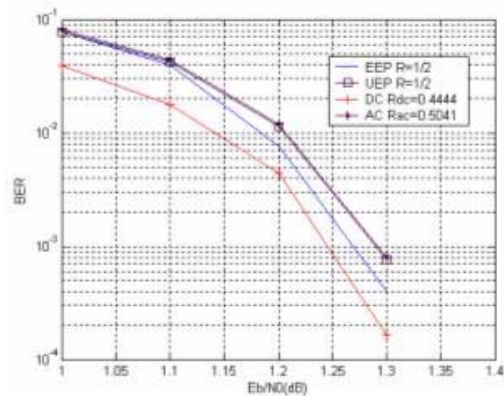

Figure 6. *BER performance comparison of EEP and 1st UEP scheme for S-random interleaver (1st structure type).*
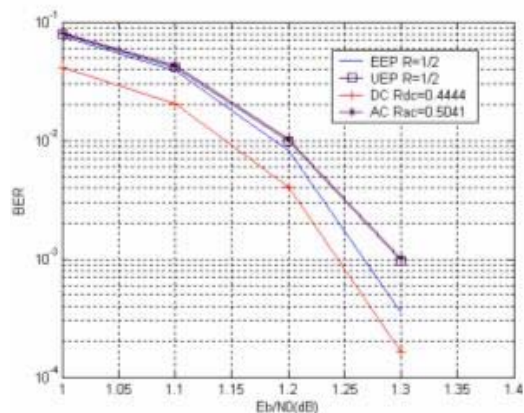

Figure 7. *BER performance comparison of EEP and 1st UEP scheme for S-random odd-even interleaver (1st structure type).*

Figure 4. *SNR performance comparison of EEP and UEP scheme for S-random interleaver (1st structure type)*

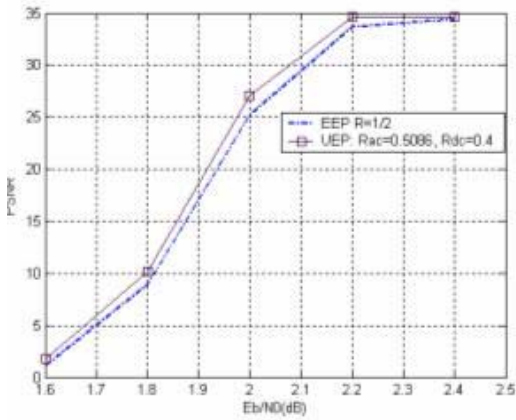*Abdelmounaim MOULAY LAKHDAR, Rachida MÉLIANI, Malika KANDOUCI*

Figure 8. *PSNR performance comparison of EEP and UEP scheme for S-random interleaver (2nd structure type)*
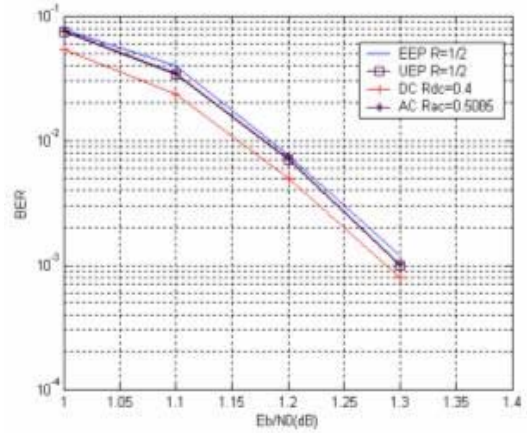

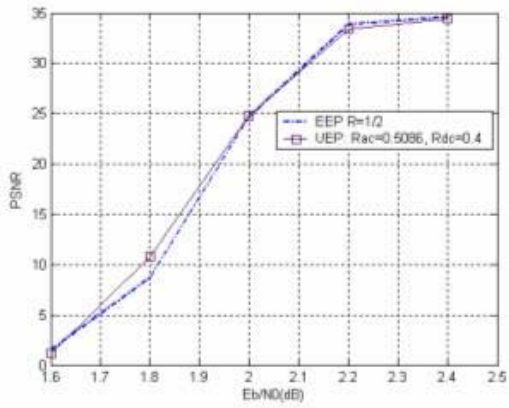**Figure 10.** *BER performance comparison of EEP and UEP scheme for S-random interleaver (2nd structure type).*

Figure 9. *PSNR performance comparison of EEP and UEP scheme for S-random odd-even interleaver (2nd structure type)*
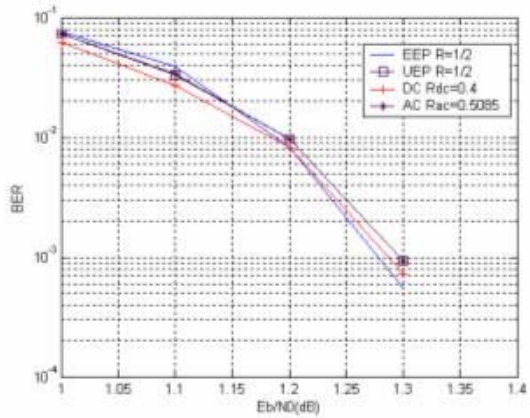

Figure 11. *BER performance comparison of EEP and UEP scheme for S-random odd-even interleaver (2nd structure type).*