Performance Improvement for Medical Image Transmission Systems using Turbo-Trellis Coded Modulation (TTCM)

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II. TURBO-CODE

The TC corrects error produced by transmission noise. This code, invented and presented by Claude-Berrou [4], is obtained by concatenation of two or more ECCs of low complexity [5], allowing to approach the theoretical limit of correction. Their decoding uses an iterative (or turbo) process. In the principal plan of TC [9] the input binary message of length k is encoded in its natural order and in a permuted order, by two coders called C1 and C2. The two elementary coders are identical, but this is not necessary. In our example, the performance of the natural encoding, without punching is 1/3, for each source bit (di) three bits (x, y, z) are sent on the channel [7]. Turbo-decoding is carried out according to the principle of iterative decoding [10], based on the use of SISO (Soft-Input, Soft-Output) decoders which exchange information from each other's reliability Zk [11]. These are called extrinsic information, through a feedback, to improve the correction over the iterations. The circuit of a turbo-decoder is constituted by cascading P modules, corresponding to the P identical decoding iterations and its structure is perfectly modular [9]. The input of the Pth module consists of the properly received delayed sequences {x(1)p-1}, {y(1)p-1} and the sequence {Z(1)p} of the feedback generated by the (P-1)th module.

III. TURBO-TRELLIS CODED MODULATION

TTCM is an ECC introduced by Robertson and Wörz in 1995 [12, 13]. This code is based on the concatenation of two Trellis Coded Modulations (TCM). The TCM was introduced in the early 80s [14] and is based on the joint optimization of error correcting coding and modulation. Coding is done directly in the signal space, so the ECC and the binary signal code of the modulation can be represented all along using a single trellis. The optimization criterion for a TCM consists in maximizing the minimum Euclidean distance between two coded sequences. In the TTCM scheme each MCT coder consists of a recursive systematic convolutional coder, or CSR coder, of efficiency q/(q+1) and of a modulation without order memory Q = 2q+1 [15]. Binary symbols from the source are grouped by q-bit symbols. These symbols are coded by the first MCT in the order they are issued by the source and by the second after interleaving.

IV. SIMULATION RESULTS

To eliminate the noise introduced by the channel and to improve the reception quality of a given communication system, an error correction coder must be used [9, 16-20]. The aim of the conducted simulation is to show the effect of the TC and TTCM on a medical image transmission chain in a Gaussian channel and to make a comparison between the performance of these two codes. In all simulations we use code of 1/2 return and MAQ16 modulation to have the same spectral efficiency in the two transmission chains. The spectral efficiency of a transmission is given by [9, 16]:

$$\eta = R \log_2 M \text{ (bit/s/Hz)} \quad (1)$$

So in both cases of our transmission chain, spectral efficiency is given by:

$$\eta = 1/2 \log_2 16 = 2 \text{bit/s/Hz} \quad (2)$$

The results are obtained by evaluating the signal to noise ratio (E_b/N_0) for a number of iterations. In each case the (BER) and the Structural Similarity Index (SSIM) are calculated. Two ways are generally used to measure the quality of degraded images, the subjective methods and the objective methods. In this paper, besides the evaluation criteria, we will use a new criterion, which is the SSIM. This criterion presents the similarity and compares the luminosity, the contrast, and the structure between each pair of vectors of the two images (original and received). The SSIM between two signals x and y is given by [9]:

$$\text{SSIM}(x, y) = L(x, y), C(x, y) \text{ and } S(x, y) \quad (3)$$

where L(x, y) represents the comparison of the brightness between the original and the received image, C(x, y) represents the comparison of the contrast between the original and the received image, and S(x, y) represents the comparison of the structure between the original image and the received image.

The proposed simulation algorithm for the image transmission chain coded with TC and TTCM is presented in Figure 1.

Figure 2 shows the effect of TC in the transmission chain of the image. The obtained simulation results represent the evaluation of the BER function of the signal-to-noise ratio in a image transmission in a Gaussian channel using TC with rate R=1/2 and MAQ16 modulation.

Figure 3 shows the effect of TTCM in the transmission chain. The obtained simulation results represent the evaluation of the BER function of the signal-to-noise ratio in a medical image transmission in a Gaussian Channel using TTCM with rate R=1/2 and MAQ16 modulation.

Figure 4 shows the performance comparison between the TC whit $\eta=2$ and TTCM whit $\eta=2$ in the transmission chain.
The BER measurement gives a numerical value on the damage, but it does not describe its type, it does not quite represent the quality perceived by human observers. For medical imaging applications, where the degraded images must eventually be examined by experts, traditional evaluation remains insufficient. For this reason, objective approaches are needed to assess the medical imaging quality [21]. A new paradigm is evaluated to estimate the quality of medical images. For this reason and to have more details on our system the SSIM will be used as indicated above. Figures 5 and 6 show the effect of TC and TTCM in the transmission chain of a medical image. The obtained simulation results represent the evaluation of the SSIM function of the signal-to-noise ratio in a medical image transmission in a Gaussian channel using TC and TTCM with R=1/2 rate and MAQ16 modulation. Figure 7 shows the comparison between the performance of the TC and TTCM. The results are represented in detail in Tables I and II and the histograms in Figures 8 and 9.
V. COMMENTS AND INTERPRETATION OF THE OBTAINED RESULTS

From the simulation results, it can be noticed that the role of the ECCs is very important in the transmission of images. The simulation results show that by using transmission systems with TTCM, there is a coding gain compared to transmission systems that use TC. With TTCM, the BER and SSIM results as functions of SNR are quite satisfactory. In the case of TTCM it is more adequate to remain at the 3rd iteration, allowing the receiver to have an easy structure to put in. The decoding will be simpler and the time shorter leading to optimal results. To see the importance of our work and in order to justify the reliability of our system, we have compared the obtained results with the ones obtained in [21, 22]. In these articles, the authors chose joint encoding with TCM with a spectral efficiency of $\eta=2$bit/s/Hz. It can be said that the obtained results of the current study have a significant coding gain and also we arrived at SSIM = 1 (100%) which is not the case in the cited articles.

VI. CONCLUSION

The main objective of our work is to study the performance of TC and TTCM when transmitting medical images over a Gauss channel. The simulation results obviously depict that our proposed transmission scheme performs better for the transmission of digital images and BER is significantly decreased (BER=0). This efficiency leads to the best reception quality of the digital images, 100% close to the transmitted ones (SSIM=1). Moreover, we demonstrated that the TTCM implementation outperforms the TC. By using TTCM, it is suggested to stop the process at the 3rd iteration. This allows having a simple architecture of the decoder and optimizes the decoding process in terms of time and complexity. The obtained results make the proposed transmission scheme a strong candidate when transmitting medical images, allowing medical staff to have best quality at the reception and facilitate the diagnosis process. The obtained results are better than the results found in [21].

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