Improving Turbo Decoding via Cross-Entropy Minimization

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Abstract — **We show that the decoding performance of a simple turbo code can be improved by cross-entropy minimization via manipulation of the initial *a priori* probabilities.**

I. Improving Turbo Decoding

While Turbo decoding of parallel concatenated codes (PCC) has been shown to offer near Shannon-limit performance, it is known that the decoding is sub-optimal. For example it has been shown analytically by McEliece *et al.* [1] that, for certain received values of a (14, 3) PCC, the turbo decoding process does not converge . However, this does not cover all cases of non-convergence. Furthermore, there are also cases where the turbo decoding process converges to a non-maximum *a posteriori* probability (non-optimum) decision.

We investigated the turbo decoding performance when the initial *a priori* probabilities (APRP) are biased to the optimally decoded message for this (14,3) turbo code. This method, which assumes knowledge of the optimum decision, is referred to in this paper as the "Genie" Turbo Decoding method (GT). Figure 1a shows the BER surface when initial APRPs for the first two of the three information bits are biased with respect to the optimum decision with values ranging from $\delta_1 = \delta_2 = 0$ (correctly biased) to $\delta_1 = \delta_2 = 1$ (incorrectly biased). The BER, which is measured for an E_b/N_o of 5dB, shows a slight improvement when both bits are biased correctly as opposed to the unbiased case ($\delta_i = 0.5, \forall i$).

Hagenauer *et al.* [2] have proposed using cross-entropy between the outputs of the component decoders to detect convergence. The similarity between the cross-entropy surface (figure 1b) and the BER surface (figure 1a) suggests that the cross-entropy values may be used to infer initial APRP settings in order to improve decoding performance.

We modified the turbo-decoding process by biasing the APRPs to the eight possible messages, each for a fixed number of iterations. The output of the bias that yields the lowest cross-entropy at the final iteration is then chosen. We refer to this technique as Entropy Minimization Turbo Decoding (EMT). Table 1 compares the percentage increase in BER with respect to optimum decision decoding for the traditional turbo decoding, EMT, and GT approaches at various E_b/N_o values. The performance for GT and the traditional turbo decoding are shown for the average obtained between 50 and 100 iterations, while the EMT performance is for just 2 iterations (at each of the 8 possible messages).

II. Results

It is seen that GT always out-performs the traditional turbo decoder showing that there is a potential for improvement at all E_b/N_o by biasing the initial APRPs; further, this potential for improvement is significantly greater at higher E_b/N_o. Above 2 dB, EMT also performs better than traditional turbo decoding and nears the performance of GT at 5 dB.

Based on these results, we believe it is possible to improve the performance of more practical turbo-decoders by pre-setting the initial APRPs.

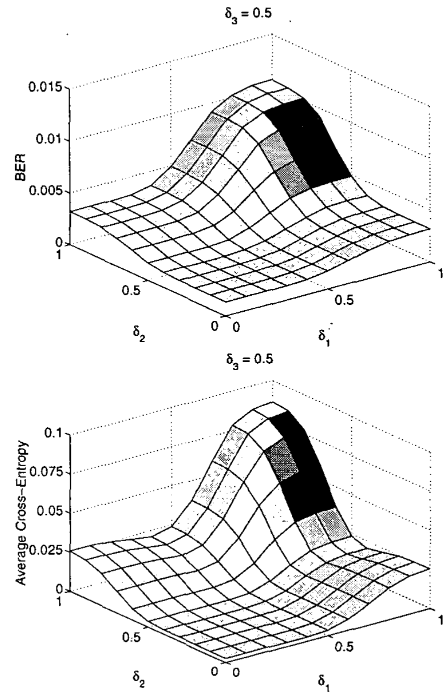

Figure 1: BER and Cross-Entropy Surfaces

	2 dB	3 dB	4 dB	5 dB
Turbo	6.07	8.17	10.81	14.74
EMT	6.93	7.29	8.67	8.71
GT	5.10	6.15	7.40	8.46

Table 1: Percentage Increase in BER w.r.t. Optimum

References

[1] R.J. McEliece, E.R. Rodemich and J.-F. Cheng, "The Turbo Decision Algorithm", *Thirty-Third Annual Allerton Conference on Communication, Control, and Computing*, pp. 366-79, 1995.

[2] J. Hagenauer, E. Offer, L. Papke, "Iterative decoding of binary block and convolutional codes," *IEEE Transactions on Information Theory*, vol. 42, no. 2, March 1996.

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