A B S T R A C T

TITLE : Empirical Bayes Adaptive Decoding for Sources with Unknown Distribution

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A decoding algorithm for sources with unknown distribution is presented, which uses adaptive decision thresholds. The method is based upon a decision-directed receiver and in results derived from the empirical Bayes unsupervised learning technique, being appropriate for channels with low SNR. The Algorithm's convergence is analysed and it is shown that the decoding error probability almost surely converges for the value that would be obtained if the source prior distribution were known. An application for binary transmission with digital modulation is discussed and the association of the technique with linear block codes is considered, which results in an adaptive MAP decoding procedure for such codes.

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ABSTRACT

An decoding algorithm for sources with unknow distribution is presented, which uses adaptive decision thresholds. The method is based upon a decision-directed receiver and in results derived from the empirical Bayes unsupervised learning technique , being appropriated for channels with low SNR. The Algorithm's convergence is analysed and it is shown that the decoding error probability almost surely converge for the value that would be obtained if the source prior distribution were known. An application for binary transmission with digital modulation is discussed and the association of the technique with linear block codes is considered, which results in an adaptive MAP decoding procedure for such codes.

SUMMARY

The decoding of sources with unknown prior distribution is a problem of special interest in the field of communication which has been investigated by many researchers[3,4]. The algorithm presented in this paper results in an adaptive receiver which uses the received information for updating the knowledge about the source statistics. It is based on the Davisson-Schwartz decision-directed receiver (DDR) as well as in unsupervised learning techniques similar to empirical Bayes[4,5,6], and prevents the possibility of a runaway. The problem is formulated within the decision theory context[1], where the bayesian risk (unknown) represents the decoding error probability when hard decision is used. Applying the unsupervised learning technique, allows the estimation of the prior distribution when the channel distribution is an identifiable family[8,10]. From such estimate it is possible to find optimum decision thresholds in the sense that the estimated bayesian risk is minimized. The essential idea in the algorithm is to consider two different classes of decision thresholds in the decoding process. In the first, the thresholds are fixed and are used only for the prior estimation, while the second class contains adaptive thresholds for decoding. Such modification is responsible for eliminating the inconveniences in the DDR[4].

The conditions for an assymptotically optimum (a.o.) performance in error probability are analysed. If such conditions are met, it can be shown that the sequence of thresholds almost surely (a.s.) converges for the optimum thresholds and the error probability a.s. converges to the minimum value. In the binary case, the algorithm's applicability for any channel with nonzero capacity is demonstrated.

An application for binary communication systems is considered next, where it is shown how to implement adaptive receivers for use with digital modulation techniques and either coherent or envelope detection. Computer simulations results are shown, analyzing the rate of convergence and comparing the adaptive receiver performance with maximum likelihood decoding (MLD). It is shown that the technique is extremely interesting for low SNR's or high error rates, which makes an analysis of channel coded systems an important point in the overall system assessment. Also, when the source entropy is low, a substantial improvement in error rate with regard to MLD is obtained, again for low SNR.

Finally, block error control codes are considered, and it is shown that the algorithm's complexity increases with the number of redundant digits, thus making it attractive for high rate codes. The adaptive thresholds are defined by the code structure in such a way that an a.o. hard decision is performed. The algebraic decoding techniques may then be put to work to its full capacity for decoding the received vector. If soft decision is ėsed, it is possible to perform an adaptive MAP decoding without knowing the codewords prior distribution. For linear codes, decoding can be done with the help of the code trellis or subtrellis[7,9].

The adaptive receiver overall error probability, converges with probability one to the minimum value, therefore characterizing the decoding method described in this paper as an efficient and attractive one.

REFERENCES

1. FERGUSON, T.S., Mathematical Statistics, Academic Press, 1967.
2. SCHWARTZ, M., BENNETT, W.R. and STEIN, S., Communication Systems and Techniques, McGraw-Hill, 1966.
3. WOLFENSON, M. and ROCHA JR., V.C., Soft Decision Decoding with Unknow source Distribuition, Electronics Letters, Vol 16, pp 25-6, 1980.
4. DAVISSON, L.D. and SCHWARTZ, S.C., Analysis of a Decision-directed Receiver with Unknown Priors, IEEE Trans. Info. Theory, Vol IT-16, pp 270-76, May 1970.
5. SPRAGINS, J.D., Learning Without a Teacher, IEEE Trans. Info. Theory, Vol IT-12, pp 223-30, Apr 1966.
6. ROBINS, H., The Empirical Bayes Approach to Statistical Decision Problems, Ann. Math. Stat., Vol 35, pp 1-20, 1964.
7. WOLF, J.K., Efficient Maximum Likelihood Decoding of Linear Block Codes using a Trellis, IEEE Trans. Info. Theory, Vol IT-24, pp 76-80, Jan 1978.
8. TEICHER, M., Identifiability of Finite Mixtures, Ann. Math. Stat., Vol 34, pp 1265-69, 1963.
9. MATIS, K.R. and MODESTINO, J.K., Reduced-Search Soft Decision Trellis Decoding of Linear Block Codes, IEEE Trans. Info. Theory, Vol IT-28, pp 349-55, Mar 1982.
10. YAKOWITZ, S.J. and SPRAGINS, J.D., On the Identifiability of Finite Mixtures, Ann. Math. Stat., Vol 39, pp 209-14, 1968.