International Journal of Modern Communication Technologies & Research (IJMCTR)
ISSN: 2321-0850, Volume-2, Issue-4, April 2014

Blind identification of convolutional codes in soft-decision situations

Zhou Jing, Huang Zhiping, Su Shaojing, Zhang Yimeng

***Abstract*— This paper proposes a metod of blind parameter identification of a convolutional encoder in soft-decision situations. The problem can be addressed on the context of the non-cooperative communications or adaptive coding and modulations (ACM) for cognitive radio networks. We consider an intelligent communication receiver which can blindly recognize the coding parameters of the received data stream. The only knowledge is that the stream is encoded using binary convolutional codes, while the coding parameters are unknown. Some previous literatures have significant contributions for the recognition of convolutional encoder parameters in hard-decision situations. However, soft-decision systems are applied more and more as the improvement of signal processing techniques. In this paper we propose a method to utilize the soft information to improve the recognition performances in soft-decision communication systems. Finally we give the simulation results to show the efficiency of the proposed algorithm.**

***Index Terms*— blind recognition, channel coding, convolutional codes, adaptive coding and modulation (ACM), non-cooperative communications.**

I. Introduction

In digital communication systems, error-correction codes are widely used. To meet high quality of services, new coding schemes are being developed ceaselessly. Therefore, for a communication receiver it is very difficult to remain compatible with all standards used. But if an intelligent receiver which is able to blindly recognize the coding parameters of a specific transmission context, it can adapt itself to the perpetual evolution of digital communications. Furthermore, the blind recognition techniques are also applied in non-cooperative communications. In non-cooperative communication contexts, the receivers do not know the coding parameters so it must blindly recover the encoder before decoding. In this paper we focus the blind recognition of coding parameters of an encoder which uses convolutional codes as error-correction coding and propose a method to take advantage of the soft information in soft-decision situations.

Manuscript received April 01, 2014

Zhou Jing, College of Mechatronic Engineering and Automation, National University of Defense Technology, Changsha, China, +86-731-84576387

Huang Zhiping, College of Mechatronic Engineering and Automation, National University of Defense Technology, Changsha, China, +86-731-84576387

Su Shaojing, College of Mechatronic Engineering and Automation, National University of Defense Technology, Changsha, China, +86-731-84576387,

Zhang Yimeng, College of Mechatronic Engineering and Automation, National University of Defense Technology, Changsha, China, +86-731-84576387

Some previous literatures discussed the problem of blind recognition of convolutional codes. The authors of [1-3] developed blind recognition of convolutional codes in noiseless context, including the rate1/n and k/n codes. These methods are not suitable for noisy environment. For the case of noisy context, some algorithms were proposed in recent years [4-7]. The algorithm proposed in [7] completely solved the blind parameter recognition of k/n convolutional codes with low complexity and excellent recognition performances.

However, the previous works are all discussed in hard-decision situations. In modern communication systems, more and more soft-decision based algorithms are applied to improve the signal processing performances. For example, the soft-decision based decoding methods always have better performances than hard-decision situations [8-12]. Similarly, some soft-decision based blind recognitions of block code parameters also outperform the hard-decision ones [13-14]. In this paper, based on [6-7] we propose a method to utilize the soft information to improve the recognition performances in soft-decision systems. And because the authors of [6-7] did not give a normative algorithm to automatically identify the parameter n for a computer program, we propose a formalized scheme to optimize the recognition of n. At the end of the paper, we show the efficiency of the proposed algorithm by simulation results for some different convolutional codes.

II. Blind Frame Synchronization of Error Correcting Codes Having a Sparse Parity Check Matrix

The details of the dual code method based recognition algorithm of rate *k*/*n* convolutional encoder parameters are introduced in [7]. The algorithm includes three major sections:

(1) Identification of code length *n*;
(2) Identification of a dual code basis;
(3) Identification of the generator matrix.

In the first procedure, the authors of [7] propose to recognize *n* with the following steps.

1. Set the minimum and maximum value of l, i.e. $l_{\min}$ and $l_{\max}$. Initialize l to be $l_{\min}$.

2. According to l and a sequence of received bits, we generate an observed data matrix R_l as shown in Figure 1, the numbers in which denote the arriving order of the bits in the received data stream.

3. Transform the matrix R_l to a lower triangular matrix G_l by the Gauss Jordan Elimination Through Pivoting (GJETP, see [15] for details):

$$G_l = A_l R_l B_l \qquad (1)$$

4. Obtain the set Z_l as follows:

$$Z_l = \text{Card}\left\{ i \in \{1,...,l\} \mid N_l(i) \le \frac{L-l}{2}\gamma_{opt} \right\} \qquad (2)$$

where N_l(i) is the number of “1” in the lower part of the i^{th}

column in the matrix G_l, γ_{opt} is an optimal threshold [6-7] and Card$\{x\}$ denotes the cardinal of x. An N_l(i) smaller than $(L-l)\gamma_{opt}/2$ indicates that the i^{th} column of R_l has high probability to be dependent on the other columns.

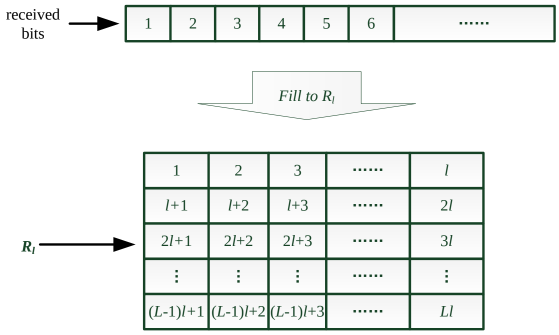

Fig. 1 *Generation of the observed matrix R_l*

5. If l=l_{max}, execute step 6. If l<l_{max}, let l=l+1 and go back to step 2.

6. Output the gap between two consecutive non-zero cardinals, Z_l, as the estimated codeword size $\hat{n}$. The principle of this estimation is that when $l = mn (m \in \mathbf{Z}^+)$ and l is larger than the overall memory length of the dual code, some columns of C_l can be determined by other columns, where $C_l = R_l + E_l$ and E_l is the error pattern corresponding to R_l.

According to the GJETP algorithm, the reliability of upper part of R_l has larger influences on the successful detection of dependent columns in R_l. Therefore, here we propose the following processing procedure inserted into the steps (between step 2 and step 3) mentioned above.

(1) Fill the observed matrix R_l with the soft-decision bits. For each row in R_l we find the decision bit that has the lowest reliability and record its reliability value as RL_l.

(2) Arrange the rows of R_l according to each row's lowest reliability value RL_l to make the first row of R_l has the highest RL_l, the second row has the second highest RL_l, and so on.

(3) Obtain the hard-decisions of the bits in the re-arranged R_l and continue step 3 mentioned above.

After this processing, the upper rows of the re-arranged R_l have higher reliabilities and therefore have lower probabilities to include error decision bits. So the probability of successful detection of dependent columns can be improved. And as the value of L rising, the improvement of the reliabilities of the upper part of R_l becomes more effective, so the recognition performance can be improved more obviously than the previous algorithm in [7]. After the estimation of n, we use the Algorithm 1 and Algorithm 2 in [7] to identify other coding parameters.

III. Formalizing the Estimation Algorithm of *n*

Note that in step 6 shown in the previous section, the authors of [7] only give the idea of the estimation of n. When the noise level is high, there exists a problem that the number of error decision bits is high and some cardinals Z_l corresponding to the values of l that equals to mn are blank. So not all the gaps between two consecutive non-zero cardinals, Z_l, equal to n. In this case, we need a formalized algorithm to estimate the value of n more exactly. This can be done by simply searching all the gaps between two consecutive non-zero cardinals and find out which gap value appears mostly. The detailed algorithm steps are listed below.

(1) Let $V_l = [l_1, l_2, ..., l_s]$ be the vector that consists of the values of l corresponding to the detected non-zero cardinals Z_l in step 6.

(2) Calculate the vector $\Delta V_l = [\Delta l_1, \Delta l_2, ..., \Delta l_{s-1}]$, the elements of which are calculated by

$$\Delta l_i (1 \le i \le s) = l_{i+1} - l_i \qquad (3)$$

(3) Initialize a vector Q with length l_{max} to be overall zeros and for each value of i from 1 to s-1, we let

$$Q(\Delta l_i) = Q(\Delta l_i) + 1 \qquad (4)$$

(4) Finally we find the maximum element in Q and output the corresponding gap value Δl_i to be the estimated codeword size $\hat{n}$.

IV. Simulation Results

In this section we give the simulation results of the blind recognition of the convolutional coding parameters by utilizing the algorithm introduced in this paper. The simulations include two parts corresponding to our proposed recognition algorithm on different noise level and different observed matrix size L. In the simulations we assume that the signal is transmitted on a binary symmetry channel (BSC) which is corrupted by an Additive-White-Gaussian-Noise (AWGN) with the channel error probability (CEP) τ.

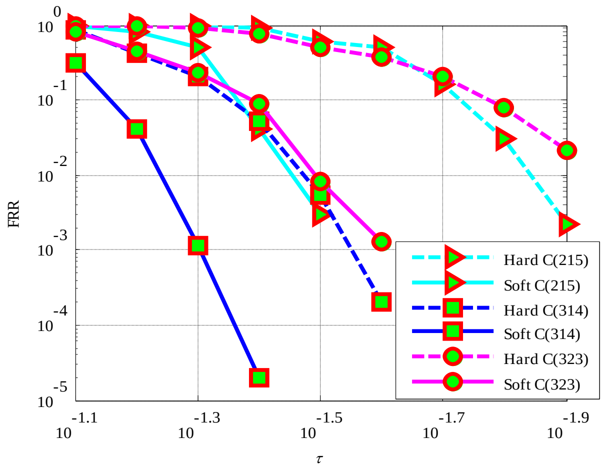

Fig. 2 *Recognition performances for several convolutional codes*

In Figure 2 we show the false recognition ratios (FRR) for several convolutional codes on different channel conditions when the observed window size L=200. And we also compare the proposed method with the hard-decision based algorithm proposed in [7]. We can see from the simulation results that when the soft information is introduced into the recognition algorithm, the recognition performances can be improved obviously. And as the CEP rising, the FRR curves descend more rapidly.

Figure 3 shows the recognition performance of two convolutional codes for different observed matrix size, when the CEP $\tau = 10^{-1.5}$. It shows that the soft information can help to make the FRR descends more rapidly when L is rising. This fact means that in soft-decision situations, we can improve the recognition performance by increasing the number of rows of the intercepted matrix R_l, while we cannot in soft-decision situations.

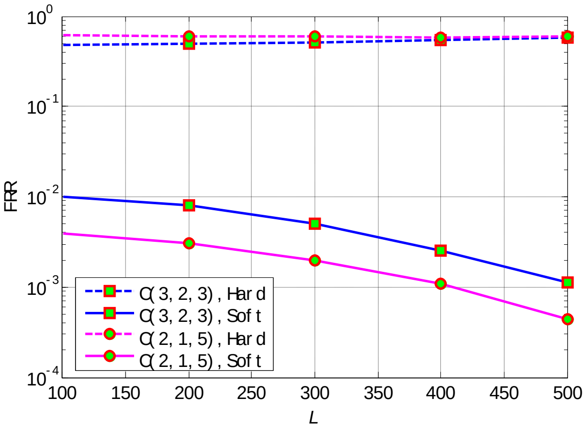

Fig. 3 *Recognition performances on different size of R_l for soft and hard decisions*

V. CONCLUSION

This paper proposes the methods of utilizing soft information to improve the recognition performance of convolutional encoder parameters. And we propose a formalization of the estimation of the parameter *n*. When introducing the soft information the recognition performance can be obviously improved and the simulations show the efficiency of the proposed methods.

REFERENCES

[1] B. Rice, "Determining the parameters of a rate 1/*n* convolutional encoder," *Proceedings of the International Conference on Finite Fields and Applications*, Glasgow, UK, 1995.

[2] E. Filiol, "Recognition of convolutional encoders over GF(p)," *Proceedings of the 6th IMA Conference on Cryptogrophy and Coding, Cirencester*, UK, 1997.

[3] M. Marazin, R. Gautier, G. Burel, "Blind recovery of the second convolutional encoder of a turbo-code when its systematic outputs are punctured," *MTA Rev*., vol. XIX, 2009, pp. 213-232.

[4] F. Wang, Z. Huang, Y. Zhou, "A method for blind recognition of convolution code based on Euclidean algorithm," *Proceedings of IEEE WiCom*, Shanghai, China, 2007, pp. 1414–1417.

[5] J. Dingl, J. Hagenauer, "Parameter estimation of a convolutional encoder from noisy observations," *Proceedings of IEEE Int. ISIT*, Nice, France, 2007, pp. 1776-1780

[6] M. Marazin, R. Gautier, G. Burel, "Dual code method for blind identification of convolutional encoder for cognitive radio receiver design," *Proceedings of the 5th IEEE GLOBECOM*, Honolulu, USA, 2009.

[7] M. Marazin, R. Gautier, G. Burel, "Blind recovery of *k*/*n* rate convolutional encoders in a noisy environment," *EURASIP J. Wirel. Comm.*, vol. 2011(168), pp. 1-9.

[8] S. Lin, D. J. Costello, "Reliability-Based Soft-Decision Decoding Algorithms for Linear Block Codes". In *Error Control Coding*, 2nd ed. J. M. Horton, D. W. Riccardi. Eds.; Pearson Prentice Hall: Upper Saddle River, NJ, USA, 2004; pp. 395–452.

[9] L. Ni, F. Yao, L. Zhang, "A rotated quasi-othogonal space-time block code for asynchronous cooperative discovery," *Entropy* vol. 14, 2012, pp. 654–664.

[10] X. Liu, X. Geng, "A Convolutional Code-Based Sequence Analysis Model and Its Application," *Int. J. Mol. Sci.* vol. 14, 2013, pp. 8393-8405.

[11] J. Hagenauer, L. Papke, "Iterative Decoding of Binary Block and Convolutional Codes," *IEEE Trans. Inform. Theory*, vol.42, 1996, pp. 429-445.

[12] Z. Huang, M. Chen, C. Diao, "Low Compexity Weighted Reliability –Based Iterative Decoding of LDPC Codes," *IEICE Trans. Commun.* vol. *E95B*, pp. 3572-3575.

[13] J. Jiang, K. R. Narayanan, "Iterative Soft-Input-Soft-Output Decoding of Reed-Solomon Codes by Adapting the Parity Check Matrix," *IEEE Trans Inf. Theory* vol. 52, 2006, pp. 3746-3756.

[14] J. Zhou, Z. Huang, C. Liu, S. Su, Y. Zhang, "Information–dispersion –entropy-based blind recognition of binary BCH codes in soft decision situations," *Entropy*, vol. 15, 2013, pp.1705-1725.

[15] J. Zhou, Z. Huang, S. Su, S. Yang, "Blind recognition of binary cyclic codes," *EURASIP J. Wirel. Comm.*, vol. 2013(218), 2013, pp. 1-17

[16] G. Sicot, S. Houcke, J. Barbier, "Blind detection of interleaver parameters," *Signal Processing* vol. 89, 2009, pp. 450-462.

Zhou Jing is now a graduate student in National University of Defense Technology (NUDT). His research interests include error control coding and information theory, especially the blind signal processing and cognitive networks. Now his focus is on blind parameters recognizing of error-correcting codes.

Huang Zhiping received the Ph.D. degree from Beijing Institute of Technology in 1993 and now is a professor and Ph.D. supervisor in the national university of defense technology. His research interests include information and communication theory, high speed information processing and modern measurement and instruments.

Su Shaojing received the Ph.D. degree in from the national university of defense technology (NUDT), in 2001. Now he is an associate professor in NUDT. His research interests include optical communication test and high-speed optical communication systems.