Blind Recognition Algorithm of Turbo Codes for Communication Intelligence Systems

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Abstract

Turbo codes are widely used in land and space radio communication systems, and because of complexity of structure, are custom in military communication systems. In electronic warfare, COMINT systems make attempt to recognize codes by blind ways. In this Paper, the algorithm is proposed for blind recognition of turbo code parameters like code kind, code-word length, code rate, length of interleaver and delay blocks number of convolution code. The algorithm calculations volume is$0.5L^3$+1.25L, therefore it is suitable for real time systems.

Keywords: *Blind Recognition, Turbo Code, Convolution Code, Recursive Systematic Convolution (RSC) Code, Interleaver.*

1. Introduction

Communication Intelligence systems (COMINT) play important role in electronic warfare. COMINT systems receive unknown signals and make attempt to demodulate, decode and decipher by blind ways.

Channel coding is used in communication systems to correct errors. Several methods have represented for channel coding by various aims and conditions. Because of complexity of decoding, turbo codes are custom in military communication systems. COMINT systems must be able to blind recognition of turbo codes. In this paper, an algorithm is proposed to finding turbo code parameters like code rate, length of interleaver and delay blocks number of convolution code. In continue turbo code is explained and then the proposed algorithm is described, simulated and evaluated [1].

Turbo decoder and encoder are illustrated in figure 1, 2 [2] [3]. In turbo encoder, RSC & interleave are used. RSC codes at first was suggested by Berrou[4]. The code rate change number of RSC and interleaver blocks. For example for 1/3 code rate two encoder RSC blocks and one interleaver block is needed. If X is the string of input bits, output of branches of encoder will be:

$$v^{(0)} = X = (v_0^{(0)}, v_1^{(0)}, \dots, v_{k-1}^{(0)})$$

$$v^{(1)} = (v_0^{(1)}, v_1^{(1)}, \dots, v_{k-1}^{(1)})$$
$$v^{(2)} = (v_0^{(2)}, v_1^{(2)}, \dots, v_{k-1}^{(2)})$$
$$\dots$$
$$v^{(n)} = (v_0^{(n)}, v_1^{(n)}, \dots, v_{k-1}^{(n)}) \qquad (1)$$

And string of output bits will be:

$$V = (v_0^{(0)}, v_0^{(1)}, \dots, v_0^{(n)}, v_1^{(0)}, v_1^{(1)}, \dots, v_1^{(n)}, v_{k-1}^{(0)}, v_{k-1}^{(1)}, \dots, v_{k-1}^{(n)}) \qquad (2)$$

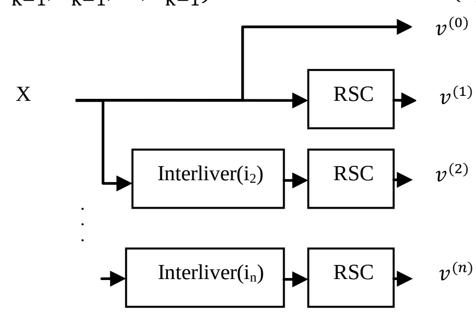

Fig. 1: Outline of a turbo code encoder [2] [3].

In turbo decoder, the noisy systematic and parity bits decode in two stages and message bits are estimated. Decoding stages uses different BCJR (Bahi, Cocke, Jelinek and Raviv) algorithm to solve detection problem by MAP (Maximum A Posteriori probability).

2. Proposed Algorithm

Flowchart of algorithm is illustrated in figure 3. Input coded string bits are named L. Matrix H contains encoded string bits and have N_c columns and N_r rows, that in first step N_c=1, N_r=L. Matrix H is divided to two matrices Z ($N_c * N_c$) and Y ($(N_r - N_c) * N_c$):

$$H = \begin{bmatrix} [Z] \\ [Y] \end{bmatrix}$$

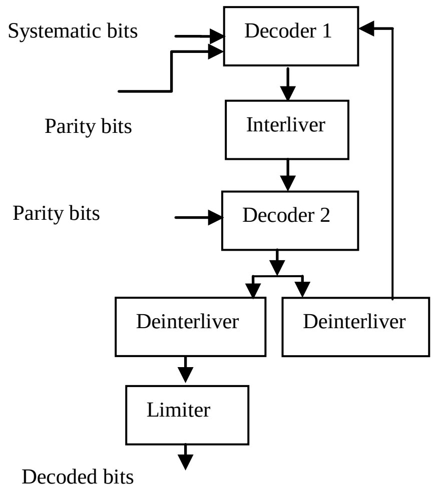

Fig. 2: Outline of a turbo code decoder [3].

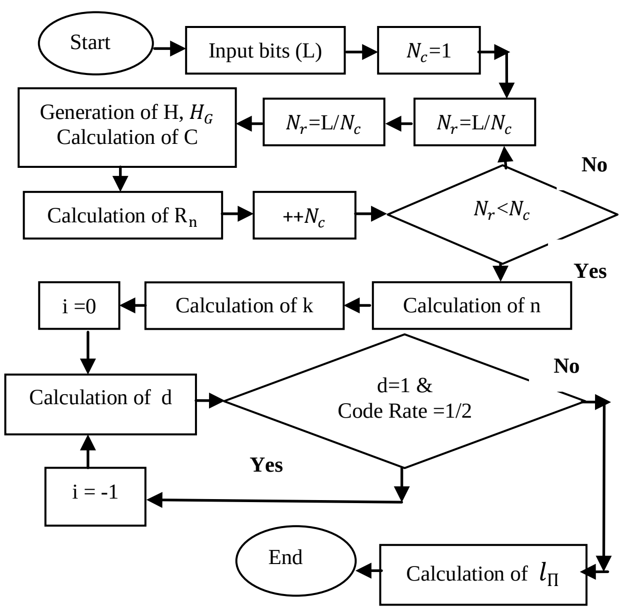

Fig. 3: Flow chart of blind recognition algorithm of turbo code.

Z converts to lower triangular matrix by Gauss-Jordan method and result is named Z_1. Matrix H_G defines as follows:

$$H_G = \begin{bmatrix} [Z_1] \\ [Y] \end{bmatrix}$$

Algorithm runs until N_r<N_c, then R_n calculated:

$$R_n = \frac{N_c - C}{N_c} = \begin{cases} 1 & \text{if } N_c \neq pn \\ < 1 & \text{if } N_c = pn \end{cases} \qquad (3)$$

That C is number of zero columns of matrix H_G, n is the length of the code word and p is a positive integer.

From $R_n - N_c$ diagram, turbo code parameters extract:

* When $R_n < 1$, the distance between two samples is equal to n for all code rates, except when code rate is 1/2, then distance will be equal to (2n).

* The integer part of n * (absolute (minimum (R_n)) is equal to k.

* The delay blocks number is:

$$d = \begin{cases} \frac{X_n}{2n} - (1 + N_{CTC1}) & \text{for} \quad \text{code rate} = \frac{1}{2} \\ \frac{X_n}{n} - (1 + N_{CTC1}) & \text{for} \quad \text{other} \end{cases}$$

$$N_{CTC1} = 0,1,2, \dots \qquad (4)$$

That X_n is block length or samples on horizontal axis, n is output bits number, d is delay blocks number and $N_{CTC1}$is counter turbo code number. N_{CTC1} counts samples that is not equal to one. If the code rate is 1/2 and after calculation d=1, d must recalculate by $N_{CTC1} = -1,0,1, \dots$.

* The size of interleaver is:

$$l_\Pi = \frac{X_n}{nN_{CTC2}} \quad , \qquad N_{CTC2} = 1,2,3, \dots \qquad (5)$$

l_Π is size of interleaver and N_{CTC2} is counter of samples of l_Π that starts from first non-contiguous sample and continues.

3. Simulation and Evaluation of Algorithm

Input data and proposed algorithm are simulated by MATLAB. Inputs are generated by changing code rates, delay blocks number and interleaver size. String bits of turbo code have specifications that are described in table 1 and results of simulation are illustrated in figures 4 to 8.

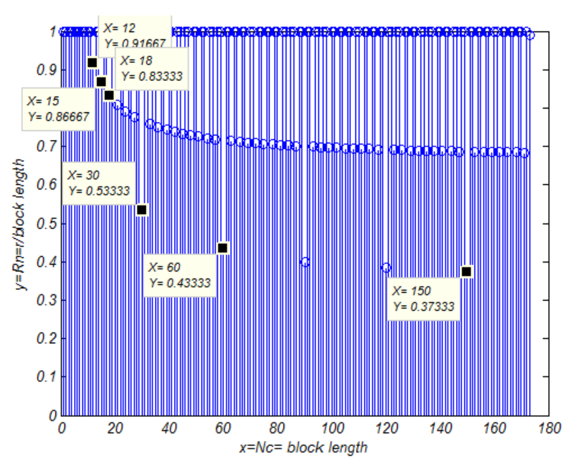

Fig. 4: Result of algorithm for code strings NO.1 of table 1.

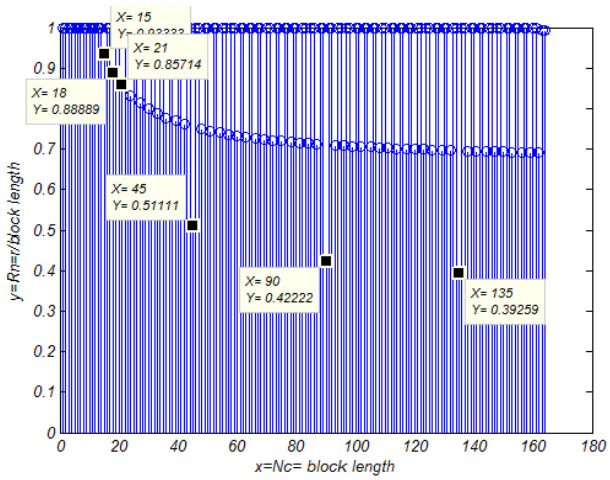

Fig. 5: Result of algorithm for code strings NO.2 of table 1

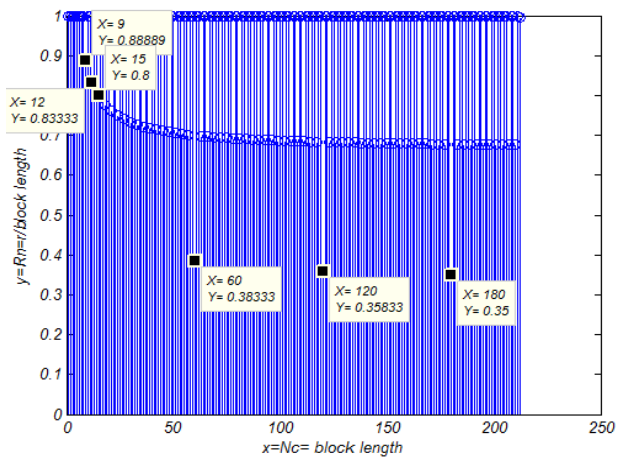

Fig. 6: result of algorithm for code strings NO.3 of table 1.

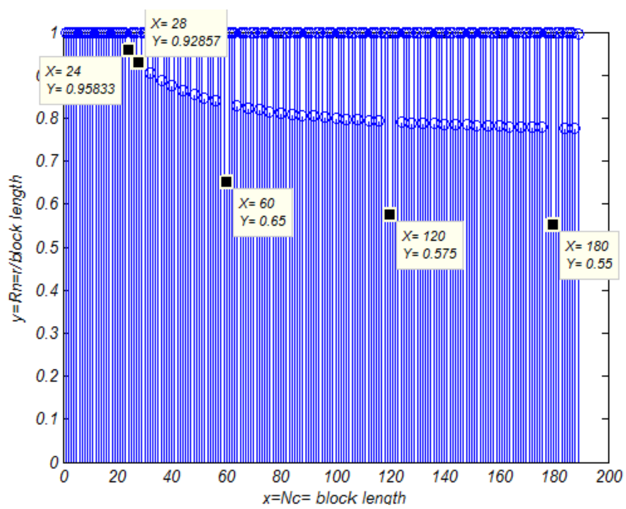

Fig. 7: result of algorithm for code strings NO.4 of table 1.

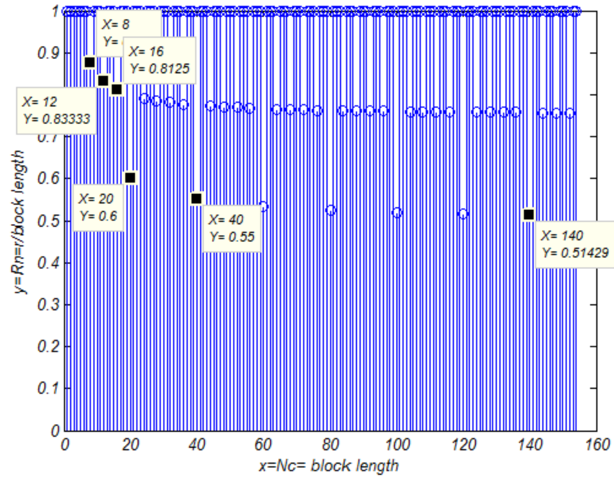

Fig. 8: result of algorithm for code strings NO.5 of table 1.

The results of calculating code rate, delay blocks number and size of interleaver are summarized in table2.

For evaluation of algorithm in various bit error rates (BER) from 10^{-1} to 10^{-6}, string bits is generated with code rates 1/2 and 1/3.

Table 1: Specification of input data

Code string	***Size of interleaver***	***Delay blocks number***	***Code rate***	***Length of string bits***
1	10	3	1/3	10000
2	15	4	1/3	9000
3	20	2	1/3	15000
4	30	5	1/2	18000
5	10	2	1/2	12000

In this condition, average of turbo code parameters is estimated. Results of statistical analysis, when algorithm runs 200 times, are illustrated in figures 9, 10, 11. Any information extract when BER is more than 10^{-2}, when BER is 10^{-2} to 10^{-4} percentage of recognition of turbo code increase, and when BER is 10^{-4} and less, turbo code is recognized completely. Results declare that algorithm has suitable performance in acceptable BER.

4. Conclusions

In this paper, the algorithm represented for blind recognition of turbo code. The proposed algorithm analyzes encoded string bits with new equations and

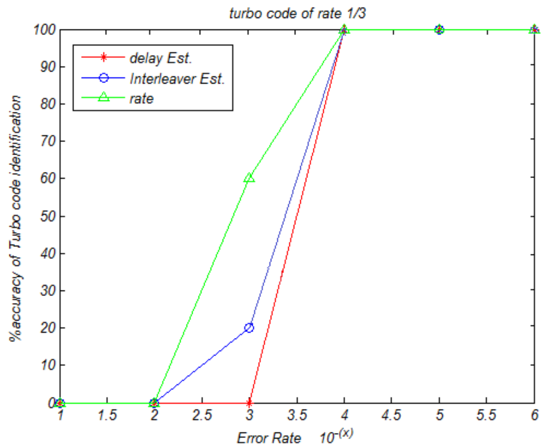

Fig. 9: Prediction value of correctly recognition with code rate1/3.

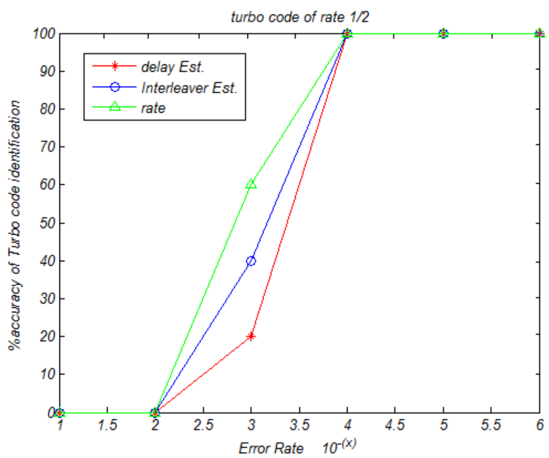

Fig. 10: Prediction value of correctly recognition with code rate1/2.

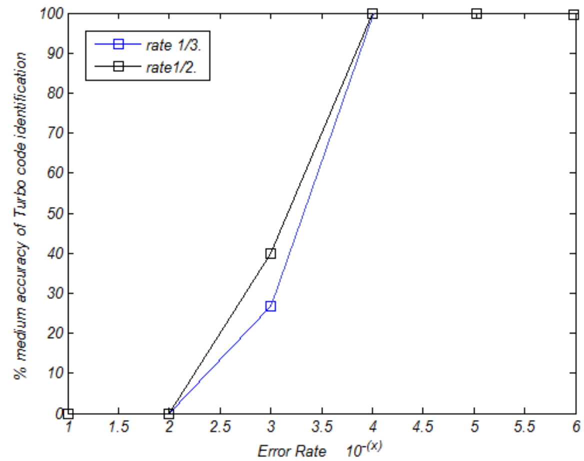

Fig. 11: Average of prediction values of correct recognition with code rates 1/3, 1/2.

extracts code rate, delay blocks number and size of interleaver. The volume of calculations of the proposed algorithm is $0.5L^3+1.25L$. Therefor the executing time of algorithm is suitable for practical issue and real time systems.

Table 2: result of analyzing

Parameters	***Fig8***	***Fig7***	***Fig6***	***Fig5***	***Fig4***
N_c for first $R_n \neq 1$	8	24	9	15	12
N_c for second $R_n \neq 1$	12	28	12	18	15
n	2	2	3	3	2
Absolute (minimum (R_n))	0.514	0.555	0.350	0.392	0.373
k= [min(n*R_n)]	2	1	1	1	1
k/n	1/2	1/2	1/3	1/3	1/3
First sample of N_{CTC1}	-1	0	0	0	0
Second sample of N_{CTC1}	0	1	1	1	1
$X_n(= \mathrm{N_c}$ in first sample of $N_{CTC1})$	8	24	9	15	12
$X_n(= \mathrm{N_c}$ in second sample of $N_{CTC1})$	12	28	12	18	15
d	2	5	2	4	3
First sample of N_{CTC2}	1	1	1	1	1
Second sample of N_{CTC2}	2	2	2	2	2
$X_n(= \mathrm{N_c}$ in first sample of $N_{CTC2})$	20	60	60	45	30
$X_n(= \mathrm{N_c}$ in second sample of $N_{CTC2})$	40	120	120	90	60
	10	30	20	15	10

References

[1] P.Grant, J.Collins."Introduction to Electronic Warfare",IEEE Processing, Vol.129, No.3, 1982.

[2] S.Lin, D.Costello, "Error Control Coding Fundamentals and Applications", Pearson Education, Inc, 2005.

[3] Todd k, Moon, "Error Correction Coding Mathematical Methods and Algorithms", John Wiley& Sons, 2005.

[4] P.Sweeney, "Error Control Coding from Theory to Practice", John Wiley & Sons, 2002.

[5]L.Bahi, J.Cocke, F.Jlinek, J.Raviv, "Optimal Decoding of Linear Codes for Minimizing Symbol Error Rate", IEEE Transaction, 1974.

[6] G.Burel, R.Gautier, "Blind Estimation of Encoder and Interleaver Characteristics in an Non-Cooperative Context", International Conference of Communications, Internet and Information Technology, 2003.

[7] J.Barbier, G.Sicot, S.Houcke, "Algebraic Approach for the Reconstruction of Linear and Convolutional Error Correcting Codes", International Journal of Applied Mathematics and Computer Sciences, 2006.

[8] J.Barbier, "Analyse de Canaux de Communication Dansun Context Non-Cooperatif. Application aux Codes Corecteurs d'Erreurset a la Steganalyse" PHD Dissertation, Ecole Polytechnique, 2007.

[9] L.Lu, K.Li, Y.Guan, "Blind Detection of Interleaver Parameters for Non-Binary Coded Data Streams", School of Electrical and Electronic Engineering Nanyang, 2009.

[10] G.Sicot, S.Houcke, "Blind Detection of Interleaver Parameters", IEEE International Conference of Acoustics, Speech and Signal Processing, 2005.

[11] A.Valembois, "Detection and Recognition of a Binary Linear Code", Discrete Applied Mathematics, 2001.

[12] J.Barbier, "Reconstruction of Turbo Codes Encoders", Space Communication Technologies Symposium, 2005.

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