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Performance of Heuristic Algorithms in minimizing BER for Robust Turbo Codes

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Abstract -The third component introduced in conventional turbo codes in recent days is effective in improving the performance of the code. But under noisy environments the parameters such as permeability and permittivity rates are static and hence their adapatability to noisy environment is poor. To overcome the aforesaid drawback A3D-TC was proposed in our previous paper[29].In our present paper a comparison has been made between two heuristic algorithms viz.,Genetic algorithm and Simulated annealing algorithm. The parameters are made adaptive by generating a knowledge source using both Genetic algorithm and Simulating Annealing algorithm. The source output is fed to the feed forward neural network. The bit error rate at decoding section is tried to minimize in an effective way by the third component parameters generated from the neural network. Under various noisy environments, the experimental results compare the performance of A3D-TC using both Genetic algorithm and simulated annealing algorithm.

Index terms
A3D-TC, knowledge feeding, GA-based knowledge source, simulated annealing, adaptive, permeability rate, permittivity rate, and third component

1 INTRODUCTION

Information passing through a practical communication channel may be corrupted by noise present in the channel. The basic block diagram of communication shown in Figure1. Channel coding is the process of signal transmission designed to improve communications performance by enabling the transmitted signals to better withstand the effects of various channel impairments such as noise, interference and fading.

Channel coding is partitioned as waveform coding and structure sequences. Waveform coding deals with transforming waveforms into better waveforms to make the detection process less subject to errors.

Structured sequences deals with transforming data sequences into better sequences having structured redundancy. These redundant bits are used for the detection and correction of errors. A major concern in digital communication therefore is to develop error correcting technique that covers the gap between the performance of practical communication systems and the ideal channel capacity. In wireless based digital communication systems, Forward Error Correction codes (FEC) or channel codes have become inevitable [1]. A desired quality of service over a link can be achieved within a transmit power or antenna gain by allowing a system to operate at a lower signal to noise ratio.
FEC is a system of error control for data transmission. Redundant bits are added to its messages at the transmitting side. The receiver detects and corrects errors without the need to ask the sender for additional data. The use of FEC codes in communication system is an integral part of ensuring reliable communication [7] and also these codes have become a practical solution in improving system capacity in Optical fiber communication [12].

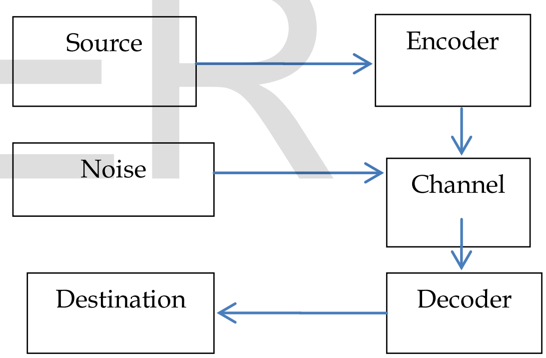

Figure1: Basic block diagram of Communication

A Turbo Code can be thought of as refinement of the encoding structure plus an iterative algorithm for decoding the associated code sequence. The introduction of Turbo Code in the mid-90's marked the beginning of a lot of research work addressing the analysis, design and application of iterative decoding in digital communication [16]. The development of Turbo Code created a new interest in knowing how closely practical codes can approach the theoretical limit on code performance [2]. Shannon limit is the theoretical limit of maximum information transfer rate over a noisy channel [20]. Turbo codes performance is very close to the limit of Reliable communication given by Shannon Limit. It has also been proved that these codes offer remarkable performance especially over low SNR domains. They achieve a bit error probability of 10^{-5}, using a rate ½ code over an AWGN channel at E_b/N_0 of 0.7dB.

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The Turbo encoder includes an interleaver between two constituent recursive convolutional encoders to permute the information sequence in a random fashion [10] and decoder consists of the corresponding decoders with a de-interleaver in between to modify error patterns in the received sequence [18].

2.The Adaptive Third Component Turbo Codes

The error correction capability is improved to a certain extent by the proposed A3D-TC by generating the special intelligence (SI), where the permeability and permittivity rate of the third component encoder is decided. Tuning is done by generating both Genetic Algorithm and Simulated Annealing Algorithm based knowledge source and also by knowledge feeding. Once tuning is completed the third component parameters are generated dynamically according to the noise variance. The block diagram of A3D-TC encoder and decoder is given in Figure 2&3.

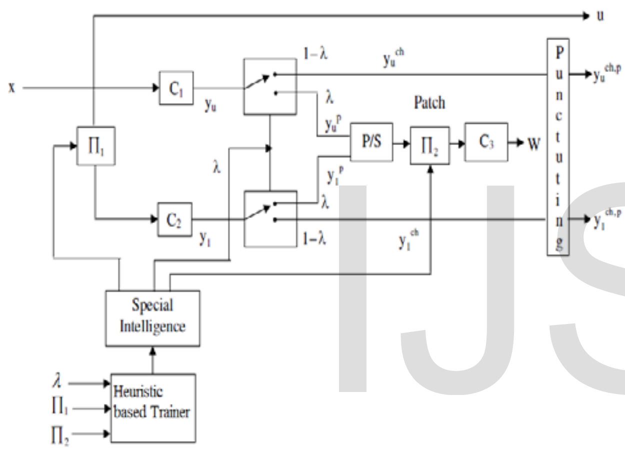


Figure 2: Proposed A3D-TC Encoder

The special intelligence added to the third component of the encoder never disturbed the conventional third component decoder [28], which is given in Figure. 3. Here feed forward neural network is used as the special intelligence, whose structure is shown in Figure 4.

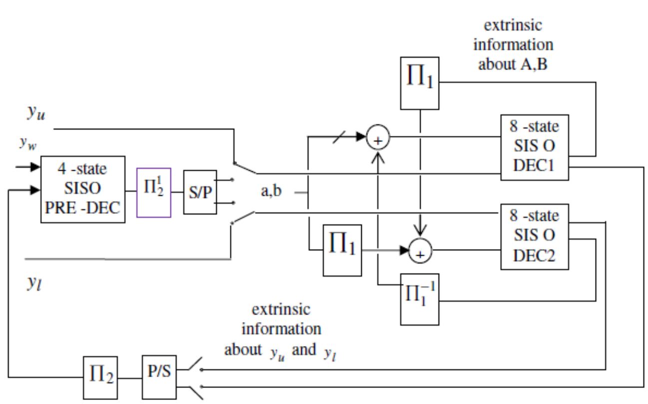


Figure 3: Proposed A3D-TC Decoder

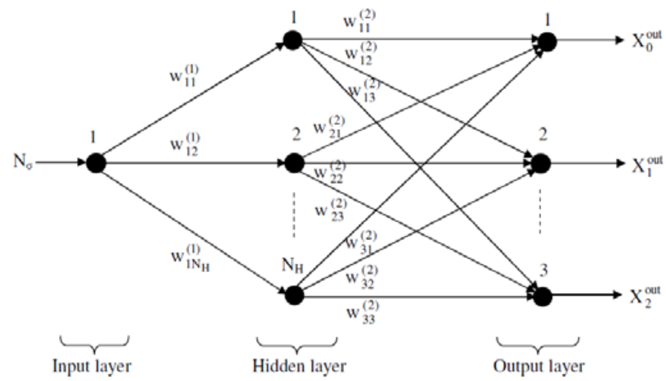


Figure 4: Structure of feed forward neural network used for A3D-TC Encoder

The special intelligence has a single input node, three output nodes and N_H hidden nodes. The hidden nodes and output nodes use sigmoid function and purelin function as activation/ transfer functions respectively. Noise variance N_σ is given as input to SI and the A3D-TC parameters such as permeability rate λ, permutation rate Π_1 and permutation rate Π_2 i.e. $X_1^{out} = \lambda$, $X_2^{out} = \Pi_1$, and $X_3^{out} = \Pi_2$ are obtained as outputs. The complete model of the SI can be given as

$$X_g^{out} = \sum_{h=1}^{N_H} \frac{w_{hg}^{(2)}}{1 + \exp(N_\sigma w_{1h}^{(1)})} \quad g = 0,1,2 \tag{1}$$

where, $w_{1h}^{(1)}$ and $w_{hg}^{(2)}$ are the weights between input-hidden layers and hidden-output layers respectively.

3. Knowledge Feeding

For the special intelligence, appropriate prior knowledge should be given, which is generally called as training (or) learning. The process of prior knowledge feeding (training) includes the generation of knowledge source and then training. The major steps to be done for prior knowledge feeding is given below

(i) Initialize $l = 0$

(ii) Generate a knowledge source for $N_\sigma(l) \rightarrow X_l^{best}: 0 \le l \le |N_\sigma| - 1$, where LHS represents input and RHS represents output.

(iii) Input knowledge source to SI and determine output X_l^{out}(or $X_{l_g}^{out}$) (output calculation is described in Eq. (1)

(iv) Calculate error

$$E_l = X_l^{out} - X_l^{best} \tag{2}$$

(v) If $l = |N_\sigma| - 1$, continue otherwise go to step (ii)

(vi) Determine mean squared error

$$\xi = \frac{1}{|N_\sigma|} \sum_{l=0}^{|N_\sigma|-1} E_l^2 \quad (3)$$

(vii) If $\xi < \xi_T$, terminate the feeding, otherwise continue
(viii) Determine new weights as follows and go to step (iii)

$$w^{new} = w^{old} + \gamma X^{out} \xi \quad (4)$$

Where, γ is the learning rate (usually set as 0. 2)

4. Genetic algorithm based knowledge Source

Genetic algorithm starts by creating an initial population consisting of chromosomes to which a random collection of genes are given.
It then continues by following the steps given below.

(i) Create chromosomes for an initial population.
(ii) Fitness evaluation or selection of each chromosome that makes up the population is done.
(iii) Based on the fitness level, chromosomes are selected that will mate, or those that have the privilege to mate.
(iv) The process of crossover is done and a new offspring
is produced.
(v) Random mutation is done with some of the genes of the chromosomes.
(vi) Steps three through five are repeated until a new population is created.
(vii) When the best solution has not changed for a preset number of generations, the algorithm ends.

Genetic algorithms strive to determine the optimal solution to a problem by utilizing three genetic operators. The operators include selection, crossover, and mutation. Its search for the optimal solution until specific criteria are met and then the process terminates. The results of the process include good solutions, as compared to one "optimal" solution, for complex problems.

The Genetic Algorithm based knowledge source is used in the coding system to support, in training the special intelligence. This can be proficient by generating a precise training dataset, in which N_σ is considered as input and the suitable A3D-TC parameters such as permeability rate λ, permutation rate $\Pi_1$and permutation rate Π_2 are obtained as output. In order to obtain the suitable A3D-TC parameters provided N_σ, the classical GA procedure is described below.

Generate a population pool of N_c chromosomes, in which each chromosome can be represented as

$$X_i = [x_0\ x_1\ x_2]_i;\ \ 0 \le i \le N_c - 1 \quad (5)$$

where, x_0, x_1 and x_2 are the genes of the chromosomes that are generated arbitrary within the corresponding limits i.e. $x_0 \in [\lambda_{min}, \lambda_{max}]$, $x_1 \in [\Pi_1^{\min}, \Pi_1^{\max}]$ and $x_2 \in [\Pi_2^{\min}, \Pi_2^{\max}]$ such that λ_{min}, $\Pi_1^{\min}$ and $\Pi_2^{\min}$ are the minimum limits of λ, Π_1 and Π_2, whereas λ_{max}, $\Pi_1^{\max}$ and $\Pi_2^{\max}$, are the maximum limits of λ, Π_1 and Π_2, respectively. In the most probable cases, $\Pi_1^{\min} = \Pi_2^{\min}$ and $\Pi_1^{\max} = \Pi_2^{\max}$.

The following steps are followed to decide the fitness of each and every chromosome.
(i) As per the chromosome parameters A3D-TC is designed.
(ii) It is encoded with random input bits.

(iii) The channel is added with AWGN noise variance N_σ .
(iv) The data is decoded
(v) The mean Bit error rate is determined.

$$\xi_{BER} = \frac{1}{|N_\sigma|} \sum_{l=0}^{|N_\sigma|-1} BER_l^2 \quad (6)$$

Among all the chromosomes that are present in the population pool, $\frac{N_c}{2}$ chromosomes are selected.
At a rate of C_r and M_r crossover and mutation are respectively performed so that $3C_r$ genes are exchanged between two chromosomes in crossover operation to obtain child chromosomes. Similarly $3M_r$ genes are replaced by new genes in every child chromosomes.

After crossover and mutation, new $\frac{N_c}{2}$ chromosomes, which combine with the parent $\frac{N_c}{2}$ chromosomes (selected based on fitness) and form a new population pool. The new population is submitted for fitness evaluation and the process gets repeated till a maximum number of iterations I_{max} get reached.

We obtain a best set of A3D-TC parameters X_{best}, at the end of the iterations which are used for knowledge feeding for the corresponding number of chromosomes

5.Simulated Annealing (SA) algorithm based Knowledge Source

Simulated Annealing is developed to optimize the design of IC chips by simulating the actual process of annealing. It is an iterative procedure that continuously updates one candidate solution until a termination condition is reached. This algorithm is used for combinatorial optimization problems, where functions are minimized of very many variables.

The training of the special intelligence is done using simulated annealing algorithm. This is done by generating a precise training dataset, as was done for Genetic Algorithm.

Simulated Annealing (SA) is a probabilistic method for finding the global optima of a cost function, proposed in it[30]. It is basically an imitation of the annealing process in which a liquid freezes so that when the structure settles down, it has a minimum energy configuration. We give a short introduction to the basics of SA in this section.

The main advantage of SA is that it avoids local minima (or optima) by "jumping" from the current solution to a point in the neighbourhood. The probability of this jump depends on the value of the cost function at the current solution and the neighbour and also on the temperature value. The temperature function is to be selected such that at the initial stages, these jumps are to be relatively frequent compared to the later stages, when the structure cools down.

Let f be the real-valued cost function to be minimized, defined on a set S. Let T(t) be the temperature of the structure at time t. We start with an initial feasible solution, $s(0)$ and an initial temperature T_0. We proceed towards the optimum as follows:

1. From the current solution, s, select a random point s^* in S, in the neighbourhood of the solution
2. Calculate the value of $f(s^*)$
3. If $f(s^*) \leq f(s), s = s^*$
4. Else, select s^* with probability $\exp\left(-\frac{f(s^*)-f(s)}{T(t)}\right)$
5. If $T(t) \geq T_{limit}$, make $t = t + 1$ and go to step 1
6. Otherwise stop annealing

6. Implementation Results

The proposed A3D-TC is implemented and validated in the working platform of MATLAB (version 7.12).The comparison is done over A3D-TC using both Genetic Algorithm and Simulated Annealing Algorithm for various noise variances. A3D-TC is evaluated for different ANN structures by varying N_H as 20, 30 and 40 to analyze the influence of network structure in TC performance. Ten experiments are carried out for every structure and the results are presented in the Table 1.

From figure (5) and Table 1, it can be seen that A3D-TC implemented using Genetic Algorithm exhibits minimum BER in all the experiments.

For 20 neurons the noise variances such as 0.15, 0.25, 0.35 and 0.45, the performance deviation is 0.00312, 0.01761, 0.0133 and 0.04108 respectively. Overall success deviation for genetic algorithm is 0.0187775.

Moreover, figure 5(iii) illustrates that increasing network complexity i.e., increasing number of hidden neurons in the selected network will minimize the BER undoubtedly.

Table 1: BER performance of A3D-TC implemented using Genetic Algorithm(GA) and Simulated Annealing Algorithm(SA) with network structure having (i) 20 hidden neurons, (ii) 30 hidden neurons and (iii) 40 hidden neurons for different noise variances from different rounds of experiments

(i)GA and SA(20)

Experiment No	Noise Variance							
	0.15		0.25		0.35		0.45	
	GA	SA	GA	SA	GA	SA	GA	SA
1	0.158	0.134	0.104	0.121	0.074	0.121	0.027	0.103
2	0.075	0.135	0.141	0.113	0.137	0.103	0.059	0.082
3	0.128	0.145	0.101	0.121	0.074	0.115	0.018	0.086
4	0.116	0.110	0.128	0.124	0.121	0.102	0.134	0.103
5	0.121	0.117	0.114	0.136	0.119	0.111	0.107	0.120
6	0.141	0.148	0.163	0.133	0.064	0.117	0.026	0.109
7	0.110	0.135	0.058	0.126	0.057	0.115	0.050	0.110
8	0.118	0.115	0.077	0.126	0.088	0.115	0.042	0.110
9	0.143	0.128	0.087	0.115	0.060	0.104	0.085	0.103
10	0.149	0.123	0.085	0.116	0.180	0.102	0.036	0.065

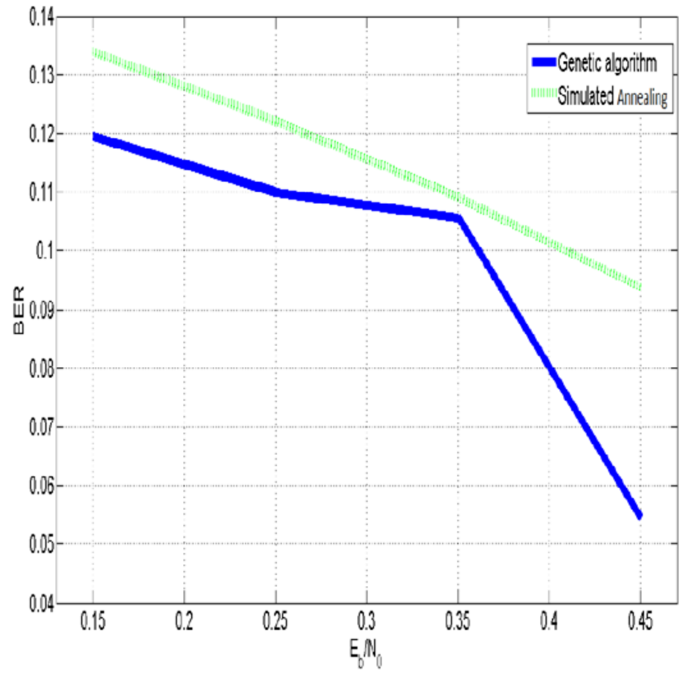
(ii)GA and SA(30)

Experiment No	Noise Variance							
	0.15		0.25		0.35		0.45	
	GA	SA	GA	SA	GA	SA	GA	SA
1	0.109	0.113	0.127	0.108	0.111	0.109	0.024	0.080
2	0.132	0.130	0.114	0.117	0.086	0.085	0.040	0.101
3	0.142	0.140	0.054	0.116	0.091	0.080	0.023	0.064
4	0.173	0.141	0.118	0.119	0.140	0.119	0.042	0.107
5	0.131	0.125	0.061	0.122	0.108	0.130	0.057	0.099
6	0.064	0.136	0.129	0.137	0.085	0.113	0.078	0.106

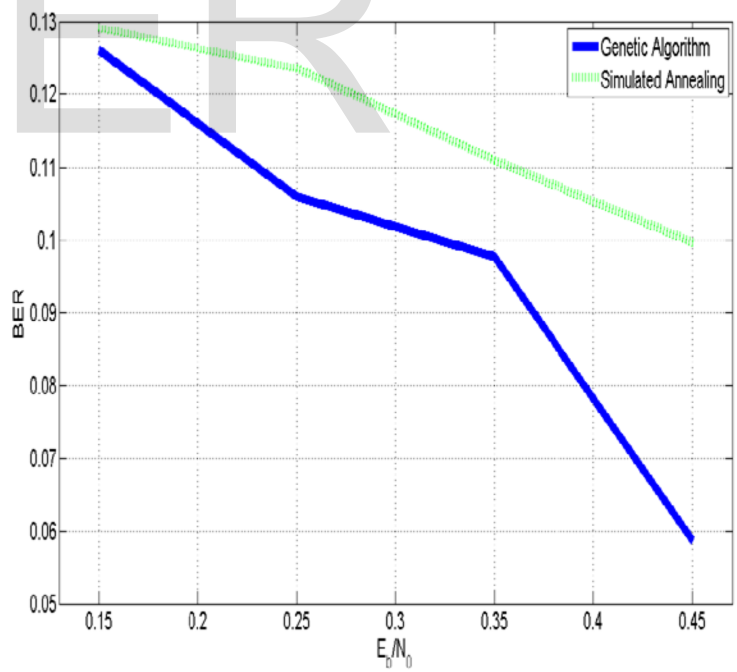
7	0.097	0.133	0.121	0.125	0.151	0.118	0.060	0.103
8	0.118	0.148	0.121	0.134	0.102	0.089	0.018	0.101
9	0.155	0.127	0.102	0.120	0.112	0.109	0.146	0.109
10	0.071	0.141	0.061	0.120	0.067	0.134	0.054	0.064

(iii)GA and SA(40)

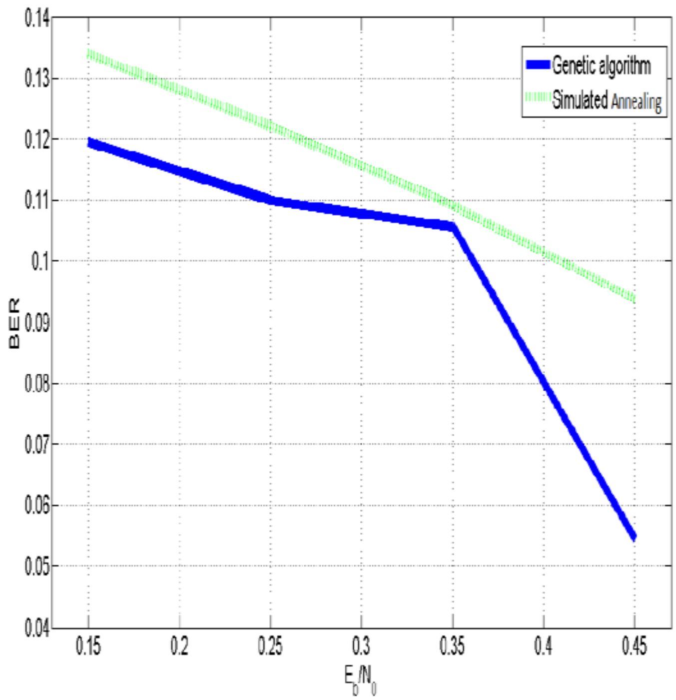
Experi-ment No	Noise Variance							
	0.15		0.25		0.35		0.45	
	GA	SA	GA	SA	GA	SA	GA	SA
1	0.123	0.133	0.158	0.131	0.111	0.101	0.027	0.092
2	0.150	0.151	0.075	0.124	0.086	0.108	0.014	0.109
3	0.111	0.131	0.128	0.138	0.091	0.106	0.154	0.117
4	0.132	0.142	0.116	0.134	0.040	0.103	0.018	0.093
5	0.101	0.121	0.125	0.125	0.108	0.109	0.161	0.101
6	0.126	0.135	0.144	0.137	0.185	0.119	0.029	0.089
7	0.151	0.119	0.010	0.121	0.151	0.107	0.121	0.104
8	0.144	0.135	0.018	0.142	0.102	0.102	0.012	0.086
9	0.115	0.128	0.147	0.130	0.021	0.115	0.002	0.096
10	0.102	0.125	0.106	0.128	0.033	0.107	0.067	0.109



(i)



(ii)



(iii)

Figure 5: Comparative Chart for BER vs Eb/No performance between Genetic Algorithm and simulated Annealing Algorithm to implement A3D-TC for network structure with (i) 20, (ii) 30 and (iii) 40 hidden neurons.

7. Conclusion

In this paper, the proposed A3D-TC is implemented using both Genetic Algorithm and Simulated Annealing Algorithm. A comparison has been developed.10 experiments are carried out using both the algorithms by subjecting them into various noisy environments. The influence of Neural Network structure over the performance of A3D-TC was also analyzed by varying the size of hidden layer. The experimental results explained that Genetic Algorithm achieves minimum BER than Simulated Annealing Algorithm in most of the situations. Further, it is also obtained from the results that increasing the network complexity increases A3D-TC performance using Genetic Algorithm. It can be concluded that A3D-TC using Genetic Algorithm is performing better based on the experimental results such as (i) achieving minimal BER when increasing network complexity and (ii) The success deviation of A3D-TC using Genetic Algorithm is substantially much better than Simulated Annealing Algorithm.

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