Adaptive code book with neural network for CELP speech signal coding

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Abstract - **The adaptive code book in CELP speech signal coding method is one of the most intensive calculation parts of the coding algorithm. It is very important to prove the possibility to represent this code book with a suitable neural network and make an analysis of the performance and time of calculations comparison with ordinary adaptive code book. This is the goal of this article. There are present the results of a Matlab simulation with the proposed neural network embedded in a CELP coding algorithm.**

Keywords - **CELP speech coding, adaptive code book, neural networks.**

I. INTRODUCTION

The adaptive code book in CELP coder represent the long term prediction filter (LTP) [1], which is described as:

$$d(n) = x(n) - b.d(n-T), \qquad (1)$$

where

$d(n)$ is the difference or error signal;

$x(n)$ - the input signal;

$d(n-T)$ - the signal of time delay T equal of pitch period;

b – coefficient of long term prediction filter (LTP).

In the Federal Standard FS1016 [2] it is proposed to change the open loop long term prediction filter with a closed loop method – adaptive code book. The principle of adaptive code book is shown in Fig. 1.

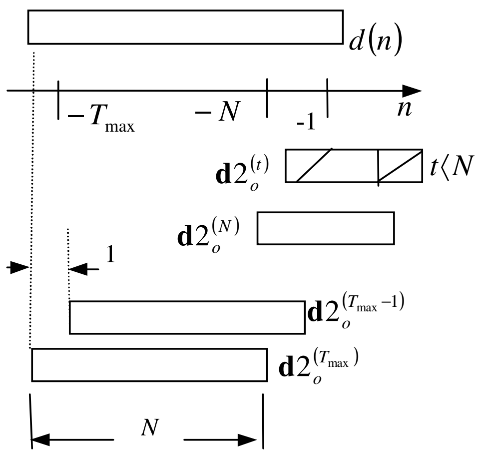

Fig. 1. Principle of adaptive code book

The content of the book is shown as a one dimensional vector $d(n)$ and parts of this vector are the current vectors for the range of pitch period $T = 20 \div 140$.

In the present article it is proposed to represent the adaptive code book with a neural network.

II. THE STRUCTURE OF THE NEURAL NETWORK AS AN ADAPTIVE CODE BOOK

It can be investigated, that the most useful type of a neural network as an adaptive code book is the adaptive linear neural network is shown in Fig. 2.

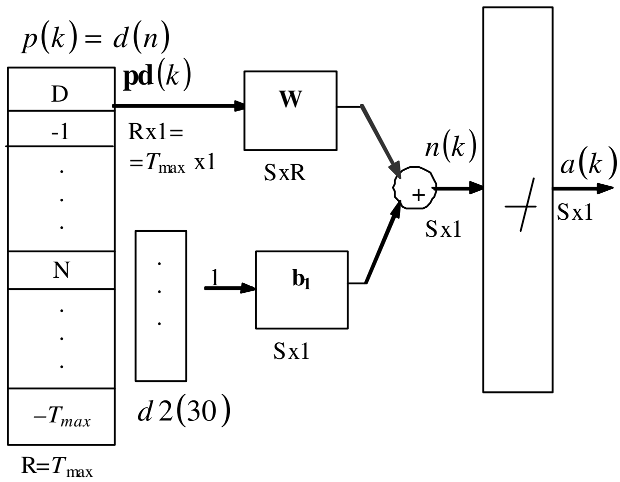

Fig. 2. The adaptive linear neural network as an adaptive code book

The equations, which describe this structure are given here:

$$p(k) = s(n), \qquad (2)$$

$$\mathrm{pd}(k) = p(k), p(k-1), \ldots, p(k-R) = s(n), s(n-1), \ldots, s(n=N). \qquad (3)$$

$$p(k) = d(n); \qquad (4)$$

$$pd(k) = d(n), d(n-1), \ldots, d(n-N), \ldots, d(n-T_{\max}). \qquad (5)$$

They gives also the relationships between the symbols used in CELP adaptive code book and the symbols related with neural network terminology.

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III. SIMULATION PROGRAM OF NEURAL NETWORK ADAPTIVE CODE BOOK REPRESENTATION

The simulation program made for examination of the proposed neural network as an adaptive code book in a CELP coder is shown in Fig. 3.

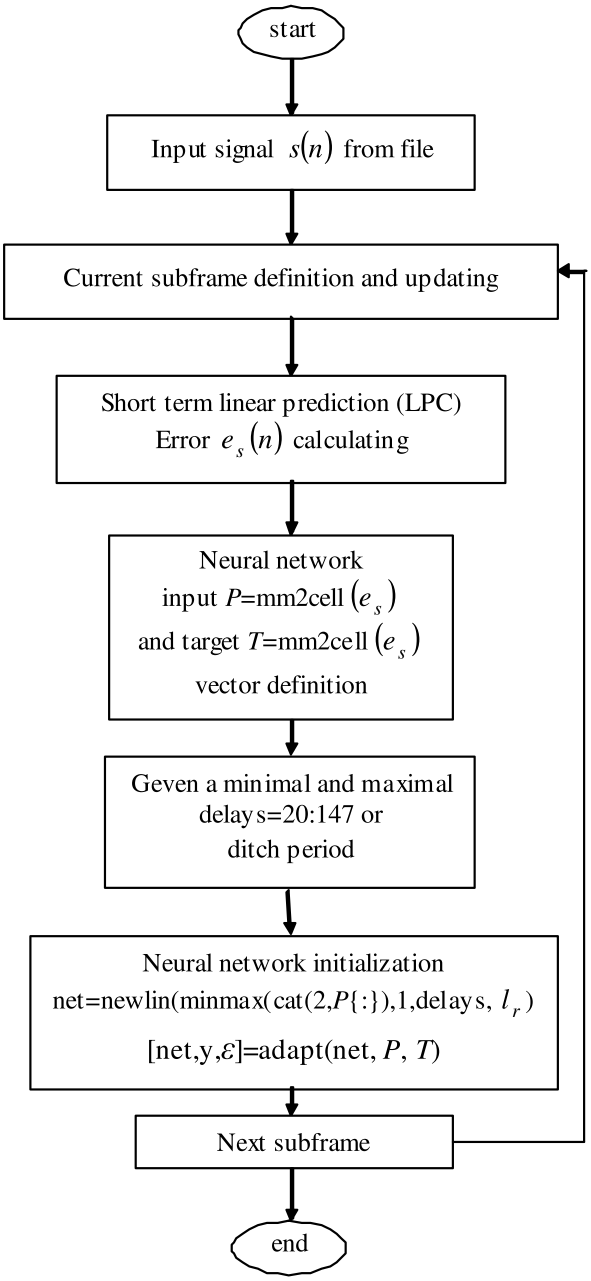


Fig. 3. Simulation program of adaptive neural network

There are involved in this Matlab simulation program all necessary actions for speech signal $s(n)$ input from file, current subframe defining and updating, short term linear predicttion for error e_s calculating etc.

Neural network is initialized with input and target vectors:

$$P = \text{num2cell}(e_s); \quad T = \text{num2cell}(e_s). \tag{6}$$

$$\text{net} = \text{newlin}(\text{minmax}(\text{cat}(2,P\{:\})),1,\text{delays},\ l_r) \tag{7}$$

The minimal and maximal pitch period or delays are setting 20 and 147, respectively to give the neural network taped delay line initialization.

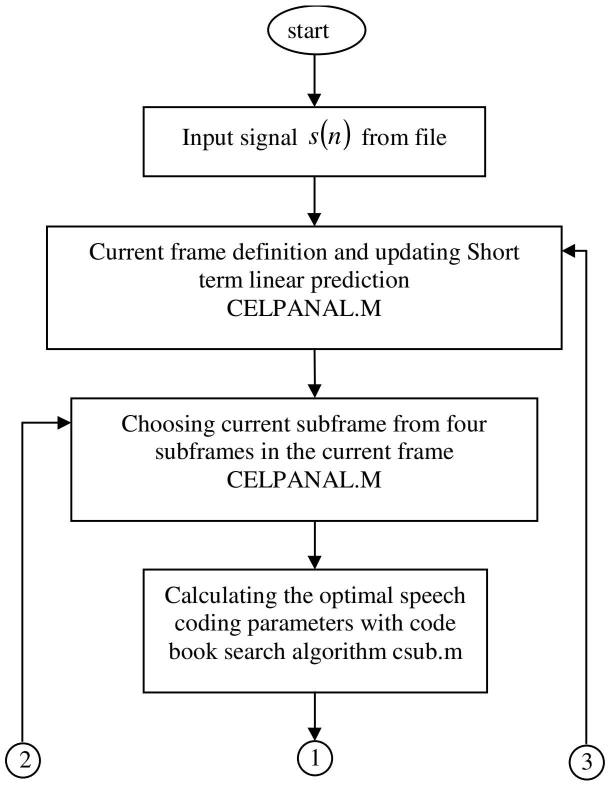
Finally it is made a neural network training:

$$[\text{net},\text{y},\varepsilon]=\text{adapt}(\text{net},\ P,\ T) \tag{8}$$

IV. NEURAL NETWORK EMBEDDED AS AN ADAPTIVE CODE BOOK IN STANDARD FS1016 CELP CODER

The described Matlab program is made as an independent program. It gives the results, that it is possible to represent the adaptive code book with a neural network. But it is more realistic, to embedded this neural network in the Federal Standard CELP algorithm FS1016, and to make the comparison of speech signal CELP coding using both standard adaptive code book and embedded neural network.

The possibility to make the replacement of standard adaptive code book with neural network is shown in Fig. 4.



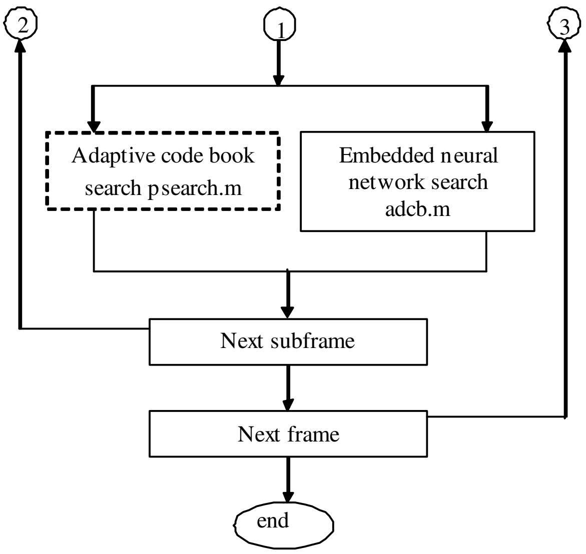


Fig. 4. The replacement of standard adaptive code book with neural network

V. RESULTS FROM THE NEURAL NETWORK SIMULATION

The results, which gives the simulation of neural network as an adaptive code book in an independent Matlab program and as an embedded function in the Federal Standard FS1016 CELP coding algorithm are shown in the next ten figures. The time diagram of input speech signal $s(n)$ is shown in Fig. 5.

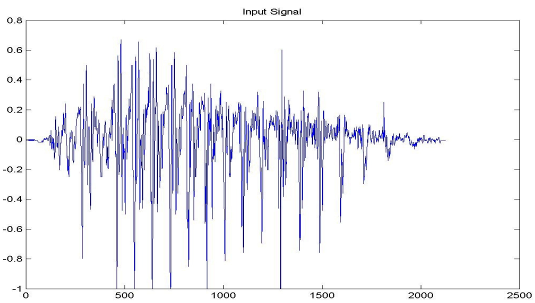


Fig. 5. Time diagram of input speech signal.

The result of short term linear prediction (LPC) error (e_s) estimation in the current frame in given in Fig. 6.

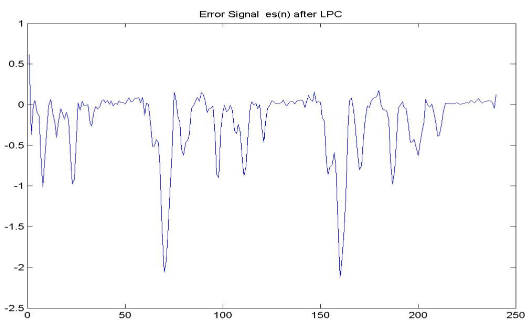


Fig. 6. The error signal of LPC.

The presences of the residual pitch period correlation in the error e_s is shown in Fig. 7.

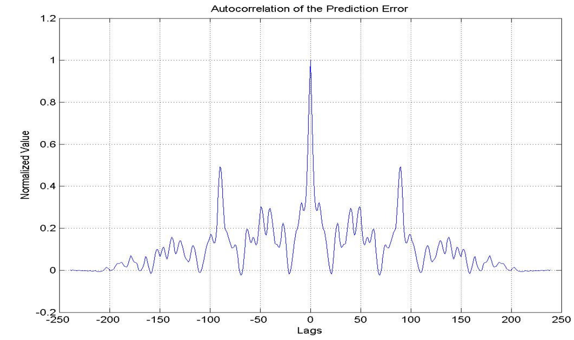


Fig. 7. The residual pitch period correlation in the error signal.

The amplitude and phase spectrum of current frame is given in Fig. 8.

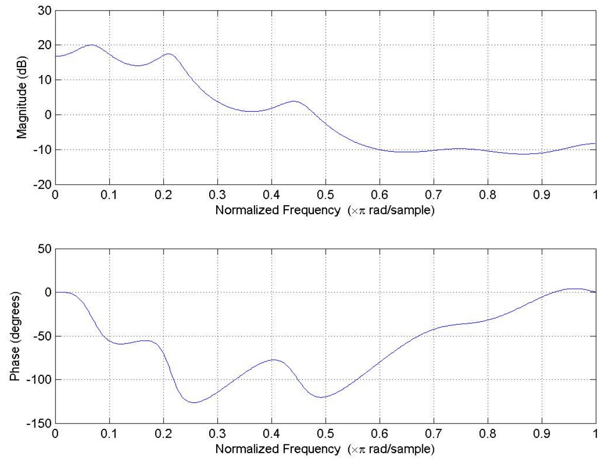


Fig. 8. The amplitude and phase spectrum of current frame

The guarantee of presences of pitch period in the error signal e_s is the autocorrelation function of this signal – Fig. 9.

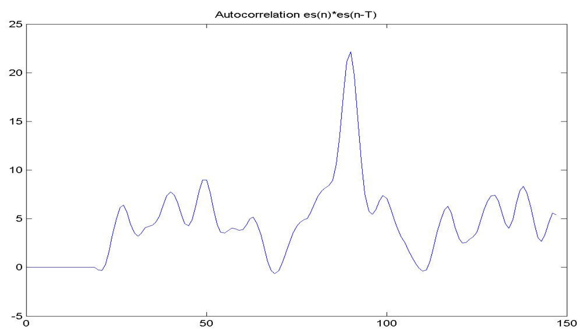


Fig. 9. The pitch period in the error signal.

The error signal after neural network simulation and training show the place of a strong minimum, which can be used to calculate pitch period T with an appropriate precision – Fig. 10.

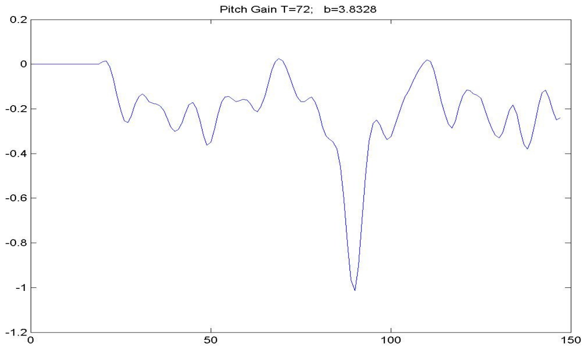


Fig. 10. The error signal after neural network simulation for long term filter pitch period *T* calculation.

The same is shown in Fig. 11 for long term filter coefficient *b* calculation.

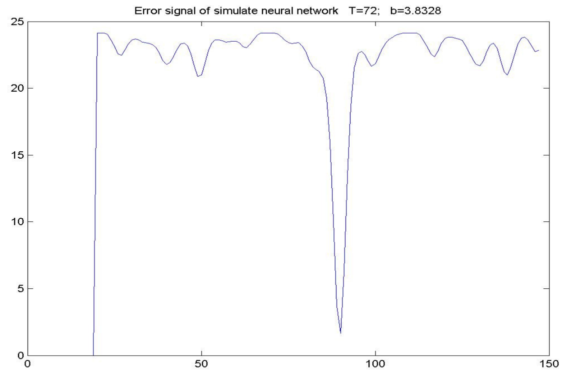


Fig. 11. The error signal after neural network simulation for long term filter coefficient *b* calculation.

An overall picture of the total algorithm of CELP coding and decoding of a speech signal using an embedded neural network an adaptive code cook in the Federal Standard FS1016 is shown in the Fig. 12 and Fig. 13. The fig. 12 represent a comparison in time domain of input and decoded speech signal. The same comparison in spectral domain is given in the Fig. 13.

VI. Conclusion

The theoretical analysis and the presented practical Matlab simulations of proposed neural network shows, that in is really possible to represent the adaptive code book in CELP coding method as an adaptive linear neural network. The time and spectral comparisons gives the assurance to embedding of the proposed neural network as a part of Federal Standard FS1016 CELP algorithm.

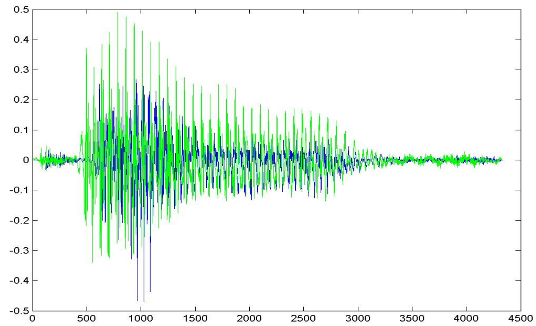


Fig. 12. Comparison in time domain of input and decoded speech signal.

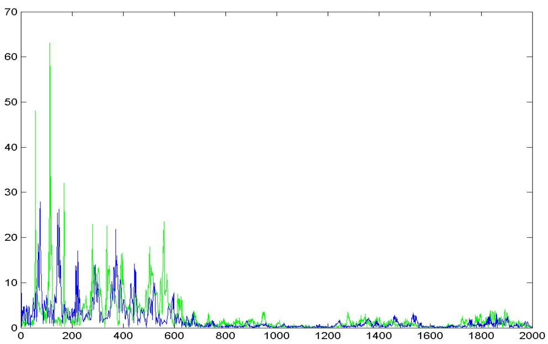


Fig. 13. Comparison in time domain of input and decoded speech signal.

Reference

[1]. Atal B.S., Schroeder M.R. “Stochastic coding of Speech at Very Low Bit Rates”, Proceedings of ICC, pp. 1610-1630,1984.

[2]. Federal Standard 1016, “Telecommunications: Analog to digital conversion of radio voice by 4800 bit/second code excited linear prediction (CELP)“, National Communication System-Office of Technology and Standards, Feb. 1991.