Investigation of analog neural network used for numbers recognition in images

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Abstract – Because of the similarity of analog VLSI Neural Networks signalling to the brain signalling, ones are a preferable implementation for analog signal processing. With the help of the analog neural networks certain computations that are difficult or time-consuming for digital neural network can be done. Nevertheless analog design can be very difficult because of need to compensate the variations in manufacturing, in temperature, etc. In this article has been investigated the parameter variation influence over the behaviour of analogue neural network used for numbers recognition in images.

Keywords – **Analog neural network, VLSI implementation, Image processing.**

I. INTRODUCTION

Analog neural networks have advantages as high speed, low power consumption and compact implementation in comparison with competing digital signal processing approaches. Disadvantages of analog neural networks are their limited accuracy and nonlinear behavior. Variation in the size of discrete transistors and the local mobility will cause random parameter variation [4], [5]. Moreover increase in the precision of any component has as a consequence an increase of its area. Some of these problems: learning algorithm and weight initialization effects on the analog neural networks are investigated and solved [1]. In this paper analog neural network with Backpropagation algorithm used for numbers recognition in images has examined. The aim of this paper is to investigate influence of some analog neural network parameters onto its recognition ability.

II. AN ANALOG NEURAL NETWORK MATHEMATICAL MODEL

The mathematical model of an analog neural network and it VLSI implementation is depicted in [3]. On the base of the neuron and synapse equations described in this implementation are proposed the equations about analog parameter variation over analog neural network behavior and they have been worked out [1]. On this way now in this article is proposed to investigate parameters variation influence over analog neural network behavior.

Equation 1 is the neuron equation including parameter variation.

$$u_{yk}^{l} = \frac{(\alpha_{FC}+\Delta\alpha_{FC})(I_B+\Delta I_B)}{(\beta_{OR}+\Delta\beta_{OR})U_{OR}} \tanh\left(\frac{\frac{g_{mk}+\Delta g_{mk}}{W_0/L_0 U_c} \sum_j W_j/L_j U_{W_{kj}} u_{zj}}{2(\beta_{is}+\Delta\beta_{is})U_{is}U_t} \right), \quad (1)$$

where

u_{yk}^{l} is the neuron output voltage;

k – number of neuron,

l - neural network layer number,

W/L - the MOS resistive circuit multiplier width/length ratios;

α_{FC} - the emitter-collector current gain;

I_B - the bias current;

β - the MOSFET tranconductance parameter;

U_t - the thermal voltage

Δ -a symbol of variable variation [1,2,3].

The following substitution has been done (equations 2 and 3) with the purpose to achieve simplicity of equation:

$$\chi_k^l + \Delta\chi_k^l = \frac{(\alpha_{FC}+\Delta\alpha_{FC})(I_B+\Delta I_B)}{(\beta_{OR}+\Delta\beta_{OR})U_{OR}} \quad (2)$$

$$\xi_k^l + \Delta\xi_k^l = \frac{(g_{mk}+\Delta g_{mk}).W_j/L_j}{2(\beta_{is}+\Delta\beta_{is})U_{is}U_t U_c.W_0/L_0} \quad (3)$$

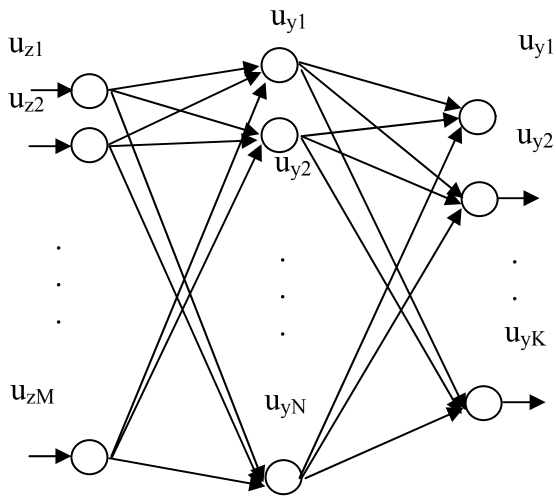

Fig. 1. The structure of neural network that is for numbers recognition in images.

In order to examine the parameter variation influence over the behavior of analog neural network used for numbers recognition in images it is chosen Multi-Layer perceptron (M:N:K) (figure 1), as a well-known feedforward layered

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neural network, on which the Backpropagation learning algorithm is implemented. For this neural network architecture equation (1) can be written as:

$$u^2_{yk}(t) = \left(\chi^2_k + \Delta\chi^2_k\right)\tanh\left(\left(\xi^2_k + \Delta\xi^2_k\right)\sum_{j=1}^{N} U_{W_{kj}} u^1_{yj}(t)\right) \qquad (4)$$

The equivalent error of the k[th] neuron of the 2[th] layer δ^2_k is calculated as:

$$\delta^2_k(t) = \left[d_k - \left(\chi^2_k + \Delta\chi^2_k\right)\tanh\left(\left(\xi^2_k + \Delta\xi^2_k\right)\sum_{j=1}^{N} U_{W_{kj}} u^1_{yj}(t)\right)\right]. \qquad (5)$$

$$.\left(\chi^2_k + \Delta\chi^2_k\right)\left(\xi^2_k + \Delta\xi^2_k\right)\left(1 - \tanh^2\left(\left(\xi^2_k + \Delta\xi^2_k\right)\sum_{j=1}^{N} U_{W_{kj}} u^1_{yj}(t)\right)\right).$$

It can be noted that the terms ($\chi+\Delta\chi$) and ($\xi+\Delta\xi$) directly takes part in equation 5. The weight update for the 2[th] layer is given by:

$$U^2_{wyk}(t+1) = U^2_{wyk}(t) + (\eta.\delta^2_k(t).u^1_{yj}(t)) \qquad (6)$$

The neuron output voltage for the 1[th] layer u^1_{yj} is calculated as:

$$u^1_{yj}(t) = \left(\chi^1_j + \Delta\chi^1_j\right)\tanh\left(\left(\xi^1_j + \Delta\xi^1_j\right)\sum_{j=1}^{M} U_{W_{ji}}(t) u^1_{yz}(t)\right) \qquad (7)$$

The equivalent error of the j[th] neuron for the 1[th] layer δ^1_j is calculated as:

$$\delta^1_j(t) = \left(\chi^1_j + \Delta\chi^1_j\right)\left(\xi^1_j + \Delta\xi^1_j\right)\left(1 - \tanh^2\left(\left(\xi^1_j + \Delta\xi^1_j\right)\sum_{j=1}^{M} U_{W_{ij}}(t) u_{yz}(t)\right)\right)\sum_{j=1}^{K} U_{W_{kj}}(t)\delta^2_k(t), \qquad (8)$$

u_{yz} is the input voltage for the neural network.
The weight update for the 1[th] layer is given by:

$$U^1_{wyk}(t+1) = U^1_{wyk}(t) + (\eta.\delta^1_k(t).u_{yz}(t)) \qquad (9)$$

From equation 4÷9 can be seen that the terms ($\chi+\Delta\chi$) and ($\xi+\Delta\xi$) directly influence over whole (entire) learning phase. This is the reason for the partial neutralization of the parameter variation influence over neural network behavior.

The aim of this paper is to define the boundaries of parameter variation in which numbers recognition in images can be accomplish.

III. Investigation of Analog Neural Network Used for Numbers Recognition in Images

In order to investigate the influence of some analog neural network parameters onto its recognition ability a multilayer perceptron with (M:N:K) structure is used (figure 1), where M=20,N=22 and K=10. The neural network is trained to recognize the numbers shown in figure 2. The numbers are applied to the neural network as a vector with dimension of 20.

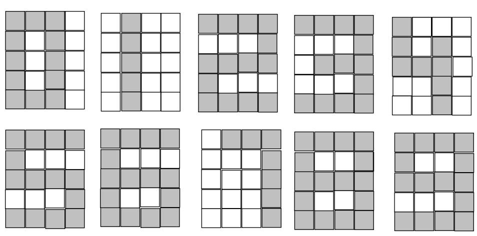

Fig. 2. The patterns.

The desired values are shown in Table I. For the desired values corresponding to the numbers $d_{k,p}$=1, and for desired values at other position are $d_{k,p}$= -1 (equation 10).

Table I
The desired values for the patterns

k \ p	0	1	2	3	4	5	6	7	8	9
0	1	-1	-1	-1	-1	-1	-1	-1	-1	-1
1	-1	1	-1	-1	-1	-1	-1	-1	-1	-1
2	-1	-1	1	-1	-1	-1	-1	-1	-1	-1
3	-1	-1	-1	1	-1	-1	-1	-1	-1	-1
4	-1	-1	-1	-1	1	-1	-1	-1	-1	-1
5	-1	-1	-1	-1	-1	1	-1	-1	-1	-1
6	-1	-1	-1	-1	-1	-1	1	-1	-1	-1
7	-1	-1	-1	-1	-1	-1	-1	1	-1	-1
8	-1	-1	-1	-1	-1	-1	-1	-1	1	-1
9	-1	-1	-1	-1	-1	-1	-1	-1	-1	1

$$d_{k,p} = \begin{cases} 1, \ for & k = p \\ -1, \ for & k \neq p \end{cases} , \qquad (10)$$

where
k=1,2…K is the number of the output neuron,
p=1,2…P is the number of the pattern that is recognizing.

Table II
The influences of the parameter χ over weight and error values of the neural network

χ	w^1	w^2	E
0.7	[-38;38]	[-7;0]	0.174
0.8	[-10;8]	[-5;5]	0.054
0.9	[-1;1]	[-2;2]	0.013
1	[-1;1]	[-1;1]	$9.7.10^{-4}$
1.1	[-8;8]	[-27;22]	1.4

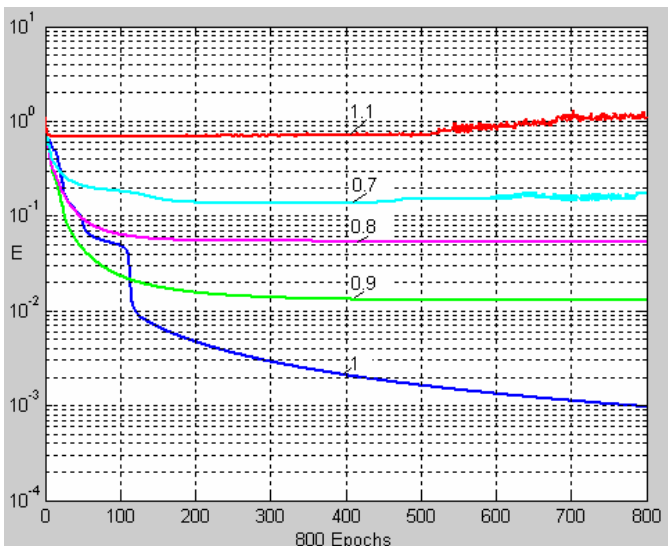

Fig. 3. The influences of the parameter χ variation over output neural network error.

The neural network is trained with backpropagation algorithm, but in the equations the parameters of the real neural networks components take part. The neural network is simulated with Matlab.

Table II shows the influences of the parameter χ over weight and error values of the neural network. It is observed that the parameter χ variation strongly affect to the weight values range.

Figure 3 shows the influences of the parameter χ variation over output error values of the neural network. It san be seen that neural network recognizes correct input patterns in narrow range of parameter χ variation.

Table III shows the influences of the parameter ξ over weight and error values of the neural network.

TABLE III

THE INFLUENCES OF THE PARAMETER ξ OVER WEIGHT AND ERROR VALUES OF THE NEURAL NETWORK

ξ	w^1	w^2	E
0.1	[-1.8;1.8]	[-1.7;1.7]	0.283
0.2	[-1.8;1.8]	[-1.6;1.6]	0.066
0.3	[-1.7;1.3]	[-1.7;1.3]	0.017
0.4	[-1;1]	[-1.4;1.4]	$7.8.10^{-3}$
0.5	[-1.3;1.3]	[-1.2;1.2]	$4.5.10^{-3}$
0.6	[-1;1]	[-1;1]	$2.9.10^{-3}$
0.7	[-1;1]	[-1.3;1.4]	$2.1.10^{-3}$
0.8	[-1;0.8]	[-1.1;1.2]	$1.6.10^{-3}$
0.9	[-0.8;0.8]	[-1;1.1]	$1.2.10^{-3}$
1	[-1;1]	[-1;1]	$9.7.10^{-4}$
1.1	[-0.8;0.8]	[-1.8;1.5]	$7.9.10^{-4}$
1.2	[-0.8;0.8]	[-1;1]	$6.5.10^{-4}$
1.3	[-0.8;0.8]	[-1;1]	$5.6.10^{-4}$
1.4	[-0.8;0.8]	[-0.7;1]	$5.5.10^{-4}$
1.5	[-0.5;0.5]	[-0.5;1]	0.04

Figures 4 and 5 show the influences of the parameter ξ over output error values of the neural network. The range of the ξ variation in which neural network recognizes correct applied input patterns is larger then parameter χ variation.

TABLE IV

THE INFLUENCES OF THE PARAMETER χ OVER WEIGHT AND ERROR VALUES OF THE NEURAL NETWORK FOR NOISY PATTERNS

χ	w^1	w^2	N_e
0.7	[-30;30]	[-7;0]	6
0.8	[-8;8]	[-4;4]	3
0.9	[-1;1]	[-1;1]	1
1	[-1;1]	[-1;1]	0
1.1	[-8;8]	[-22;22]	-

Some noise is added to the original pattern to create test patterns (figure 6). Tables IV and V show the influences of the parameters χ and ξ over weight and error values of the neural network. With N_e is denoted the number of patterns, that aren't recognized. Neural network recognizes correct the input patterns only for χ=1. The variation of the parameter χ

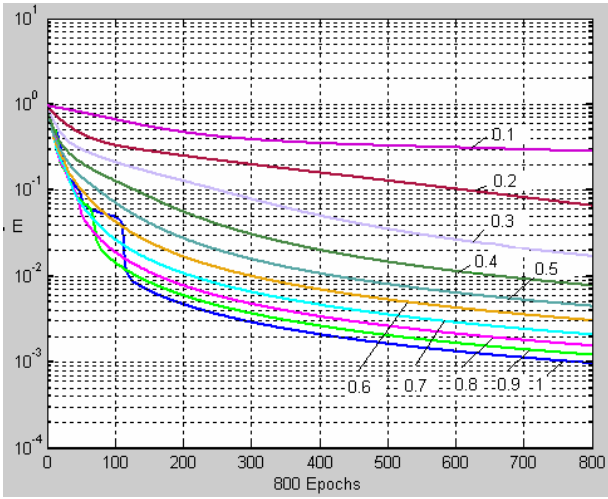

Fig. 4. The influences of the parameter ξ variation over output neural network error for $0.1<\xi<1$.

affect to increasing weight values range and decrease recognition ability of the neural network. For χ=0.9 eight of

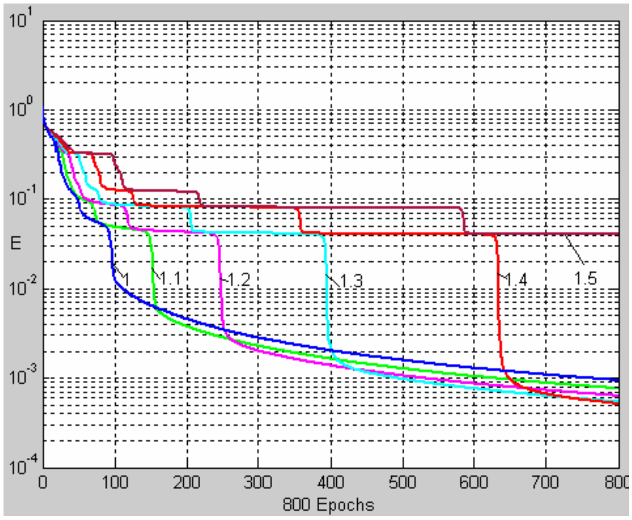

Fig. 5. The influences of the parameter ξ variation over output neural network error for $1<\xi<1.5$.

ten images

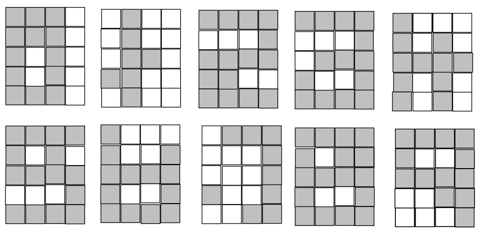

Fig. 6. The noisy patterns.

are recognized for the test patterns from figure 6. If χ=0.8 the recognized images become seven of ten.

The parameter ξ variation have a weak effect over neural network behavior. It can be seen from Table V that the neural network recognizes all patterns for the test sequence for range 0.1<ξ<1.5. Furthermore the variation of the parameter ξ don't increase weight values range.

TABLE V

THE INFLUENCES OF THE PARAMETER ξ OVER WEIGHT AND ERROR VALUES OF THE NEURAL NETWORK FOR NOISY PATTERNS

ξ	w^1	w^2	N_e
0.1	[-1.7;1.7]	[-1.7;1.7]	-
0.2	[-1.5;1.5]	[-1.5;1.5]	0
0.3	[-1.5;1.5]	[-1.5;1.5]	0
0.4	[-1.5;1.5]	[-1.5;1.5]	0
0.5	[-1.3;1.3]	[-1;1]	0
0.6	[-0.8;0.8]	[-1;1]	0
0.7	[-0.7;0.7]	[-1;1]	0
0.8	[-0.7;0.7]	[-1;1]	0
0.9	[-0.7;0.7]	[-1;1]	0
1	[-1;1]	[-1;1]	0
1.1	[-1;1]	[-1;1]	0
1.2	[-0.7;0.5]	[-0.7;0.6]	0
1.3	[-0.7;0.5]	[-0.7;0.6]	0
1.4	[-0.7;0.5]	[-0.7;0.6]	0
1.5	[-0.5;0.6]	[-0.5;0.5]	1

IV. CONCLUSION

In this paper analog neural network used for pattern recognition has examined. The neural network is trained with backpropagation algorithm, but in the equations the parameters of the real neural networks components take part. There is investigated influence of some analog neural network parameters onto its recognition ability. It is observed that the variation of the parameter χ affect to increasing weight values range and decreases recognition ability of the neural network. The neural network recognizes correct input patterns in narrow range of parameter χ variation. The parameter ξ variation have a weak effect over neural network behavior.

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