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Simulating social objects with an artificial neural network using a computer cluster

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Abstract

This paper describes results of the simulation of social objects, the dependence of schoolchildren's professional abilities on their personal characteristics. The simulation tool is the artificial neural network (ANN) technology. Results of a comparison of the time expense for training the ANN and for calculating the weight coefficients with serial and parallel algorithms, respectively, are presented.

Keywords: artificial neural networks, social simulation, computer clusters, parallel calculations, gradient method of training weight coefficients.

1 Introduction

Nowadays there are many technologies for simulating social objects. Among otherds, these are the multi-agent approach and artificial neural networks [1]. The artificial neural network (ANN) technology is used in different branches of science which need to develop a model of an object whose structure cannot be easily defined by simple rules of this branch of science [2].

We think that it is very interesting to use the ANN technology in the social sphere. Our analysis (which was done earlier) shows that the ANN is a very effective mathematical tool for simulation in the psychological and social spheres [3, 4, 5]. And we have developed special programs allowing to simulate objects which are social [6]. The main defect of this technology is the long time expense for building an ANN-model. The usage of computer clusters allows to abate time expenses [7] .

The aim of this paper is to build an ANN-model which can define the dependence of schoolbchildren's professional ability on their personal characteristics and to compare the time for building the model using parallel and serial algorithms, respectively

2 Preparing the pattern

For building the ANN-model we used data which were collected in 2004 and 2005 by employees of the Department of Computing and Mathematical Simulation of Tambov State University named after G.R. Dezhavin (Tambov, Russia) [8].

Data collection was done with the help of a questionnaire which included questions allowing to detect different personal and professional characteristic of schoolchildren.

Pupils of three standard state schools (these are school numbered 3, 26 and 36) and one lyceum (numbered 6) in Tambov were analysed. Most respondents (about 99.4%) lwere between 14 an 18 year of age. 20.8 % of the respondents were 14 years old, 34.4 % were 15 years old is 34.4%, 32.3 % were 16 years old, 11.6 % were 17 years old, and 0.3 % were 18 years old. 51.0% were girls [8].

The questionnaires were converted into a dataset with 57 input columns (for its 57 questions) and one “output column”. The output value codes for the professional sphere the pupils had selected for their future careers. All data were mapped to the interval [0; 1] [9, 10].

3 Building the ANN-model

For defining the dependence of the pupils professional ability on their personal characteristics it is necessary to minimize the inaccuracy value ε in formula (1). For this it is necessary to select the parameters $\vec{w}$ of function F from formula (2).

$$\varepsilon = \sum_{i=0}^{N-1} (y_i - d_i)^2 \tag{1}$$

$$\vec{y} = F(\vec{x}, \vec{w}) \tag{2}$$

where $\vec{x}_i$ contains the recoded answer to the i-th questionnaire, $\vec{w}$ is the vector of weight coefficients , d_i is the selected professional sphere index of the i-th questionnaire, N is the number of questionnaire.

A multilayer perceptron consisting of three layers (input, output and hidden) was selected as the ANN-model structure. The multilayer perceptron input layer has 57 neurons (because the input pattern consists of 57 columns), the output layer has one neuron and the number of the neurons in the hidden layers were selected automatically. Initially, the hidden layer had one neuron and then new neurons were added. After adding hidden neurons weight coefficients were searched, and the inaccuracy value ε was calculated by formula (1).

For checking the sufficiency of ANN-model it was calculated how many empirical object output values (y) were equal to ANN-model output values (d). The number of rows where these values are equal was called M. So the sufficiency coefficient value β can be calculated by formula (3) [9].

$$\beta = \frac{M}{N} \tag{3}$$

Figure 1 shows the dependence of inaccuracy value on the number of neurons in the hidden layer. One can see that the inaccuracy valuechanged from since 90 % to 10 %. The first value was calculated by an ANN with only one neuron in the hidden layer and the last value was calculated by the ANN with 99 hidden neurons. The ANN structure which was thus built is shown in Figure 2.

In this paper the gradient algorithm of steepest descent was used for the minimization of the function (1 . This algorithm calculates the gradient value $\nabla\varepsilon$ (calculated by

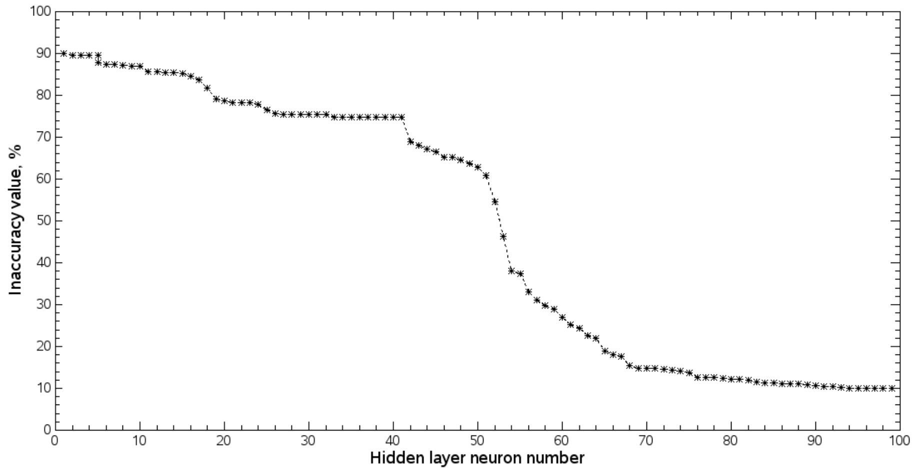

Figure 1: The dependence of the inaccuracy value on the number of neurons in the hidden layer.

formula (4)) and updates the weight coefficients in the opposite direction (as is shown in formula (5)).

$$\nabla\varepsilon = \frac{\partial\varepsilon(w)}{\partial w} = \left(\frac{\partial\varepsilon(w_0)}{\partial w_0}, \frac{\partial\varepsilon(w_1)}{\partial w_1}, \ldots, \frac{\partial\varepsilon(w_{l_w-1})}{\partial w_{l_w-1}}\right) \tag{4}$$

where l_w is the size of the weight coefficients vector.

$$\vec{w}^{(I)} = \vec{w}^{(I-1)} + \Delta\vec{w}^{(I)} = \vec{w}^{(I-1)} - \nabla\varepsilon^{(I)}\vec{s}^{(I)} \tag{5}$$

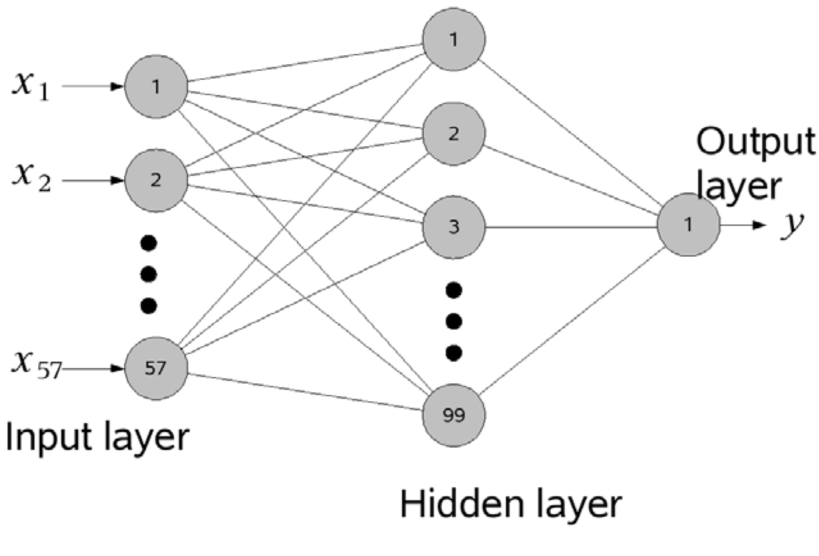

Figure 2: The multilayer perceptron structure which is used for the training ANN.

4 Using computer clusters

In this section we adapt the gradient algorithm of steepest descent for computer clusters as the algorithm for training the ANN.

Calculating the $w_i^{(I)}$ value needs vector $\vec{w}^{(I-1)}$ only, so if we know weight coefficients values in the $(I-1)$-th iteration ($\vec{w}^{(I-1)}$) then we can calculate the values of this vector in the I-th iteration absolutely from each other.

If there are n processors then it is possible to divide the weight coefficients vector into n parts (as shown in Figure 3). The part which is located in the lead processor consists of $\hat{N}_w$ weights coefficients and the other parts consist of $\hat{l}_w$ weights coefficients (as shown in formulas (6)-(7)) [11].

$$\hat{l}_w = \begin{cases} \frac{l_w}{n}, & l_w \ mod \ n = 0; \\ \frac{l_w}{n-1}, & l_w \ mod \ n \neq 0; \end{cases} \tag{6}$$

$$\hat{N}_w = \begin{cases} \hat{l}_w, & l_w \ mod \ n = 0; \\ l_w - \hat{l}_w(n-1), & l_w \ mod \ n \neq 0; \end{cases} \tag{7}$$

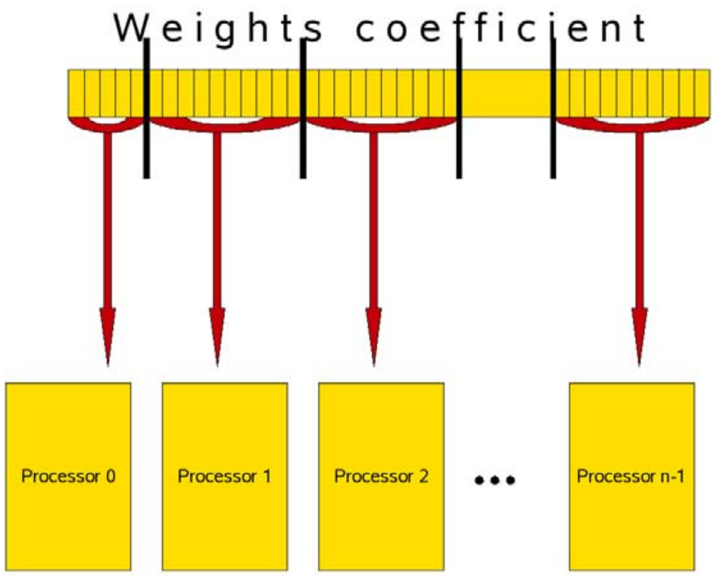

Figure 3: The scheme allocating the weights coefficient to processors.

Figures 4 and 5 show diagrams of searching weights coefficients by the parallel gradient algorithm. Figure 4 shows the diagram of searching weights coefficients in the lead processor. The numbered blocks have the following meaning:

1) The ANN structure is set, the neurons activation functions are formed and the weight coefficients are initialised.

2) The weight coefficients are sent to all non-zero processors.

3-4) The new weight coefficients located in the lead processor are calculated by formula (7).

5-6) The calculated weight coefficients are received from the other processors.

7-8) The weight coefficients are sent to all processors.

9) The criterion is checked to determine whether it is necessary to continue training the ANN. This criterion may be the number of iterations, the inaccuracy value achieved so far or something else.

Figure 5 shows the diagram of the algorithm for searching weight coefficients. The numbered blocks have the following meaning:

1) The lead processor sends the ANN structure, and the non-lead processors receive it.

2-3) The new weight coefficient values which are located in the current processor are calculated. The values of A and B are calculated by formulas (8) and (9).

4) The weight coefficients are sent to the lead processor.

5-6) The new weight coefficients values are received by the lead processor.

7) The message is received whether the serach for weight coefficients continues or stops.

$$A = \hat{l}_w(k-1) + \hat{N}_w \quad (8)$$

$$B = \hat{l}_w k + \hat{N}_w - 1 \quad (9)$$

Here k is the processor index.

The result of executing these operations (which are shown in figures 4-5) is the vector of weights coefficients which is the optimal for this ANN-model.

For training the ANN we have used the computer cluster of Tambov State University named after G.R. Derzhavin (Tambov, Russia) consisting of 8 calculating nodes. Each node has two processors so this computer cluster has 16 processors. The software used is the universal simulator based on the artificial neural network technology which can be executed on computer clusters as described in [12].

Figure 6 shows the dependence of time expenses on the number of processors used . One can see that building the ANN-model serially needs about 347 hours and building the ANN-model in parallel needs about 184 hours if it has 2 processors and 23 hours if it has 16 processors. It is necessary to count multiplicative and additive operations executed by the serial and parallel algorithms. The efficiency coefficient can be calculated by formula (10).

$$\alpha = \frac{z}{n \max\limits_{k=0..n-1} (\zeta_k + \sigma\zeta_k)} \quad (10)$$

where z is the number of multiplicative and reduced additive operations executed by the serial algorithm, ζ_k is the number of multiplicative operations executed by the serial algorithm in the k-th processor, $\hat{\zeta}_k$ is the number of additive operations executed by the serial algorithm in the k-th processor and σ is the coefficient which allows to reduce additive to multiplicative operations, its value is calculated by formula (11) and shows how many multiplicative operations are necessary for replacing one additive.

$$\sigma = \frac{t_a}{t_m} \quad (11)$$

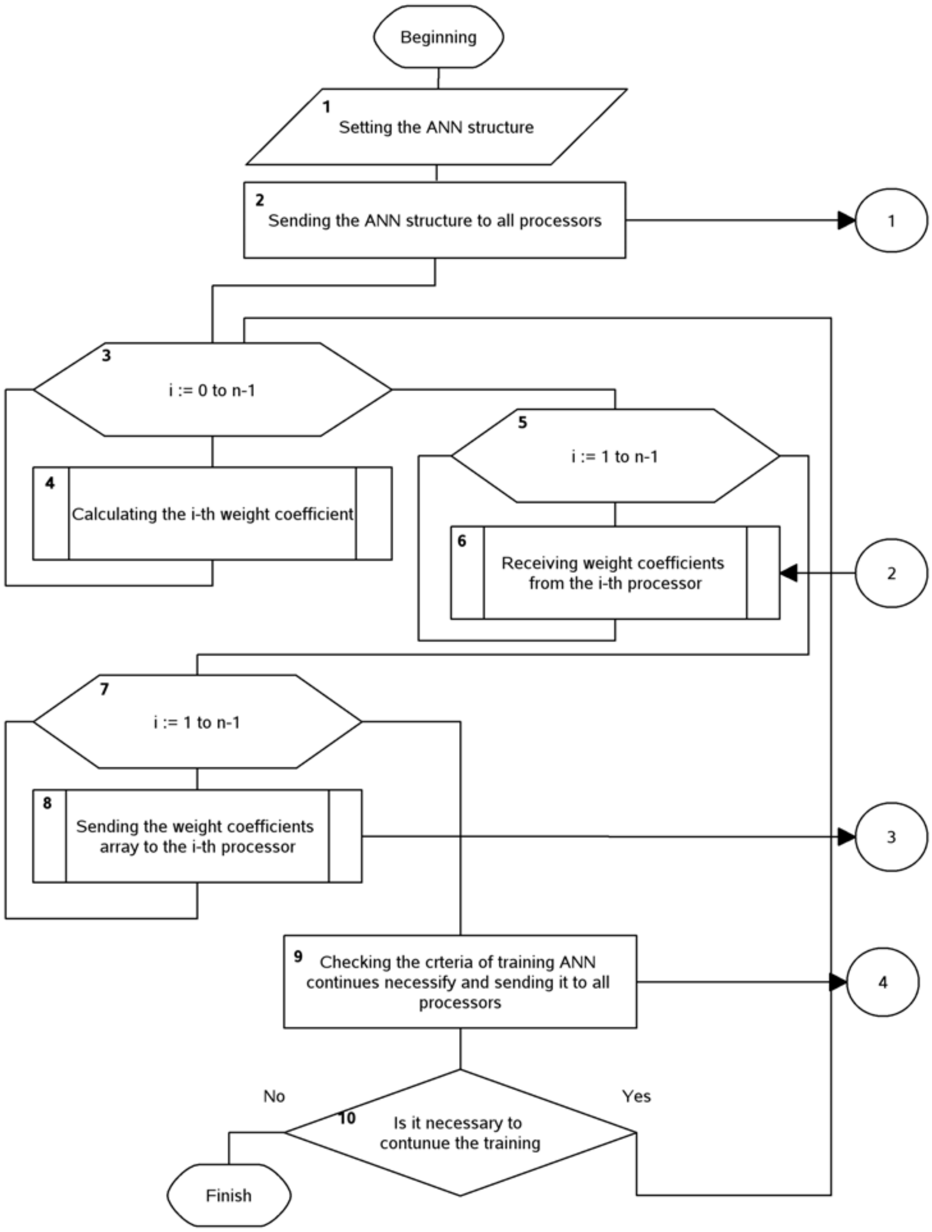

Figure 4: The diagram of the algorithm of the searching weight coefficients in the lead processor.

where t_a and t_m are time expense for one additive and multiplicative operation.

Using formula (10) is difficult, so the number of operations can be replaced with the time expense.This is possible because the time expenses are directly proportional to the number of operations. So formula (10) can be changed to (12).

$$\alpha = \frac{t}{n\tau(n)} \tag{12}$$

where t is the time expense of the serial algorithm, $\tau(n)$ is the time expense of the parallel algorithm with n processors.

Table 1 and Figure 6 show the efficiency coefficient values which are achieved by

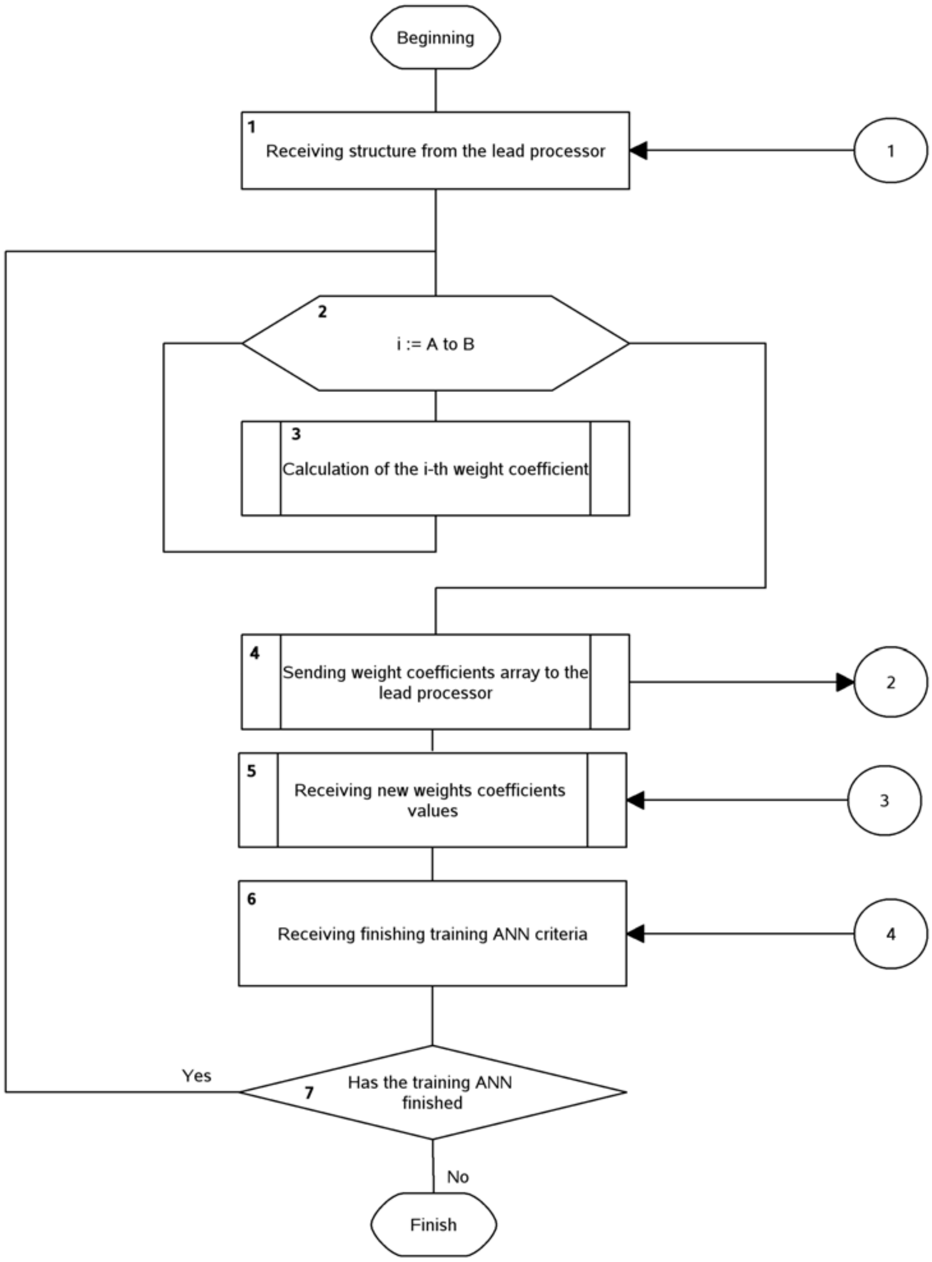

Figure 5: The diagram of the algorithm of the searching weight coefficients in non-lead processors.

the parallel algorithm. We can see that the efficiency coefficient value is about 92.1 % for the computer cluster of the Tambov State University named after G.R. Derzhavin. Such value shows that it is efficient to use computer clusters for calculating such tasks.

5 Conclusion

This paper has shown how an the ANN-model was built which can define the dependence of pupils' professional ability on their personal characteristics. Sserial and parallel algorithms of building the ANN-model were compared. This comparison shows the

Table 1: Efficiency coefficient value which is gotten by the parallel algorithm.

Processors number	**Efficiency coefficient value, %**
2	92.12 ± 0.01
4	92.12 ± 0.01
6	92.12 ± 0.01
8	92.11 ± 0.01
10	92.11 ± 0.01
12	92.11 ± 0.01
14	92.10 ± 0.01
16	92.10 ± 0.01

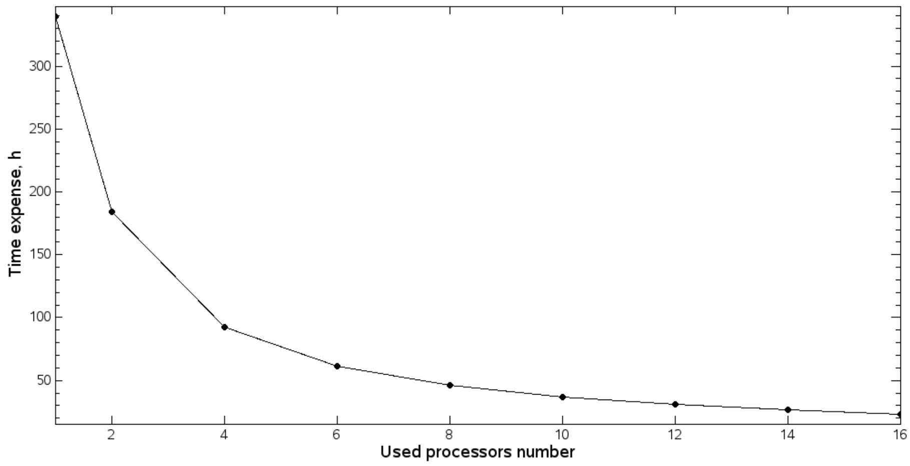

Figure 6: The dependence of the time spent for training the ANN on the number of processors used.

efficiency of using computer clusters for simulating social objects . So one can say that using computer clusters is efficient for simulating social objects using the ANN technology.

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Glossary

β	the sufficiency coefficient value, 3
$\nabla\varepsilon^{(I)}$	the gradient value in the I-th iteration, 3
σ	the coefficient of the reducing additive operations to multiplicative, 6
$\tau(n)$	the time expense of the parallel algorithm with n processors, 7
$\vec{s}^{(I)}$	the coefficient value of the training in the I-th iteration, 3
ζ_k	the number of additive operations executing by the parallel algorithm in the k processor, 6
ζ_k	the number of multiplicative operations executing by the parallel algorithm in the k processor, 6
l_w	the weight coefficients vector size, 3
n	the number of processors which are used for the training, 4
t	the time expense of the serial algorithm, 7
t_a	time expense for one additive operations, 6
t_m	time expense for one multiplicative operations, 6

z	the number of multiplicative and reduced additive operations executing by the serial algorithm, 6
N_w	the number of weights searching by the lead processor, 4
$\hat{l}_w$	the number of weights searching by nonzero processors, 4

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