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Simulating medical objects simulation using an artificial neural network whose structure is based on adaptive resonance theory

Oleg V. Kryuchin, Alexander A. Arzamastsev, Natalia Zenkova, Klaus G. Troitzsch, Denis V. Sletkov

Abstract

This paper describes artificial neural networks which are based on the adaptive resonance theory. The usage of these artificial neural networks for classification tasks is presented. The example uses is the classification of patient health from the results of general blood analysis.

Keywords: artificial neural networks, blood analysis, classification, adaptive resonance theory.

1 Introduction

The human brain executes difficult tasks of the analysis of the continuous thread of the sensorial information which it recieves from the environment. It distinguishes important data from the thread of trivial information and adapts to the former. Then usually it registers the important infomation in the long-term memory. Understanding the process of the human memory is very difficult because new patterns are memorized but old patterns are not forgotten or modified.

Many scientists have tried to analyze the working process of the human brain using artificial neural networks (ANNs), but traditional ANNs could not solve the problem of compatibility and plasticity. Very often after adding new patterns, results of previous training are destroyed or changed. Sometimes this is not important, for example if there is a constant group of training vectors, as in this case the results can be produced cyclically in the process of the training. In structures with back-propagation training vectors are given to the input layer serially until the network has been trained to all input of this group. But if a network which was trained absolutely has memorized a new training vector then it can change weights and the ANN will need new training [1, 2].

In the real situation the network is subject to different stimuli and maybe it never sees the same training vector twice. So the network often is not trained, it changes weights but it cannot get good results. And there are networks which cannot be trained if four training vectors are produced cyclically because these vectors force weights to change without interruption [1].

This actuality was one of reasons of the development of the adaptive resonance theory (ART) in 1969. The ART is a theory developed by Stephen Grossberg and Gail Carpenter on aspects of how the brain processes information. It describes a number of neural network models which use supervised and unsupervised learning methods and address problems such as pattern recognition and prediction [3]. One of the main problems which are solved by ART-structures is the classification.

The aim of this paper is to simulate a medical object which is the dependence of the medical treatment course on the condition of the patient's blood. Formerly such simulation was done by multilayer perceptron but the adequacy of the model which was developed was low [4].

2 Adaptive resonance theory network

2.1 Overview and learning models

"The primary intuition behind the ART model is that object identification and recognition generally occur as a result of the interaction of ['top-down']observer expectations with ['bottom-up']nsensory information. The model postulates that ['top-down']expectations take the form of a memory template or prototype that is then compared with the actual features of an object as detected by the senses. This comparison gives rise to a measure of category belongingness. As long as this difference between sensation and expectation does not exceed a set threshold called the 'vigilance parameter', the sensed object will be considered a member of the expected class within memory." [5].

"The basic ART system is an unsupervised learning model and typically consists of neuron layers for comparison recognition, a vigilance parameter, and a reset module. The vigilance parameter ... has considerable influence in the classification: the higher is the vigilance parameters, the more accurate is the classification." [9, p. 294] "... higher vigilance produces highly detailed memories (many, fine-grained categories), while lower vigilance results in more general memories (fewer, more-general categories). The comparison field takes an input vector (a one-dimensional array of values) and transfers it to its best match in the recognition field. Its best match is the single neuron whose set of weights (weight vector) most closely matches the input vector. Each recognition field neuron outputs a negative signal (proportional to that neuron quality of match to the input vector) to each of the other recognition field neurons and inhibits their output accordingly. In this way the recognition field exhibits lateral inhibition, allowing each neuron in it to represent a category to which input vectors are classified. After the input vector is classified, the reset module compares the strength of the recognition match to the vigilance parameter. If the vigilance threshold is met, training commences. Otherwise, if the match level does not meet the vigilance parameter, the firing recognition neuron is inhibited until a new input vector is applied; training commences only upon completion of a search procedure. In the search procedure, recognition neurons are disabled one by one by the reset function until the vigilance parameter is satisfied by a recognition match. If no committed neuron's recognition match meets the vigilance threshold, then an uncommitted neuron is committed and adjusted towards matching the input vector. [10, p. 252], see also [6, 7].

2.2 ART-2 structure

To date only few types of ART networks have been developed. In this paper the type called ART-2 will be used. These networks self-organize stable recognition categories in response to arbitrary sequences of analog input patterns, as well as binary input patterns. Computer simulations are used to illustrate the dynamics of the system [8].

ART networks consist of two layers. These are the input layer of the comparation which has L neurons and the output layer of the clarification which has P neurons. Each neuron of ithe nput layer is connected to each neuron of the output layer using ascendant synaptic links ($\vec{w}$), and each neuron of the output layer is connected to each neuron of the input layer using descending links ($\vec{\vec{w}}$) [11]. Figure 1 shows the ART structure in which the input layer (blue) has 8 neurons and the output layer (magenta) has 6 neurons.

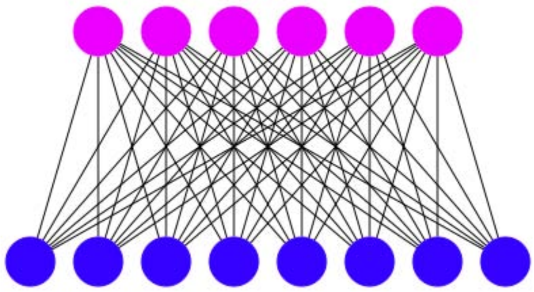

Figure 1: ART structure.

The specificity of the ART-2 structure is the availability of six sublayers in the input layer. Each sublayer consists of L neurons. The availability of these sublayers is conditional upon necessity for the normalization of input values. An example of such a structure is shown in Figure 2. This network has fift-seven neurons in the sublayers of the input layer (they are shown in blue) and fifteen neurons in the output layer (they are shown in magenta) ($L = 57$, $P = 15$). The input values of this network are the vectors $\vec{x}$ which are given serially. Each vector $\vec{x}_k$ has L elements (formula (1)).

$$\vec{x} = (x_0, x_1, \ldots, x_{L-1}) \tag{1}$$

The ART-2 network has few parameters:

- The threshold of the aboutness (closeness) c_ρ. This is a real number which lies in the interval $(0; 1)$. A value near zero means a good aboutness or closeness.
- The oefficients c_a, c_b and c_c. These are numbers which are greater then zero. They are needed for minimising the function.
- The coefficient δ_ε which is a small real number. It is greater then zero and is needed for avoiding a division by zero.
- The small real number δ_θ which is the criterion for the truncation of the noise. This truncation uses formula (2).

$$f(x) = \begin{cases} 0, & 0 \le |x| \le \delta_\theta; \\ x, & x > \delta_\theta; \end{cases} \tag{2}$$

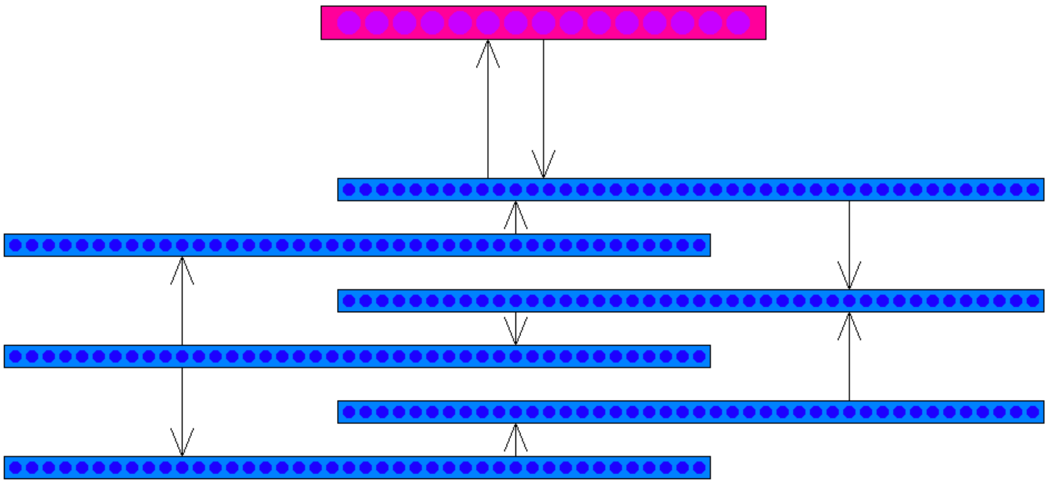

Figure 2: The detailed structure of ART-2 network.

2.3 The training algorithm

When the training of ANN sarts, it has L neurons in each sublayer of the input layer and one neuron in the output layer. The weights of the links are initialized by formulas (3-4) for each i-th neuron.

$$w_{0,i} = \frac{1}{1+L} \tag{3}$$

$$\hat{w}_{i,0} = 0 \tag{4}$$

The conditions of all neurons in the sublayers of the input layer are zero. When a new vector $\vec{x}_k$ (formula (5)) is given then it executes the following few operations:

1. All neurons of the output layer are updated.
2. The values of the neurons in the sublayers of the input layer are calculated serially by formulas (6)-(11) (for each i-th neuron):

$$\vec{x}_k = (x_{k,0}, x_{k,1}, \ldots, x_{k,L-1}) \tag{5}$$

$$\hat{y}_{0,i} = x_{k,i} + c_a \hat{y}_{2,i} \tag{6}$$

$$\hat{y}_{1,i} = \frac{\hat{y}_{0,i}}{\delta_\varepsilon + \sum_{j=0}^{L-1} \hat{y}_{0,j}} \tag{7}$$

$$\hat{y}_{2,i} = f(\hat{y}_{1,i}) + c_b f(\hat{y}_{5,i}) \tag{8}$$

$$\hat{y}_{3,i} = \frac{\hat{y}_{2,i}}{\delta_\varepsilon + \sum_{j=0}^{L-1} \hat{y}_{2,j}} \tag{9}$$

$$\hat{y}_{4,i} = \hat{y}_{3,i} \tag{10}$$

$$\hat{y}_{5,i} = \frac{\hat{y}_{4,i}}{\delta_\varepsilon + \sum_{j=0}^{L-1} \hat{y}_{4,j}} \tag{11}$$

where $\vec{x}$ is the vector of input signals and $\vec{\hat{y}}_k$ is the vector of values of the k-th sublayer of the input layer.

3. The values of neurons of the output layer are calculated by formula (12) (for each neuron of the output layer).

$$y_{1,i} = \sum_{j=0}^{L-1} w_{i,j} \hat{y}_{4,j} \tag{12}$$

4. If there are active neurons then the neuron having the maximal value (the neuron-champion) is selected and enumerates the values of the neurons of the input layer by formula (13).

$$\hat{y}_{4,i} = \hat{y}_{3,i} + y_{i,\iota} \hat{w}_{\iota,i} \tag{13}$$

where ι is the index of the neuron-champion.

Then the aboutness of the neuron-champion is checked by formula (14).

$$\frac{c_\rho}{\delta_\varepsilon + r} \leq 1 \tag{14}$$

where r is calculated by formula (15).

$$r = \sum_{i=0}^{L-1} \left(\frac{\hat{y}_{3,i} + c_c \hat{y}_{4,i}}{\delta_\varepsilon + \sum\limits_{j=0}^{L-1} \hat{y}_{3,i} + c_c \sum\limits_{j=0}^{L-1} \hat{y}_{4,i}} \right) \tag{15}$$

If the assumption (14) is executed then the weight coefficients of the neuron-champion are updated by formula (15) otherwise the neuron-champion is disactivated and a new champion is selected from the other active neurons. If there are no more active neurons then a new output neuronis generated (new class is created) with weights calculating by formulas (16)-(19) where $i = 0 \ldots L-1$.

$$\hat{w}_{i,\iota} = \frac{\hat{y}_{4,i}}{1 - y_{1,\iota}} \tag{16}$$

$$w_{\iota,i} = \hat{w}_{i,\iota} \tag{17}$$

$$w_{P-1,i} = \frac{\hat{y}_{4,i}}{1 + \sum\limits_{j=0}^{L-1} \hat{y}_{4,i}} \tag{18}$$

$$\hat{w}_{i,P-1} = \hat{y}_{4,i} \tag{19}$$

The result of the ANN work is either the index of the neuron having the maximal value (ι) which was checked on the aboutness (the image was associated to the known class (claster) of objects) or the information about necessity for creating a new class (the class for the current vector is absent).

3 The objectof discussion

3.1 Blood factors

The data for the experiment is data which was given by Kosenkova N.A. who is the director of the clinical laboratory of the Rasskazovo (a town in the Tambov region, Russia). This is the result of general analyses of the blood of patients. For training the ANN results of the blood analyses of four hundred patients were used. The age of these patients was greater than 18 years because sometimes younger people have other bounds of parameters of their blood and the analysis for them will not be correct.

The general clinical discussion of the blood is one of the most important methods of the diagnostics and it reproduces how hematopoietic agents react to the influence of different physiologic and abnormal factors in the organism. Very often this is very important for diagnostics and it is the most important if the hematopoetic system is impaired.

The notion „the general clinical discussion of the blood“ incorporates the examination of the hemoglobin concentration, the count of erythrocytes , the count of leukocytes, the color factor and the leucocytal formula. Sometimes the time which is necessary for blood coagulation is defined, the time of the hemorrhage and the number of reticulocytes and thrombocytes. Nowadays most of these factors are analysed by automatic hematologic analysers which can define between 5 and 24 parameters. The most important of these is the concentration of hemoglobin, the hematocrit, the number of erythrocytes, the average volume of an erythrocyte, the average concentration of the hemoglobin in the erythrocyte, the half-breadth of the distribution of the volume of the erythrocytes, the number of thrombocytes, the average volume of a thrombocyte and the number of leukocytes.

Inputs of the pattern are ten factors of the general analysis of the blood. These are:

1. the hemoglobin (g/l);
2. the rate of the sedimentation of erythrocytes (mm/h);
3. leukocytes (10^9/l);
4. erythrocytes (10^{12}/l);
5. the color factor;
6. the leucocytal formula;
7. basophiles;
8. stab neutrophils;
9. microxyphil neutrophils;
10. lymphocytes;
11. monocytes.

3.2 Forming the he pattern

As ialready mentioned the input values of the pattern are ten factors of the general analysis of the blood. Values of these factors lie in different bands that is why for the purpose of this analysis all factor values are normalised in the interval [-1; 1].

4 Experiment

For the experiment 400 rows of pattern were used. The pattern consisted of four classes:

- the hospitalization;
- the stationary medication;
- the ambulatory medication;
- the absence of the necessity of the medication.

After the analysis we excluded two patterns because they were erratic (there were identical images in different classes). In the process of the training the algorithm created seven classes which were packed in assumed classes (images which appertained to different assumed classes appertained to different produced classes too). So the developed model is sensibly sufficient.

For the assessed value of the developed model it conducts few new experiments. In each experiment the assumed pattern consisting of 400 rows of the general analysis of patients blood was divided into two parts. The first part was used for training the ANN and the second part was used for checking the sufficiency of the developed model. The number of rows of the first and second parts were different for different experiments. In the first experiment the second part consisted of four rows, in the second experiment it had eight rows, in third experiment it had twelve rows and etc. The pattern always has equal parts of each class. Figure 3 shows the dependence of the difference between network diagnostic and doctor diagnostic on the number of rows in checking the pattern.

5 Implementing the program

This model was implemented in the form of an expert system and was written in C++. The user interface was implemented using the library Qt4. The expert system consists of three components (as shown in Figure 4) [12]:

- the universal neural networks simulator (UNS) [13];
- the universal neural networks simulators server (UNSS);
- the component of the interaction with user;

These components can be located in one or in several computers. The first two components (UNS and UNSS) can be executed in the GNU/Linux operation system only and the third component (which interacts with the user) can be executed in the MS Windows operation system, too. Figure 5 shows the client program (the program which interacts with the user).

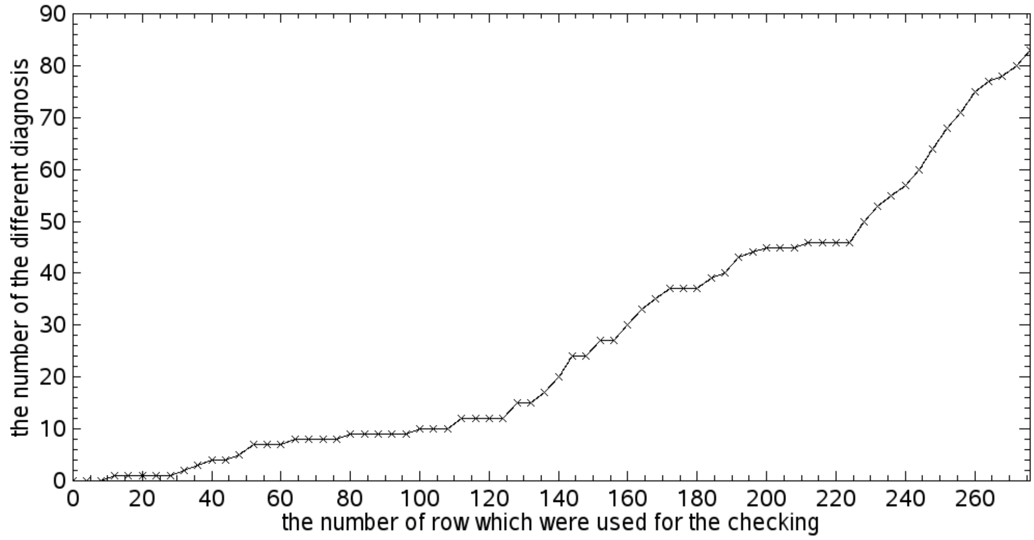

Figure 3: The dependence the difference between network and doctor diagnostic on rows number in checking pattern

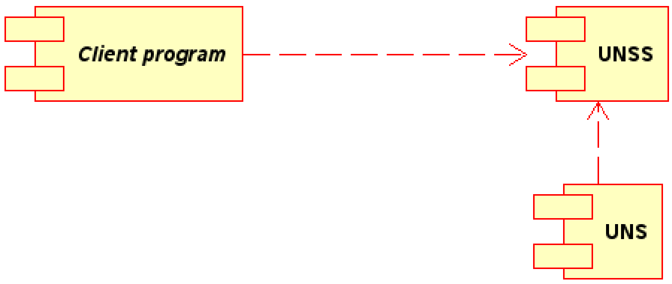

Figure 4: The architecture of the expert system.

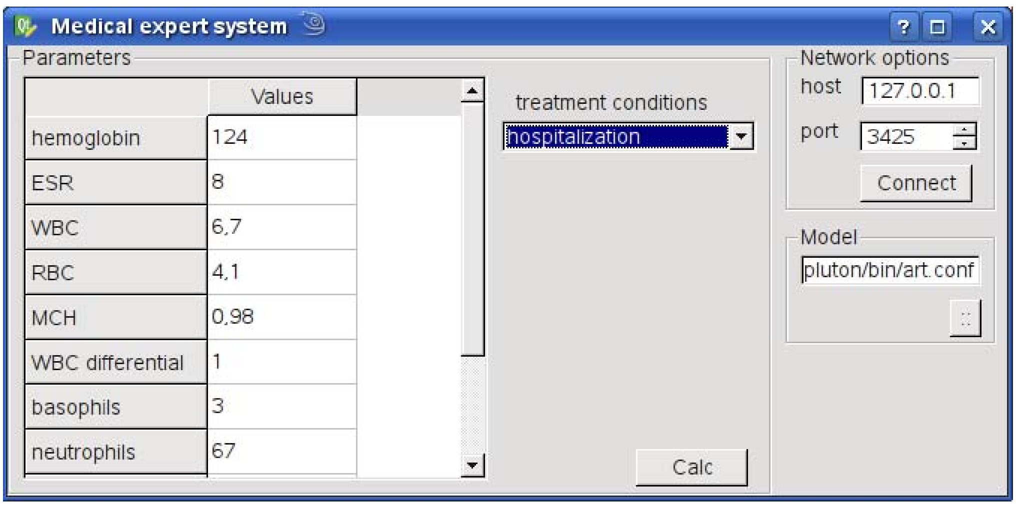

Figure 5: The client program.

6 Conclusion

So the ANN-model of medical objects and its implementation have been developed using the neural network classifier based on the adaptive resonance theory. This model allows medics to evaluate the best treatment conditions based on the complete blood count. We show that the low model inaccuracy allows to use it in the medical practice as an expert system.

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Glossary

L	the output pattern row number, 3
P	the input pattern row number, 3
δ_θ	the criterion of the truncation of the noise, 4
δ_ε	the number which needed for the keeping from the division by zero, 4
$\vec{w}$	ascendant synaptic links of neurons, 3
$\vec{x}$	the input pattern, 4
$\vec{y}_1$	values of the output layer, 6
$\vec{\tilde{w}}$	descending synaptic links of neurons, 3
c_ρ	the coefficient of the checking the aboutness, 4
c_a	the coefficient of the function minimization, 4
c_b	the coefficient of the function minimization, 4
c_c	the coefficient of the function minimization, 4
$\vec{\tilde{y}}_i$	values of the i-th sublayer of the input layer, 6

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