«ЕНЕРГОЗБЕРЕЖЕННЯ ПРИ ЕКСПЛУАТАЦІЇ МЕХАНОТРОННИХ СИСТЕМ»

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NEURAL NETWORK DECISION SUPPORT IN THE CASE LAW SYSTEM

The paper considersissues associated with neural network decision support in the case law system. Thefunctional dependence of the degree of the subject guilt of the set of situations (informative features) is described. This problem is solved by using the technology of forced learning of neural networks and implemented by an ensemble of models as a pattern recognition problem. The neural network support for decision making in the precedent law system is implemented in the basis of artificial neural networks in the environment of existing neuroemulator packages as an application in the program code of the technical analysis package.
***Keywords**: subject guilty, error backpropagation algorithm, neural networks, decision-making support, case law system.*

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НЕЙРОМЕРЕЖЕВЕ ЗАБЕЗПЕЧЕННЯ ПРИЙНЯТТЯ РІШЕНЬ В ПРЕЦЕДЕНТНІЙ СИСТЕМІ ПРАВА

У статті розглядаються питання, пов'язані із нейромережевим забезпеченням прийняття рішень у прецедентній системі права. Описано функціональну залежність ступеня вини суб'єкта від набору ситуацій (інформативних ознак). Це завдання вирішено застосуванням технології примусового навчання нейромереж та реалізовано ансамблем моделей як завдання розпізнавання образів. Нейромережеве забезпечення прийняття рішень у прецедентній системі права реалізовано в базисі штучних нейронних мереж серед існуючих пакетів нейроемуляторів як додаток у программному коді пакета технічного аналізу.
Ключові слова: *виновність суб'єкта,зворотнє поширення помилки,нейронні мережі, підтримка прийняття рішень, прецедентна система права.*

Introduction.

Case law is a legal system in which the main source of law is judicial precedent. Judicial precedent is a decision made in a case that is mandatory for all courts of equal and lower instance when considering similar cases [1-4].

Case law has a certain obligation, which is manifested in the duty of judges to be guided by the decisions of situational similar cases, the impossibility to deviate from them even in the presence of some contradictory factors affecting the expediency or fairness. The judge must recognize truth and legitimacy of the issues that have already received court decisions [3-4].

The increasing number of similar decisions becomes burdensome for an expert if there are numerous differences on the merits of the case. This fact creates a contradiction in the approach to decision-making and confronts the expert with a choice: to deviate from the precedent or to reject it if there are differences on the merits of a particular situation. During the proceedings of one case, it is impossible for the expert to take into account all the precedents associated with it, which leads to the emergence of conflicting and contradictory decisions [2-4].

Automated neural network expert systems do not have this drawback, since they operate all knowledge (precedents) accumulated and stored in databases and they are not limited either memory or speed in the analysis of the entire possible set of precedents [5]. Accuracy is achieved through a large number of cases in the reports. They provide solutions for many specific situations. This allows us to speak about the representativeness of the example samples and suggests that the forced training of neural network models in the basis of similar court decisions on the entire set of recorded cases provides an objective basis for the synthesis of neural network systems for automatic decision-making within the framework of case law.

Purpose of the study. It is proposed to synthesize an ensemble of neural network models for recognizing the degree of guilt (or innocence) of a research subject based on a set of historical precedents accumulated in the database to ensure the reliability, efficiency, uncompromising, and accuracy of decision-making in the judicial system of case law.Domain expert compiles a list of signs from a set of precedents corresponding to a particular court decision and fills in the initial table. In this table the classes are the decisions (guilty or not guilty), and the features are the presence or absence of appropriate conditions. The available feature alphabet with the existing precedent set from the history [6] allows us to reduce the task of making a judicial decision to the recognition of classes in the space of nominal features [7], since the considered cases have the same type. Taking into account the existing practice of making court decisions on a set of similar precedents [1, 2], it is feasible to solve this problem on the basis of forced training of an ensemble of neural network models of different paradigm, architecture, complexity and to synthesize the network as a decision-making tool based on assigning a set of investigated features of a given subject to the appropriate class. This corresponds to the establishment of the degree of guilt (or innocence) in the domain.

Thus, the ultimate goal of the study is to synthesize an ensemble of neural network models for decision support in the space of the same type of features, indicating their presence or absence in each specific situation. In this case, their presence or absence is recorded in nominal terms (symbols) and can be easily represented in a table [5,8].

Mathematical formulation of the problem. From the point of view of the class recognition formalizing (responsibility of a subject of law), it is necessary to construct a mapping between the input data vector and result of the expertise, which approximates the dependence “feature presence and conclusion”. In general case, features and classes in this problem are vector quantities:

$$|Y(t)| = F|X(t)|, \tag{1}$$

where $Y(t)$ is a class number of the subject's state; $X(t)$ is a vector of current values of input features; *F* is functional for converting a feature array into a class number. The classification is based on the use of a trained artificial neural network with backerror propagation as a tool for automatic class recognition.

Let us formalize the problem of class recognition in the space of established features by the expression:

$$Max\, F(S,X)\ at\ \delta \le \delta_0\ , \tag{2}$$

where $F(S, X)$ is the decision rule for recognizing classes S in the feature space X;

$s \in S$, S is a set of recognizable situations of the subject's responsibility;

$x \in X$, X is a set of input factors;

δ is degree of model adequacy;

δ_0 is allowable error of model training.

The set of input factors $X^n = \{x_1, x_2, ..., x_n\} \subset X$ together with the class alphabet ensure the implementation of the well-known pattern recognition rule [3]: subject with a set of features belongs to the corresponding class if the likelihood function $L(\omega, \{\omega_g\})$ reaches its maximum value, i.e.:

$$\omega_g \in \Omega_k \text{, if}$$

$$L(\omega, \{\omega_g\}) = \sup_i L(\omega, \{\omega_i\}), \tag{3}$$

where, $\vec{X} = (x_{1,....,}x_n) \in X$;

$L(\omega, \{\omega_g\})$ is the rule for assigning the degree of subject responsibility to the appropriate class;

ω_g is the set of possible states of the subject (*p*, *g*) in the feature space (*k*, *l*) for all their possible combinations (ω_{pk} , ω_{gl}) .

Approximation of the function of the subject responsibility degree in the space of fixed features.

Neural network modeling in the problem of assessing the degree of responsibility in a court decision is based on the well-known theorem on the representation of a function of several arguments through the sum of the compositions of functions of one variable and its adaptation to the Hecht-Nielsen neural network format [5]:

$$y(x) = \alpha \sum_{i=1}^{H} v_i \left(w_{i1}x_1 + w_{i2}x_2 + ... + w_{in}x_n + u_i \right), \tag{4}$$

where *H* is the power of the training sample, α, v are the parameters of the neural network, *n* is the number of neurons, and $w_{i1}, w_{i2}, ..., w_{in}$ are the weight coefficients of neurons.

It is suggested that there is a set of numbers H, n, α, v_i, u_i, for which the function *y* is approximated by the series (4) on the entire domain of its definition and can be implemented using a three-layer neural network with any predetermined error [5]. This is a classic generally accepted position; it is the basis of all subsequent procedures. Indeed, if it is possible to establish a deterministic analytical relationship of the entire set of selected features with a set of established classes (degree of responsibility), then the task is reduced to the implementation of simple instrumental procedures for assigning a class number to a set of features on the input of the synthesized model.

In our case training set is implemented in the nominal view (symbol) and it is represented tabularly as shown in fig. 1.

	1 Var1	2 Var2	3 Var3	4 Var4	5 Var5	6 Var6	7 Var7	8 Var8	9 Var9	10 Var10	11 NewVar
1	1	1	0	1	0	1	1	1	0	1	1
2	0	0	0	1	0	0	0	0	1	0	0
3	1	1	1	0	0	1	1	1	0	0	1
4	1	0	0	0	0	0	0	1	1	1	0
5	1	0	0	1	0	0	1	1	0	0	0
6	0	1	1	1	1	0	1	1	0	0	1
7	0	0	0	1	1	0	1	0	0	0	0
8	1	1	0	0	1	0	0	1	1	1	1
9	0	0	1	1	0	1	0	1	0	0	0

Fig. 1. View of a fragment of the training set of historical examples

Here the degree of guilty can have different gradations. In our case a simple option was taken to demonstrate the efficiency of the technology:

1 – guilty;

0 – not guilty.

The presence or absence of certain conditions (factors) in the case is also fixed by the numbers 1, 0 (presence, absence).

Analytical representation of modification of network coefficients.

Modification of the synaptic set of a neural network is based on enumerating all possible combinations of synapse weights according to the error backpropagation algorithm, based on the gradient method [5]:

$$W^{t+1} = W^t - \eta \cdot gradE(W^t) \tag{5}$$

$$\text{or } w_{hq}^{(n)}(t) = w_q(t-1) + \Delta w_{hq}^{(n)}(t), \tag{6}$$

where $w_q(t-1) = w_q(t) + \alpha \cdot \dfrac{\partial E(k)}{\partial w_q(t)}$;

w is an array of synaptic coefficients;

*q*is the number of the output of the neuron in the *n*-th layer;

h is the number of the neuron input in the *n*-th layer;

n is network layer number.

The end of the learning process is determined by the achievement of the condition:

$$\frac{1}{mn}\sum_{j=1}^{n}\sum_{i=1}^{m}(y_{ij}-d_{ij})^2 \Rightarrow \min\,(\delta \le \delta_0), \qquad (6)$$

where y_{ij} is the current state of the subject;

d_{ij} is the result of training (response) of the network at the j-th output for i-th example of the training sample;

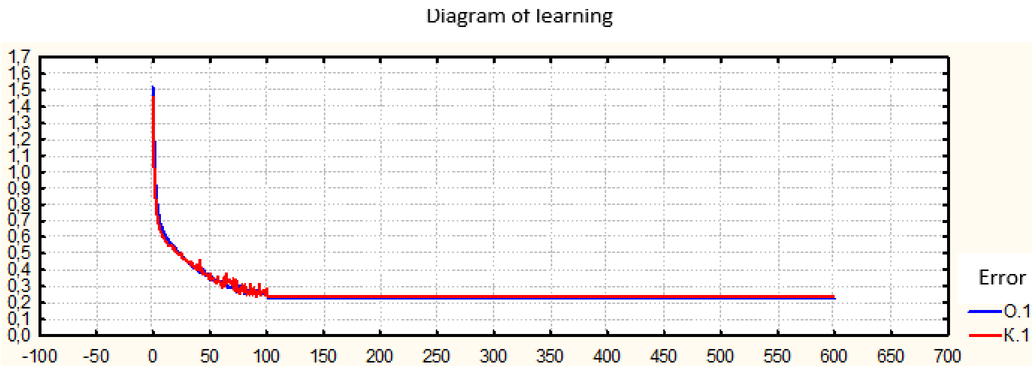
$j=1,n$ is network output number;

$i=1, m$ is example number;

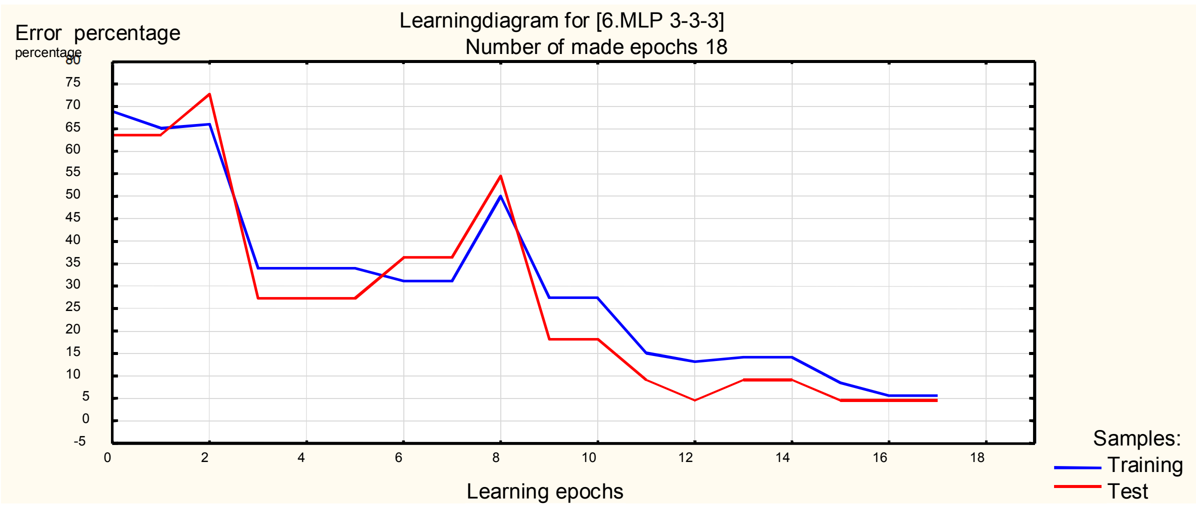
m,n are dimensions of the example array and the number of output network elements.

Thus, as a result of forced training of a model ensemble of on a representative sample of examples from judicial practice of similar situations, an algorithm for back error propagation is implemented until condition (6) is reached. Next, an ensemble of effective models is fixed according to the values of the required performance and the allowable values of errors on the training and test sets.

Experimental research for various options (fig.2a, fig.2b)of the dimensions of the input features vector and the power of the example sample showed stable convergence of the learning process in acceptable time, reflected by the number of epochs when visualizing the results:



a)



b)

Fig 2. Visualization of the dynamics of the iterative learning process

Instrumentally, the problem is solved by a standard package of technical analysis data.

Thus, the neural network support for decision making in the precedent law system is implemented in the basis of artificial neural networks in the environment of existing neuroemulator packages and is implemented as an application in the program code of the technical analysis package.

The adequacy of the ensemble of models is achieved by ensuring the required performance and acceptable errors on the training and test sets.

Conclusions

1. It is necessary to find the functional dependence of the degree of the subject guilt on the set of situations (informative features) for neural network support of decision-making in the precedent system of law. This problem is solved by using the technology of forced learning of neural networks and implemented by an ensemble of models as a pattern recognition problem.

2. The practical significance of the research results is creation of software tools to support decision-making in the precedent system of law and the creation of an additional, independent of subjectivity, decision-making channel.

3. The developed technology, methodological, algorithmic, and software tools make it possible to automate the analysis and adoption of judicial decisions in order to minimize the influence of the human factor and increase objectively authority and confidence in the judicial power system.

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