The Method of Immersion the Problem of Comparing Technical Objects in an Expert Shell in the Class of Artificial Intelligence Algorithms

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Abstract: The method of dip of the underlying computational problem of comparing technical object in an expert shell in the class of data mining methods is examined. An example of using the proposed method is given.

Keywords: composite index of quality, expert shell, neural network, perceptron.

1. INTRODUCTION

It is considered that a distinctive feature concerning the theory of the modern expert systems is the use of intellect means for data mining. Data Mining is the collective name that is used to denote a set of detection methods in large amounts of data previously unknown, nontrivial and available for interpretation knowledge that is necessary for decision-making [1, 5, 10].

The basis of Data Mining is comprised by methods relating to the theory of the expert systems, classification, modeling and prediction based on the use of neural networks, genetic algorithm, multiple regression analysis, cluster analysis, the analytic hierarchy process, content-addressable memory, theory of fuzzy sets, factor analysis, the principal component analysis and etc. Generally, the mentioned methods are at the interface of database theory, statistics and artificial intelligence.
Tasks that is solved by the methods of Data Mining are to conditionally divide into descriptive and predictive. In the descriptive ones the main aim is to give a vivid description of their hidden regularities, while in predictive ones the priority is given to the problem of the prediction for the cases without available data. The descriptive tasks applied to association rule learning, clustering, indistinct-multiple description of indications, regression modelling. The predictive tasks applied to prediction, principal component regression, analytic hierarchy process, ridge regression, time series analysis and etc.

2. THE METHOD OF IMMERSION OF COMPARING TECHNICAL OBJECTS IN AN EXPERT SHELL

The method is intended for the improvement referring to solving of the class of the computational problems of the estimation and the comparison of technical objects (systems, devices, equipment) not only for technical features, but also for composite index “price-quality”.

The proposed procedure is realized in a few stages. The general principle of the expert system is the extraction method of the most informative features and the division of features into quantitative, qualitative, the availability of certain characteristics, the signs of engineering evaluation, the signs of critical evaluation applied to the set of the compared objects [2]. Depending on the impact on the general characteristics of the quality of the objects there are general characteristics of the positive effect and indicators of negative effect, for example, cost-introduction characteristics. For both characteristics different normalization is used [2].

The generated data set forms feature (factor) space that in tasks of multivariate statistical analysis is often called the set of reference data [6]. The next stage is the use of data mining to the given reference set: analytic hierarchy process, fuzzy-set theory, multiple linear model, principal component analysis, ridge regression, a method of contiguity learning of a neural network, subsumption algorithm, clusterization, forecasting of the generalized indicator on the basis of multivariate calibration, the visualization of received results and etc.

Name the initial task of comparing technical objects as the basic task to which we are going to apply data mining methods. The immersion in the expert shell supposes, firstly, the preparation of input data for the basic task (analytic hierarchy process, principal component analysis, fuzzy-multiple representation and etc.). Secondly, it is necessary to present final results of the basic tasks in the most complete and qualitatively interpreted way (contiguity learning, classification of object of expertise, clustering algorithm and etc.).

At this stage it is important to choose the most rational techniques of the visualization of results. As it is well known, the problem of visualization is far from trivial [4]. The realization of most listed above methods of data mining is based on neural network method [3, 7]. Thus, the feedforward neural network with a back-propagation is used for forecasting the values of composite index of the quality of object, for realization of contiguity learning it is used the neural network with softmax activation function. The neural network perceptron is used for
solving the problem of classification, and the Kohonen network with competlayer activation function is used for the clusterization of object examination.

The feature of solving this tasks is the use of object-oriented programming. So the new object, neural network is created with the realization of the network using the packet nntool of the GUI (graphic user interface) in Matlab R2012. Consider the following the following basic task as an example of using the proposed method.

3. THE COMPARISON OF INTEGRATED SECURITY SYSTEMS (ISS) WITH VARIOUS FUNCTIONALITY

The description of the main functions \( f_1 - f_8 \) of a SIS structure chart in minimum configuration as a result of functional and structural decomposition, presented in the paper [8].

Consider and compare 8 structures of ISS, received as a result of the assumption about the functionality of all subsystems or about the refusal of one of subsystems and, thus, the failure of one of functions \( f_1 - f_8 \). The results of the analysis of 8 structures ISS in the terms of their effectiveness are presented in the table.

### Table I: Analysis of the effectiveness of the compared ISS structures

| Number of structure ISS | Inoperative subsystem \( f_k \) | The effectiveness of the implementation of objective function | Designations and ranks of ordered systems | Cost estimate of ISS structure, conventional monetary units (USD) |
|-------------------------|-------------------------------|-------------------------------------------------|------------------------------------------|-------------------------------------------------|
| 1                       | 2                             | 3                                               | 4                                        | 5                                               | 6                                               |
| 1                       | 1                             | 3,3                                            | \( Z_5 \)                                | 5                                               | 86000                                           |
| 2                       | 2                             | 3,5                                            | \( Z_4 \)                                | 4                                               | 87000                                           |
| 3                       | 3                             | 4,1                                            | \( Z_3 \)                                | 3                                               | 83000                                           |
| 4                       | 4                             | 3,1                                            | \( Z_6 \)                                | 6                                               | 76000                                           |
| 5                       | 5                             | 4,3                                            | \( Z_2 \)                                | 2                                               | 88000                                           |
| 6                       | 6                             | 2,2                                            | \( Z_7 \)                                | 8                                               | 85000                                           |
| 7                       | 7                             | 1,4                                            | \( Z_8 \)                                | 9                                               | 41000                                           |
| 8                       | —                             | 5,0                                            | \( Z_1 \)                                | 1                                               | 91000                                           |

In this table column 1 is the original number of structure; column 3 is the estimation of ISS effectiveness without the corresponding function \( f_k \); column 4 is the designation of new structure after the ordering of new objects with the decrease of effectiveness; column 5 is ranks of analytic hierarchy process.
The estimation of effectiveness (see column 3) is given by averaging ratings on five-point scale, obtained through the questionnaires of technicians (engineers of divisions of private security, Federal State Unitary Enterprise “Security”) in Voronezh institute of the ministry of Internal affairs of Russia.

For the basic task discussed above we choose an expert shell based on the analytic hierarchy process (AHP), contiguity learning of self-organized neural network and classification of objects based on a specific neural network, the perceptron.

4. ANALYTIC HIERARCHY PROCESS

According to linguistic scale of AHP we define the ranks of ISS structure with different functions (see the table, column 5). For the use of the methodology adopted according to T. Saaty concerning constructing a pair-wise comparison matrix $W$ we arrange the comparable structures so that with increasing the number of designated systems the ranks increase.

We construct a pair-wise comparison matrix $W$ in which the first line is ranks in ascending order and the first column is reciprocals of ranks. The remaining items $W_{kl}$ are selected by the experts on the basis of the relative importance index $J_k$ and $J_l$:

$$W = \begin{pmatrix}
1 & 2 & 3 & 4 & \ldots & 9 \\
0.500 & 1 & 2 & 2 & \ldots & 8 \\
0.333 & 0.500 & 1 & 2 & \ldots & 7 \\
0.250 & 0.500 & 0.333 & 1 & \ldots & 7 \\
0.200 & 0.333 & 0.333 & 1 & \ldots & 5 \\
0.167 & 0.250 & 0.333 & 1 & \ldots & 5 \\
\ldots & \ldots & \ldots & \ldots & \ldots & \ldots \\
0.111 & 0.125 & 0.143 & 0.143 & \ldots & 1 \\
\end{pmatrix} \quad (1)$$

From the equation for eigenvalues and eigenvectors

$$WV = \lambda V \quad (2)$$

define the largest eigenvalue $\lambda_{\text{max}} = 8.318$. According to the equation

$$CI = \left( \lambda_{\text{max}} - m \right) / (m - 1), \quad (3)$$

where $m$ is order of matrix $W$, we find the consistency index $CI=0.045$.

As we can see, CI does not exceed threshold valuation 0.1 defined in the work [9]. This means that pair-wise comparison matrix is well coordinated. From the equation (2) define the matrix of eigenvectors, first of which is the priority vector for ordered structures
\[ V = (0.753 \ 0.461 \ 0.344 \ \ldots \ 0.042)^T. \]  

Realize the reverse transition from ordered structures, designated \( Z_k \) to original structures with functions \( f_1 - f_k \) according to the table above. Then the vector (4) is transformed into

\[ V = (0.165 \ 0.207 \ \ldots \ 0.042 \ 0.753)^T, \]

where the order of items already corresponds to the original numbering and designate its items (Saaty's index) as \( S_k \).

The values of the items of the priority vector (5) for less important objects appear to be unnecessary too low: compared with the maximum value 0.753 sixth and seventh objects have indicators 0.072, 0.042, i.e. less in 10.46 and 17.93 times respectively (Fig. 1). This disadvantage of AHP was repeatedly noted earlier [3].

![Fig. 1. The quality indexes after applying analytic hierarchy process and in the output of the neural network](image)

For the expert smoothing of results we use contiguity learning procedure of the neural network with normalized softmax activation function, giving to its input the priority vector (5). The procedure is based on the mixture of experts model described in the work [7].

As a result of processing the priority vector (5) by neural network with softmax activation function we receive the adjusted priority vector.

\[ \text{Adjusted priority vector} \]
whose elements are the generalized tolerant indicator.

The results of modeling are presented in the figure 1, where the upper part of the figure illustrates the excessive suppression of estimation of the analytic hierarchy process for 4, 6, 7 objects. The lower part of the figure shows the results of the processing of estimates based on the procedures of contiguity learning with the normalized softmax activation function, which leads to completely different interpretation for solving tasks of the expertise.

5. CLASSIFICATION AND VISUALIZATION OF OBJECTS OF THE EXPERTISE

Let us return to the first stage of the proposed procedure is to select the most informative features and their division into quantitative, qualitative, cost-introduction characteristics. So far we have considered only the quantitative indication of the effectiveness of the objective function, receiving after AHP values $S_k$. We introduce the second sign, it is a price indicator $P \{price\}$, the initial values of which are shown in the column 6 of the table (see the table.).

The price indicator is the indicator of a negative effect so we introduce the normalization for it according to the method of the work [2]:

$$\hat{P}_k = \frac{P_{\text{min}}}{P_k}, \quad (7)$$

where $P_{\text{min}}$ is the price of the cheapest of the object of the expertise. The normalized value of the price indicator for it equals 1,0 correspondingly. For the more expensive objects the values will be less than 1, so we call it an indicator of reciprocal pricing.

Normalize the initial price of the object (see column 6 of the table) according to the equation (7):

$$\hat{P} = (0,476 \quad 0,471 \quad ... \quad 1,000 \quad 0,450)^T. \quad (8)$$

We use of specific neural network, perceptron for the classification of objects of expertise. In contrast to the use the packet nntool and the GUI (graphic user interface) for further study it is required to use the program on the Matlab language (the so-called M-file). We form a new perceptron with two inputs and hardlim activation function:

```matlab
net=perceptron(«hardlim», «learnpn»);
net=configure(net,X,T)
```

and provide a sequence of two-dimensional vectors of "price-quality" for the various structures
to its input combining the results of (8) and (5):

$$X = \begin{pmatrix} 0.476 & 0.471 & \ldots & 1.000 & 0.450 \\ 0.165 & 0.207 & \ldots & 0.042 & 0.753 \end{pmatrix}$$  \hspace{1cm} (9)

For the division of object set into two classes and constructing the separating surface (in our case it is a straight line) it is required to assign the target vector $T$ containing items 1 or 0 according to the principle: 1 is the object referring to the field of acceptable solutions, 0 is not applicable. Choose a target vector in the following form

$$T = \begin{pmatrix} 0 & 0 & 0 & 1 & 0 & 1 & 1 \end{pmatrix},$$  \hspace{1cm} (10)

assuming that the field of acceptable solutions should relate not only to the objects of 5, 8 with the best indexes of quality, but also the object 7 that has almost twice lower cost (see column 6 of the table).

After several steps of adaptation of the neural network we get the following picture of the location of two-dimensional vectors relating to objects of expertise relative to separating line (Fig. 2).

![Classification of objects](image)

Fig. 2. Classification of examination of objects on the basis of neural network perceptron

As you can see, the perceptron correctly divided the expertise objects into two classes according to the assigned target vector (10). The implemented visualization of object properties
allows the experts to make better decisions than just using the data of source based task (see the table).

6. Conclusion

As a whole the proposed method of the immersion of the computational problem referring to the comparison of the technical objects in an expert shell in the class of program realization of artificial intelligence methods appears to be the effective means of improving the reliability of control solutions. The further extension of the expert shell in comparison with the example given above is based on methods of the neural network theory, for example, clustering of objects of the expertise using self-organized neural networks.

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