Approach to the optimization of business process models

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Abstract
An approach to the optimization of IDEF business process models of iron and steel and mechanical-engineering enterprises is suggested. The neural network system was considered to assess the complexity of IDEF-models perception by human, characterized by using expert method based on pairwise comparisons for obtaining data used for training multilayer perceptron, which allows for arbitrary IDEF- diagram to predict its complexity factor of perception, in which the IDEF-models comparison and optimization can be carried out. The results presented in the article can be useful when building IDEF-models as well as designing CASE-tools based on them.
Keywords: CASE-TOOLS, BUSINESS PROCESSES, ARTIFICIAL NEURAL NETWORK, COMPLEXITY FACTOR OF PERCEPTION, IRON AND STEEL COMPANY, EXPERT METHOD, PAIRWAISE COMPARISON METHOD

Introduction

Visual models made according to the IDEF standards group (IDEF-models) is widely used in the practice of complex systems modeling, CASE-tools and reengineering of business processes of iron and steel and mechanical-engineering enterprises [1-4]. Among IDEF-models the most widespread are: SADT (IDEF0) - functional models, DFD - data flow diagrams, IDEF3 - process models. IDEF-models are a set of diagrams linked together in a hierarchical manner. Each diagram contains from 2 to 8 units, and communications both external and between blocks.

In the construction of IDEF models, an important issue is the presentation of diagrams so as to ensure the best possible understanding of the model by human-user. It is proposed to characterize the complexity for human understanding of diagrams by positive scalar parameter - complexity factor of perception (CFP). The more the CFP for the diagram is, the harder it is perceived by the person.

To predict the CFP on the basis of diagram structure, it is proposed to use a neural network system based on multilayer perceptron. To obtain the training sample the expert method and pairwise comparison method are used, as it is quite difficult for experts to accurately assess the CFP in absolute scale for a large number of diagrams. The article considers in detail the process of obtaining the training sample, as well as the development of artificial neural network based on the expansion pack MATLAB Neural Network Toolbox [5].

1. Formation of a training sample

In accordance with the IDEF standards diagrams contain not more than 8 blocks. Diagram structure is represented by vector $\vec{S}=[n_1, n_2, ..., n_8]$, where n_j - number of connections of the *j*-th block ($j=1, 2, ..., 8$).Block must contain communications, thus if there are *k* blocks in the diagram, then $n_j=0$ at $j>k$.

The process of training sample forming consists of the following steps.

Step 1. The N IDEF-diagrams are generated with a random number of blocks (from 2 to 8) and random external and interblock communications (from 2 to 20 per block). The diagrams are matched with vectors $\vec{S}_i$ ($i=1, 2, ... N$).

Step 2. In accordance with the method of pairwise comparisons experts are sequentially presented the diagrams with numbers l and m then they are suggested to estimate how many times the CPF of the *l*-th diagram is larger than the *m*-th as coefficient $a_{lm}=Q_l/Q_m$ (a_{lm} is selected from plurality of values) [6]. In total experts need to make an estimation $M=C_N^2$ times, C_N^2 - the number of combinations from N of 2. For example, at $N=200$ experts need to answer the $M=19900$ questions, which takes about 100 man-hours.

Step 3. The antisymmetrical pairwise comparison matrix is constructed [6]:

$$\mathbf{A}=\begin{pmatrix} 1 & a_{12} & ... & a_{1n} \\ 1/a_{12} & 1 & ... & a_{2n} \\ ... & ... & ... & ... \\ 1/a_{1n} & 1/a_{2n} & ... & 1 \end{pmatrix}. \quad (1)$$

To find the CPF according to the pairwise comparisons method it is necessary to find the main eigenvector $\vec{q}=(q_1, q_2, ... q_N)^T$ of matrix $\mathbf{A}$ (see (1)), which is defined by the equation

$$\mathbf{A}\vec{q}=\lambda_{\max}\vec{q}, \quad (2)$$

where $\lambda_{\max}$ – maximum eigenvalue of the matrix $\mathbf{A}$.

Due to the fact that the matrix $\mathbf{A}$ has a large dimension, finding its principal eigenvector is rather difficult. The power method (count to determination) - a method of simple iterations with valuation at each step [7] was used to solve the equation (2).

As an initial approximation there was chosen a vector:

$$\vec{q}_0=\frac{1}{N}(1, 1, ..., 1)^T.$$

The iterative procedure is described by formulas:

$$\begin{cases} \vec{y}_{k+1}=\mathbf{A}\vec{q}_k, \\ \vec{q}_{k+1}=\vec{y}_{k+1}/\|\vec{y}_{k+1}\|_1, \end{cases} \quad (3)$$

where $\|\vec{y}\|_1=\sum_{n=1}^{N}|y_{(n)}|$ – l_1 - vector norm, $y_{(n)}$ – the *n*-th component of vector $\vec{y}$.

We may note that even holding one iteration of procedure (3) can provide acceptable of accuracy result [6].

To get the result with the specified accuracy ε it is necessary to implement an iterative procedure (3) till the inequality $\|\vec{q}_{k+1}\|-\|\vec{q}_k\|<\varepsilon$ achievement [7].

To assess how much the expert opinion is agreed when answering the questions it is necessary to find the greatest eigenvalue of the matrix $\mathbf{A}$ [6]

$$|\lambda_{\max}|=\|\vec{q}_{k+1}\|/\|\vec{q}_k\|$$

and coherence index

$$I_S=\frac{\lambda_{\max}-N}{N-1}.$$

Expert opinion is considered to be agreed at the implementation of ratio:

$$I_S/I_{SL}<0.1,$$

where I_{SL} – random index (average coherence index of randomly generated on a scale from 1 to 9 antisymmetrical matrices of dimension N).

The result of the actions described above the training sample was obtained:

$$\langle\vec{S}_i, Q_i\rangle, \; i=1, 2, ... N. \quad (4)$$

where $\vec{S}_i$ – vector of the *i*-th diagram structure, Q_i – CPF of the *i*-th diagram.

2. Designing of artificial neural network

As an artificial neural network, select multilayer perceptron with sigmoidal membership functions [5-10]. This type of neural network proved itself in solving the complex dependencies approximation, if there is sufficient training sample. Moreover, there is a large number of software packages that implement emulation of a multi-layer perceptron.

There are several empirical formulas to select the neural network structure, the following one will be used [5-12]:

$$\begin{cases} \dfrac{mN}{1+\log_2 N} \le L_w \le m\left(\dfrac{N}{n}+1\right)(n+m+1)+m, \\ L = \dfrac{L_w}{m+n}, \end{cases} \quad (5)$$

$$\frac{n}{2} \le L_S \le 3n \quad (6)$$

n – dimension of input vector, m – dimension of output vector, N – the volume of training sample, L_w – the number of weights of neural network, L – the number of neurons in network, L_S – the number of neurons in hidden layers.

Substituting the following numerical values into formulas (5) and (6):

$N = 200$, $n = 8$, $m = 1$ obtain: $3 \le L \le 29$, $4 \le L_S \le 24$.

Let us choose a three-layer perceptron with structure 12-6-1. The number of neurons in the first hidden layer - 12, in the second hidden layer - 6, in the output layer - 1, the total number of neurons - 19. The structure of artificial neural network is shown in Figure 1. Filled circles show the inputs and output of network, open circles – neurons.

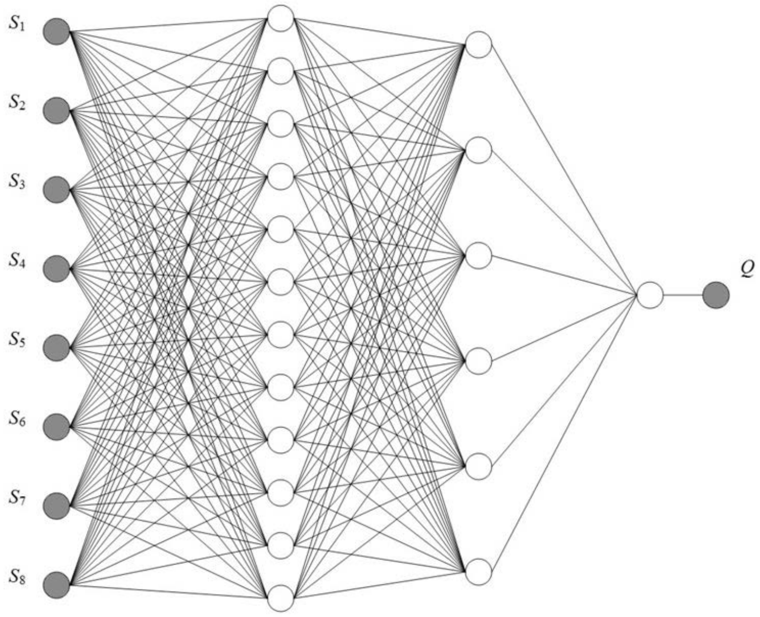

Figure 1. Structure of artificial neural network

This network was emulated using MATLAB Neural Network Toolbox package and trained on the basis of sample data (4) [5].

Trained neural network can be used to predict the CPF of IDEF-diagrams on the basis of their structure.

Conclusion

Proposed in the article neural network system for evaluation the complexity factor of IDEF-diagrams can be used in the development of CASE-tools and optimization of business processes of metallurgical and engineering enterprises. In particular, it is planned to develop algorithms and their implementing software applications that will enable to interactively construct the optimal from the perception complexity point of view IDEF-models in the process of interaction with user.

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