Forecasting the Price of Products Using Neural Networks

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Abstract. When developing new products, the justification of the price of future products is an important aspect of product competitiveness. Therefore, price assessment methods are paid great attention to. The article offers an information model for forecasting the price of pumping equipment using neural networks. The main technical characteristics of the pumping equipment used in the computational experiment were chosen. The developed and trained neural network showed a high level of correlation between predicted and real price values. Thus, price prediction using neural networks is a convenient tool in managing business processes. This is especially relevant at the stage of developing new products when comparing prices for similar products from different manufacturers.

1. Introduction

Price is an important parameter of product competitiveness. The price of products is a monetary expression of value. The cost is determined by the cost of production and sales of products, product benefits for the consumer [1].

Production costs, in accordance with the economic content, include the following groups:
- labour costs;
- tangible costs (for raw materials, consumables, parts, etc.);
- depreciation charge;
- allocations for social needs;
- other allocations.

Costing defines different types of costs: technological, shop, production and complete. The total cost is the basis for the pricing of manufactured products [2].

There is a law of supply and demand along with the law of value in a market economy. The law of demand (supply) reflects the relationship between the price of goods and the amount of demand (supply) for goods.

When choosing a pricing strategy, the following approaches are distinguished:
- calculated (method of full costs - adding of a certain size to the cost of goods, ensuring break-even);
- standard-parametric (specific indicators method, regression analysis method, aggregate method, price calculation method taking into account consumer effect, etc.);
- methods of market pricing (method of determining prestigious prices, the method of following market prices, a method with a focus on demand, etc.) [3].

Thus, many factors are to be considered while determining the price.

When forecasting the price of technical products, a correlation is often used between the price and one or several technical parameters determining the consumer properties of technical products [4,5].

Using statistical methods of data analysis (regression analysis, maximum likelihood method, etc.) leads to values averaging, and, consequently, to the loss of a certain information content.

Neural networks are one of the data mining tools. Neural networks are a powerful distributed computing process consisting of simple elements operating according to certain rules. The choice of network architecture, its parameters to solve a specific problem is an informal and difficult formalized
If there is a large amount of data, incomplete information, redundant information, and data with a high level of noise, etc., it is most advisable to use neural networks. They solve the task of finding patterns effectively. Therefore, neural networks are actively used in studies of economic processes [7, 8, 9], in forecasting [10, 11, 12], in pricing [13, 14].

The purpose of this article is to choose a neural network to forecast prices for pumping equipment.

2. The problem statement
Pumps vary in design, use, and type [15]. Centrifugal pumps were selected for pumping wastewater in this article. The main characteristics of the pumps of this group are:

- productivity ($x_1$);
- pressure head ($x_2$);
- electric motor power ($x_3$);
- nominal diameter of the discharge port ($x_4$);
- nominal diameter of the impeller ($x_5$);
- efficiency ($x_6$);
- mass ($x_7$);
- rotational speed ($x_8$);
- rated current ($x_9$).

The specified basic parameters ($x_i$, $i=1…9$) will be considered as input when simulating. Price ($Y$) is output parameter simulation. Thus, a neural network can be used to forecast the price of pumps (Figure 1).

So it is necessary:

- to develop a neural network, where the input data will be the main characteristics of the pumps, and the output value of the price;
- to train the neural network using known algorithms;
- to assess the accuracy of the trained neural network;
- to test a neural network by known combinations of characteristics – price;
- to complete price forecasting using neural network.

3. Neural network model of prices forecasting
Simulating neural networks is time consuming, and ready-made software products are used for its implementation. The first packets of neural networks appeared in the late 80s of the twentieth century. To date, the number of such packages is very extensive. These may be add-ons to software products to support neural network simulating: Deep Learning Toolbox (former Matlab Neural Network Toolbox), Statistica Automated Neural Network, a set of libraries to implement some data processing: Excel...
Neural Package, specialized neural network packets: NeuroSolutions, Neural Work Professional, Neuro Shell, Mem Brain, Neuro Pro and so on. The analysis of these software products by such criteria as functionality, data processing functionality, documentation, speed of operation showed that the most preferred is Matlab Neural Network Toolbox. This package will be used in this research.

The initial (input) data for the simulation were taken from open Internet sources; the initial database was formed on their basis. It included 520 pump items, 500 of them were training samples and 20 were control samples. A fragment of the database is shown in Figure 2.

![Database fragment for simulation](image)

The article shows the simulation used neural networks of direct recognition, consisting of two layers, one of which is hidden. The choice of the network structure was made on the grounds that insufficient complexity can lead to a significant error, and excessive complexity can lead to the perception of noise as data for simulation, i.e. deprives the neural network of important properties of generalization.

Training of the neural network was carried out by the method of back propagation of error. While training, the values of the weights of the network are determined on the basis of examples (database) that form a training set, which has the form:

\[
(x_k, y_k, \ldots, x_1, y_1, \ldots) \quad k = 1, \ldots, 500
\]

where \(x_k \in \mathbb{R}^n\) is input vector from the \(k\)-th sample (\(n=9\) is number of inputs), \(y_k \in \mathbb{R}^m\) is a vector of required values (teacher's instructions) (\(m=1\) is number of outputs). Network training is with the teacher.

For each input set there is a pair set, specifying the required output values. These sets form a training pair together.

\(w \in \mathbb{R}^W\) is a current vector of neural network weights, determining the proximity of the network response vector \(y_k\) at the \(k\)-th sample and the corresponding vector of teacher instructions \(\tilde{y}_k\). \(W\) is the number of weights in the direct propagation neural network.

The quality of training, which determines the degree of compliance with the data from the training set is determined by a function of the form:
\[
E(w) = \sum_{k=1}^{500} (y_k(w) - \tilde{y}_k)^2 = \sum_{k=1}^{500} (F(x_i,w) - \tilde{y}_k)^2
\]

(2)

The purpose of training a neural network is to determine such a value of the weight vector \( w^* \), so that function (2) takes the minimum value. Thus, the process of training a neural network is reduced to solving the problem of unconditional optimization of the form:

\[
w^* = \arg \min_{w \in \mathbb{R}^n} E(w)
\]

(3)

There are many methods for solving (3). Several algorithms to be solved can be selected in software Deep Learning Toolbox (former Matlab Neural Network Toolbox). The Levenberg-Marquardt algorithm has several advantages: a fairly fast convergence; minimum computation time; no negative effect of local minima. The Levenberg-Marquardt algorithm represents a combination of the least squares method with the gradient descent method [16]. The analysis of the Levenberg-Marquardt algorithm showed that it achieves the smallest error in neural networks [17].

Algorithm for creating and configuring a neural network simulation in Deep Learning Toolbox (former Matlab Neural Network Toolbox) consisted of several stages:
1. determination of a training set;
2. selection of the network structure;
3. the training sample is divided into three subsets: “Training”, “Validation”, “Testing” (training is done according to “Training”, the training will be stopped according to “Validation”, and the total network operation will be determined according to the “Testing” data set);
1. determine the number of neurons in the hidden layer (change to adjust the network);
2. choose the training algorithm;
3. run the network;
4. obtain and analyze the results (if the results obtained are not satisfactory, the modeling steps are repeated from stage 3).

4. Results and discussion

According to the results of computational experiments, the two-layer structure of the neural network is optimal, consisting of 25 neurons in the hidden layer and one neuron in the open layer. The network has 9 inputs pump characteristics and 1 output price pumps. The structure of the neural network is shown in Figure 3.

![Figure 3. The structure of the neural network](image)

Network training takes place in 39 iterations, i.e. training stops when the network training ability stops improving on the data set “Validation”. The accuracy of the training (the dependence of the mean square error on the training iteration) is presented in Figure 4, errors for three data sets “Training”, “Validation”, “Testing” are shown. Training is terminated when an error on the set “Validation” does not decrease. “Best” index shows the best training outcome. “Test” shows the generalizing ability of the network.

The approximation of data by a neural network and a network error is shown in Figure 5. It is considered satisfactory for research purposes. A regression dependence plot is shown in Figure 6. “Fit”
line is a regression line based on empirical data, and “Y=T” line is a line constructed on the basis of the values calculated after the training (“T” array represents the data used for training, and “Y” array of output data calculated from the neural network training and serves to verify the accuracy of the mode).

R=0.96432 is the correlation coefficient that suggests a strong relationship between variables. Thus, the constructed neural network has high accuracy.

The results are saved in “Script” (Figure 7). The saved “Script” performs data modeling, not involved in the training process of the neural network.

![Figure 4](image1.png)

**Figure 4.** Accuracy of training of the neural network (the dependence of the standard error on the iteration of training)

![Figure 5](image2.png)

**Figure 5.** Neural network data approximation and network error
To check the work of the trained neural network, one selects data not involved in the training process (Figure 2, see the fill) and run the saved “Script”. The results of the simulation are presented in Figure 8 a), and the initial value is presented in Figure 8 b). The price offered by the neural network is 228091, and the price of the source data is 231187. The obtained results suggest the possibility of using neural networks for forecasting.

5. Conclusion
The article discusses an information model developed to forecast the price of pumping equipment using neural networks.

The performed computational experiment showed a high level of correlation between predicted and real price values.

Thus, price forecast using neural networks is a convenient tool in managing business processes. Such forecasting is especially important in the development of new technical products, when comparing prices for products, analogues of different manufacturers.

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