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PREDICTING THE DEMAND FOR CHEMICAL PHARMACEUTICAL PRODUCTS USING ARTIFICIAL NEURAL NETWORKS

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Abstract: An algorithm of prediction of demand for chemical-pharmaceutical products using artificial neural networks is proposed, the determinants affecting this demand are identified; the prediction of time series on the example of a pharmaceutical product of anthelmintic group is made.

Making prediction of demand for products of multiassortment low-capacity enterprises is an urgent task to date. According to generally accepted classification pharmaceuticals and chemical pharmaceutical products are referred to chemical products along with inorganic chemistry products, polymers, coating materials, synthetic dyes, organic intermediates, chemical reagents and very-high-purity chemicals [1]. Prediction of demand for pharmaceutical products is one of the most important trends in pharmaceutical companies. In a market economy, analysis of the demand for the products is of paramount importance [2].

The development of prediction as a science in recent decades has led to the creation of a variety of methods, procedures, techniques of prediction. There are over a hundred of prediction methods, that is why specialists need to choose methods that would provide adequate predictions about the processes and systems being studied.

To solve the problems of prediction and optimization, developing experimental mathematical models (**EMM**) based on accumulated information is urgent. By EMM we mean the operator $F: T \rightarrow D$, which provides a mapping of an input vector $T = (T_1, T_2, \ldots, T_M)$ into the output vector $D = (D_1, D_2, \ldots, D_N)$. Determining the structure and parameters of the EMM is on based on the training sample.

The most commonly regression models are used as EMM. However, the approximation of functional dependency $F: T \rightarrow D$ by power polynomials used in regression analysis is applied for small M-dimensional T-vector input parameters. When M increases the number of parameters of the polynomial being adjusted increases dramatically too, and training sample of the large amount of experimental data is required. For example, to approximate the dependence with 30 input variables, a power polynomial, containing about 46,000 parameters being adjusted is required [3].

Nowadays, there is an increasing need for systems which are able not only to perform once a preset sequence of actions on pre-defined data, but are also able to analyze the newly- incoming information, to find patterns in it, and to make prediction. In this area of applications the so-called artificial neural networks proved to be the best. This is an effective mathematical tool for processing «historical» data about a process.

Neural networks solve the problem of representation of nonlinear mapping $D = D(T, W)$, the shape of which is controlled by weight vector W.

For making prediction of demand in the pharmaceutical market, you need to know the determinants affecting this demand. All the determinants of demand for pharmaceuticals can be divided into internal, relating to the activities inside the enterprise being analyzed, and external, related mainly to the specific features of economic environment. For each product the most relevant determinants are selected.

Let's consider the effect of the most important internal determinants that collectively characterize the strategy of marketing of pharmaceutical company.

1. Product quality. High therapeutic indices, modern technologies, lack of side effects of pharmaceutical products contribute to the demand for them.

2. The dosage and the form of products.

3. The amount of expenditure on research and development. The higher the expenditure on research and development of the company-provider is, the faster the new product is spread.

4. Transnational level of the industry. The higher it is, the greater is the integration of the external sector, the larger is the number of foreign markets of a new product, the faster is its distribution and the more is the increase of demand for it.

5. Price. Discounts and other price benefits help to promote a new product to the market. In addition, the price in this case can be used as a barrier to entry of new firms.

6. Communication factors. Firms are actively involved in scientific and technical seminars, specialized workshops, demonstrate their developments and achievements. Thus, even before the launch of new products, the firms introduce them to the customers, creating a demand for them.

7. Advertising. Well thought-out advertising campaign promotes the formation and increase of demand.

Let's consider the external determinants of demand, most of which characterize the functioning of business environment of the enterprise, which produces and distributes its pharmaceutical products.

1. General economic condition of the state. If it is stable and the level of inflation is low, it does not disrupt the updating technical base, research is constantly carried out and new products for which there is demand come into market which stimulates new research.

2. Features of the political environment are crucial for companies producing high technology products.

3. Legal provision of economic activity. If science and scientific services, manufacturing and investment in technical upgrading of the subjects of the market economy enjoy tax benefits, it is a powerful factor stimulating the development and introduction of innovations in the industry.

4.Unfavorable ecological situation in the region is the stimulus of demand for new pharmaceutical products for strengthening and preventive purposes. Moreover, urbanization causing environmental degradation, will gradually stimulate the demand for means of immune protection of population from harmful environmental effects.

5. Technicalprogress and rapid obsolescence of a large number of products due to its acceleration.

6. Consumer income is a factor directly affecting the nature of demand: the higher is the income, the greater is the demand.

7. The number of people who are in need of this kind of a product.

8. The number of people of different age and gender.

Initial data for solving the problem of predicting demand for products is information that characterizes the economic situation in the market. Sources of this information may be both inside and outside the enterprise. Stating the problem is formulated as follows:

For the known volume of demand for the product range: $i,\ i = 1, \ldots, I$

$$\begin{array}{l} Q^1_{(t-n)},\ Q^1_{1+(t-n)},\ Q^1_{2+(t-n)},\ \ldots,\ Q^1_{m+(t-n)} \\ Q^2_{(t-n)},\ Q^2_{1+(t-n)},\ Q^2_{2+(t-n)},\ \ldots,\ Q^2_{m+(t-n)} \\ \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \\ Q^i_{(t-n)},\ Q^i_{1+(t-n)},\ Q^i_{2+(t-n)},\ \ldots,\ Q^i_{m+(t-n)} \\ \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \\ Q^I_{(t-n)},\ Q^I_{1+(t-n)},\ Q^I_{2+(t-n)},\ \ldots,\ Q^I_{m+(t-n)} \end{array}$$

and determinants

$$\begin{array}{l} X1^i_{(t-n)},\ X1^i_{1+(t-n)},\ X1^i_{2+(t-n)},\ \ldots,\ X1^i_{m+(t-n)} \\ X2^i_{(t-n)},\ X2^i_{1+(t-n)},\ X2^i_{2+(t-n)},\ \ldots,\ X2^i_{m+(t-n)} \\ X3^i_{(t-n)},\ X3^i_{1+(t-n)},\ X3^i_{2+(t-n)},\ \ldots,\ X3^i_{m+(t-n)} \\ \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \\ XK^i_{(t-n)},\ XK^i_{1+(t-n)},\ XK^i_{2+(t-n)},\ \ldots,\ XK^i_{m+(t-n)} \\ \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \end{array}$$

it is necessary to determine product demand at time $(t + z)$

$$Q^1_{(t+z)},\ Q^2_{(t+z)},\ Q^3_{(t+z)},\ \ldots,\ Q^i_{(t+z)},\ \ldots,\ Q^I_{(t+z)}$$

Let's consider the application of prediction methods on the example of sale of anthelmintic product «Vermoks», the determinants of which are price, price of its competitors, unemployment rate, cost of living, the dollar rate, the number of sick people.

Algorithm for solving the problem of prediction (Fig. 1) includes the following steps.

1. Preparation of input data. The table shows the factors affecting the demand for product «Vermoks»: II – sales volume, III – the price of a product, IV – the product price of competitors, V – unemployment, VI – cost of living, VII – the number of sick people, VIII – dollar rate . The year in increments of 1 month (Count I) is taken as an initial period.

2. Selecting the determinants. Significance of determinants is stated by a sales manager.

Initial data

I	II	III	IV	V	VI	VII	VIII
1	2020	75,15	68,45	4812500	4402	35475994	24,44
2	2102	76,11	69	4798500	4402	35474880	24,43
3	2905	76,93	69,5	4792300	4402	35474998	24,00
4	2403	77,35	70,15	4804500	4646	35475220	23,50
5	1715	78,85	71	4821500	4646	35475850	23,66
6	1830	79,82	72,12	4811200	4646	35473860	23,75
7	1751	81,05	73,2	4791400	4630	35471956	23,41
8	1810	82,12	74,35	4785600	4630	35472123	23,42
9	2302	83,25	75,1	4787800	4630	35476250	24,67
10	3106	85,10	76,5	4790900	4693	35475542	25,37
11	4717	86,23	77,25	4791200	4693	35471253	27,10
12	1620	87,38	78	4791800	4693	35472976	27,94

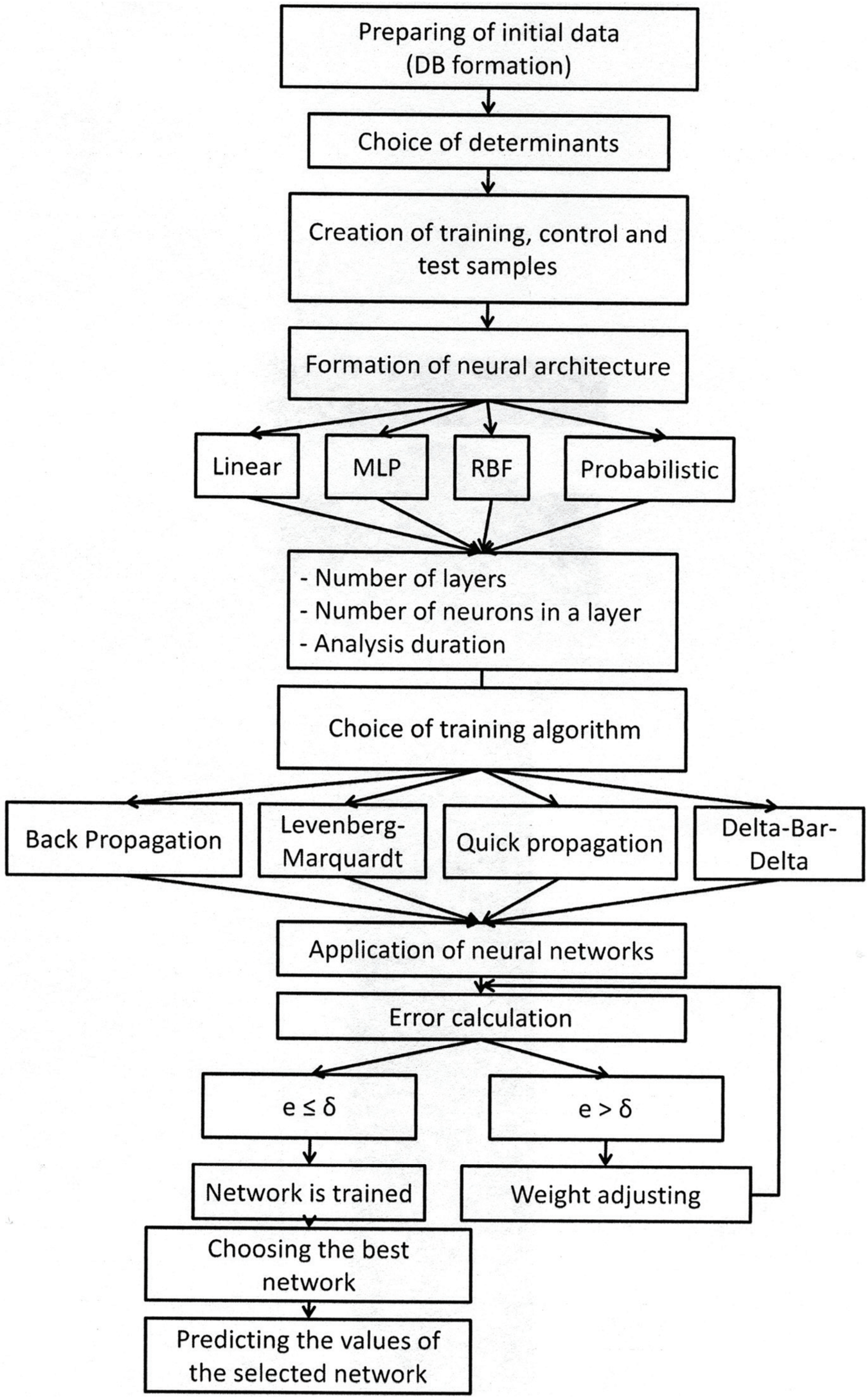

Fig. 1. Algorithm for solving the problem prediction

3. Training, control and test samples. Creation of samples required for training and testing network.

Formation of the architecture of neural networks (selection of the number of layers and the number of neurons in each layer). Selecting the type of network depends

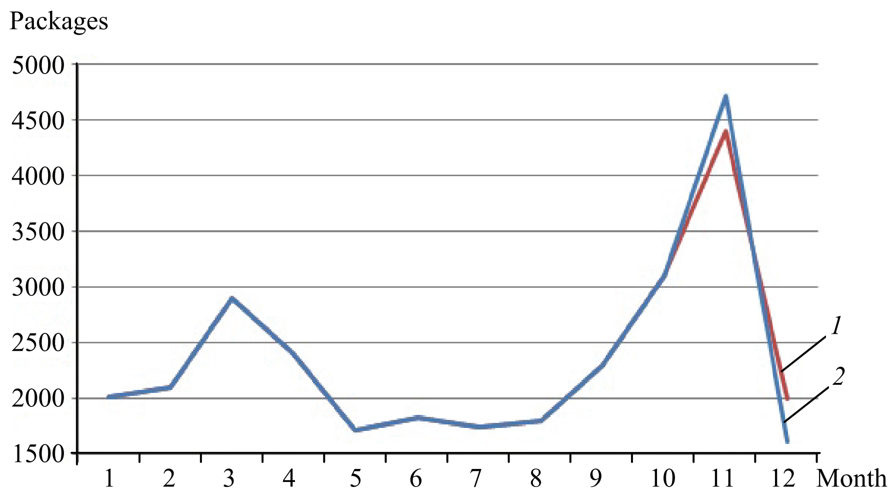

Fig. 2. Prediction error:
1 – prediction; *2* – initial series

on the type of problem being solved and the experience of the developer, who will be able to choose the best type of network for a specific task. If the choice of the type of network is unclear, you can choose several networks, and then select the best one.

4. The choice of learning algorithm (Back Propagation, Levenberg-Marquardt, Quick propagation, Delta-Bar-Delta). Studies have shown that for solving this problem, back-propagation algorithm is preferable.

5. Application of neural networks. Run the network for its learning.

6. Calculation of errors. Adapting the weights of neurons to match the training and control samples.

7. Choosing the best network. From multiple networks, the network with less error is selected.

8. Predicting the values of the selected network. Implementation of the prediction for the selected neural network. Independent verification of the prediction quality is one of the important problems in predicting. We must be sure that prediction in future will be close to the actual (observed) data. Therefore, before the analysis, the initial time series is shortened by 7–10 %, the «tail» of a series is stored for further analysis, and after that the prediction of «shortened» series is made and the result is compared with the delayed data. Provided that at the end of the observation period, the series was not intervened, we can expect that the measure of error obtained by comparing will be the estimation of an error for a future period. In other words, if our prediction of 2–5 % [4] differs from the observed data, we can expect that this problem persists in a future unobserved period.

Prediction error is within 5 % (Fig. 2), it means that it is rational to use this network for predicting future time intervals. Consequently, this network can be used for predictions of other products of anthelmintic group, and if necessary it can retrained, adding other factors.

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Прогнозирование спроса на химико-фармацевтическую продукцию методом искусственных нейросетей

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Ключевые слова и фразы: значимые факторы; искусственные нейронные сети; прогнозирование спроса; химико-фармацевтическая продукция.

Аннотация: Предложен алгоритм прогнозирования спроса на химико-фармацевтическую продукцию методом искусственных нейросетей; выявлены значимые факторы, влияющие на этот спрос, и осуществлен прогноз временного ряда на примере фармацевтического препарата антигельминтной группы.

Prognostizierung der Nachfrage auf die chemiepharmazeftische Produktion durch die Methode der künstlichen Neuronetze

Zusammenfassung: Es ist das Algorytmus der Prognostizierung der Nachfrage auf die chemiepharmazeftische Produktion durch die Methode der künstlichen Neuronetze vorgeschlagen. Es sind die wichtigen Faktoren, die auf die Nachfrage beeinflussen, gezeigt. Es ist die Prognose der Zeitreihe am Beispiel des pharmazeftischen Präparates der Anthelmintikgruppe verwirklicht.

Prognostic de la demande sur les produits chimiques et pharmaceutiques par la méthode des neuroréseaux artificiels

Résumé: Est proposé un algorithme du prognostic de la demande sur les produits chimiques et pharmaceutiques par la méthode des neuroréseaux artificiels, sont déduits les facteurs importants qui influencent sur cette demande, est effectué le prognostic du rang temporel à l’exemple de l’appareil pharmaceutique du groupe antihelminthe.

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