A Method for Forecasting the Demand for Pharmaceutical Products in a Distributed Pharmacy Network Based on an Integrated Approach Using Fuzzy Logic and Neural Networks

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Abstract. This article discusses the use of fuzzy logic and a neural network to predict the demand for pharmaceutical products in a distributed network, in conditions of insufficient information, a large assortment and the influence of risk factors. A comprehensive approach to solving forecasting problems is proposed using: the theory of fuzzy logic - when forecasting emerging and unmet needs and a neural network - if there is a lot of retrospective information about the actual sale of drugs and drugs. Using this approach to solve the problems of forecasting demand allows you to get statistics and experience. The general algorithm, mathematical interpretation and examples of forecasting the demand for pharmaceutical products in the face of uncertainty of information are given, and the general structure of the system for forecasting the demand for drugs is described.

Keywords: Pharmaceutical Market, Fuzzy Logic, Neural Networks, ABC Analysis, XYZ Analysis, Fuzzy Classification, Demand Forecasting, Uncertainty.

1 Introduction

The pharmaceutical market is an important area of the country's economy, which must be given special attention due to the fact that it is one of the necessary factors for the timely provision of human health. Today, there are a large number of pharmaceutical products (medicines and equipment), which are mass-market goods by terms, the use of which can be divided into durable goods (for example, sanitation, hygiene, medical devices) and short-term use (medicines, medicine plant materials, medical cosmetics) [1];

The main task of studying the situation in the sale of medicines is to predict and determine to what extent their state of sale corresponds to demand, how to change these indicators in the near future, and what methods should be used for forecasting in order to satisfy the failure-free provision of the population and pharmacy network with medicines and drugs.

As you know, the demand is divided into realized (satisfied - the actual sale of medicines with sufficient and constant availability in the pharmacy network), unsatisfied (medicines that are supplied to the pharmacy network in insufficient quantities or unevenly) and the emerging demand - clearly expressed demand for medicines , which, as a rule, include new and little-known types of pharmaceutical products.

Currently, there are a large number of forecasting methods [2]: - formal methods, expert forecasting, adaptive methods, etc. Studies have shown that at present there is no universal forecasting method that allows obtaining a forecast system for drug demand with sufficient accuracy for practical purposes.

In each case, it is necessary to choose the appropriate forecasting methods, focusing on the availability of reliable information. On the other hand, with insufficient information about demand satisfaction or with a small amount of retrospective, factual data, for example, in cases of emerging or unsatisfied demand, managers usually use their experience and intuition, and use unclearly formulated requirements, which leads to the use of an approach using soft computing technology [3].

2 Demand Forecasting Methods

We propose a comprehensive approach to solving the problem of forecasting using [3,4]: 1. the theory of fuzzy logic in predicting emerging and unmet demand and 2. the neural network in the presence of a large amount of retrospective information about the actual sale of drugs.

The general algorithm for predicting the demand for drugs is given below.

Step 1. Collection (taking into account the seasonality factor), filtering information on the sale of drugs and normalizing statistics. 2. Formation of interval dynamics between sales.

Step 2. Classification of sales taking into account the facts of profitability and the coefficient of variation, which allows to assess the stability of sales.

Step 3. If the drug belongs to a class for which there is not enough sales information, go to step 5.

Step 4. The use of a neural network to predict the time series of drug sales. To take into account the seasonality factor, choose the appropriate neural network architecture for predicting the insurance stock for drugs over a certain period of time.

Step 5. Applying fuzzy logic to determine the desired best quantity of demand for unmet and emerging demand. The base of fuzzy rules will be formed according to the experience, intuition of managers and taking into account the characteristics of medicines.

Step 6. According to the results of forecasting and fuzzy logic, to form a demand for medicines for a certain period.

Step 7. Calculate the total demand for medicines, taking into account the current balance of the drug in the warehouses of the pharmacy network.

3 Classification Of Drugs And Preparations According To Various Criteria And The Choice Of Method For Its Implementation

The main purpose of the classification of drugs and drugs is to understand how profitable and stable they are in demand and to determine the unprofitability of the goods sold and to give recommendations on choosing the forecasting method in step 2 of the algorithm for forecasting the demand for drugs that is described above.

Typically, these tasks in practice are solved using special methods - ABC (ranks products by contribution to total sales, which allows you to determine the importance of products) and XYZ (how easy it is to sell products and how predictable they are) analyzes [3,4]. Both methods of analysis are based on the Pareto principle and allow you to break down the weight of an assortment of goods into the following general classes:

1. ABC analysis: a). A - the most important (20% of the assortment = 80% of sales); in). B - intermediate (medium importance (30% of the assortment = 15% of sales); c). C - less important (50% of the assortment = 5% of sales).
2. XYZ analysis: a). X - steady demand and high forecast accuracy, so their sales volume is easy to predict (0 10%); in). Y is volatile demand (in particular, due to seasonality and stocks), but a forecast is possible. For more reliable results, an additional analysis can be carried out (10-25%); from). Z random demand, forecast is impossible, since there are no patterns in consumption (from 25%).

Combining both methods, you can get 9 classes of goods on the basis of which you can conduct a cross-analysis (table 1.) and give recommendations on choosing the method of forecasting them.

Table 1 Shows how important it is to correctly identify the goods belonging to the listed classes. Based on the clear interval values of the boundaries of ABC and XYZ classes based on Pareto principles, when moving between boundaries, you can incorrectly determine, for example, which class the product belongs to, for example, AX or AY, BX or BY, where it is recommended to predict and determine the insurance for classes AY and BY stock, and for classes AX and BX to conduct a forecast minus excess insurance stock.

In this regard, in this paper, a method for the classification of drugs and drugs using fuzzy logic is proposed. The foundations of the theory of fuzzy logic were developed by L. Zadeh

[5]. In the works of R.A. Aliyev [6] and other scientific researchers list the following basic algorithms for fuzzy inference:

1. Mamdani algorithm,
2. Tsukamoto algorithm,
3. Larsen algorithm,
4. Sugeno algorithm,
5. Aliyev algorithms (ALI-1, ALI-2, ALI-3,, ALI-4).

Suppose that there is 1.T {t1, t2, ..., tM}, where ti € T is the set of medicines and preparations (marketable products) for which classification is carried out; 2. set A - profitability-ordered goods (sales share), calculated as a percentage of total income, sorted in descending order and summed up by an cumulative total, which consists of fuzzy sets, for ABC classification, respectively, A1 (A), A2 (B), A3 (C); 3. the set Z - ordered by the value of the coefficient of variation (cv) of sales, which shows the percentage deviation of sales from the average and consists of fuzzy sets , for the XYZ classification, respectively, Z1 (X), Z2 (Y), Z3 (Z) and 4. the set G {g1, g2, ..., g9}, where gi € G is the set of combined classes described in Table 1. We assume that the lower the coefficient of variation, the greater the sales stability. The algorithm for ABC and XYZ analyzes is described in detail in papers, for example [5]. Assume that N rules are used to solve the problem:

$$\begin{array}{l} R_1\text{: if } x_1 \text{ is } A_1 \text{ and } x_2 \text{ is } Z_1 \text{ then } g \text{ is } G_1\ ; \\ R_2\text{: if } x_1 \text{ is } A_2 \text{ and } x_2 \text{ is } Z_2 \text{ then } g \text{ is } G_2\ ; \\ \qquad\qquad \ldots \\ R_n\text{: if } x_1 \text{ is } A_n \text{ and } x_2 \text{ is } Z_n \text{ then } g \text{ is } G_n\ ; \end{array} \tag{1}$$

, where i € 1 ... N, where N is the total number of fuzzy inference rules; x and y are the names of the input variables; g is the name of the output variable; A1, A2 ... An; B1, B2..Bn; G1, G2 ... Gn are some given membership functions, and a clear knowledge of g (0) must be determined on the basis of the information given and the clear values of x1 (0), x2 (0).

The maximum number of rules depends on the number of terms of fuzzy linguistic variables that correspond to fuzzy sets A and Z. We present the Sugeno algorithm for the general case where the number of rules is not known in advance.

1. We determine the degrees of truth for the premises of each rule (Rn, n € 1..N):

$$\begin{array}{l} R_1\text{: } \{A_1(x_1(0)),\ Z_1\ (x_2(0))\}, \\ R_2\text{: } \{A_2(x_1(0)),\ Z_2\ (x_2(0))\}, \\ \qquad \ldots \\ R_n\text{: } \{A_n(x_1(0)),\ Z_n\ (x_2(0))\}. \end{array} \tag{2}$$

2. Applying the operation of the fuzzy logical minimum (in the formulas through "∧"), we find the "cut-off" levels for the premises of each of Rn, where n € 1 ... N.

$$R_1\text{: } \alpha_1 = A_1(x_1(0)) \wedge Z_1\ (x_2(0)),$$

$$R_2\colon \alpha_2 = A_2(x_1(0)) \wedge Z_2\,(x_2(0)),$$
$$. \quad . \quad . \qquad (3)$$
$$R_n\colon \alpha_n = A_n(x_1(0)) \wedge Z_n\,(x_2(0)).$$

Table 1. Properties of fuzzy classes and recommendations for choosing a method for forecasting sales.

Class Number	Class name	Class properties	Recommendations for choosing a forecasting method
1	CZ	Low importance of goods, irregular consumption, low predictability	Insufficient information about the sale - to forecast based on the experience and intuition of managers (fuzzy logical conclusion)
2	CY	Low importance of goods, seasonal fluctuations, medium degree of predictability	The constant amount of orders is to predict, based on the neural network, with a delay of 3 months (fuzzy inference), safety stock with the possibility of the company
3	CX	Low importance of goods, stable consumption, high predictability	A large amount of retrospective static data - to forecast safety stock based on a neural network
4	BZ	Medium importance of goods, irregular consumption, low predictability	Insufficiency of information about the sale - to predict, based on the experience and intuition of managers (fuzzy inference), safety stock
5	BY	The average degree of importance of goods, seasonal fluctuations, the average degree of predictability	Neural Network Needs to Predict Safety Stock
6	BX	Medium importance of goods, stable consumption, high predictability	A large amount of retrospective static data - it is necessary to forecast demand based on a neural network and minus excess safety stock
7	AZ	Very important goods, irregular consumption, low predictability	Insufficiency of information about the sale - to predict, based on the experience and intuition of managers (fuzzy inference), safety stock
8	AY	Very important products, seasonal variations, medium predictability	Neural Network Needs to Predict Safety Stock
9	AX	Very important products, stable consumption, high predictability	A large amount of retrospective static data - it is necessary to forecast demand based on a neural network and minus excess safety stock

3. We determine the individual outputs for each of Ri, where i € 1..N:

$$
\begin{aligned}
&R_1\text{: } g_1^* = a_1x_1\ (0) + b_1x_1\ (0);\\
&R_2\text{: } g_2^* = a_2x_1\ (0) + b_2\ x_2(0);\\
&\quad\quad . \ . \ .\\
&R_n\text{: } g_n^* = a_nx_1\ (0) + b_nx_2\ (0);
\end{aligned}
\tag{4}
$$

4. Determine the clear value of the output variable:

$$
g_0 = \sum_{i=1}^{N} \frac{\alpha i *\ g_i^*}{\alpha i} \tag{5}
$$

Based on this algorithm, Sugeno developed a fuzzy inference system for the classification of medicines and drugs, which includes two inputs: share of income and coefficient variation of sales determining the level of sales stability, as well as one output - classification groups.The following is a description of a fuzzy inference system for classifying drugs and drugs.

3.1 Definition Of Input Variables

As a linguistic variable for the input variable share of income (x1), three sets of fuzzy variables were chosen (Figure 1) having the following nonlinear forms of membership function [5,6]:

1. high profitability - zmf (Z-shaped membership function) with parameters [0.7685 0.8241];
2. average profitability - miidle gbellmf (Generalized bell-shaped membership function) with parameters [0.0467 5.46 0.8443];
3. low profitability - smf (S-shaped membership function) parameters [0.8717 0.9114].

For the input variable x2 (sales stability - determined by the values of the coefficient of variation of sales), three sets of fuzzy variables were selected (Fig. 2) having the following nonlinear forms of membership function:

1. High sales stability (corresponding to the concept - the coefficient of variation is low) - zmf c parameters [0.09656 0.167];
2. average sales stability (corresponds to the concept - the coefficient of variation is average) - gbellmf with parameters [0.082 8.17 0.218];
3. low sales stability (consistent with the concept - the coefficient of variation is high) sigmf (Sigmoidal membership function) with parameters [150 0.2976].

Note that the calculated values of these input parameters are in the range x € [0..100]. Normalization of these indicators is carried out with the separation of the values of the input parameters to their maximum value.

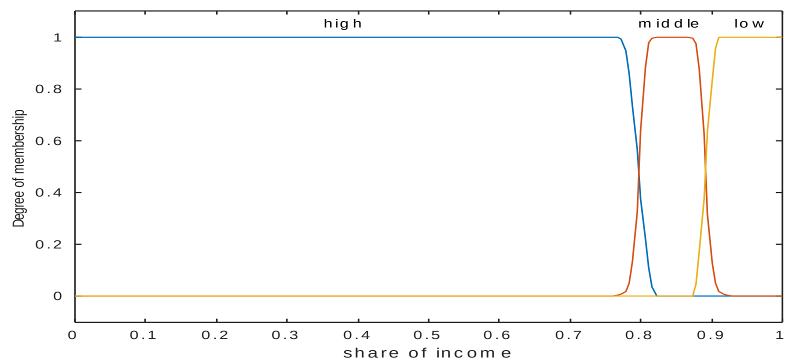

Fig. 1. Membership functions of the input variable x1 (share of income)

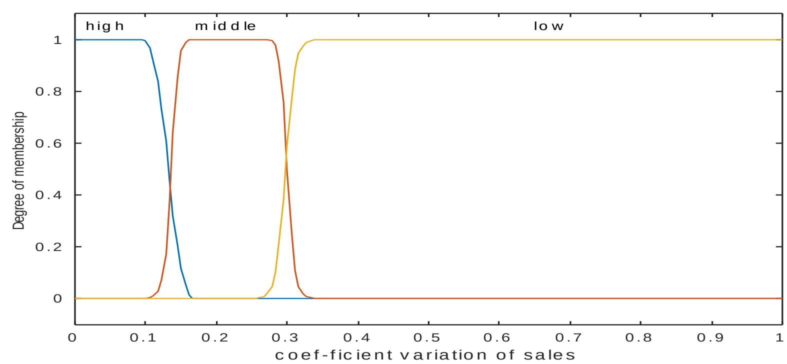

Fig. 2. Membership functions of the variable x2 (coefficient variation of sale (sales stability))

3.2 Output Variable

The output variable Qroups has 9 linear expressions corresponding to discrete class values shown in Table 1., respectively: Output = 9 - group ‘AX’, Output = 8 - group ‘AY’, Output = 7 - group ‘AZ’; Output = 6 - group ‘BX’, Output = 5 - group ‘BY’, Output = 4 - group ‘BZ’ , Output = 3 - group ‘CX’, Output = 2 - group ‘CY’, Output = 1 - group ‘CZ’.

3.3 Rules

Nine rules were created for the connection of input and output variables, formed on the basis of table 2.

These rules provide the choice of one of the output expressions, depending on the

Table 2. Inference rules.

share of income	Sales stability		
	high	**middle**	**low**
high	AX	AY	AZ
middle	BX	BY	BZ
low	CX	CY	CZ

values of the input variables.A weighted average (wtaver) was used as a defuzzification method [3].The resulting approximated surface of the inference system is shown in Fig. 3.

3.4 Analysis of the results

Evaluation of the effectiveness of the developed inference algorithm for the classification of drugs and drugs was carried out using the approximate data shown in tables 3.

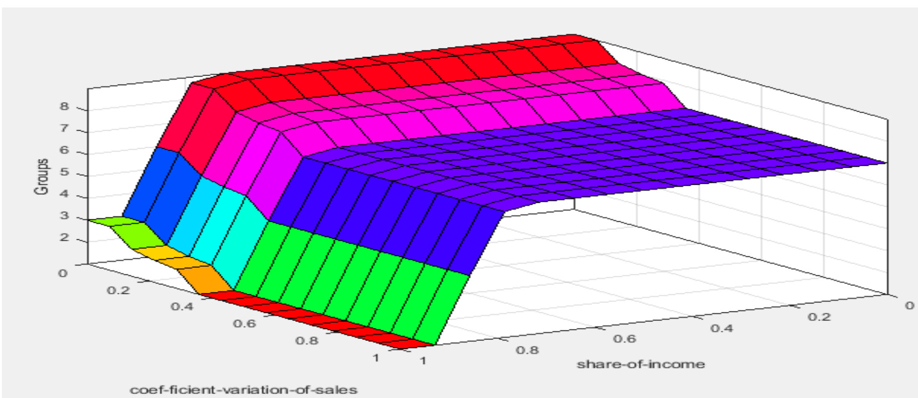

Fig. 3. Approximate surface

The results of a fuzzy logical conclusion are given, where the corresponding classes for each drug are determined: 1.Drug1 corresponds to class AX, 2. Drug2 corresponds to class BY, 3. Drug3 corresponds to class CY, 4. Drug4 corresponds to class CZ, 5. Drug5 corresponds to class CZ 6. Drug6 corresponds to the class AZ, 7. Drug7 corresponds to the class CZ, 8. Drug8 corresponds to the class AX.

An analysis of the results shows the high efficiency of the proposed inference algorithm for the classification of drugs.

Table 3. The share of sales of goods and the coefficient variation of sales.

Drugs	Share of income			Coefficient variation of sales					
	Income	Share		Sales					
				March	April	May	June	July	
Drug1	284	18.66%	0.75	80	68	75	76	73	0.05
Drug2	154	10.12%	0.85	36	37	28	40	18	0.25
Drug3	28	1.84%	0.99	26	25	30	18	23	0.16
Drug4	16	1.05%	1	20	10	15	7	21	0.37
Drug5	70	4.60%	0.97	20	7	30	21	28	0.38
Drug6	360	23.65%	0.57	27	32	12	10	10	0.52
Drug7	110	7.23%	0.93	15	27	32	18	10	0.39
Drug8	500	32.85%	0.33	18	19	22	25	21	0.12

After determining the class in accordance with the proposed recommendations, you can choose a method for forecasting demand for each product individually: 1. In conditions of sales stability, a large amount of retrospective static data and uncertainty, it is mainly proposed to use a neural network solution as a forecasting method [3,4,7,8,9].

The forecasting problem is posed as the problem of approximating a number of dynamics, i.e. It is proposed to use the Generalized Regression Neural Network (GRNN) [7] to construct a function by a finite set of points, by the number of sales of medicines taken by months, and for ease of calculation and the reliability of forecasting sales for goods from classes such as AX, BX, CX. 2. For goods from the class AY, BY, CY which are characterized by quarterly, steady changes repeating from month to month in levels, i.e. seasonal variations, it is proposed to use a neural network with a delay at the entrance. 3.

The lack of information and the small amount of statistics on the sale determines the use of an expert system for making decisions on determining the demand for goods from the class AZ, BZ, CZ. To this end, to solve this subproblem, we built an expert system based on the Mamdani fuzzy logic inference algorithm in the Fuzzy Logic Toolbox of the MATLAB computing environment [7].

CONCLUSION

Using this approach to solve the problem of demand forecasting allows taking into account both statistical data and the experience and intuition of the managerial staff of the pharmacy network at various stages of demand forecasting and is flexible in terms of the availability of sufficient information about demand. Since, with an increase in the sale of medicines and drugs using this approach, demand moves from the class of dissatisfaction to realized demand.

Due to the fact that drugs have their own specific features, we are conducting further research to improve the expert system in order to determine the desired best amount of demand for unmet and emerging demand.

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