Possibilities of Mathematical Modeling of a Self-Organizing System

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ABSTRACT

The article focuses on the creation of regression models for forecasting the development of manufacturing enterprises engaged in trade, using information technology, based on self-organizing information systems. The article considers the possibility of developing methods and algorithms to improve the efficiency of the functioning of a self-organizing information system by forecasting and searching for the collection of relevant information. This article aims to show the role of information systems in the trading processes of an enterprise using the method of regression and correlation analysis. Specific mathematical models of nonlinear type have been developed for forecasting and analysis, commercial and private property. Graphical interpretations of the results obtained using the WindowsXP office application are given.

Keywords: Regression and correlation analysis, information system, least squares method, forecast.

Let's consider the possibilities of developing mathematical models for forecasting the development of trade enterprises using a single information base on trade. Automation of trade analysis and forecasting using information technology based on self-organizing information system (SIS) requires special scientific research [1].

Based on the above, as well as the analysis of foreign experience in improving the management of a trading enterprise [5] showed that there is currently no scientifically sound approach to automating the solution of trading tasks using new information technologies and mathematical methods. It should be noted that mathematical modeling of enterprises' activities requires initial data, the discreteness of information technology and the structure of a trade enterprise. At the same time, the trading enterprise is a dynamic, non-stationary system, the structure and technology of which requires updating. As a result, these updates are the end result of the enterprise itself, or rather its information systems, which gives reason to consider the trading enterprise a self-organizing system.

At the same time, the governing bodies are provided with reliable data for making informed decisions. The implementation of the above approach requires the following work:

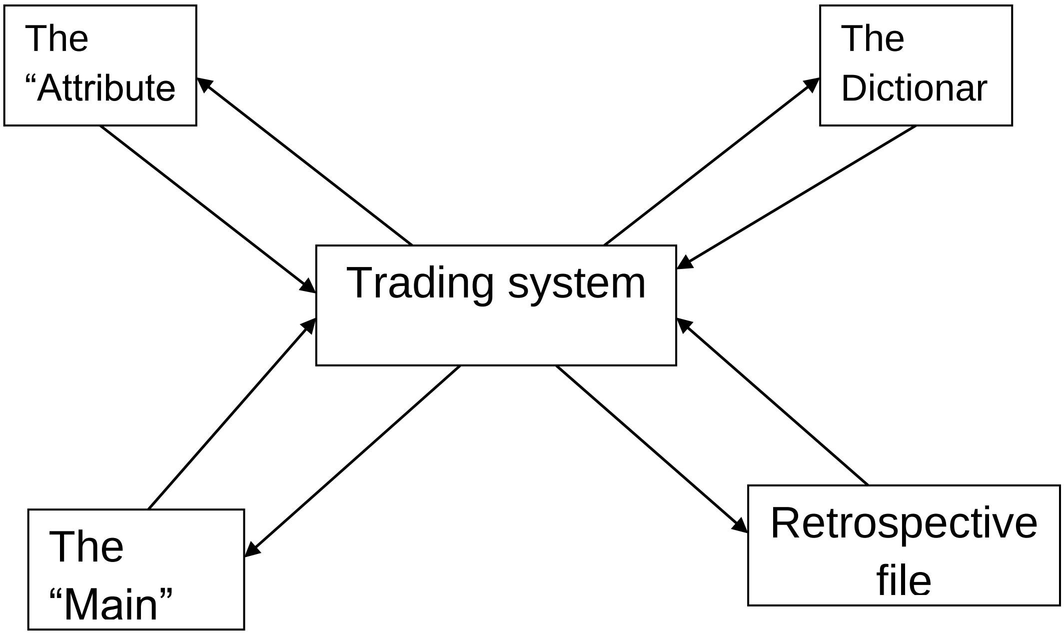
-determination of the initial features necessary for the analysis and forecast of the development of trading enterprises;

- formation of a unified trade information base;

-definition of the type of mathematical models intended for the analysis and forecast of the development of trade enterprises;

-generation of input data using IPS to solve the developed mathematical models.

Figure 1 shows the functional scheme of processing trade information based on the SIS.



Pic.1

One of the main issues is the choice of the type of mathematical models. They should clearly define the output results by processing and using the information base stored on the server of computer networks. The composition and structure of the information base is dynamic (due to new and knocked-out enterprises) and works on-line. Based on this, we have selected regression models for forecasting the development of trade enterprises, which are described below.

Let an endogenous trait be described as a function of exogenous features $X = (x_i, i = 1, N)$ in the form:

$Y = F(X, A)$ (1)

The parameters are $A = (a_i, i = 1, N)$ selected in such a way that the condition is met:

$$\sum_{i=1}^{N}[Y_i - F(x_i, a_i)]^2 \to \min$$

where is the $i-$ surveillance number;

Y_i – the actual value of the endogenous trait at the point X_i;

$F(x_i, a_i)$ – the calculated value Y at the point x_i; .

The method of determining the parameters a_i is described in [3].

When developing adequate models for predicting the retirement of trading enterprises, we hypothesized that the future is a continuation of the retrospective period while maintaining the stability of existing trends. The forecast error is estimated by the formula

$$S_Y = \sqrt{\frac{1}{N-1}\sum_{t=1}^{N}[Y_t - Y_t^{\Phi}]^2}$$

where $N-$ is the total number of observations related to the retrospective period;

Y_t- the calculated value of an endogenous trait Y in a period of time t;

Y_t^{Φ} – the actual values of the attribute Y in the period t;

Further, we assumed that the prediction error obeys the normal distribution law. With probability, $p = 0{,}95$ the expected forecast values of the function will be in the interval

$Y_t - 2S_Y \le Y \le Y_t + 2S_y$

The accuracy of the approximation can be estimated by the formula

$$\varepsilon = \frac{1}{N}\sum_{t=1}^{N}\frac{\Delta Y_t}{Y_t^{\Phi}}100\%$$

where $\varepsilon-$ is the allowable approximation error, which varies within 5-10%;

$\Delta Y_t = \left| Y_t^{\Phi} - Y_t \right|$ – it is used when analyzing values in the interval $\lfloor -2S_y, 2S_y \rfloor$.

The forecast values of the function need to be adjusted. To do this, the value is calculated:

$$\eta_t = \left| (Y_{t+1}^{\Phi} - Y_{t+1}) - (Y_t^{\Phi} - Y_t) \right|$$

Where Y_{t+1}^{Φ} - is the retrospective data of the function (1) in the time $t+1$ period;

Y_{t-1} – the theoretical value of a function (1) in a time $t+1$ period;

$t+1$ sliding step, in a period t of time.

The average value of the sliding step for the period is $N-$ calculated by the formula:

$$\eta = \frac{1}{N-1}\sum_{i=1}^{N-1}\eta_i;$$

We use acceptable limits for values ΔY_t in the form $z_1 = 2{,}66\eta, z_2 = -2{,}66\eta$

Based on this $\Delta Y_t \in [z_1, z_2]$, if the values are , then the predictive function is sufficiently adequate for the process under study. At $\Delta Y_t \notin [z_1, z_2]$, then it is necessary to analyze the predictive (1) functions and features describing the process under study, which are included in (1) .

To develop the model (1), we used retrospective data on the disposals of private property trading enterprises, which are shown in Table 1.

Table 1.

Year												
	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021
Number of enterprises thousand pcs.	10	13	17	16	26	23	29	36	41	46	44	48

The authors developed programs for determining the coefficients of the function,and also used the application of the WindowsXP[2].As a result of calculations, a specific type of dynamic model is determined, which has the following form:

$$Y = 11{,}04 - 0{,}75t + 0{,}79t^2 - 0{,}04t^3$$

To check the adequacy of the model, the Fisher criterion was used, the calculated value of which is equal to $F_p = 94{,}81$. Let 's compare it with a tabular value at the level of significance $\alpha = 0{,}05$ and the number of power $K_1 = 3,\ K_2 = 8.$ freedom It is equal to $F_t = 4{,}04$ Therefore, at the level of significance $\alpha = 0{,}05$ and retrospective data t over time are significant. Based on the above data, we calculate the accuracy of the approximation

$$\varepsilon = \frac{1}{N}\sum_{t=1}^{N}\frac{\left|\Delta Y_t\right|}{Y_t^{\Phi}}100\% = 7{,}83$$

Thus, the accuracy of the approximation does not exceed the permissible error value. To check the stability of the retirement of trading enterprises during the retrospective period, we calculate the average moving step

$$\eta = \frac{1}{N-1}\sum_{t=1}^{N-1}\eta_t = 3{,}65$$

Let's define the control limits:

$$z_1 = 2{,}66 * \eta = 2{,}66 * 3{,}65 = 9{,}70$$

$$z_2 = -2{,}66 * \eta = -2{,}66 * 2{,}65 = -9{,}70.$$

Analysis of Table 2 shows that the values ΔY_t do not exceed the control limits. Thus, the developed model is adequate for forecasting the development of trading enterprises. Giving now t the values $t = 13{,}14{,}15{,}16 ...,$ we calculate the forecast values of the development of trading enterprises until 2021. Table 3 shows the lower and upper limits of the expected retirement of trading enterprises

Table 2.

Years in quarters(t)	Actual values ($Y^{\phi}{}_t$)	Forecast values (Y_t)	$\Delta Y_t = Y_t{}^{\Phi} - Y_t$	Sliding step (η_t)
1	10	11,05	-1.05	1,65
2	13	12,40	0,60	1,54
3	17	14,86	2,14	4,34
4	16	18,20	-2,20	6,03
5	26	22,17	3,83	7,38
6	23	26,55	-3,55	1,46
7	29	31,09	-2,09	2,53
8	36	35,55	0,45	0,84
9	41	39,71	1,29	1,39
10	46	43,32	2,68	4,83
11	44	46,15	-2,15	2,19
12	48	47,05	0,05	
Total				34,18
13		46,95		
14		45,60		
15		42.40		
16		37.4		

Table 3.

Lower bound (Y_t)	Forecast values (Y_t)	Upper bound (Y_t)
6,53	11,05	15,56
7,88	12,40	16,92
10,34	14,86	19,38
13,68	18,20	22,72
17,66	22,17	26,69
22,03	26,55	31,07
26,57	31,09	35,61
31,04	35,55	40,07
35,19	89,17	44,23
38,80	43,32	47,84
4163	46,15	50,66
43,43	47,95	52,47

Thus, for the implementation of this method, we have proposed and performed the following stages of work that allow us to analyze and predict the development activities of trade enterprises:

-the most significant signs affecting the level of trade have been identified;

-information links between the signs are determined -the analysis of the dynamics of the development of trading enterprises is carried out;

-the confidence intervals of the forecast of the development of trading enterprises are calculated.

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