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Modeling of information processing in the Internet of Things at agricultural enterprises

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Abstract. The paper discusses the features of solving problems related to the modeling of information in the Internet of things in the organizations of the agricultural sector. It is noted that by improving the efficiency of information processing increases competitiveness, reduced costs. It is shown how the reduction of indicators of monitoring evaluation in the Internet of things in terms of importance for the optimization of resource efficiency of agricultural companies. The features of using a combination of several methods for processing and modeling of reduced monitoring information in the Internet of things system are given. The block diagram of the implementation of a combination of methods for processing reduced monitoring information in the Internet of things system is given.

1. Introduction

The main objectives in the field of agriculture are to ensure competitiveness and resource efficiency. If competitiveness is largely determined by reputational factors and the level of service partners, the resource efficiency depends on factors affecting the financial and economic condition of the agricultural enterprise. Administrative management of resource efficiency is carried out separately in two areas: increasing revenues and reducing costs for the implementation of an agricultural company. It is interesting to develop an algorithm in which the processing and modeling of reduced monitoring information in the framework of the Internet of Things in agriculture.

2. The reduction of monitoring evaluation indicators in the Internet of Things system in order to optimize the resource efficiency of an agricultural company

There are different sets of control actions that affect income and costs in an agricultural company.

1. The monitoring-the rating assessment with the technology of the Internet of Things happens for $i = \overline{1, I}$ activities of agricultural companies. Each i -th direction includes estimates for j_i indicators $W_{ji}, j_i = \overline{1, J_i}, i = \overline{1, I}$, the values of which form time series for the entire period of monitoring observations (random processes) [1, 2].

$$W_{ji}(t), t = \overline{1, T}. (1)$$

There is also information about the position of the agricultural company in the rating lists [3, 4]



$$G_i(t), t = \overline{1, T}, h = \overline{1, H},$$

where $h = \overline{1, H}$ is the numbering set of ratings in which the i –th agricultural company participates.

Optimization of resource efficiency depends on the ratio of income and expenses for a certain calendar period, the level of which in turn is influenced by the performance indicators of the agricultural company, the values of which are obtained on the basis of annual monitoring evaluation [5].

Making a quality management decision on the basis of a formalized optimization problem essentially depends on its dimension [6].

In this case, the dimension is determined by the number of indicators in the monitoring $W_{ji}, i = \overline{1, I}, j_i = \overline{1, J_i}$. Therefore, there is a need to reduce their number. To reduce the set of indicators of the optimization model, we select those that have the most significant impact on the change in income and expenses, taking into account the entire period of monitoring indicators in the Internet of Things system $t = \overline{1, T}$.

Changes in income, expenses and ratings are presented in the form of random processes

$$Q(t); D(t); G(t); t = \overline{1, T}; \tag{2}$$

the tightness of correlation links between random processes (1) and (2) varies depending on the time shift $\tau = \overline{0, T - 1}$ between them;

as a quantitative estimate of the closeness of connections, we will use the unbiased estimate of the normalized mutual correlation function [7] characterizing the degree of influence of one random process on another, in particular, $W(t)$ on $Q(t)$

$$K_{y_{jic}}(\tau) = \frac{\sum_{t=\tau+1}^T [W_{ji}(t) - \overline{W_{ji}}][Q(t + \tau) - \overline{Q}]}{(T - \tau - 1)\sigma_{y_{ji}}\sigma_c}, \tau = \overline{0, T - 1}, \tag{3}$$

where $\overline{W_{ji}}, \overline{Q}$ – is an unbiased estimator of the mathematical expectation of random processes $W_{ji}(t), Q(t)$

$$\overline{W_{ji}} = \frac{\sum_{t=1}^T W_{ji}(t)}{T}, \overline{Q} = \frac{\sum_{t=1}^T Q(t)}{T};$$

$\sigma_{W_{ji}}, \sigma_G$ – unbiased estimates of the standard deviation of random processes

$$\sigma_{y_{ji}} = \sqrt{\frac{\sum_{t=1}^T (W_{ji}(t) - \overline{W_{ji}})^2}{T-1}}, \sigma_c = \sqrt{\frac{\sum_{t=1}^T (Q(t) - \overline{Q})^2}{T-1}};$$

to select significant indicators, in addition to quantitative correlation estimates, the results of their visual transformation and expert assessments should be used.

Based on these assumptions, the following procedure of reduction of monitoring evaluation indicators is proposed.

1. Calculation of unbiased estimates of mathematical expectation and standard deviation of random processes (1), (2).
2. Calculation of unbiased estimates of normalized mutual correlation functions according to (3):

$$K_{W_{jic}}(\tau), K_{W_{jiz}}(\tau), i = \overline{1, I}, j_i = \overline{1, J_i}. \tag{4}$$

3. Determination of τ values at which the values of functions (4) reach the maximum [8]:

$$\hat{\tau}_{W_{jic}} \rightarrow K_{W_{jic}}(\hat{\tau}) = \max_{\tau}, i = \overline{1, I}, j_i = \overline{1, J_i}; \hat{\tau}_{W_{jiz}} \rightarrow K_{W_{jiz}}(\hat{\tau}) = \max_{\tau}, i = \overline{1, I}, j_i = \overline{1, J_i}. \tag{5}$$

4.The visual transformation of sets (5) is carried out by construction for all $i = \overline{1, I}$ the rank of the diagram changes of \hat{t} depending on $j_i = \overline{1, J_i}$ to reflect changes in the influence W_{ji} on $Q, j_i = \overline{1, J_i}$, W_{ji} on $Q, j_i = \overline{1, J_i}$ from smallest time period \hat{t} in which the influence is maximum, to more.

5.Expert evaluation of the ordered numeration set of indicators before the jump of $\bar{\tau}$ change in the diagrams at $i = \overline{1, I}$ [9, 10] effects $W_{j_{1i}}$ on $Q, i = \overline{1, I}, j_{1i} = \overline{1, J_{1i}} \in \overline{1, J_{1i}};$ (6)
 $W_{j_{2i}}$ on $D, i = \overline{1, I}, j_{2i} = \overline{1, J_{2i}} \in \overline{1, J_{2i}};$

6.Completion of the first stage of reduction by forming a reduced set of indicators depending on the quantitative estimates of correlation and expert assessments of the results of visual transformation (6):

$$W_{i1} = \bigcup_{i=1}^I W_{j_{1i}}, j_1 = \overline{1, J_1}; W_{i2} = \bigcup_{i=1}^I W_{j_{2i}}, j_2 = \overline{1, J_2}. \tag{7}$$

7.Transition to the second stage of set reduction (7) based on optimization modeling and expert evaluation. We associate this transition with quantitative estimates.

3. The use of many methods in the processing and modeling of reduced monitoring information in the Internet of Things

Pre-reduction indicators, monitoring of assessment in the system of Internet of things in order of importance for optimization of resource efficiency allows as a source of information for subsequent processing and plotting the dependencies required in the formulation of optimization problems use the following random processes:

indicators affecting changes in income of agricultural companies

$$W_{j_1^*}(t), j_1^* = \overline{1, J_1^*}; \tag{8}$$

indicators affecting changes in agricultural companies' expenditures

$$W_{j_2^*}(t), j_2^* = \overline{1, J_2^*}. \tag{9}$$

An important role in making optimal management decisions is played by the amount of costs that contribute to increasing revenues and improving the resource efficiency of agricultural companies

$$D'_{j_3}(t), j_3 = \overline{1, J_3}, \tag{10}$$

where $j_3 = \overline{1, J_3}$ – direction that contribute to the increase of incomes and increase resource efficiency. Thus $\sum_{j_3}^{J_3} z'_{j_3} = z'$ – the additional costs.

For the control object under study, random processes (8) – (10) will be input processes and output processes (2).

On the basis of random processes the values of resource efficiency at time $t = \overline{1, T}$ are calculated

$$F = V_F(Q(t), D(t)) \tag{11}$$

Considering random processes (2), (8)-(11) as time series [11] we construct prognostic models for them:

$$W_{j_1^*}(t) = f_{j_1^*}(t); W_{j_2^*}(t) = f_{j_2^*}(t); D_{j_3^*}(t) = f_{j_3^*}(t); \tag{12}$$

$$Q(t) = f_Q(t); D(t) = f_D(t); F(t) = f_F(t); G_e(t) = f_{G_e}(t). \tag{13}$$

The success of solving the forecasting problem using models (12), (13) depends on the validity of the choice of the method of its solution, taking into account the volume and quality of information about the predicted process [12].

It is proposed to apply a multi-method approach, which allows to use for the construction of models $f(W, t)$ a number of ways to select their structure and determine the parameters in order to provide a compromise between the accuracy and computational complexity of forecasting. As part of this approach, we will focus on the analysis of the above indicators in the case of the following model structures.

The figure 1 shows how the reduction mechanism works in time series describing monitoring information in the Internet of Things system.

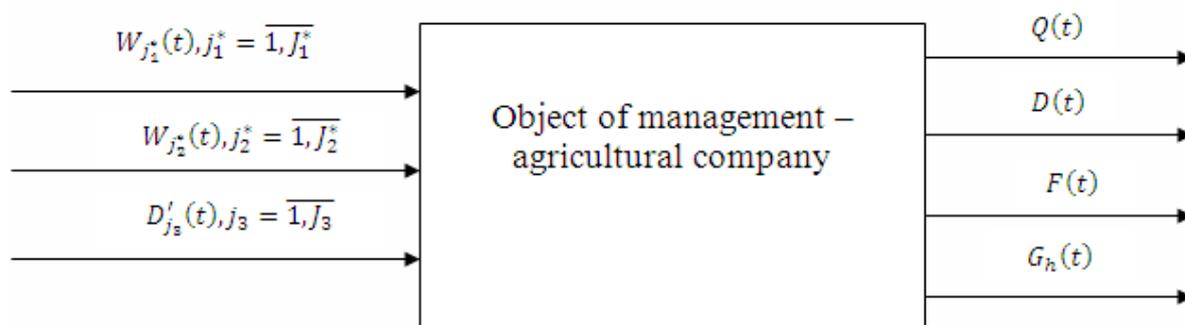


Figure 1. Illustration of the mechanism of information reduction in time series describing monitoring information in the Internet of Things system.

1. Additive function

$$f(W, t) = \sum_{x=1}^X a_x \varphi_x(t), \tag{14}$$

where $\varphi_x(t)$ – time functions of the simplest form; a_x – unknown parameters.

When comparing the forecasting indicators, we use power-law time functions

$$\varphi_x(t) = t^{xp},$$

where $p \geq 0$ – a parameter that is selected from a set of positive integers or fractional numbers specified during the comparative analysis. The parameters $a_x, x = \overline{1, X}$ should be determined by the least squares method [11, 13].

2. In the form of elementary functions:

linear

$$f(W, t) = at; \tag{15}$$

quadratic

$$f(W, t) = a_0 + a_1t + a_2t^2; \tag{16}$$

significant

$$f(W, t) = a_1e^{a_2t}. \tag{17}$$

The parameters of these functions are determined by the exponential smoothing method. The resulting predictive models are used in conjunction with the models (14) in a comparative analysis of the accuracy and complexity. As a result, the final predictive model for each time series (12), (13) is selected.

The multi-method approach involves not only the selection of the structure and parameters of prognostic models (14)-(17), which are functions of time on the interval $t = \overline{1, T}$ and allow to determine their values for a given criteria of planning the activities of agricultural companies $T + t_1, t_1 = \overline{1, T_1}$. In addition, it is required to present the dependence of time series (13) on time series (12). Use for this purpose the regression equation with the inclusion of the number of variables of time t [7, 8]:

$$Q = \varphi_Q(W_{j^*1}, D'_{j_3}, t), \quad D = \varphi_D(W_{j^*2}, D'_{j_3}, t), \quad F = \varphi_F(Q, D) = \varphi_F(W_{j^*1}, W_{j^*2}, D'_{j_3}, t), \quad G_h = \varphi_{Gh}(W_{j^*1}, W_{j^*2}, D'_{j_3}, t). \quad (18)$$

Models (18) allow us to calculate for the given planning boundaries $t_1 = \overline{1, T_1}$ the values $Q(t_1), D(t_1), F(t_1)$, previously performing calculations on models (12) $W_{j^*1}(t_1), W_{j^*2}(t_1), D'_{j_3}(t_1)$. However, with this approach, the prediction accuracy decreases with the expansion of the planning horizon, since the regression equations with a given accuracy describe the dependencies (13)-(17) only on the interval $t = \overline{1, T}$.

In figure 2 the block diagram of the implementation of a combination of methods for processing reduced monitoring information in the Internet of things system is given.

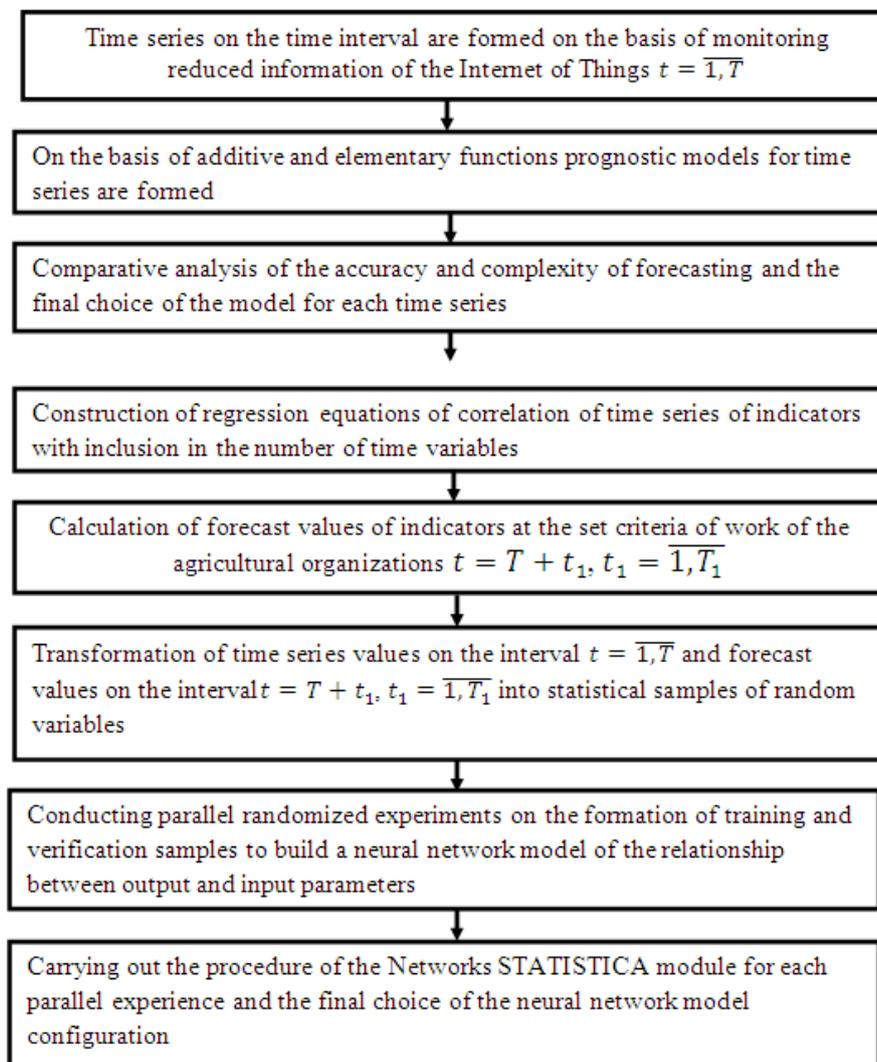


Figure 2. Block diagram of the implementation of a combination of methods for processing reduced monitoring information in the Internet of things system.

4. Results

When assessing the effectiveness of the developed approaches, we considered the statistical data of monitoring and rating evaluation. Statistical samples of time series for several years of monitoring the efficiency of agricultural companies were formed. They included information on financial and economic activities, infrastructure of organizations, personnel, etc. the graphs of time series of key indicators are Formed and analyzed. A sample of the financial statements for the last years is made. The analysis of the rating of agricultural organizations. Indicators of monitoring the effectiveness of organizations are divided into 2 groups: affecting the change in income; affecting the change in costs. The impact of the prognostic assessments was assessed. The integral rating index was considered as the sum of indices of different activities of organizations.

5. Conclusion

The analysis of ways to optimize the management of resource efficiency of agricultural companies and shows the possibility of using the information of monitoring and rating evaluation to build a model and develop procedures for intellectual support of management decision-making. A combination of methods for processing time series of monitoring information with the focus on optimization of resource efficiency management in combination with rating management is carried out. Optimization models and algorithmic procedures for the formation of a variety of alternative options for management decision-making to improve resource efficiency in the long-term planning of agricultural companies.

References

- [1] Odu G O and Charles-Owaba O E 2013 Review of Multi-criteria Optimization Methods *Theory and Applications* **3** 1-14
- [2] Shah A and Ghahramani Z 2015 Parallel predictive entropy search for batch global optimization of expensive objective functions *Advances in Neural Information Processing Systems* pp 3330-8
- [3] Pekka Neittaanmki, Sergey Repin and Tero Tuovinen (Eds.). 2016 *Mathematical Modeling and Optimization of Complex Structures; Series: Computational Methods in Applied Sciences* (Springer International Publishing AG, Switzerland)
- [4] Rios L M and Sahinidis N V 2013 Derivative-free optimization: a review of algorithms and comparison of software implementations *Journal of Global Optimization* **54** 1247-93
- [5] Hugo Morais, Péter Kádár, Pedro Faria, Zita A Vale, Khodr H M 2010 Optimal Scheduling of a Renewable Micro-Grid in an Isolated Load Area Using Mixed-Integer Linear Programming *Elsevier Editorial System(tm) for Renewable Energy Magazine* **35(1)** 151-6
- [6] Orlova D E 2018 Stability of solutions in ensuring the functioning of organizational and technical systems *Modeling, optimization and information technologies* **6(1)** 325-36
- [7] Albert Lutakamale S, Shubi Kaijage 2017 Wildfire Monitoring and Detection System Using Wireless Sensor Network: A Case Study of Tanzania *Wireless Sensor Network* **9** 274-89
- [8] Talluri S, Kim M K, Schoenherr T 2013 The relationship between operating efficiency and service quality: are they compatible? *Intern J Prod Res* **51** 2548-67
- [9] Minerva R, Biru A, Rotondi D 2015 Towards a definition of the Internet of Things (IoT) *IEEE Internet Initiative*
- [10] Stankovic J A 2014 Research directions for the internet of things *IEEE Internet of Things Journal* **1** 3-9
- [11] Groefsema H, van Beest N R T P 2015 Design-time compliance of service compositions in dynamic service environments *Int. Conf. on Service Oriented Computing & Applications* pp 108-15
- [12] Yao Y and Chen J 2010 Global optimization of a central air-conditioning system using decomposition-coordination method, *Energy and Buildings* **5** 570-83