THE USE OF INTELLECTUALIZATION MANAGEMENT DECISION-MAKING IN THE INTERACTION OF TERRITORIALLY CONNECTED SYSTEMS

V. V. Goryachko[1], O, N. Choporov[2], A. P. Preobrazhenskiy[1], O. Ja. Kravets[2]

[1]Voronezh institute of high technologies, [2]Voronezh state technical university
e-mail: Komkovvivt@yandex.ru
Russian Federation

Abstract: Modern possibilities of digital transformation in socio-economic systems increase the possibility of intensive interaction of objects of these systems regardless of their geolocation. In the new conditions, the effectiveness of the operation of geographically distributed objects of the main organizational system depends on the degree of influence of the results of their activities on the objects of the organizational system associated with the main system. A set of procedures has been developed for a multivariate analysis of spatio-temporal information and the interaction of geographically related socio-economic systems, focused on the intellectualization of managerial decision-making. The structure of the control system for geographically connected socio-economic systems has been formed and algorithms for the intellectual support of managerial decision-making have been developed. The analysis of the effectiveness of the use of intellectualization in the practice of managing geographically related socio-economic systems is carried out.

Key words: intellectualization, management decision-making, territorially connected systems.

1. INTRODUCTION

Modern possibilities of digital transformation in the socio-economic systems increases the possibility of an intensive object interaction of these systems, regardless of their geolocation. Under the new conditions the effectiveness of the functioning of geographically distributed objects basic organizational system [1] depends on the degree of the impact of their performance on the objects of the organizational system connected to the main. Such territorial cohesion essentially manifests itself in social and economic systems (education, culture, health care, banking, commerce), and requires the involvement of decision-making management of intellectual support methods [2, 3].

However, these methods do not take into account a number of features of management of objects geographically related systems: 1.for management decisions using spatio-temporal information; 2.digital transformation spatiotemporal data objects functioning performed using GIS-based monitoring and assessment of the rating; 3.improving the efficiency of management is achieved on the basis of intellectual support of the traditional forms of administration by combining the optimization and expert approach to decision-making, and by reducing the time to search and analyze information in a single cartographic data visualization. These features require a problem orientation invariant control methods in social and economic systems.

2. ALGORITHM FOR IDENTIFICATION OF THE STRUCTURE AND THE MODEL PARAMETERS AGGREGATION INTERACTION BETWEEN GEOGRAPHICALLY BOUND SYSTEMS

We consider as basic forms of implementing the adaptive approach to the identification of structure and parameters of a two-level model of the aggregation parameters of objects related systems procedure simulation experiment [4].

Here, the simulation experiment we mean a computational procedure of forming a ranked sequences investigated elements based on historical information about the values of monitored parameters and finding the best model structure and parameters of the interaction on certain criteria. The process of finding the best structure is regarded as a structural model identification and parameters - both parametric identification in a random environment [5]. Thus, instead of expert estimation preferences on the set of monitored parameters entered expert assessment on a set of ranked sequences [6].

We form the input data for the experiment.

1. A group of experts coordinated teaching numbering many ranks (r_i), based on the views of the significance of the object of the basic system in contact with the control center and the territorial entities associated systems for the most important object $r_i^0 = 1,$ the least - $r_i^0 = I.$ Each rank value r_i^0 is translated into binary system - r_i^0.

2. Prepared training set parameters values, f_{ijg}, $i = \overline{1, I}$, $j_g = \overline{1, J_g}$, $g = \overline{1, G}$.

3. It defines a set of alternatives for the integrated assessment model $F_i = \Psi(f_{ijg})$.

4. Introduced three methods of valuation metrics f_{ijg}.

Origin - is focused on the use of the learning sample for the construction of the rank order for each indicator $i'_{jg}(i)$, followed by transfer of discrete values i'_{jg} to a single dimensionless scale $[O, A]$ by converting

$$\hat{f}_{ijg} = \theta\left(i'_{jg}\right) , \tag{1}$$

where θ - transforming function. Second - determined by the linear transformation parameters desired in a single dimensionless scale $[O, A]$ rank ordering without considering maximum $f_{jg}^{\max}$ and minimum $f_{jg}^{\min}$ values in the sample

$$\hat{f}_{ijg} = \frac{f_{ijg} - f_{jg}^{\min}}{f_{jg}^{\max} - f_{jg}^{\min}} \cdot A \ . \tag{2}$$

Third - uses statistical characteristics evaluation of the expected values $m\left(f_{jg}\right)$, the standard deviation $\sigma\left(f_{jg}\right)$, calculated based on a training sample and a function that allows to convert the values of the indicators into a single dimensionless scale $[O, A]$.

5. For each of the alternative embodiment based on the learning sample for given values λ_g^1 of numbers of ranks are determined by simulations r_i^e, which are translated into a binary number system - $\hat{r}_i^e$.

For the choice of structure and parameters of the integral estimation models introduce optimization criterion as the Hamming distance between the reference numeral the object in the training sample represented in binary number $\hat{r}_i^0$ and positions of the same object [7], the calculated result of simulation experiment $\hat{r}_i^e(i)$:

$$\sum_{i=1}^{I} \chi\left(\hat{r}_i^0 - \hat{r}_i^e\right) \to min, \tag{3}$$

where χ the Hamming distance (number of different positions in the binary codes $\hat{r}_i^0 - \hat{r}_i^e$). Determination prepared variant functions structure (1) and the normalization process by criterion (2) is achieved through exhaustive search of all combinations $w = \overline{1, W}$. Internal sorting cycle is parametric identification using the randomized circuit numerical optimization parameter vector $\lambda = \left(\lambda_1, \ldots, \lambda_g, \ldots, \lambda_G\right)$:

$$\varphi(\lambda) = \sum_{i=1}^{I} \chi\left(\hat{r}_i - \hat{r}_{iw}^e(\lambda)\right) \to \min_{\lambda}, w = \overline{1, W}. \tag{4}$$

Selection of randomized scheme associated with the uncertain nature of the objective function values of the step (2). It allows you to build a search process parameter vector $\lambda_g, g = \overline{1, G}$ in which the uncertainty is disclosed on the basis of current information, i.e. move to an adaptive procedure similar to the case when the system is subject to random perturbations [8, 9]. In this case, at each *k*-th iteration the search parameter $\lambda_g, g = \overline{1,G}$ is treated as a random variable with a probability density function $\omega^c\left(\tilde{\lambda}_g\right)$, wherein the parameter designation random realization λ_g. In this case, the functional dependence of the transition from *k*-th to the *(k+1)*-th search iteration remains constant changes only the expectation of a random variable $\tilde{\lambda}_g$

$$m^{k+1}\left(\tilde{\lambda}_g\right) = \lambda_g^k, \tag{5}$$

where λ^{k+1} - the value of the parameter λ for the *(k+1)*-th iteration, calculated by an adaptive algorithm based on the procedure Kiefer-Wolfowitz

$$\lambda_g^{k+1} = \lambda_g^k + \alpha_g^{k+1}\frac{\varphi\left(\lambda_g^k + \gamma_g^{k+1}\right) - \varphi\left(\lambda_g^k - \gamma_g^{k+1}\right)}{2\gamma_g^{k+1}}, \tag{6}$$

where the values of steps α_g^k, γ_g^k, subject to the following conditions of convergence

$$\sum_{k+1}^{\infty}\frac{\alpha_g^k}{\gamma_g^k} \to \infty, \sum_{k+1}^{\infty}\left(\alpha_g^k\right)^2 < \infty, \left(\alpha_g^k = \frac{a_g^1}{k^2}, \gamma_g^k = \frac{\gamma_g^{'}}{k}\right), \tag{7}$$

and the distribution density $\omega^{k+1}\left(\tilde{\lambda}_g\right)$ corresponds to the density distribution of a uniform distribution law

$$\omega^{k+1}\left(\tilde{\lambda}_g\right) = \frac{1}{2}\left[\delta\left(\lambda_g^k + \gamma_g^{k+1}\right) - \delta\left(\lambda_g^k - \gamma_g^{k+1}\right)\right] \tag{8}$$

$\delta - \delta -$ function notation, where

$$m^{k+1}\left(\tilde{\lambda}_g\right) = \lambda_g^k . \tag{9}$$

Because the adaptive algorithm Kiefer-Wolfowitz carried coordinatewise searching internal parameter number is randomized scheme coordinates $g = \overline{1,G}$. For this purpose, the discrete value $g = \overline{1,G}$ is converted into a discrete random variable $\tilde{g} = \overline{1,G}$ with probability $p_g, g = \overline{1,G}, \sum_{g=1}^{G} p_g = 1$. The first step is adopted a uniform distribution of discrete values $\tilde{g}$

$$p_g^1 = \frac{1}{G}, g = \overline{1,G} . \tag{10}$$

In subsequent steps this distribution is adjusted depending on the significance of the coordinates on the criterion (2) according to the algorithm:

$$p_{g_1}^{k+1} = \frac{p_{g_1}^k + \varepsilon}{1+\varepsilon}, p_{g_1}^{k+1} = \frac{p_g^k}{1+\varepsilon}, g = \overline{1,G}, g \neq g_1, \tag{11}$$

g_1 – number of the coordinate by which the search is performed; $\varepsilon > 0$ – step value set by the expert.

The search ends when k reaches a predetermined value K.

3. DEVELOPMENT OF A COMPLEX OF PROCEDURES OF MULTI-VARIANT ANALYSIS SPACE-TIME INFORMATION USING THE MODEL INTERACTIONS OF TERRITORIAL RELATED SYSTEMS

The directions in which the analysis of spatial and temporal information on the interaction of geographically related systems depend on the diversity of this interaction. When a formalized description productive interaction management processes [10] distinguish this characteristic as the intensity of the interaction. In the case of a formalized description of the control processes of resource and resource-efficient interaction should first characterize the significance level of interaction with the control center and connected systems [11]. For each of these areas require different options for estimating the above features with a focus on specific management processes. It is therefore important to develop a multivariate approach to the analysis procedures, depending on the characteristics of the control processes as the interaction of geographically-related systems and their constituent objects [12].

Time series of monitoring assessment of functioning of the primary system of volume indicators of effective interaction [13] with related systems

$$f_{j^0}(t), j^0 = \overline{1, J^0}, \tag{12}$$

where $j^0 = \overline{1, J^0}$ – a plurality of volume indicators numbering effective interaction (effective volume of the primary system interaction with bound by j^0 – th direction) for periods $t = \overline{1, T}$;

time series of results of evaluation of the monitoring indicators for the *n*-th geographically bound system

$$f^c_{j^c n}(t), j^c n = \overline{1, J^c_n}, n = \overline{1, N}, t = \overline{1, T} \tag{13}$$

where $n = \overline{1, N}$ – numbering set of geographically-related systems, $j^c n = \overline{1, J^c_n}$ numbering set indicators for the *n*-th coupled system;

monitoring the time series estimation object operation of the basic system on volume indicators effective interaction with the objects associated with the geolocation systems $d = \overline{1, D}$ objects

$$f_{j^0 i}(t, d), j^0_{in} = \overline{1, J^0_i}, i = \overline{1, I}, t = \overline{1, T}, d = \overline{1, D} \tag{14}$$

where $i = \overline{1, I}$ – the numbering system set main objects;

time series of monitoring indicators for the evaluation of objects n-th territorially bound system based on their geolocation

$$f^{c}_{j^c i^c n}(t,d),\ j^{c}_{i^c n}=\overline{1,J^{c}_{i^c n}},i^{c}_{n}=\overline{1,I^{c}_{n}},n=\overline{1,N},\quad t=\overline{1,T},d=\overline{1,D} \tag{15}$$

where $i^{c}_{n}=\overline{1,I^{c}_{n}}$ – numbering many objects related to the second system.

To account for the diversity of management processes effective interaction, consider the following options for the analysis of the intensity of this interaction.

1. Analysis of intensities of the primary links and related systems on indicators (12), (13) on the basis of simple correlation coefficients

$$\rho\left(f_{j^0},f_{f^c,n},T\right)=\frac{\sum_{t=1}^{T}\left[f_{j^0}(t)-m\left(f_{j^0}\right)\right]\left[f^{c}_{j^c n}(t)-m\left(f^{c}_{j^c n}\right)\right]}{\sigma\left(f_{j^0}\right)\sigma\left(f^{c}_{j^c n}\right)\cdot T} \tag{16}$$

where

$$m\left(f_{j^0}\right)=\frac{\sum_{t=1}^{T}f_{j^0}(t)}{T},m\left(f^{c}_{j^c n}\right)=\frac{\sum_{t=1}^{T}f_{f^c j^c,n}(t)}{T}.$$

$$\sigma\left(f_{j^0}\right)=\sqrt{\frac{\sum_{t=1}^{T}\left[f_{j^0}(t)-m\left(f_{j^0}\right)\right]^2}{T-1}}\ \sigma\left(f^{c}_{j^c n}\right)=\sqrt{\frac{\sum_{t=1}^{T}\left[f^{c}_{j^c n}-m\left(f^{c}_{j^c n}\right)\right]^2}{T-1}}.$$

Analysis by quantitative estimates (9) to determine the operating area efficient interaction, where the most evident effect on the performance of the basic system operation of connected systems [14, 15].

2. Analysis of the intensities of the primary links objects and related systems (14), (15) on the basis of simple correlation coefficients tied to a specific zone geolocation $d=\overline{1,D}$

$$\rho\left(f_{j^0},f_{f^c i^c,n},T,d\right)=\frac{\sum_{t=1}^{T}\left[f_{j^0}(t,d)-m\left(f_{j^0 i^0}(d)\right)\right]\left[f^{c}_{j^c i^c n}(t,d)-m\left(f^{c}_{j^c i^c n}(d)\right)\right]}{\sigma\left(f_{j^0_i}(d)\right)\sigma\left(f^{c}_{j^c i^c n}(d)\right)*T} \tag{17}$$

Analysis by quantitative estimates (16) to determine the effective region of the control zone $d=\overline{1,D}$ by reacting a primary geographical location of objects and associated systems, where at most pronounced effect on the objects of the basic system operation parameters of objects related systems.

Control process number is associated not only with the monitoring information in the form of the structural time series (11) - (14), but also with projections and expertise for a period of forward planning effective interaction periods $T+t_1,t_1=\overline{1,T_1}$.. For forming time series forecast estimates the values necessary to calculate the parameters for the period $T+t_1,t_1=\overline{1,T_1}$ from using predictive models [16, 17]. We assume that the order of the control center of the main system is to increase the effective volume of interaction with geographically-related systems. Then this trend reflects the exponential forecasting model

$$f_{j^0}\left(T+t_1\right)=a_1 e^{a_2\left(T+t_1\right)}, t_1=\overline{1, T_1}. \quad (18)$$

To determine the parameters a_1, a_2, depending of (11) from the values of the time series (11) using the exponential smoothing method, assuming that the prognostic evaluation periods $T+t_1, t_1=\overline{1, T_1}$ have a greater impact indicator values $f_{j^0}(t)$ at times close to T. Since the connected systems also tend to increase the metric values $f_{j^c n}(t)$ at the transition from one period $t=1$ to $t=T$ use as a predictive model, similar to (17)

$$f_{j^c n}^c\left(T+t_1\right)=a_{1n}^c e^{a_{2n}^c\left(T+t_1\right)}, t_1=\overline{1, T_1}, \quad (19)$$

determining parameters a_{1n}^c, a_{2n}^c based on time series (13) using the method of exponential smoothing. In addition to the forecast estimates on long-term planning period (18) control center attracts experts to assess the capacity of effective interaction volumes, which set the $w=\overline{1, W}$ options $f_{j^o w}\left(T+t_1\right), t_1=\overline{1, T_1}$, focusing on the values (17). Thus for analyzing a time series (11) - (14) are added:

time series of volume indicators predictive estimates the effective interaction of the basic system with related systems, the values of which correspond to (18)

$$f_{j^0}\left(T+t_1\right), j_0=\overline{1, J_0}, t_1=\overline{1, T_1} \quad (20)$$

time series forecasting operation related metrics estimates the values of which correspond to the (18)

$$f_{j^c n}^c\left(T+t_1\right), j_n^c=\overline{1, J_n^c}, t_1=\overline{1, T_1}; \quad (21)$$

main system on long-term planning periods

$$f_{j^0 w}\left(T+t_1\right), j_w^0=\overline{1, J_w^0}, w=\overline{1, W}. \quad (22)$$

Using the additional data (19) - (21), it is possible to further analysis.

3. Analysis of the intensity of the main connections and associated systems Ratios (19), (20) on the basis of simple correlation coefficients

$$\rho\left(f_{j^0}, f_{j^c n}^c, T+t_1\right)=\frac{\sum_{t=1}^{T+t_1}\left[f_{j^0}(t)-m\left(f_{j^0}\right)\right] \cdot\left[f_{j^c n}^c(t)-m\left(f_{j^c n}^c\right)\right]}{\sigma\left(f_{j^0}\right) \cdot \sigma\left(f_{j^c n}^c\right) \cdot\left(T+t_1\right)}, t_1=\overline{1, T_1} \quad (23)$$

where the sample $f_{j^0}(t)$ is formed by combining a time series $f_{j^0}(t)$, $t_1=\overline{1, T_1}$ and $f_{j^0}\left(T+t_1\right), t_1=\overline{1, T_1}$, and sample $f_{j^c n}^c(t)-$ by combining the time series sampling $f_{j^c n}^c(t), t_1=\overline{1, T_1}$ and $f_{j^c n}^c\left(T+t_1\right), t_1=\overline{1, T_1}$.

Analysis by quantitative estimates (23) to determine the region of efficient management reacting core and related systems at the control center forward planning volume indicators for the periods $T+t_1, t_1=\overline{1,T_1}$ of the basic system.

4. Analysis of the intensity of the main connections and associated systems indicators (20) on the basis of simple correlation coefficients

$$\rho\left(f_{j^0w}, f_{j^cn}^c, T+t_1\right)=\frac{\sum_{t=1}^{T+t_1}\left[f_{j^0w}(t)-m\left(f_{j^0w}\right)\right]\left[f_{j^cn}^c(t)-m\left(f_{j^cn}^c\right)\right]}{\sigma\left(f_{j^0w}\right)\cdot\sigma\left(f_{j^cn}^c\right)\left(T+t_1\right)}, t_1=\overline{1,T_1}, \qquad (24)$$

where the sample $f_{j^0w}(t)$ is formed by combining a time series $f_{j^0}(t)$, $t_1=\overline{1,T_1}$ and $f_{j^0w}(T+t_1), t_1=\overline{1,T_1}$, and sample $f_{j^cn}^c$ by combining the time series $f_{j^cn}^c(t)$, $t=\overline{1,T}$ and $f_{j^cn}^c(T+t_1), t_1=\overline{1,T_1}$.

Analysis by quantitative scores (24) allows for comparison of the intensity of interaction for $w=\overline{1,W}$ advance planning expert for this and to determine the best mode control region and the main productive interaction related systems based on expert evaluation periods $T+t_1, t_1=\overline{1,T_1}$. The block diagram of a multivariate analysis of spatio-temporal information from the intensity of the effective interaction geographically related systems shown in Fig. 1. Other qualitative assessment, which is used in formalizing resource management and resource-efficient interaction sites associated with the importance of the basic system in this interaction. The importance on the one hand determines the distribution control center planned amounts effective interaction between the main system objects [18] belonging to it, and the other - the volume of the resource and resource-efficient interaction systems associated with objects of the basic system [19]. It is proposed to use as a quantitative value of the importance ratings characterizing the $i-$th object space of the basic system $t=\overline{1,T}$ in a sequence ordered by magnitude aggregate (1) in view of long-term monitoring $t=\overline{1,T}$ of scheduling periods $T+t_1, t_1=\overline{1,T_1}$ and periods of territorial object belonging to $d-$th a regional formation $d=\overline{1,D}$. In this case, the initial information is provided by the following spatiotemporal data indicators for the main objects $i=\overline{1,I}$ of the system with reference to the geographical location of the $d-$th region time series

$$f_{ijg}(t,d), i=\overline{1,I}, j=\overline{1,J}, g_j=\overline{1,G_j}, t=\overline{1,T}, d=\overline{1,D} \qquad (25)$$

time series of indicators of socio-economic status of regions within their geographical locations $d=\overline{1,D}$

$$f_{j^pd}^p(t), d=\overline{1,D}, j_d^p=\overline{1,J_d^p}, t_1=\overline{1,T_1}. \qquad (26)$$

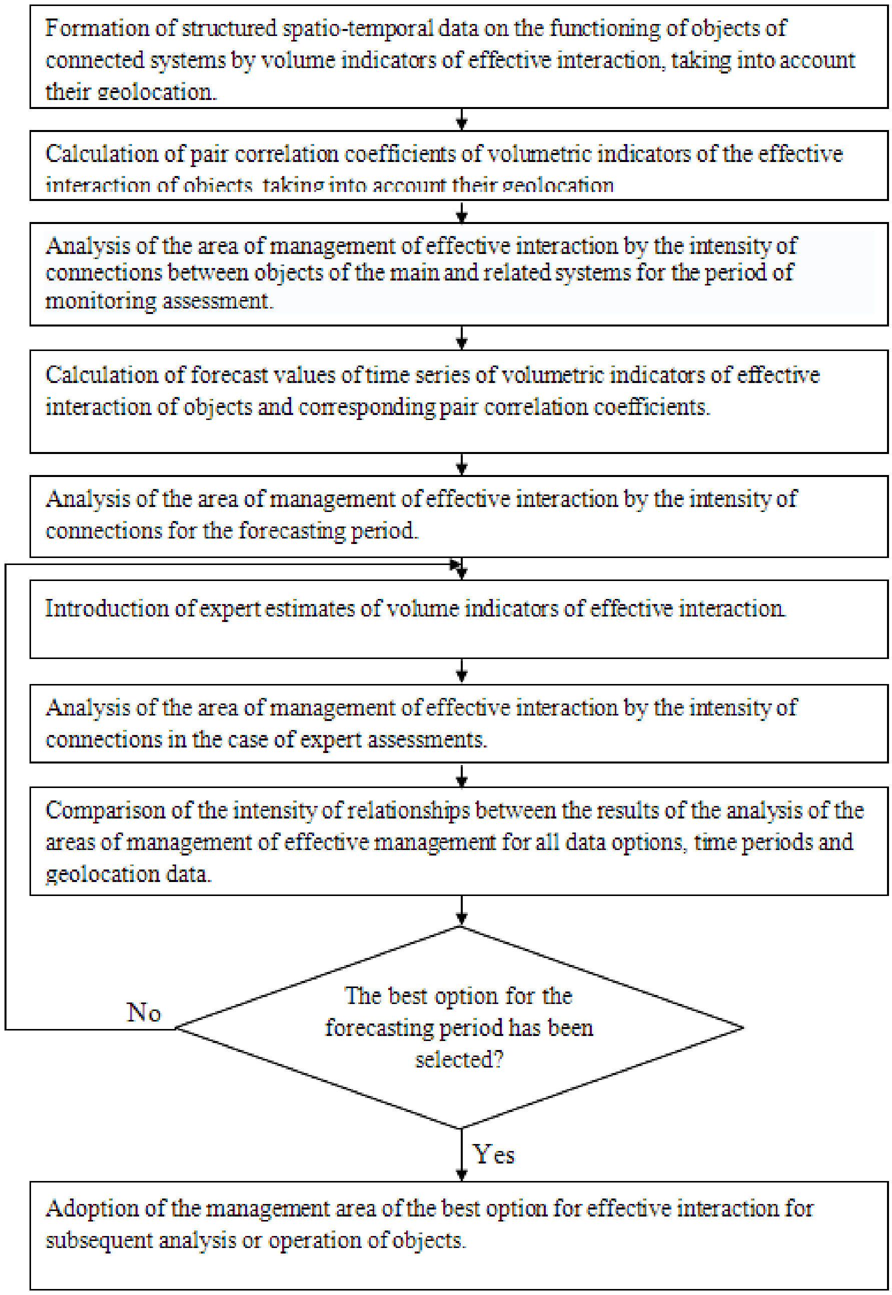

Fig.1. The block diagram of a multivariate analysis of spatio-temporal information from the intensity of the effective connections object interaction

Using the time series (8) for the region identification carried aggregation structure and parameters of the model (1)

$$F_i(T,d), i=\overline{1,I}, d=\overline{1,D} \ . \qquad (27)$$

On the basis of the structured data (25) - (26) is realized by three variants significance analysis objects [20] primary system resource management [21] and resource-efficient interaction with geographically-related systems.

1. Analysis of primary importance objects based systems determine their ranks on a discrete scale.

2. Analysis of the significance of the main objects of the system through the establishment of quantitative estimates on a continuous scale [22].

3. Analysis of the significance of the main objects of the system based on their territorial jurisdiction in the region.

4. CONCLUSION

For the purpose of multivariate analysis of space-time information about the formation objects geographically related systems should be guided by the values of aggregate object calculated based on a model of local aggregation indicators. To analyze spatial-temporal information to assess the intensity of connections and management of forming productive interaction of the main objects and geographically related systems are acceptable estimates pair correlation local indicators calculated on the basis of historical data, prognostic and expertise..

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Information about the authors:

Vyacheslav Vyacheslavovich Goryachko – senior lecturer of Voronezh institute of high technologiesv, areas of scientific research – system analysis, optimization, simulation of complex objects,

Oleg Nikolaevich Choporov – professor of Voronezh state technical university, areas of scientific research – system analysis, optimization, simulation of complex objects,

Andrey Petrovich Preobrazhenskiy – professor of Voronezh institute of high technologies, areas of scientific research – system analysis, optimization, simulation of complex objects,

Oleg Jacovlevich Kravets – professor of Voronezh state technical university.

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