ІНФОРМАЦІЙНІ ТЕХНОЛОГІЇ, СИСТЕМНИЙ АНАЛІЗ ТА КЕРУВАННЯ

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METHOD FOR DETERMINING AND OPTIMIZATION OF OBSERVABILITY OF MULTIVARIABLE SPATIALLY DISTRIBUTED SYSTEMS USING GEOINFORMATION PARAMETER SPACE

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МЕТОД ВИЗНАЧЕННЯ ТА ОПТИМІЗАЦІЇ СПОСТЕРЕЖУВАНОСТІ БАГАТОЗВ'ЯЗНИХ ПРОСТОРОВО-РОЗПОДІЛЕНИХ СИСТЕМ З ВИКОРИСТАННЯМ ГЕОІНФОРМАЦІЙНОГО ПРОСТОРУ ПАРАМЕТРІВ

Purpose. Elaboration of a method of defining and raising the topologic observability level of multivariable space-distributed systems, processes in which are formalized both by analytical and algorithmic relations between the GIS object parameters of these systems.

Methodology. Definition and optimization of topologic observability of multivariable space-distributed systems based on the transformation of their models, formalized in the geoinformational space of these system parameters, into a classical bichromatic graph.

Findings. The need for solving the defining and optimization problems of topologic observability of multivariable space-distributed systems is well-founded. The method of formalization of the systems of such type was analyzed; special attention was paid to the original model formalization method in the geoinformational parameter space related with GIS. We have suggested the method of transformation of the model from this parameter space into a classical bichromatic one, for which the solutions of the topological system's observability optimization problem are known. The suggested method was realized on an example of the mathematical normalization model of the mine microclimate.

Originality. For the first time, the method defining the topologic observability of a multivariable space-distributed system (MSDS) has been suggested. It was based on the formalization of this system in the geoinformational space of its parameters with further transformation into a classical bichromatic graph, which allows defining not only the MSDS observability level but also an appropriate variant of the model improvement, which will ensure full observability of this system.

Practical value. The use of the given method of defining observability of multivariable space-distributed systems allows us quickly and efficiently optimize their system of collecting and processing information, add and delete control and observation devices, improve the model of the system and take other measures for its full observability.

Keywords: observability, geoinformation systems, geoinformational space of parameters, multivariable system, bichromatic graph, matching

Introduction. Many modern multivariable systems belong to the class of space-distributed systems, for example, electric energy and electric systems, pipeline and transport systems, river systems, etc. Such systems have a big number of parameters that vary in time and space. It is typical for them when in some areas or in some periods of time these parameters are observable and in other areas or periods they are not.

Analysis of the latest researches and works. For solving the observability problems, there is a developed mathematic apparatus for electric energy systems (EES). Firstly, their mathematic models are well studied, as they are not natural objects but results of mathematic modeling and technical projecting. Secondly, all their prescribed parameters can be measured precisely. Thirdly, raising controllability and efficiency of functioning at least 0.01% have given a significant economic effect. It is necessary to mention the scientists that are known for defining system observability, including EES: Gamm A.Z., Golub I.I., Clements K.A., Krumpholz G.R. and others [1, 2]. These scientists usually define observability of space-distributed systems with the help of a bichromatic graph (a graph with two node types: variables-nodes and dependencies between these variable nodes) and classical methods of its analysis and optimization by searching for maximum matching between different type nodes and their number optimization.

However, one of the main problems of this mathematic apparatus use for EES or other multivariable space-distributed systems (MSDS) is the problem of constructing a corresponding bichromatic graph. This problem becomes especially difficult when processes in an MSDS are described not only analytically but also algorithmically, and systems consist of a big number of subsystems or their separate areas for every of which there is a separate mathematic model and the structure of this model can vary in certain moments or under certain conditions. Meanwhile, geoinformation systems are known as an optimal formalization of MSDS parameters that consist of many subsystems and areas with different characteristics [3]. V.B. Mokin and O.V. Havenko suggested a method formalization method of a model similar MSDS as a graph in the geoinformation parameters space (GSP) that is spatially-logically related to objects in the GIS of MSDS while the model, formalized in the GSP, can be stored in the system layer of the same GIS due to the method [4]. A model in the GSP also looks like a bichromatic graph but different from the classical bichromatic graph with the help of which the analysis of MSDS model topologic observability is carried out.

Previously unsolved parts of the general problem. There is a need for improvement of the approaches and methods of solving the general problem of defining and optimizing topologic MSDS observability based on the model analysis in a bichromatic graph form of this system. In particular, a search for automation ways of such a MSDS model construction taking into account analytical and algorithmic dependencies between parameters that should have spatial or logical relation with objects of this GIS. Automation of model construction would significantly accelerate the process of its identification and optimization associated with the search for an optimal variant of the model improvement that would make the system observable.

Setting the problem. As the method of formalization of the MSDS model like a graph in its GSP which is the GIS element of this system suggested by Mokin V.B. and Havenko O.V. eliminates the automation problem of such a model construction taking into account analytical and algorithmic dependencies between parameters that should have spatial or logical relation to objects of the GIS of this system, the optimal solution of the above-mentioned problem would combine the formalization method of the MSDS model of in the GSP with a method of analysis and optimization of this MSDS for topologic observability. However, the construction and marking principles differ a little for bichromatic graphs of these two methods. Therefore, it is necessary to elaborate an algorithm and rules of transformation of one graph type into the other for combining all advantages of the both methods.

Presentation of the key material. Let us characterize the construction method of the MSDS model in its GSP in more details.

Let us consider such a vivid MSDS example as a city transport net. The geoinformational parameter space is a geometric image represented with a multitude of all possible parameters possessing the natural proximity notion of all possible spatial objects at all layers of which the MSDS geoinformation system consists [3]. The multitude of all parameters represented as points (nodes) with coordinates (x, y) from a mathematical point of view creates a two-dimensional sub-space and from an informational point of view, a system layer of the geoinformation system the parameters of which it describes.

It is suggested to use GSP for formalization of possible analytical (functional) or algorithmic relation between parameters by means of polygon creation, nodes of which are the GSP points that correspond to all interrelated parameters, while the dependencies that describe these relations from the informational point of view are formalized ("are bound to") as attributes (parameters) of these polygons that are stored in the GSP data basis. If K is the parameter number of the dependence that it relates, then three variants of such dependencies can be singled out:

- $K > 2$: the GSP points are nodes of the polygon (multangular) the attribute of which is the dependence that relates these parameters.
- $K = 2$ (a confluent variant of the first type): two GSP points are connected by a line the attribute of which is the correspondence that relates these two parameters.
- $K = 1$ (a confluent variant of the second type): the very point of the GSP is a geometric image of the relation, for example, when a parameter is prescribed with a constant or a function that depends, for example, on time but not on other GSP parameters (however time, of course, can also be a spatial object parameter of the GSP MSDS, then this dependence transforms into a confluent variant of the first type).

In every dependency that is formalized in the GSP, all parameters are divided into incoming if $K>1$ and one resulting that is calculated through the incoming ones, meaning that every dependence is a solution to a certain mathematic model concerning one resulting variable or an algorithmic calculation of this variable from the incoming variables. Every parameter can be incoming in one dependence and resulting another in such a way formalizing a system of dependencies. Such a model formalization approach also limits the use of the method – in the GSP it is impossible to formalize dependencies that cannot be solved (expressed) in relation to one variable.

A parameter is considered dependent on another parameter if its change results in a change of the other parameter. A parameter is considered independent of another parameter if its change does not result in a change of the other parameter. A parameter is called independent (input) if there is no parameter which it depends on.

A parameter is called influencing other parameters if it is dependent on this other parameter. A parameter is called non-influencing other parameters if it is independent of the other parameter.

A parameter is called non-influencing if there is no parameter that depends on it. A multitude of influencing parameters of a parameter is a multitude, every parameter of which influences on this parameter. A multitude of non-influencing parameters of a parameter is a multitude of the GSP parameters, no parameter of which influences on this parameter.

Thus, every parameter (signified as P_q) in the GSP corresponds to two multitudes of parameters:

- a multitude of influencing parameters P_V

$$P_V = [P_1, P_2, \dots, P_{k1}],$$

where k_1 − a number of parameters that influence the parameter P_q;

- a multitude of non-influencing parameters P_{NV}

$$P_{NV} = [P_1, P_2, \dots, P_{k2}],$$

where k_2 – the number of parameters that do not influence the parameterP_q , $k_1 + k_2 = K - 1$, excluding the P_q parameter in every multitude. Namely, general possible 2^{k1}combinations of parameters that influence the parameter P_q. In general, any r combination of parameters (signified as B_r) from the multitude of influencing parameters P_V, that influence the parameter P_q can be represented as

$$B_r = [b_1 b_2 b_3 \cdot \dots \cdot b_{k-1} b_k],\ k \le k_1,$$

parameter j from the multitude of influencing parameters P_V is irrelevant; $b_j = 1$ –parameter j from the multitude of influencing parameters P_V is relevant.

Every object from the GSP preserves a dependence identifier (FID) based on which the calculation of the parameter is carried out. Thus, for $K = 4$ an example of the system model formalization in the GSP and schemes of correspondence of the graph elements to dependencies between the parameters of the model is shown in fig. 1.

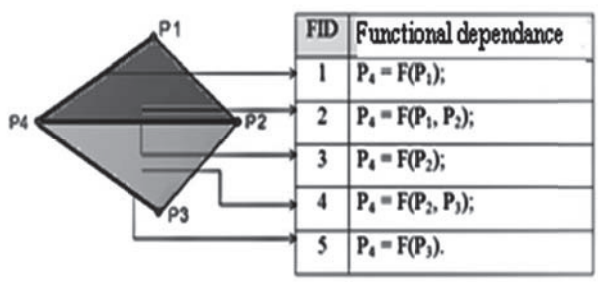


Fig. 1. An example of a scheme correspondence between elements of the GSP and dependencies between parameters of the GSP

Let us compare models of systems formalized in the GSP with the above mentioned classical bichromatic system graph used for identifying its topologic observability (table 1).

Table 1

Differences between Model Formalizations as a Graph in the GSP and as a Bichromatic Graph

Element of Model	Formalizing a Graph in GSP	Formalizing as a Bichromatic Graph
Variable	Allocate of influential and dependent nodes	First type of nodes
The relationship between the variables	Edge of the graph	Second type of nodes

Thus, in table 1, one can see that for transforming the first graph into the second it is necessary to transform variables-nodes into nodes of the first type and edges of the graph, into nodes of the second type. In addition, if transforming variables of the first type nodes into a multitude of the first type nodes is a simple procedure, transforming edges of the first graph into nodes of the second one requires study in more details. Let us suggest a system of rules (table 2) for transforming edges of the model formalized in the GSP into nodes of the second type of the bichromatic graph. In case a model formalized in the GSP has a shape of a geometric figure, we find its center, which is transformed into a dependence-node. If a model formalized in the GSP is a confluent variant of the first type, then the very edge is transformed into a dependence-node that is bound to other edges with variables-nodes. Thus, having constructed a bichromatic graph, we can apply to it typical identification methods of the system observability. In particular, one of such methods is the search for maximum matching described in the work [1]. This method lies in finding a multitude with a maximum edges number of the formed graph that does not have pairwise common nodes. It is known that if there is a match where every variable that describes the system state corresponds to a strong edge then the system that is described with a prescribed equation is topologically observable or fully observable [1, 2]. A strong edge means an edge that belongs to the maximum matching.

If at least one of variable class nodes in the studied graph does not correspond to an edge from the maximum matching, then we deal with partial observability in space or in time depending on the system model specificity.

In this analysis, special attention is paid to identifying so-called “black spots”, namely parts of the graph where precise defining of parameters, results of measuring, values of the system state indicators is impossible. The task of distinguishing “dark spots” is equivalent to distinguishing so-called deficit submultitudes in a bichromatic graph, which are submultitudes with nodes that are not included into the maximum matching. Theoretically, these submultitudes can be simply excluded leaving only observable areas, which will make the selected subsystem observable. However, the main goal is to eliminate these submultitudes. It is possible to achieve this only by adding new nodes both from the class of dependencies and from the class of variables, which will make the system observable. It will provide a possibility to estimate effectively the state of the MSDS under any conditions.

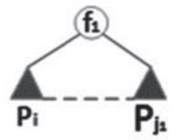
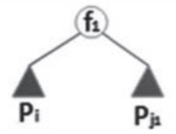
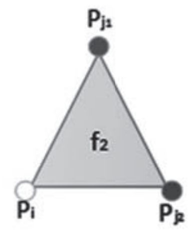
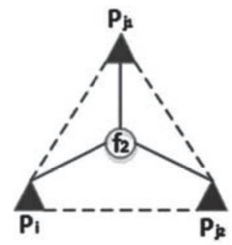
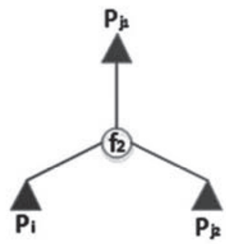
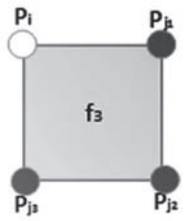
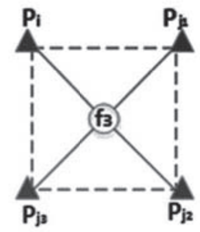
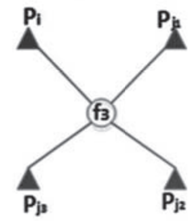
So, for solving the set problem the following algorithm is suggested:

1. The model formalization in the GSP.
2. Transforming the model formalized in the GSP into a bichromatic graph by means of the rule system (table 2).
3. Searching for maximum matching in the synthesized bichromatic graph.

Optimizing the MSDS model (placing additional devices at not observed areas, identifying new dependencies in the model, etc.).

Table 2

The Rule System for Transforming a Model Formalized in the GSP into Second Type Nodes of the Bichromatic Graph

Type of Depending	The Formalization of GSP	Rules for Transforming the Model Formalized in the GSP into a Bichromatic Graph	The Formalization of Bichromatic Graph
The dependence f_1 on one input parameters $P_i = f_1(P_{j1})$			
The dependence f_2 on two input parameters $P_i = f_2(P_{j_1}, P_{j_2})$			
The dependence f_3 on three input parameters (for more options this rule applies similarly) $P_i = f_3(P_{j_1}, P_{j_2}, P_{j_3})$			

Thus, having transformed the model of the system formalized in the GSP into a classical bichromatic graph it is possible to analyze it for identifying topologic observability and optimization – for its raising.

Taking into account the advantages provided by formalization of the system model in the GSP, such transformation significantly broadens the application sphere of the identifying method and topologic observability optimizing of the system with the help of a bichromatic graph constructed according to its model, since in the GSP not only analytical dependencies but algorithmic ones are formalized too. Besides there is a technology of adapting the GSP to models of various structures and integrating the model with the GSP objects parameters of which it contains [3]. On the other hand, taking into account the advantages and the wide sphere of use of the identifying method and the system optimizing topologic observability with the help of the bichromatic graph constructed according to its model, the suggested transformation methodology from a model formalized in the GSP to the graph significantly raises the formalization importance of the model in the GSP. Now it is possible not only to conveniently store and carry out calculations according to the model of the MSDS at the system layer of its GIS but also to analyze and optimize the MSDS observability.

Let us consider an example of a problem solving for the microclimate normalizing process in deep metal mines which is described with a model with such equations [5]

$$t_1(z) = t_н - \frac{k}{b_1} + k \cdot z + \left(t_0 - t_н + \frac{k}{b_1}\right) e^{-b_1 z}, \quad (0 \le z \le H); \qquad (1)$$

$$t_2(x) = t_н + k \cdot H + \left(\left(t_0 - t_н + \frac{k}{b_1}\right) e^{-b_1 H} - \frac{k}{b_1}\right) e^{-b_2 x}, \quad (0 \le x \le L); \qquad (2)$$

$$t_3(z) = t_н + \frac{k}{b_3} + k \cdot z + \left(-\frac{k}{b_3} + \left(\left(t_0 - t_н + \frac{k}{b_1}\right) e^{-b_1 H} - \frac{k}{b_1}\right) e^{-b_2 L}\right) e^{b_3 (z-H)}, \quad (0 \le z \le H), \qquad (3)$$

where $t_j(d) (j = 1, 2, 3)$ – the identified temperature at area j, t_0 – the temperature of the air at the first area at $z = 0$, t_n – the temperature of the neutral layer, °C, b – a coefficient that takes into account increasing temperature, k, b – a coefficient that takes into account the mine geometrical sizes and the air physical parameters; H – the depth of

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the mine shaft, *m*, *L* – the length of the horizontal working mine, m, z – a current coordinate during movement of the air down the shaft.

Let us apply the method suggested in this article to the model (2–4).

At the first stage, let us select a set of parameters from the above described model that are interrelated and most characterizing the system state or influence it, namely: t_0 – the temperature of the air at the first area at $z = 0$, $t_1(z)t_1\left(t_1(z)\right)$ – the temperature of the air at the first area of the shaft, $t_2(x)t_2\left(t_2(x)\right)$– the temperature of the air at the second area of the shaft, $t_3(z)t_3\left(t_3(z)\right)$– the temperature of the air at the third area of the shaft, L, H.

The next step is defining of the connections and relations between the parameters, their types, meaning defining incoming data and such data that have to be calculated. Then we formalize the model of relations between the parameters (1–3) in the GSP.

The model of the system (1–3) formalized in the GSP looks as shown in fig. 2.

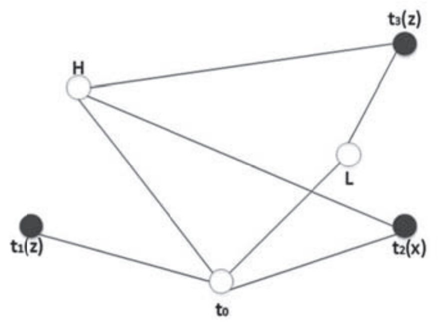

Fig. 2. The process model of microclimate normalizing in deep ore mines formalized in the geoinformational space of its parameters $t_1(z)$ *– the air temperature at the shaft first area;* $t_2(z)$ *– the air temperature at the shaft second are;* $t_3(z)$ *– the air temperature at the shaft third area;* t_0 *– the air temperature at the first area at* $z = 0$

The next step is a bichromatic graph constructing on the basis of the model formalized in the GSP; the result is shown in the fig. 3. The triangular graph nodes indicate the variables (parameters) of the model while the circle nodes signify the dependencies that relate these parameters, which help to identify resulting parameters, or parameters that characterize the system state.

The next step of the algorithm of the suggested method is searching for maximum matching in the bichromatic graph. The analysis has shown that under the present conditions, parameter relations and dependencies, it is impossible to find maximum matching for the given graph, i.e. there is no maximally full edge set which could not be supplemented with another one that would satisfy the conditions. In other words, not for every variable-parameter there is a corresponding strong edge.

Thus, this graph presentation proves that under the given conditions the system is not observable. Therefore, there is a need for supplementing the graph either with variables-nodes or with dependencies-nodes. For solving the problem, we suggest supplementing the present system of equations (1–3) with initial and extreme conditions of these same equations, namely

$$t_1(0) = t_0;$$

$$t_2(0) = t_1(H);$$

$$t_3(0) = t_2(L);$$

$$t_1(H) = f_1(t_1(0), H);$$

$$t_2(L) = f_2(t_2(0), H, L);$$

$$t_3(H) = f_1(t_3(0), H, L).$$

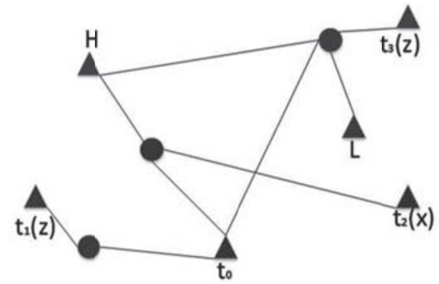

Fig. 3. The bichromatic graph for the model of the microclimate normalizing process in deep ore mines

Thus, besides the already present variables-nodes of the graph,: t_0, L, H, new variables-nodes appear, namely: $t_1(0)$, $t_2(0)$, $t_3(0)$, $t_1(H)$, $t_2(L)$, $t_3(H)$. Consequently, having substituted the variables on this graph and added new nodes, which reflect the relations between the above-mentioned variables we receive a graph represented in fig. 4. At once, let us carry out a search for maximum matching on the graph and mark the edges that are included with a bolder line in a different color. The search for maximum matching is successful when every variable value corresponds to a strong edge that is included in the maximum matching.

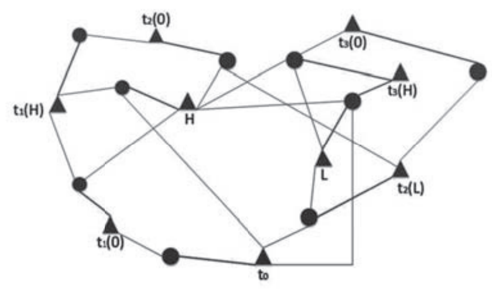

Fig. 4. The optimized bichromatic graph for the model of the microclimate normilizing process in deep ore mines: $t_1(0)$ *– the air temperature at the first area at* $z = 0$*;* $t_2(0)$ *– the air temperature at the second area at* $z = H$ *;* $t_3(0)$ *– the air temperature at the third area at* $z = H$ *and* $x = L$

For the sake of full observability, as it can be seen from the analyzed microclimate normalizing model in deep ore mines, it is not always necessary formalizing the very equations described the system state, it is enough to consider as variables-nodes the initial and extreme conditions which describe the system. The main thing is to understand clearly for what values the equations are made.

In this case, it is not for the state variable values at any point of the mine but for their values at the ends and certain areas. That is this model is acceptable for projecting or optimizing the microclimate managing system in the mine but not for current control of its functioning.

This example does not show clearly the efficiency of the model formalizing in the GSP. If a big mine had been considered which consisted of many different areas and we had had to think through many different scenarios of microclimate change with ensuring an automated model identification for each of them, then the advantages of such model formalization would have become clear immediately. However, solving such a problem can be the material for next separate research.

Conclusions. Thus, the article deals with the identifying topological observability of MSDS and the distinguishing areas or periods when these systems are not observable. For the first time, the identifying MSDS observability method based on the system model formalization in the geoinformational space of their parameters with further transformation into classical bichromatic graphs has been suggested. The method allows not only identifying the MSDS observability level but also finding the appropriate variant of the model improving which will ensure full system observability. The provided example proves the efficiency of the suggested method.

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Мета. Розробка методу визначення та підвищення рівня топологічної спостережуваності багатозв'язних просторово-розподілених систем, процеси в яких формалізуються як аналітичними, так і алгоритмічними залежностями між параметрами об'єктів ГІС цих систем.

Методика. Визначення та оптимізація топологічної спостережуваності багатозв'язних просторово-розподілених систем (БПРС) на основі трансформації їх моделі, формалізованої в геоінформаційному просторі параметрів цих систем, у класичний біхроматичний граф.

Результати. Обґрунтована необхідність вирішення задачі визначення та оптимізації топологічної спостережуваності багатозв'язних просторово-розподілених систем. Проведено аналіз методів формалізації системи такого типу, особлива увага приділена авторському методу формалізації моделі в геоінформаційному просторі параметрів, пов'язаному з ГІС системи. Запропоновано метод трансформації моделі з цього простору параметрів у класичний біхроматичний граф, для якого відомі рішення задачі оптимізації топологічної спостережуваності системи. Реалізовано запропонований метод на прикладі математичної моделі нормалізації мікроклімату в шахтах.

Наукова новизна. Уперше запропонований метод визначення топологічної спостережуваності БПРС, оснований на формалізації моделі цієї системи в геоінформаційному просторі її параметрів з подальшою трансформацією у класичний біхроматичний граф, що дозволяє не тільки визначити рівень спостережуваності БПРС, але й знайти оптимальний варіант удосконалення моделі, що забез-печить повну спостережуваність цієї системи.

Практична значимість. Використання даного методу визначення спостережуваності багатозв'язних просторово-розподілених систем дозволить швидко та ефективно проводити оптимізацію їх систем збирання та обробки інформації, додавати та вилучати прилади контролю й спостереження, удосконалювати модель системи, здійснювати інші заходи для забезпечення її повної спостережуваності.

Ключові слова: *спостережуваність, геоінформаційні системи, геоінформаційний простір параметрів, багатозв'язна система, біхроматичний граф, паросполучення*

Цель. Разработка метода определения и повышения уровня топологической наблюдаемости многосвязных пространственно-распределенных систем, процессы в которых формализуются как аналитическими, так и алгоритмическими зависимостями между параметрами объектов ГИС этих систем.

Методика. Определение и оптимизация топологической наблюдаемости многосвязных пространственно-распределенных систем (МПРС) на основе трансформации их модели, формализованной в геоинформационном пространстве параметров этих систем, в классический бихроматический граф.

Результаты. Обоснована необходимость решения задачи определения и оптимизации топологической наблюдаемости многосвязных пространственно-распределенных систем. Проведен анализ методов формализации систем такого типа, особое внимание

уделено авторскому методу формализации модели в геоинформационном пространстве параметров, связанном с ГИС системами. Предложен метод трансформации модели из этого пространства параметров в классический бихроматический граф, для которого известны решения задачи оптимизации топологической наблюдаемости системы. Реализован предложенный метод на примере математической модели нормализации микроклимата в шахтах.

Научная новизна. Впервые предложен метод определения топологической наблюдаемости МПРС, основанный на формализации модели этой системы в геоинформационном пространстве ее параметров с последующей трансформацией в классический бихроматический граф, позволяющий не только определить уровень наблюдаемости МПРС, но и найти оптимальный вариант усовершенствования модели, который обеспечит полную наблюдаемость этой системы.

Практическая значимость. Использование данного метода определения наблюдаемости многосвязных пространственно-распределенных систем позволит быстро и эффективно проводить оптимизацию их систем сбора и обработки информации, добавлять и удалять приборы контроля и наблюдения, совершенствовать модель системы и осуществлять другие меры по обеспечению полной наблюдаемости.

Ключевые слова: *наблюдаемость системы, геоинформационные системы, геоинформационное пространство параметров, многосвязная система, бихроматический граф, паросочетание*

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AN EFFICIENT METHOD OF CLASSIFICATION OF FULLY POLARIMETRIC SAR IMAGES

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ЕФЕКТИВНИЙ МЕТОД КЛАСИФІКАЦІЇ ПОВНІСТЮ ПОЛЯРИМЕТРИЧНИХ РСА-ЗОБРАЖЕНЬ

Purpose. Synthetic Aperture Radar (SAR) can be used to acquire high-resolution images of ground targets during night as well as day or in good weather as well as inclement weather, so it plays an important role in the national economy and defense. However, according to the characteristics of SAR imaging mechanisms, a geometric distortion and a form of multiplicative noise, known as coherent speckle, generally corrupt the resulting image. SAR image classification is the foundation of SAR image interpretation. For the existing of speckle, traditional image classification technologies cannot work well. In this paper, in order to further improve the effect of polarimetric SAR image classification, an efficient classification method of fully polarimetric SAR image that is based on polarimetric features, the scattering intensity information, and Fuzzy C-Means (FCM) Algorithm is proposed.

Methodology. Combining the scattering properties of fully polarimetric SAR image with the scattering intensity information, the total scattering power, based on *H/α/A/SPAN(H*, Entropy; α, Scattering angle; *A*, Anisotropy degree; SPAN, the total power of polarization), we obtained the initial classification result of polarimetric SAR image. Then with FCM Algorithm, the result of the polarimetric SAR image classification was achieved.

Findings. The experimental results show that the proposed method is superior to the traditional methods of fully polarimetric SAR images classification.

Originality. The proposed method not only considers the scattering properties of fully polarimetric SAR data but also combines the statistical characteristics information. The proposed method provides good result of classification of polarimetric SAR image and, to some extent, keeps the scattering properties.

Practical value. The experiments have proved that the proposed algorithm can keep the texture and details of SAR image better, can give better classification result to the traditional classification methods of fully polarimetric SAR image. The proposed method is useful in SAR image interpretation.

Keywords: *polarimetric SAR, coherent speckle, image classification, H/α/A/SPAN, complex Wishart distance, Fuzzy C-Means*

Introduction. Polarimetric Synthetic Aperture Radar (PolSAR) sends and receives Radar signal with different polarimetric mode, by which the Radar system can obtain abundant information of scattering properties of the ground object targets. Compared with the conventional SAR system, polarimetric SAR can obtain complex polarimetric scattering matrix according to electromagnetic scattering characteristics of different targets which can reflect objective inherent characteristic (fully polarimetric mode corresponding to fully polarimetric scattering matrix, double polarimetric mode corresponding to double polarimetric scattering vector). Based on