УДК 550.8.05+631
DOI: 10.25559/SITITO.14.201802.487-492

INTELLECTUAL METHODS OF ANALYSIS OF GEOGRAPHIC INFORMATION INFRASTRUCTURE OF THE REGION

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ИНТЕЛЛЕКТУАЛЬНЫЕ МЕТОДЫ АНАЛИЗА ГЕОИНФОРМАЦИОННОЙ ИНФРАСТРУКТУРЫ РЕГИОНА

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Keywords

Geographic information systems;
system of systems;
cognitive frame;
fuzzy granules.

Abstract

Fuzzy methods of exploration of geo-informational space as a system of systems are considered. The ar-eas of application of digital specialized plan-schemes as fuzzy projections of geo-informational space are dis-cussed. In the process of presentation of the research materials the necessity of forming a single geo-informational space (UGIS) on the principles of geo-interoperability is formulated and substantiated. The sources and tools for obtaining initial data were evaluated. The components of the mechanism of information interaction of geographical, economic and social characteristics of regions were considered. The principles of using the concept of cognitive space to describe UGIS in the project frame SMART (Satellite monitoring of agricultural devel-opment of territories). The problem of manifestation of various types of uncertainties at the main levels of ob-taining and processing of information is considered. It is shown that for each type of uncertainty it is necessary to carry out: search of the corresponding mathematical description and representation of concrete type of uncer-tainty; the choice of the mathematical device by means of which it is possible to operate (to adjust parameters) model with the chosen uncertainty; existence of an effective way of measurement of real uncertainty in any ana-lyzed situation; development of methodology of formation of adequate models for real objects and processes of monitoring to choose indicators of uncertainty which can be calculated. It is shown that the spatially distributed information obtained, including by remote sensing of the Earth is three large groups: semantic, metric and topo-logical. The structured set of these groups of information about a particular area, presented in the form suitable for automated processing, forms a digital model of the area. This model is based on the ability of one group of information (as a complex system) to use parts of another group, that is, the ability to mutually use information in each of these groups (systems). In other words, we are talking about geo-interoperability, which is used in the study of the model of UGIS, in the process of forming a digital plan-schemes for receiving of additional infor-mation about the objects included in the resulting information product.

Ключевые слова

Геоинформационные системы;
системы систем;
когнитивное пространство;
нечеткие гранулы.

Аннотация

Рассмотрены нечеткие методы исследования геоинформационного пространства как системы систем. Обсуждаются области применения цифровых специализированных план-схем, как нечетких проекций геоинформационного пространства. В процессе изложения материалов исследования сформулирована и обоснована необходимость формирования единого геоинформационного пространства (ЕГИП) на принципах геоинтероперабельности. Оценивались источники и инструменты получения исходных данных. Рассматривались компоненты механизма информационного взаимовлияния географических, экономических и социальных характеристик регионов. Обоснованы принципы использования концепции когнитивного пространства для описания ЕГИП в рамках проекта СМАРТ (Спутниковый Мониторинг Аграрного Развития Территорий). Рассмотрена проблема проявления различного вида неопределенностей на основных уровнях получения и обработки информации. Показано, что для каждого вида неопределенности необходимо осуществить: поиск соответствующего математического описания и представления конкретного типа неопределенности; выбор

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математического аппарата, с помощью которого можно управлять (настраивать параметры) моделью с выбранной неопределенностью; существование эффективного способа измерения реальной неопределенности в любой анализируемой ситуации; разработку методологии формирования адекватных моделей для реальных объектов и процессов мониторинга, чтобы выбрать показатели неопределенности, которые можно вычислить. Показано, что пространственно-распределенная информация, получаемая, в том числе и с помощью дистанционного зондирования Земли составляет три большие группы: семантическую, метрическую и топологическую. Структурированная совокупность этих групп информации о конкретной территории, представленной в форме, пригодной для автоматизированной обработки, образует цифровую модель местности. В основе такой модели заложена способность одной группы информации (как сложной системы) использовать части другой группы, то есть способность взаимно использовать информацию в каждой из этих групп (систем). Иначе говоря, речь идет о геоинтероперабельности, которая используется в рамках исследования модели ЕГИП, в процессе формирования цифровых план-схем для получения дополнительной информации об объектах, включаемых в результирующий информационный продукт.

Introduction

In recent years, the emergence of the concept of a digital society, in which most of the workers are engaged in the storage, processing and use of information, especially the highest form of knowledge, has been clearly reflected in the development and development of the Digital Earth Project [1].

Within the framework of this direction, the SMART (Satellite Monitoring for Active Development of Territories) project is being implemented, developed and realized in the Southern Federal District [1-2].

The main stages of the "life cycle" of satellite information in GIS geographic information systems include the following main points:

1. Satellite data acquisition
2. Archiving
3. Primary processing
4. Thematic processing
5. Formation of information product (Maps, reports, digital plan diagrams (DPD)

To implement the version of the last three stages, research was conducted, methods and application of the methods [2, 3], devices [2, 4, 5] and software products [6, 7] for intellectual support of relevant digital technologies were created [8-14].

In the process of these studies, the need for the formation of a single geographic information space (UGIS) on the principles of geo-interoperability was formulated. The sources and instruments for obtaining initial data were evaluated. The components of the mechanism of information interaction of geographical properties of regions were considered.

According to the modern interpretation [15, 16]. Ontology in Geoinformatics is "an exact specification of the conceptualization of the subject area", of course, "with certain restrictions depending on the area of interest, and should include a dictionary of terms and some specifications of their meanings. The use of ontologies contributes to the creation of adequate conceptual models, providing high-quality, controlled information integration" [16].

The concept of *Cognitive Space* (*CP*) which appeared originally in linguistics, is used in other subject areas, including geographic information systems. At the same time, CP is "an operational self-generating and self-regulating system in which human communicative experience is formed, developed and transformed" [8].

The concept of cognitive space can be used for the interests of providing cognitive interoperability in the formation of geographic information environment. The concept of CP allows to take into account the multifactorial interaction of individual systems, studied and investigated in the space monitoring of the earth's surface in [17], within the concept of *SoS* (System of Systems), for which reference systems, thought processes, quantitative analysis, instruments and design methods are incomplete and/or fuzzy.

The prospect of types UGIS

With regard to **UGIS**, we note the prospects of the following types of System of Systems (SoS):

- directed [18], in which there is a dominant moderator who has the right to issue orders to the constituent systems and managing their resources;
- acknowledged) [19,20], which, though has a dominant a moderator, but having the ability only to recommend to the constituent systems to change itself according to the chosen scheme (architecture);
- collaborative, in which systems coordinate their actions with each other on each emerging problem, but there is no single moderator, project manager or similar dedicated management body [21, 22].

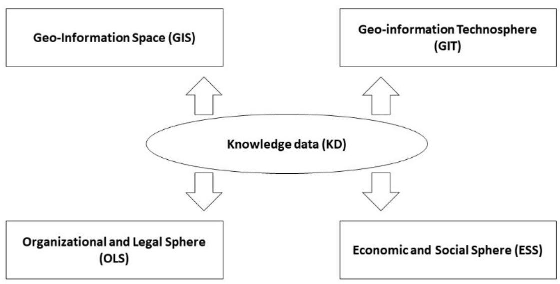

Fig. 1. The unified geo-information space (UGIS)
Рис. 1. Единое геоинформационное пространство (UGIS)

This approach complements the concept of cognitive (in this case, geo-information) space with the aspect of situational response to search for coordinated images of information they operate in the course of their activities.

UGIS as System of Systems

Linking systems with a joint SoS provides interaction and synergy of enterprise management systems, computer management, communication and information, intelligence and so on. A system of systems [11,14] - is large-scale parallel and distributed systems whose components are the complex systems themselves. The system of system education includes the integration of systems into a system that ultimately contributes to the evolution of social infrastructure. The most important features of SoS are their synergy and initial uncertainty of real functioning situations.

The uncertainty of information in UGIS

Considering the problem of uncertainty at the main levels of obtaining and processing information [23-26] for each type of uncertainty, it is necessary to implement:

- search for the appropriate mathematical description and representation of a particular type of uncertainty;
- choice of mathematical mechanism, with which it is possible to control (adjust parameters) model with the selected type of uncertainty;
- finding an effective way to measure real uncertainty in any situation under analysis;
- development of a methodology to generate adequate models for real objects and monitoring processes to select the uncertainty indicators that can be calculated.

In fuzzy logic, as in natural language, all concepts are graded by the degree of truth. Besides, in fuzzy logic everything is granular.
The granule, in this case, means [Zadeh L. A., 1997] a group of objects, united by in distinguish ability, similarity, proximity (i.e. relations, which have at least symmetry properties).

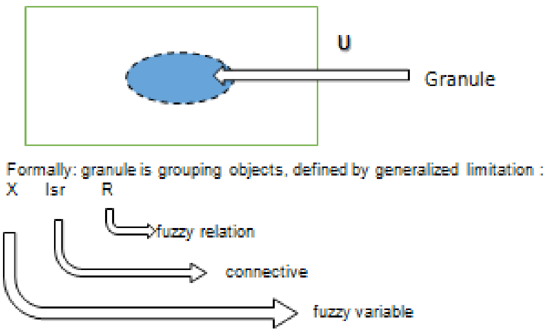

Fig. 2. Cognitive frame as a collection of fuzzy granules
Рис. 2. Когнитивный фрейм как совокупность нечетких гранул

A *cognitive frame* is a fuzzy frame whose slots correspond to fuzzy or linguistic values [14, 17, 25].
The cognitive frame can be seen as the result of granulation of UGIS information, as a linguistic variable in which the family of fuzzy sets is compared to a term set. That is, it consists of normal fuzzy sets *F={A1,..., An}*, where any two adjacent sets have an overlap region.
In this case, the domain of reasoning X must satisfy the conditions of fuzzyα-covering and so-called se-mantic consistency, which are reduced to the following restrictions:
a) the number of elements of the set f is small; according to Miller's law it is within 7+ 2;
b) every A_i is unimodal and normal fuzzy set;
c) neighboring fuzzy sets A_i, A_j should have a small overlap area; it is generally assumed that $A_i \cap A_j < 0.5$.
As an example of fuzzy granulation, it is possible to take a set of values of the linguistic variable "error binding to a local coordinate system". Here 7 terms form a covering set of terms, but not its partition, because neighboring terms are crossing.

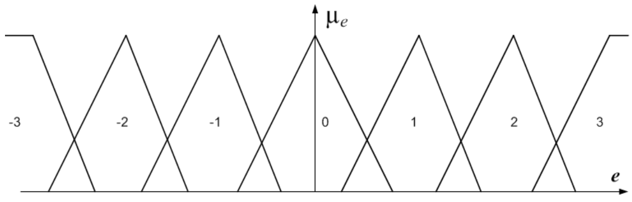

Fig 3. Spas form a cover term sets
Рис. 3. Spas формируют накрытие множеств терминов

Granular values of linguistic variable: 0 – zero error; +1 – small affirmative error; +2 – middle affirma-tive error; +3 – big affirmative error; -1 –small negative error; -2 – middle negative error; -3 – big negative error.

The structure of the information granulation in the framework of triangulated model [13, 25]

The study used the following common scheme of granulation of information:
GR = ⟨X, G, C, M, T⟩, where:
X - field of reasoning;
G - a family of information granules;
C - the set of generalized constraints, (each type of restriction defines the requirements for the choice of the method of granulation);
M - many formal methods of granulation;
T - the set of transitions between levels of granulation of (transformations of the granules).

Features of formation of SoS geographic information space

Spatially distributed information obtained, including by remote sensing of the Earth (ERS) is three large groups: semantic, metric and topological. A structured collection of these groups of information about a specific area, presented in a form suitable for automated processing, forms a digital terrain model (DTM).
The base of such DTM is the ability of one information groups (as systems) use parts of another group [9, 10, 27], that is, the ability to mutually use information in each of these groups (systems).
In other words, we are talking about geo-interoperability.

Geo-interoperability.

International organization for standardization ISO 19119: "Interoperability is the ability to connect, execute programs or transfer data among various functional modules in a way that does not require user to have knowledge about the characteristics of these modules» [27].
This means that two (or more) systems can work together to accomplish the task, provided that they are mutually interoperable.
In the framework of geographic information systems "interoperabili-

ty is the ability of information sys-tems to:

- free exchange of all kinds of spatial information about the Earth and about objects and phenomena, and also above and below the Earth's surface;
- joint network use of the software intended to manage this information».

Received results

It is obviously, storing and maintaining such a constantly evolving model requires appropriate information resources available, at this stage, within the framework of the data warehouse (DW) concept.

The form of geo-database organization that combines DTM and relational databases is the most common form of organization at the moment. However, the complexity of such an organization caused by a set of instruments for creating and maintaining a data topology creates certain problems.

The problems of application of the algorithm and fuzzy triangulation methods in the framework of triangulated model of SoS components in the process of formation of digital diagrams for more information about the objects included in the resulting information product were considered.

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Submitted 16.04.2018; revised 10.06.2018; published online 30.06.2018.

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Поступила 16.04.2018; принята в печать 10.06.2018; опубликована онлайн 30.06.2018.

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