Technology of establishment of terrestrial objects aerospace survey-based object-oriented monitoring systems

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Abstract. The paper studies a technology for the establishment of Earth remote sensing systems based on the object-oriented approach to the complex system analysis and design. The technology relies upon the system of knowledge combining the knowledge of a certain subject domain, the knowledge of image processing algorithms and the typology of the problems in question. Another important element of the technology is a set of human-computer interaction methods that make it possible to arrange a task setting and solving cycle without or with little involvement of image processing experts. The paper presents the input conditions and the main stages of the technology, as well as examples of possible use of the system in agricultural monitoring.

1 Introduction

The improving consumer quality of the ERS (earth remote sensing) data makes them more and more attractive for the end users in different domains, therefore bringing up the need for the development of hardware and software tools for the data intelligence and analysis.

By the present moment, the researcher community has developed a concept for the remote monitoring systems (RMS) [1-3] that provide the software and hardware infrastructure for special data processing. As a rule, such systems are designed for fixed situation monitoring, when the task is clearly formulated and formalized, when the scope of interest and the scope of programs and algorithms involved is clearly determined. The main downside of this approach is the lack of flexibility: any new inquiries from the users require the involvement of data intelligence programming specialists.

The key approach to changing the situation is replacing the “end user – specialist” interaction method with the “end user – solution system” in the monitoring systems [4, 5].

In the process of building of such remote monitoring systems, the researchers face the problems of diversity, dissimilarity, spatial and temporal variability of space monitoring objects. To ensure the effective interpretation of the changes that occur to a monitoring object with airspace images, the interpretation system has to be capable of operating the knowledge of its structural and behavioral properties and their relations with the spectral,

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textural, and structural properties of the analyzed scenes. One of the most promising approaches to the design of the multipurpose software and technological monitoring media is the object-oriented paradigm [6-10] that applies the object-oriented approach principles to the presentation of special data and the design of algorithms for the symbol interpretation of images. The review of the current publications brings us to the conclusion that both Russian and foreign research groups are actively studying the methods and algorithms of object-oriented monitoring manifested in the object segmentation and classification models [8-12]. The object-oriented methods are being tested and adjusted to different classes of objects including agricultural fields, water bodies, coal mining areas for the studies of dust emissions [9, 12-13] etc. The most remarkable results in the development of object-oriented monitoring methods and systems were achieved by the scientists of the Russian Space Research Institute using Vega-Science multipurpose system [13]. Besides, it should be remarked that the research groups have not yet arrived at a unified concept of the object-oriented monitoring of various special objects.

The paper presents the technology of object-oriented monitoring designed to simplify the relations between the end users and RMS by implementing the knowledge presentation and processing tools with special interactive techniques. The technology is developed at the School of Space and Information Technology of Siberian Federal University.

2 Technology description

The scope of the technology is the monitoring or special objects within a definite subject domain. The input condition is the presence of renewable sources of spatial data and (or) services supplying relevant information for the monitoring; the presence of the infrastructure ensuring the possibility of collection and processing of the spatial data along with the open access for the end user setting the task (hereinafter referred to as the Task Setter).

Main stages of the technology.

1. Domain ontology setting. To ensure the system's "understanding" of the user, the intrasystem presentation of the survey domain knowledge is required to limit the class of the survey domains. The authors have developed a database setting concept formulated as a system of principles invariant to the survey domain, ensuring the presentation of the thematic ontologies for the monitoring purposes [14-15]. The knowledge of the monitoring object (Object) semantics is presented as thematic ontologies in the OWL format.

Generally, an individual notion would be associated with a number of measurable properties. The lower hierarchy notions inherit the parent properties. Every measurable property is characterized with its measurement scale and the permitted value limits with the format individual for the selected scale. The property may be associated with one or more related measurement methods. The measurement method is an estimation procedure with such significant properties as the currency and correctness of the information.

2. Organization of access to the renewable spatial data base (SDB) being the region of interest for the end user. The research is based on the SDB of the SibFU School of Space and Information Technology [16] and Vega Science open web services of the Russian Space Research Institute [1]. The technology implies no constrains for the SDB presentation. It can be based on a local renewable set of vector and bitmap layers supplied with the respective attributive information or as dynamically formed sets of spatial data created with the outside web GIS services. To ensure the possibility of ontology interpretation through connecting the ontology classes and the spatial object units, the correlation between the formed domain knowledge base and the spatial object database is made to correlate every individual spatial object to an entry in the respective DBMS table that supports the presentation of such spatial relations.

3. The end user sets the task within the interface solution concept, according to which the basis for the interface organization is the abovementioned domain database and the global dialogue structure invariant to the subject domain of the survey [17]. The task-setting dialogue is carried out as a hierarchic descend on the taxonomy of the domain notions, in the process of which the user determines the target properties. The survey object properties may be used as limitations for the information search; in the given situation, the value interval shall be determined. Besides that, the target properties of the survey object to be measured in the monitoring process are determined. Based on the respective types of relations within the database, the limits for the monitoring time interval and the spatial localization of the monitoring object are set. For every measurable property, a standard pattern for its changes in time and the rules for the interpretation of possible deviations of the measurement results from the planned values may be set. A relevant parameter of the monitoring task setting is the requirement for the frequency of submission of the ERS processing results.

The paper relies upon the task-setting method developed by its authors, determining the basic steps of the dialogue (Fig. 1 *a–d*) and regulating the actions of the user and the system in the process, including: the selection of the monitoring object type and the properties of interest with the option of combining the hierarchic descend down the domain notion tree and the keyword search; the indication of the spatial location of the monitoring object by means of navigation operation, replacement of mounts, territorial division and zoning systems, as well as specification of the mentioned information in the dialogue process; setting the temporal interval for the measurement by direct or indirect methods; specification of the monitoring object model elements related to the permitted and threshold values of the measurable properties, adjustment of the policy for notification of the user of any critical situations.

4. Interpretation of the task setting by the System. In general, the task setting is considered as the System's capacity of interpreting the actions of the Task Setter in the dialogue into its intrasystem representation. The two main interpretation scenarios have been implemented and tested.

The first scenario implies that the Task Setter makes a choice within the limited multitude of previously formulated tasks (for example, the most frequently solved tasks or the tasks the System is capable of solving without additional learning). At that, the System database has the established relations of "task – solution algorithm". The variables for the previously determined algorithms can be object coordinates, points in time or date intervals as limits for the selection of data to be processed in order to solve the task.

The second scenario suggests that in according with the global dialogue structure stages the Task Setter moves down the hierarchy of the notion tree within the domain context, attributing the key properties of the monitoring object stage by stage.

This task setting method is based on resolving the monitoring task in a dialogue with the end user [18] that provides a multitude of possible actions of the user, with the System database that provides a multitude of relations of the "action – computational procedure" type.

Within the framework of the suggested technology, a model for organization of knowledge of operating spatial data in the monitoring process has been developed [18]. Unlike the models embedded in ENVI, ERDAS Imagine, IMC, ESA-SNAP and other software packages [21], the developed model makes it possible to present the knowledge of the composition, sequence, and relation of the algorithmic flowcharts of the geospatial data processing along with the relations between the spatial object, the task, the cumulation of algorithms and the temporal sequence of solving the task under prior uncertainty. The model presents the problem solving procedure as a multitude of discreet changes of the syntactic (spectral, textural) properties of the object within the given time interval; it is characterized with cyclicity, multi-tasking and distribution capacity.

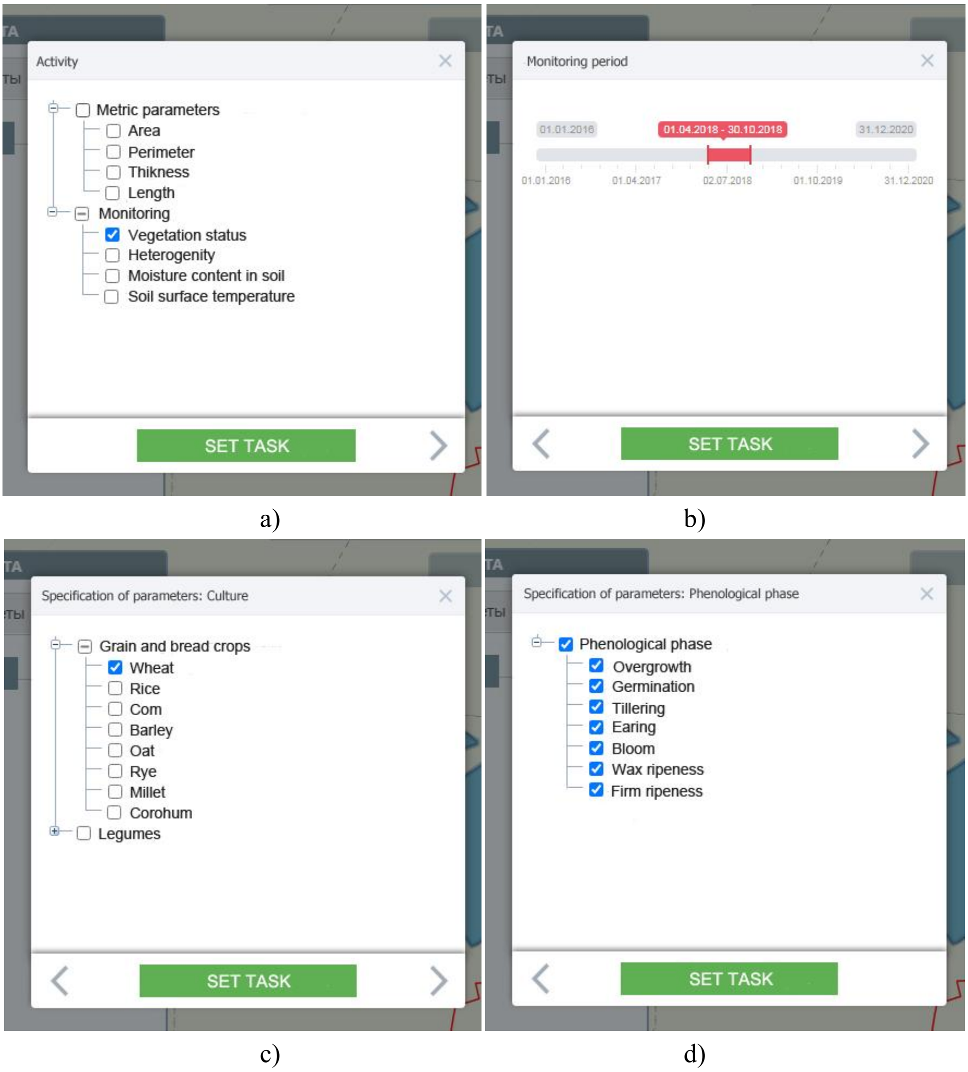

Fig. 1. Grain culture monitoring task-setting (for wheat)

5. The totality of actions described in paragraphs (1)-(4) is a compulsory condition for the launch of the monitoring procedure. The process is limited to the totality of measurements taken with the frequency determined by the task description. The monitoring results are presented to the end user as the triggers set in the task setting process are activated.

3 Implementation and testing of the technology components

The software and information components of the technology described in the present paper have been implemented in the remote monitoring system of the SibFU School of Space and Information Technology [16].

In particular, the following software tools have been produced:

- The functional prototype of the monitoring task setting web interface;
- The web service for building the performed algorithmic structures for the ERS data analysis and processing;
- Set of distributed auxiliary software modules to ensure the supply of relevant aerospace data to the system, the preparation and proper processing of data, the connection of the functional blocks of algorithmic structures etc.;
- System knowledge database in the OWL format for the storage of themed references for the selected domains.

The domain selected for the technology testing was agricultural monitoring. The tasks selected for the testing of the technology components are the analysis of spatial unevenness of the agricultural circuit, the forecasting of the grain culture crops, the monitoring of the grain culture condition, and the monitoring of adherence to the agricultural technology of handling the fallow land [18-20], Fig. 2.

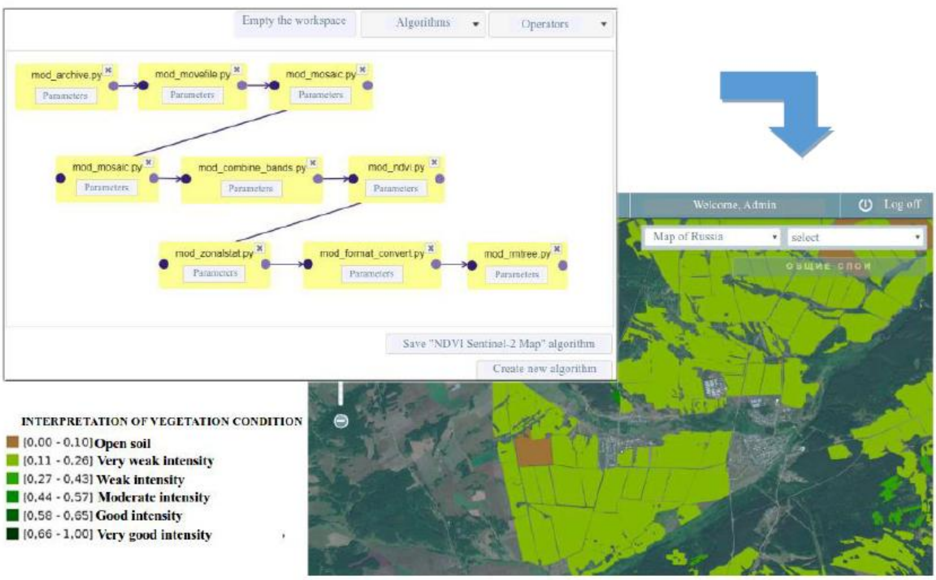

Fig. 2. Algorithmic structure for the monitoring of the grain culture condition and the results of one of its cycles

4 Conclusions

A technology of creation of the terrestrial object-oriented monitoring information systems based on aerospace survey was developed. It relies upon the object-oriented approach applied to the organization of storage of the spatial monitoring objects, the presentation of data and the knowledge of objects in relation to the temporal aspects of the alternation of their life phases and the technology workflow in order to develop some service-oriented applications based on a unified software and technological platform, including the distributed functional components intended for the collection, processing, analysis and presentation of the derived cartographic products with the capacity of adaptive adjustment of the information and computational processes of resolving the themed inquiries of the end users. The technology is intended to align the mental model of the end user on one hand with the totality of the processed data, algorithm of its adoption, presentation and processing on the other. The result of such alignment is the task solving mechanism interpreted into the intrasystem presentation. The software, information, and methodical aspect of the technology have been tested for compliance for solving the agricultural monitoring problems in the remote monitoring system of the SibFU School of Space and Information Technology.

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