An Interactive Environment for Modeling the Processes of ERS Data Processing and Analysis

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Abstract. Article presents the concept of interactive technology modeling processes and the data analysis of the Earth remote sensing developed at Institute of space and the information technology SFU. The technology allows to interpret models of processes in real algorithmic designs data processing in the local and distributed conditions, and also to use them for automatization permission queries of the end users in the remote monitoring multi-purpose system of ISIT SFU (MSRM).
Keywords. Remote sensing, information systems, satellite data processing, processes modeling, interactive modeling environment, algorithmic sequence, information query, end user.

1 Introduction

The development of the global ERS satellites' constellation will significantly broaden the range of issues to be solved by the RS data. This will increase the demand for geospatial data and services in government control, commercial activities and among the public. The concept of the remote monitoring software is changing, they become multi-purpose. The multi-purpose remote monitoring systems (MPRMS) are characteristic of the end-user orientation which assumes availability of comprehensive facilities for spatial monitoring definition and solution and reduces the role of experts in data processing and interpretation as the mandatory problem solution participants. Such possibility is identified by the following factors: "capacity" of the spatial data processing system which is defined by the number and variety of the software models to process, analyze and interpret data, such number and variety being enough to solve the common jobs' pool in one subject area or another, and by degree of such system reasonableness marked by the expert knowledge transfer to the system knowledge data base.

The number and variability of the processing algorithms for raster and vector spatial data as developed nowadays by the world society and realized in the respective software packages such as ENVI, Erdas Imagine, ScanEx Image Processor, QGIS and others are enough to solve the set of common jobs. In addition, the algorithms and software are being continuously improved in response to development of the new tools to acquire the spatial information and the computational accuracy is increased. However, most of the existing software packages are meant to be used by the image processing experts.

Development of the web-service architectures which make it possible to solve the common jobs shall be noted among the end-user solutions. Nevertheless, the end users often have the individual demands which means a specific procedure of the data input, processing and presentation of results. As a rule, the particularity of the solved topic-related issues makes it necessary to build the algorithmic sequences of the various range of complexity based on the combination of the known data processing and analysis algorithms. Thereat solving of new jobs requires not only the data processing expert being engaged to build the processing logics which is quite natural, but also the programmer to program the respective sequences. Such approach is inflexible as the system functioning logic is securely fixed as regards its internal implementation and enhancement of functionalities requires, as a matter of fact, a new cycle of development.

This fact makes actual the researches aimed at development of unified technological platforms providing the data processing expert with the interactive tools for the adaptable arrangement and debugging of the chain of operators which present the algorithmic structures solving some job [1, 2, 3] and, thereat, allowing to exclude the source-weaving of data processing operators which is inappropriate as regards the technology buildup process. The example of such approach is the Sentinel Application Platform (SNAP) software package of European Satellite Agency (ESA) or the Russian Image Media Center (IMC) of the Innovative Technologies Center.

2 Structure of the interactive process modelling environment

The major concepts of the spatial systems development are more specifically discussed in [4-8]. The systems considered in the mentioned works are of various unifications and, in most cases, require the systematic approach and programming experience to adapt for the new ranges of the monitoring jobs.

As an alternative this article presents the architecture of the software complex providing the interactive environment for ERS processing and analysis modelling (Fig. 1, a). It includes the below components presented on the conceptual level.

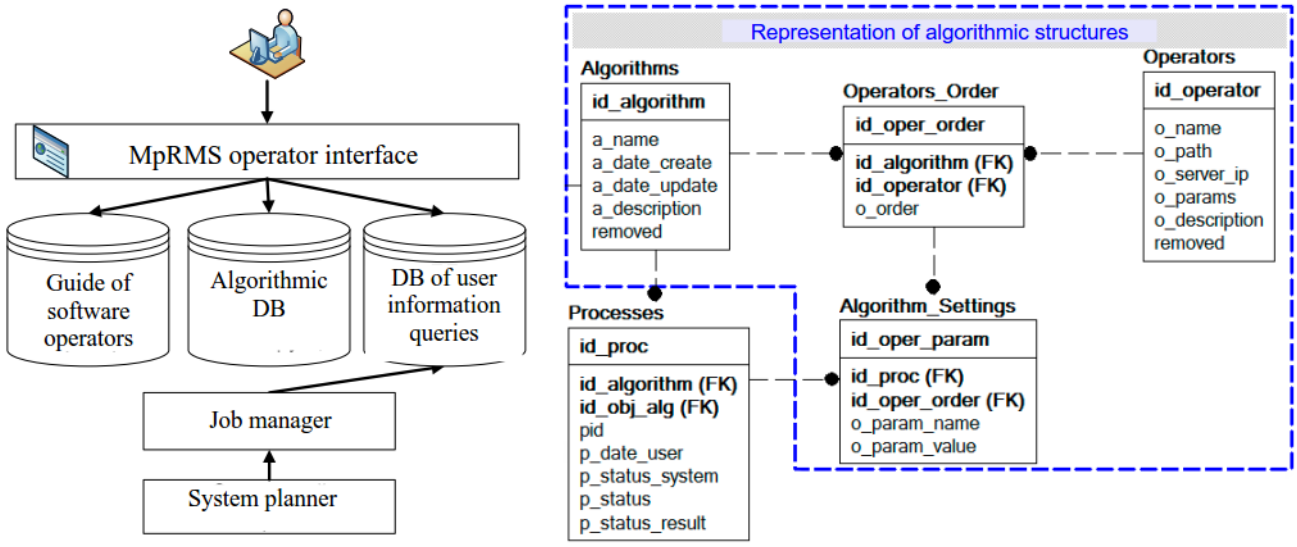

Fig.1. a - Structure of the process modelling software package; b - algorithmic structures' View Model.

2.1 The Guide of Software Operators

The Guide of Software Operators (Table «Operators», Fig. 1, b) keeps the list of operators available for experts during the algorithmic design. Operator is a complied library or a software unit which can be realized in any interpreted language (Python, Perl, PHP and others). The software units shall have the below properties to function as part of the algorithmic structures:

- Autonomy is one of the key properties of the operator functioning which characterizes its ability to execute the given set of functions without other system operators and allows considering it as an independent element of the control chain. Thereat the operator is considered as the programming interface for cooperation between a user being a customizer and an objective system model represented by the collection of libraries. Thus, the autonomy does not result in duplication of functions by different operators. The operator programming interface may be realized as a command line or a graphic interface to uptake the user setups (Fig. 3).
- Controllability. This property means the restricted number of input I_A and output O_A parameters which are partially designated by an expert during algorithmic design and partially automatically determined when obtaining the interim processing results. Input parameters dictate the scenario of an autonomous operator behavior. This means that the operator itself shall build-up its functioning logics depending on the parameters' contents and their possible values.
- Parameters are determined by the "qualifier-value" principle where, for instance SQL, SPARQL-structures may be used as the values instead of common numerical or line data in order to communicate the interim operation results from the preceding i-d operator to the successive i+1 or i+n ($i = 1,\acute{n}$) operator when the results is not apriori known. Also, the files' search, files' content search, regular expressions and etc may be considered in parameters.
- Stability. The property which gives an indication of an operator capability to function properly with the wrong set content or sequence of parameters. This means that the parameters should not be listed in a strict order and the surplus or non-existent parameters coming out in the list shall not lead to the operator failure. If the required parameter has been missed, the operator shall inform the user thereof in a dialog mode.
- Security. The property which gives an indication of the operator capability to resist the willful or unintentional destructive actions of the user.
- Understandability is indicative of a well-documented and structured operator description, in particular, of its functionability, content and assignment of input parameters, combination of parameters and behaviors.

2.2 Algorithmic Data Base

Each algorithmic structure is characterized by its own specific set of parameters which are generalized in the below expression:

$$A =< I_A, O_A, R_A, F_A >, \quad (1)$$

where I_A is a set of input parameters of algorithm A; O_A is a set of input parameters; F_A is a set of algorithmic functions; R_A is a set of relations with the other algorithms which shall be taken into account as $F_{A_i} \cap F_{A_j}$ and at the physical level this property is indicative of the modular approach to algorithm design which, in its turn, implements the principle of the program code re-use or the principles of the object-oriented approach.

Relational approach is the most correct and flexible as regards presentation of the system knowledge of the structure and content of algorithmic structures, such approach allowing the operators to be bound in the logical sequences, defining the set members I_A and storing the unlimited sets of such sequences. Fig. 1, b, shows the part of the data base meant for algorithmic structures. Model includes the following tables:

- Algorithms is a reference guide of generated algorithmic structures.
- Tables Operators_Settings and Operators_Order are binders to establish the conformities between algorithms, their integral operators and parameters of the operators. They identify the set of operators' sequences, their parameters and their order in the structure.

2.3 MpRMS Operator Interface

Provides the customizer with interactive tools for the process model visualization and the process initialization and startup (Fig. 2). Interface shall also account for the possibility to manage the Operators' Reference Guide, algorithmic structures and task performance schedule, namely, to add, edit and delete lines, as well as the possibility to establish binds between information queries of users and algorithmic structures designed to settle the queries.

2.4 Data base of user information queries

Data base of user information queries is a part of the Data Base (Table Processes) meant to record the incoming data processing queries of end users. Therewith there may be two types of queries: single and cyclic. Single queries mean the queries of the one-time calculation of some set parameters, for instance, calculation of area. Cyclic queries provide for the multiple calculation of the set parameters for the set objects at the certain time interval which corresponds with the monitoring jobs. This way the model of the user information query allows presenting the query as the monitoring plan be described by certain status and binding the job definer, group of objects and the respective algorithmic structure (Fig. 1, b).

2.5 Job manager

Job manager is a programming module meant to be activated to perform the algorithmic structures in accordance with the performance time schedule. The activated algorithmic structure is a system process of various status as regards the operational system. The Manager allows interpreting the system status and changing it. As the multi-job demand means that the operators of various algorithmic structures may be performed in parallel, then the job manager shall control the system resources which are a priori limited. Therefore, on the one hand, the thread (Thread) queue (Queue) procedure is foreseen for the structure operators to be performed in strict compliance with the expert-set order. On the other hand, the control subsystem shall control the system memory and prevent the simultaneous performance of more than 5 structures.

2.6 Planner

The system planner shall activate the job manager from time to time, namely once in a minute. The alternative solution of the automated no-planner operators' start job is to create the services that continuously supervise the jobs' status [9].

3 The Experimental Testing of Technology

The status of spring sown cereal during the growing season was chosen as a monitoring job for the experimental testing. The status is assessed based on the periodical calculations of the vegetation index and status charting to be published in web-interface of ISIT MSRM [10, 11].

The system has an algorithmic structure to deal with this query, such structure consisting of the following operators presented in the relevant order (Fig. 2):

- Archive Retrieval Module. USGS open-source data are used where image channels are distributed in ZIP or TAR archives. That is why the first action is to expand the archive to the specified temporary directory. The module shall self-recognize the type of the archive. The batch mode is used whereat all the archives of one date are successively extracted to the set directory. The preloaded data for the set date and area are the prerequisites for the module operation.
- Files' Moving Module is used to move the initial archives to the data storage.
- Mosaic Gathering module is meant for the channel-by-channel gathering of mosaics from the individual images. The module shall determine the number of images of the set spectral channel. When there is more than one image of one channel after the archives' extraction, the mosaic shall be gathered, otherwise it should not. Thus,

two channels are required to calculate NDVI: RED and NIR, therefore the module in the structure shall be used twice.

- Multiplexing Module is meant to combine the individual spectral channels into one multi-channel file to optimize the processing.
- NDVI Calculation Module calculates the spectral NDVI index and creates a channel with NDVI values.
- Regional Statistics Module shall function for calculation of statistical characteristics and their storage in one of the vector formats. Used for calculation of the NDVI average ($\acute{N}$) for each object. The calculation results are stored in GeoJSON file with reference to which the vegetation status map is being generated (Fig. 2).
- Format Conversion Module is meant for conversion of one bit map format into another. Used for conversion of the Sentinel satellite channels from JPEG2000 to the conventional GeoTIFF format to be further treated under the other processes.
- Files' Delete Module is meant for recursive cleaning of directories. Used to delete the temporary directory with the interim findings of the algorithmic structure function.

Fig 2. Example of the algorithmic model and its findings.

The described algorithm allows mapping the status of the cultures under review as per Sentinel-2A, B data.

Process modelling provides for just several major steps: selection and addition of a listed program operator to the workspace and setting a subset of parameters for it (Fig. 3); the operators' sequence is set by arrows (Fig. 4).

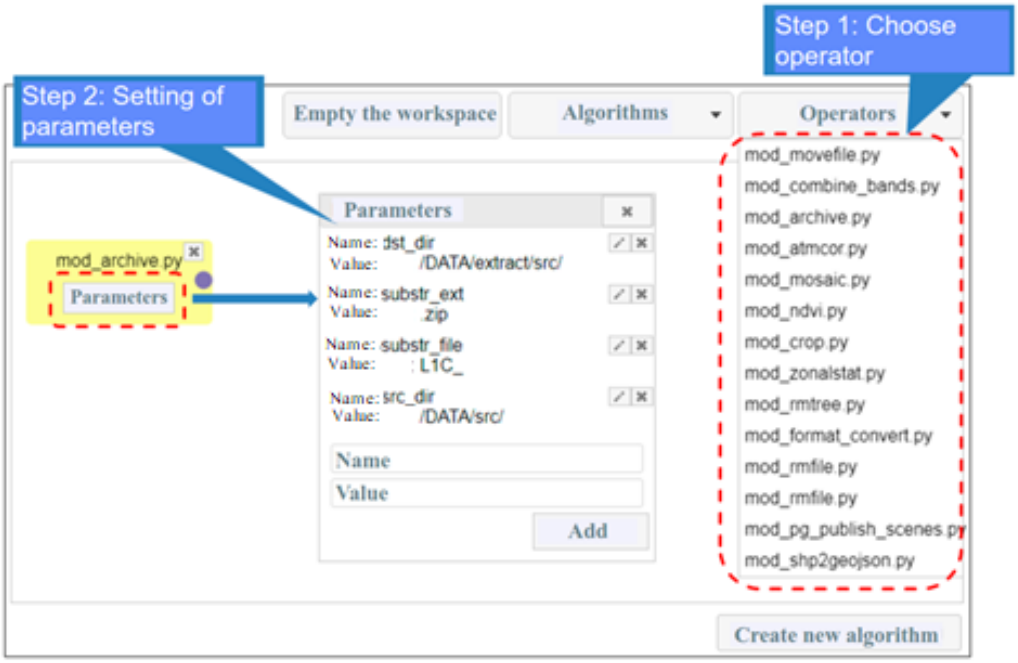

Fig 3. Steps 1 and 2 of the process modelling dialogue

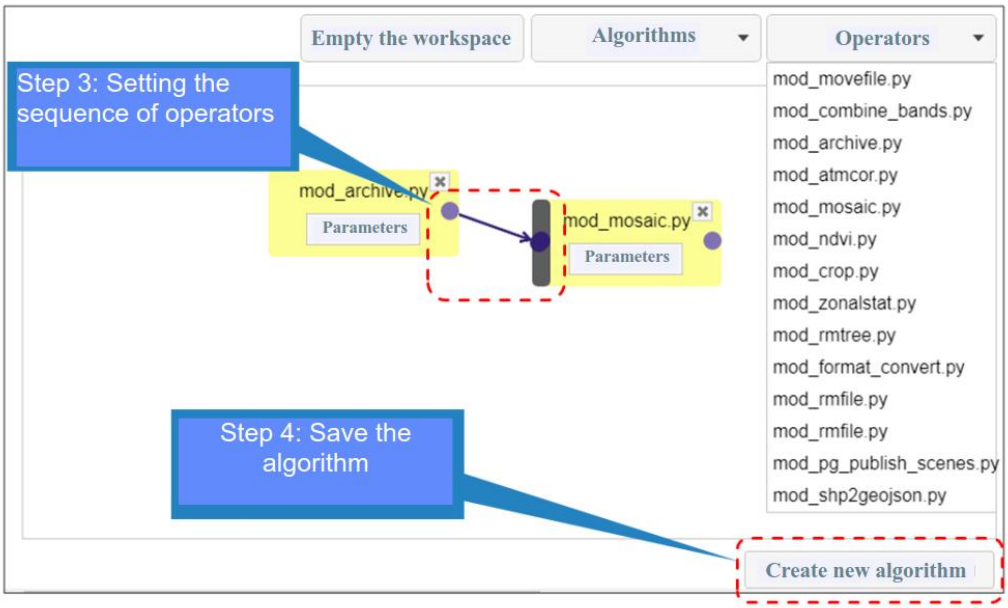

Fig 4. Steps 3 and 4 of the process modelling dialogue

4 Conclusion

The interactive environment for modelling of ERS data processing and analysis as presented herein is realized as the software and hardware complex being part of the multi-purpose ISIT remote sensing system and was successfully tested. The algorithm classifier is being created based on the algorithmic structures for this environment, such classifier being used in the designed job setting interface [12] in the form of the operations with the set spatial objects available for an end user. Besides that, the development also allows arrangement of computational procedures in a distributed environment when program operators indexed in the unified guide are physically located at different servers.

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LITERATURE

[1] V.N.Lobzenyov Complete cycle of ERS data processing in IMC software package // Publications of the International Conference “From Image to Map: Digital Photogrammetric Technologies”. Hainan, China, 2014. P. 13-19.

[2] Michael Foumelis, Jose Manuel Delgado Blasco, Yves-Louis Desnos and other ESA SNAP – StaMPS Integrated Processing for Sentinel-1 Persistent Scatterer Interferometry // IGARSS. 2018. P.1364–1367.

[3] R.V.Brezhnev, A.A.Perevalova Technology of the graphic development of the ERS data processing and analysis procedures// Publications of the International Conference Regional issues of the Earth Remote Sensing. Krasnoyarsk : Siberian Federal University, 2018. P. 40-43.

[4] A.A.Matveev, A.S. Mamaev, A.A.Proshin, E.V.Flitman. Arrangement of control over operation of the distributed remote sensing information system of RosLesKhoz//Modern issues of the Earth Remote Sensing from space. Moscow, 2009. V. 6, No 2. P. 535-541.

[5] Yu.A.Maglinets, R.V.Brezhnev Development of the automation tools to receive and process the satellite data of the regional ERS system of SFU//Modern issues of the Earth Remote Sensing from space. Moscow, 2011. V. 8, No 3. P. 120-128.

[6] I.V.Balashov, V.Yu.Efremov, A.A.Mazurov Junior, A.S.Mamaev, A.M.Matveev, A.A.Proshin Peculiarities of arrangement of monitoring and control of the distributed RS systems//Modern issues of the Earth Remote Sensing from space. Moscow, 2011. V. 8, No 3. P. 161-166.

[7] P.A.Loshkarev, O.O.Tokhiyan, A.M.Kurlykov, K.V.Koshkin, A.P.Gladkov Development of ERS UGDIS with clouds//GEOMATIKA. Moscow, 2013. No 4. P. 22-26.

[8] Brezhnev R.V., Maltsev E.A. An Ontological Spatial Monitoring System for Agricultural Land Monitoring // Pattern Recognition and Image Analysis. 2015. Vol. 25, No. 2. P.201–208.

[9] A.V.Kashnitski, I.V.Balashov, E.A.Lupyan, V.A.Tolpin, I.A.Uvarov Creation of tools for remote processing of the satellite data in the modern information systems//Modern issues of the Earth Remote Sensing from space. Moscow, 2015. V. 12. No 1. P. 156-170.

[10] Brezhnev R.V., Maglinets Yu.A., Raevich K.V., Tsibulski G.M. Modeling of Agricultural Spatial Objects with Heterogeneous Dynamically Changing Spatial Structure // CEUR Workshop Proceedings. Samara, Russia, 2018. Vol. 2210 P.316–322.

[11] Brezhnev R.V., Maglinets Yu.A. The dynamic model of agricultural land structure on the space images in the precision agriculture tasks // E3S Web of Conferences. 2019 Vol. 75, 01001.

[12] Brezhnev R.V., Maglinets Yu.A. Information Support Technique for Solving Agricultural Land Monitoring Tasks Based on Earth Remote Sensing Data // Journal of Siberian Federal University. Engineering & Technologies. Krasnoyarsk, 2017. Vol.10. NO 6. P. 819-827