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APPLIED INFORMATION TECHNOLOGY OF THEMATIC SEGMENTATION OF OPTICAL-ELECTRONIC IMAGES FROM ON-BOARD SYSTEMS OF REMOTE SENSING OF THE EARTH

Abstract. The **subject matter** of the article is applied information technology of thematic segmentation of optical-electronic images from on-board systems of remote sensing of the Earth. The **goal** is to develop an applied information technology for thematic segmentation of optical-electronic images from on-board Earth remote sensing systems using the system modeling methodology IDEF0. The **tasks** are: analysis of features of optical-electronic images, formulation of requirements for methods, techniques and information technologies of thematic segmentation of optical-electronic images from on-board systems of remote sensing of the Earth, development of applied information technology for thematic segmentation of optical-electronic images from on-board systems of remote sensing of the Earth. The **methods** used are: methods of probability theory, mathematical statistics, methods of optimization, mathematical modeling and digital image processing, analytical and empirical methods of comparative research. The following **results** were obtained. In accordance with the syntax and semantics of IDEF0, the applied information technology of thematic segmentation of optical-electronic images from on-board systems of remote sensing of the Earth can be presented in the form of: a tuple, an upper child diagram, and child diagrams. A block diagram of the algorithm that implements the methods of applied information technology of thematic segmentation of optical-electronic images from on-board systems of remote sensing of the Earth is given. A block diagram of the algorithm that implements the methods of applied information technology of thematic segmentation of optical-electronic images from on-board systems of remote sensing of the Earth is given. **Conclusions.** The scientific novelty of the results is as follows: an applied information technology has been developed for thematic segmentation of optical-electronic images from on-board systems of remote sensing of the Earth, which, unlike the known ones, use the system modeling methodology IDEF0, which is based on the SADT structural analysis and design method.

Keywords: remote sensing of the Earth; optical-electronic image; thematic segmentation; information technology; system modeling methodology; structural analysis and design method.

Introduction

Formulation of the problem. It is known that the result of deciphering optical-electronic images from on-board remote sensing systems of the Earth depends on the quality of methods for thematic segmentation of optical-electronic images [1-3]. This posed for developers of image processing systems the task of developing methods, techniques and information technologies for thematic segmentation of optical-electronic images from on-board remote sensing systems of the Earth.

The following requirements are put forward to the methods, techniques and information technologies of thematic segmentation of optical-electronic images from on-board remote sensing systems of the Earth [1-3]:

– high speed when processing large data arrays;

– the possibility of sharing spectral and textural features.

It is known that at present there is no general theory of optimal representation and image processing. The choice of a specific image processing technology depends on the tasks that are being solved and the requirements imposed on the result of the processing.

Analysis of recent research and publicatins.

It is known that a characteristic feature of thematic segmentation of optical-electronic images from on-board systems of remote sensing of the Earth is the search for rational solutions in the multidimensional space of alternatives. Under such conditions, the use of classical methods for finding the extremum of an objective function becomes ineffective. Currently, global extremum search methods are being developed that provide convergence to the exact solution of the optimization problem and provide the optimal (minimum or maximum) value of the fitness function [4].

Metaheuristic methods have the following properties [4, 5]: managing the process of finding the optimal solution; effective study of the search space to find the optimal solution; use of simple local search procedures and complex learning processes; approximate methods and, as a rule, non-deterministic; take into account the possibility of falling into a trap in a limited search space; are universal (they solve various applied problems); use a priori information to find the optimal solution.

There are four main groups of metaheuristic optimization methods: evolutionary methods; swarm methods; methods that mimic physical processes; multi-start methods [6, 7].

To evolutionary methods include: genetic methods; imitation methods immune systems of organisms; scattering methods; evolutionary transformation strategy correlation matrices; dynamic network method; methods of differential evolution and others [6].

The swarm methods include: the method of behavior of particles in a flock; ant method, artificial bee colony method; method, imitating the behavior of schools of fish and others [8, 9].

The **goal** of the article is to develop an applied information technology for the thematic segmentation of optical-electronic images from on-board systems of remote sensing of the Earth.

Main results

The information technology of thematic segmentation of optoelectronic images from on-board remote sensing systems of the Earth will be considered as a set of functions that are definitely connected with each other. And implement the techniques, ways and methods that provide for the receipt, storage, processing, transmission and use of optical-electronic images.

For visualization and further formal presentation of the structure and composition of information technology for thematic segmentation of optical-electronic images (information technology for the thematic segmentation of optical-electronic images (ITTSOEI)), we will use the system modeling methodology IDEF0 (ICAM (Integrated Computer Aided Manufacturing) Definition) [10].

In general, the IDEF0 methodology is used to create a functional model that displays the structure and functions of the system, as well as the flows of information and material objects linking these functions. IDEF0 methodology is based on SADT (Structured Analysis & Design Technique) structural analysis and design method. The IDEF0 methodology is based on a standardized graphical language for describing (modeling) systems [10]. In accordance with the syntax and semantics of IDEF0, it is formally possible to present the ITTSOEI technology in the form [11] (tuple ITTSOEI – expression (1); set $\{D_l^{ITTSOEI}\}$ – expression (2); set $\{L_j^l\}$ – expression (3)):

$$T^{ITTSOEI} = \left\langle In^{ITTSOEI}, \{D_l^{ITTSOEI}\} \right\rangle, \quad (1)$$

$$D_l^{ITTSOEI} = \left\{ \{F_i^l\}, \{L_j^l\} \right\}, \quad (2)$$

$$L_j^l = \left\{ \{V_j^l\}, \{C_s^l\}, \{I_m^l\}, \{O_n^l\}, \{M_r^l\} \right\}, \quad (3)$$

where $In^{ITTSOEI}$ – formulation of the goal.

In this case, it is the development of a system of related functions that implement the techniques, methods and methods of collecting, storing, processing, transmitting and using knowledge (data) of thematic segmentation of optical-electronic images from on-board Earth remote sensing systems as information technology;

$\{D_l^{ITTSOEI}\}$ – a set of levels of detail in the ITTSOEI information technology presentation;

l=0,…,3, where when l = 0, a top level context diagram (model) is formed, when l = 1 – the upper child diagram, when l = 2, l = 3 – child diagrams;

$\{F_i^l\}$ – a set of functions that implement the techniques, methods and methods of working with knowledge (data) at $\{D_l^{ITTSOEI}\}$ the level of detail of the presentation of information technology ITTSOEI.

As functions with l = 0, we consider the generalized "activity" (function-activity) with ITTSOEI. When l = 1, the main "processes" (functions-processes) of working with knowledge (data) in ITTSOEI implemented in ITTSOEI are considered as functions.

As functions with $l = 2$, we consider “subprocesses” (functions-subprocesses) of working with knowledge (data) within the framework of the corresponding “process” at the stages of development and operation of the subsystem of thematic segmentation of an optical-electronic image.

As functions with $l = 3$, we consider "operations" (functions-operations) of working with knowledge (data) during the development and operation of the thematic segmentation subsystem as part of the corresponding "process" at the stages of the development and operation of the thematic segmentation subsystem of the optical-electronic image from the on-board remote sensing systems of the Earth:

$\{L_j^l\}$ – a set of internal and boundary interactions of system elements;

$\{V_j^l\} \subseteq \{L_j^l\}$ – a set of internal interactions between functions from a set $\{F_i^l\}$;

$\{C_j^l\} \subseteq \{L_j^l\}$ – a set of control limit interactions of software and hardware implementing ITTSOEI information technology;

$\{I_j^l\} \subseteq \{L_j^l\}$ – a set of input control limit interactions that reflect data (information, knowledge), which turn into a function;

$\{O_j^l\} \subseteq \{L_j^l\}$ – a set of output control limit interactions that reflect the data (knowledge) about the objects produced by the function;

$\{M_j^l\} \subseteq \{L_j^l\}$ – a set of limit interactions that reflect the mathematical apparatus used to formalize knowledge on thematic segmentation of optical-electronic images.

In Fig. 1 shows a formal view of the ITTSOEI technology in accordance with the expression (4):

$$D_0^{ITTSOEI} = \left\{ \{F_1^0\}, \{C_1^0, I_1^0, O_1^0, O_2^0, M_1^0\} \right\}. \quad (4)$$

In Fig. 2 shows the upper child diagram describing the functions-processes of information technology ITTSOEI in accordance with the expression (5):

$$D_1^{ITTSOEI} = \left\{ \{F_i^1\}, \{C_1^0, I_1^0, O_1^0, O_2^0, M_1^0, \{V_t^1\}\} \right\}, \quad (5)$$

where t=1,2,…7.

As functions from the set $\{F_i^1\}$ of the upper child level diagram $D_1^{ITTSOEI}$, created when decomposing a level diagram $D_0^{ITTSOEI}$, the functions processes that implement the techniques, ways and methods are considered:

– collection of knowledge (data) of the results of thematic segmentation of optical-electronic images $F_1^1 \in \{F_i^1\}$;

– storage of knowledge (data) of the results of thematic segmentation of optical-electronic images $F_2^1 \in \{F_i^1\}$;

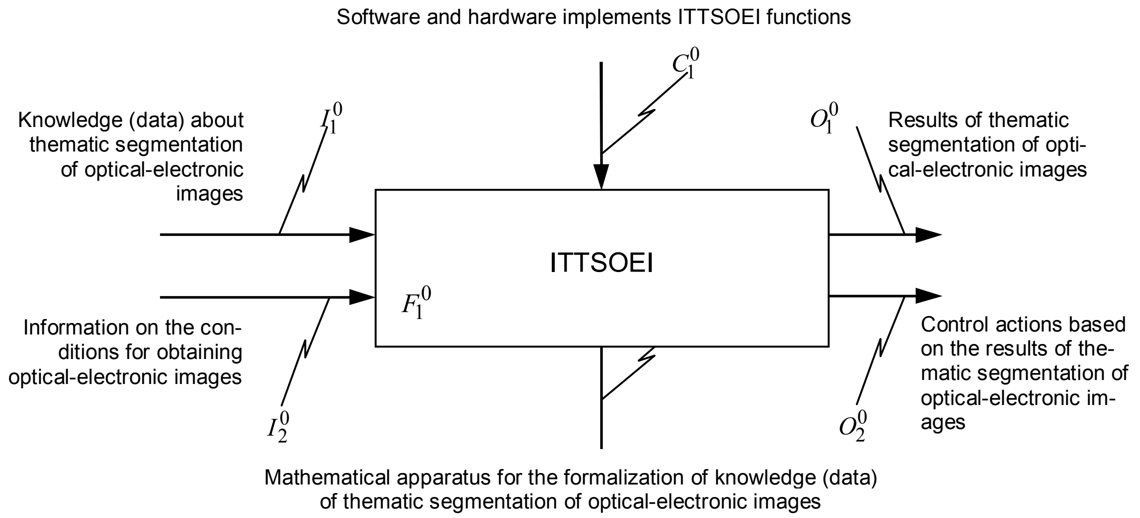

Fig. 1. Formal view of ITTSOEI information technology

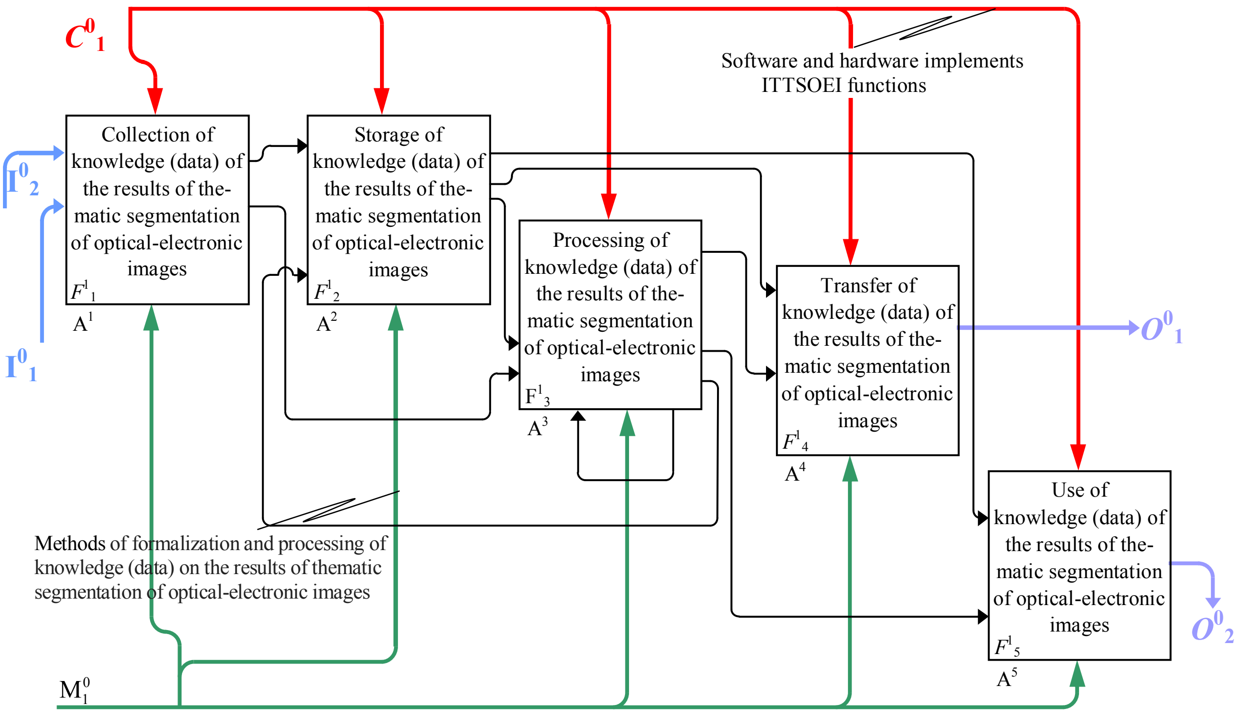

Fig. 2. Upper child diagram that describes the functions-processes of information technology ITTSOEI

– processing of knowledge (data) of the results of thematic segmentation of optical-electronic images $F_3^1 \in \{F_i^1\}$;

– transfer of knowledge (data) of the results of thematic segmentation of optical-electronic images $F_4^1 \in \{F_i^1\}$;

– use of knowledge (data) of the results of thematic segmentation of optical-electronic images $F_5^1 \in \{F_i^1\}$.

Let us briefly review the main functions of the ITTSOEI information technology processes.

The function-process of collecting knowledge (data) of thematic segmentation of optical-electronic images from on-board systems of remote sensing of the Earth $F_1^1 \in \{F_i^1\}$ is implemented by performing the following functions-subprocesses:

– function-subprocess $F_{11}^2 \in F_1^1$ of collecting knowledge (data) of thematic segmentation results, which is implemented in the development of software and hardware complex of thematic segmentation of optical-electronic images from on-board remote sensing systems of the Earth;

– function-subprocess $F_{12}^2 \in F_1^1$ of collecting knowledge (data) of the results of thematic segmentation of the optical-electronic image, which is implemented during the operation of the software and hardware complex of thematic segmentation of optical-electronic images from the on-board systems of Earth remote sensing.

During the implementation of the function-subprocesses F_{11}^2, the composition of knowledge (data) is determined (including from the point of view of identifying declarative and procedural knowledge) of thematic segmentation of optical-electronic images from on-board remote sensing systems of the Earth.

During the implementation of the function-subprocesses F_{12}^2, if necessary, adjustments are made to the composition of existing knowledge (data) on thematic segmentation of optical-electronic images from on-board remote sensing systems of the Earth, and data (facts) are currently being received from external sources of information (for example, in the area of observation, phono-object target situation, etc.).

The function-process of storing knowledge (data) of the results of thematic segmentation of optical-electronic images from on-board systems of remote sensing of the Earth $F_2^1 \in \left\{F_i^1\right\}$ is realized by performing the following functions-subprocesses:

– the function-subprocess $F_{21}^2 \in F_2^1$ of the development of a knowledge base (data), which is implemented in the development of a software and hardware complex for thematic segmentation of optical-electronic images from on-board remote sensing systems of the Earth;

– the function-subprocess $F_{22}^2 \in F_2^1$ of the process of direct storage of knowledge (data) of the results of thematic segmentation of optical-electronic images from onboard systems of remote sensing of the Earth, which is implemented during the operation of the software and hardware complex of thematic segmentation of optical-electronic images from onboard systems of remote sensing of the Earth.

The function subprocess F_{21}^2 is implemented by performing the following function-operations:

– the architecture of the software-hardware complex of thematic segmentation of optical-electronic images from on-board remote sensing systems of the Earth is being developed, which determines the structure, functions and interrelation of the components of the software-hardware complex;

– the composition of technical means is determined for the implementation of the components of the hardware-software complex for the thematic segmentation of optical-electronic images from the on-board remote sensing systems of the Earth;

– the composition of software is determined for the implementation of the components of a software and hardware complex for thematic segmentation of optical-electronic images from on-board Earth remote sensing systems (operating system, programming language, knowledge engineering tools (CASE tools (Computer-Aided Software Engineering)) and the like);

– software implementation of the hardware and software components of the thematic segmentation of optical-electronic images from the on-board Earth remote sensing systems based on the selected hardware and software implementation is being carried out;

– filling the rule base of the software and hardware complex for thematic segmentation of optical-electronic images from on-board Earth remote sensing systems.

During the implementation of the subprocess function F_{22}^2, the following is used:

– storing in the base of rules the hardware and software complex of thematic segmentation of optical-electronic images from the on-board Earth remote sensing systems of the rules introduced or corrected at the previous stage,

– storing in the database of the hardware and software complex of thematic segmentation of optical-electronic images from the on-board Earth remote sensing systems data on the conditions for conducting reconnaissance, phono-object conditions and the results of knowledge processing (data) on thematic segmentation of optical-electronic images from the on-board Earth remote sensing systems.

The function-process of knowledge processing (data) based on the results of thematic segmentation of optical-electronic images from onboard Earth remote sensing systems $F_3^1 \in \left\{F_i^1\right\}$ is implemented by performing the following functions-subprocesses (Fig. 3):

– function-subprocess $F_{31}^2 \in F_3^1$ of developing knowledge processing methods (data) on thematic segmentation of optical-electronic images from onboard systems of remote sensing of the Earth (implemented at the stage of creating a software and hardware complex of thematic segmentation of optical-electronic images from onboard systems of remote sensing of the Earth);

– function-subprocess $F_{32}^2 \in F_3^1$ of implementation of the process of direct automated processing of knowledge (data) on thematic segmentation of optical-electronic images from onboard systems of remote sensing of the Earth during the operation of a software and hardware complex of thematic segmentation of optical-electronic images from on-board systems of remote sensing of the Earth.

The function subprocess F_{31}^2 is implemented by performing the following function-operations:

– tasks are being set to formalize the processing of knowledge (data) of the thematic segmentation of optical-electronic images from on-board systems of remote sensing of the Earth;

– the ways of knowledge (data) presentation are determined (the choice of the mathematical apparatus (knowledge representation model (data)) is substantiated) of the thematic segmentation of optical-electronic images from on-board systems of remote sensing of the Earth;

– a formal presentation of the knowledge (data) processing of the results of thematic segmentation of optical-electronic images from on-board systems of remote sensing of the Earth, namely:

a) method of thematic segmentation of images from on-board systems of remote sensing of the Earth;

b) processing method of multiscale optical-electronic image sequence from on-board systems of remote sensing of the Earth.

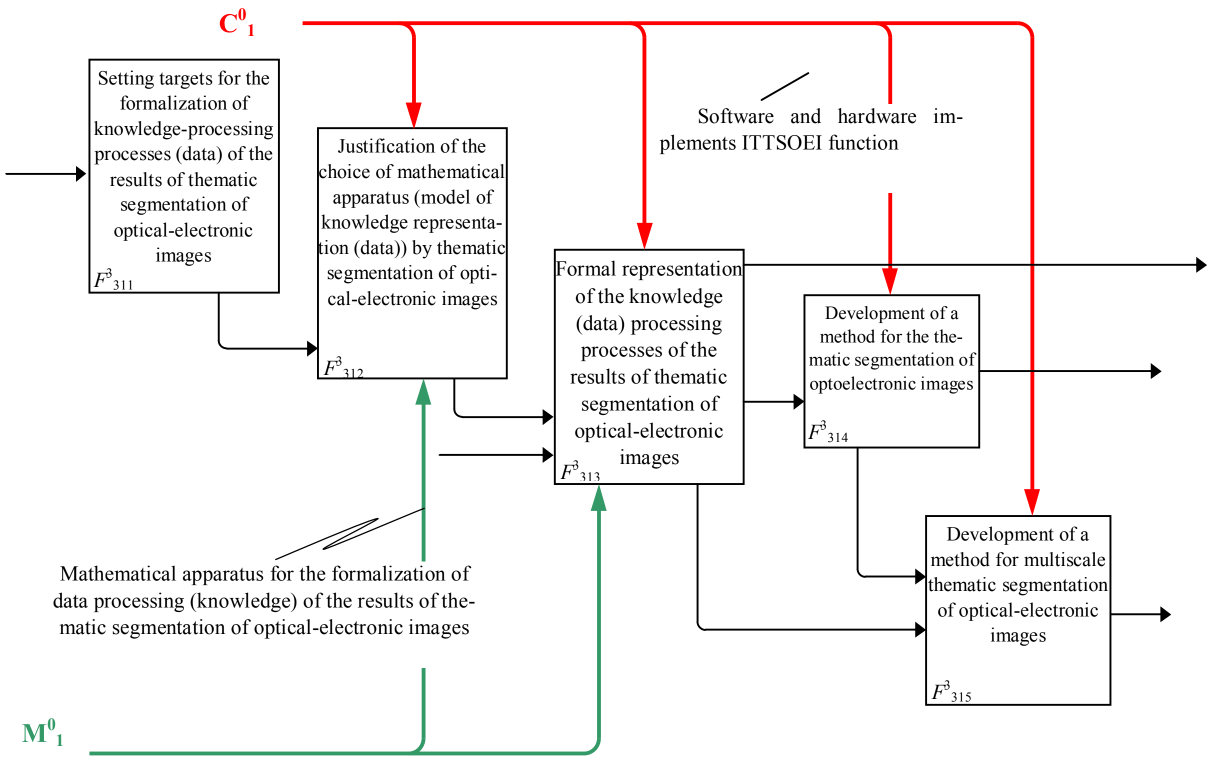

Fig. 3. A child diagram that describes the functions-subprocesses of the information technology ITDUIEI for the implementation of the function-subprocess of developing methods for processing knowledge (data) of thematic segmentation of optical-electronic images from on-board systems of Earth remote sensing

The structure of the algorithm that implements the methods of applied information technology of thematic segmentation of optical-electronic images from on-board systems of remote sensing of the Earth is shown in Fig. 4. The algorithm is based on the method of thematic segmentation of optical-electronic images and the method of processing a multiscale sequence of optical-electronic images from on-board remote sensing systems of the Earth.

It has been established that, in contrast to the well-known, the advanced applied information technology of thematic image segmentation of optical-electronic images from on-board Earth remote sensing systems uses the system modeling methodology IDEF0, which is based on the SADT structural analysis and design method, provides for determining image presentation spaces, highlighting the brightness channels of each color space, applying for thematic segmentation optical-electronic images methods swarm artificial bee colony.

Conclusions

The article developed an applied information technology for thematic segmentation of optical-electronic images from on-board Earth remote sensing systems, which, unlike the known ones, uses the system modeling methodology IDEF0, which is based on the SADT structural analysis and design method.

It has been established that, in contrast to the well-known, the advanced applied information technology of thematic image segmentation of optical-electronic images from on-board Earth remote sensing systems uses the system modeling methodology IDEF0, which is based on the SADT structural analysis and design method, provides for determining image presentation spaces, highlighting the brightness channels of each color space, applying for thematic segmentation optical-electronic images methods swarm artificial bee colony.

In further studies, it is necessary to consider in detail the structure of the algorithm that implements the function-subprocess F_{31}^{2} and the corresponding functions-operators of the applied information technology of thematic segmentation of optical-electronic images from on-board systems of Earth remote sensing.

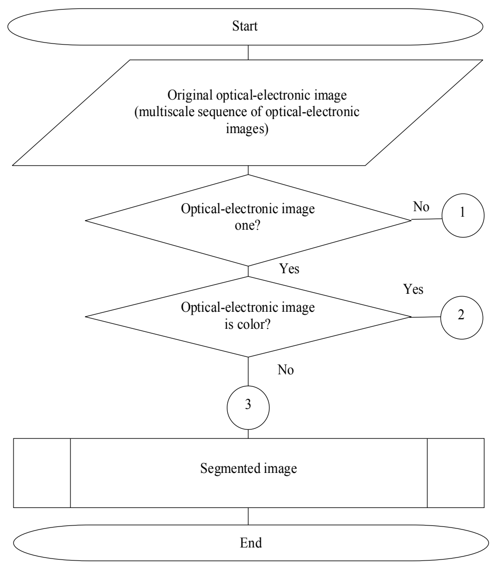

Fig. 4. The structure of the algorithm (Part 1)

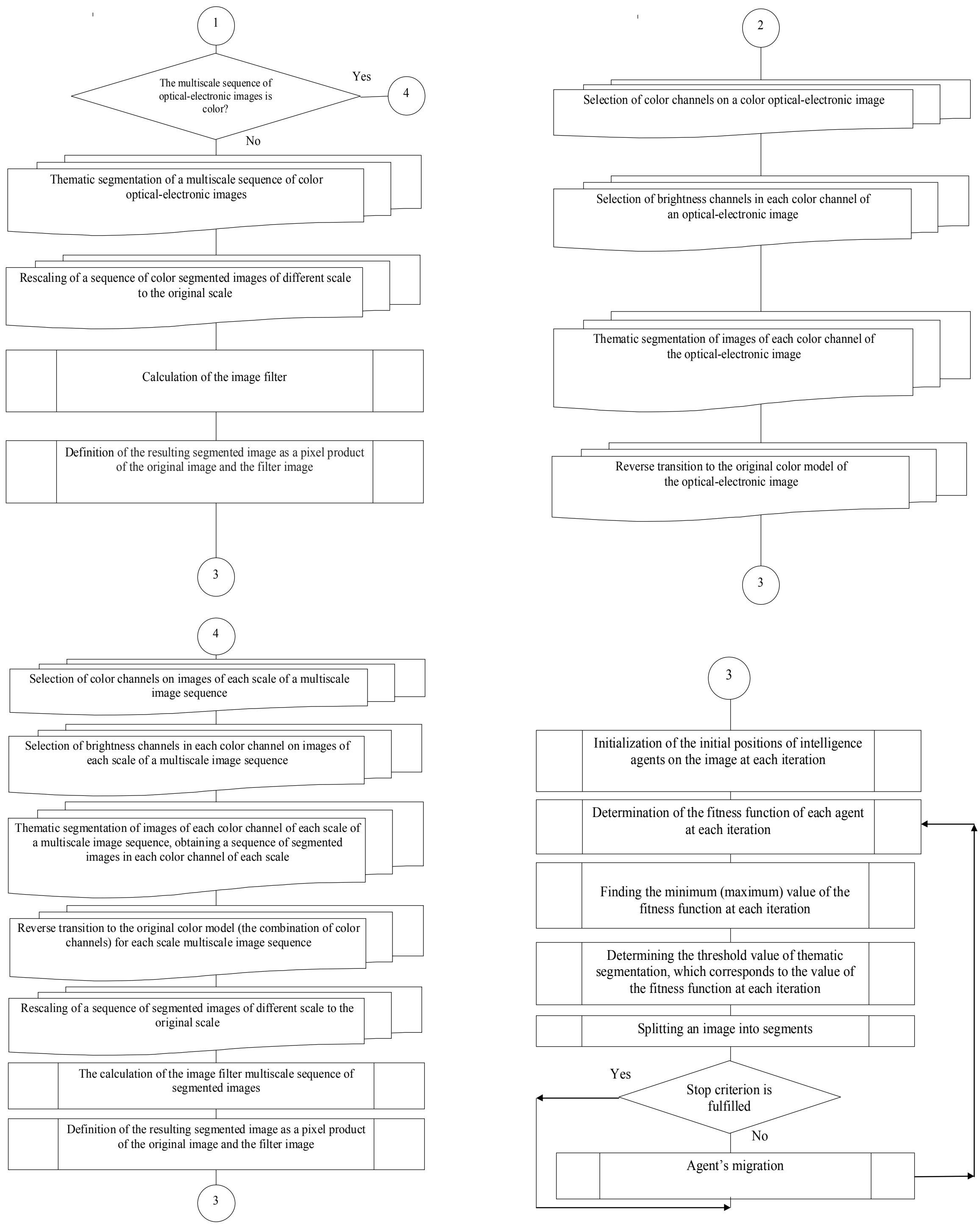

Fig. 4. The structure of the algorithm that implements the methods of applied information technology of thematic segmentation of optical-electronic images from on-board systems of remote sensing of the Earth (Part 2)

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Прикладная информационная технология тематической сегментации оптико-электронных изображений с бортовых систем дистанционного зондирования Земли

И. А. Хижняк

Аннотация. Предметом изучения в статье является прикладная информационная технология тематической сегментации оптико-электронных изображений с бортовых систем дистанционного зондирования Земли. **Целью** является разработка прикладной информационной технологии тематической сегментации оптико-электронных изображений с бортовых систем дистанционного зондирования Земли с использованием методологии системного моделирования IDEF0. **Задачи**: анализ особенностей оптико-электронных изображений, формулировка требований к методам, методикам и информационным технологиям тематической сегментации оптико-электронных изображений с бортовых систем дистанционного зондирования Земли, разработка прикладной информационной технологии тематической сегментации оптико-электронных изображений с бортовых систем дистанционного зондирования Земли. Используемыми **методами** являются: методы теории вероятности, математической статистики, методы оптимизации, математического моделирования и цифровой обработки изображений, аналитические и эмпирические методы сравнительного исследования. Получены следующие **результаты**. В соответствие с синтаксисом и семантикой IDEF0 прикладная информационная технология тематической сегментации оптико-электронных изображений с бортовых систем дистанционного зондирования Земли может быть представлена в виде: кортежа, верхней дочерней диаграммы, дочерних диаграмм. Приведена структурная схема алгоритма, реализующего методы прикладной информационной технологии тематической сегментации оптико-электронных изображений с бортовых систем дистанционного зондирования Земли. **Выводы.** Научная новизна полученных результатов заключается в следующем: разработана прикладная информационная технология тематической сегментации оптико-электронных изображений с бортовых систем дистанционного зондирования Земли, в которой, в отличие от известных, используется методология системного моделирования IDEF0, основанная на методе структурного анализа и проектирования SADT.

Ключевые слова: дистанционное зондирование Земли; оптико-электронное изображение; тематическая сегментация; информационная технология; методология системного моделирования; метод структурного анализа и проектирования.

Прикладна інформаційна технологія тематичного сегментування оптико-електронних зображень з бортових систем дистанційного зондування Землі

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Анотація. Предметом вивчення в статті є прикладна інформаційна технологія тематичного сегментування оптико-електронних зображень з бортових систем дистанційного зондування Землі. **Метою** є розробка прикладної інформаційної технології тематичного сегментування оптико-електронних зображень з бортових систем дистанційного зондування Землі з використанням методології системного моделювання IDEF0. **Завдання:** аналіз особливостей оптико-електронних зображень, формулювання вимог до методів, методик та інформаційних технологій тематичного сегментування оптико-електронних зображень з бортових систем дистанційного зондування Землі, розробка прикладної інформаційної технології тематичного сегментування оптико-електронних зображень з бортових систем дистанційного зондування Землі. Використовуваними **методами** є: методи теорії імовірності, математичної статистики, методи оптимізації, математичного моделювання та цифрової обробки зображень, аналітичні та емпіричні методи порівняльного дослідження. Отримані такі **результати.** У відповідності до синтаксису та семантики IDEF0 прикладна інформаційна технологія тематичного сегментування оптико-електронних зображень з бортових систем дистанційного зондування Землі може бути представлена у вигляді: кортежу, верхньої дочірньої діаграми, дочірніх діаграм. Наведена структурна схема алгоритму, що реалізує методи прикладної інформаційної технології тематичного сегментування зображень з бортових систем дистанційного зондування Землі. **Висновки.** Наукова новизна отриманих результатів полягає в наступному: розроблена прикладна інформаційна технологія тематичного сегментування оптико-електронних зображень з бортових систем дистанційного зондування Землі, в якій, на відміну від відомих, використовується методологія системного моделювання IDEF0, що заснована на методі структурного аналізу та проектування SADT.

Ключові слова: дистанційне зондування Землі; оптико-електронне зображення; тематична сегментація; інформаційна технологія; методологія системного моделювання; метод структурного аналізу і проектування.