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Articles

Remote Control of Spacecraft Flights

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Abstract

The article explores the technology of spacecraft flight control. The expansion of technologies for the use of spacecraft was noted. The main tasks of spacecraft control are described. The increase in the complexity of the flight situation entails an increase in the complexity of spacecraft control. It is shown that such control is remote. Remote control of space vehicles is spatial. Therefore, it requires the use of methods of geoinformatics and space geoinformatics. The article introduces a new concept of “flight control loop”. This model serves as the basis for controlling the spacecraft. The spacecraft flight control system is described. The article shows that the quality of spacecraft flight control depends on the training of operators of ground control services. It is shown that the best way to train flight control center operators is to use simulators. The methodology for the use of simulators is described. The content of the principles of remote control of spacecraft flights is revealed. The features of the collection of spatial information for management are highlighted. The value of information units for flight control is shown. The connection of flight control models with models of spatial information situations is substantiated.

Keywords: space research, spatial control, geoinformatics, space geoinformatics, spacecraft, flight control operator, control loop, information spatial situation, information perception channel, cognitive perception channel model.

1. Introduction

The current stage of development of space research is characterized by an increase in the number of functioning spacecraft, an increase in the duration of their flight, an expansion of the scope of their use (Rozenberg i dr., 2009). Currently, permanent orbital scientific complexes, space systems for the study of natural resources and the environment, space communication systems, meteorological systems, etc. Are being operated their research was led by the development of a new scientific direction – space flight control (UCP). The tasks of the UCP consist in the creation of both methods and means to control the flight of the spacecraft. Space flight control is an integrated technology that includes various technologies methods and approaches (Markelov, 2013). In controlled flight, spatial information is the most important. This leads to the use of

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geoinformatics and ballistics methods for controlling spacecraft (SC). Geographic information systems (GIS) are a decision-making tool (Markelov, 2013). Geoinformation technologies are used to support decision-making (Tsvetkov, 2001). This brings together geoinformatics and the theory of UCP in the field of application of spatial information. Flight control of spacecraft requires the use of space geoinformatics methods. Mission control can be divided into two areas: direct flight control, training of mission control specialists. Remote flight control is carried out by the operators from the mission control center (MCC). There are no educational institutions that train flight control operators. Flight control operators are trained with additional training and advanced training. Thus, remote control of spacecraft missions includes the following components: training of specialists in management, the use of spatial information for control, monitoring the state of the spacecraft, the use of general control principles in relation to the UCP, the use of situational control technologies during the movement of the spacecraft, the solution of spatial problems to determine the location of the position.

2. Discussion and results

Technological flight control solution

When controlling flights, you have to process a large amount of various information. The volume and variety of this information exclude its processing by one person. To reduce the information load on the operator, automated control systems (ACS) are used (Soloviev, 2006; Savelyev, 2019; Rozenberg, Tsvetkov, 2010). When controlling for space flights, an automated control system is used, which performs the functions of decision support systems. The main technological link in the control of the flight of the space apparatus is the “flight control circuit” (Bronnikov, 1987). This circuit includes a feedback line and a direct control line. Fig.1 shows a generalized diagram of the control loop.

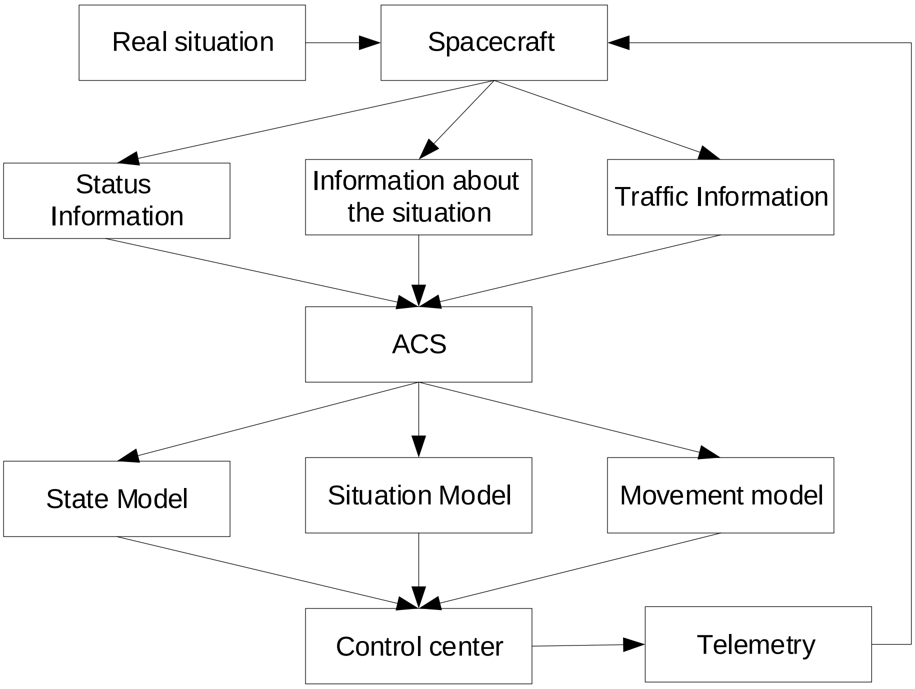

Fig. 1. Flight Control Loops

The flight control circuit has two information flows: informing and controlling. The information channel is based on the modification of monitoring and geomonitoring technologies (Markelov, Tsvetkov, 2015; Kudzh, 2015; Hohensinn et al., 2021). The informing channel describes the state of the spacecraft. Spatial information informs about the location of the spacecraft. Dynamic information informs about the speed and direction of movement. Information about the state of the spacecraft, its location and position, and its movement together forms a model of the information situation (Tsvetkov, 2012).

The prototype of the model of the information situation is the first situation of the flight. It is recorded using the sensors of the spacecraft. When analyzing spatial information, geodata (Bakhareva, 2016) are formed as systematized data, but built on cosmic information.

Therefore, the methods of space geoinformatics and (Bondur, Tsvetkov, 2015) are used for processing. The ACS of the spacecraft receives a diverse, large amount of information and converts it into models that are more understandable to the operator and intuitively perceived by him. The ACS of the spacecraft forms three groups of models: models of the state of the spacecraft, models of the situation surrounding the spacecraft, models of the motion of the spacecraft. All information is sent to the mission control center for analysis using software and intelligent software and cognitive analysis by the center's operators.

The mission control center is a complex human-machine system and a complex organizational and technical system. Operators make decisions in spacecraft flight control. But they use information from the spacecraft automated control systems. The reliability of flight control determines the work of operators. To increase reliability, group control of the spacecraft is used. Group work of flight control operators reduces the likelihood of individual error. Group work of flight control operators provides a condition for complementarity (Potapov, 2020) of actions in the group. Group work of flight control operators creates accumulated reliability (Titov, Tsvetkov, 2020) of control technologies

Heterogeneous spatial information is converted into systematized geodata (Savinykh, Tsvetkov, 2014). With the help of geodata, the position of the spacecraft and the speed of the spacecraft are determined. The position includes the coordinates of the center of mass, the orientation of the spacecraft relative to the orbit. Velocity is usually defined as the translational velocity of the center of mass and the angular velocity around the center mass.

The main feature of UCP technologies is the transformation of models into systems of information units (Ozhereleva, 2014; Tsvetkov, 2014). This ensures the unification of the development of managerial decisions on the basis of the onomasiological approach. And the information units are included in various qualitative groups. The first group is informational linguistic (ILU) units. The second group is formed by paralinguistic information (PIU) units (Tsvetkov, 2013).

Use of situational control technologies

During the flight control of the spacecraft, various deviations from the originally developed flight program are possible. The statistics of the occurrence of emergency situations during flight control shows that a significant proportion of deviations from the normal course of the flight occurs due to errors of the MCC personnel and the crew.

This leads to the need to use situation models. The external situation is related to the state and position of the spacecraft. The internal situation is related to the state of operators and the quality of their work. Taking into account situations leads to the application of situational management. Situational management uses a semiotic approach.

The actual control of the spacecraft is reduced to the transfer of the spacecraft from one spatial situation to another. Therefore, such management should be considered situational. At the same time, the transfer from one situation to another must be continuous.

The models of spacecraft flight control are closely related to various models of spatial (Pavlov, 2016) and managerial information situations (Ozherel'eva, 2016a). The basic model of the situation is a model of the real situation in which the spacecraft is located. It is transformed through the feedback channel into various smaller models. Hence, the situation model is an indispensable factor in controlling the spacecraft. This leads to the need for systematics of information situations (Tsvetkov, 2016) for informed decision-making.

The models of situations used in the control of the spacecraft are qualitatively different. The real situation exists in real space, and the operator works with the information situation (model), which is a reflection of the real situation and the operator's capabilities to control the spacecraft. The situational analysis performed by the operator and the ACS of the spacecraft has the following varieties: retrospective, current, cause-and-effect, target, predictive. Retrospective analysis is associated with the analysis of previous situations and states. There are the main tasks of situational spatial analysis:

- formation of a model of the current situation in which the spacecraft is located;
- formation of a model of the target situation in which the spacecraft should be located;
- formation of a model of the situation of deviations of parameters from acceptable values;
- formation of causal factors of deviations;
- analysis of the causes of deviations;

The peculiarity of the control of the spacecraft is that it is carried out blindly as an unmanned control of transport. At the same time, different models are used.

Training and retraining of operators

Training and retraining of operators determines the quality of management and leads to a decrease in erroneous actions during management. One of the methods of reducing erroneous actions is the use of a “match scheme”. The essence of this scheme is to parallelize the same control tasks to different operators. As a result of the coincidence of management decisions from different operators, the reliability of control is assessed and an adequate management solution is chosen.

Spatial models are the basis of spacecraft control in real space. Therefore, the training and retraining of operators is based on the ability to navigate in space and the skill of spatial modeling. To ensure the ability of spatial modeling, high professional training of operators is necessary. Training and retraining of operators is carried out through the use of special simulators (Bronnikov, Sudachenko, 1979; Bronnikov i dr., 1983) and their modernization during operation.

UCP uses cognitive and information channels for perceiving information. This should be taken into account and implemented in the development of simulators. And the cognitive perception of information is simulated in simulators by creating artificial interference with clear information perception.

When developing simulators, the real situation is transmitted through three-dimensional virtual models. This is the virtual spatial aspect of the software of simulators.

On the simulator, the main flow of information goes through the visual channel of human perception. This imposes a requirement on the software in terms of applying visual modeling methods. This is a visual aspect of the creation of simulators and their operation.

When developing simulators, it is necessary to simulate the situations in which the spacecraft can be found. This is a situational aspect in the development of simulators.

A single situation does not solve the problems of flight and flight control. Therefore, it is necessary to create scenarios for the development of situations. This is a scenario aspect in the development of simulators.

All of these aspects are used in geoinformatics. Therefore, the use of geoinformatics is mandatory in the development of spatial models and scenarios for the simulator.

In addition to the listed aspects of the creation of simulators, it is necessary to apply the principles of: a systematic, anthropocentric approach; ergonomic approach, ergodic approach, resource principle.

The systemic principle (Tsvetkov, 2018) requires that the simulator as a technological system be complete and complete in terms of possible control situations. The principle of the anthropocentric approach requires that the interface of the simulator take into account the peculiarities of information reception (Nomokonova, 2015) and perception (Nomokonova, 2020) of information by the operator.

The principle of the ergonomic approach requires that the interface of the simulator be convenient to use. Did not cause temporary fatigue before.

The principle of the ergodic approach is that the simulator is considered as a human-machine or ergatic (Mordvinov, 2017) system. The features of such systems are informational cognitive aspects. Ergative systems have a number of advantages. For example, the possibility of application as fuzzy logic, the possibility of evolutionary development, the possibility of making decisions in non-standard situations. Other parameters of such systems are: aircraft control system, airport dispatch service, station dispatch service. Ergative systems are used in situations in which the operator's intervention in the operation of the object is a prerequisite for the reliable functioning of the object.

The resource principle requires the availability of a stock of information resources (Tsvetkov, 2016) (and information models) for the activities of the operator. At his disposal as a management resource should be information models, stereotypes, precedents, scenarios in order improve the efficiency of their activities.

Spatial analysis with remote control.

Simulators prepare operators for a set of possible actions. But practical flight control is based on the operator's ability to act in a real situation. Such management requires the ability to perform spatial and situational-spatial analysis.

When creating simulators, the principles of geoinformatics should be applied. Consequently, geoinformatics plays an important role in the formation of methodological support for simulators and even greater role in remote spatial control.

Spatial analysis is used in space research for control and spatial design, for navigation and orientation. The theoretical basis for statistical analysis in space research is space geoinformatics. Along with space geoinformatics, geodetic astronomy (Gospodinov, 2018), satellite geodesy, and space geodesy are used.

Spatial analysis is associated with situations in which management is carried out. This leads to the use of models of situational modeling (Buchkin, Potapov, 2020) and situational management. Spatial analysis is associated with the acquisition and use of spatial knowledge (Tsvetkov, 2015; Lin et al., 2020) and geoscience (Ozherel'eva, 2016; Tsvetkov, 2016; Raev, 2020). The basis of spatial analysis is a systematic approach. Spatial analysis in space exploration uses data integration, which brings it closer to geoinformatics.

3. Conclusion

Spacecraft mission control is a remote technology. The mission control circuit is the basis of the UCP. An important feature of the control is the decomposition of feedback channel models into information units. These information units serve as the basis for the formation of management decisions. The UCP is a complex technology that includes information and cognitive factors. Space flight control includes human factors that need to be reduced. ACS and geoinformatics methods act as a management support system. A number of specific features of the application of geoinformatics arise.

In mission control, it's not a single operator that works, but a group of operators, and they're the organizational component of the mission control systems, which includes the spacecraft automated control systems. The entire management system is a complex organizationally technical system. The board of space missions uses a channel of technical information and a channel of spatial information. The perception of information goes through the information and cognitive channels. The main information is transmitted through the information channel – visual information. The information load in the UCP falls on the operator's vision. The cognitive channel of perception and analysis uses paralinguistic information units. An important factor in the UCP is the simulator training of operators

The spacecraft model is partly invisible to the operator and located in a certain area. Therefore, the management is carried out using models of information spatial situations. About the peculiarity of the information situation in the UCP in the fact that it is formed as a cognitive model in the mind of the operator. Its objective part ends at the level of information units that describe the situation and are perceived by the operator. Hence, cognitive factors are most important in controlling the flight of a spacecraft. The model of the information situation is not static, but situationally dynamic. Electronic models take into account the dynamics of the development of the situation and the dynamics of the core of the situation – the object of control.

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Information Fields in Space Research

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Abstract

The article explores the information fields in space research. It is shown that the information field is a multidimensional concept. There is no single model of the information field. There is a clear or objective information field. There is a combined information field. In an object information field, the information units of the field are units of objects. They have object semantics. In a combined information field, the information units of the field are spaces, not objects. They may or may not be meaningful. They can be clear or fuzzy. These units have no semantics. The information units of the combined information field are interpreted in a group or in a cluster. There are information fields that reflect certain physical fields. An information space is associated with information fields. The information space allows you to link and combine information fields, as well as superimpose them on each other. The information field in space research is a complex information model that contains space, spatial and parametric information.

Keywords: space research, information field, information space, general information field, space sciences, integration of sciences.

1. Introduction

The world is a system of systems (Monakhov i dr., 2004) and a system of nested spaces (Tsvetkov, 2015). Information is the basis for the development of modern civilization. Space research develops a model of the world and a model of society. The importance of space research is determined by how much its theories, concepts and models contribute to the development of civilization. Considering the process of space exploration as a process of cognition of the world, it is possible to consider the process of cognition of the world. To believe that space research expands the space of knowledge of mankind. When exploring the surrounding world, a field concept is used. The development of this concept is reflected in the emergence of the model of the information field (Raev, 2021). Therefore, it is quite natural that the ideas of the information field began to be used in space research (Bondur, 2015). Information fields in space research are a reflection and information description of real fields in outer space and near-Earth space.

2. Discussion and results

Fields in near-Earth space.

The information field performs two functions (Tsvetkov, 2014a): reflection and description. The function of reflection is that the information field reflects real fields. In this reflection, a person has an idea of real fields and models them in an information field. The function of description is that the information field is a global model of the world and how a photograph reflects everything.

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In this reflection, a person has no idea about real fields and objects. He learns them on the basis of information modeling in the information field.

Thus, it is necessary to distinguish between two qualitative types of information field. The first type is an information field with a clear selection of objects and the exclusion of uncertainty. There is no redundant information in this field. The second type is the information field with the presence of certainty and uncertainty. In this field, you should select the necessary information. There is a lot of redundant information in it and the information volume of the models of such an information field is 3-4 orders of magnitude higher than the information volume of the models of the information field of the first type. Analogues of such fields are vector and raster models.

It is necessary to distinguish between information fields and information space. Information space as a description of the world can contain different information fields reflecting different physical fields. An information field contains a field variable (Tsvetkov, 2014b). If there is no field variable, then there is no field. The information space is a shell and serves as a tool to support the description of information fields. The most striking example is the coordinate information space. The peculiarity of the information space is that its description depends on the chosen coordinate system: spherical, cylindrical or Cartesian system Coordinate. An example of the relationship between fields and spaces is near-Earth space (Barmin et al., 2014)

The following types of spaces are divided (Tsvetkov, 2015; Barmin et al., 2014) as they move away from the Earth's surface: atmosphere (100 km); near-Earth space (60 Earth radii); sublunar space (radius of the Moon's orbit); Saline space (1 astronomical unit from the Earth); near space (Solar System); deep space (outside the Solar System) Near-Earth space space (OKP) (60 radii of the Earth). It is characteristic that all types of spaces are characterized by a geometric characteristic of a certain radius associated with a geocentric or heliocentric system. There are a number of fields, field processes, and these include:

- Continuous gravitational, magnetic and electric fields of the Earth;
- Field processes in the Earth's ionosphere;
- Field process thermal radiation;
- Field processes cosmic rays and solar radiation;
- Discretely continuous fields are the Radiation Belts of the Earth.
- Discrete fields of space debris.

Each of the considered physical fields has its own private information field.

Integration of sciences and information fields

Information fields reflect real physical fields and physical processes. Such fields can be interpreted as specialized information models. They are all connected to space and through space to each other. Hence the important role of the information space: it integrates models and fields into a single model. It should be emphasized here that we are talking about real space, not phase space or parametric space.

The basis for the integration of space sciences is geoinformatics. It arose and is developing on the basis of integrations of various scientific areas (Savinykh, 2015). As the first feature of the integration of space sciences, it should be noted the integration of geoinformatics with remote sensing technologies (Savinykh, Tsvetkov, 1999). As a second feature of the integration of space sciences, it should be noted the transformation of Earth sciences into space disciplines: space geoinformatics (Bondur, Tsvetkov, 2015), space geodesy (Jin, van Dam, Wdowinski, 2013), geodetic astronomy (Gospodinov, 2018; Gospodinov, 2022) and so on.

As a third feature of the integration of space sciences, it is necessary to single out the problem of big data (Buravtsev, Tsvetkov, 2019), characteristic of information fields of the second type.

Integration in space research is related to space geoinformatics. Space geoinformatics unites private sciences and solves the global problem of space exploration.

Space geoinformatics implements the compatibility of different data in a single model called geodata (Zuo, 2020). The essence of this model is not the term "geo", but a special structuring. It consists in dividing all data into three categories: coordinates, time and thematic data. But the main thing in geodata is to combine three categories into a single model, which is called a single integrated information base (Kovalenko, 2014). The integrated information base ensures the comparability of data from different sources.

Space geodesy serves as the basis for transferring geodetic methods and measurements into space. But the main thing in it is the use of geodetic measurement methodology for processing space information. However, space geodesy works with real space and does not affect the information space. Comparative planetology stands apart (Tsvetkov, 2018), which is the transfer of the theory of comparative analysis into the processing of cosmic information. Comparative analysis is effective in information fields.

In addition to space geodesy, space geoinformatics extracts information from the information field, studies and creates spatial knowledge (Tsvetkov, 2016) and geoscience (Tsvetkov, 2016) and cosmic knowledge (Savinych, 2016). As a means of forming a picture of the world, space geoinformatics creates an information description of the picture of the world (Tsvetkov, 2014). Research methods. Space geoinformatics are aimed at the study of outer space.

3. Conclusion

An information field is not a single model, but a collection of different information fields. There is a clear or object information field. An example of such a field would be a map or drawing. This field contains recognizable objects and does not contain uncertainties. In this information field, the information units of the field are units of objects. They have object semantics and content. They are interpreted independently of other information units. For example, conventional signs. There is a combined clear and fuzzy information field. An example of such a field would be a photograph or a bitmap. In this information field, the information units of the field are not units of objects. They reflect the value (density) of the pixel. They do not have object semantics. Their interpretation is possible by combining a group of neighboring information units into a cluster. These two types of fields are generalized, applicable to most real-world phenomena.

There are different physical fields, for example, magnetic, electric, gravitational. To describe a field, it is important to choose a spatial coordinate system. Therefore, the information space is inextricably linked with the information field. Selecting a coordinate system specifies the description of objects and fields. The information space plays an integrating role. It allows you to combine fields and superimpose them on top of each other. The information field is an important generalized information model that includes smaller models of objects and processes. The use of the information field model allows you to systematically study the processes and phenomena of the surrounding world. The information field allows you to more fully form a picture of the world. The information field in space research can be considered as a complex information model containing space information that is connected to space using coordinate space. The information field and information space play an integrating role in building a picture of the world and describing spatial phenomena. From the standpoint of the integration of sciences, the information field is an integrated model that combines different models and different sciences. Information the field allows you to conduct comprehensive research.

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The Evolution of Space Geodesy

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Abstract

The article considers the state and development of space geodesy. Geodesy is the science of space, and space geodesy is the science of outer space. The connection between space geodesy and space geoinformatics is shown. The directions of development of space geodesy are described. Space geodesy is developing in two different directions. The first direction is connected with the study of the Earth from space. The second direction is directed from the Earth to the exploration of outer space. Space geodesy can be applied independently or to support other sciences and technologies. It is shown that fuzzy sets and fuzzy situations can be used in ground and space geodesy. With fuzzy or incomplete information, it is necessary to replace the concept of the optimal solution with the concept of an expedient solution. Fuzzy sets are used when classical geodetic computational methods fail. Studies have shown the expediency of introducing the concepts and models of "spatial information situation", "fuzzy spatial information situation". These models allow solving new problems and expand the possibilities of spatial analysis. The methods of space geodesy provide opportunities for establishing cause-and-effect relationships of past events. This is possible due to the fact that space observations are recorded and accumulated in databases. Space geodesy applied to support other technologies is called space geodesy. There are strategic and tactical tasks of space geodesy. The article confirms the conclusion that space geodesy and space geoinformatics are applicable to the study and measurement of space bodies.

Keywords: space research, geodesy, space geodesy, space geoinformatics, space geodetic measurements.

1. Introduction

Space geodesy (Bertiger et al., 2020) and space geoinformatics (Bondur, Tsvetkov, 2015) are constantly increasing. Space geodesy is developing in five directions. Creation of new methodological solutions for information processing. Development of space geodesy tools. Solution of new applied problems. Integration of ground-based methods technologies with methods of space geodesy. Accumulation of experience and improvement of methods of application of space geodesy in the exploration of outer space. The study of near-Earth space continues (Barmin et al., 2014). The GLONASS/GPS system is developing (Ryabov et al., 2019). Space geodesy has created new opportunities for the development of ground geodesy, photogrammetry and geoinformatics. Space technologies make it possible to solve the problems of cadastre and real estate management. The information content of space images is great and creates the problem of big data. The satellite image replaces containing information from hundreds of aerial photographs. Toosmic research showed (Savinykh, 2019) that time geodesy has gone beyond the science of the Earth and has

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become a science of terrestrial and extraterrestrial space. Geodesy is used to support space research (Oznamets, 2020). Space geodetic support integrates: space geodesy, geodetic astronomy, space geoinformatics, geodynamics and satellite geodesy. Space geodetics. Securing is one of the stages of development toosmic geodesy. Space geodesy requires periodic systematics and generalization.

2. Discussion and results

Creation of new methodological solutions for information processing

The creation of new methodological solutions for information processing can be shown on the example of a geodetic survey of the territory to find suitable sites for landing spacecraft (SC) (Tsvetkov, Oznamets, 2018). The problem of choosing a site for landing a returned spacecraft belongs to the class of placement problems. The problem of placement is a typical problem of geodesy and geomarketing. In the work (Kamynina i dr., 2021), the theory of geodesy is developed by applying the theory of fuzzy sets. That is, theory of fuzzy sets is used to process the results of complex geodetic surveys.

Complex geodetic surveys include not only geodetic measurements, but also the collection of various thematic information. This information describes the planting conditions and analyzes the risks *(*Tsvetkov, 2014). The information situation model was used methodically as a spatial analysis tool.

In addition to the results of comprehensive geodetic surveys, customer information was used, defining fuzzy placement criteria. Complex information was a collection of interval variable information. The method consists in constructing linguistic variables to describe fuzzy situations given by fuzzy criteria. The technique includes fuzzy optimization, which replaces the problem of global discrete optimization with the choice of a rational solution. A clear spatial situation is described using the results of a geodetic survey. Fuzzy spatial is built according to fuzzy customer criteria and compared with the data of each possible landing site. The work was carried out in accordance with the task of Roscosmos. The paper proves that in the presence of fuzziness, the optimal solution should be replaced by a rational solution. Geodetic processing includeswithituational analysis (Tsvetkov, 2014) and is associated with the application of the model of the information situation. Two models of a clear information situation and a fuzzy information situation are used in the work.

This technique allows you to make rational decisions with information fuzziness for trapezoidal and interval variables that characterize the information situation. However, the results of the assessment are conditional. Conditionality is determined by a finite set of evaluation criteria and the sample size of the objects being compared. If the number of criteria or the totality of research objects changes, the evaluation result may or may not change. The results of the technique cannot be called optimal. They can be called appropriate. This is an important takeaway. With unclear information, you cannot talk about the optimal solution, but you can talk about an appropriate solution. This is natural, since with incomplete information there are no guarantees of obtaining an optimal solution. However, this method is applicable in situations where classical methods are powerless.

The proposed method makes it possible to obtain estimates of spatial situations in case of fuzzy information. It is applicable when classical optimization methods do not give a result. Of interest is the philosophical and mathematical aspect of the relationship between quality and quantity. This relationship begins at the level of the ordinal scale, that is, at the level of ranking the qualities that correspond to fuzzy numbers: interval or trapezoidal. The method requires further research and development. For example, while there is arbitrariness in the choice of the number of thermos. At the same time, the method is new in the field of situational analysis. Studies have shown that it is advisable to introduce the concepts and models of “spatial information situation”, “fuzzy spatial information situation”. New models make it possible to solve new problems in new conditions and expand the possibilities of using space geodesy.

Development of instrumental support for space geodesy

The development of instrumental support for space geodesy is based on the development and application of new devices. One example is the demonstration of a broadband interferometric system with an ultra-long base: a new tool for high-precision space geodesy (Niell et al., 2018). The paper (Niell et al., 2018) describes a broadband geodetic interferometric system with an ultra-long base. Measurements of the length of the baseline are carried out to test the system, develop operational procedures and assess geodetic accuracy for broadband surveillance. The work was carried out for two years. Statistical analysis of data from 19 sessions that were observed during this period yielded a weighted average root square deviation of the residues of the original length of about 1.6 mm. Laser geodetic satellites (Pearlman et al., 2019) are a typical tool of space geodesy.

Integration of ground-based technology methods with space geodesy methods

The integration of ground-based technology methods with space geodesy methods can be shown by the example of space geodetic observations of the critical infrastructure of the Morandi Bridge, Genoa, Italy (Milillo et al., 2019). This work contains a retrospective analysis of the past event. However, it demonstrates the possibilities of space geodesy to establish cause-and-effect relationships of past events. The paper provides a methodology for assessing the past event. possible deformations of the bridge before destruction. The bridge was destroyed on August 14, 2018. Synthetic aperture radar (SAR) observations are used as a basis. A displacement map was created for the structure from space.

Satellite data sets for 2003–2011 allowed for retrospective analysis. The results of the treatment show that the deformations of the bridge grew over time until it collapsed. It was revealed that the decking next to the collapsed pier since 2015 was characterized by an increase in relative movements. It was concluded that the interferometric synthetic aperture radar (InSAR) and constant scattering interferometry (PSI) make it possible to track the deformation of the surface of objects due to the presence and density of coherent radar targets. The results of the study showed that the technique can detect deformations of millimeter scale. The use of the technique reduces the risks associated with the deformation of urban infrastructure objects.

Another example of the application of space geodesy is the study of soil deformation and fault velocity in the Greater San Francisco Bay Area (Xu et al., 2018). The work states that the accumulation of deformation and creep on large faults in the northern part of the San Francisco Bay Area (North Bay) are poorly understood. The study jointly processed synthetic aperture interferometric radar data from satellites with continuous GPS data. SAR data from ascending and descending orbits were used to separate the horizontal and vertical components of the deformation.

Development of spacegeodesy

Space geodesy is evolving in two different directions. The first direction is related to the study of the Earth from space. The second direction is directed from the Earth to the study of outer space.

Space geodesy, used to support other technologies, is called geodetic space support (Oznamets, 2020). Geodetic space support uses space geodesy as a basis (Calonico et al., 2019). Geodetic space support is characterized by a small number of data measurements and a large number of data modeling.

Modern space geodesy is associated with the need to process large amounts of information, which is due to the improvement of measuring instruments and the variety of sensors that receive spatial information. It comes into contact with the problem of “big data” (Buravtsev, Tsvetkov, 2019).

Osmic geodesy in relation to Earth exploration is supported by the following scientific areas:

- Study of the Earth Figure;
- study of the Earth's gravitational field;
- creation of a coordinate system for different ones;
- conducting geodetic measurements on the surface, subsurface and above the surface of the Earth;
- representation of spatial information on topographic maps and plans;
- formation of digital models and digital maps (Tsvetkov, 2016);
- study of dynamic displacements of the earth's crust.

The creation of a single coordinate system on the territory of different scales of a single state, a continent and the entire Earth as a whole is included in the tasks of space geodesy (Merkowitz et al., 2019). In relation to geodetic support for space research, special geodetic networks for space research have been developed (Merkowitz, 2019). Some of theadacsand geodetic space support are not directly related to comic research.

There is a state program for the transition from ground-based geodetic measurements to satellite measurement methods. Satellite-based positioning, as well as the creation of a spatial data infrastructure, currently rely on space geodesy.

The tasks of geodetic support for space research are of wide importance (Savinykh, 2012). New measurement methods have appeared, and the accuracy of geodetic space measurements has increased.

The use of artificial Earth satellites (SATELLITES) for solving geodetic problems contributed to the development of space geodesy. Initially, osmic geodesy was engaged in determining the size and figure of the Earth, the parameters of its gravitational field. The basis of these works was the results of observations obtained from satellites of various types and purposes, as well as from the board of spacecraft. This defined the first group of space geodesy technologies as providing ground research from space and near-Earth space exploration (Barmin et al., 2014). Then space geodesy research was directed away from Earth into comic space. Asteroid-comet hazard played a big role in this. This determined the second group of space geodesy technologies to support space extraterrestrial research.

Satellite geodesy uses methods of finding a connection between the points of location of satellites based on the laws of motion dynamics. Satellite geodesy technologies do not require simultaneous measurement at all points. Satellite geodesy technologies have led to the creation of a new geodetic network. This is a space geodetic network. This is a network on the earth's surface, which is created and developed on the basis of geodetic points, the position of which is determined from the observations of satellites. Measurements on the earth's surface are carried out on the basis of the theory of spatial serif. According to this theory, it is necessary to use at least 4 spatial points (satellites) visible from this surface.

The dynamic tasks of space geodesy include the determination of the parameters of the Earth's gravitational field. For this purpose, measurements of satellite orbit parameters calculated from the results of positional and rangefinder observations are used. Space geodesy makes it possible to solve a number of existing problems in a new way. These are satellite triangulation, measurement of large-scale objects, measurement of geopotential, application of satellite altimetry.

Satellite triangulation is the one of the methods of space geodesy. It involves the synchronous observation of satellites from several points on the earth's surface. If the positions of two (or more) of these points are known in the earth's coordinate system, then by solving spatial triangles with one of the vertices at the point of location of the space object, it is possible to calculate the positions of other points from which observations were made.

Conducting coordinate and rangefinder observations from satellites make it possible to develop the geodetic vector course in a new way. With this method, the location point of the satellite is analogous to the ground observation point transferred beyond the earth's surface.

Measuring large objects on the earth's surface has always been a problem due to the peculiarity of displaying the earth's surface by zones. From a great height, a person was able to measure extended linear objects on the surface of the Earth (hundreds and thousands of kilometers).

The measurement of the geopotential is carried out using dynamic methods. Using comparative analysis, experimental and theoretically calculated positions of the satellites in space are compared. On the basis of comparison, differences are found that allow you to build a dynamic model. The differences between theory and experiment are attributed to the information uncertainty of determining the harmonic coefficients of the geopotential. According to statistical data and corresponding equations, it is possible to clarify the primary parameters of the harmonic coefficients of the geopotential. In turn, the refined values of the geopotential coefficients make it possible to determine with greater accuracy the location or localization of the satellite, as well as to obtain a refined position of its orbit. This process can be repeated iteratively and the methods of successive approximations increase the accuracy of determining the geopotential coefficients. Thus, an incremental research model is obtained, increasing the accuracy of determining orbital coordinates and geopotential parameters.

In 1950, only one parameter was known for sure - the compression of the earth's ellipsoid. Another parameter, the compression of the equator, was determined with less accuracy. After the start of satellite launches, it became possible to obtain the values of harmonic coefficients of high degrees. In particular, fairly accurate values of harmonic coefficients for the order *of* $n = 8$ and the degree $m = 8$ were calculated. Modern methods of studying the geopotential make it possible to calculate the values of harmonic coefficients for order $n = 24$ and the degree $m = 24$. This order and degree make it possible to determine not two as in 1950, but about 500 coefficients characterizing the model of the Earth's gravitational field. Thus, methods of space geodesy make it possible to increase the accuracy of spatial models of the Earth and, in principle, of any planet when using satellite observations of this planet

Satellite altimetry has been developing since 1974. Laser, as well as radio altimeters (altimeters) on satellites, provided data that made it possible to determine the parameters of the orbit of the satellite. Here the same situation developed as with the geopotential. With the increase in the accuracy of determining the height of the Earth's surface, methods for introducing corrections to the orbital parameters appeared. The introduction of corrections to the orbital parameters made it possible to determine the orbital height with greater accuracy. More accurate determination of orbital parameters led to a more accurate determination of orbital parameters. In particular, the Geos satellite uses an altimeter to measure the distance to the ocean surface with an accuracy of 1 to 3 m. This accuracy makes it possible to refine the shape of the geoid in the World Ocean and to identify spatial anomalies. Comparative analysis of measurements using an altimeter and measurements by other methods showed a high information correspondence when measuring the profile of the geoid by these methods. It is possible to increase the accuracy of satellite altimetry to 10 cm. Laser altimetry provides an accuracy of the order of altitude determination up to 1 cm.

The geocentric coordinate system is harmonized with other networks. First of all, this is a high-precision geodetic network (GHS), as well as a satellite geodetic network of the 1st class (GHS-1). GHS-1. The coordination of these networks provides optimal conditions for the implementation of accurate and operational measurements using satellite equipment. Networks as a whole ensure the creation of a High-Precision National Geocentric Coordinate System.

Global navigation satellite systems work with the help of equipment for SATELLITES of GPS systems and for satellites of the GLONASS system. There is equipment for GPS systems and for the GLONASS system. There is hybrid equipment for both systems. Dynamic measurements in real time allow you to create a single navigation field for determining the coordinates of points on the earth's surface and mobile objects. Application efficiency. Geodetic support for space extraterrestrial research is manifested on the example of research in the field of cometary-astroid danger. It is associated with the calculation of the trajectories of dangerous cosmic bodies and measurements on the surface of other planets or other celestial bodies.

3. Conclusion

Studies show that the methods of space geodesy are constantly evolving and allow solving an increasingly wide range of tasks. It is shown that fuzzy sets and fuzzy situations can be used in terrestrial and space geodesy. In case of unclear or incomplete information, it is necessary to replace the concept of the optimal solution with the concept of an expedient solution. Fuzzy sets are used when classical geodetic methods of calculations do not give a result. Studies have shown the expediency of introducing the concepts and models of “spatial information situation”, “fuzzy spatial information situation”. These models allow you to solve new problems and expand the possibilities of spatial analysis. Methods of space geodesy provide opportunities for establishing cause-and-effect relationships of past events. This is possible due to the fact that space observations are recorded and accumulated in databases. Unlike ground geodesy, space geodesy stores a large number of images that allow for the reconstruction of events. The development of terrestrial sciences increases the potential of space geodesy. Methods of space geodesy are applicable to the study of other planets Space geodesy is a criterion for the potential for scientific development of mankind.

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Digital Simulation in Space Research

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Abstract

The article explores the features of digital modeling in space research. The content of digital modeling is revealed. The difference between digital modeling in terrestrial conditions and digital modeling in space research is shown. Space research technologies refer to the technologies of spatial analysis and processing of spatial information. The basis for the processing of spatial space information is space geoinformatics. Methods of space geoinformatics serve as the basis for digital modeling. In digital modeling in space research, situational analysis is used. A feature of digital modeling in space research is a significant number of angular measurements that exceeds the number of linear measurements. The features of digital modeling are noted: the transition from a continuum to a countable set and vice versa. The definition of a digital model in space research is formulated. The digital modeling of planetary surfaces is described. The application of onomasiological modeling and semasiological modeling in space research is shown.

Keywords: space research, digital modeling, space geoinformatics, discrete transformations.

1. Introduction

Space research is aimed at obtaining knowledge (Savinych, 2016), spatial knowledge (Tsvetkov, 2015) and geoscience (Tsvetkov, 2016). Geoscience is formed when studying the Earth from space. One of the tasks of space research is to build an information picture of the world. In relation to the Earth's surface, space research is divided into two groups. The first group of research is aimed at the Earth and is engaged in the study of the Earth from space (Drinkwater, 2004), as well as parts of near-Earth space (Barmin et al., 2014). The second group of studies is directed from the Earth and explores the lunar, beyond the lunar and solar space. This group is characterized by a large number of angular measurements (Savinykh, 2021; Tsvetkov, 2021). Space research is characterized by the problem of big data (Power et al., 2021). Digital modeling in space research is also aimed at obtaining spatial knowledge.

2. Results and discussion

Space research as spatial technologies

Space research technologies are based on the processing of spatial information. They belong to the technologies of spatial analysis. Space research belongs to the class of spatial research. Ideologically, they are closer to geoinformatics than to geodesy, so their basis is space geoinformatics (Bondur, Tsvetkov, 2015a). The organization of data and models in modern space

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research is based on the methodology of data construction in geoinformatics. In space research and in space research geoinformatics modeling is more important than in terrestrial geodesy or ground geoinformatics. This is due to the fact that in space research it is difficult to carry out direct and linear measurements, which in terrestrial conditions are not difficult. Because of this, more modeling appears in space research, which is absent in terrestrial sciences. In ground conditions, modeling solves the problems of describing objects and processes, predicting processes and searching for retrospective dependencies. In space exploration, a new kind of modeling is emerging that replaces missing measurements or simulates situations due to incomplete measurements. This means the inclusion of situational geoinformation modeling (Tsvetkov, 2014a) in the process of space research. Situational modeling in real space is a geoinformation situational modeling or geoinformation modeling. There are virtually no bodies or objects in space that are independent of other objects. All objects move in a gravitational field and their movement is affected by planets and stars. It is impossible to fully take into account all interactions and influences. This leads to the third type of modeling – simplifying the motion of cosmic ones or simplifying their relative state.

Content of digital modeling

A universal type of modeling that combines other types of modeling is digital modeling (Peluso, 2004; Hengl, Evans, 2009). Digital modeling has its own peculiarities. The first formal feature of digital modeling is the discrete form of representing information or models. This feature comes from the advent of digital computers. Digital computers worked with discrete information. From this point of view, digital modeling is discrete modeling using computers. The term “digital” means discrete.

The second feature of digital modeling is the compression of information about the object. For example, a digital elevation model is formed as a finite set of three-dimensional points. But these points are enough to build a continuous surface. This feature imposes a condition on the discreteness of the model. The discreteness of the digital model should be such that it allows you to build continuous surfaces, calculate areas and volumes within the framework of the tasks and the specified accuracy of calculations. The second feature actually means the use of analog-digital conversion when collecting information.

The third feature of digital modeling is the indirect representation of information about a space object or a latent representation of the object. An example is the angular measurements of the apparent diameter of the planet (Savinykh, 2021; Tsvetkov, 2021), according to which the true diameter of the planet is restored.

The fourth feature of digital modeling is the use of digital-analog conversion when building a model of an object based on a digital model. The second and fourth features of digital modeling provide a basis for applying the methods of communication theory and information theory to describe and study digital modeling. From the standpoint of mathematics, digital modeling involves the transition from a continuum set to a countable set, and then from a counting set to a continuum set.

It is possible to define a digital model in space research. A digital model in space research is a discrete model that allows you to model measurements, contains latent information and allows you to build analog models from their discrete values.

Digital space modeling is modeling to build a digital model in space research and using a digital model to build continuous analytical surfaces.

Digital modeling of planetary surfaces

Digital modeling of planets is a type of digital space modeling. Digital modeling in space is most often aimed at describing surfaces. The exception is geostatistics (Tsvetkov, 2007, Tolosana-Delgado, Mueller, van den Boogaart, 2019), which describes the internal content of a phenomenon or state. Digital models of planets use the theory of surface modeling. It is developed in terrestrial conditions in practical and theoretical terms. Technology Digital modeling of planetary surfaces is the application of the technology of the case of modeling surfaces in terrestrial conditions. The theory of digital modeling of planetary surfaces is a special case of the theory of information modeling. Information modeling sets the main task of the information description of the object of research.

Digital models of planetary surfaces form as discrete sets of points. The theory of digital modeling of planetary surfaces is described by the theory of information modeling. Information modeling in a broad sense is interpreted as a universal method of cognition and modeling

(Maksudova, Tsvetkov, 2001; Raev, 2020). It uses the general principles of modeling. Information modeling as a method of cognition serves as the basis for the formation of a picture of the world (Tsvetkov, 2014b; Kovalenko, 2015). Information modeling as a method of generalization takes the form of metamodeling (Tsvetkov i dr., 2020; Zaitseva, 2021). In information modeling, the constructive (Shaitura, 2019) and theoretical aspect prevails.

At the first stage of digital modeling of planets, onomasiological modeling is carried out (Pavlov, 2019). It consists in the fact that they collect information about the surface of the planet in the form of point measurements and measurements of the elements of the planet's surface. Onomasiological modeling collects the elements from which models are formed. The formation of discrete models occurs in accordance with the Shannon-Nyquist-Kotelnikov reference theorem. This imposes conditions on the collection of information. Cosmic information is not collected arbitrarily, but with the condition of the subsequent construction of the object or is. This creates a dilemma: a large number of points give a complete description, but increases the information volume of information collected. A large amount of information creates difficulties for analysis and computer processing. A small number of points reduces the information volume of information collected, but may not give a complete description of the object or phenomenon. In terrestrial conditions, information about the surface is collected by direct measurements on the surface. In space conditions, information about the surface of the planet is collected remotely using photography or laser sensing.

3. Conclusion

A digital model is a discrete model containing latent information. The digital model in space research allows you to simulate measurements and form analog models. The formation of discrete models occurs in accordance with the Shannon-Nyquist-Kotelnikov reference theorem. There is a difference between digital modeling in real conditions and digital modeling in space research. Digital modeling in terrestrial conditions uses direct measurements on the ground. Digital modeling in space research uses remote and indirect methods. Digital modeling in terrestrial conditions uses linear measurements on the ground or angular measurements from different points of the basis of observation, which allow the formation of linear metric values. Digital modeling in space research uses mainly angular measurements and estimation and correction methods to obtain linear metric values. Common to both types of modeling is the onomasiological approach, which reduces the analog model to a discrete one.

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Satellite Monitoring

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Abstract

The article explores satellite monitoring. This technology is one of the space research technologies. The difference between space monitoring and satellite monitoring is shown. Two implementations of satellite monitoring are described. The systematics of satellite monitoring is given. The influence of Earth sciences on the development of satellite monitoring is described. The importance of the concept of the information field and information space on the concept of satellite monitoring is noted. The key concepts of satellite monitoring are described. The content of satellite monitoring is revealed through key concepts. The monitoring field, monitoring situation, monitoring methods, monitoring result models are described. The value of the information situation model for satellite monitoring is revealed. The difference between the information situation and the monitoring field is shown. Methods and models of monitoring are described. Object monitoring and process monitoring are described. The difference between active and passive satellite monitoring is shown. The difference between indicator and analytical monitoring is shown. Detective and interpretive monitoring is described. Prospective satellite monitoring is described, which, based on time series, makes it possible to make forecasts. It is shown that, unlike space monitoring, in which angular measurements predominate, satellite monitoring makes it possible to obtain the linear dimensions of objects. In relation to space monitoring, satellite monitoring is internal. Satellite monitoring is applicable in the study of other planets. In this case, it should be called orbital monitoring.

Keywords: space research, monitoring, space monitoring, satellite monitoring, spatial modeling, space geoinformatics.

1. Introduction

In the practice of space exploration and the Earth's surface, the term “space monitoring” is often used (Savinych, 2017; Kudzh, 2022) and less often the term “satellite monitoring”. There is a significant difference between these concepts. Space monitoring is aimed at studying near-Earth space (Barmin et al., 2014), at studying the Earth's satellite – the Moon, at studying the space of the Solar System, at studying near and far space. Space monitoring investigates the problem of astreoid-cometary hazard (Tsvetkov, 2016). Satellite monitoring is aimed primarily at studying the Earth from space. Satellite monitoring also investigates the problem of astreoid-cometary hazard.

Technologically, both monitorings are close. But the purposes of information processing differ. The connecting element between them is space geoinformatics. Therefore, both monitorings incorporate technologies and methods of Earth sciences and complement them with space

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exploration technologies. The development of satellite monitoring is an indicator of the state of science and technology. Satellite monitoring has two implementations. The first is associated with the automatic registration of the earth's surface without human intervention. The second implementation is related to the use of orbital scientific stations (Savinych, 2018). This type of satellite monitoring uses cognitive technologies. In particular, they use technologies for visually instrumental observations.

The effectiveness of satellite monitoring is manifested when global observations are needed. This is a global ecology. Satellite monitoring is characterized by long observation distances and large objects of observation. This leads to the emergence of a big data problem (Allam, Dhunny, 2019). Satellite monitoring is divided into indicative, periodic and continuous. Continuous satellite monitoring also poses a big data challenge.

To improve the reliability of observations, multispectral observation of the earth's surface is used. Multispectral observation of the earth's surface creates the need for integrated data processing. Geodata is used for integrated data processing.

The modern development of satellite monitoring is characterized by the widespread use of Earth sciences, transformed into space research. Among these sciences: space geodesy (Bertiger et al., 2020), geodetic astronomy (Gospodinov, 2018), satellite altimetry, space geoinformatics (Bondur, Tsvetkov, 2015a). System analysis is used in satellite monitoring (Bondur, Tsvetkov, 2015b).

Satellite monitoring technologies and techniques use Earth science techniques. Satellite monitoring uses information methods in research. In addition to system analysis, the conceptual directions of space monitoring are the concept of the information field and information space. A feature of satellite monitoring is the use of various types of modeling, including metamodeling.

2. Results and discussion

Analysis of the content of satellite monitoring

The key concepts of satellite monitoring are: the object of monitoring, the field of monitoring, the monitoring situation, monitoring methods, models of the monitoring result.

The monitoring field is a subset of the information field. It sets the possible limits of monitoring and limits unnecessary observations. The monitoring field is characterized by spatial factors and spatial relationships. The monitoring field is a relatively stationary model.

The monitoring situation is related to the model of the information situation. In relation to the monitoring field, it is a subset. Unlike the monitoring field, the monitoring situation takes into account operational factors and the dynamics of the state of the monitored object. The monitoring situation takes into account the trends in the state of the monitored object. The monitoring situation is characterized by spatial and temporal factors. The monitoring situation is a dynamic model. These concepts complement each other. For example, the monitoring of a bridge from space is determined by the field where the bridge is in space. But the condition of the bridge and its collapse determine the monitoring situation (Milillo et al., 2019).

Models of the monitoring result are determined by the tasks of monitoring and the mathematical apparatus that the observer has. Models of the monitoring result are determined by the level of intelligence and knowledge that the specialist has.

Monitoring methods are related to technical means and methods of information processing. For example, if you have a small amount of data, you can apply direct algorithms. If you have big data, you need to use big data processing methods.

Systematics of various types of satellite monitoring is carried out on key aspects. It is possible to distinguish key aspects: the object of observation, monitoring activity, monitoring methodology, forecasting aspect, spectral characteristics, the relationship of the object to the earth's surface, types of object models and others.

The key indicator “object of observation” allows you to distinguish between the monitoring of objects and the monitoring of processes. Object monitoring examines the state of the object. Process monitoring investigates the dynamics of an object or situation and processes. For example, fire monitoring in a certain area is procedural monitoring. Object monitoring can be indicative. It is important for him to indicate the presence of an acceptable state or an unacceptable state. Procedural monitoring uses complex dynamic models of information processing. With comprehensive monitoring, objects and processes are simultaneously observed.

According to activity, satellite monitoring is divided into active and passive monitoring. An example of active satellite monitoring is radar surveillance. In this technology, the monitored object is irradiated and information is received in the reflection of the radar signal. Another example is laser sensing. An example of active monitoring is X-ray imaging. Passive monitoring is environmentally friendly. For example, the use of photography in the optical or infrared range is passive monitoring. Passive monitoring is preferable in the examination of unknown space objects, since active radiation from the monitoring system can be perceived as aggression to initiate unknown response processes.

According to the method of satellite monitoring, it is divided into different dichotomous pairs: indicative and analytical; discrete and continuous; detecting and interpreting. If satellite monitoring only records the presence or absence of a sign, then such a KM is called indicative. Analytical monitoring uses time series of observations and complex time dependencies. If satellite monitoring observes an object with time gaps, then it is called discrete. If satellite monitoring tracks a phenomenon in real time, then it is called continuous, although this continuity is conditional.

Satellite monitoring aimed at detecting an object is called detecting. Satellite detection monitoring often uses spatial logic. Satellite monitoring aimed at studying a known object and its condition by interpreters.

The forecasting aspect divides monitoring into perspective and retrospective. Long-term satellite monitoring based on time series makes it possible to build forecasts. It makes it possible to conduct a prospective analysis. Time-series-based retrospective satellite monitoring allows you to look into the past and look for cause-and-effect relationships. It makes it possible to conduct a retrospective analysis.

The peculiarity of satellite monitoring is that it is carried out from a mobile object in relation to objects on the surface of the Earth. This requires in some cases to take into account the dynamics of the movement of the satellite. At the same time, its advantage is the ability to observe the object from different points of view. Unlike space-based monitoring, which is dominated by angular measurements, satellite monitoring makes it possible to obtain linear dimensions of objects.

If the wave range is chosen as a criterion for monitoring characteristics, then this gives the following systematics: radar monitoring (Kozlov et al, 2020), optical monitoring (Huang et al., 2018), thermal monitoring (Martín et al., 2020), laser monitoring (Anthony et al., 2010).

Many types of satellite monitoring are characterized by the use of information and geoinformation modeling. According to the models of the monitored object in satellite monitoring, the use of statistical models of objects and dynamic models of objects are distinguished. Static models are usually independent of time for example. Flood or fire area Dynamic models have time as one of the arguments.

According to the models of the object, taking into account the information environment in space monitoring, the use of information models of the situation (situational monitoring) is distinguished. Application of models of information interaction of different objects (communicative monitoring).

Satellite monitoring is aimed at studying the surface of the earth and oceans from the orbit of a space station or satellite. In relation to space monitoring, it is internal. Internal monitoring explores the part of near-Earth space that lies between the satellite and the Earth's surface.

3. Conclusion

Satellite monitoring is a particular type of spatial monitoring and a type of space monitoring. Analysis of various types of spatial monitoring and satellite monitoring shows the feasibility of introducing the "information situation" model (Tsvetkov, 2012). The information situation during shooting exhaustively determines the conditions of shooting and allows you to compare different shooting situations with each other. Modern satellite monitoring is built on the basis of the integration of various technologies. Often satellite monitoring acts as an information measuring system. The final processing of information obtained using satellite monitoring is carried out in terrestrial conditions. Satellite monitoring is applicable to the study of other planets. In this case, it can be called orbital monitoring. Satellite monitoring evolves and evolves. Its evolution is close to evolution space monitoring (Savinych, 2017).

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Remote Sensing in Real Estate Management

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Abstract

The article studies the use of remote sensing for real estate management. The advantage of remote sensing in the observation of global processes on the earth's surface is shown. It is shown that the greatest effect from the use of remote sensing is obtained with a comprehensive study of objects and territories. The importance of processing space images for solving ground-based problems is determined. The feature of multispectral shooting and its use is shown. The difference between active and passive methods of remote sensing is shown. Weak use of this technology for real estate management is revealed. An analogue of this technology has been found. These are precision agriculture technologies. Technology of precision agriculture is based on the application of remote sensing of the Earth. They are aimed at the study of territories and the analysis of land resources. Remote sensing technologies for property management are also aimed at the exploration of territories. But then they are directed to properties. Remote sensing technologies for property management use space-based methods to monitor objects and determine their condition. The article introduces a new concept of “real estate field”. It is analogous to the concept of “monitoring field”. The concepts of using remote sensing in real estate management are described.

Keywords: space research, remote sensing, real estate, real estate management, real estate field.

1. Introduction

Remote sensing data are effectively used to solve a wide range of control problems in the native environment and anthropogenic objects. Remote sensing data (DDS) are highly informative and reliable (Pearlman et al., 2019). The main areas of use of DDSinclude: the study of natural resources; the study of subsoil; study of large engineering structures and construction projects; environmental monitoring; global monitoring. The greatest effect from the use of DDS is obtained in a comprehensive study of objects and territories.

Space images are multi-purpose (Yeh et al., 2020). They are used as an integrated information base for conducting complex, interconnected studies of the natural environment. The results of thematic processing of space images can be presented in the form of a series of coordinated thematic maps reflecting the spatial location, qualitative and quantitative characteristics of natural and economic objects of the corresponding territory.

Space images contain valuable information about the relationship of natural-territorial complexes, since all these components are reflected simultaneously on them. Landscapes are indicators for determining the properties of various components of the natural environment. Very

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often, complex or industry case studies use the landscape indicative method of data interpretation. It is most widely used in geological, agricultural, municipal, hydrogeological studies. Landscape indication consists in identifying hard-to-observe components from easily observable components.

Tothe osmic images of different ranges, it is possibleto study trends in the development of the urban environment and real estate (Yeh et al., 2020). They make it possible to identify and study these dynamics and to find anthropogenic impacts.

Remote sensing includes passive and active methods. Space imaging is divided into photographic, television, scanner thermal and radar. Photographic and scanner surveys of the earth's surface are formed in panchromatic, zonal, multizonal and multizonal versions. Differences in the reflection spectra of real estate objects serve to assess their physical condition.

With multi-zone imaging (ElMasry et al., 2019), a series of geometrically combined images are obtained in several narrow zones of the electromagnetic wave spectrum. The set of zonal images is much more informative than images in one spectral range. A series of zonal images allows you to use the “spectral image” of the studied objects as a classification feature, providing an opportunity to formalize the spectral brightness of objects. Remote sensing methods of the earth's surface provide a new additional tool for property management

2. Results and discussion

Control technologies and analogues.

The basis for the transfer of remote sensing methods to the field of real estate management is geoinformatics. Geoinformatics is widely used in spatial *economics (*Tsvetkov, 2013) and in the field of real estate management. The emergence of space geoinformatics (Bondur, Tsvetkov, 2015a) is a connecting bridge between space research and real estate management.

An analogue of the application of space technologies for property management are precision agriculture technologies (Sishodia et al., 2020, Tsouros et al., 2019, Shafi et al., 2019). Precision agriculture is a comprehensive agricultural management technology that uses remote sensing techniques. This technological complex includes: global positioning technologies (GPS), geographic information systems (GIS), yield assessment technologies (Yield Monitor Technologies), Variable Rate Technology, remote sensing technology (ERS) and Internet of Things (IoT) technologies. Many solutions Precision agriculture is applicable for property management. Precision agriculture oversees land. Property management also oversees land and plots. The difference lies in the direction of analysis for precision agriculture technologies and for real estate management technologies. There is every reason to apply fragments of precision agriculture technology in the field of property management. These snippets should be complemented by property management tasks.

General principles of real estate monitoring

The scientific concept of remote sensing applications in real estate management is based on a systematic approach (Bondur, Tsvetkov, 2015b). The object of monitoring is treated as a heterogeneous territory. These inhomogeneities can be considered as granules or as heterogeneous sets. Assessment and isolation of these inhomogeneities is carried out using the global positioning system, radar images, space images and space geoinformatics, using geographic information systems. You can introduce a new concept of the property management field. The property management field is an environment that includes the territory and all the factors that affect property management.

When monitoring real estate, an information field model is used (Tsvetkov, 2014) to extract and analyze information as a related mechanism.

The solution of these problems is carried out using artificial intelligence technologies. The collected data is used to assess the condition of the property and management. This concept necessarily requires taking into account the ecological and social characteristics of the territories.

The use of remote sensing for real estate management is aimed at ensuring the sustainable development of territories. Sustainable development of territories and real estate includes three components: social sustainability, environmental sustainability, economic sustainability.

Heterogeneities within the real estate field depend on a number of factors: building density, ecology, transport accessibility, distance from the center and others. To create a field of real estate, geodata is used that takes into account metric, social and economic factors.

The results of remote observations taking into account geodata allow you to create an accurate map of the real estate field. According to remote sensing data, it is possible not only to monitor legal buildings, but also to identify illegal real estate. The peculiarity of real estate maps is that they can be superimposed with models of fields, for example, environmental pollution.

Management decisions are based on spatial and economic models that take into account the dynamics of real estate development and other external factors. The property management manager makes a specific decision independently, based on maintaining a balance of economic and environmental goals.

Space monitoring

Real estate management technology using satellite technology requires the use of space monitoring and processing of its results. This monitoring is performed in two closed and real-time modes. Closed monitoring includes capturing high-resolution images, processing snapshots, and generating information to support decision-making.

Real-time space real estate monitoring includes online monitoring of real estate objects, including different areas of the spectrum, radar images provide information about the physical condition of real estate and serve as the basis for additional work. The peculiarity of this technology is that it allows real-time monitoring of the state of real estate in a large area in cities and outside cities.

This technology allows you to connect real estate with other infrastructure objects and identify spatial and environmental patterns. This technology allows you to form an extensive statistical base for comparisons based on historical monitoring data. A significant advantage of the technology is a high level of automation of the processes of monitoring real estate crops and interpreting information into an interactive map understandable to a wide range of managers.

The technology of space monitoring of real estate is used by:

- municipal staff to monitor the state of the urban environment;
- business owners (assessment of the state and prospects of the business, making a decision on additional investments, making management decisions);
- investors and analysts (assessment of investment potential, making investment decisions, creating and adjusting forecasts);
- insurance brokers (collection and control of information, verification of data provided by clients, calculation of the tariff scale and the amount of insurance payments);
- road builders (condition and development of the road network);
- state and sectoral institutions dealing with agricultural issues and solving issues of food and environmental security.

Currently, methods are used to quantify the dynamics of urban areas using high-resolution satellite imagery (Shafi al., 2019). Satellite remote sensing provides significant opportunities for monitoring real estate and urban areas through remote sensing capabilities. Video information processing plays a major role in monitoring.

Recently, object-based image analysis (OBIA) has been increasingly used to classify images (Hu et al., 2018).

Remote sensing is used in many industries, from mining to city management, mapping and geoinformatics.

Every year, new applications of remote sensing are developed in various fields: construction, real estate management, transport, urban planning, disaster relief, architecture. There is an online list of the 100 best use cases for remote sensing satellites.

3. Conclusion

To date, critical work in the field of real estate operations and urban development financing has been concentrated within the framework of ground technologies. Property management is based on the interaction of the investor, the developer and the government. Land-based real estate management shows how real estate, assets and investors' goals are being realized through regulatory and tax reforms. Real estate management in a broad sense shows the construction of cities. However, the relationship between real estate transactions and space technologies has not yet been given much attention. However, spatial knowledge and geo-knowledge are necessary for real estate management. Obtaining complete spatial knowledge possibly using space technology.

The connection of remote sensing data to property management expands the possibilities of real estate management strategy and tactics. First of all, this is important for corporate governance. A new emphasis on the application of space information increases the information content of management models and helps to understand how real estate values penetrate in space.

In particular, it demonstrates the key role of information and spatial information in the theory and practice of real estate management.

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