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Satbayev University

ХАБАРЛАРЫ

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ALGORITHM FOR CONTROL OF REMOTE SENSING SPACECRAFT FOR MONITORING SUBSOIL USE OBJECTS

Abstract. In modern conditions of conducting geological research, the most effective is the use of methods of remote sensing of the Earth. The most important research methods are prospecting, geological-surveying and engineering-geological. Technologies for studying the relief of the earth's surface involve the processes of recognition, interpretation and binding of the obtained images to real conditions. Depending on the object, different research methods are used. In particular, when deciphering sedimentary rocks, the nature of the banded pattern of the image is taken as the basis, and when deciphering bedrock formations, the main attention is paid to the nature of occurrence and material composition. It is necessary to take into account the fact that when compiling general geomorphological maps, geomorphological interpretation is used.

In order to update geomorphological maps and obtain timely and reliable information about subsoil use objects located on the territory of the Republic of Kazakhstan, it is necessary to use images from remote sensing spacecraft. Taking into account the vast area of the territory of the Republic of Kazakhstan, an important role is given to the issues of increasing the efficiency of controlling the spacecraft for remote sensing of the earth.

The authors propose a spacecraft control algorithm developed by them. The paper presents the research results conducted by the authors and proposals for their practical implementation.

Key words. Algorithm, spacecraft, remote sensing, subsoil users, geology, database, methods, satellite images, efficiency, object.

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ЖЕР ҚОЙНАУЫН ПАЙДАЛАНУ ОБЪЕКТІЛЕРІН МОНИТОРИНГТЕУ МАҚСАТЫНДА ҚАШЫҚТЫҚТАН ЗОНДТАУ ҒАРЫШ АППАРАТЫН БАСҚАРУ АЛГОРИТМІ

Аннотация. Ғылыми мақалада авторлар жер қойнауын пайдалану саласын дағы проблемаларға байланысты өте маңызды және өзекті мәселелерді зерттейді. Соңғы онжылдықта Қазақстан Республикасында геологиялық-барлау жұмыстарын жүргізу қарқынының баяулауы байқалады. Мұның себебі жер қойнауын пайдалану объектілері туралы мәліметтер базасының толық болмауы. Жер қойнауын пайдалану объектілері туралы толыққанды деректер базасын қалып тастыру үшін ғылыми мақаланың авторлары Жерді қашықтықтан зондтау әдістерімен алынған ең өзекті мәліметтерді пайдаланады. Қазақстан Республикасының аумағында орналасқан жер қойнауын пайдалану объектілері туралы уақытылы және дұрыс ақпарат алу үшін қашықтықтан зондтау ғарыш аппараттарынан алынған суреттерді пайдалану қажет. Қазақстан Республикасы аумағының үлкен аумағын ескере отырып, ғарыш аппаратын басқару тиімділігін арттыру мәселелеріне маңызды рөл беріледі.

Ғылыми мақаланың авторлары өздері жасаған ғарыш аппараттарын басқару алгоритмін ұсынады. Жұмыста авторлар жүргізген зерттеулердің нәтижелері және оларды практикалық іске асыру бойынша ұсыныстар берілген.

Түйін сөздер: алгоритм, ғарыш аппараты, қашықтықтан зондтау, жер қойнауын пайдаланушылар, геология, дерекқор, әдістер, ғарыштық суреттер, тиімділік, объект.

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АЛГОРИТМ УПРАВЛЕНИЯ КОСМИЧЕСКИМ АППАРАТОМ ДИСТАНЦИОННОГО ЗОНДИРОВАНИЯ В ЦЕЛЯХ МОНИТОРИНГА ОБЪЕКТОВ НЕДРОПОЛЬЗОВАНИЯ

Аннотация. В современных условиях при проведении геологических исследований наиболее эффективным является применение методов дистанционного зондирования Земли. Наиболее важными методами исследования являются поисковые, геолого-съемочные и инженерно-геологические. Технологии исследования рельефа земной поверхности предполагают процессы распознавания, дешифрирования и привязки полученных снимков к реальным условиям. В зависимости от объекта применяются различные методики исследования. В частности при дешифрировании осадочных пород за основу берется характер полосчатого рисунка изображения, а при дешифрировании коренных образований основное внимание уделяется характеру залегания и вещественному составу. Необходимо учитывать тот факт, что при составлении общих геоморфологических карт используется геоморфологическое дешифрирование.

В целях актуализации геоморфологических карт и получения своевременной и достоверной информации об объектах недропользования, расположенных на территории Республики Казахстан, необходимо использовать снимки с космических аппаратов дистанционного зондирования. Учитывая большую площадь территории Республики Казахстан, важная роль отводится вопросам повыше ния эффективности управления космическим аппаратом дистанционного зондирования земли.

Авторы научной статьи предлагают разработанный ими алгоритм управления космическим аппаратом. В работе представлены результаты проведенных авторами исследований и предложения по их практической реализации.

Ключевые слова: алгоритм, космический аппарат, дистанционное зондирование, недропользователи, геология, база данных, методы, космоснимки, эффективность, объект.

Introduction. When compiling general geomorphological maps using the interpretation of aerial and satellite images with high spatial resolution, it is necessary to use high resolution images. As the method of geological interpretation of aerial and space images develops, the results of interpretation are increasingly used in geological production - in geological mapping and prospecting.

The remote basis of maps of geological content is an information product created on the basis of remote sensing materials, the results of their formalized transformations,

decoding and interpretation. The basis is presented in digital form, including in a form suitable for printing at a scale of 1:100,000 and 1:500,000 color composites of the visible and infrared spectral ranges. The requirements are also mandatory for mediumscale deep geological mapping, as well as for geological and mineralogical mapping.

Monitoring and evaluation of various subsoil use objects for the Republic of Kazakhstan is one of the strategic directions. This is due to the fact that in recent decades the pace of scientific research in the development of new mineral deposits has sharply decreased. Moreover, control by law enforcement organizations over the state of existing subsoil use facilities has decreased. All this led to the need to create a database of existing subsoil use objects and fix at the legislative level the procedure for conducting research on newly developed subsoil use objects.

Taking into account the severe climatic conditions of the Republic of Kazakhstan and the fact that such phenomena as wind, precipitation, floods, sudden temperature changes on the territory of the Republic of Kazakhstan occur with a certain frequency, it is necessary to carefully approach the development of new mineral deposits (https://www.intechopen.com/books/geoscience-and-remote-sensing-new-achievements/development-of-flood-space-monitoring-in-kazakhstan). Unfortunately, we should admit the fact that the availability of operational geospatial information on the state of the proposed subsoil use object for decision makers is still insufficient and does not meet modern environmental protection requirements.

The need to conduct monitoring over a larger territory of the Republic of Kazakhstan prompts us to consider satellite observations by remote sensing methods as one of the main sources of up-to-date, complete and reliable data on their condition.

The main objective of the study is to identify and assess the risks that may arise in the process of development and further operation of proposed new subsoil use objects using satellite imagery materials. Also, to obtain the most reliable information coming from the spacecraft, it is necessary to optimize the errors in the spacecraft control system by developing the most efficient algorithm.

Materials and methods. In the development of new mineral deposits it is very important to determine the seismic resistance of the proposed region. Also, a significant role is played by the predicted change in climatic conditions in one or another part of the Republic of Kazakhstan. In particular, for existing subsoil use facilities on the shelf of the Caspian Sea, the issue of obtaining prompt and reliable information about possible weather changes is of no small importance. There is a map of seismically active zones on the territory of the Republic of Kazakhstan. Also, the seismic activity of the zones can be determined using the program shown below https://www.emsc-csem.org/Earthquake/?filter=yes (Fig. 1)

Figure 1. Software package for determining seismically active zones

Since the advent of the first systems of the Earth remote sensing, allowing to carry out shooting in real time, one of the main directions of their use is to obtain reliable information in real time.

The most important source of information is the data of the Earth remote sensing (ERS) from space (Archive of space images from Landsat satellites; http://www.kosmosnimki.ru, Source of ScanEx Engineering and Technology Center). Space monitoring consists in continuous, repeated obtaining of information on the qualitative and quantitative characteristics of natural and anthropogenic objects and processes with accurate geographical reference. It also makes it possible to obtain homogeneous and comparable in quality objective information at the same time for vast territories, which is practically unattainable with any ground-based surveys. Now there are about 100 remote sensing satellites in orbit. It should be emphasized that at present there is a steady trend of more and more active interest in the introduction of integrated space monitoring technologies.

There are two directions for obtaining spatial information about the Earth's surface from space. This is shooting in the visible and infrared ranges of electromagnetic wave lengths (optoelectronic systems) and shooting in the centimeter radio range (radar systems). Space monitoring data is also divided according to the spatial resolution of the imaging equipment, according to the possibility of shooting in different spectral channels, the possibility of stereo shooting, current relevance, etc. With the help of space monitoring on the territory of the Republic of Kazakhstan, some moments can be distinguished by blocks: overview and analytical, modeling, operational monitoring, data transmission.

Since 2014, Landsat optical data (spatial resolution 30 m) has been regularly processed in the Republic of Kazakhstan, which are taken from 180x180 km scenarios and have high communication accuracy. It should be noted that the images from the SENTINEL-1 A satellite (in IWS mode; in 3 looks mode), having a spatial resolution of 25 m in a 240 km band between the radar data of this level, are dual polarized (VV/VH).

Access to these two data is free, but satellite imagery does not cover the entire territory of the Republic of Kazakhstan, the repetition period is 12-16 days.

In addition to seismically active zones, it is also necessary to take into account the influence of climatic and weather factors when predicting promising objects of subsoil use. In this regard, an important role is played by the analysis of space weather data (Fig. 2)

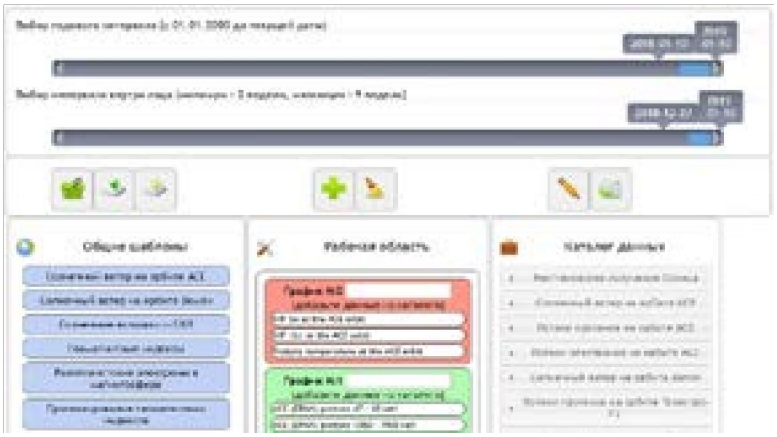


Figure 2. Analysis of space weather data

Research results. Let us consider the results of space monitoring of floods, which can cause significant damage to existing subsoil use facilities. The functional basis for the operation of the flood area monitoring system in the operational mode is the stations for receiving remote sensing data, located in Astana and Almaty. They regularly receive data from NOAA, EOS Terra and Aqua, Indian IRS satellites and the Canadian radar satellite RADARSAT-1. The radio visibility zones of receiving stations cover Kazakhstan, a significant part of Russia and the Asian region. Figure 3 shows a functional diagram of creating databases for developing a technique for space monitoring of floods based on the merging of multi-temporal radar and optical remote sensing data.

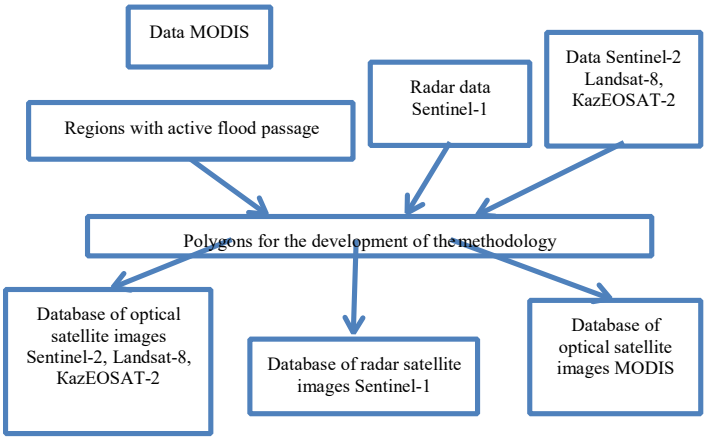


Figure 3. Functional diagram of creating databases

The flood area monitoring technology is based on daily EOS - Am Terra MODIS images of areas that are at high risk of flooding, including areas located in neighboring countries. The main task is the operational mapping of flood zones during the passage of flood waters. Based on these images, after thematic processing, masks of flood areas are created. Flood zones are defined as the difference between water surfaces under normal conditions and during high water. A cloud mask is used to exclude cloud cover and cloud shadows. To exclude wet soil, the NDVI vegetation index is used. The operational situation is compared with the maps for the previous day and the most dangerous territories with high dynamics of natural water development are identified (Fig. 4).

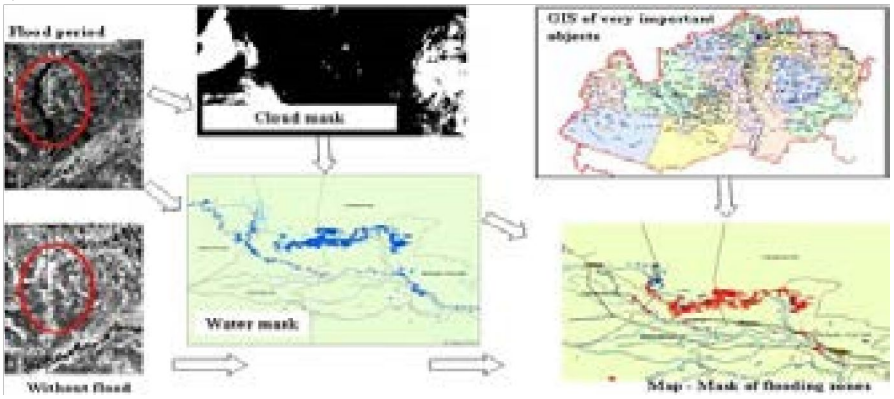


Figure 4. Images obtained after thematic processing

To assess the potential risk of flooding, a special geographic information system is used. It contains information about settlements and settlements, road and railway networks, power lines, oil and gas pipelines, forests, especially important objects, etc.

By combining these layers and flood zones, one can determine their location relative to the nearest settlements and especially important objects and distance to them. Final flood zone maps are sent by email to regional emergency agencies.

Algorithm for identifying flood zones on satellite images.

The task of identifying flood zones according to remote sensing data was solved using automatic classification algorithms in the ArcGIS-9.1 programming environment and takes place in three stages (Fig. 6). At the first stage, five main classes of objects are distinguished: cloud cover, snow cover, water surface covered with ice, water surface and land surface free from snow.

The main interest is the water surface. Therefore, at the second stage, an additional analysis of this class is carried out to identify false objects. First of all, these are shades from clouds, recently plowed deposits and moist soils. To remove vapors falsely attributed to water objects, masks of agricultural fields and analysis of their structure are used. Wet soils are excluded by analysis using vegetation indices. Note that sometimes sunlight blinds from the surface of the water, creating additional interference. In addition, it is necessary to know the normal state of water objects in order to indicate deviations in their location.

At the third stage, the operational maps of flooded territories (Fig. 6) at the level of the region and individual districts are formed using a mask of the water surface under normal conditions, determined for the autumn of satellite images (Fig. 7).

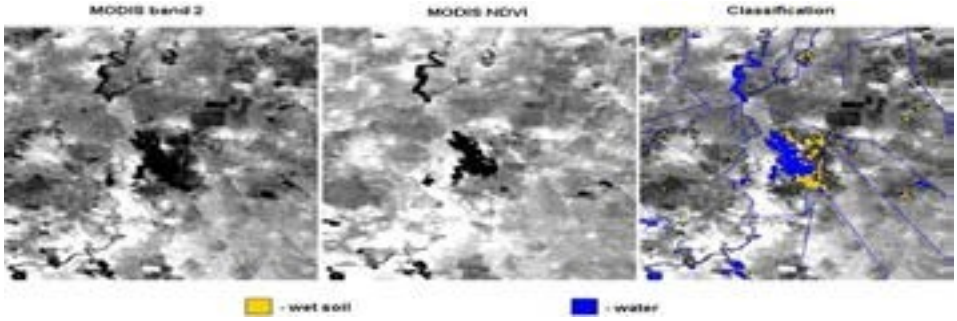


Figure 7. Classification of water surfaces and wet soils according to MODIS data

Merging optical and radar data (Fig. 8)

Composite images Sentinel-1 Sentinel-2
(VV NDVI MI)
Composite images Sentinel-1 Sentinel-2
(VV NDVI MI)
Composite images Sentinel-1 Sentinel-2
(VV NDVI MI)
Composite images Sentinel-1

Sentinel-2 (VV NDVI MI)

Composite images Sentinel-1

Figure 8. Merging optical a

Sentinel-2 (VV NDVI MI)

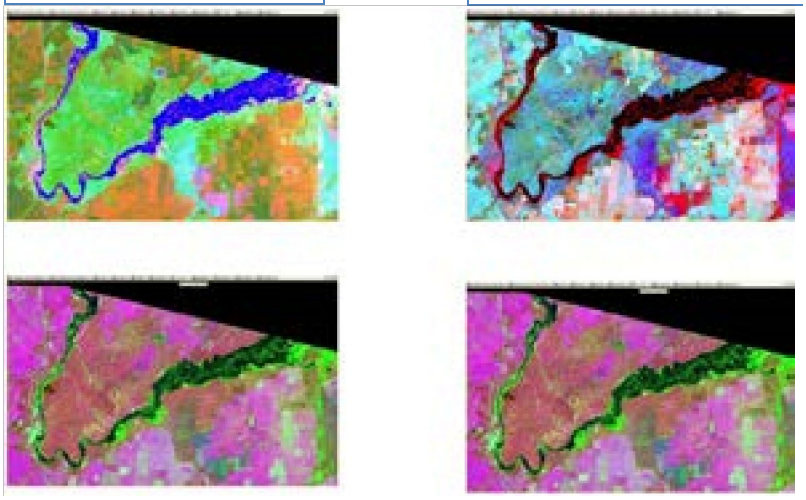
Composite images Sentinel-1 nd

radar data **Sentinel-2 (VV NDVI MI)**

Figure 8. **Composite images Sentinel-1** Merging optical

and **Sentinel-2 (VV NDVI MI)** radar data **Composite images Sentinel-1**

Sentinel-2 (VV NDVI MI)



Algorithm of the program for controlling the angular motion of a spacecraft for surveying curvilinear routes.

To compile the algorithm for controlling the angular motion of spacecraft for shooting curved routes, it is necessary to use the principle applicable to objects, to which forces are applied that act on the center of gravity. In this case, initially we accept the condition that the mass of the body and the force of inertia are constant values. The model simulates body position between ± 180 degrees for longitude and ± 90 degrees for geodetic latitude (Fig. 9).

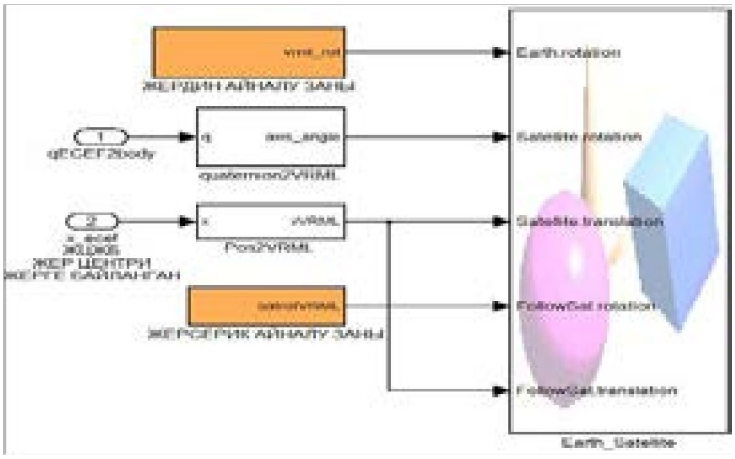


Figure 9. Visualization of the movement of the spacecraft

The geocentric system can be chosen as the base coordinate system for calculating the motion parameters of dynamic objects; however, in visualization systems, a coordinate system is often chosen that is rigidly associated with the spacecraft. In this case, the spacecraft is assumed to be stationary, and the Earth's motion is modeled relative to the spacecraft. In this case, the Earth model is located and oriented in such a way that the area of the Earth's surface observed from the spacecraft coincides with the area that the observer would see if the origin of the base coordinate system were located at the center of the Earth, and the spacecraft moved in orbit around it (Fig. 10).

Figure 10. Model of spacecraft flight in orbit

Thus, as a result of the compiled algorithm, a spacecraft flight program is built (Fig. 11).

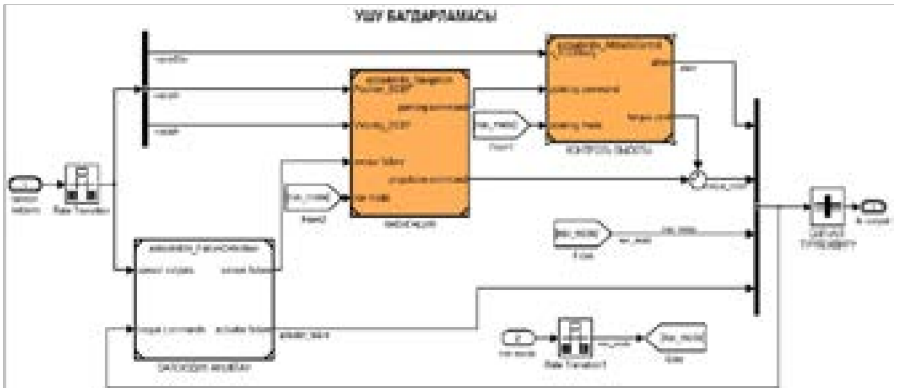


Figure 11. Spacecraft flight program

Discussion. The arguments given in the study are based on the use of spacecraft flight theory and spacecraft motion control theory. The analysis of the given models confirms the fact that the construction and implementation of programs for controlling the angular motion of spacecraft for Earth remote sensing for shooting various parts of the Earth's surface have a decisive influence on the main indicators of the devices. Achieving the desired indicators in terms of efficiency, productivity and quality of the information received depends on the capabilities of the onboard control systems to provide survey of surface areas - observation routes with different characteristics. The characteristics may include the geometric shape of the central line of the routes, their length and width (the acquisition band of the sounding equipment), and others.

Modern earth remote sensing satellites are designed for surveying routes, the central line of which is the flight path of the spacecraft or equidistant to it, as well as for conducting azimuthal surveys. At present, most spacecraft for remote sensing of the earth with high-resolution optoelectronic sensing equipment installed on them are shooting the earth's surface in the so-called «sweeping» mode. In this mode, during exposure, the movement of the line of sight of the terrain (optical axis AZ) does not exceed the projection of one photosensitive element on the terrain in the scanning direction.

Conclusion. Thus, as a result of the research, the authors proposed methods for constructing admissible areas of curvature of the route for spacecraft for remote sensing of the earth during angular motion. Algorithms have also been developed to improve their performance. In addition, an assessment of the accuracy of the implementation of the program for controlling the angular motion of the spacecraft was given and the possibility of operational processing of Landsat-8 data using the application program for overlaying images was substantiated.

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