3D MODELING OF SATELLITE-DERIVED GEOSPATIAL DATA FOR OIL AND GAS SYSTEM DESIGN.

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KEYWORDS

Design of oil and gas systems, Satellite, GIS, satellite imagery, map, MODIS, Landsat, Sentinel.

ABSTRACT

In recent decades, during the period of rapid development of science and technology, a new fundamental method for identifying and studying resources in oil and gas fields has enabled the use of a satellite system. Having a detailed understanding of the types of satellites and their use, as well as the use of AI tools, ensures the acquisition of fast and accurate information. This article presents information on the creation and use of a software package for creating 3D models of satellite geospatial data in the design of oil and gas systems.

INTRODUCTION

Currently, planning oil and gas exploration processes in the regions using precise satellite data, especially solving this problem using modern tools, can lead to increased efficiency. A number of scientific studies are being conducted on modeling the processes of digitizing oil and gas systems, developing an algorithm for generating two-and three-dimensional images, creating modern software for developing oil and gas field design using information systems and technologies for precise analysis and modeling.

This research, to a certain extent, serves to fulfill the tasks outlined in the Decree of the President of the Republic of Uzbekistan No. UP-4664 of April 4, 2020 "On Priority Measures to Improve the Financial Stability of the Oil and Gas Industry" and the Decree of the President of the Republic of Uzbekistan No. UP-60 of January 28, 2022 documents such as the Decree "On Accelerating Transformation Processes in the Oil and Gas Sector" can be considered as a basis.

It is planned to use experience in the field of creating intelligent software and technical tools, developing algorithms for creating two-and three-dimensional images using new information technologies, expanding the functionality of multi-core and multi-processor computing systems, and increasing their efficiency by foreign and Uzbek scientists for modeling digital processes in oil and gas systems.

METHODOLOGY

Several scientists have conducted research on the creation of 3D models of satellite geodata, including researchers such as Hayder Dibs, Nadhir Al-Ansar, who proposed the creation of a detailed three-dimensional model by integrating high-space satellite imagery for modeling 3D buildings using geospatial algorithms and architectural environments, as well as integrating geographic information systems (GIS) and architectural software environments, and the final results of the 3D model demonstrate a perfect image of the research area compared to the remote sensing method [1].

In their scientific research, researchers such as Daniela Poli and Thierry Toutin considered the development of geometric modeling of high-precision satellite push-bromous sensors, and to obtain accurate geolocation data from images, a corresponding sensor model was analyzed, representing the geometric relationships between the coordinates of the satellite image and the corresponding ground coordinates [2].

Remote sensing using the geographic information systems of Katerina Kavoura, Maria Konstantopoulou and Aggeliki Kyriou, 3D geological modeling of the subsurface based on

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well data, and a model that provides an automated well forecast for the area to the end user at a specific point using satellite data, were proposed, and the possibilities of manipulating spatial and non-spatial data using ArcGIS software were analyzed[3].

ANALYSIS OF THE PROBLEM

For the process of creating modern software for the development of oil and gas field design using information systems and technologies, as well as modeling for precise analysis using satellite data in 3D modeling of oil and gas fields, the following tasks should be addressed, including:

- Formation of an information model using satellite data in 3D modeling of oil and gas fields;
- Development of geoinformation and hydrogeological models and databases for modeling fluid and gas filtration processes in a heterogeneous porous medium, taking into account the properties of the productive layer;
- Development of effective algorithms for solving problems of monitoring and forecasting nonlinear filtration processes of liquids and gases in multilayer porous media.
- Development of computational algorithms for solving problems of monitoring, forecasting, and managing underground mixing processes.
- Development of a software product for the design and development of mineral deposits, taking into account environmental protection;
- Development of a package of applied programs for creating 3D models of geodata obtained from satellites during the design of oil and gas systems.

The use of satellite data to improve the efficiency of oil and gas fields significantly simplifies exploration processes. Analysis of oil fields using satellite data includes several advanced techniques and methods that utilize remote sensing technology.

The oil and gas field environment is complex and variable, and the formation properties require extremely accurate analysis. This is a key process in determining the range that will lead to the shutdown of drilling power. It is one of the most basic information for oil field development and oil recovery. Currently, 3D visualization technology is used for oil development and oil collection. It not only improves efficiency, but also increases the speed of oil reservoir exploration at the same time.

MATERIALS AND METHODS

Satellite imaging analysis should reflect the terrain of the Earth's surface and the structure of the outer crust, the structure of the deposit, its state, and the entire landscape. To do this, software tools are used, including the Moderate Resolution Imaging Spectroradiometer (MODIS), a satellite-based data system used for measuring ground objects and climate indicators. There are two MODIS sensors in Earth orbit, the Terra (2001) and Aqua (2002) satellites launched by NASA. MODIS satellite data consists of 36 spectral data with wavelengths ranging from 400 nm to 14.4 μm, with regional accuracy of 250 m^2, 500 m 5 of, and 1 km has 29 images. The advantage of MODIS satellite data is that it receives new images of the entire globe every 1-2 days. MODIS satellite data is intended for analysis and mapping of global scale measurements[4].

Landsat is the longest-running satellite imagery of the Earth the initial information was obtained in 1972, and today the Landsat-8OLI (2013) and Landsat-9 continues to operate. Measuring instruments installed on Landsat[5] satellites received billions of images globally. Landsat satellite data is a unique resource for conducting various scientific research in the fields of agriculture, cartography, geology, forestry, education, and national security. For example, Landsat-8OLI, according to its territorial accuracy (15m, 30m, and 100m), provides images at spectral widths of 0.4-12.5 μm from 11 wavelengths every 16-18 days.

Sentinel-2 is collected by the European Space Agency (ESA) as part of the Copernicus Program (the world's largest surface observation program) to monitor and monitor processes on the Earth's surface, for forest monitoring, disaster management, and to monitor changes in the Earth's surface and to study climate change. Sentinel-2A (2015) and Sentinel-2B (2016) satellite data provide the necessary information, in particular, for monitoring the state of growth and development of agricultural crops and forecasting

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yields. The territorial accuracy of the Sentinel-2 multi-spectral satellite data from 10 to 60 meters, based on images consisting of 13 bands of visible, infrared, and short infrared spectral waves, allows for the determination of the state of plants at different stages of development, including the study of periodic changes and photosynthetic processes every 5 days. Satellite data is practically indistinguishable from aerial photography in terms of its geometric features, but has features related to[8]:

Table 1.

Analysis of programs working with satellite data.

Main indicators:	MODIS	Landsat-8	Sentinel-2
First flight	1999 year	2013 year	2015 year
Geometric accuracy	250 m-1 km	15 m-120 m	10 m - 60 m
Number of seats	36	11	12
Periodicity	1-2 days	16 days	5 days

Satellite data can be used in 3D modeling of oil and gas fields for the following purposes:

- Satellite images can be used to determine the exact location of lines and wells obtained as a result of seismic surveys, which speeds up the process of studying the field.
- Helps monitor oil spills in offshore areas, determine protection and safety measures.
- Maps of geological structures facilitate the process of identifying and exploring fields.
- Updating the location coordinates of old wells and updating the location of existing wells and their better management.
- It helps to determine the diversity of rocks, the location of resources, and the strategies for developing deposits.
- Satellite imagery can be useful in assessing the productivity of different regions and identifying them in search strategies.

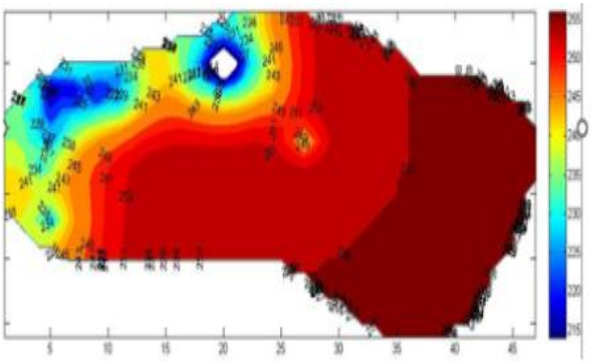


Fig.1. 3D model view of the mine.

The creation of 3D field images using SIC (Spatial Information and Communication) technologies allows for detailed analysis and comparison in more efficient planning of oil and gas exploration projects.



Fig.2. 3D terrain visuals interface.

Geological features affecting oil and gas exploration projects are determined by high-precision digital terrain models and considered in 3D terrain visualization environments. The data can be further prepared for complex analyses such as hydrocarbon indices or fracture analysis to ensure the best decisions on the drilling sites.

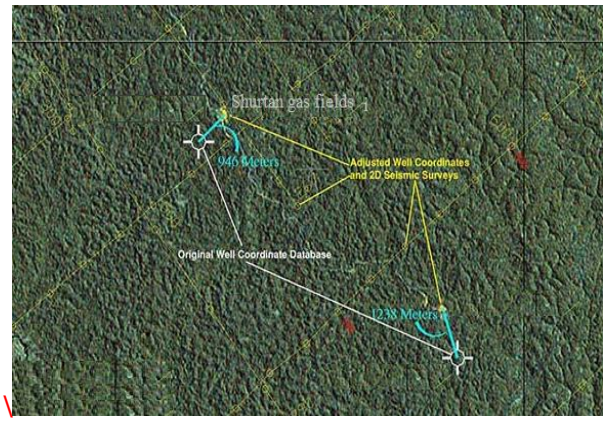
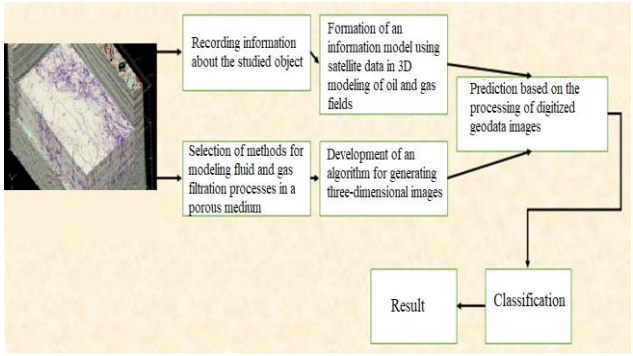


Fig.3. Analysis of the studied field.

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The process of creating an information model using satellite data in 3D modeling of oil and gas fields is carried out in the following stages, namely:

In recent years, with the development of various type of oil reservoir exploration, it requires that people must understand distribution and geometry of space and time in sand under various environments. In particular, we must master the feature of single sand body geometry and 3D spatial continuity and the configuration of the relationship, and start modeling research in this area A large number of three oil field experimental results of indoor tests so far less ideal in recent years.



The reason is that the reservoir model is so different from the indoor simulation, and there may be the existing reservoir model is too rough or some geological factors are not found. With the increasing difficulty of exploration, it requires people to make a quantitative prediction to the physical parameters of reservoir. Only in the quantitative study of detailed first-hand information, and to find out the formation mechanism and a detailed analysis of mathematical statistics, it can be forecasted effectively as far as possible. With the visualization technology of 3D geological modeling, we can describe the oilfield more clearly, solidly and really. Hence, this paper briefly reviewed the basic concept and the principles of 3D geological modeling, and described the 3D geological modeling in the oilfield. In conclusion, 3D geological modeling technology can reduce the error rate between the reservoir and the well, and also improve the survey efficiency of reservoir which built the milepost of basic geological research of oilfield.

COMPUTATIONAL EXPERIMENTS

Mathematical modeling in the design of artificial satellite geo-data is a complex process that is carried out using various algorithms and models.

The following models are used for acquiring artificial satellite images or sensor data, and they take the following forms:

CNN (Convolutional Neural Networks) or Random Forest models are used for object classification based on artificial satellite data. Object classification is the process of segmenting, analyzing, and identifying data from artificial satellite images, where machine learning models such as CNN (Convolutional Neural Networks) and Random Forest are widely used.

Object classification in artificial satellite images is carried out in two main approaches:

- Unsupervised Classification – Algorithms automatically analyze the image and group objects based on their unique spectral characteristics (e.g., K-means, ISODATA).
- Supervised Classification – The model is trained on predefined samples and then classifies new data (e.g., CNN, Random Forest, SVM).

CNN (Convolutional Neural Network) is a deep learning model used for image analysis and object detection. CNN consists of the following key layers:

- Convolutional Layer – Extracts essential features from images.
- ReLU Activation Layer – Used to learn nonlinear features.
- Pooling Layer – Compresses the image and retains the main features.
- Fully Connected Layer – Generalizes the results for classification.

CNN Model Operation Phases:

Data Preparation – Satellite images are preprocessed.

Training the CNN Model – Samples of predefined objects are used for training.

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Classification – The model separates new images based on objects.

CNN Mathematical Model

The core mathematical model of CNN is based on the convolution operation[9]:

$$Y(i,j) = \sum_m \sum_n X(i-m, j-n) \cdot K(m,n)$$

Here:

$Y(i,j)$ - the value of the output image,

$X(i-m, j-n)$ - input image pixel,

$K(m,n)$ - filter (kernel) matrix,

m,n - filter volume.

The use of artificial satellite geomagnetic data in mine planning makes it possible to determine the mine's location, the height of mine peaks, underground reserves, and other important parameters through mathematical models and software tools that calculate indicators. The data obtained from artificial satellites (for example, geospatial data provided by GPS, GLONASS, or Galileo systems) are highly accurate, and their integration into mathematical models allows the mine planning process to be carried out more efficiently.

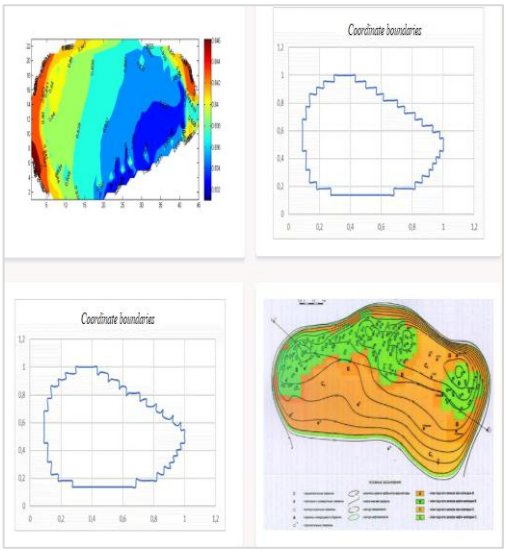


Fig.4. Measuring the coordinates of the corners in the program

Advantages of CNN

- Allows classification with high accuracy.
- Separates objects based on complex features.
- Efficiently handles large-scale data from satellite images.

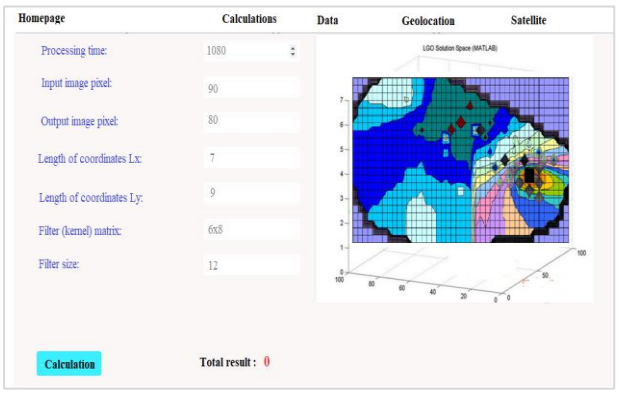


Fig.5. Software-calculated mine surface visualization

Using software tools for applying artificial satellite geo-data in mine design and real-time analysis of images is an effective process. With the help of these software tools, it is possible to determine the location of the mine, optimally allocate resources, and minimize environmental impacts.

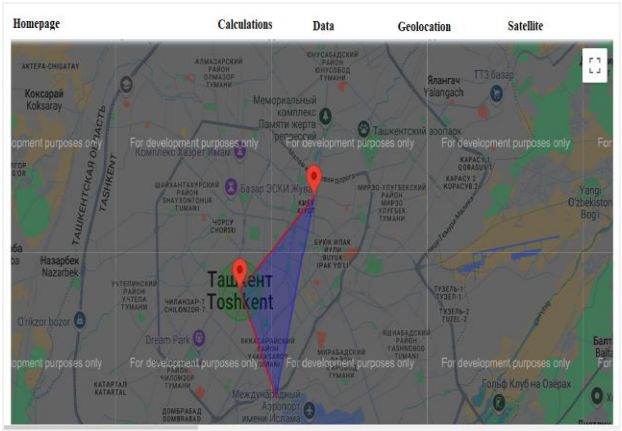
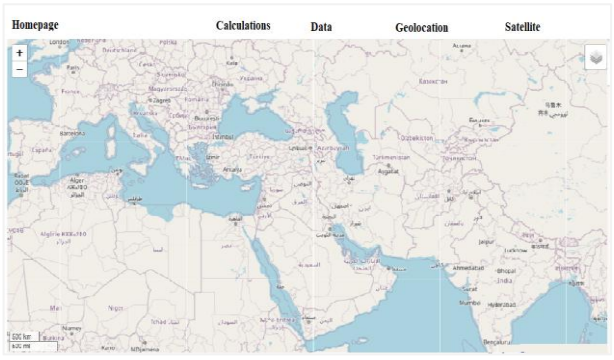


Fig.6. Object identification using a map

It is possible to digitize geospatial data images using software, meaning that maps and images in analog format can be converted into digital form, enabling the collection of satellite images, drone-captured photographs, aerial images, and ground-based observation data. Maps and images can be scanned, and automated object detection algorithms can be utilized. Additionally, the obtained data can be integrated into geographic information systems and analyzed spatially, providing the opportunity to study these processes.

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CONCLUSION

Satellite data can be widely used in various fields, including the study and mapping of regional aspects in the design of oil and gas systems. Geographic information systems and other artificial intelligence tools enable decision-making through rapid and accurate analysis of events. It is possible to conduct research based on digital modeling of oil and gas systems and modern technologies, in particular, artificial intelligence tools, and implement the obtained results in the production process. The use of satellite data based on artificial intelligence tools also increases the effectiveness of research, meaning that time and money can be saved. At the level of accuracy, compared to oil and gas field research, measurements and data acquisition can be used in cases where accessibility is difficult and high accuracy is not required[10].

ACKNOWLEDGMENTS

Satellite data can be widely used to study and map the territorial aspects of various fields. By utilizing Geographic Information Systems (GIS) and other artificial intelligence tools, it becomes possible to analyze events and phenomena quickly and accurately, facilitating effective decision-making. In cartography and other fields, modern technologies, particularly artificial intelligence tools, can be applied to conduct research and integrate the obtained results into production processes. Using satellite data based on artificial intelligence tools enhances research efficiency, saving both time and resources.

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