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QUALITY CONTROL OF THE SURFACE OF TERRESTRIAL OBJECTS USING REMOTE SENSING METHODS

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Abstract. It is of particular importance to determine the various factors affecting the development of methods of remote monitoring of the surface quality of terrestrial objects based on the information obtained by modern techniques and technologies, methods and measurements, and the improvement of remote monitoring of the surface quality of terrestrial objects is achieved in different ranges and with different research methods. In remote sensing, hyper and multispectral, LIDAR, and radio detection and ranging (RADAR) systems are attracting increasing attention due to their great potential for using the information in various remote sensing applications, and LIDAR and RADAR systems not only generate irregularly spaced 3D point clouds but also detects the laser reflection intensity. The information obtained based on remote sensing is particularly useful in land use and surface mapping, forestry, urban planning, land mapping, archaeological research, military observation, geomorphological research, land cover change, deforestation, vegetation dynamics, water quality dynamics, smart village, and city planning is important. The article also reviews approaches and environments for performing analytics in the cloud for Big Data, Cloud computing, and Machine Learning applications, explores the potential of supervised machine learning, identifies possible gaps in the technology through a detailed survey, and explores cloud-enabled Big Data, Machine Learning computing, and analytics solutions recommendations for future research in these areas have been presented.

Keywords: surface, the surface of research objects, quality, remote sensing, LIDAR system, RADAR system, Big Data, Machine Learning, Cloud Computing.

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1 Introduction

Global population growth results in surface use changes in many natural ecosystems, leading to the deterioration of environmental conditions affecting the quality of the surface, so the results obtained by the methods that study the surface in direct connection with various environmental factors that make it difficult to obtain data from large areas basically, prompt evaluation and solution of the problems occurring in those areas becomes impossible. The application of spectroscopy and statistical integrative methods for the comprehensive assessment of surface quality increases the accuracy of the prediction for the monitoring of the surface of terrestrial objects and the assessment of degradation processes in arid environments. Table I shows the quality characteristics of the surface and their respective affiliation, measurement units, and analysis methods.

The last step toward a comprehensive assessment of surface quality is a regional forecast based on acquired and processed remote hyperspectral imagery, and the integration of physical, biological, and chemical indicators of surface quality characteristics with spectroscopy for a comprehensive assessment of surface quality allows to reveal the causes of spatial variations for surface indicators (Levi et al., 2022).

Table 1: Quality characteristics of the surface and their respective affiliation, measurement units, and methods of analysis

Indicators	Unit of measurement	Analysis methods
Physical properties		
Surface structure	-	Particle size suspension
Amount of water available	%	Variation in drying and weight
Biological properties		
Extracted nitrate	mg/kq	Potassium chloride extract
Organic matter on the surface	%	Organic carbon furnace method
Chemical properties		
Acidity level	-	Removal of 1:1 water-soil suspension
Electrical conductivity	dS/m	
Chloride removed	mg/l	
Sodium removed	mg/l	
Extracted calcium and magnesium	mg/l	
Sodium adsorption ratio	-	
Removed phosphorus	mg/kq	
Extracted potassium	mg/kq	

Over time, under the influence of various natural and anthropogenic factors, surface water and soil bodies are compressed, expanded, change their appearance or flow direction, and these changes have a significant negative impact on other natural resources and anthropogenic factors, the environment.

Quality monitoring of the surface of terrestrial objects based on remote measurements in various formats obtained using satellites and sub-satellites (manned and unmanned aerial vehicles, airplanes, helicopters, balloons, drones, etc.), as well as various sensors (optical, microwave sensor, etc.) based on data.

Compared to traditional measurements, remote sensing is more efficient due to the possibility of continuous observation of the Earth's surface at different scales and databases, so it can be used appropriately for mapping the scale of water and land bodies in regional and global measurements, regularly measuring their dynamics and often several physical they provide spatial observational data of attributes. A heat map was created using Landsat images of global surface water and land changes and is shown in Figure 1. Blue light indicates where land is turning into water, green light is where water is turning into the land, and color intensity indicates the spatial extent of the change (Chang et al., 2018).

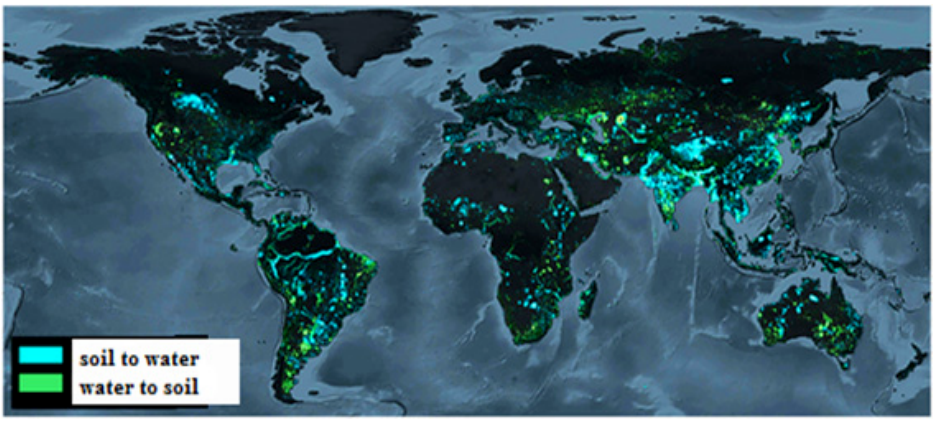

Figure 1: Heat map of global surface water and land changes

2 Comparative analysis of remote measurement systems

An important aspect of remote monitoring of the surface quality of terrestrial objects is the increase in the number of sensors with different characteristics, which allows the collection of different types of information, the possibilities of environmental monitoring applications, as well as the expansion of the main types of sensors used. Measurement systems for remote monitoring of the environment with various characteristics are presented below:

- Colorimetric, multi-optical, and hyperspectral systems;
- RADAR (radio detection and ranging) system;
- LIDAR (light detection and ranging) system.

Colorimetric, multi-optical and hyperspectral, RADAR and LIDAR, etc. type systems are considered bases for monitoring the quality of the surface of terrestrial objects based on remote measurements, and these systems allow obtaining and collecting relevant data in the visible and near-infrared spectral ranges and short waves of the electromagnetic spectrum, and at this time, the Sun is mainly used as an energy source, which is active is considered a sensor, is based on the principle of passive measurement, has the main energy sources used in this type of imaging, which can only collect images during the day, and thus can collect data at night, records energy in the microwave range, and can acquire data regardless of meteorological conditions, but suffers from some difficulties in certain weather conditions, mainly unable to collect images in cloudy weather.

Since the main energy source used in the colorimetric, multispectral, and hyperspectral systems from the mentioned systems is the sun, they are based on the passive measurement method and can obtain information only during the day, and the correct operation of the process and obtaining information with high accuracy depends on the weather conditions, if the weather conditions are bad (for example, the weather is rainy, cloudy, etc.), it is difficult to obtain accurate, correct, error-free information (Khalilova, 2019).

RADAR-type systems, regardless of day or night, record the energy radiated by objects on the Earth's surface and can receive information, in fact, by sending and receiving pulses of active microwave energy, they can measure the distance from the Earth's surface, comparing the received signal with the transmitted signal and as a result of such comparative imaging, radar detects frequency changes that are the basis of capabilities not possible with other sensors, as well as radar systems, active illuminations can penetrate clouds, fog, and smoke by microwaves, regardless of light conditions and weather conditions. Radar, environmental monitoring (◦ Vegetation mapping o Monitoring of vegetation regrowth, tree productivity; ◦ Flood detection, flood mapping; ◦ Environmental damage assessment of vegetation), hydrology (◦ Soil moisture and vegetation water content monitoring; ◦ Snow cover and humidity maps; ◦ Measurement of precipitation rates in tropical storms) and oceanography (◦ Monitoring of ship traffic and routing; ◦ Detection of oil slicks (natural and artificial); ◦ Measurement of surface current speed; ◦ Monitoring of sea ice type and icebreaker guidance) widely used.

LIDAR is considered a system based on the principle of active measurement, and since it has its energy sources, it records the signal from the object in the microwave range day and night, it can receive information and determine the shape of the Earth's surface, its natural and man-made features, regardless of meteorological conditions.

The first and simplest LIDAR system collects a profile of almost equal points along the sensor path, while the second LIDAR technology collects samples in a range, transmitting its pulse from a rare point, effectively collecting a "cloud" of data points, as well as complex geomorphological LIDAR data, map products can be combined with GIS data and other survey data to create building descriptions, advanced 3D modeling/earthworks, and other high-quality mapping products (Labutina et al., 2011).

Several application examples characterize terrestrial objects based on the results of remote sensing:

- Monitoring of quantitative and qualitative aspects of vegetation;
- Water quality monitoring;
- Monitoring of erosion processes.
- Fire monitoring;
- Monitoring of sources of thermal pollution of water bodies;
- Biomass and forest carbon monitoring;
- Monitoring of mass movement, etc.

Regarding the technological trends in the field of information storage and processing, we can highlight the availability of large collections of satellite images in cloud storage and processing services such as Amazon Earth on AWS and Google Earth Engine on Google.

The advantages of monitoring solutions based on this type of technology include the ease of manipulating large amounts of data without the need to transfer files, the ability to process using cloud computing power, and the ability to develop algorithms using widely used deep learning (such as PyTorch and Tensorflow) and machine learning platforms (Bekirova et al., 2012).

From this point of view, cloud computing and storage technologies, etc., are used to obtain accurate information that allows the assessment of problems from both social and ecological aspects in the solution of monitoring and management of land resources, vegetation cover of natural areas, and water basins obtained based on remote measurements. The development of innovative techniques, technology, and software solutions is an urgent issue.

3 Influence of environmental factors on surface quality of terrestrial objects

Climatic factors, external environmental factors, including air temperature, sunlight radiation, air humidity, different forms of precipitation (rain, snow, etc.), wind speed, and direction, are undoubtedly important, and the influence of these factors varies with seasons and intra-seasonal variability, and each of these affects the surface quality of terrestrial objects in different ways.

An increase in wind speed can affect the surface of a terrestrial object in several ways, i.e. wind carries liquid and solid particles from the air to the surface of the object, where they cause internal erosion, leading to erosion of the surface of the object.

Solar radiation causes temperature changes on the surface of objects and can cause changes in the quality of the surface of the object in the pores due to the expansion of water heated by solar radiation. About 10% of the total energy impinging on the surface of a terrestrial object is ultraviolet radiation (UV), 45% is visible light, and 45% is IR radiation. Visible and UV radiation induces the formation of free radicals in wood, and oxidation of these radicals leads to the formation of oxidation products or radical decay with the production of low molecular weight products.

As a result of the increase in ambient temperature, the rate of moisture deposition in tropical and subtropical regions is higher than in temperate regions, and higher ambient temperatures reduce the effects of freeze-thaw cycles.

Elevated ambient temperatures in a contaminated environment can accelerate material damage due to increased rates of chemical reactions on the object's surface, while low ambient temperatures increase the chance of damage. If the object's surface temperature falls below the dew point, a layer of condensation will form on the surface, and if contaminants are present, this will accelerate deterioration.

The formation of a moisture layer on the surface of an object depends on precipitation, which can be caused by the reaction of adsorbed water with the surface of the object, particles deposited on the surface of the object, and particles precipitated by reactive gases. When condensation occurs on the surface of the object, both gas, and particle flow increase, and when evaporation occurs, it decreases (Moncmanova, 2007).

4 Problem solution and material

Given the increasing availability of remote sensing technologies, Big Data, Cloud computing (cloud computing and computer vision services), Machine Learning (machine learning), as well as remote sensing information (for example, SpaceNet, CleanSeaNet services), all problems arising on the Earth's surface, water and all pollution on the soil surface can be reduced. Due to the miniaturization of sensor technology, intelligent and innovative technology, modern measurement methods and tools, and advances in unmanned aerial vehicles (UAV) technology, the development of real-time remote monitoring of UAV surface quality, contamination detection systems is inevitable, and the development of remote sensing and computational simulation technologies is complex allows for the collection and creation of mass information at different Spatio-temporal scales every second for the monitoring, understanding, and presentation of earth systems (Rami et al., 2020).

Big Data has emerged in the last few years as a new paradigm that provides a wealth of information and capabilities to improve and provide research and decision-making of unprecedented value for digital location applications, including business, science, and engineering. present challenges to store, transport, process, host and serve them, while cloud computing provides fundamental support for solving problems related to shared computing resources, including computing, storage, networking, and analytics software.

For the geospatial field, Big Data has become a broader concept than simple information that integrates technology and manpower, and the focus is on geographic aspects of big data from social networks, earth observation, sensor observation service, cyber infrastructure, social networks, and business, that is, social and business data specific geographical and with temporal traces (i.e. Spatio-temporal data) are generated faster (Chaowei et al., 2016).

The use of advanced remote sensing technologies allows high-dimensional multi-resolution Big Data to be easily accessible to researchers and to obtain information about the Earth's surface from satellite images with different spectral, spatial, and temporal resolutions (for example, using only topography), so that which is only drone cameras that can extract geographic data, land cover, lithology, etc. used to create interpretive maps that facilitate critical tasks and applications such as surface observation and remote monitoring. Large amounts of remote sensing data are currently classified as big data.

From our research, we conclude that despite the trend towards deep learning, less sophisticated ML (machine learning) can still work in a wide range of applications. Data about the Earth's surface and human activity can be obtained through remote sensing methods, allowing analysts to detect problems before they occur allows doing. This trend makes it possible to effectively use Big Data in remote sensing, analysis, and model them, but the main problem is which algorithm to apply and which variables/features to choose based on objectivity and bias when working with Big Data (Kalantar et al., 2020).

Intelligent data analysis allows for a complex approach to information in various fields and the correct analysis of interacting sources and prompt solutions to problems. The proposed intelligent system allows to identify and solve the problem by using the electronic digital map of the research area and with the appropriate algorithmic and software solution, using different quality sensors made of different types of sensors, and such systems are used to predict the state of the research object and track it in space-time, it allows using Big Data usefully. The creation of a digital intelligent system for monitoring the environment brings to the fore the activities of the areas that directly and indirectly affect the ecological system. One of the important issues is the selection of appropriate software and technical tools that collect and exchange information from the environment and build a functional-structural model based on them.

The innovative system is based on the Big Data database obtained by various sensors in real-time and allows to create of predictive and characteristic models related to the diagnosis of research objects, as well as to make operational decisions and differentially evaluate the sources of environmental factors affecting them, thus it uses machine learning uses, but the research object allows to create an intelligent monitoring system based on deep learning remote monitoring of vegetation conditions by evaluating NDVI to organize an innovative ecosystem can also yield positive results.

For example, to automatically determine the location of the soil and vegetation of the research area and monitor its condition, spectral work intervals are selected according to the type of the research area, and preliminary information about the object is recorded based on additional and auxiliary data, and measurements are obtained according to the type of the research area and based on the intelligent algorithms proposed in the existing database, it is done with appropriate sub-scaling, classification, and analysis of the machine learning (ML) subject area.

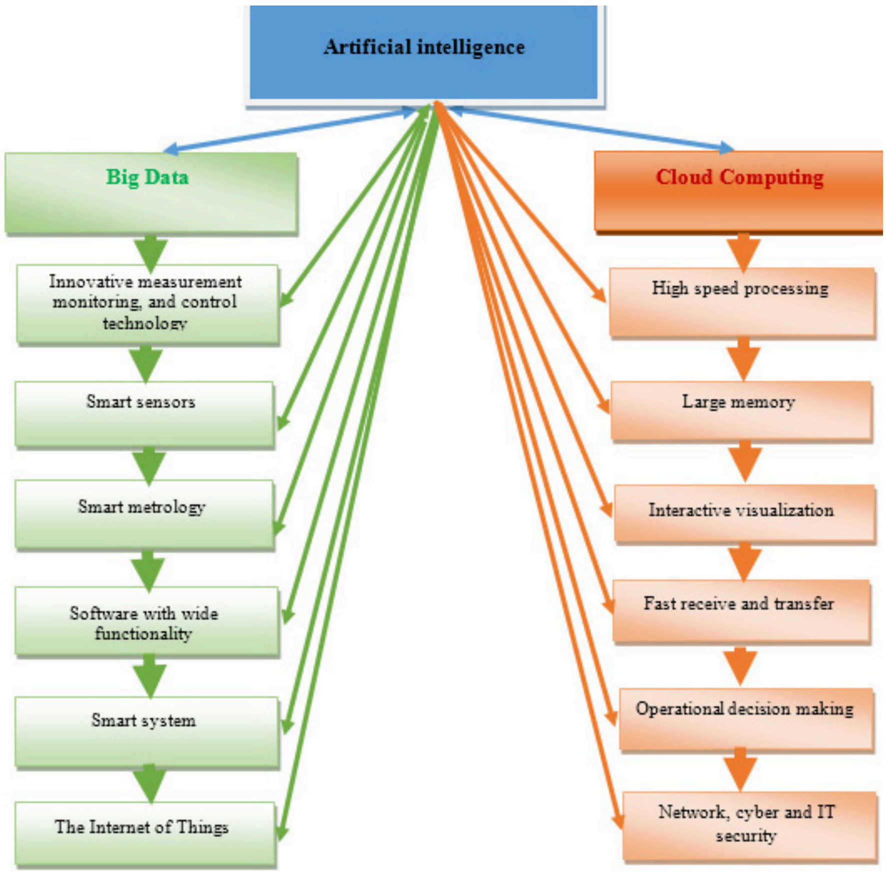

Figure 2: Structural scheme of innovative technology, and software for innovative ecosystems

At this time, recently widely used Support Vector Machine, Decision Trees, Random Forest and Artificial Neural Networks, etc. are used for classification and monitoring of machine learning (ML) algorithms, it is possible to use supervised learning algorithms (Kalantar et al., 2020; Bekirova, 2017).

The structural scheme of innovative technology and software for innovative ecosystems is shown in Figure 2.

5 Conclusion

The structure of an automated system was developed to control the processes and assess the environmental condition of the relevant relief areas, which allows for remote monitoring of the condition of the studied surface at the same time as controlling the main production processes for a comprehensive solution to the problem.

From the aspects of sources, problems, technology status, and research opportunities, cloud computing, and Big Data enable scientific discoveries and applied developments, cloud computing provides key solutions for Big Data, Big Data, Spatio-temporal thinking and various application fields are the new development of cloud computing and related technologies prompts progress with requirements, Big Data and geospatial principles internal Spatio-temporal principles to optimize technical and cloud computing and Big Data processing, Big Data's open access, and processability create significant social challenges in a geospatial and innovative field, and the innovative touch of Big Data in geographic as research, engineering, and commercial value.

Modern innovative technologies will allow the assessment of the vegetation and soil cover of the environment, the response of natural and artificial water bodies to natural and anthropogenic influences, the changes occurring in them, the correct direction and sequence of restoration work in these areas, and the remote control of the surface quality of terrestrial objects.

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