AP22788508. Development of Methodological Approaches for Monitoring Critical Hydraulic Infrastructure in Kazakhstan Using UAVs and Remote Sensing. sc. sp. – Nizametdinov N.F.

Relevance

Hydraulic structures are critical infrastructure facilities, the violation of the integrity of which has the potential to cause serious catastrophic consequences. These accidents can cause significant damage to the population, industrial enterprises, agriculture and existing infrastructure, which in turn negatively affects the country's economy. Thus, it is necessary to focus on preventing accidents and reducing their negative consequences, given the high importance of hydraulic structures.

In 2014-2015, dam failures on reservoirs in the Karaganda region led to the flooding of residential buildings and territories, loss of life, harm to the health of local residents, the environment and agricultural facilities. From 2009 to 2023, there were more than 13 significant cases of dam failures around the world, which were accompanied by a significant number of victims.

Consequently, the scale and relevance of this problem extends beyond the regional level and has an impact on the global context. Currently, special attention is paid to the state of hydraulic structures and water resources in the Republic of Kazakhstan, in connection with which the National Projects “Technological Breakthrough through Digitalization, Science and Innovation” and “Green Kazakhstan” note the priority of digitalization of hydraulic structures for effective management and coordination of their activities.

Monitoring with the use of unmanned aerial vehicles (UAVs) and Earth remote sensing (ERS) data is a cost-effective solution that has no negative impact on the environment and human health, while providing extensive information about the object under study with a high degree of detail in the shortest possible time.

Using the radar interferometry method will provide an area-based, time-differentiated representation of the distribution of vertical displacement values at any point in the area under study and at any point in time preceding the actual date of the survey. Space radar surveys are performed in the ultra-short-wave (ultra-high-frequency) region of radio waves, subdivided into X-, C-, S-, L- and P-bands. For the tasks of monitoring the displacements of the earth's surface, critical objects for each specific territory, data will be selected in one or more of these ranges based on the type of relief, type of vegetation, expected displacement values, etc.

The Gaofen-3 spacecraft is a low-orbit satellite of China that receives in the C-band with resolution of up to 1 m. GF-3 is capable of performing twelve-mode radar survey of the entire earth's surface 24 hours a day, regardless of weather conditions.

The use of high-resolution orthophotoplans and a highly detailed point cloud allows solving engineering-geological and mine surveying-geodetic problems in a complex. High-resolution orthophotoplans provide accurate and prompt identification of deformation zones in embankments, as well as analysis of the nature and mechanisms of their deformation. The use of drones equipped with a high-resolution thermal imaging sensor allows identifying water leaks and cracks.

Expected and achieved results

It is proposed to develop methodological approaches for the systematic monitoring of the current state of hydraulic structures using the example of studying the Sherubay-Nura reservoir. In the process of monitoring, advanced means of collecting high-precision geospatial data, such as unmanned aerial vehicles (UAVs) and Earth remote sensing (ERS) materials, will be used.

Using innovative data analysis methods and advanced computational methods, including machine learning and artificial intelligence, forecasting of possible geomechanical processes that may affect the state of hydraulic structures will be carried out. Based on the results of monitoring and data analysis, recommendations will be developed aimed at improving the level of safety,

reliability and uninterrupted operation of critical infrastructure facilities. The developed methodological approaches will reduce the likelihood of catastrophic consequences that can cause damage to enterprises, the population, the environment and agricultural facilities.

The scientific novelty of the project lies in the development of a unique system of digital monitoring of the surface of hydraulic structures, dams and embankments. With the development of information and communication technologies, including such powerful tools as intelligent data analysis (Data Mining), methods of storing and processing big data (Big Data), deep learning (Deep learning), blockchain (Blockchain), the Internet of Things (IoT), analytics of end devices (Edge Analytics), electronic identification of a person (e-ID), Web-scalable IT environments (Web-Scale IT), hybrid clouds (Hybrid cloud), geographic information systems, geospatial data analysis, as well as with the advent of UAVs and the possibility of obtaining satellite data, there have opened up new opportunities for monitoring critical infrastructure facilities in the Republic of Kazakhstan.

Figure 1 – 3D model of the earth dam of the Sherubay-Nura reservoir

Figure 2 – Carrying out high-precision leveling of an earthen dam

Figure 3 – PowerRay underwater drone

Figure 4 – Wingtra One unmanned aerial vehicle

List of publications for the period of 2020-2024

1. Igemberlina M.B., Nizametdinov N.F., Zhunussova G.E., Rakhimov G. Design of a geodynamic test site for geodetic monitoring of the earth's surface displacement. Mining Journal of Kazakhstan, 2023 No. 1, P 24-30 http://surl.li/omidn

2. Nizametdinov N.F., Nizametdinov F.K., Nizametdinov R.F. Monitoring the state of backfilled ore masses at a heap leaching site. Proceedings of the IX International Conference on Geomechanics, Varna, 2020, P. 91-97

3. Nizametdinov N.F., Baryshnikov V.D., Nizametdinov R.F., Studying the process of earth's surface displacement during the repeated development of the Zhezkazgan deposit. Physical and technical problems of mineral development journal, Novosibirsk: Publishing house RAS SB, 2021, No. 2, pp. 11-17.

4. Nizametdinov N.F., Nizametdinov F.K., Yestayeva A.R. GPS for wife satellitetik zhuyeler, pozitonirley tehnologiyalara: Tutorial, Karaganda: KSTU, 2021. 60 p.

5. Nizametdinov N.F., Nizametdinov F.K., Elimanov D.K., Igemberlina M.B. System of automated monitoring of the condition of bulk dams of tailings of processing plants. Mining Journal, Moscow, 2023, No. 2, pp. 63-67.

As part of the project, an application for a patent of the Republic of Kazakhstan was submitted (Nizametdinov Nail Faritovich, Ozhigin Dmitry Sergeyevich, Grossul Pavel Pavlovich, Kazantseva Victoria Vladimirovna, Kossarev Nikolay Sergeyevich, Yartseva Vera Faridovna, Baigali Ruslan Kanatuly, Satbergenova Assel Kuandykovna, Kubaidullina Ulpan Aitkuzhiyevna No. 2024/0806.1 dated 10/02/2024).

Research team

1. Nizametdinov Nail Faritovich – PhD, Acting Associate Professor of the MS&G Department
ORCID - 0000-0002-8881-1259
Scopus ID 57191986266

2. Ozhigin Dmitry Sergeyevich – PhD, Acting Associate Professor of the MS&G Department
ORCID - 0000-0002-2443-3068
Scopus ID 55827717400

3. Kossarev Nikolay Sergeyevich, PhD, Associate Professor of the Higher Attestation Commission, Researcher of the Research Institute of Geodesy, Topography and Cartography. Czech Republic
ORCID - 0000-0003-1806-3651
Scopus ID 57226373393

4. Satbergenova Assel Kuandykovna – M.Sc., senior lecturer, doctoral student in the Geodesy specialty of the the MS&G Department
ORCID - 0000-0001-5806-2827
Scopus ID 5720941133

5. Yartseva Vera Faridovna – M.Art. lecturer, PhD candidate in the Mining specialty
ORCID - 0000-0003-3015-0280

6. Kazantseva Victoria Vladimirovna – M.Eng, lecturer, PhD candidate in the Geodesy specialty
ORCID - 0000-0002-5915-1677

7. Kubaydullina Ulpan Aitkuzhiyevna – M.Eng, lecturer, PhD candidate in the Mine surveying specialty
ORCID - 0000-0002-2445-5590

8. Baygali Ruslan Kanatuly – M.Eng, lecturer, PhD candidate in the Mine surveying specialty
ORCID - 0000-0003-4431-2172

Information for potential consumers

Based on the studies conducted in subsequent years of the project implementation, a mathematical model will be developed for predicting probable manifestations of geomechanical processes based on multi-temporal digital models of the studied object using machine learning and artificial intelligence methods, which will allow combining two or more series of measurements performed by UAVs and the remote sensing method to identify hazardous areas characterized by a high probability of deformation processes.

Scope

Hydraulic structures

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