ABSTRACT

of the dissertation work Omarova Perizat Tanirberdievna
on the topic: **"Development of sediment transport model for pollution and silting in river channels based on data driven approaches and remote sensing data",** submitted for the degree of PhD in the specialty "6D075100 – Computer science, computer technology and management"

Relevance of the research topic. Water is a vital resource that requires careful management and conservation, especially in the context of climate change and growing human settlements. Dams play a central role in the control and distribution of water resources, although they carry risks including potential flooding and environmental degradation. Dam safety issues remain at the forefront, requiring not only proper maintenance and upgrades, but also accurate monitoring to prevent failures.

Modern monitoring systems use advanced machine learning techniques to analyze data, enabling early detection of potential anomalies. These systems use both traditional statistical approaches and newer techniques such as artificial neural networks, support vector machines, and random forests to analyze and interpret the vast amount of data generated by automated monitoring systems.

The problem of siltation in river systems is particularly pressing given the threats it poses to infrastructure and populations. Effective management of silted rivers requires complex hydrodynamic studies. Laboratory experiments and numerical simulations serve as important tools in this research, although actual experiments and observations are often limited due to their high cost and difficulty in performing them.

The development of computer vision and natural language processing has increased the role of artificial neural networks in analyzing and predicting the behavior of dams and river systems. Physics-based neural networks such as PINN provide an innovative approach to modeling without the need for large amounts of experimental data. PINNs are attractive because of their ability to learn from generated samples, making them ideal for problems where data is limited.

This study uses PINNs to analyze water velocity, pressure, and density parameters to improve the prediction of river channel siltation. A comparison of results obtained using PINN and traditional numerical simulations in Ansys demonstrates the advantages of the new method, including faster calculations and improved forecast accuracy.

Purpose of the thesis: The development of sediment transport models for predicting pollution and siltation of river channels is based on solving physical problems using numerical modeling. Neural networks and remote sensing data are used to speed up the process of obtaining forecast results.

Research tasks:

1. Collection of data, including topographic parameters of study sites, meteorological characteristics and geological information;
2. Based on remote sensing data and field measurements, it is necessary to develop a three-dimensional numerical model of the research object, taking into account the complex topography of the Syrdarya River and other geometric parameters;
3. Construction of data models for predicting pollution and siltation in river channels and river beds based on preprocessing of remote sensing data taking into account field data;
4. Building models and conducting numerical calculations of siltation and pollution, as well as sediment transport in river channels and river beds using ANSYS;
5. Building a PINN model and conducting computational experiments to predict siltation and pollution of river channels and river beds;
6. Comparative analysis and evaluation of the results of computational experiments on models of pollution, siltation and sediment transport on river channels and river beds.

Object of research: The research area is the Syrdarya River in the area of the Shardara reservoir. The Shardara reservoir is a system of cascade reservoirs, and the lower, flat part of the Syrdarya River basin consists of loess-like sandy loam (composition of clay and sand) and loam (soil type: a mixture of sand, silt, clay and soil in equal proportions). As a result, channel reservoirs completely retain the flow of suspended sediment, which forms the process of siltation. Ignoring this problem will lead to siltation of a whole cascade of reservoirs.

Subject of research: The Syrdarya River and its channels, processes of siltation and pollution, dams.

Research methods: Navier-Stokes model and numerical implementation, ANSYS, PINN, neural network technology, learning process, remote sensing methods, programming technology

Scientific novelty:

1. For the first time, numerical modeling was carried out in the area of the Syrdarya River, taking into account real terrain parameters in order to predict pollution and flooding of river channels.
2. Fine-tuning of PINN (Physics-Informed Neural Networks) neural networks was carried out to solve Navier-Stokes problems in the applied problem of identifying siltation in river channels, allowing to reduce calculation time in comparison with traditional numerical methods.

Theoretical and practical importance. The study contributes to the development of predictive methods based on mining and remote sensing data to predict pollution and siltation of river channels. These methods improve the management of water systems and prevent negative impacts on the environment.

Forecasting pollution and siltation of river channels contributes to the adoption of measures to prevent and restore aquatic ecosystems. The thesis contributes to the development of sediment transport theory by proposing a model

that will take into account hydrodynamic conditions, bottom topography, and mechanical and natural influences to predict the spread of pollution and siltation in river channels.

The scientific statements are to be defended

The developed method and models for forecasting sedimentary rocks for pollution and siltation of river beds and river canals based on the neural network of the PINN architecture and numerical modeling in ANSYS make it possible to effectively identify problem areas of the objects under study; the use of the PINN method with the Navier Stokes model allows reducing the calculation time by more than 20%, compared to numerical simulation.

The level of reliability and the results of approbation

The main results of the dissertation research were published in 6 publications. Of which 3 articles in journals recommended by the Committee of Science of the Ministry of Education and Science of the Republic of Kazakhstan, 1 publication in international scientific publications included in the Web of science database and 2 publications in international conferences.

The main provisions of the dissertation are presented in 6 printed works, of which:

- 1 article in international scientific journals indexed in Web of Science with a high impact factor Q2: (Applied Sciences – miscellaneous),

Perizat Omarova, Yedilkhan Amirgaliyev, Ainur Kozbakova, Aisulyu Ataniyazova (2023). Application of Physics-Informed Neural Networks to River Silting Simulation. Applied Sciences. 13(21), 11983, https://doi.org/10.3390/app132111983 (WoS, Q2, 2022 Impact Factor: 2.7, SJR= 0.492, Percentile= 75)

3 articles in journals from the list recommended by the Committee for Control in the Sphere of Education and Science of the Ministry of Education and Science of the Republic of Kazakhstan (KKSON):

Amirgaliyev Y., Merembayev T., Omarova P., (2023), Mathematical modeling of water movement during a dam break using the vof method // Scientific Journal of Astana IT University, 14(14), 116–126. https://doi.org/10.37943/14NEBW7927.

Amirgaliev E., Merembaev T., Omarova P.T. (2023), Numerical modeling of dam break for incompressible viscous flow // KazATK Bulletin/ Automation, telemechanics, communications, computer science/ VOLUME 127 No. 4 (2023): KazATK Bulletin (project)/ https://vestnik.alt.edu.kz/index.php/journal/article/view/1335

Amirgaliev E., Merembaev T., Omarova P.T. (2023), Numerical modeling of the process of pollution of river channels and siltation of rivers // Vestnik KazATK / Automation, telemechanics, communications, computer science / Volume 128 No. 5 (2023): Vestnik KazATK (project) https://vestnik.alt.edu.kz/index.php/journal/article/view/1416

2 articles in materials of international and republican conferences and reports at scientific seminars:

Vladislav Rudakov, Timur Merembayev, Yedilkhan Amirgaliyev, Perizat

Omarova. Time Series Analysis of Biogas Monitoring with Deep Learning Approaches // 5th International Conference on Problems of Cybernetics and Informatics (PCI 2023), Baku, Azerbaijan. August 28-30, 2023

Yedilkhan Amirgaliyev, Beibut Amirgaliyev, Perizat Omarova. Methods of data mining and their industrial applications. // 5th International Conference on Problems of Cybernetics and Informatics (PCI 2023), Baku, Azerbaijan. August 28-30, 2023

1 monograph:

Omarova P.T., (2023), Mathematical modeling for forecasting environmental processes. Monograph // "Daryn" baspasy, ISBN 978-601-269-397-3, Almaty, IIVT KN MES RK, 2023, – 152 pages.

Personal contribution of the researcher. The applicant demonstrates a high level of scientific independence and exceptional independence, successfully solving key research problems. The author's contribution to the dissertation is confirmed by original results obtained personally by the researcher. The conceptual basis of the study and scientific methodology were developed in collaboration with a respected domestic scientist, Doctor of Physical and Mathematical Sciences, Professor E. Amirgaliev, and an honored foreign specialist, Professor Waldemar Wójcik from the Technical University of Lublin in Poland, which emphasizes the integration of the international scientific community and contribution to world science.

The author's work constituted a significant part of the entire research process, including the development of theoretical principles, collection and analysis of data, conducting experiments and modeling. It is noted that the researcher's personal participation in the project reaches 90%, which indicates the depth of knowledge, originality of approaches and direct contribution to the achievement of scientific results presented in the dissertation.

Scope and structure of the work. The dissertation consists from introduction, four sections, conclusion and bibliography. Total volume of the dissertation: 112 pages written text, V volume number 57 drawing, 10 tables, list literature out of 69 sources, 5 applications.

In the introduction of the dissertation by Omarova P.T. the relevance of the topic of work is substantiated, which is closely related to the problems of monitoring and analyzing the condition of engineering structures that are important for ensuring safety under conditions of man-made and natural influences. The goals, object, and subject of the research are determined taking into account modern requirements for monitoring systems; the research results demonstrate the scientific novelty and practical significance of the developments.

The first section of the dissertation analyzes in detail methods and approaches to diagnosing potentially emergency conditions of dams and other hydraulic structures. The object of study is described, including equipment for data collection and visualization in interactive graphs, which allows you to assess the current state and dynamics of changes.

The second section focuses on a new class of differential equation models, including a formal definition of time series and a review of existing forecasting

models. Both classical approaches and the latest developments in this area are discussed in detail, including models taking into account the nonlinear dynamics of processes.

The third section introduces the basics of differential equations underlying neural network PDEs. The use of mathematical apparatus for parameterizing neural networks and approximating PDE solutions is described, which provides flexible opportunities for modeling the dynamics of processes.

The fourth section covers the full cycle of development and implementation of a monitoring system, starting from digitalization of structures to data visualization. Open software solutions are presented at each stage of working with data. It is demonstrated that the proposed PDE-based model works effectively on irregular and noisy time series, providing better analysis and prediction capabilities compared to traditional methods.

In the final part the main achieved results of the study are outlined, conclusions on the dissertation are drawn, and directions for future research in this area are outlined **.**