ANNOTATION
of the dissertation work of Alpar Sultan Duisenuly on the topic: "Development of Machine Learning for Finding a Complex of Thermophysical Parameters of a Heterogeneous Medium", submitted for the degree of Doctor of Philosophy (PhD) on the «8D06105 – Data Science» educational program.

General description of work. This paper presents a detailed and developed machine learning method for determining the nonlinear thermal characteristics of the soil. Two-chamber container complexes are constructed. Which side faces are thermally insulated, so that a one-dimensional heat equation can be used. In order not to solve the boundary value problem with a contact discontinuity and not to lose the accuracy of the solution method, a temperature sensor was placed at the junction of two media, and a mixed boundary value problem was solved in each region of the boundary medium.

The relevance of research. The thermophysical characteristics of the soil play a major role in the modeling of processes on the earth's surface due to the large influence on a wide range of chemical, physical and biological processes of energy distribution in many soil laysers. Thermophysical properties determine the movement of heat in soils and influence the distribution of energy in the soil profile. Knowledge of these quantities is critical in various branches of engineering, environmental and geosciences and, most importantly, for influencing the energy balance. Due to the fact that the vast majority of processes occurring in nature are non-linear. Accounting for nonlinearity greatly complicates the mathematical formulation of the problem.

The purpose of the dissertation work: The purpose of this work is development of machine algorithm and conduction of experimental work for determining the thermophysical properties of two different types of soils: sand and chernozem using the machine learning method.

The following **research objectives** were set:

- study of the influence of temperature on the thermophysical parameters of the soil;
- carrying out numerical calculations of the nonlinear problem of heat conduction;
- study of sensitivity and identifiability coefficients for heat transfer problems;
- development of a machine learning method for calculating all thermophysical parameters of a heterogeneous soil: thermal conductivity coefficient, heat capacity, density and heat transfer using experimental data;

- development of an algorithm for the damping factor or speed/rate of learning of the machine learning optimization algorithm;
- writing a software package for the calculation of all thermophysical parameters of soil and soil;
- carrying out experimental work: creation of an experimental setup for measuring the temperature of heterogeneous soil;

Object of study. The object of research is the coefficient inverse problem of thermal conductivity, described by a system of differential equations with partial derivatives and the effect of temperature on the thermophysical characteristics of the soil.

Subject of study. The subject of the study is the thermophysical characteristics of the soil.

Research methods. Newton's method was applied to solve the nonlinear direct problem of heat transfer. The finite difference method is used to discretize partial differential equations. To solve the inverse coefficient problem, a machine learning method using regularization is used. To analyze the identifiability, the matrix correlation method is used. For the implementation of algorithms, computational work and obtaining graphs, a program code was written from scratch using the Python language. To obtain real soil-ground temperature data, a two-chamber setup was designed and a physical experiment was carried out.

Scientific novelty of the work:

- study of the influence of temperature on all thermophysical parameters of the soil;
- development of a method for calculating all thermophysical parameters of heterogeneous soil: thermal conductivity coefficient, heat capacity, density and heat transfer using experimental data;
- development of an algorithm for calculating the learning rate coefficient;
- development of an algorithm and implementation of a software package for calculating all thermophysical characteristics of an inhomogeneous medium;
- creation of an experimental setup for measuring the temperature of heterogeneous soil and soil;

Scientific provisions submitted for defense:

- developed method for calculating all thermophysical parameters of heterogeneous soil;
- developed algorithm for calculating the learning rate coefficient;
- developed algorithm and program for calculating the thermophysical characteristics of the soil;
- analysis of the identifiability of the thermophysical coefficients of the soil;

- study of the influence of temperature on the thermophysical parameters of the soil;
- experimental setup for measuring the temperature of heterogeneous soil;

The reliability and validity of the scientific provisions, conclusions and results of the dissertation work is confirmed by the use of a nonlinear heat transfer problem based on partial differential equations, which are based on the energy conservation law, the consequence of which is the heat conduction equation, comparison and analysis of the obtained numerical results with experimental data.

Theoretical and practical significance of the research. The theoretical significance of the work lies in the development and construction in the development of optimization methods and algorithms for machine learning, numerical methods for solving nonlinear, coefficient, inverse and ill-posed heat transfer problems, in the development of methods and algorithms for calculating the learning rate coefficient for machine learning methods.

The practical significance of the dissertation research lies in the use of the results of this work in an accurate prediction of the values of all thermophysical characteristics of a heterogeneous soil and soil and experimental setup application in engineering problems of soil science, agronomy and agrophysics, building physics.

Communication of this work with other research works. The dissertation research was carried out under the grant funding program of the Ministry of Science and Higher Education of the Republic of Kazakhstan:

- "Development of machine learning methods and iterative methods for finding a complex of thermophysical parameters of an inhomogeneous medium, creation of a program complex" (2020–2022, No. AP08855955).

Approbation of work. The main results of the work were presented and reported at the following scientific events:

- Traditional international April mathematical conference, in honor of the Day of Science Workers of the Republic of Kazakhstan, dedicated to the 75th anniversary of Academician of the National Academy of Sciences of the Republic of Kazakhstan Kalmenov Tynysbek Sharipovich, April 5–8, 2021.
- Eurasian Conference on Applied Mathematics, December 16–22, 2021, Novosibirsk, Akademgorodok, Russia.
- 2nd International Symposium on Automation, Information and Computing (ISAIC 2021) 03/12/2021 - 06/12/2021, Beijing Jiaotong University, China.
- Copyright certificate, Certificate of Copyright No EC-02-211210KZ, International Depository of Copyright Works, December 10, 2021.

Publications. On the topic of the dissertation, 7 works were published, including 3 publications in scientific journals included in the list recommended by the

Committee for Quality Assurance in the Field of Science and Higher Education of the Ministry of Science and Higher Education of the Republic of Kazakhstan for the publication of the main results of scientific activity; the ranking scientific publication indexed by Scopus and Thomson Reuters is 1, with an impact factor of 4.0, citescore 7.9, SJR 0.96 and percentile 95; 3 publications in the proceedings of international conferences, including 2 publications in the proceedings of foreign conferences.

Structure and scope of work. The dissertation consists of a title page, contents, symbols and abbreviations, introduction, six sections, conclusion, and a list of 120 sources used. The total volume of the dissertation is 86 pages, including 9 illustrations and 4 tables.