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Content

Altayeva A.B. Study of Smart City Platform Based on OneM2M standards	7
Asanov A. A CLASS OF SYSTEMS OF LINEAR FREDHOLM INTEGRAL EQUATIONS OF THE THIRD KIND WITH MULTIPOINT SINGULARITIES IN THE AXIS	8
Sholpanbaev B.B, Dairbaeva L.M, Askarova Z.B THE PROBLEM OF CONTINUATION OF THE ELECTROMAGNETIC FIELD TO A GIVEN DEPTH	9
Bektemessov A.T., Kuvatbayeva A.A. USING OF MODEL CHECKING FOR COMBINING TASKS	10
Kabanikhin S.I., Bektemessov M. A., Shishlenin M. A., Yang XS., Bektemessov Z. M. PARAMETER ESTIMATION IN ECONOMIC MATHEMATICAL MODELS USING DIFFERENTIAL EVOLUTION ALGORITHM	11
Gorbunov V.K., Lvov A.G. THE PRODUCTION FUNCTION CONSTRUCTION WITH THE EFFECTIVE PRODUCTION FUNDS ESTIMATION	12
Kabanikhin S. I., Novikov N. S., Shishlenin M. A. DIRECT LINEAR SEISMIC DATA PROCESSING	13
Kabanikhin S. I., Shishlenin M. A. CONTINUATION PROBLEMS IN GEOPHYSICS	14
Shishlenin M.A., Kasenov S.E., Askerbekova Zh.A. ALGORITHM FOR SOLVING THE INVERSE PROBLEM FOR THE HELMHOLTZ EQUATION	15
Kenzhebaeva M.O. THE RESTORATION OF THE DENSITY OF A HOMOGENEOUS ANOMALY FROM THE MEASUREMENT OF THE GRAVITATIONAL POTENTIAL AND ITS DERIVATIVE ON THE EARTH'S SURFACE	16

Kirillov E.V. DIRECT SPECTRAL PROBLEM FOR ONE MATHEMATICAL MODEL OF HYDRODYNAMICS	17
Klyuchinsky D. V., Shishlenin M. A. NUMERICAL METHODS FOR THE SOLUTION OF THE CONTINUATION PROBLEM OF A PARABOLIC EQUATION	18
Klyuchinskiy D.V., Godunov S.K. AN EXPERIMENTAL INVESTIGATION OF DISCONTINUOUS SOLUTIONS OF A NEW FINITE-DIFFERENCE MODEL OF FLUID DYNAMICS WITH ENTROPY NONDECREASING	19
Kondakova E.A., Krivorotko O.I., Kabanikhin S.I. INVERSE PROBLEMS IN FINANCIAL ECONOMICS: OVERVIEW AND ALGORITHMS	20
Kozhabekova A.S. THE MODEL OF APPLICATIONS PROCESSING FOR OPTIMAL DELIVERY OF GOODS TO CUSTOMERS IN E-COMMERCE SYSTEM	21
Kultaev T.Ch. OPTIMIZATION OF DISTRICTS PURCHASE OF RAW MATERIALS AND THE VOLUME OF PROCESSED PRODUCTS	22
Latyshenko V.A., Krivorotko O.I., Kabanikhin S.I. Identifiability of parameters of mathematical models in the field of biology	23
Leonov A.S. OPTIMAL AND EXTRA-OPTIMAL METHODS FOR SOLVING ILL-POSED OPTIMIZATION PROBLEMS	24
Mamatkasymova A.T. NUMERICAL SOLUTION OF THE DIRECT AND INVERSE PROBLEM OF THE MAXWELL EQUATION WITH INSTANTANEOUS AND LACE SOURCES	25
Matanova K.B. ON INVERSE PROBLEM FOR A PSEUDOPARABOLIC THIRD ORDER INTEGRO- DIFFERENTIAL EQUATION WITH VARIABLE COEFFICIENTS	26
Mukhambetzhano S.T., Abdiakhmetova Z.M., Shazhdekeeva N.K. ON THE DIRECT AND INVERSE PROBLEM OF THE THEORY OF FILTRATION ON SPECIFICATION OF TECHNOLOGICAL INDICATORS	27
Novikov N.S. NUMERICAL SIMULATION OF TWO-DIMENSIONAL ACOUSTIC TOMOGRAPHY	28
Prikhodko A. Yu., Shishlenin M. A. INVERSE PROBLEMS IN THE SOFTWARE DEVELOPMENT OF THE DIGITAL SMART OIL AND GAS FIELD	29

Prikhodko A. Yu., Shishlenin M. A. INVERSE PROBLEMS IN MATHEMATICAL MODELS OF CATALYTIC REACTORS	30
Rysbaiuly B., Satybaldina A.N. MATHEMATICAL MODELING OF THE MOLECULAR DIFFUSION MODEL FOR PREDICTING WAX DEPOSITION	31
Satybaev A.D., Alimkanov A.A., Anishenko Yu.V., Kokozova A.Zh. EXISTENCE OF THE SOLUTION OF A TWO-DIMENSIONAL DIRECT PROBLEM OF WAVE PROCESSES WITH INSTANT AND CURRENT SOURCES	32
Serovajsky S., Nurseitov D., Nurseitova A., Azimov A. POSSIBILITIES OF DETERMINATION PARAMETERS OF THE GRAVITATIONAL ANOMALY ACCORDING TO THE RESULTS OF MEASURING THE GRAVITATIONAL FIELD ON THE EARTH SURFACE	33
Shayakhmetov N. FORMULATION OF PROBLEM OF THE OPTIMAL CHOICE OF THE WELL PATTERN FOR THE PRODUCING OF MINERALS USING IN-SITU LEACHING WITH A LIMITED VOLUME OF THE LEACHING SOLUTION	34
Shishlenin M. A. INVERSE PROBLEM FOR THE MATHEMATICAL ECONOMIC MODEL	35
Sigalovsky M.A. OPTIMIZATION METHODS FOR INCORRECT PROBLEMS WITH CONDITIONS ON THE BOUNDARY PARTS IN THE SIMPLE 2D CASE	36
Sultanov M.A., Bakanov G.B. ON THE CONVERGENCE OF SOLUTION OF THE THREE-LAYER PERTURBED DIFFERENCE SCHEME TO SOLUTION OF ILL-POSED CAUCHY PROBLEM	37
Temirbekova L.N. NUMERICAL METHOD FOR SOLVING TWO DIMENSIONAL FREDHOLM INTEGRAL EQUATIONS	38
Turarbek A.T., Begadil Z., Kozhakenov G. SEISMIC RISK ESTIMATION OF ALMATY CITY USING GIS ITRIS	39
Yermolenko D.V., Krivorotko O.I., Kabanikhin S.I. THE SOLUTION OF THE INVERSE PROBLEM OF DETERMINING PARAMETERS FOR THE MATHEMATICAL MODEL OF HIV DYNAMICS	40
Zakirova G.A., Kadchenko S.I. ABOUT ONE INVERSE PROBLEM FOR OCEANOLOGY	41
Zhumat F.S., Duisebekova K.S. THE BLOCKCHAIN HYPE: CURRENT RESEARCH STATE OF TECHNOLOGY	42

Bidaibekov Y.I., Sholpanbaev B.B., Akimzhan N.Sh.

The use of digital educational resources in teaching ill-posed system of linear algebraic equations **43**

ALGORITHM FOR SOLVING THE INVERSE PROBLEM FOR THE HELMHOLTZ EQUATION

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We consider the initial-boundary value problem for the Helmholtz equation, which is ill-posed. We reduce the solution of the operator equation $Aq = f$ to the problem of minimizing the functional $J(q) = \langle Aq - f, Aq - f \rangle$. We construct an algorithm for solving the inverse problem [1].

Algorithm for solving the inverse problem

1. We choose the initial approximation $q^0 = (q_1^0, q_2^0)$;
2. Let us assume that q_n is known, then we solve the direct problem numerically

$$\begin{aligned} u_{xx} + u_{yy} - \left(\frac{\rho_x}{\rho} u_x + \frac{\rho_y}{\rho} u_y \right) + \left(\frac{\omega}{c} \right)^2 u &= 0, & (x, y) \in \Omega, \\ u(0, y) = h_1(y), \quad u(1, y) &= q_1^n(y), & y \in [0, 1], \\ u(x, 0) = h_2(x), \quad u(x, 1) &= q_2^n(x), & x \in [0, 1]. \end{aligned}$$

3. We calculate the value of the functional

$$J(q_{n+1}) = \int_0^1 [u_x(0, y; q_1^{n+1}, q_2^{n+1}) - f_1(y)]^2 dy + \int_0^1 [u_y(x, 0; q_1^{n+1}, q_2^{n+1}) - f_2(x)]^2 dx;$$

4. If the value of the functional is not sufficiently small, then go to next step;
5. We solve the conjugate problem

$$\begin{aligned} \psi_{xx} + \psi_{yy} + \left(\frac{\rho_x}{\rho} \psi \right)_x + \left(\frac{\rho_y}{\rho} \psi \right)_y + \left(\frac{\omega}{c} \right)^2 \psi &= 0, & (x, y) \in \Omega, \\ \psi(0, y) = 2(u_x(0, y; q_1, q_2) - f_1(y)), \psi(1, y) &= 0, & y \in [0, 1], \\ \psi(x, 0) = 2(u_y(x, 0; q_1, q_2) - f_2(x)), \psi(x, 1) &= 0, & x \in [0, 1]. \end{aligned}$$

6. We calculate the gradient of the functional $J'(q^n) = (-\psi_x(1, y), -\psi_y(x, 1))$;
7. We calculate the following approximation $q^{n+1} = q^n - \alpha J'(q^n)$;

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