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AJINIYOZ NOMIDAGI NUKUS DAVLAT PEDAGOGIKA INSTITUTI

«Aniq va tabiiy fanlarni masofaviy o'qitishning dolzarb masalalari» mavzusidagi Respublika ilmiy-nazariy konferensiya

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«Aniq va tabiiy fanlarni masofaviy o'qitishning dolzarb masalalari» atamasidagi Respublika ilmiy-nazariy konferentsiya materiallari to'plamiga O'zbekiston Respublikasining oliy ta'lim muassasalari professor-o'qituvchilari, katta ilmiy xodim-izlanuvchilar, magistrantlar, talabalar, ilmiy-tadqiqot instituti olimlari, kasb-hunar va umumiy o'rta ta'lim maktabi o'qituvchilarining tezislari kiritilgan. Aniq va tabiiy fanlarining dolzarb masalalari, zamonaviy tadqiqotlar va rivojlanish kelajagi, shu jumladan aniq va tabiiy fanlarni o'qitishning metodlari va innovatsion texnologiyalariga aloqador dolzarb masalalarini, yangi ilmiy kontseptsiyalar va muammolar bo'yicha materiallar jamlangan.

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upper regularization $V*(z,K) := \lim_{w\to z} V(w,K)$ *of this function is called the Green's function of* K. *If* $V(z,K) = V*(z,K)$, *we say compact set* K *is regular.*

Let $K_t \subset \mathbb{C}^k$ be a continuous family of regular compact sets. Our aim to find a relation between continuity of compact sets and continuity of their Green functions. Let K_t be polynomial convex compact sets, i.e $K_t = \widehat{K_t} = \{z \in \mathbb{C}^k : |P(z)| \leq ||P||_{K_t}, \forall p\ polynomial\}$.

Theorem 1. *Let* $K_t \subset \mathbb{C}^k$, $t \in M$ *be regular compact set and its Green function* $V(z,K)$ *is continuous by both* (z,t) *variables. Suppose that the following conditions are hold:*

1. K_t *-is a polynomial convex;*

2. There exist strictly increasing function $u : [0;+\infty) \to [0;+\infty)$, *such that* $u(dist(z,K_t)) \leq V(z,K_t)$ *and* $u(0) = 0$. *Then* K_t *is continuous.*

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INVESTIGATION IN AN INTEGRO - DIFFERENTIAL EQUATION OF PARABOLIC TYPE WITH NONLOCAL CONDITION

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Let $T > 0$ be fixed number and $D_{Tl} = \{(x,t): 0 < x < l, 0 < t \leq T\}$. Consider the inverse problem of determining of functions $u(x,t), k(t)$ such that it satisfies the equation

$$u_t - u_{xx} = \int_0^t k(t-\tau)u(x,\tau)d\tau, (x,t) \in D_{Tl}, \qquad (1)$$

with the nonlocal initial condition

$$u(x,0)+\lambda u(x,T)+\int_0^T p(\tau)u(x,\tau)d\tau=\varphi(x), \quad x\in[0,l], \qquad (2)$$

the boundary conditions

$$u|_{x=0}=u|_{x=l}=0, \quad t\in[0,T], \qquad (3)$$

here $\lambda\geq 0$ is a given number, $\varphi(x),p(t)$ are given functions of $x\in[0,l]$ and $t\in[0,T]$.

In the problem, for given numbers l,T,λ and sufficiently smooth functions $k(t),\varphi(x)$, it required to find a function $u(x,t)\in C^{2,1}(D_T)$ satisfying nonlocal initial-boundary problem (1)-(3) for $(x,t)\in D_T$.

The solution of equation (1) with the nonlocal initial condition (2) and the boundary conditions (3) satisfies the relation

$$u(x,t)=\Phi(x,t)+\int_0^t\int_0^l G(x,\xi,t-\beta)\int_0^\beta k(\beta-\tau)u(\xi,\tau)d\tau d\xi d\beta-$$

$$-\lambda\int_0^T\int_0^l G_0(x,\xi,t+T-\beta)\int_0^\beta k(\beta-\tau)u(\xi,\tau)d\tau d\xi d\beta-$$

$$-\int_0^T\int_0^\mu\int_0^l p(\mu)G_0(x,\xi,t+\mu-\beta)\int_0^\beta k(\beta-\tau)u(\xi,\tau)d\tau d\xi d\beta d\mu, \qquad (4)$$

where

$$\Phi(x,t)=\int_0^l \varphi(\xi)G_0(x,\xi,t)d\xi,$$

$$G(x,\xi,t)=\frac{2}{l}\sum_{n=1}^\infty e^{-(\frac{\pi n}{l})^2 t}sin\frac{\pi n}{l}\xi sin\frac{\pi n}{l}x,$$

$$G_0(x,\xi,t)=\frac{2}{l(1+\lambda e^{-(\frac{\pi n}{l})^2 T}+\int_0^T p(\tau)e^{-(\frac{\pi n}{l})^2\tau}d\tau)}\sum_{n=1}^\infty e^{-(\frac{\pi n}{l})^2 t}sin\frac{\pi n}{l}\xi sin\frac{\pi n}{l}x.$$

Now we write property of Green function which will be needed in the future.

Denote the operator taking the function $u(x,t)$ to the right-hand side of (4) by A. Then (4) is written as the operator equation

$$u=Au, \qquad (5)$$

Let

$$\Phi_0=\max_{(x,t)\in\overline{D}_T}|\Phi(x,t)|, k_0=\max_{t\in[0,T]}|k(t)|, p_0=\max_{t\in[0,T]}|p(t)|,$$

let $S_d(0)=\{u:\parallel u\parallel\leq d\}$, let d be some positive number.

We use the Schauder principle to the existence of solution of the operator equation (5).

Theorem (Schauder principle)[see 3, p. 411]:*Let the operator A map a closed bounded convex set $S_d(0)$ of a Banach space X into itself. Then if A is completely continuous on $S_d(0)$, then it has a fixed point on $S_d(0)$.*

Lemma.*Suppose that the following conditions are satisfied: $\varphi(x) \in C[0,l]$, $k(t) \in C^1[0,T], \varphi(0) = \varphi(l) = 0$. Then for all T satisfying the estimate*

$$0 < T \leq T_1 \tag{6}$$

where T_1 is a positive root of the equation

$$2p_0T^3 + 3k_0d(1+\lambda)T^2 + 6(\Phi_0 - d) = 0,$$

the operator A is uniformly bounded and equicontinuous.

Then there exists a classical solution of problem (1)-(3) in the space $C^{2,1}(D_T)$.

Proof. First, we establish the uniform boundedness of the operator A. To this end, we show that there exists a $\rho \in (0,d]$ such that $\| Au \| \leq \rho$, where $\| Au \| = \max_{(x,t)\in\overline{D}_T}|Au|$. For $u \in S_d(0)$ and $(x,t) \in \overline{D}_T$, we find estimate $\| Au \| \leq \Phi_0 + k_0d(1+\alpha)\frac{T^2}{2} + p_0k_0d\frac{T^3}{3} \equiv \rho$. For T that satisfy the estimate (6), the operator A is uniformly bounded.

Definition.*An operator A is said to be equicontinuous if for each $\varepsilon > 0$ there exists a $\delta_0 = \delta_0(\varepsilon) > 0$ such that the inequality*

$$\| Au_1 - Au_2 \| \leq \varepsilon$$

holds for all $u_1, u_2 \in S_d(0)$ with $\| u_1 - u_2 \| \leq \delta_0$.

We consider the estimates

$$\| Au_1 - Au_2 \| \leq$$

$$\leq \max_{(x,t)\in\overline{D}_T} \left| \int_0^t \int_0^l G(x,\xi,t-\beta) \int_0^\beta k(\beta-\tau)(u_1(\xi,\tau) - u_2(\xi,\tau))d\tau d\xi d\beta \right| +$$

$$+ \max_{(x,t)\in\overline{D}_T} \left|\lambda \int_0^T \int_0^l G_0(x,\xi,t+T-\beta) \int_0^\beta k(\beta-\tau)\big(u_1(\xi,\tau) - u_2(\xi,\tau)\big)d\tau d\xi d\beta\right|$$

$$+ \max_{(x,t)\in\overline{D}_T} \left| \int_0^T \int_0^\mu \int_0^l p(\mu)G_0(x,\xi,t+\mu-\beta) \int_0^\beta k(\beta-\tau)(u_1(\xi,\tau) - u_2(\xi,\tau))d\tau d\xi d\beta d\mu \right| \leq (1+\lambda+p_0\tfrac{2T}{3})k_0\tfrac{T^2}{2} \| u_1 - u_2 \| \leq (1+\lambda+p_0\tfrac{2T}{3})k_0\tfrac{T^2}{2}\delta.$$

Consequently, if we take $\delta_0 = \frac{2\varepsilon}{(1+\lambda+p_0\frac{2T}{3})k_0T^2}$, then inequality (6) will hold for $\delta \in (0, \delta_0]$, the operator A is equicontinuous. Then the operator A is completely continuous on S_d, and it has at least one fixed point on S_d by the Schauder principle (see [20], p. 411). The proof of the lemma is complete.

Thus, Lemma imply the following assertion on the existence of a solution of the operator equation (5).

Now show that this solution is the only one. Suppose that there are two solutions $U^1(x,t)$ and $U^2(x,t)$. Then their difference $Z(x,t) = U^2(x,t) - U^1(x,t)$ is a solution to the equation

$$Z(x,t) = \int_0^t \int_0^l G(x,\xi,t-\beta) \int_0^\beta k(\beta-\tau)Z(\xi,\tau)d\tau d\xi d\beta -$$

$$-\lambda \int_0^T \int_0^l G_0(x,\xi,t+T-\beta) \int_0^\beta k(\beta-\tau)Z(\xi,\tau)d\tau d\xi d\beta -$$

$$- \int_0^T \int_0^\mu \int_0^l p(\mu)G_0(x,\xi,t+\mu-\beta) \int_0^\beta k(\beta-\tau)Z(\xi,\tau)d\tau d\xi d\beta d\mu,$$

Let $\tilde{Z}(t)$ denote the supremum of the module of the function $Z(x,t)$ for $x \in (0,l)$ at each fixed $t \in (0,T)$. Then we have the inequality

$$\tilde{Z}(t) \le 2k_0(1+\lambda+p_0T)T \int_0^T \tilde{Z}(\tau)d\tau, \ \ t \in [0,T].$$

Applying the Gronwall lemma (see [1]) here, we obtain that $\tilde{Z}(t) = 0$ for $t \in [0,T]$, which means that $Z(x,t) = 0$in D_T, i.e. $U^1(x,t) = U^2(x,t)$. in D_T. Therefore, equation (4) has a unique solution in D_T. The Lemma is proved.

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TWO-DIMENSIONAL INVERSE PROBLEM OF DETERMINING THE KERNEL OF THE INTEGRO-DIFFERENTIAL HEAT EQUATION

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Consider the problem of determining the unknown functions $u(x,y,t)$ and $k(t)$ in the space $D_T = \{(x,y,t) | x \in (0,p), y \in (0,q), t \in (0,T), 0 < T < +\infty\}$ such that the pair u, k satisfies the following integro-differential equation for parabolic type of second order

$$u_t - a^2 \Delta u = \int_0^t k(\tau) u(x,y,t-\tau) d\tau, (x,y,t) \in D_T, \qquad (1)$$

with the initial condition

$$u|_{t=0} = \varphi(x,y), x \in [0,p], y \in [0,q] \qquad (2)$$

the boundary conditions

$$u|_{x=0} = 0, u|_{x=p} = 0, u|_{y=0} = 0, u|_{y=q} = 0, \qquad (3)$$

and additional condition

$$\int_0^p \int_0^q u(x,y,t) dy dx = f(t), \qquad (4)$$

in which a is a positive constant, p, q and T are arbitrary positive numbers and $\varphi(x,y), f(t)$ are given functions.

Definition. A function $u(x,y,t)$ is said to be a classical solution of problem (1)-(3) if all four of the following conditions are satisfied:

1. The function $u(x,y,t)$ with the derivatives $u_{xx}(x,y,t), u_{yy}(x,y,t)$and $u_t(x,y,t)$ are continuous in the domain D_T.
2. The function $k(t)$ is continuous on the interval $[0,T]$.
3. The equation (1) and conditions (2)-(3) are satisfied in the classical sense.
4. The matching conditions $\varphi(0,y) = \varphi(x,0) = \varphi(p,y) = \varphi(x,q) = 0$ are met.

Lemma 1.*If $\varphi(x,y) \in C([0,p] \times [0,q]), k(t) \in C([0,T])$, then there is the unique classical solution $u(x,y,t)$ to the problem (1)-(3) of the class $C^{2,1}(D_T)$*

($C^{2,1}(D_T)$ is the class of twice continuously differentiable with respect to x, y and once continuously differentiable with respect to t in the domain D_T functions). In what follows we also use the usual class $C(D_T)$ of continuous in D_T functions.

Lemma 2. *Problem (1)-(4) are equivalent to the auxiliary problem of determining the functions $\omega(x,y,t), k(t)$ from the following equations:*

$$\omega_t - a^2\Delta\omega = k(t)\varphi(x,y) + \int_0^t k(\tau)\omega(x,y,t-\tau)d\tau, \tag{5}$$

$$\omega|_{t=0} = a^2\Delta\varphi(x,y), \tag{6}$$

$$\omega|_{x=0} = 0, \omega|_{x=p} = 0, \omega|_{y=0} = 0, \omega|_{y=q} = 0, \tag{7}$$

$$\int_0^p \int_0^q \omega(x,y,t)dydx = f'(t). \tag{8}$$

The existence and uniqueness then follow immediately. From problem (5)-(7), we obtain

$$\omega(x,y,t) = \omega_0(x,y,t) + \int_0^t \int_0^p \int_0^q G(x,y,\xi,\eta,t-\tau)k(\tau)\varphi(\xi,\eta)d\eta d\xi d\tau +$$

$$+ \int_0^t \int_0^p \int_0^q G(x,y,\xi,\eta,t-\tau) \int_0^\tau k(\alpha)\omega(\xi,\eta,\tau-\alpha)d\alpha d\eta d\xi d\tau, \tag{9}$$

where

$$G(x,y,\xi,\eta,t-\tau) =$$

$$= \frac{4}{pq}\sum_{n,m=1}^{\infty} e^{-(a\pi)^2\left(\frac{n^2}{p^2}+\frac{m^2}{q^2}\right)(t-\tau)} sin\left(\frac{\pi n}{p}\xi\right) sin\left(\frac{\pi m}{q}\eta\right) sin\left(\frac{\pi n}{p}x\right) sin\left(\frac{\pi m}{p}y\right)$$

is the Green function of the initial-boundary problem for two-dimensional parabolic equation,

$$\omega_0(x,y,t) = \int_0^t \int_0^p \int_0^q G(x,y,\xi,\eta,t-\tau)a^2\Delta\varphi(\xi,\eta)d\eta d\xi d\tau.$$

Using the additional condition (8) and the integral equation (9), we hold folliwing integral equation with respect to unknown function $k(t)$:

$$k(t) = \frac{1}{\varphi_0}[f''(t) - \int_0^p \int_0^q \omega_{0t}(x,y,t)dydx -$$

$$+ \int_0^p \int_0^q \int_0^t \int_0^p \int_0^q G_t(x,y,\xi,\eta,t-\tau)k(\tau)\varphi(\xi,\eta)d\eta d\xi d\tau dydx -$$

$$-\int_0^p \int_0^q \int_0^t k(\alpha)\omega(x,y,t-\alpha)d\alpha dy dx -$$

$$-\int_0^p \int_0^q \int_0^t \int_0^p \int_0^q G_t(x,y,\xi,\eta,t-\tau)\int_0^\tau k(\alpha)\omega(\xi,\eta,\tau-\alpha)d\alpha d\eta d\xi d\tau dy dx]. \quad (11)$$

Theorem 1. *Assume the conditions* $f(t) \in C^2[0,T], \varphi(x,y) \in C^2([0,p] \times [0,q])$, $\Delta\varphi(0,0) = 0, \varphi_0 \neq 0$, $\varphi(0,y) = \varphi(x,0) = \varphi(p,y) = \varphi(x,q) = 0$, $\int_0^p \int_0^q \varphi(x,y)dydx = f(0), a^2 \int_0^p \int_0^q \Delta\varphi(x,y)dydx = f'(0), \Delta\varphi(0,y) = \Delta\varphi(x,0) = \Delta\varphi(p,y) = \Delta\varphi(x,q) = 0$ *are hold. Then there exists sufficiently small number* $T^* \in (0,T)$ *that the solution to the integral equations (10), (11) in the class of functions* $\omega(x,y,t) \in C^{2,1}(D_{T^*})$, $k(t) \in C[0;T^*]$ *exist and unique.*

In the work, the solvability of inverse problem for integro-differential second-order parabolic equation with initial-boundary conditions was studied. The considered problem was reduced to an auxiliary problem in a certain sense and its equivalence to the original problem was shown. Then the auxiliary problem was reduced to an equivalent closed system of Volterra-type integral equations with respect to unknown functions. Applying the method of contraction mappings to this system in the continuous class of functions with weighted norms, we proved the main result of the article, which is a global existence and uniqueness theorem of inverse problem solutions. We note that global solvability of this kind of n dimensional problem is open issue.

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МЕТОДЫ И ПРИЕМЫ В ОРГАНИЗАЦИИ ПОЛЕВОЙ ПРАКТИКИ ПО ЗООЛОГИИ С ОБУЧАЮЩИМИСЯ