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SAMARKAND STATE UNIVERSITY NAMED AFTER SHAROF RASHIDOV

ILMIY AXBOROTNOMA

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DIVERGENT KO‘RINISHDAGI BIOLOGIK POPULYATSIYA SISTEMALARINING AVTOMODEL YECHIMLARI ASIMPTOTIKASI

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Annotatsiya. Ushbu maqolada chiziqsiz ajratish usuli yordamida chiziqsiz biologik populyatsiya masalalarining turli avtomodel yechimlar asimptotikalarining bosh hadlari olingan. Bu asimptotikalar nochiziqli masalani sonli yechganda muhim hisoblangan boshlang’ich yaqinlashish sifatida foydalaniladi.

Kalit so’zlar: etalon tenglama, asimptotika, avtomodel yechim.

Асимптотика автомодельных решений дивергентных биологических популяционных систем

Аннотация. В данной работе начальные члены асимптотики различных автомодельных решений нелинейных биологических популяционных задач выводятся с использованием метода нелинейного разделения. Эти асимптотики используются в качестве начальных приближений, важных при численном решении нелинейных задач.

Ключевые слова: эталонное уравнение, асимптотика, автомодельное решение.

Asymptotics of automodel solutions of divergent biological population systems

Abstract. In this paper, the initial terms of the asymptotics of various automodel solutions of nonlinear biological population problems are derived using the nonlinear separation method. These asymptotics are used as initial approximations that are important when solving nonlinear problems numerically.

Key words: standard equation, asymptotics, automodel solution.

1.Kirish. $Q=\{(x,t): x\in R, 0<t<\infty\}$ sohada quyida berilgan parabolik tipdagi biologik populyatsiya sistemasi bilan Koshi masalasini qaraymiz:

$$\begin{cases} \dfrac{\partial u}{\partial t}=\dfrac{\partial}{\partial x}\left(u^{m-1}\dfrac{\partial u}{\partial x}\right)+k_2 u\left(1-\gamma u^{q_2}\right) \\ \dfrac{\partial v}{\partial t}=\dfrac{\partial}{\partial x}\left(v^{m-1}\dfrac{\partial v}{\partial x}\right)+k_1 v\left(1-\gamma v^{q_1}\right) \end{cases} \tag{1}$$

$$u(x,0)=u_0(x),\ v(x,0)=v_0(x),\ x\in R, \tag{2}$$

bu yerda $m, q_1, q_2 -$ musbat haqiqiy sonlar.

(1) tenglamalar sistemasi turli chiziqsiz jarayonlarni tavsiflaydi [1-2]. Xususan, $k_1=0$ da (1) tenglamalar sistemasi berilgan bosim darajasiga va politropik shart ostidagi ko‘chish tezligiga bog‘liq ravishda nostatsionar suyuqlik oqimining g‘ovak muhitlardagi harakatini ifodalaydi. Bu holda (1) tenglamalar sistemasi politropik filtratsiyaning nonyuton tipidagi tenglamalari sistemasi deb atalib, ko‘pgina mualliflar tomonidan intensiv ravishda o‘rganilgan. (2) nochiziqli chegaraviy shart $x=0$ chegara orqali kiritilayotgan energiya oqimini tasvirlash uchun qo‘llaniladi. Masalan, issiqlik tarqalishi jarayonida (2) shart issiqlik oqimini ifodalaydi, shuningdek u chegaradagi nurlanishning chiziqsiz qonuniyatini tasvirlaydi. Bunday ko‘rinishdagi chegaraviy shart reaksiya faqat konteyner chegarasida sodir bo‘ladigan yonish masalalarida ham vujudga keladi [2-3].

Ma’lumki, (1) ko‘rinishdagi buziluvchi tenglamalar sistemasi $u,v\equiv 0$ sohalarda klassik ma’nodagi yechimga ega bo‘lmasligi mumkin. Bunday hollarda (1) sistemaning

$$u(x,t),v(x,t)\geq 0,\ \ u^{m-1}\frac{\partial u}{\partial x},\ u^{m-1}\frac{\partial u}{\partial x}\in C(Q)$$

sinfga tegishli va (1) tenglamalar sistemasini taqsimot ma'nosida qanoatlantiruvchi umumlashgan yechimlarini o'rganishga to'g'ri keladi.

[4-7] da M. Aripov va D. Muxamediyevalar tomonidan (1) sistemaning $k_1 = K_1\lambda_1(t), k_2 = K_2\lambda_2(t)$ bo'lgan holdagi avtomodel yechimlarining asimptotikalari tadqiq etilgan. Populyatsiya jarayonining chekli tezlikda sodir bo'lish va jarayonning lokallashish effektlari aniqlangan. Shuningdek, sonli yechimlari olinib, ularning tahlili va tatbiqi bayon etilgan.

[8] da esa

$$\begin{cases} \dfrac{\partial(\rho(x)u_1)}{\partial t} = div\left(|x|^n u_2^{m_1-1}|\nabla u_1|^{p-2}\nabla u_1\right) + \rho(x)k_1u_1(1-\gamma u_1^{q_1}), \\ \dfrac{\partial(\rho(x)u_2)}{\partial t} = div\left(|x|^n u_1^{m_1-1}|\nabla u_2|^{p-2}\nabla u_2\right) + \rho(x)k_2u_2(1-\gamma u_2^{q_1}), \end{cases}$$

bu yerda $\rho(x) = |x|^{-1}$, n, m_1, $m_2 > 0$, q_1, $q_2 > 0$, biologik populyatsiya sistemasining avtomodel yechimlari asimptotikalari o'rganilgan. Sonli parametrlarga bog'liq ravishda tarqalishning chekli tezlikda sodir bo'lish va lokalizatsiya xodisasining vujudga kelish shartlari topilgan. Bu effektlar sonli yechish asosida ham ko'rsatib berilgan.

2. **(1) sistemaning avtomodel yechimlari va ularning asimptotikalari**.

(1), (2) masalaning avtomodel yechimini quyidagi ko'rinishda qidiraylik:

$$u(x,t) = e^{k_1t}D_1(x,t),\ \ v(t,x) = e^{k_2t}D_2(x,t).$$

U holda (D_1, D_2) noma'lum funksiyalarga nisbatan quyidagi tenglamalar sistemasini hosil qilamiz:

$$\begin{cases} \dfrac{\partial D_1}{\partial \tau_1} = \dfrac{\partial}{\partial x}\left(D_1^{m-1}\dfrac{\partial D_1}{\partial x}\right) + k_2 e^{[(q_2-m)k_2]t}D_1^{q_2+1} \\ \dfrac{\partial D_2}{\partial \tau_2} = \dfrac{\partial}{\partial x}\left(D_2^{m-1}\dfrac{\partial D_2}{\partial x}\right) + k_1 e^{[(q_1-m)k_1]t}D_2^{q_1+1} \end{cases} \tag{3}$$

$\tau(t)$ funksiyani

$$\tau(t) = \frac{e^{[(q_1-m)k_1]t}}{mk_1} = \frac{e^{[(q_2-m)k_2]t}}{mk_1},$$

ko'rinishda tanlab, quyidagi sistemaga kelamiz:

$$\begin{cases} \dfrac{\partial D_1}{\partial \tau_1} = \dfrac{\partial}{\partial x}\left(D_1^{m-1}\dfrac{\partial D_1}{\partial x}\right) + a_1(t)\tau^{n_1}(t)D_1^{q_2+1} \\ \dfrac{\partial D_2}{\partial \tau_2} = \dfrac{\partial}{\partial x}\left(D_2^{m-1}\dfrac{\partial D_2}{\partial x}\right) + a_2(t)\tau^{n_2}(t)D_2^{q_1+1} \end{cases} \tag{4}$$

bu yerda $a_1(t) = k_2(t)\cdot[mk_2]^{b_1}$, $a_2(t) = k_1(t)\cdot[mk_1]^{b_1}$, $b_1 = \dfrac{q_2-m}{m}$, $b_2 = \dfrac{q_{1.}-m}{m}$.

(4) tenglamalar sistemasi uchun avtomodel tenglamalar sistemasini hosil qilish uchun quyidagi oddiy differensial tenglamalar sistemasini yechib olamiz

$$\begin{cases} \dfrac{d\bar{D}_1}{d\tau} = -a_1\tau^{b_1}\bar{D}_1^{q_1+1}, \\ \dfrac{d\bar{D}_2}{d\tau} = -a_2\tau^{b_2}\bar{D}_2^{q_2+1}, \end{cases}$$

bunda

$$\bar{D}_1(\tau) = \tau^{-c_1},\ \bar{D}_2(\tau) = \tau^{-c_2},\ c_1 = \frac{b_1+1}{\beta_1},\quad c_2 = \frac{b_2+1}{\beta_2}.$$

(4) sistemaning yechimini quyidagi ko'rinishda qidiramiz:

$$D_1(x,t) = \bar{D}_1(t)w_1(\tau,x),\ D_2(t,x) = \bar{D}_2(t)w_2(\tau,x) \tag{5}$$

bu yerda $\tau = \tau(t)$ quyidagicha tanlaymiz:

$$\tau(t) = \int_0^{\tau} \overline{D}_1^{m-1} dt = \int_0^{\tau} \overline{D}_2^{m-1} dt =$$

$$= \begin{cases} \dfrac{1}{1-mc_1}(T+\tau)^{1-(m-1)c_1}, \text{ agar } 1-(m-1)c_1 \neq 0, \\ \ln(T+\tau), \text{ agar } 1-(m-1)c_1 = 0. \end{cases}$$

U holda $w_i(\tau, x),\ i = 1,2$ funksiya uchun quyidagi tenglamlar sistemasini hosil qilamiz:

$$\begin{cases} \dfrac{\partial w_1}{\partial \tau} = \dfrac{\partial}{\partial x}\left(w_1^{m-1} \dfrac{\partial w_1}{\partial x} \right) + \psi_2 \left(w_1^{q_2+1} - w_1 \right) \\ \dfrac{\partial w_2}{\partial \tau} = \dfrac{\partial}{\partial x}\left(w_2^{m-1} \dfrac{\partial w_2}{\partial x} \right) + \psi_1 \left(w_2^{q_1+1} - w_2 \right) \end{cases}, \tag{6}$$

bu yerda

$$\psi_i = \frac{1}{(1-[c_i(m-1) + c_{3-i}\alpha_i])\tau},\ i = 1,2 \tag{7}$$

.

(6) sistemaning quyidagi ko‘rinishdagi avtomodel yechimini qaraylik [9-10]:

$$w_1(t,x) = f(\xi),\ w_2(t,x) = \varphi(\xi),\ \xi = |x| / (T+\tau)^{1/2} \tag{8}$$

U holda (8) funksiyalarni (6) ga qo‘yish orqali quyidagi avtomodel tenglamalar sistemasini hosil qilamiz

$$\begin{cases} \dfrac{d}{d\xi}\left(f^{m-1} \dfrac{df}{d\xi} \right) + \dfrac{\xi}{p} \dfrac{df}{d\xi} + \psi_1 (f - f^{q_1+1}) = 0, \\ \dfrac{d}{d\xi}\left(\varphi^{m-1} \dfrac{d\varphi}{d\xi} \right) + \dfrac{\xi}{p} \dfrac{d\varphi}{d\xi} + \psi_2 (\varphi - \varphi^{q_2+1}) = 0. \end{cases} \tag{9}$$

Etalon tenglamlar usulini (9) ga nisbatan qo‘llash orqali olingan funksiyalarni ko‘rib chiqamiz:

$$\overline{f}(\xi) = A(a - \xi^2)_+^{\beta_1},\ \overline{\varphi}(\xi) = B(a - \xi^2)_+^{\beta_2},$$

bu yerda

$$(b)_+ = \max(0,b),\ B = \left(\frac{1}{2p\beta_2 (m\beta_2 - 1)} \right)^{\frac{1}{m-1}},\ A = \left(\frac{1}{2p\beta_1 (m\beta_1 - 1)} \right)^{\frac{1}{m-1}},\ \beta_1 = \beta_2 = \frac{1}{m-1}.$$

Teorema. Faraz qilaylik $\min\{\beta_1, \beta_2\} > 0$ bo‘lsin, u holda (9) tenglamalar sistemasining kompakt yurituvchili yechimlari uchun $\xi \to a^{1/\lambda}$ da quyidagi asimptotik ifoda o‘rinli:

$$f(\xi) = \overline{f}(\xi)(1 + o(1)),\quad \varphi(\eta) = \overline{\varphi}(\eta)(1 + o(1)),$$

bu yerda $\tilde{\varphi}(\xi)$, $\tilde{\phi}(\eta)$ yuqorida aniqlangan funksiyalar.

Isbot. (9) sistemaning yechimini quyidagi qidiraylik

$$\begin{cases} f(\xi) = \overline{f}(\xi) w_1(\psi), \\ \varphi(\eta) \square \overline{\varphi}(\xi) w_2(\psi), \end{cases} \tag{10}$$

bu yerda

$$\psi = -\ln(a - \xi^2)$$

$w_1(\psi)$, $w_2(\psi)$ - manfiy bo‘lmagan va chegaralangan funksiyalar. ψ funksiyani aniqlanishiga ko‘ra $\xi \to \sqrt{a}_-$ da $\psi \to \infty$. (10) ifodani (11) ga qo‘yib, quyidagi sistemani hosil qilamiz

$$\begin{cases} \dfrac{d}{d\psi}Lw_1+\left(\phi_1(\psi)-\beta_1 m+1\right)Lw_1+ \\ +\dfrac{\beta_1}{4A^{m-1}}\left(\beta_1 Aw_1-2w_1'\right)-\dfrac{\psi_1}{A^{m-1}B^{\alpha_1}}\left(\phi_2(\psi)w_1-\phi_3(\psi)w_1^{q_1+1}\right)=0, \\ \dfrac{d}{d\psi}Lw_2+\left(\phi_1(\psi)-\beta_2 m+1\right)Lw_2+ \\ +\dfrac{\beta_2}{4B^{m-1}}\left(\beta_2 Bw_2-2w_2'\right)-\dfrac{\psi_2}{B^{m-1}}\left(\phi_4(\psi)w_2-\phi_5(\psi)w_2^{q_2+1}\right)=0, \end{cases} \tag{11}$$

bu yerda

$$Lw_1=w_1^{m-1}\left(\beta_1 Aw_1-2w_1'\right),\quad Lw_2=w_2^{m-1}\left(\beta_2 Bw_2-2w_2'\right),$$

$$\phi_1(\psi)=\frac{e^{-\psi}}{a-e^{-\psi}},\quad \phi_2(\psi)=\frac{e^{-\psi\left(\beta_1(1-m)_2+2\right)}}{a-e^{-\psi}},\quad \phi_3(\psi)=\frac{e^{-\psi\left(\beta_1(q_1-m+1)+2\right)}}{a-e^{-\psi}},\quad \phi_4(\psi)=\frac{e^{-\psi\left(\beta_2(1-m)+2\right)}}{a-e^{-\psi}},$$

$$\phi_5(\psi)=\frac{e^{-\psi\left(\beta_2(q_2-m+1)+2\right)}}{a-e^{-\psi}}.$$

Hosil bo‘lgan sistemaning yechimlarini o‘rganish (1) sistemaning yechimlarini o‘rganish bilan teng kuchli bo‘lib, ular quyidagi xossalarga egadir

$$\begin{cases} \overline{f}(\xi)>0,\ \ w_1'(\psi)>0, \\ \overline{\varphi}(\xi)>0,\ \ w_2'(\psi)>0, \end{cases}$$

va $\left[\xi_0,+\infty\right)$, oraliqda quyidagi tengsizliklarni qanoatlantiradilar:

$$w_1(\psi)>0,\ \beta_1 Aw_1-2w_1'\neq 0,$$
$$w_2(\psi)>0,\ \beta_2 Bw_2-2w_2'\neq 0.$$

Biz (11) tenglamalar sistemasi $\left(w_1(\chi),w_2(\psi)\right)$ yechimlarining $\psi\to+\infty$ da chekli limitga ega ekanligini ko‘rsatamiz. Faraz qilaylik

$$\begin{cases} h_1(\chi)=Lw_1, \\ h_2(\psi)=Lw_2. \end{cases} \tag{12}$$

U holda

$$\begin{cases} h_1'=-\left(\phi_1(\psi)-\beta_1 m+1\right)h_1+ \\ -\dfrac{\beta_1}{4A^{m-1}}\left(\beta_1 Aw_1-2w_1'\right)+\dfrac{\psi_1}{A^{m-1}}\left(\phi_2(\psi)w_1-\phi_3(\psi)w_1^{q_1+1}\right)=0, \\ h_2'=-\left(\phi_1(\psi)-\beta_2 m+1\right)h_2+ \\ -\dfrac{\beta_2}{4B^{m-1}}\left(\beta_2 Bw_2-2w_2'\right)+\dfrac{\psi_2}{B^{m-1}}\left(\phi_4(\psi)w_2-\phi_5(\psi)w_2^{q_2+1}\right)=0. \end{cases} \tag{13}$$

Oxirgi sistema yechimlarini tahlil qilish uchun quyidagi yordamchi funksiyalardan foydalanamiz

$$\begin{cases} G_1(\mu_1,\psi)=-\left(\phi_1(\psi)-\beta_1 m+1\right)\mu_1+ \\ -\dfrac{\beta_1}{4A^{m-1}}\left(\beta_1 Aw_1-2w_1'\right)+\dfrac{\psi_1}{A^{m-1}}\left(\phi_2(\psi)w_1-\phi_3(\psi)w_1^{q_1+1}\right)=0, \\ G_2(\mu_2,\psi)=-\left(\phi_1(\psi)-\beta_2 m+1\right)\mu_2+ \\ -\dfrac{\beta_2}{4B^{m-1}}\left(\beta_2 Bw_2-2w_2'\right)+\dfrac{\psi_2}{B^{m-1}}\left(\phi_4(\psi)w_2-\phi_5(\psi)w_2^{q_2+1}\right)=0. \end{cases} \tag{14}$$

bu yerda μ_1, μ_2 - haqiqiy sonlar. Ko‘rish mumkinki, oxirgi tenglamalar sistemasining o‘ng qismi ishora saqlaydi, hamda $\left[\psi_\mu,+\infty\right)$ oraliqda quyidagi tengsizliklardan birini qanoatlantiradi:

$$G_1(\mu_1,\chi)>0,\ G_2(\mu_2,\psi)>0,$$
$$G_1(\mu_1,\chi)<0,\ G_2(\mu_2,\psi)<0. \qquad (15)$$

U holda, Bol [8] teoremasiga ko‘ra $(w_1(\chi),w_2(\psi))$ chekli limitga ega bo‘ladi. Shuningdek, (11) sistema uchun limitga o‘tsak

$$\lim_{\psi\to\infty}\phi_1(\psi)=0,\ \lim_{\psi\to\infty}\phi_2(\psi)=0,\ \lim_{\psi\to\infty}\phi_3(\psi)=0,$$
$$\lim_{\psi\to\infty}\phi_4(\psi)=0,\ \lim_{\psi\to\infty}\phi_5(\psi)=0$$

yechimi $w_1^0=(1+o(1))$, $w_2^0=(1+o(1))$ bo‘lgan chiziqli tenglamalar sistemasini hosil qilamiz. Teorema isbotlandi.

Xulosa. Maqolada chiziqsiz ajratish usuli hamda avtomodel yondashuv yordamida parabolik tipdagi divergent tenglamalar sistemasi uchun Koshi masalasining turli avtomodel yechimlar asimptotikalari olindi. Topilgan avtomodel yechimlardan masalani sonli yechganda boshlang’ich yaqinlashish sifatida foyladalaniladi.

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