ISSN 1512-1232

UDC 093A30, 00A71

CONTINUOUS NONLINEAR MATHEMATICAL AND COMPUTER MODEL OF INFORMATION WARFARE WITH PARTICIPATION OF AUTHORITATIVE INTERSTATE INSTITUTES

Chilachava Temur, Chakhvadze Aleqsandre

Sokhumi State University, St. Anna Politkovskaya No. 9.
St. Andrew the First Called Georgian University of The Patriarchy of Georgia, 53 a Chavchavadze avenue

Abstract

In work the new nonlinear mathematical and computer model of nformation warfare with participation of interstate authoritative institutes is offered. The model is described by Cauchy's problem for nonlinear non-homogeneous system of the differential equations. Confronting sides in extend of provocative statements, the third side (the peacekeeping international organizations) extends of soothing statements, interstate authoritative institutes the peacekeeping statements call the sides for the termination of information warfare. In that specific case, modes of information warfare "aggressor- victim", for the third peacekeeping side are received exact analytical solutions, and functions defining number of the provocative statements distributed by the antagonistic sides satisfy to Cauchy's problems for Riccati certain equations which are solved by a numerical method. For the general model computer modeling is carried out and shown that irrespective of high aggression of confronting sides, interstate authoritative institutes will be able to extinguish information warfare and when for this purpose efforts of only the international organizations insufficiently.

Keywords. *Information warfare, continuous nonlinear mathematical and computer model, Riccati certain equation.*

Introduction

Mathematical and computing modeling in the last decades gained all-round recognition in science as the new methodology which is roughly developing and widely introduced not only in natural science and technological spheres, but also in economy, sociology, political and historical sciences and other public disciplines [1, 2].

Works [3 - 7] are devoted to creation of mathematical model of such social process what administrative (state) management is. The last can be carried out as at macro-level (for example, the state) and at micro-level (for example, an educational or research institution, industrial or financial facility, etc.).

In work [8] we consider the nonlinear mathematical model of bilateral assimilation without demographic factor. It was shown that the most part of the population talking in the third language is assimilated by that widespread language which speaks bigger number of people (linear assimilation). Also it was shown that in case of zero demographic factor of all three subjects, the population with less widespread language completely assimilates the states with two various widespread languages, and the result of assimilation (redistribution of the assimilated population) is connected with initial quantities, technological and economic capabilities of the assimilating states.

ISSN 1512-1232

The theory of the information warfare, which formalization of which began thirty-forty years ago, now has a wide applied meaning. It is actively considered by many countries at elaboration of information safety. The presidential commission for protection of a so-called critical infrastructure was created in the USA at first. Then on the basis of the conclusion of this commission directive № 63 of the president was elaborated which in 1998, became the basis of the governmental policy of maintenance of information safety [9]. The leading countries have already begun purposeful preparation of experts in a narrow field of information warfare. In the USA, at national university of defense operates the school of information warfare and strategy. At Californian marine school courses of lectures on: principles of information operations; psychological operations; information warfare: planning and an estimation; an estimation of information warfare are delivered to the group of information warfare.

Russia, though with delay, operates in this direction to. The Ministry of Defense of Russia has created the information and propaganda centre which along with tasks will prepare hacker attacks on information resources of the opponent. This decision of the Ministry of Defense of Russia was the answer to the task of the president of Russia - to prepare the offers concerning the creation of the centre of preparation of experts which will be able to conduct information warfare using the newest technologies [10]. According to some sources tasks of the information and propaganda centre will be: intimidation of the opponent, destruction of its information communications and preservation of its own, creation of information and disinformation parts and rendering of influence on public opinion before the conflict as well as during the confrontation. For the necessity of creation of information forces the management of armed forces of Russia cited the analysis of war with Georgia in 2008.

Originally the term ”information warfare” was used Thomas Rona in his report in 1976 “Systems of weapons and information warfare” which meant for company **Boeing** [11]. T. Rona noted that by then, the information infrastructure was becoming the central and at same time simple component of the economy of the USA, less protected target both in state and in peaceful time.

Information warfare also implies complex of actions for creation of information influence on public consciousness to change behavior of people, to impose purposes on them which are not their interests. On the other hand, protection against the same influence is necessary.

As the state information resources often become objects of an attack and protection, the state is compelled to pay a great attention to information technologies. Accordingly, in the theory of information warfare the great number of researches is devoted to the safety of information, information systems and processes.

Earlier us the new direction in modeling of information warfare – mathematical models of information streams was offered and a number of actual problems are solved [12, 13].

In the [12 - 14] purpose the studying of quantity of information streams by means of new mathematical models of information warfare. By information warfare the authors mean an antagonism by means of mass media (an electronic and printing press, the Internet) between the two states or the two associations of states, or the economic structures (consortiums) conducting purposeful misinformation, propagation against each other.

In a world information field for ideological, political and economic targets the purposeful information and the misinformation is actively used, from which in most cases the separation of the general background for the unprepared person is very difficult.

The aims of information warfare can be:

- Infliction of losses to the image of the antagonist country – creating the image of the enemy.
- Discredit of the management of the antagonist country.
- Demoralization of the personnel of the armed forces and the civilians of the antagonist country.
- Creation of public opinion, inside and outside of the country, for justification of argumentation of possible military operations.

ISSN 1512-1232

- Opposition to the geopolitical ambitions of the antagonist country etc.

International organizations react to occurring processes in the modern world in this or that form and activity. Therefore as the third side in the course of information warfare we consider association of international organizations (the United Nations, OSCE, EU, the WTO, etc.) efforts of which are directed on removal of tension between the rival states, the sides and the cessation of information warfare.

In the [12 - 14] works we have constructed the general continuous linear mathematical model of information warfare between two antagonistic sides, in the presence of the third, peace-making side. The model considers the case of confrontation between the unions of equal ("yak-bear") as well as strong different ("wolf-lamb") strength.

Exact analytical solutions to a Cauchy's problem for the system of the linear differential equations of the first order with constant factors are received.

Parities between the constants of the model and initial conditions are revealed, at which:

1. The antagonistic sides, despite increasing appeals of the third side, intensify information attacks.
2. One of the antagonistic sides, under the influence of the third side stops information warfare while another strengthens it.
3. Both antagonistic sides, after achieving maximum activity, reduce it under the influence of the third side, and through finite time, stop information attacks at all.

In the first case, the transformation of information warfare into a hot phase is expected, in the second – it is less probable, in the third - it is excluded at all.

The offered model of information warfare, except theoretical interest has as well an important practical meaning. At allows, on the basis of observation and the analysis, at an early stage of information attacks, to establish true intentions of each side and the character of the development of information warfare.

Further in works [15 - 22] linear and nonlinear mathematical models of information warfare, and also optimizing problems are considered.

It is also necessary to note that the new direction offered by us in 2009 in mathematical modeling of information warfare caused a certain interest and among some famous scientists who used our scenario of information warfare [13], mathematical model (system of the equations), exact analytical decisions for computer modeling a cyber wars [23].

In [13, 15] it was shown that in case of high aggression of the contradictory countries, not preventive image the operating peacekeeping organizations won't be able to extinguish the expanding information warfare.

In works [24 – 26] new linear, nonlinear continuous and discrete mathematical models of information war with expeditious participation of the authoritative religious and public institutes operating in the contradictory countries are offered (see appendix 1, scenario information warfare).

I. System of the equations and initial conditions

The mathematical model describing information warfare of two warring sides (the country, the coalition), with the assistance of the third peacekeeping side (the authoritative international organizations), and also interstate religious institutes having impact only on leaders of the countries for the purpose of the termination of information warfare, has an appearance:

ISSN 1512-1232

$$\begin{cases} \dfrac{dN_1(t)}{dt} = \alpha_1 N_1(t) + \alpha_2 N_1(t) N_2(t) - \alpha_3 N_3(t) - \beta_1(t) \\ \dfrac{dN_2(t)}{dt} = \alpha_4 N_2(t) + \alpha_5 N_1(t) N_2(t) - \alpha_6 N_3(t) - \beta_2(t) \\ \dfrac{dN_3(t)}{dt} = \gamma_1 N_1(t) + \gamma_2 N_2(t) + \gamma_3 N_3(t) \end{cases} \tag{1.1}$$

$$N_1(0) = N_{10} > 0,\ N_2(0) = N_{20} > 0,\ N_3(0) = N_{30} \geq 0, \tag{1.2}$$

$$\alpha_1, \alpha_3, \alpha_4, \alpha_6, \gamma_1, \gamma_2 > 0,\ \gamma_3 \geq 0,$$

$$\alpha_2, \alpha_5 = const,\ \beta_1(t), \beta_2(t) > 0,\ t \in [0,T],\ N_i(t) \in C^1[0,T], i = \overline{1,3}, \quad \beta_i(t) \in C[0,T], i = 1,2.$$

Confronting sides in a time-point t extend $N_i(t), i = 1,2$ number of provocative statements, the third side (the peacekeeping international organizations) extends $N_3(t)$ number of soothing statements, interstate authoritative institutes the peacekeeping statements $\beta_1(t), \beta_2(t)$ call the sides for the termination of information warfare.

Thus nonlinear mathematical model of information warfare with participation of interstate authoritative institutes is described by Cauchy's problem for nonlinear non-homogeneous system of the differential equations (1.1) and initial conditions (1.2).

Now we will consider a special case

$$\begin{cases} \dfrac{dN_1(t)}{dt} = \alpha_1 N_1(t) + \alpha_2 N_1(t) N_2(t) - \alpha_3 N_3(t) - \beta_1(t) \\ \dfrac{dN_2(t)}{dt} = \alpha_1 N_2(t) + \alpha_4 N_1(t) N_2(t) - \alpha_3 N_3(t) - \beta_2(t) \\ \dfrac{dN_3(t)}{dt} = \gamma_1 (N_1(t) + N_2(t)) \end{cases} \tag{1.3}$$

when in system (1.1) takes place

$$\alpha_1 = \alpha_4,\ \alpha_3 = \alpha_6,\ \alpha_2 = -\alpha_4,\ \gamma_3 = 0 \tag{1.4}$$

and initial conditions (1.2).

In this case from system (1.3) and initial conditions (1.2), it is easy to receive the following Cauchy's problem for function $N_3(t)$

$$\frac{d^2 N_3(t)}{dt^2} - \alpha_1 \frac{dN_3(t)}{dt} + 2\alpha_3 \gamma_1 N_3(t) = -\gamma_1(\beta_1(t) + \beta_2(t)) \tag{1.5}$$

$$N_3(0) = N_{30} \geq 0,\ \frac{d}{dt} N_3(0) = \gamma_1(N_1(0) + N_2(0)) = \gamma_1(N_{10} + N_{20})$$

We will enter designation

$$D = \alpha_1^2 - 8\alpha_3\gamma_1 \tag{1.6}$$

Consider three qualitatively various cases:

1. $D > 0,\ \lambda_1 \neq \lambda_2 \in R$

ISSN 1512-1232

$$\lambda_1 = \frac{\alpha_1 + \sqrt{D}}{2} > 0 \ \lambda_2 = \frac{\alpha_1 - \sqrt{D}}{2} > 0 \tag{1.7}$$

Then the exact solution of Cauchy's problem (1.5) has an appearance

$$N_3(t) = \frac{\gamma_1(N_{10} + N_{20}) - \lambda_2 N_{30}}{\sqrt{D}} e^{\lambda_1 t} - \frac{\gamma_1(N_{10} + N_{20}) - \lambda_1 N_{30}}{\sqrt{D}} e^{\lambda_2 t} -$$
$$-\frac{\gamma_1 e^{\lambda_1 t}}{\sqrt{D}} \int_0^t \frac{\beta_1(\tau) + \beta_2(\tau)}{e^{\lambda_1 \tau}} d\tau + \frac{\gamma_1 e^{\lambda_2 t}}{\sqrt{D}} \int_0^t \frac{\beta_1(\tau) + \beta_2(\tau)}{e^{\lambda_2 \tau}} d\tau \tag{1.8}$$

2. $D = 0$

$$\lambda_1 = \lambda_2 = \lambda = \frac{\alpha_1}{2} \in R \tag{1.9}$$

Then the exact solution of Cauchy's problem (1.5) has an appearance

$$N_3(t) = N_{30} e^{\lambda t} + [\gamma_1(N_{10} + N_{20}) - N_{30}\lambda] t e^{\lambda t} +$$
$$+ \gamma_1 e^{\lambda t} \int_0^t \frac{(\beta_1(\tau) + \beta_2(\tau))\tau}{e^{\lambda \tau}} d\tau - \gamma_1 e^{\lambda t} \int_0^t \frac{\beta_1(\tau) + \beta_2(\tau)}{e^{\lambda \tau}} d\tau \tag{1.10}$$

3. $D < 0$

$$\lambda_1 = \frac{\alpha_1}{2} - i\frac{\sqrt{-D}}{2}; \ \lambda_2 = \frac{\alpha_1}{2} + i\frac{\sqrt{-D}}{2}; \tag{1.11}$$
$$\lambda = \frac{\alpha_1}{2}; m = \frac{\sqrt{-D}}{2}$$

Then the exact solution of Cauchy's problem (1.5) has an appearance

$$N_3(t) = N_{30} e^{\lambda t} \cos(mt) + \frac{\gamma_1(N_{10} + N_{20}) - N_{30}\lambda}{m} e^{\lambda t} \sin(mt) +$$
$$+ \frac{\gamma_1 e^{\lambda t}}{m} \cos(mt) \int_0^t \frac{(\beta_1(\tau) + \beta_2(\tau)) \sin(m\tau)}{e^{\lambda \tau}} d\tau - \frac{\gamma_1 e^{\lambda t}}{m} \sin(mt) \int_0^t \frac{(\beta_1(\tau) + \beta_2(\tau)) \cos(m\tau)}{e^{\lambda \tau}} d\tau \tag{1.12}$$

Further from the third equation of system (1.3), it is easy to receive

$$N_1(t) + N_2(t) = \frac{1}{\gamma_1} \frac{dN_3(t)}{dt} \tag{1.13}$$

Having entered designation

$$\varphi(t) \equiv N_1(t) + N_2(t) = \frac{1}{\gamma_1} \frac{dN_3(t)}{dt}$$

$$N_2(t) = \varphi(t) - N_1(t) \tag{1.14}$$

Then from the first equation (1.3), taking into account (1.14) we will receive Cauchy's problem for Riccati certain equation

ISSN 1512-1232

$$\frac{dN_1(t)}{dt} = (\alpha_1 + \alpha_2\varphi(t))N_1(t) - \alpha_2 N_1^2(t) - \alpha_3 N_3(t) - \beta_1(t) \tag{1.15}$$

$N_1(0) = N_{10}$

The received Riccati equation (1.15) generally in quadratures isn't solvable therefore it is necessary to apply numerical methods to his decision.

a) We will consider some special cases for functions $\beta_1(t), \beta_2(t)$

a.1. $\beta_1(t) = \beta_1 = const,\ \beta_2(t) = \beta_2 = const$ (1.16)

Then from (1.8) and (1.16) we will receive

$$N_3(t) = \frac{1}{\sqrt{D}}\left\{[\gamma_1(N_{10} + N_{20}) - \lambda_2 N_{30} - \frac{\gamma_1(\beta_1 + \beta_2)}{\lambda_1}]e^{\lambda_1 t} - A\right\} \tag{1.17}$$

$$A \equiv [\gamma_1(N_{10} + N_{20}) - \lambda_1 N_{30} + \frac{\gamma_1(\beta_1 + \beta_2)}{\lambda_2}]e^{\lambda_2 t} + \frac{\gamma_1(\beta_1 + \beta_2)}{\lambda_1} + \frac{\gamma_1(\beta_1 + \beta_2)}{\lambda_2}$$

a.2. Then from (1.8) and (1.10) we will receive

$$N_3(t) = N_{30}e^{\lambda t} + (\gamma_1(N_{10} + N_{20}) - N_{30}\lambda)te^{\lambda t} + \gamma_1(\beta_1 + \beta_2)(t + \frac{t}{\lambda} + \frac{1 - e^{\lambda t}}{\lambda}) \tag{1.18}$$

a.3. Then from (1.8) and (1.12) we will receive

$$N_3(t) = N_{30}e^{\lambda t}\cos(mt) + \frac{\gamma_1(N_{10} + N_{20}) - N_{30}\lambda}{m}e^{\lambda t}\sin(mt) + B \tag{1.19}$$

$$B \equiv e^{\lambda t}\cos(mt)\frac{\gamma_1(\beta_1 + \beta_2)}{m}\int_0^t \frac{\sin(m\tau)}{e^{\lambda\tau}}d\tau - e^{\lambda t}\sin(mt)\int_0^t \frac{\cos(m\tau)}{e^{\lambda\tau}}d\tau$$

We will consider two cases of monotonous functions $\beta_1(t), \beta_2(t)$

b) $\beta_1(t) = \beta_1 e^{\pm\frac{t}{T_1}}, \beta_1, T_1 = const > 0, \qquad \beta_2(t) = \beta_2 e^{\pm\frac{t}{T_2}}, \beta_2, T_2 = const > 0$ (1.20)

b.1. Then from (1.8) and (1.20) we will receive

$$N_3(t) = \frac{\gamma_1(N_{10} + N_{20}) - \lambda_2 N_{30}}{\sqrt{D}}e^{\lambda_1 t} - \frac{\gamma_1(N_{10} + N_{20}) - \lambda_1 N_{30}}{\sqrt{D}}e^{\lambda_2 t} -$$

$$-\frac{\gamma_1}{\sqrt{D}}\left(\frac{\beta_1}{\pm\frac{1}{T_1} - \lambda_1}(e^{\pm\frac{t}{T_1}} - e^{\lambda_1 t}) + \frac{\beta_2}{\pm\frac{1}{T_2} - \lambda_1}(e^{\pm\frac{t}{T_2}} - e^{\lambda_1 t})\right) +$$

$$+\frac{\gamma_1}{\sqrt{D}}\left(\frac{\beta_1}{\pm\frac{1}{T_1} - \lambda_2}(e^{\pm\frac{t}{T_1}} - e^{\lambda_2 t}) + \frac{\beta_2}{\pm\frac{1}{T_2} - \lambda_2}(e^{\pm\frac{t}{T_2}} - e^{\lambda_2 t})\right) \tag{1.21}$$

b.2. Then from (1.10) and (1.20) we will receive

$$N_3(t) = N_{30}e^{\lambda t} + (\gamma_1(N_{10} + N_{20}) - N_{30}\lambda)te^{\lambda t} +$$
$$+\gamma_1 e^{\lambda t}\int_0^t (\beta_1 e^{\tau(\pm\frac{1}{T_1}-\lambda)} + \beta_2 e^{\tau(\pm\frac{1}{T_2}-\lambda)})\tau d\tau -$$
$$-\gamma_1[\frac{\beta_1}{\pm\frac{1}{T_1}-\lambda}(e^{\pm\frac{t}{T_1}} - e^{\lambda t}) + \frac{\beta_2}{\pm\frac{1}{T_2}-\lambda}(e^{\pm\frac{t}{T_2}} - e^{\lambda t})] \quad (1.22)$$

b.3. Then from (1.12) and (1.20) we will receive

$$N_3(t) = N_{30}e^{\lambda t}\cos(mt) + \frac{\gamma_1(N_{10}+N_{20}) - N_{30}\lambda}{m}e^{\lambda t}\sin(mt) + C \quad (1.23)$$

$$C \equiv \frac{\gamma_1}{m}e^{\lambda t}\cos(mt)\int_0^t \frac{(\beta_1 e^{\pm\frac{\tau}{T_1}} + \beta_2 e^{\pm\frac{\tau}{T_2}})\sin(m\tau)}{e^{\lambda\tau}}d\tau - \frac{\gamma_1}{m}e^{\lambda t}\sin(mt)\int_0^t \frac{(\beta_1 e^{\pm\frac{\tau}{T_1}} + \beta_2 e^{\pm\frac{\tau}{T_2}})\cos(m\tau)}{e^{\lambda\tau}}d\tau$$

II. Computer modeling of information warfare

We will carry out computer modeling of a task Cauchy's problem (1.3), (1.2) for various values of parameters of model and initial conditions (see, appendix 2).

a.1 "Aggressor- a victim" model (1.1 – 1.5 - $N_1(t)$ is aggressor; (1.6) - $N_1(t)$ is victim)

n	N_{10}	N_{20}	N_{30}	α_1	α_2	α_3	α_4	γ_1	β_1	β_2	T
1.1	10	10	4	0.12	0.2	0.2	-0.2	0.3	2	3	5
1.2	17	10	4	0.11	0.02	0.02	-0.02	0.3	2	1	12
1.3	7	10	4	0.11	0.02	0.03	-0.02	0.3	2	1	4
1.4	7	5	0	0.21	0.02	0.02	-0.02	0.3	2	1	8
1.5	7	5	4	0.02	0.04	0.02	-0.04	0.07	1	1	33
1.6	7	5	4	0.11	-0.04	0.02	0.04	0.07	1	1	12

a.1 "Aggressor- a aggressor" model (2.1 – 2.3), "Aggressor- a victim" model (2.5 - $N_1(t)$ is aggressor; 2.4, 2.6 - $N_1(t)$ is victim).

n	N_{10}	N_{20}	N_{30}	α_1	α_2	α_3	α_4	γ_1	β_1	β_2	T
2.1	7	5	0	0.17	0.14	0.2	0.02	0.01	1	1	8
2.2	10	10	10	0.11	0.02	0.2	0.01	0.3	5	3	2
2.3	7	5	2	0.1	0.3	0.21	0.01	0.2	3	3	4
2.4	7	5	0	0.13	-0.14	0.02	0.04	0.07	1	1	5
2.5	3	5	4	0.12	0.14	0.02	-0.04	0.2	1	1	2
2.6	7	5	4	0.13	-0.14	0.02	0.04	0.07	1	1	3

ISSN 1512-1232

Conclusion

In work the new nonlinear mathematical and computer model of information warfare with participation of interstate authoritative institutes is offered. The model is described by Cauchy's problem for nonlinear non-homogeneous system of the differential equations. Confronting sides in extend of provocative statements, the third side (the peacekeeping international organizations) extends of soothing statements, interstate authoritative institutes the peacekeeping statements call the sides for the termination of information warfare.

In that specific case, models of information warfare "aggressor-victim", for the third peacekeeping side are received exact analytical solutions, and functions defining number of the provocative statements distributed by the antagonistic sides satisfy to Cauchy's problems for Riccati certain equations which are solved by a numerical method.

For the general model computer modeling is carried out and shown that irrespective of high aggression of confronting sides, interstate authoritative institutes will be able to extinguish information warfare and when for this purpose efforts of only the international organizations insufficiently.

References

1. Samarskii A.A., Mikhailov A.P. Mathematical modeling. Moscow: Fizmathlit, 2006 (russian).
2. Chilachava T.I., Dzidziguri Ts.D. Mathematical modeling. Tbilisi: Inovation, 2008 (georgian).
3. Chilachava T.I., Dzidziguri Ts.D., Sulava L.O., Chakaberia M.R. Nonlinear mathematical model of administrative management. Sokhumi State University, Proceedings, Mathematics and Computer Sciences Series, 2009, №7, p.169–180.
4. Chilachava T.I., Chakaberia M.R., Dzidziguri Ts.D., Sulava L.O. Nonlinear mathematical model of administrative pressure. Georgian mathematical union. First international Conference. Books of Abstracts. Batumi: 2010, pg. 74 – 75.
5. Chilachava T.I., Dzidziguri Ts.D., Sulava L.O.,Chakaberia M.R. About one nonlinear mathematical model of administrative management. Theses of reports of the International conference "Information and Computer Technologies, Modeling, Management", devoted to the 80 anniversary since the birth of I.V. Prangishvili.Tbilisi:2010, pg. 203 – 204 (russian).
6. Chilachava T.I., Sulava L.O., Chakaberia M. R. About one nonlinear mathematical model of management. Problems of management of safety of difficult systems. Works XVIII of the International conference. Moscow: 2010, pg. 492 – 496 (russian).
7. Chilachava T.I., Sulava L.O. About one nonlinear mathematical model of management. Georgian Electronic Scientific Journal: Computer Science and Telecommunications, 2013, № 1(37), pg. 60 – 64 (russian).
8. Chilachava T.I. Nonlinear mathematical model of bilateral assimilation. Georgian Electronic Scientific Journal: Computer Science and Telecommunications, 2014, № 1(41), pg. 61 – 67.
9. Joint Pub 3 – 13 “Information Operations”, DOD US, December, 1998.
10. Pochentsov G.G. Propagation and counter-propagation. Publish house, “Center”, Moscow, 2004 (russian).
11. Rona T.P. “Weapon Systems and Information War”, Boeing Aerospace Co., Seattle, WA, 1976.
12. Chilachava T.I., Kereselidze N.G. About one mathematical model of the information warfare. Fifth congress of mathematicians of Georgia. Abstracts of contributed talks. Batumi/Kutaisi, 2009, p. 85.

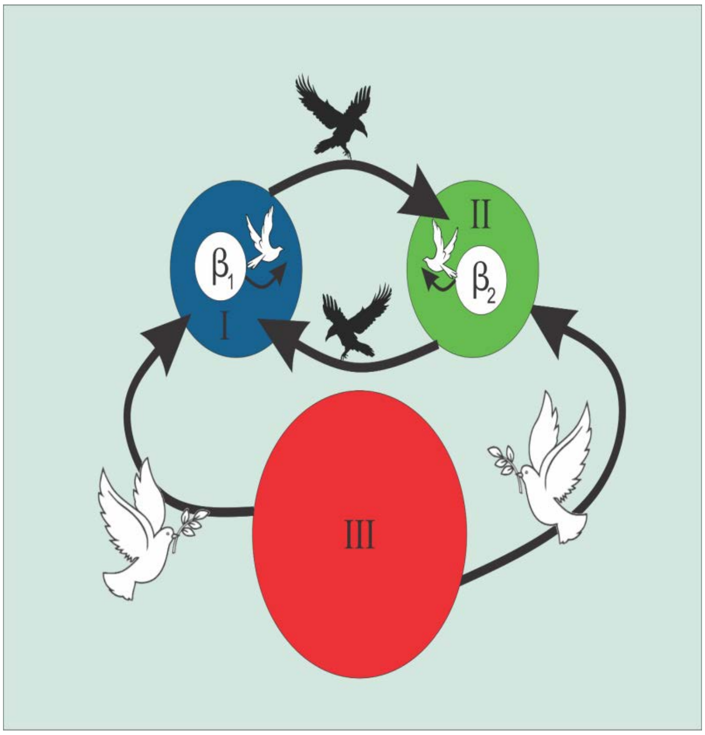
ISSN 1512-1232

13. Chilachava T.I, Kereselidze N. G. Non-preventive continuous linear mathematical model of information warfare. Sokhumi State University Proccedings, Mathematics and Computer Sciences, 2009, № 7, p. 91 – 112.
14. Chilachava T.I, Kereselidze N. G. Continuous linear mathematical model of preventive information warfare. Sokhumi State University Proccedings, Mathematics and Computer Sciences, 2009, № 7, p. 113 – 141.
15. Chilachava T., Kereselidze N. Mathematical modeling of information warfare. Georgian Electronic Scientific Journal: Computer Science and Telecommunications 2010|No. 1(24), pg. 78 – 105 (georgian).
16. Chilachava T.I, Kereselidze N. G. Mathematical and computer model of preventive information warfare. Georgian mathematical union. First international conference. Book of abstracts. Batumi, 2010, p. 75 – 76.
17. Chilachava T.I, Kereselidze N. G. Mathematical modeling of information warfare. Information warfare. 2011. №1(17), ст. 28 – 35 (russian).
18. Chilachava T.I, Kereselidze N. G. Continuous nonlinear mathematical model of information warfare. International conference continuum mechanics and related problems of analysis to Celebrate the 70th Anniversary of the Georgian National Academy of Sciences & the 120th birthday of its First President Academician Nikoloz (Niko) Muskhelishvil.i. Book of abstracts. Tbilisi, 2011, p. 155 - 156.
19. Chilachava T.I, Kereselidze N. G. General continuous linear mathematical model of information warfare. Abstracts II International conference of Georgian mathematical union, Dedicated to the 70th Anniversary of the Georgian National Academy of Sciences & the 120th birthday of its First President Academician Nikoloz (Niko) Muskhelishvil.i. Book of abstracts. Batumi, 2011, p. 117 – 118.
20. Chilachava T.I, Kereselidze N. G. Optimizing problem of mathematical model of preventive information warfare .Informational and Communication Technologies – Theory and Practice: Proceedings of the International Scientific Conference ICTMC-2010 Devoted to the 80th Anniversary of I.V. Prangishvili. USA, Imprint: Nova, 2011.
21. Kereselidze N. G. Mathematical model of information warfare taking into account technological possibilities of the parties. Georgian mathematical union. III International conference. Book of abstracts. Batumi, 2012, pg. 166 – 167.
22. Kereselidze N. G. About relations of levels of information technology sides in one of the mathematical model information warfare. Georgian mathematical union. IV International conference. Book of abstracts. Batumi, 2013, pg. 168 – 169.
23. Mishra B.K., Prajapati A. Modelling and Simulation: Cyber War, Elsevier, Procedia Technology 10, 2013, pg. 987 – 997.
24. Chilachava T.I, Kereselidze N. G., Kharaishvili Q.Nonlinear discrete mathematical and computer model of information warfare “an aggressor – the victim” with participation of interstate authoritative organizations. Georgian mathematical union. V International conference. Book of abstracts. Batumi, 2014, pg. 77.
25. Chilachava T.I, Chakhvadze A. Nonlinear mathematical and computer model of information warfare with participation of authoritative interstate institutes. Georgian mathematical union. VInternational conference. Book of abstracts. Batumi, 2014, pg. 76.
26. Chilachava T.I, Akhvlediani G., Miruashvili M. Continuous mathematical models of information warfare with participation of authoritative international and interstate institutes. Georgian mathematical union. V International conference. Book of abstracts. Batumi, 2014, pg. 75.

Article received: 2014-12-18

ISSN 1512-1232

Appendix 1

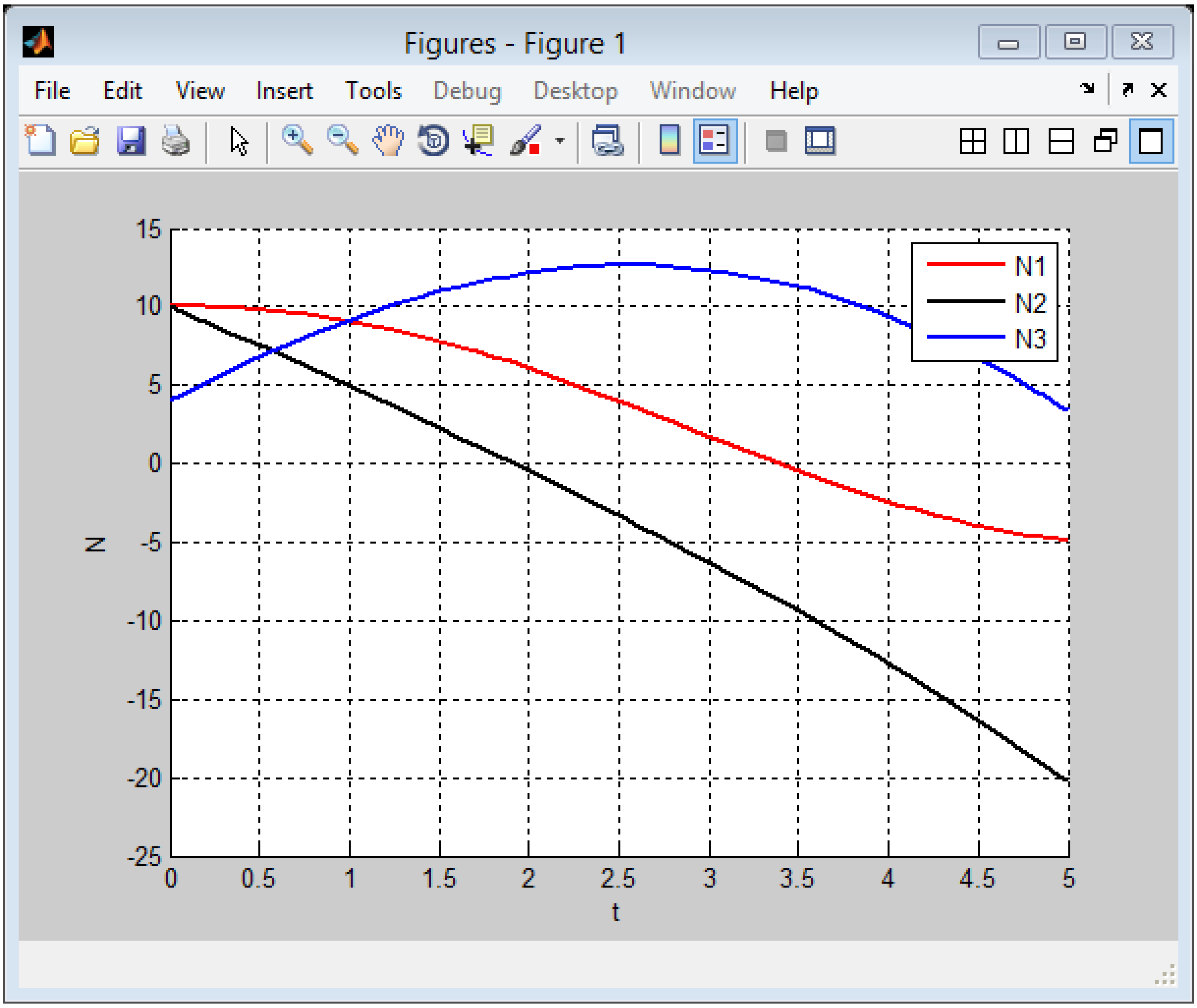


Scenario information warfare

1.1

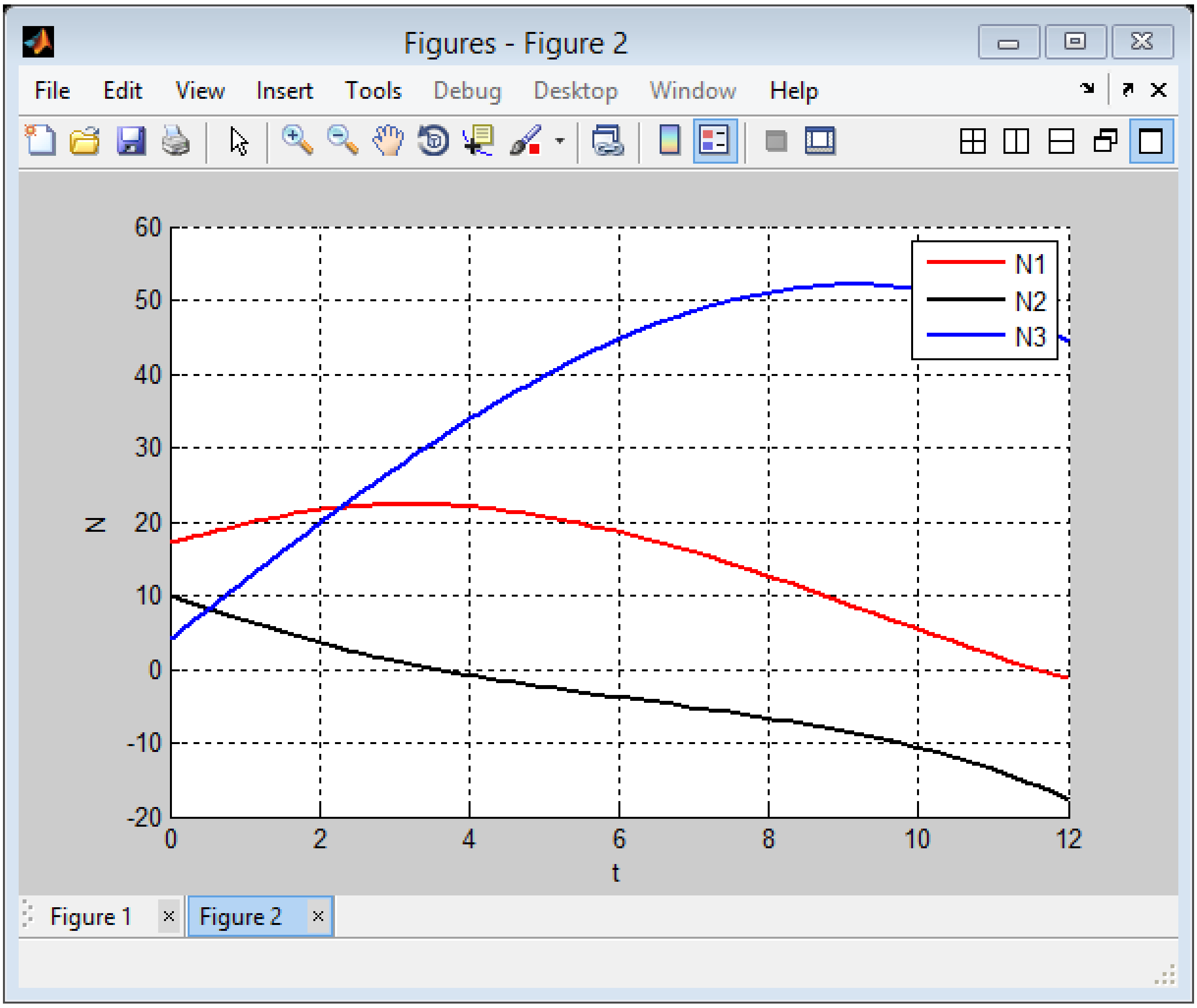
```
function main
options=odeset('RelTol',1e-6);
No = [10;10;4];
 tspan = [0,5];
 [t,N] = ode45(@TestFunction,tspan,No,options);
figure
hold on
plot(t,N(:,1));plot(t,N(:,2));plot(t,N(:,3),':')
legend('N1','N2','N3');ylabel('N');xlabel('t')
grid on
return
function [dx_dt]= TestFunction(t,x)
dx_dt(1) = 0.12*x(1) + 0.02*x(1)* x(2)-0.2*x(3)-2;
dx_dt(2) = 0.12*x(2) - 0.02*x(1)*x(2)-0.2*x(3)-3;
dx_dt(3) =0.3*(x(1)+x(2)) ;
dx_dt = dx_dt';
return
```

ISSN 1512-1232



1.2

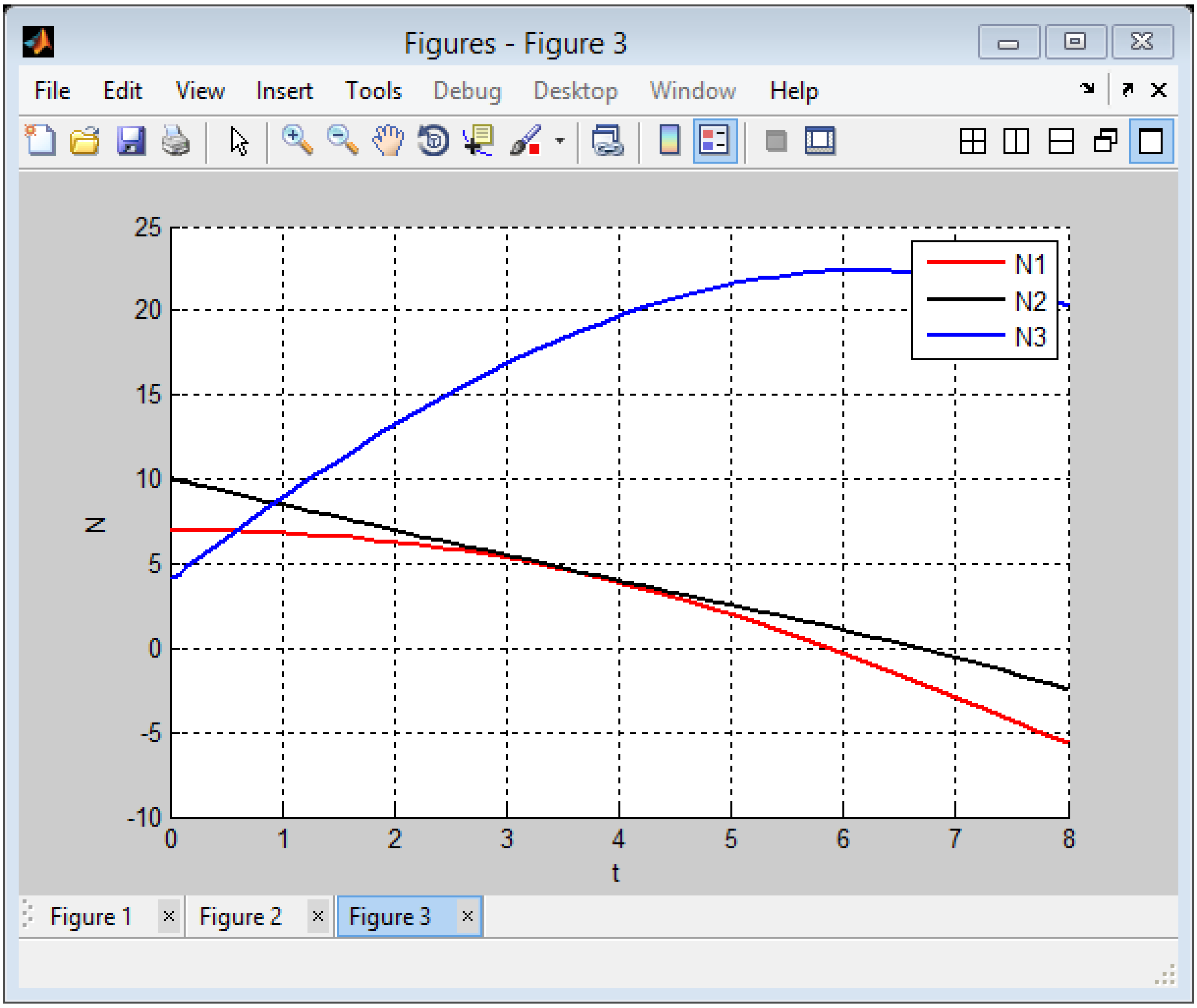
```
function main
options=odeset('RelTol',1e-6);
No = [17;10;4];
 tspan = [0,12];
 [t,N] = ode45(@TestFunction,tspan,No,options);
figure
hold on
plot(t,N(:,1));plot(t,N(:,2));plot(t,N(:,3),':')
legend('N1','N2','N3');ylabel('N');xlabel('t')
grid on
return
function [dx_dt]= TestFunction(t,x)
dx_dt(1) = 0.11*x(1) + 0.02*x(1)* x(2)-0.02*x(3)-2;
dx_dt(2) = 0.11*x(2) - 0.02*x(1)*x(2)-0.02*x(3)-1;
dx_dt(3) =0.3*(x(1)+x(2)) ;
dx_dt = dx_dt';
return
```



1.3

```
function main
options=odeset('RelTol',1e-6);
No = [7;10;4];
 tspan = [0,8];
 [t,N] = ode45(@TestFunction,tspan,No,options);
figure
hold on
plot(t,N(:,1));plot(t,N(:,2));plot(t,N(:,3),':')
legend('N1','N2','N3');ylabel('N');xlabel('t')
grid on
return
function [dx_dt]= TestFunction(t,x)
dx_dt(1) = 0.11*x(1) + 0.02*x(1)* x(2)-0.03*x(3)-2;
dx_dt(2) = 0.11*x(2) - 0.02*x(1)*x(2)-0.03*x(3)-1;
dx_dt(3) =0.3*(x(1)+x(2)) ;
dx_dt = dx_dt';
return
```

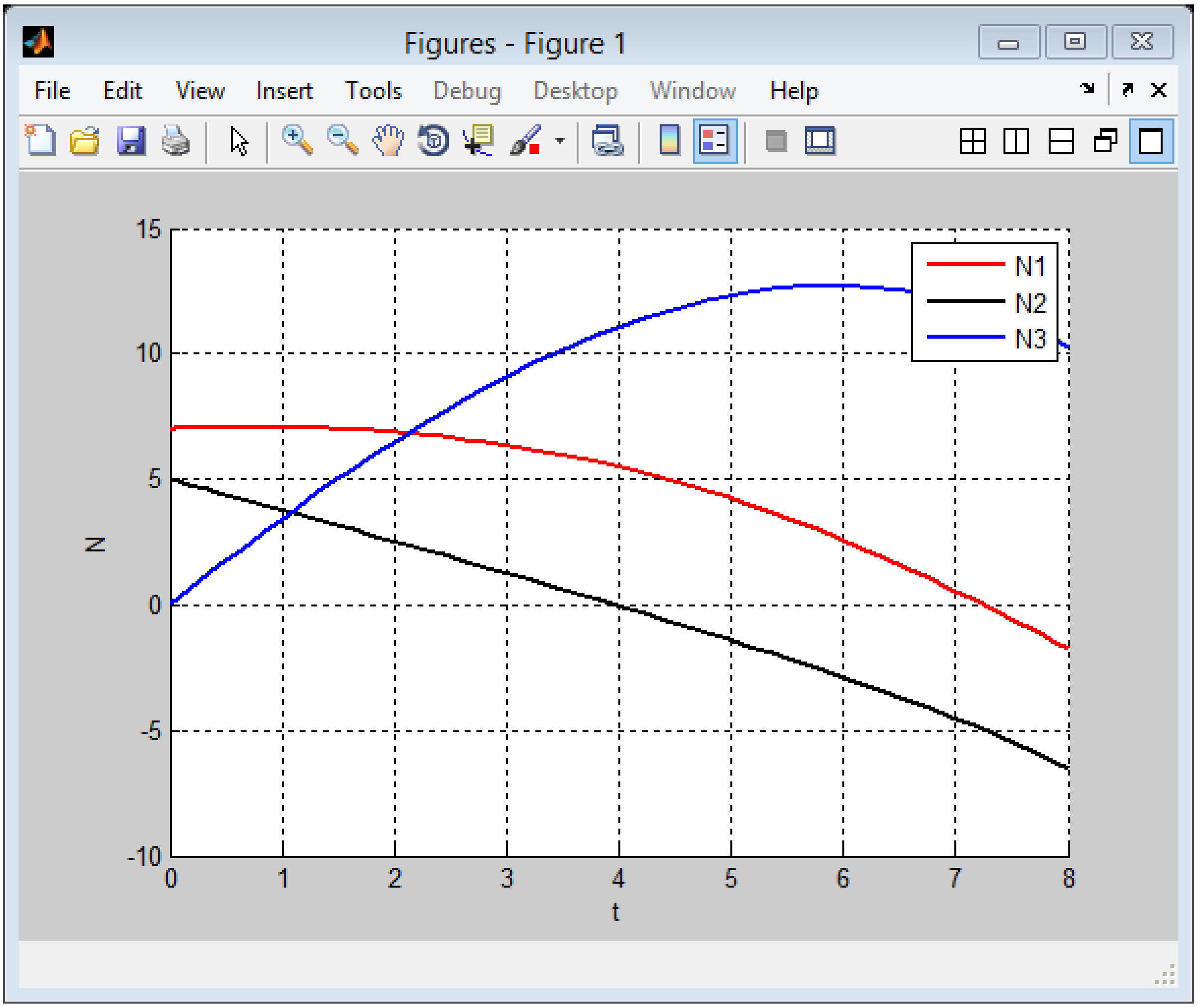
ISSN 1512-1232



1.4

```
function main
options=odeset('RelTol',1e-6);
No = [7;5;0];
 tspan = [0,8];
 [t,N] = ode45(@TestFunction,tspan,No,options);
figure
hold on
plot(t,N(:,1));plot(t,N(:,2));plot(t,N(:,3),':')
legend('N1','N2','N3');ylabel('N');xlabel('t')
grid on
return
function [dx_dt]= TestFunction(t,x)
dx_dt(1) = 0.21*x(1) + 0.02*x(1)* x(2)-0.02*x(3)-2;
dx_dt(2) = 0.21*x(2) - 0.02*x(1)*x(2)-0.02*x(3)-1;
dx_dt(3) =0.3*(x(1)+x(2)) ;
dx_dt = dx_dt';
return
```

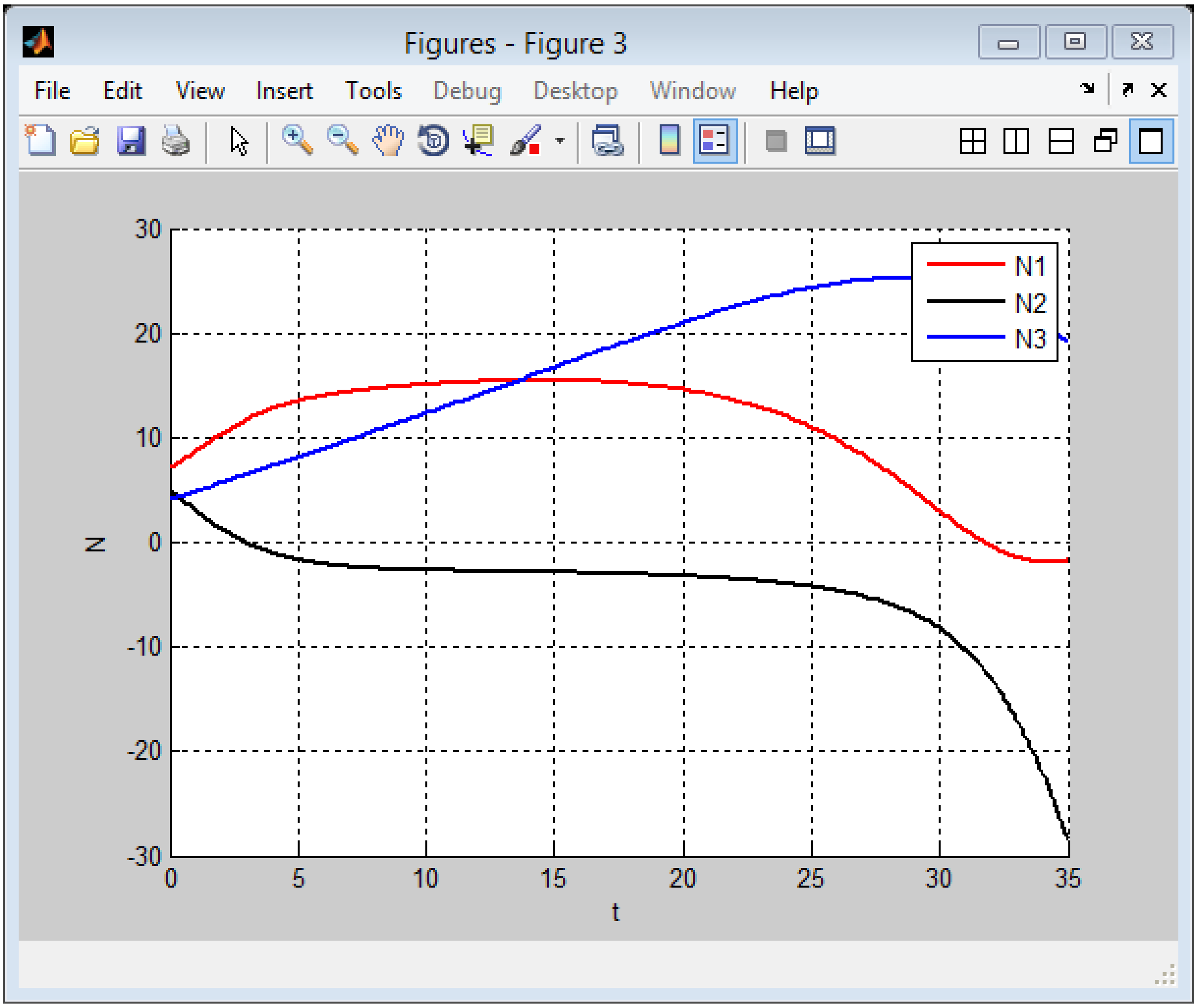
ISSN 1512-1232



1.5

```
function main
options=odeset('RelTol',1e-6);
No = [7;5;4];
 tspan = [0,35];
 [t,N] = ode45(@TestFunction,tspan,No,options);
figure
hold on
plot(t,N(:,1));plot(t,N(:,2));plot(t,N(:,3),':')
legend('N1','N2','N3');ylabel('N');xlabel('t')
grid on
return
function [dx_dt]= TestFunction(t,x)
dx_dt(1) = 0.2*x(1) + 0.04*x(1)* x(2)-0.02*x(3)-1;
dx_dt(2) = 0.2*x(2) - 0.04*x(1)*x(2)-0.02*x(3)-1;
dx_dt(3) =0.07*(x(1)+x(2)) ;
dx_dt = dx_dt';
return
```

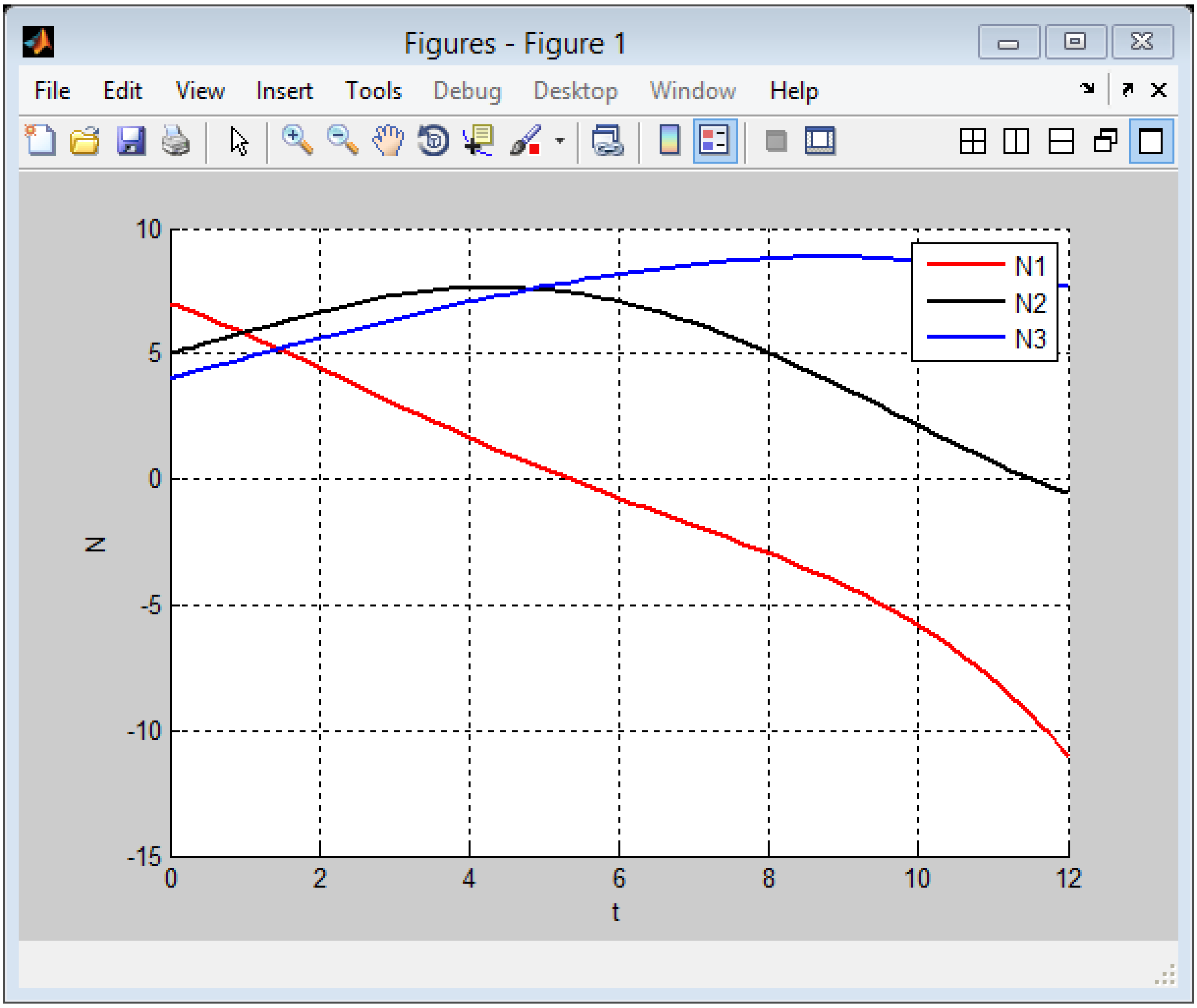
ISSN 1512-1232



1.6

```
function main
options=odeset('RelTol',1e-6);
No = [7;5;4];
 tspan = [0,12];
 [t,N] = ode45(@TestFunction,tspan,No,options);
figure
hold on
plot(t,N(:,1));plot(t,N(:,2));plot(t,N(:,3),':')
legend('N1','N2','N3');ylabel('N');xlabel('t')
grid on
return
function [dx_dt]= TestFunction(t,x)
dx_dt(1) = 0.11*x(1) - 0.04*x(1)* x(2)-0.02*x(3)-1;
dx_dt(2) = 0.11*x(2) + 0.04*x(1)*x(2)-0.02*x(3)-1;
dx_dt(3) =0.07*(x(1)+x(2)) ;
dx_dt = dx_dt';
return
```

ISSN 1512-1232

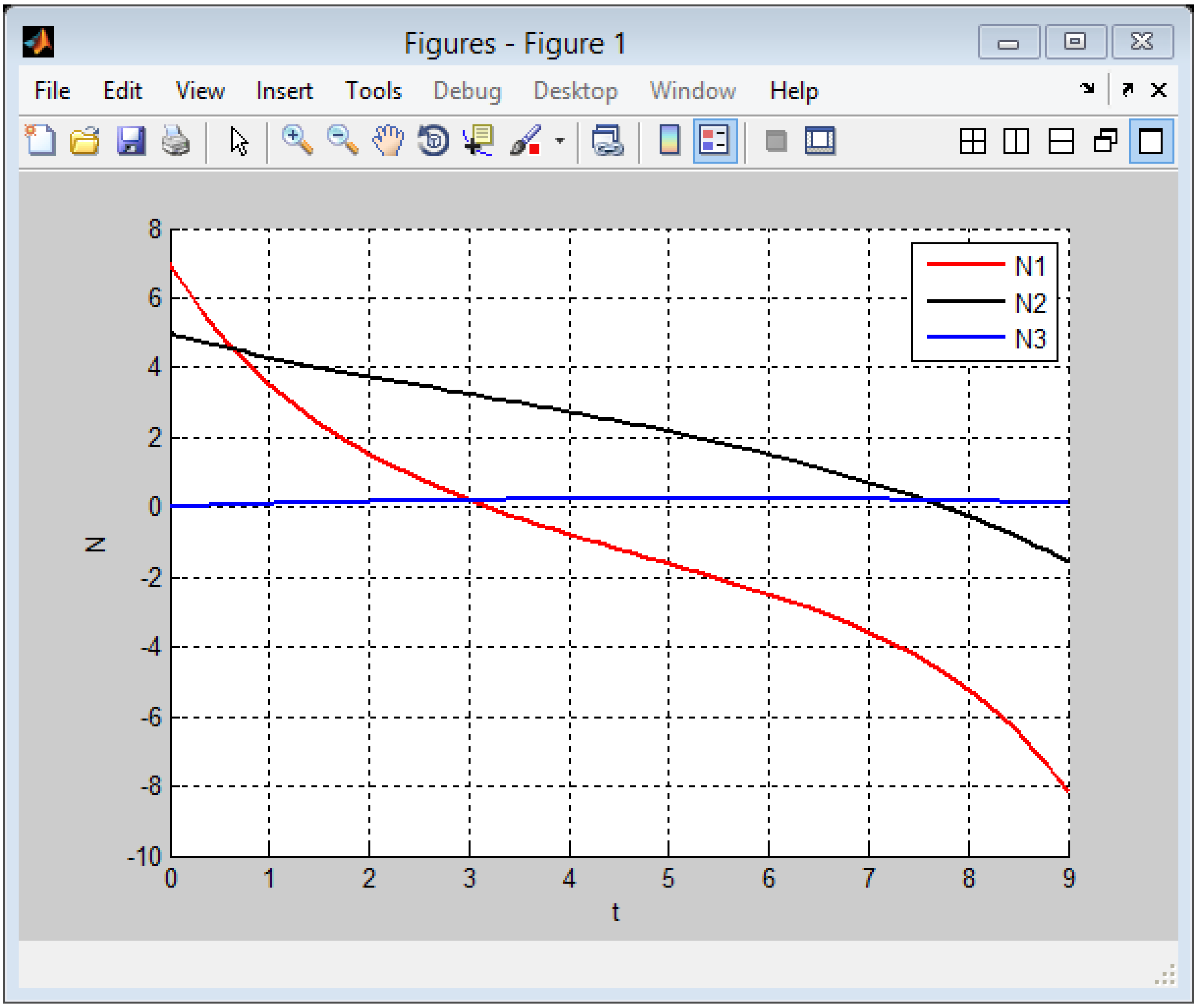


Appendix 2

2.1

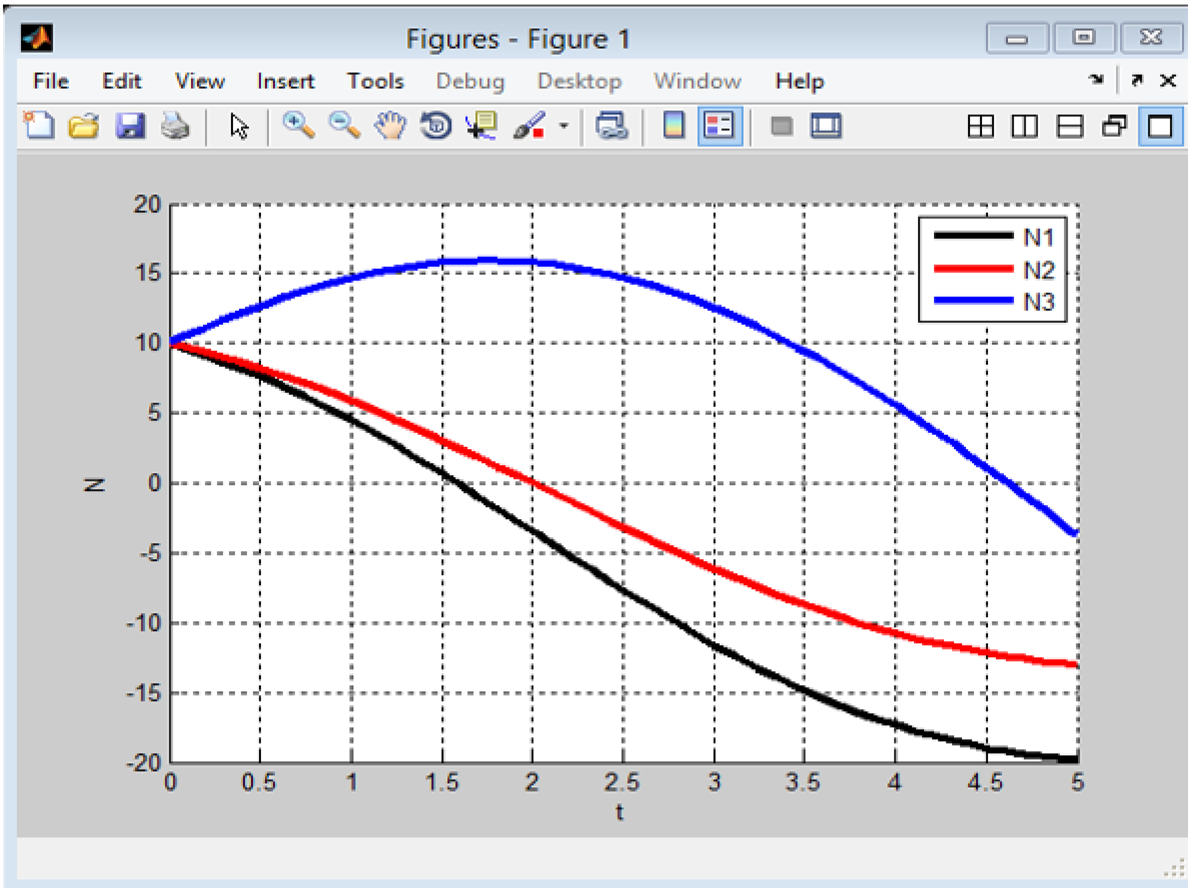
```
function main
options=odeset('RelTol',1e-6);
No = [7;5;0];
 tspan = [0,9];
 [t,N] = ode45(@TestFunction,tspan,No,options);
figure
hold on
plot(t,N(:,1));plot(t,N(:,2));plot(t,N(:,3),':')
legend('N1','N2','N3');ylabel('N');xlabel('t')
grid on
return
function [dx_dt]= TestFunction(t,x)
dx_dt(1) = 0.17*x(1) - 0.14*x(1)* x(2)-0.2*x(3)-1;
dx_dt(2) = 0.17*x(2) - 0.02*x(1)*x(2)-0.2*x(3)-1;
dx_dt(3) =0.01*(x(1)+x(2)) ;
dx_dt = dx_dt';
return
```

ISSN 1512-1232



2.2

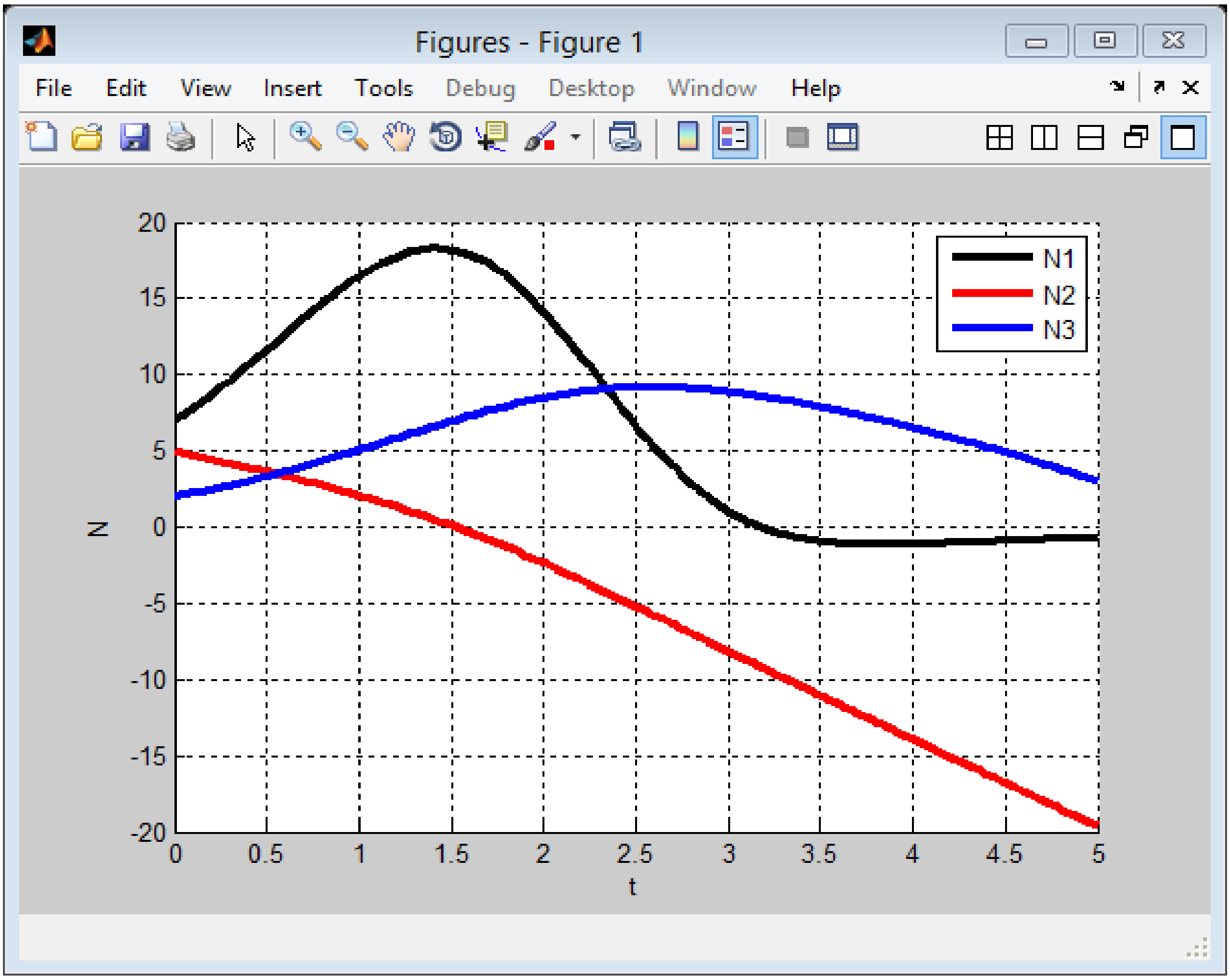
```
function main
options=odeset('RelTol',1e-6);
No = [10;10;10];
 tspan = [0,5];
 [t,N] = ode45(@TestFunction,tspan,No,options);
figure
hold on
plot(t,N(:,1));plot(t,N(:,2));plot(t,N(:,3),':')
legend('N1','N2','N3');ylabel('N');xlabel('t')
grid on
return
function [dx_dt]= TestFunction(t,x)
dx_dt(1) = 0.11*x(1) + 0.02*x(1)* x(2)-0.2*x(3)-5;
dx_dt(2) = 0.11*x(2)+0.01*x(1)*x(2)-0.21*x(3)-3;
dx_dt(3) =0.3*(x(1)+x(2)) ;
dx_dt = dx_dt';
return
```



2.3

```
function main
options=odeset('RelTol',1e-6);
No = [7;5;2];
tspan = [0,5];
 [t,N] = ode45(@TestFunction,tspan,No,options);
figure
hold on
plot(t,N(:,1));plot(t,N(:,2));plot(t,N(:,3),':')
legend('N1','N2','N3');ylabel('N');xlabel('t')
grid on
return
function [dx_dt]= TestFunction(t,x)
dx_dt(1) = 0.1*x(1) + 0.3*x(1)* x(2)-0.21*x(3)-3;
dx_dt(2) = 0.1*x(2)+0.01*x(1)*x(2)-0.21*x(3)-3;
dx_dt(3) =0.2*(x(1)+x(2)) ;
dx_dt = dx_dt';
return
```

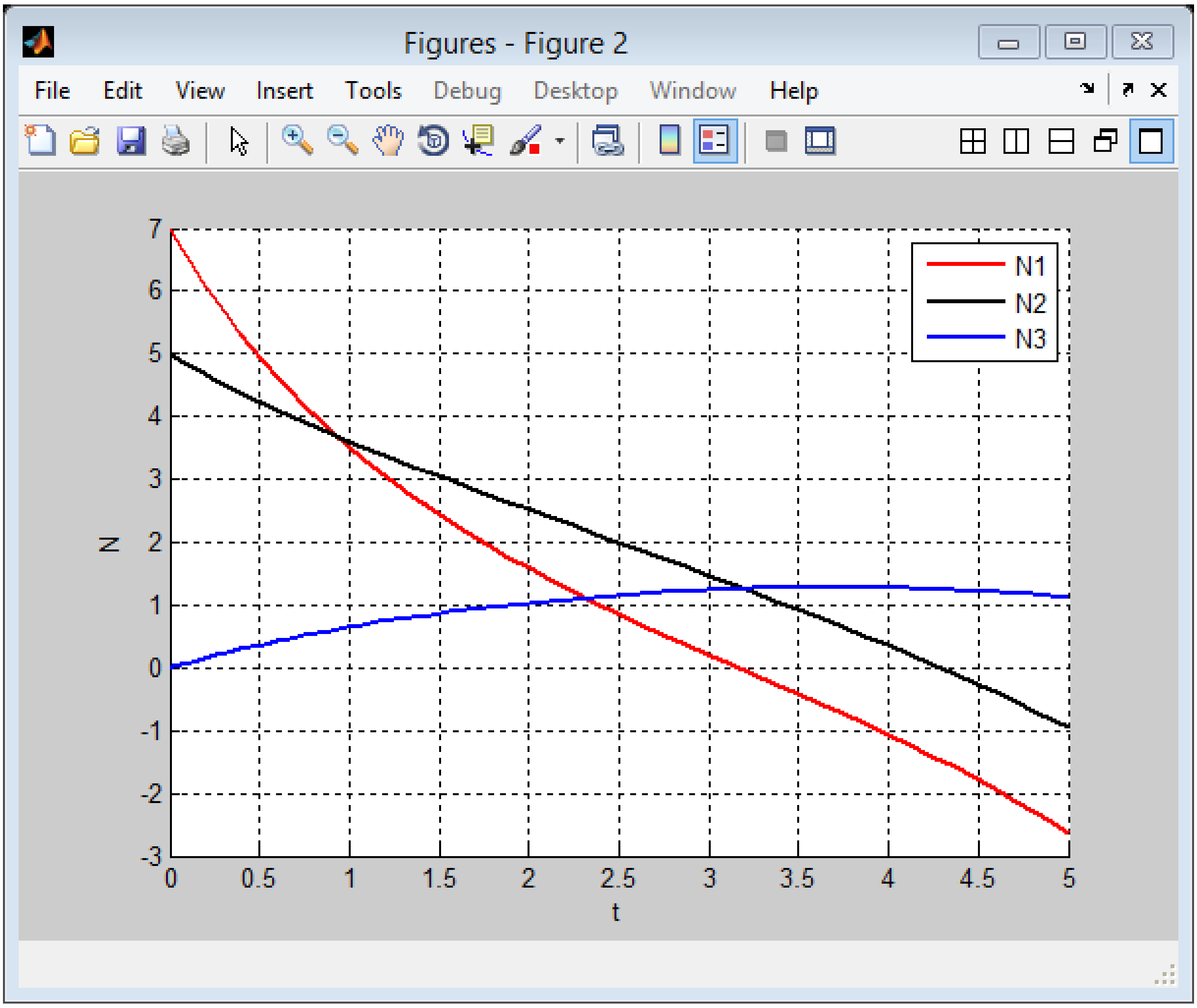
ISSN 1512-1232



2.4

```
function main
options=odeset('RelTol',1e-6);
No = [7;5;0];
 tspan = [0,5];
 [t,N] = ode45(@TestFunction,tspan,No,options);
figure
hold on
plot(t,N(:,1));plot(t,N(:,2));plot(t,N(:,3),':')
legend('N1','N2','N3');ylabel('N');xlabel('t')
grid on
return
function [dx_dt]= TestFunction(t,x)
dx_dt(1) = 0.13*x(1) - 0.14*x(1)* x(2)-0.2*x(3)-1;
dx_dt(2) = 0.13*x(2) - 0.04*x(1)*x(2)-0.2*x(3)-1;
dx_dt(3) =0.07*(x(1)+x(2)) ;
dx_dt = dx_dt';
return
```

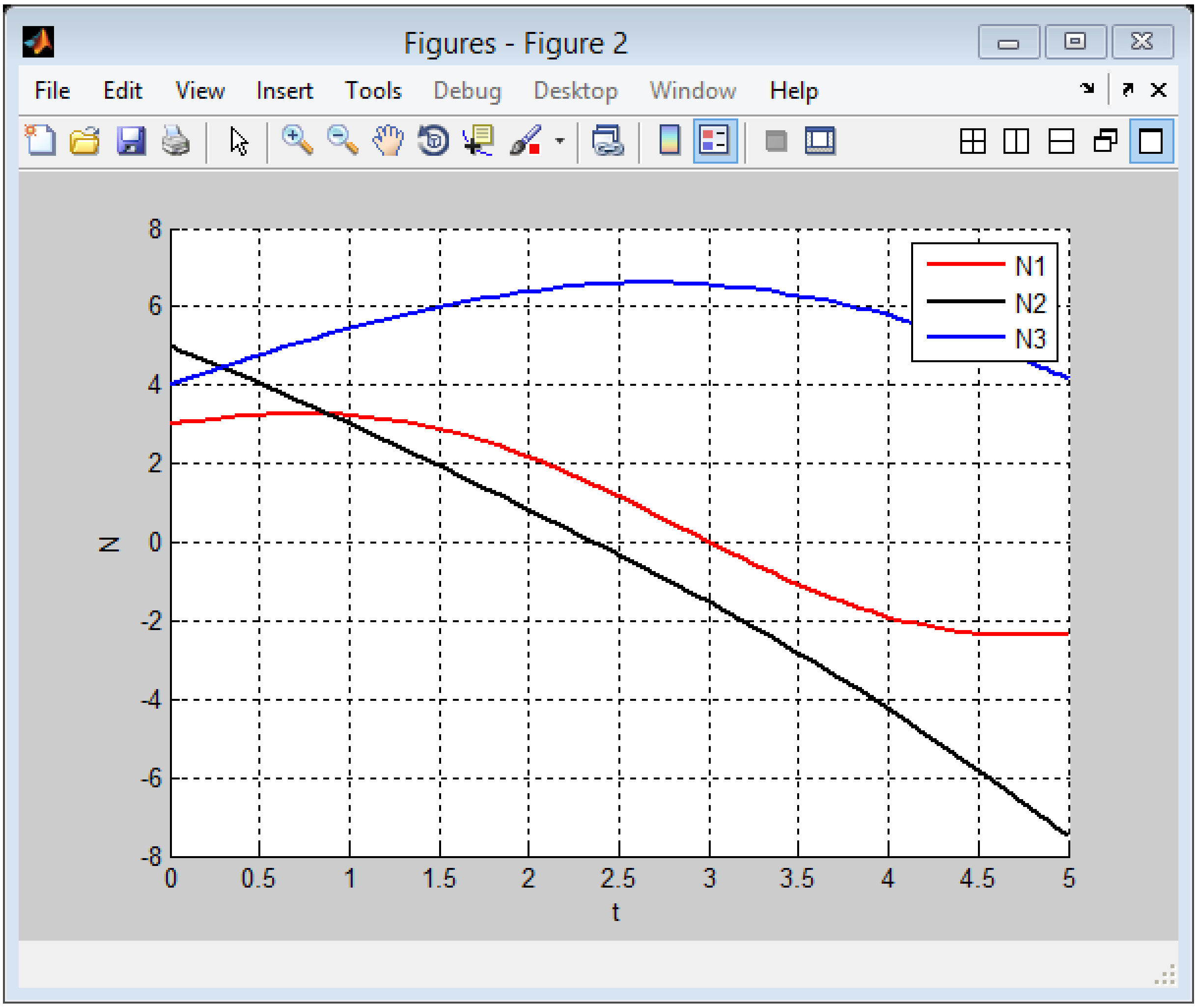
ISSN 1512-1232



2.5

```
function main
options=odeset('RelTol',1e-6);
No = [3;5;4];
 tspan = [0,5];
 [t,N] = ode45(@TestFunction,tspan,No,options);
figure
hold on
plot(t,N(:,1));plot(t,N(:,2));plot(t,N(:,3),':')
legend('N1','N2','N3');ylabel('N');xlabel('t')
grid on
return
function [dx_dt]= TestFunction(t,x)
dx_dt(1) = 0.12*x(1) + 0.14*x(1)* x(2)-0.2*x(3)-1;
dx_dt(2) = 0.12*x(2) - 0.04*x(1)*x(2)-0.2*x(3)-1;
dx_dt(3) =0.2*(x(1)+x(2)) ;
dx_dt = dx_dt';
return
```

ISSN 1512-1232



2.6

```
function main
options=odeset('RelTol',1e-6);
No = [7;5;4];
 tspan = [0,5];
 [t,N] = ode45(@TestFunction,tspan,No,options);
figure
hold on
plot(t,N(:,1));plot(t,N(:,2));plot(t,N(:,3),':')
legend('N1','N2','N3');ylabel('N');xlabel('t')
grid on
return
function [dx_dt]= TestFunction(t,x)
dx_dt(1) = 0.13*x(1) - 0.14*x(1)* x(2)-0.2*x(3)-1;
dx_dt(2) = 0.13*x(2) - 0.04*x(1)*x(2)-0.2*x(3)-1;
dx_dt(3) =0.07*(x(1)+x(2)) ;
dx_dt = dx_dt';
return
```

ISSN 1512-1232