Innovative Technology of Mathematical Modeling of Regulatory Mechanisms Medical Informatization

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Abstract: The article is devoted to modeling the regulatory mechanisms of the health care informatization process and analyzing the risk of the telemedicine business depending on the resource supply, availability and quality of IT technologies, highly qualified specialists, etc. Studies show that interconnected telemedicine centers have the following modes of functioning: stable functional activity, the possibility of oscillatory modes of functioning, irregular fluctuations (chaotic uncontrolled activities) and the black hole effect (collapse of projects)

Keywords: mechanisms, mathematical modeling, medicine, regulatory, innovative technology.

I. INTRODUCTION

Currently, intensive research is being carried out in the leading scientific centers of the world on the informatization of medicine, which is aimed at supporting decision-making on healthcare regulation, diagnosis, treatment and prevention using the latest medical information technologies, studying the mechanisms of the occurrence, existence and development of diseases using a computer. to study the patterns of regulation of information events involved in this process. It should be noted the ever-growing need in the world for regulatory science [1] not only in the field of medicine and biology, but also in other fields of science.

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At the moment, regulatory science includes basic and applied medical and social sciences, and contributes to the development of universal measures that do not affect the particular manifestations of certain diseases or phenomena, but regulate the state of the systems in question. In its strategic development plan, the European Agency for Medical Products put the following task at the forefront: “modernization of existing regulatory mechanisms, development of new regulatory mechanisms in areas where they are absent” [2]. It should be noted that the topic of developing regulatory mechanisms (regulation) of medical informatization in the context of globalization processes is poorly understood. Intensive research in the field of health informatization, carried out in recent years, has not led to significant progress in improving the availability and quality of medical care for people in remote regions, improving patient feedback, and reducing mortality due to various diseases. The problem of human health is a global problem, and multidisciplinary approaches, including mathematical modeling of the regulation of medical informatization, are needed to solve it.

II. FORMULATION OF THE PROBLEM

The following task is posed:

Analysis of the regulatory framework of two telemedicine centers in the context of globalization of health informatization, the activities of the first (X (t)) are characterized by a large number of highly qualified specialists and are based on highly developed medical information technology, and the second center (Y (t)) is less equipped and depends on the first . Currently, there is an increase in the number of software tools used in biology and medicine. However, the existing software systems are not intended for the study of dynamic systems with temporary relationships, cooperative processes and combined feedbacks, which is characteristic of the regulation of living systems and the introduction of information technology in healthcare. Their quantitative analysis can be carried out by means of the regulatory methodology, which will allow developing highly effective mechanisms for using modern means of communication for the remote provision of medical and consulting services, creating effective means of information technology for diagnosing, treating and predicting disease outcomes to provide objective, operational, environmentally friendly and resource-saving analysis technology mechanisms of living systems in biology and medicine, revealed effective points of influence in their regulatory system and to optimize the functional activity of biosystems in order to achieve normal modes of their life.

III. RESULTS AND DISCUSSIONS

The accumulated rich experimental material in biology and medicine, theoretical provisions regarding the mechanisms of the emergence, existence and development of living systems at the molecular genetics, cellular and cellular communities, the basic laws and principles developed in the field of structural and functional organization of living systems (for example, laws Mendel, Jacob-Mono, Drisha, the principles of Virchow, Liebig, Miln-Edwards, Holdein, Rashevsky, effects of Olli, Baldwin, Hayflick, etc.), the development of methods of exact sciences and means of inf radiation technologies (see the review works of large scientists on the eve of the new century JF Baily, 1998; AB Rubin, 1998; VA Ratner, 2001; VN Novoseltsev, 2012), the experience of modeling the regulation of living systems [3 -10] (taking into account the basic levels of organization, temporary relationships, cooperative processes, as well as non-linear feedbacks), they are a scientific and methodological platform for analyzing the regulatory mechanisms of the occurrence, development and consequences of human diseases, developing software for optimizing the treatment process organism. The theoretical foundations of regulatorics made it possible to develop general, basic equations (in the class of nonlinear functional differential equations) of the regulatorics of living systems, allowing for the spatial separation of biological processes, cooperativity, competition for signals and the presence of combined feedback in the cell regulation system [6]. Methods were developed for the qualitative and quantitative analysis on RS of the characteristic solutions of the equations of regulatorics using the analysis of the corresponding phase and parametric portraits, calculation of the Kolmogorov entropy, Lyapunov exponent, Hausdorff, information and higher dimensions of the system under consideration. Software tools for diagnosing, treating, and predicting the outcome of diseases have been built taking into account the structural and functional organization of cells, intercellular relationships, and body control in specific areas of the organs and tissues under consideration [3-8]. This allows us to carry out computational experiments at an object that is usual for representatives of medicine, to efficiently interpret the results of computer modeling of the functioning of the body under normal conditions and with anomalies, to develop real scientifically based recommendations for improving the body's condition in diseases, including using modern telemedicine for remote medical monitoring the patient’s health.

In individual countries, and indeed in the world as a whole, there are vast hard-to-reach regions where there is a lack of medical care for patients. The development of medical informatization can solve this problem. Consider the regulation of the two telemedicine centers and let the activity of the first (X (t)) be characterized by a large number of highly qualified specialists and based on highly developed medical information technology, while the second center (Y (t)) is less equipped and depends on the first. The system of equations governing the interconnected functioning of these centers has the form.

$$\varepsilon_1 \frac{dx(t)}{dt} = ax^2(t-1)e^{-y(t-1)} - x(t);$$

$$\varepsilon_2 \frac{dy(t)}{dt} = bx(t-1)y(t-1)e^{-x(t-1)} - y(t),$$

$\varepsilon_1, \varepsilon_2$ - regulatory parameters, a, b – resource supply parameters of centers ($\varepsilon_1, \varepsilon_2, a, b > 0$).

Consider the equilibrium position (Figure 1). Trivial equilibrium exists $O(x_0, y_0)$ always. Let be $x_0, y_0 > 0$. We have

$$ax_0e^{-y_0} = 1; bx_0e^{-x_0} = 1.$$

At $b = e$ we have one root, with $b > e$ two roots (x_1, y_1) moreover

$$0 < x_1 < 1 < x_2.$$

Table- II: Name of the Table that justify the values

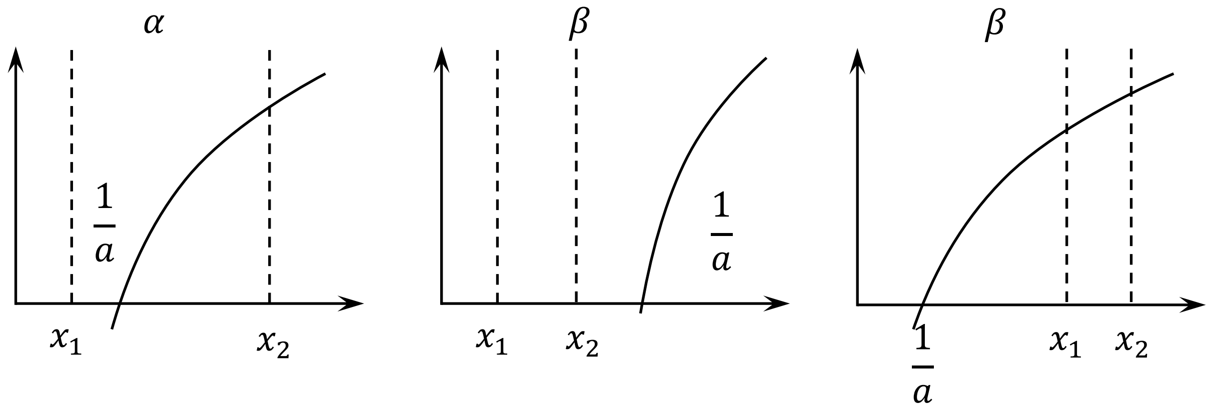

Figure 1 – Equilibrium positons of the system (1)

In this way,

1) If $e < b < ae^{\frac{1}{a}}, a > 0$, then
$$\frac{1}{a} < x_1 < 1 < x_2.$$
2) If $e < b < a^{\frac{1}{a}}, a < 1$, there are two roots
$$0 < x_1 < 1 < \frac{1}{a} < x_2.$$
3) If $b < e$ x_1, y_1 does not exist.
4) If $b > ae^{\frac{1}{a}}$ then
$$0 < x_1 < 1 < x_2 < \frac{1}{a}.$$

The parametric portrait (1) is shown in Figure 2.

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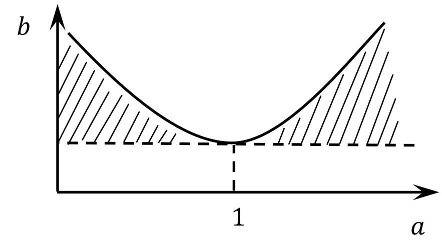

Figure 2 - Parametric portrait (1)

The first case is very interesting when system (1) has four equilibrium positions $O(0{,}0)$, $A(\frac{1}{a},0)$, $B(x_1,y_1)$, $C(x_2,y_2)$, (Figure 3).

Studies show that the positions *O*, *B* in equilibrium are attractors, and *A*, *C* are anti-attractors.

The linearized system of equations has the form

$$\begin{cases} \varepsilon_1 \dfrac{dx(t)}{dt} = 2x(t-1) - xy(t-1) - x(t); \\ \varepsilon_2 \dfrac{dy(t)}{dt} = y_1(\dfrac{1}{x} - 1)x(t-1) + y(t-1) - y(t). \end{cases}$$

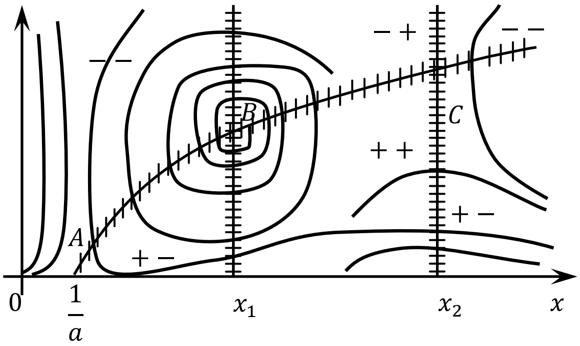

Figure 3 - Isoclines of the system (1)

The characteristic equation has the form

$$\begin{vmatrix} 2e^{-\lambda} - \varepsilon_1\lambda - 1 & -xe^{-\lambda} \\ y(\dfrac{1}{x} - 1)e^{-\lambda} & e^{-\lambda} - \varepsilon_2\lambda - 1 \end{vmatrix} = 0$$

or

$$(2e^{-\lambda} - \varepsilon_1\lambda - 1)(e^{-\lambda} - \varepsilon_2\lambda - 1) + xy(\frac{1}{x} - 1)e^{-2\lambda} = 0.$$

We denote

$$F = (2e^{-\lambda} - \varepsilon_1\lambda - 1)(e^{-\lambda} - \varepsilon_2\lambda - 1) + y(1-x)e^{-2\lambda} = 0.$$

$F(\lambda)$ is a continuous function.

$$\begin{cases} F(0) = 1 - y(1-x); \\ F(\infty) = \varepsilon_1\varepsilon_2\lambda^2. \end{cases}$$

Therefore, if $1 - y(1-x) < 0$, then there is a root $\lambda > 0$ and the equilibrium position is unstable.

Qualitative studies show that *O*, *A*, *C* are unstable, and *B* is a functional attractor, i.e. can be both stable and lose its stability. At certain values of the parameters of the system of equations (1), a transient economic collapse appears in the mutual functioning of the two centers (Figure 4).

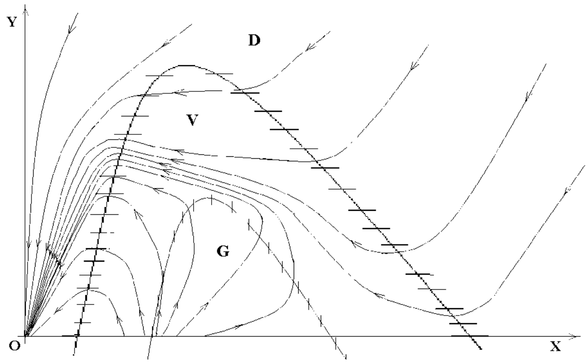

Figure 4 - Economic collapse in system interactions (1)

There are many parameter values for which the system of equations (1) describes the significant dominance of the first center and the repression of the second. The most interesting and important is the presence of (1) a regime of joint mutually beneficial cooperation (Figure 5).

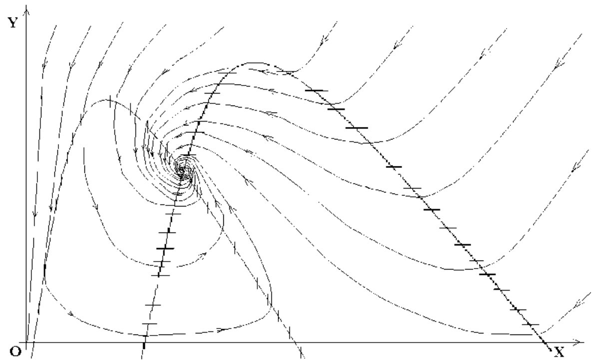

Figure 5 - Symbiotic regimen of the system (1)

The results of computer studies have shown the presence in the interconnected mutually beneficial functioning of the systems under consideration (in addition to the modes observed during a qualitative study) of the regime of dynamic chaos and the black hole effect. In the latter case, the activity of the first center decreases sharply and irreversibly. The regime of dynamic chaos is characterized by a violation of the system's regulatory system with a consequent deterioration in its functional activity.

Thus, we have determined, using the methods of qualitative analysis, the conditions for the occurrence of violations in the regulation of the interconnected activities of the two centers. Thus, a sequential increase in the regulation parameter, with an increase in the load and a change in the resource supply of the simulated system, there are successive transitions from stable functioning to periodic fluctuations, to uncontrolled chaotic activity and to sharp destructive activity disruptions.

IV. CONCLUSION

The introduction of fundamentally new information technologies in healthcare is necessary for the development in medicine of high technology, modern advanced methods and ways to improve public health systems; creation, on the basis of scientific achievements of biotechnology and the regulation of living systems of new diagnostic and therapeutic strategies in the treatment of people, highly effective drugs.

The main tasks of mathematical modeling of the regulatory mechanisms of the health care informatization process and the risk analysis of the telemedicine business are the knowledge of the laws of structural and functional formation of medical structures at any level of the hierarchy, the study of the complexity of their organization when interacting with other more equipped organizations, the analysis of regulatory processes both within the structures under consideration and when their interaction with the environment. The developed mathematical and computer models of the regulation of medicine informatization, taking into account the concomitant disturbances and the possibilities of correcting the regulatory mechanisms of functioning of the systems in question, can be used to analyze the conditions for the occurrence of disturbances in the regulation of functioning of the studied structures and organs at various levels of the organization; identifying regular, bifurcational and irregular behaviors; conducting computational experiments on choosing effective ways to correct the regulatory system of the studied systems using appropriately classified groups of regulatory parameters.

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