Digitalization as the Basis for the Automation of the Treatment Process

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ABSTRACT

The public health crisis and the pandemic threat have shown the urgent need to improve the management and implementation of medical care. Digitalization is seen as an effective tool for managing the disease treatment process. The problem is solved on the basis of the influence of factors x on the target indicator Y. The aim of the study is to improve the efficiency of treatment process management based on digital models. To achieve this goal, one needs to solve the following tasks: 1.To develop a methodology for building a strategy for managing the treatment process based on a digital model. 2 Visualize the implementation of a treatment strategy based on a digital model. For modeling, statistical information is used that reflects the values of factors and patient targets, using multivariate correlation and regression analysis. On the example of a digital model of a patient, a systematization of a set of numerical values characterizing the patient's condition for the corresponding disease has been carried out. It is shown that the visualization of digital information in projections with numerical marks provides the necessary effective communication between the user and the computer and allows you to make unambiguous decisions in determining and implementing the treatment process management strategy. This creates the prerequisites for automating the research process in the treatment of diseases.

Keywords: *digitalization, management of the treatment process, visualization*

1. INTRODUCTION

World Health Organization (WHO) formally recognizes COVID-19 coronavirus outbreak as a public health pandemic. The public health crisis and the pandemic threat have shown the urgent need to improve the management and implementation of medical care. The number of infected exceeded million people. The damage to the global economy from this disease has exceeded $ 1 trillion (1). The public health crisis and the pandemic threat have shown the urgent need to improve the management and implementation of medical care (2, 3).

According to Stephen Morse, a Professor at Columbia University's school of public health, the new drugs development requires a huge amount of time and resources (4). The lack of understanding of the mutation mechanisms naturally leads to the inability to create an adequate vaccine that would be able to develop immunity to this disease. Therefore, treatment of the disease does not always lead to a successful and quick result. Available medications may produce different effects, or may appear useless (5, 6). Research shows that the development of the scientific analysis experience with the analyzed parameters is a powerful incentive to achieve the benefits of using information technologies.

It is noteworthy that the Cambridge University has established the center for mathematical visualization in healthcare (CMIH). The centre was created after announcing a £10 million investment in five new UK research centres. The goal of these centers is to study how mathematics and statistics can help clinicians solve serious health problems (7).

1.1. Setting goals and objectives of the study

The complexity and special responsibility of the tasks to be solved in the field of health implies the mandatory need for a research approach to their solution. Digitalization is a powerful tool for solving research problems (8). "As we move toward more personalized, predictive, accurate healthcare, this data will be key... Continuous collection, analysis, and use of data on the health status of patients and the population can accelerate significant improvements in the delivery, measurement, and improvement of medical care" (9).

It should be noted that digitalization is currently limited to obtaining information for storing and receiving medical data of patients, remote monitoring of medical care, expanding the ability of patients to use information related to the provision of medical care, combining with data from other information sources, etc. (10-12).

In particular, the "Digital patient" model. The project is based on building virtual personal models of anatomical structures and functions of the patient's organs and tissues based on data from medical images, functional and laboratory studies. The new project will provide an individual research approach to diagnosis, planning and control of treatment. To implement the project, hardware and software systems are used for entering, processing and storing diagnostic information, providing visualization, processing and analysis of two-dimensional, three-dimensional, dynamic and multidimensional parametric images (10, 13).

Elements of fuzzy logic, genetic algorithm, artificial neural networks, and neuro-fuzzy hybrids are used to solve medical diagnostic problems (14). However, the use of fuzzy logic is limited by the impossibility of mathematical analysis of fuzzy systems by existing methods. In addition, the use of a fuzzy approach, in comparison with the probabilistic approach, does not lead to an increase in the calculations' accuracy. Digitalization is not limited to using a computer to improve the processing, storage, and visualization of information. This is a necessary, but only the initial step of digitalization. An important problem is not only the use of a computer as a research tool, but also the use of information technologies to improve the effectiveness of medical management (15, 16). It is necessary that these technologies accompany all the main stages of the treatment process from diagnosis to the practical implementation of the treatment strategy. This requires digital models of diseases, medications, and patients.

The aim of the study is to improve the efficiency of treatment process management based on digital models.

To achieve this goal, one needs to solve the following tasks:

1. To develop a methodology for building a strategy for managing the treatment process based on a digital model.
2. To illustrate the implementation of a strategy based on a digital model.

2. DEVELOPMENT OF A METHODOLOGY FOR BUILDING A STRATEGY FOR MANAGING THE TREATMENT PROCESS BASED ON A DIGITAL MODEL

Digitalization has been widely used, first of all, in the development of a strategy for the development of processes and their monitoring. A strategy is understood as a plan of actions coordinated in space and time, aimed at achieving the main goal in a special way. If there are no sufficiently accurate forecast calculations, therefore, it is impossible to clearly formulate a goal, and therefore it is impossible to develop an effective strategy.

One of the first stages of calculating a digital model, for example, of a patient, is to systematize a set of numerical values that characterize the patient's condition for the corresponding disease (17, 18, 19). For example, the results of analyses for a certain period. As a result of calculations, the correlation between factors x (analysis results) and the target indicator Y, which is characterized by the patient's health status, is established. In general, the task is to influence the x factors to achieve the desired result of the target Y. Statistical information from research materials that reflect the values of x factors and patient's y targets can be processed using, for example, a multivariate correlation and regression analysis. Then it is advisable to use a function, for example, of the following form:

$$Y = C_0 \prod_{i=1}^{n} x_i^{\alpha_i}$$

. Where Y is a target index; xi , $i = \overline{1,n}$ factors influencing Y; αi, $i = \overline{1,n}$ degree indicators that characterize the "contribution" of xi into Y; C0 – coefficient. Let's consider a digital model based on the specified function, for example, of the following form:

Y=1.231 x11.228 x21.602 x3 0.413 x40.321 x5 0,132 (1)

It should be emphasized that this patient model allows us to consider factors and the target indicator in a system where factors and the indicator are interrelated and interdependent. The resulting digital model (1) describes the hypersurface, which uses an analytical form to reflect the state of a particular patient under study, which makes it possible to perform various actions on this surface related to optimizing the strategy for solving a specific medical problem.

To facilitate visualization of the problem solution, we will limit ourselves to a three-dimensional model that includes factors x1 and x2 as having the greatest impact on Y. We use a simplified two-factor digital model of the studied patient and, giving different values for x1 and x2, we get the calculated values of Y.

3. VISUALIZATION OF THE TREATMENT MANAGEMENT STRATEGY

When speaking about the strategy of a scientific problem solution we understand a synchronized plan of actions in time and space according to large groups of indicators which are determined by a definite way (innovative constituent) and which provides the achievement of the main goal on the basis of adequately used conditions and means (20).

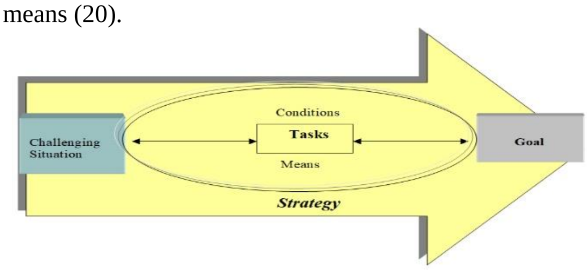

Figure 1 Management diagram on the basis of a strategy

The need to solve a complex problem is associated with the emergence of a problem situation (Fig.1). Objectively, the occurrence of a difficult situation is determined by the process of the development of the disease and progress. To find a solution to a difficult situation, it is necessary that each finite set of existing factors A have an appropriate finite set of necessary factors B that provide a solution to the problem. Then we can write a mathematical expression as follows:

A ~ B, (2)

If sets An do not intersect, so

$A_n \bigcap A_{n'} = \varnothing$ at $n \neq n'$, (3)

And sets Bn also do not intersect, i.e.

$B_n \bigcap B_{n'} = \varnothing$ at $n \neq n'$ (4)

For all n An~Bn . Then every has

$a_0 \in \bigcup_{n=1}^{m} A_n$ (5)

A corresponding unique element

$b_0 \in \bigcup_{n=1}^{m} B_n.$ (6)

If every element from the set A according to a certain rule can be related to one and only one element of the set B and at the same time every element from the set B will be related to one and only one element from the set A then

$\bigcup_{n=1}^{m} A_n \sim \bigcup_{n=1}^{m} B_n.$ (7)

Achieving a one-to-one correspondence (7) through the implementation of a number of measures that may be related to solving a problem may indicate that the problem situation has a solution.

4. RESULTS AND DISCUSSION

The obtained values (1) for the two-factor digital model allow you to build a three-dimensional surface, for example, Figure 2, which can be used to search for a management strategy, for example, achieving a set value of Y (7).

Curves 1Y and 2Y are isoquants that connect the calculated points to the same values of target indicators. Curve -2Y connects the calculated points with the same numerical values of the target indicator, the value of which should be achieved as a result of therapy.

As seen in Fig.2, the same value of 2Y can be achieved by an infinite number of combinations of x1 and x2 factors. For example, at the start of treatment actions, the level of target index 1Y is characterized by point A and its projections A1, A 2, and A3.

An infinite number of treatment options can be used to achieve the 2Y target from point A. Let's consider three options, for example, output to B, C, and D. Each point is characterized by projections B1, B2, B3, C1, C2, C3, D1, D2, D3 and Bx1, Bx2, Cx1, Cx2, Dx1, Dx2, which determine the parameters of the factors when the target value of 2Y is reached. As can be seen from Fig. 2, achieving the 2Y target is accompanied by different combinations of factor values. For example, OCx1<ODx1, but OCx2>O .

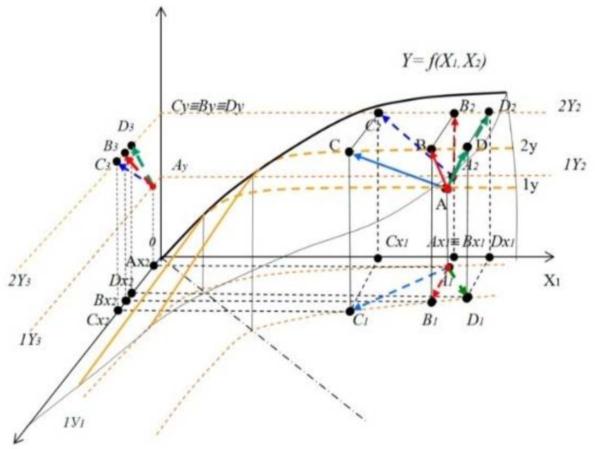

Figure 2 Three-dimensional graphical model of the implementation of the disease treatment strategy

Therefore, in the current system under study, the 2Y can be achieved by different values of x1 and x2 factors. For the implementation of therapeutic measures, depending on the actual conditions (the patient's condition, the availability of appropriate conditions, equipment and medicines, etc.), the corresponding values of

x1 and x2 are selected. From the mathematical point of view, the best option is AB, since AB is perpendicular from point A to the overlying isoquant to the tangent at point B and is the shortest distance between the isoquants.

An illustration of the formation of a strategy for managing the medical problem solution in development is clearly seen in Figure 3 in projections with numeric marks.

There can be an infinite number of options for a management strategy. Let's describe the three in detail.

For example, the variant A1D1E1 with constant values of the x1 factor and a constant increase in x2, ultimately provides for achieving the goal N.

Similarly, the A1F1G1 strategy can be developed. However, the direction of A1B1C1 clearly and convincingly indicates that an effective strategy has a different direction, providing passage over the shortest distance between the isoquants.

It should be noted that the digital model implemented in projections with numerical marks also reflects the qualitative characteristics of the strategy. For example, the isoquants at the same scale for two different strategies can indirectly determine the time spent on their implementation. The smaller the distance between them, the greater steepness the digital model surface has, the more intense the influence of factors is on the target indicator, and the less time is spent on the treatment process.

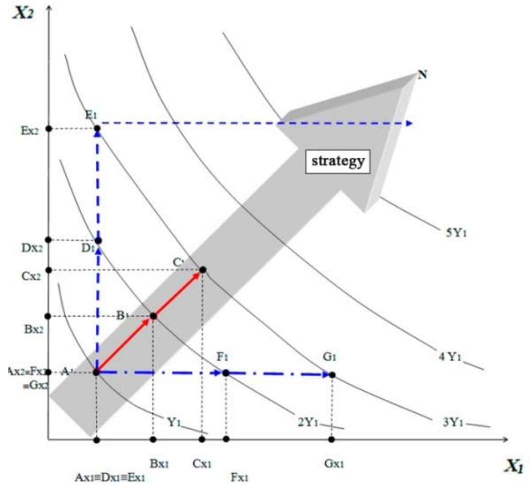

Figure 3 Direction of the treatment process strategy

Let's illustrate the consequences of avoiding the chosen management strategy. For example, in Figure 4, the operational management of A1E1D1 retains the direction of the strategy, yet a bias is allowed, due to a significant decrease in the value of the x1 factor, which can be seen in the parameters Ex1 and Ex2.

The implementation of this management will not lead to the achievement of the target indicator, characterized by N point. This can be seen from the trajectory E1D1H1. After reaching the 3Y1 target, despite the further increase in the x1 and x2 values (Hx1 and Hx2), the value of the target indicator increases slightly at first, and then decreases after H1, as can be seen in Figure 4. In this example, the visualization of a strategy based on a three-dimensional graphical model of software cannot be considered complete enough, because only two factors of the model (1), x1 and x2 of the five that have the greatest impact on Y are used. For a more precise definition of the strategy, it is advisable to conduct an

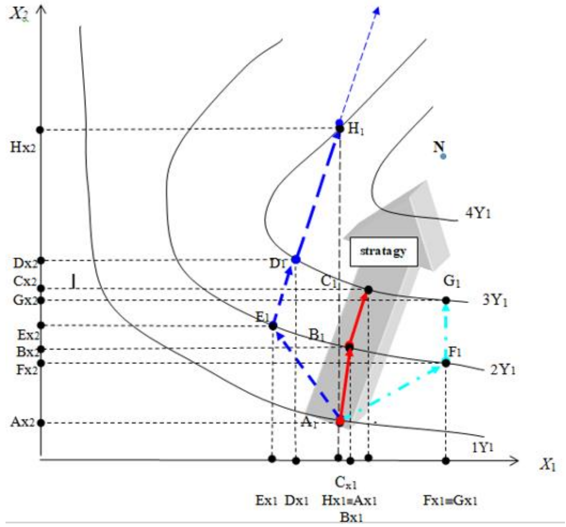

Figure 4 Visualization of the consequences of evasion from optimal strategy

analytical analysis on a multidimensional model, which from the standpoint of mathematics is not very difficult, for example, (17, 21). It should be noted that the actual direction of the strategy for A1B1C1 is determined not only by the shortest distance between the isoquants, but also by the conditions for using factors. To optimize their combination is a separate task, for example, (22,23,24).

The proposed approach to managing the treatment process based on a digital model, such as a patient, does not require the development of special software, since it is included in the standard set of modern computers.

According to experts at Stanford University, "biological science and technology will become even more important for our societies, and we need strategies to learn how to manage their power" (25,26).

5. CONCLUSION

Digital models are a promising tool for unambiguous diagnosis of diseases and their effective treatment. It is established that the digital model can be used to build a strategy for managing the treatment process. This creates the prerequisites for increasing the efficiency, accuracy and automation of research activities associated with the treatment process. The digital model is formed from a set of statistical information reflecting various retrospective results of the studied processes of target indicators and factors' interdependence. Visualization of the digital model allows to illustrate the construction of various options for managing the treatment process. The optimal management strategy is determined by the accepted optimality criterion. It is shown that one of the primary tasks of digitalization is a fairly accurate and rapid numerical determination of the treatment process' prognostic results based on the results of the factors' use. Based on the retrospective information of research results that characterize the patient's condition, a multi-factor correlation and regression analysis was used to perform digital modeling that allows solving treatment problems by forming a management strategy and implementing targeted treatment methods. The proposed approach can be implemented in the development of digital models of diseases and medicines, which creates prerequisites for a significant reduction in the cost of time and money in solving health problems.

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