Modeling of biosystems from the stand point of "complexity" by W. Weaver and "fuzziness" by L.A. Zadeh

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Abstract. The founder of information theory W. Weaver in 1948 and the theory of "Fuzziness" L.A. Zadeh spoke about the specifics of the behavior of living systems. In particular, W. Weaver took all living systems-systems of the third type-beyond the stochastic and deterministic approaches. Over the past many decades, no one has tried to test the hypotheses of these scientists from the standpoint of a special information approach to the description of biosystems. In recent years, the Eskov-Zinchenko effect was discovered, which dramatically changed the methods in the description of living systems. This effect is based on the proof of statistical instability of the samples of parameters of any functions of the human body. In this case, an analog of the Heisenberg uncertainty principle is introduced in the description of biosystems. As a result, new information technologies and new models for describing biological systems are emerging.

1. Introduction
The basis of any information approach in the study of any living systems is the stochastic approach. For the last 100-150 years, the principle of causality has firmly dominated biomedicine and other life sciences. This means that the past state of the biological system can determine its future state. However, this fundamental statement is now undergoing revision [1-6].

In the framework of modern deterministic and stochastic science, this means that the information about the parameters of the state vector of the biosystem \( x = x(t) = (x_1, x_2, ..., x_m)^T \), in the \( m \)-dimensional phase space of states is historical (unique). It is impossible to predict the future state of the biological system from the information about the parameters of the initial state of the vector \( x(t_0) \) and from the equation (in the form of differential, integral, difference, etc.), which described the past dynamics.

It is significant that as early as 1948, W. Weaver [7] took all systems of the third type (STT) beyond the limits of stochastics. He proposed the hypothesis that living systems (STT) cannot be described in the framework of stochastics [7]. A year before its publication, N. A. Bernstein [8] proposed the hypothesis of "repetition without repetition" in biomechanics. However, over the past 70 years, no one has tried to prove this hypothesis. Obviously, both of these scientists came into conflict with the entire deterministic and stochastic science and they were simply silenced all these decades [1-6].

However, over the past 20 years, many facts have accumulated that prove the reality of these two hypotheses [1-6, 9-13]. As a result, we now come to a new science – the theory of chaos-self-organization (TCS). In this TCS, according to the theorem of K. Gödel, new concepts, new laws and new models are introduced to describe STT. In this connection, there is a special complexity of the entire information science when describing systems of the third type [1-6].
2. The emergence of real complexity for deterministic and stochastic science in the works of N. A. Bernstein and W. Weaver

First of all, we note that chronologically, the work of N. A. Bernstein was the first to appear [8]. In it, he proved that at least five different systems (A, B, C, D, E) participate in the organization of movements, which are chaotically involved in the work of muscles (for a chaotic time interval, not a periodic one). Therefore, N. A. Bernstein put forward the hypothesis of "repetition without repetition" in biomechanics. However, he did not specify what "repetitions" could be discussed. Are there no exact repetitions (within the framework of determinism) or are there no statistical repetitions for the phase trajectory \( x(t) \) and its final state \( x(t_{\text{final}}) \)?

A year later, W. Weaver made a revolutionary statement in general. For the first time (in the history of all science) he gave a general classification of all the systems of nature. At the same time, he singled out all living systems in a special class (STT), which cannot be described in the framework of stochastics (this was his hypothesis). As a result, N.A. Bernstein and W. Weaver for the first time put forward hypotheses that living systems cannot be the object of stochastic research methods. However, these hypotheses have not been proven in all modern science. For more than 70 years, they were simply ignored [1-6].

Now they are proved in the framework of the Eskov-Zinchenko effect (EZE), first in biomechanics, and then for all other parameters of human functions [14-20]. For this proof, it is enough to register 15 samples of tremorograms (TMG) from the same person in a row, and then build a matrix of paired comparisons of these samples. In this matrix, the values of the Wilcoxon criterion \( P_i \) are entered for each pair of the i-th and j-th TMG samples being compared. As a result, in such matrices, we find the numbers \( K \) of pairs of samples for which \( P_{ij} \geq 0.05 \). In this case, such a pair of TMG samples may have one (common) general population, i.e. these two TMG samples may statistically coincide [14-20].

For example, we present a single, characteristic matrix of paired comparisons of 15 samples of TMG (the same subject) from several hundred such matrices that were calculated for TMG, TPG, for RR intervals (cardiointervals), electromyograms (EMG), electroencephalograms (EEG) and other parameters of human body functions. In the Table 1 we have an extremely low value of \( K_{ij}=4 \), which proves the lack of statistical stability of the TMG samples. Similar data were obtained for TPG, RR intervals, EMG, and EEG.

**Table 1.** Example of matrix for pairwise comparison of tremorograms samples of test subject (no load, number of repetitions \( N=15 \)), the Wilcoxon test was used (significance \( p<0.05 \), number of matches \( k_{ij}=4 \)).

|     | 1   | 2   | 3   | 4   | 5   | 6   | 7   | 8   | 9   | 10  | 11  | 12  | 13  | 14  | 15  |
|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|
| 1   | -   | 0.00| 0.00| 0.00| 0.00| 0.00| 0.00| 0.00| 0.00| 0.00| 0.00| 0.00| 0.00| 0.00| 0.00|
| 2   | 0.00| -   | 0.00| 0.00| 0.00| 0.00| 0.00| 0.00| 0.13| 0.00| 0.00| 0.00| 0.00| 0.00| 0.00|
| 3   | 0.00| -   | 0.00| 0.00| 0.00| 0.00| 0.00| 0.00| 0.00| 0.00| 0.00| 0.00| 0.00| 0.00| 0.00|
| 4   | 0.00| 0.00| -   | 0.00| 0.00| 0.00| 0.00| 0.00| 0.00| 0.00| 0.00| 0.00| 0.00| 0.00| 0.00|
| 5   | 0.00| 0.00| 0.00| -   | 0.00| 0.00| 0.00| 0.00| 0.00| 0.00| 0.00| 0.00| 0.00| 0.00| 0.00|
| 6   | 0.00| 0.00| 0.00| 0.00| -   | 0.00| 0.00| 0.00| 0.00| 0.00| 0.00| 0.00| 0.00| 0.00| 0.00|
| 7   | 0.00| 0.00| 0.00| 0.00| 0.00| -   | 0.00| 0.00| 0.00| 0.00| 0.00| 0.00| 0.00| 0.00| 0.00|
| 8   | 0.00| 0.00| 0.00| 0.00| 0.00| 0.00| -   | 0.00| 0.00| 0.00| 0.00| 0.00| 0.00| 0.00| 0.00|
| 9   | 0.00| 0.00| 0.00| 0.00| 0.00| 0.00| -   | 0.00| 0.00| 0.00| 0.00| 0.00| 0.00| 0.00| 0.00|
| 10  | 0.00| 0.00| 0.00| 0.00| 0.00| 0.00| 0.00| -   | 0.00| 0.00| 0.00| 0.00| 0.00| 0.00| 0.00|
| 11  | 0.00| 0.00| 0.00| 0.00| 0.00| 0.00| 0.00| 0.00| 0.06| 0.00| 0.00| 0.00| 0.00| 0.00| 0.00|
| 12  | 0.00| 0.00| 0.00| 0.00| 0.00| 0.00| 0.00| 0.00| 0.00| 0.00| 0.00| 0.00| 0.00| 0.00| 0.00|
| 13  | 0.00| 0.00| 0.00| 0.00| 0.00| 0.00| 0.00| 0.00| 0.00| 0.00| 0.00| 0.00| 0.00| 0.00| 0.00|
| 14  | 0.00| 0.00| 0.00| 0.00| 0.00| 0.00| 0.00| 0.00| 0.00| 0.00| 0.00| 0.00| 0.00| 0.00| 0.00|
| 15  | 0.00| 0.00| 0.00| 0.00| 0.00| 0.00| 0.00| 0.00| 0.00| 0.00| 0.00| 0.00| 0.00| 0.00| 0.00|

As a result, we come to the proof of the lack of statistical stability of samples of various parameters \( x_i(t) \) of the human body. If the samples are unique (statistically non-repeatable), then there is a problem
of further application of stochastics in the study of biosystems. W. Weaver was right, because statistics are not applicable for STT (living systems) and new information technologies are required to describe living systems. Let us consider them in detail from the standpoint of the new theory of chaos-self-organization.

3. An analogue of the Heisenberg uncertainty principle in the description of CTT

Recall that in the Heisenberg principle, restrictions are imposed on two phase coordinates: $x_1(t)$ – the coordinate of the particle and $x_2=dx_1/dt$ – the speed of motion of the quantum object. Indeed, if the mass $m$ of the particle does not depend on the velocity (this will be for small $x_2$-velocities), then the mass $m$ in the Heisenberg inequality $\Delta x \times \Delta p \geq \hbar/4\pi$ can be moved to the right, and we get the inequality for the two phase coordinates:

$$\Delta x_1 \times \Delta x_2 \geq \hbar/(4\pi m)$$  \hspace{1cm} (1)

For biosystems, we proposed a system of inequalities, where restrictions are imposed on the same phase coordinates $x_1$ and $x_2$ both from above and from below (on the numerical axis):

$$Z_{\text{max}} \geq \Delta x_1 \times \Delta x_2 \geq Z_{\text{min}}$$ \hspace{1cm} (2)

Here, $Z_{\text{max}}$ and $Z_{\text{min}}$ are some constants that characterize the state of a particular person’s body and they limit the resulting variation ranges in the form of $\Delta x_1$ and $\Delta x_2$ for these phase coordinates. As a result, for any biological system in the phase coordinates $x_1$ and $x_2=dx_1/dt$, we can always plot the phase trajectories for the vector $x(t)=(x_1, x_2)$ and determine the area $S=\Delta x_1 \times \Delta x_2$, within which the phase portrait of this biosystem is located. We emphasize that the TCS proves the strict limitation of the area $S=\Delta x_1 \times \Delta x_2$, within which this phase portrait is located [1-6, 19-23].

For all such samples of TMG, TPG, EMG, EEG, and RR intervals, thousands of phase portraits were constructed and the areas of rectangles $S$ were found for them, within which the phase portraits are located. In all cases, it was found that the area $S$, which is denoted as the area of the pseudoattractor (PA), is a numerical characteristic of the physiological state of a person. When this state changes, the area for the PA also changes significantly [9-13, 15-23].

To illustrate the above, we present an example of comparing samples of 15 areas of pseudoattractor for human TMG before loading (see figure 1) and after the static load $F=3N$. Obviously, this load significantly increases the area $S$ of the PA. Indeed, in figure 1 the mean area $S_1$ for PA before the load was $<S_1>=S_1=0.23 \times 10^{-6}$ a.u. However, after a static load on the finger with $F=3N$, we observe a sharp increase in the mean area of PA $S_2$ to the value $<S_2>=S_2=1.30 \times 10^{-6}$ a.u. As a result, such an area can be an invariant for assessing the immutability of homeostasis (or the state of the human functional system), or, conversely, this all proves the presence of these changes under external influences. Figure 1 clearly demonstrates this.

![Figure 1. Phase portraits of the movement of the fingers of the test subject: A-without load (pseudoattractor area S1=0.23*10^{-6} a.u.), B - with load 3N (pseudoattractor area S2=1.30*10^{-6} a.u.).](image-url)
We emphasize that we have obtained a great number of such tables, and all of them prove that the area of PA (in contrast to the statistical functions f(x) and various statistical characteristics) accurately show the immutability of the human body or its change, if it occurs under the influence of factors or under observation (in medicine). In the latter case, the area of the PA also changes. As a result, we can now talk about new estimates of the parameters of human body functions based on the calculation of the parameters of pseudoattractors (PA). This is a fundamentally different approach, because these PA are preserved, while the statistical functions f(x) continuously (and chaotically) change [18-23].

In fact, we are talking about new information technologies that should replace the methods of stochastics [1-6]. We emphasize that within the pseudoattractor, the samples continuously demonstrate a chaos of statistical distribution functions (and this is considered a change in stochastics, but there are no changes in STT). At the same time, the boundaries of the PA in the framework of statistics remain unchanged, if nothing significant happens to the human body. Now we offer new methods for assessing the immutability of the states of the functions of the human body. At the same time, models in the form of PA clearly show real changes in the body, which is impossible to perform within the framework of stochastics.

4. Discussion
More than 70 years ago, two outstanding scientists of the 20th century, N. A. Bernstein and W. Weaver, hypothesized that further application of statistical methods in the study of biological systems would be useless. W. Weaver proposed a revolutionary hypothesis that living systems (STT) are not the object of a stochastic approach. However, neither he nor other researchers in these 70 years have offered a proof of the hypotheses of W. Weaver and N. A. Bernstein (about "repetition without repetition"). As a result, for more than 150 years, all biomechanics has been based on the theory of dynamical systems (determinism and stochastics). This is the dogma of the entire deterministic and stochastic approach in biomedicine.

However, over the past 20 years, our scientific schools have proven the Eskov-Zinchenko effect. In this EZE, there is no statistical stability of samples of any parameters of human body functions. In fact, EZE proves the uniqueness of any sample and it reliably refutes the cause-and-effect relationship. If the past does not affect the future, then all modern deterministic-stochastic science cannot describe biosystems (they are unique).

According to the theorem of K. Gödel, we then have to go beyond the deterministic and stochastic science and create a new theory, new concepts, new models for describing living systems. It is obvious that in such a new science, the basic concepts of deterministic and stochastic science will also change. For example, within pseudoattractor the state vector fo biosystem x(t) performs a continuous and chaotic motion. Obviously, if the biosystem does not change its state, then the parameters of its PA will be statistically unchanged. Therefore, chaos (and the continuous motion of x(t) in the deterministic and stochastic science) will represent the rest of the biosystem in the context of the theory of chaos-self-organization-TCS [1-6, 16-23].

The reverse situation is also possible, when state of rest (immutability) of biosystem in the deterministic and stochastic science will be the movement (change) of the biosystem in the theory of chaos-self-organization. We have observed the inversion of concepts, and these are completely new concepts for deterministic and stochastic science. In general, TCS does use new concepts (for example, a pseudoattractor) and new laws of behavior of living systems. These laws have no analogues in modern science [1-6, 15-20].

5. Conclusions
More than 70 years ago, two outstanding scientists, N.A. Bernstein (the hypothesis of "repetition without repetition") and W. Weaver (the hypothesis of STT - not the object of deterministic and stochastic science), offered humanity very unusual works. In these works, in fact, living systems were taken
beyond the limits of all science. According to the theorem of K. Gödel, then it was necessary to build a new science, but for it it is necessary to know the special properties of living systems.

These special properties were discovered at the turn of the 20th and 21st centuries, and they were manifested in the absence of statistical stability of samples of any parameters of the x(t) of the human body (EZE). As a result, a new theory of chaos-self-organization is being created, which introduces the concept of a pseudo-tractor and presents an inversion of the concepts of rest and motion for STT. A special complexity and uncertainty is proved for living systems within the framework of theory of chaos-self-organization and EZE.

Uncertainty and complexity can be solved on the basis of an analog of the Heisenberg uncertainty principle for biosystems. We propose to use the calculation of the parameters of pseudotractors and the calculation of the matrices of paired comparisons of samples. In this case, we move away from uncertainty, and the parameters of pseudo-tractors characterize the state of the biological system. New information technologies are emerging based on the hypotheses of N.A. Bernstein and W. Weaver.

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