Metrology of biotechnical systems

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Abstract. The history of creation and features of functioning of biotechnical systems, types of feedbacks and their role in the work of complex systems are considered in the article. The idea of biofeedback, the prospects of its application and the difference from the traditionally used one in the technique of feedbacks are given. Due to the increasing requirements for measurement accuracy, the special role of Metrology in the development and operation of biotechnical systems is emphasize. Traditionally used sections of Metrology are specified: theoretical, legislative and applied. In relation to living objects, Metrology is considered as a special discipline-biometrology. The article proposes to consider the information in the BTS as a subjective perception relating to the subject of perception, which is a human operator. It is proved that it is the cognitive functions of the human operator that give information subjective properties. The thesis about the possibility of using the concept of "image" as a biometrological concept denoting a unit of information in bio-technical systems is put forward.

1. Introduction
Biotechnical systems (BTS) are a special class of complex systems consisting of a set of biological and technical elements combined into a single functional system of purposeful behavior. The main difficulty in creating such systems is the presence of a living organism with probabilistic non-deterministic characteristics of behavior in them, especially given the huge variety of terrestrial species of animals, plants, and microorganisms. A human, unlike other living beings, besides the direct exchange of substances between the organism and the environment, actively uses intellectual activity in order to create a variety of technical devices to improve the quality of life on Earth.

The development of scientific and technological progress was accompanied by the emergence and development of new scientific disciplines - bionics, cybernetics, systems engineering - directions that used a unified approach to the study of animate and inanimate nature objects. These three areas were the basis for the formation in the 60s. of the last century, the theory of bio-technical systems, the foundation of which was the theory of system design, the methodology of bionics and the cybernetic approach. After the emergence of this direction, especially with the increasing role of computers, in recent years, the need for the biotechnical systems development that is diverse in its purpose and increasingly complex in functions, and levels of development has been continuously increasing. All this stimulated the development of this scientific direction.

Research and creation of biotechnical systems is a process of scientific research, design, technological development associated with solving urgent problems determined by the features and goals of a specific system being created [1].

When developing, analyzing and comparing complex systems, a number of functional characteristics are introduced: efficiency, reliability, control quality, noise immunity, stability, degree of complexity.
Quantitatively, these characteristics can be obtained experimentally or analytically if there is a mathematical description of the system.

Purposefulness of the system's behavior, i.e. its self-adaptation and self-organization is ensured by the action of feedbacks aimed at controlling the quality of control of processes and the role of which is discussed in detail in the theory of automatic control (TAC) [2]

The feedback action is as follows:
- the influence of the control object on the control device;
- transfer of influence or information from the output of the system to its input;
- the influence of the result of the functioning of the system on the very nature of functioning.

The following types of feedback are distinguished: by deviation, by indignation; positive, negative.

In biotechnical systems, in addition to the traditional types of feedback used in technology, biofeedback is used ((English - biofeedback) - BFB) [3]. Such a connection is a special technology that includes a complex of research, preventive and therapeutic procedures in which a person is presented with information about the state and changes in his own physiological processes through external feedback. Thus, in real time, the possibility of their conscious control is created, strengthening or weakening the presented physiological indicator.

A huge variety of biotechnical systems, different in complexity and purpose, have been created. A typical example of such a system is the hardware complex developed at the St. Petersburg Federal State Budgetary Scientific Institution "Institute of Experimental Medicine", developed for research on the study of the mechanisms of organ’s and systemic hemodynamics’ regulation [4]. This complex allows to obtain new data on the regulation mechanisms of the conjugated functions of the various organs’ vessels (including the microcirculatory level), as well as makes it possible to determine the causes of the pathological disorders occurrence and development in the work of the circulatory system.

2. Metrology and biometrology

In connection with the development of science, technology, the introduction of new technologies, standards, measuring instruments, the need and role of using measuring equipment increases, the ranges of measurements are expanding. The requirements for the measurements accuracy are also increasing.

Metrology deals with these issues.

Metrology is the science of measurements, methods and means of ensuring their unity, and ways to achieve the required accuracy [5, 6].

In the USSR, metrology developed as a state discipline, since with the development of technical means and the military-industrial complex, the requirements for the accuracy of measurements increased. In such conditions, it has become necessary to create a unified scientific and legal framework that would ensure high quality measurements, regardless of the place and purpose of their conduct.

Currently, three interrelated sections of metrology have been formed: theoretical, legislative and applied.

Theoretical metrology is the basis of measuring technology, it studies the problems of measurements in general and the elements forming the measurement: measuring instruments, physical quantities and their units, methods and measurement techniques, statistical processing and analysis of results and measurement errors, etc.

Legal metrology - develops and implements norms and rules for performing measurements, establishes requirements aimed at achieving the uniformity of measurements, the procedure for developing and testing measuring instruments, establishes standards for metrological terms and definitions, units of physical quantities used and rules for their application.

Applied or Practical Metrology - deals with the practical application of theoretical developments and the provisions of legal metrology. With its help, metrological support of production in the national economy is carried out.

With regard to living objects, metrology is considered as a special discipline - biometrology. Traditionally (historically) this term is used as a system for recognizing people based on one or more physical or behavioral characteristics. It is often used when studying the influence of various factors
(weather conditions, psychological influences, etc.) on the body of a healthy and sick person. When considering the effect of weather conditions on humans, the term biometeorology is often used. In modern science, biometrology has a broader interpretation - it is applied not only to humans, but also to other living biological objects in determining the influence of various factors on their condition.

The complexity of the metrological control of living systems and the subsequent analysis of the obtained measurement information is determined by the fact that such systems are nonlinear, open and nonequilibrium [7, 8], under the influence of various regulatory circuits (nervous, humoral, metabolic, biophysical). General methods for the analysis of such systems are currently not given in the literature, but a number of approaches have been outlined [7, 9, 10] to the quantitative study of the processes occurring in them. At the same time, it is necessary to solve the problems of terminology in modern science. For example, if you do not discern the nuances in the interpretation of the word "consciousness", in the process of reasoning one can come to the conclusion that everything in the world has consciousness; or to the opposite conclusion - that there is no consciousness at all, even in humans. Moreover, both conclusions will be both true and false.

A particularly complex and controversial concept from the point of view of biometrology in biotechnical systems is the concept of information, which is due to the fact that information plays a special role for a human operator in BTS. In the classical theory of information, the question was somehow unnoticed, for whom exactly this "measure of uncertainty", this "novelty" or measure of "surprise" is information. It can be considered that information does not arise by itself in the form of an event, but only in connection with two subjects, between which this information is exchanged. And, depending on the current direction of information transfer, each of these subjects can act both as a source of information and as a consumer. If, however, the subject seeks to obtain information from observations of events chosen by himself, he will simultaneously act in both roles - as a source and as a consumer.

Postulating the presence of two subjects in the very definition of information, it is necessary to explain what is new with the introduction of such a model. For a better understanding of this need, we can consider the process of perceiving information simultaneously by three consumers, one of which will be a mechanical recorder, and the other two are living subjects located at points with different spatial coordinates. When an event occurs, information about it will go to all three consumers, but all consumers may find themselves in three different situations: the recorder (R) records the reception of a message on its data carrier and, depending on the capacity of this carrier and the mode work will either permanently save the record in the multivolume archive, or erase it when overwritten after the medium is full. Subject 1 (S1) will perceive the message as a fact, which will contain more information about the very arrival of this message than about its content. And subject 2 (S2) will perceive this message as very personal, filled with emotions calling for immediate action, which, perhaps, will be immediately carried out by him. Thus, for each of the subjects, the flow of information will form three different situations, in each of which the meaning, value, volume and significance of this information will be completely different. In the case of the recorder R, it is hardly possible to talk about any information at all, unless the subject S2 turns to R to replay this message. In the case of subject S1, only one thing can be said with certainty - information has been received, but its value can be determined only if subject S2 is not satisfied with listening to the message recorded by R and wants to receive a confirmation, for which he turns to S1. And only in the third case, the contained in the message information will be really very valuable information, but only for one subject - S2.

From the above example, at least one important conclusion follows that information has a lifespan determined by three parameters: the time of its distribution, the time of its storage and the time of demand. And also one consequence - quite definable qualitative and quantitative characteristics of sources and consumers of information, considered as subjects, give information the properties of subjectivity and subjectivity, which in general changes the traditional ideas about information and information processes.

In biotechnical systems, a significant part of the information from which the subject S1 selects what is of interest to him personally is presented to him on monitors, screens, scoreboards, LED panels and other visualization devices, which means that the generated video signal turns out to be an artificial
analogue of the original image. The slightest misrepresentation of information during transcoding or the loss of even a part of significant information in an artificial video signal can lead to the operator missing the information of interest.

In general, the sequence of transforming visualized information into an information model of actions when selecting the necessary information from the general information picture can be represented by the model shown in figure 1 [11].

Figure 1. Model of transformation of informational flows into information model of actions.

There (IM)_{EN}S, (IM)_{SYS}S, (IM)_{TS}S и (IM)_{ST}S - information models of the environment, systems, tasks and states of the operator, presented in sign form in one or more modalities using visualization devices. The combination of these information models forms a general information model (IM)_{IVD}; which is perceived by a human operator, transforming it into a perceptual information model of the object (PIM)_{OB}BM, formed by the operator in the form of a generalized image in the basic modality. In parallel with the accumulation of details of the entire information picture, the operator begins to develop a conceptual model of the object of perception (CM)_{SIT}OP, on the basis of which an information model of actions (IM)_{OP} of the operator's is developed.

The act of cognitive perception by the operator of the visualized information in the BTS can be represented as follows (figure 2) [12]:

Figure 2. Formalized model of the act of cognitive perception of information in BTS.

Figure 2 introduces the following designations: (PO)_{PS} - the primary image of the object, formed by the operator at the stage of primary synthesis; (PO)_{A} - the primary image of the object, formed by the operator at the stage of analysis; (VO)_{SS} - a secondary image of an object formed at the stage of secondary synthesis (verification); (GP)_{SB} - gestalts of perception when highlighting significant information from the surrounding background.

This model also shows the transition from the very first unit of the cognitive process (PO)_{PS} directly to the information model of the operator's actions (IM)_{OP}. This transition means an instantaneous reaction of a person to a threat to his life, which is recognized without a long process of awareness and presentation of results’ images.

It is clear from the model that the cognitive act of perceiving visual information is a cyclic process of the object’s primary image transformation of the perception (PO)_{PS}, formed at the stage of primary
synthesis, into the secondary image of the object (VO) \(^{SS}\), formed at the stage of secondary synthesis after the analysis of the object’s primary images at an intermediate stage (PO) \(^{A}\).

Thus, perceiving visualized information, the human brain works not with information in the traditional sense of this concept, but with images filled with meaning. Even at the moment when the operator recalls his past experience with the help of gestalts of perception, he always does some work on this memory. Using the image-memory (gestalt), the operator enriches it with a new context and, therefore, transforms this memory. His brain not only extracts images from storage and, using them, returns them back in their previous form, but each time recreates them. At the same time, the image is enriched with new semantic information, and sometimes completely new images are created, which should be connected with the previous images into a single definite structure. Our senses, perceiving the external world, not only create cognitive equivalents of objects and phenomena existing in nature, but also reflect their connection. These two parameters of reflection - "cognitive equivalents" and "interrelationships between them" are approximately the same semantically interpreted by many researchers who call them "elements" and "connections between them" [13] or "node" and "relation" [14].

The use of images as units of memorized and processed information in BTS does not mean the final victory of any one theory of identification, it is not a prototype, not a standard, and not a pattern. But, given that the incoming information, passing through several levels of processing, is subjected to an ever deeper cognitive analysis and is enriched at each level with semantic information [15], we can make an unambiguous conclusion that a recognized and remembered image turns faceless information into only subjective, but also subjective.

3. Conclusion

In conclusion, we can cite the opinion of David Chalmers [15] that the concept of subjective experience should be included in the number of fundamental explanatory scientific concepts in the same way as in the 18th century. The concept of electric charge was introduced, when it became obvious to scientists that it was impossible to explain otherwise the facts of electromagnetic interaction accumulated by physics.

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