F O R E W O R D

This publication was prepared under contract for the Joint Publications Research Service, an organization established to service the translation and foreign-language research needs of the various federal government departments.

The contents of this material in no way represent the policies, views, or attitudes of the U. S. Government, or of the parties to any distribution arrangements.

PROCUREMENT OF JPRS REPORTS

All JPRS reports are listed in Monthly Catalog of U. S. Government Publications, available for $4.50 ($6.00 foreign) per year (including an annual index) from the Superintendent of Documents, U. S. Government Printing Office, Washington 25, D. C.

Scientific and technical reports may be obtained from: Sales and Distribution Section, Office of Technical Services, Washington 25, D. C. These reports and their prices are listed in the Office of Technical Services semimonthly publication, Technical Translations, available at $12.00 per year from the Superintendent of Documents, U. S. Government Printing Office, Washington 25, D. C.

Photocopies of any JPRS report are available (price upon request) from: Photoduplication Service, Library of Congress, Washington 25, D. C.

JPRS: 17,354

CYBERNETICS

/Following is a translation of an entry entitled "Kibernetika" (Cybernetics) by A. I. Kitov, in the Russian language publication Fizicheskiy Entsiklopedicheskiy Slovar' (Encyclopedic Dictionary of Physics), Vol II, Moscow, 1962, pp 357-362/

Cybernetics is a science dealing with the general laws of control and communication processes in organized systems such as the living organism, the machine, or their combinations. Cybernetics studies control processes mainly from the point of view of information (see Information, theory of). For this reason cybernetics is also defined as the science dealing with the sensing, transmission, storage, processing, and utilization of information in living organisms, machines, and their combinations.

A systematic presentation of the general concepts and methods of cybernetics was given in 1948 by N. Wiener (1). A considerable role in the creation of cybernetics was played by the works of C. Shannon on the theory of relay and contact systems, the theory of transmission of information, and the theory of automata (2,9), as well as by the works of J. Neumann on the theory of electronic computers, the automata theory, and the mathematical theory of games.

The birth of cybernetics as a general theory of control was brought about by the practical need for producing complex automatic control systems, and was associated with the arrival of electronic computers representing a powerful tool in the automation of various data processing and control processes. It is characteristic of cybernetics that it arose as a result of the integration and interaction of the achievements and methods of a number of mathematical and biological sciences. The development of automatic control theory based largely on the work of A. M. Lyapunov and I. V. Vyshnegradskiy, and the publication by I. P. Pavlov of the objective methods of studying the activity of higher nervous systems provided a large amount of factual material on which far-reaching generalizations could be based, and helped to reveal a number of analogies and general principles of control shared by the living organism and the machine. The theory of reflex, which explains the control processes arising in a living organism as well as the mechanism of adaptation by the organism to the external environment, is essentially based on the same principles of transmission of information and feedback as those which form the basis of the theory of automatic control (17, 18, 19). A significant part in the development of cybernetics was also played by such sciences as evolution and theoretical genetics which study the processes of evolution of biological species and transmission of hereditary information. The sciences directly participating in the formation of cybernetics include mathematical economics and methods of studying war operations which were developed during World War II and deal with communication and control processes in public life on the one hand, and the theories of communication and computers dealing with transmission and processing of information in industry on the other.

In contrast with the above disciplines which study control processes in various concrete fields, cybernetics deals with general laws relating to any given control process regardless of its nature. Examples of the early specifically developed branches of cybernetics can be seen in Wiener's theory of filtering of random processes and A. N. Kolmogorov's theory of interpolation and extrapolation of random processes (12).

The importance of cybernetics resides primarily in the construction of a single theory of control processes, and in the elaboration of a single method of studying them. In spite of the extraodinarily large number of concrete manifestations of control processes, it is evident that they are basically similar in nature, and occur in accordance with a common pattern. Any given control process is always associated with an organized system which embodies its own control system, and with the controlled, or active organs connected together by means of communication channels. Living organisms are examples of natural organized systems. Apart from the living organism, the only other type of organized systems known is represented by artificial systems created by man.

The presence of purpose is the characteristic feature of any given control process. Control is equivalent with the organization of purposive behavior. The aim of the process of control in the general case is the adaptation of the organized system to its environment, which is essential to its continued existence or the performance of its functions. The aim of the process of control is the criterion of the quality of performance of the regulating system.

Control is always accomplished on the basis of reception, transmission, and processing of information under the conditions of interaction between a given organized system and its environment. Information is usually defined as new data about some occurrences or phenomena. A more precise definition of the concept of information can be given in connection with the concept of memory. Memory is the capacity of organized matter to fix selectively external stimuli, and to store in time and recall (fully or partly) their traces under certain conditions. Only living organisms and artificial control systems have memory. Their functioning in time and space is always conditioned not only by the nature of the current stimuli of the environment and their own current physical state, but also by the information stored in their memory. Thus information can be defined as the sensing by the control system of external stimuli mediated by memory. Any given external stimulus has information for the control system only when that information is associated in any giver degree with the traces of the past stimuli stored in the system's memory, provided the stimulus is recognized by that system. This form of stimulation is basically different from direct physical stimuli whose results are fully determined by the stimuli themselves. It is also of fundamental importance that the recognition of information is possible not only in the case when the received stimulus (signal) fully coincides with one received in the past. Information is recognized and extracted by the control system also from stimuli having a complex relationship with those received in the past (e.g., partial coincidence, coincidence of combinations, etc.).

The methods of recognizing information by living organisms are extremely complex and varied, and their study is still at an elementary stage. These methods vary sharply depending on the degree of organization of the living organism.

The control system transmits command information to the active organs through direct communication channels, and it receives, through the feedback channels, the information from the active organs about their actual state and about the execution of the command. The control system also receives information concerning the state of the environment from special sensing or measuring organs. On the basis of information received, the control system works out the commands which determine the action of the active organs and the future state of the entire organized system.

In contrast with the general scheme outlined above, use is made sometimes in the simpler cases of technology of direct control according to a predetermined program, without the use of feedback. Feedback is replaced by a prior calculation of the expected reactions of the environment at any given stage of control, and is thus present in a latent form. The presence of the control algorithm is characteristic of all control processes. By algorithm we mean a system of formal laws which clearly and unequivocally determine the process of attaining a given aim and, in particular, the order of solving the tasks of a given class. An algorithm is distinguished by the following characteristics: a) a definiteness of the algorithm, consisting in the sharpness of its component manifestations, their full ineligibility to the active organs which need not know the nature of the task; b) versatility of the algorithm, consisting in its applicability not to just one, but to a number of variants of the initial data, i.e., to the whole class of tasks; and c) the ability of the algorithm to arrive at results, consisting in the fact that the number of operations leading to a given result is finite for any permissible array of initial data.

The theory of algorithms arose in the 1930's out of mathematical logic in connection with studies of the theoretical aspects of the nature of some mathematical problems. As cybernetics developed, it became apparent that algorithms play an important role in the description and study of the various information processing and control processes (21, 22). The concepts of purpose and algorithms in cybernetics have a very broad interpretation. In the case of artificial control systems (technical, administrative, etc.), the purpose and algorithm of control are put into these systems from outside in the course of formation of these systems. For instance, in the case of the automatic fight control in a plane, the aim of control reduces to assuring the fulfillment of the programmed flight parameters (coordinates, speeds, accelerations), while the control algorithm consists of equations determining the position of the elements controlling the rudders and engines of the plane as the actual parameters deviate from the programmed values. Let an administrative control system be illustrated by the example of a system controlling an industrial enterprise, where the aim of control is to secure the attainment of a given value of production, and the algorithm consists of the totality of technical, engineering, planning, and economic documentation which regulates the work of the enterprise. In the case of control systems of living organisms, the purpose and algorithm of control are formed in a natural causative manner as a result of long evolution. For example, the very process of biological evolution represents a control process, whose aim it is to adapt the organism to its environment, while the algorithm consists of the laws of natural selection. Thus, the cybernetic concept of purpose also embodies such property peculiar to the control systems of living organisms as the preservation of the stability of its organization (homeostasis).

The study of the mechanism of the natural formation of purposive control systems in living organisms constitutes one of the main problem of cybernetics. The solution of this problem will permit a deeper understanding of the relationship between cause and effect in nature on the basis of an explanation of concrete mechanisms and mathematical relationships determining the transition from the causative deterministic behavior of the individual elements of the system to the purposive form of behavior of the system as a whole. It appears that the main characteristic of the cause-and-effect relationships in a purposefully functioning system is the presence of the feedback influence of the consequences on the internal causes which determine the course of the process.

Apart from its theoretical importance, cybernetics has a great practical significance as the theory providing a unified approach to the study of artificial and natural control systems, and the utilization of the principles of living control systems in technology. Bionics, which is a special branch of cybernetics, deals directly with the study and application of the principles of action of the sensing and control organs in living organisms in the construction of various man-made devices. An important practical aim of cybernetics is connected with the problem of informational symbiosis of man and machine in the process of solution of various scientific tasks. In contrast with the existing methods of an autonomous use of machines for the solution of discrete problems, the informational symbiosis envisages a close and direct interaction between man and machine in the process of creative thinking. Man reserves the function of posing the problems, formulating the questions and hypotheses, and analyzing the data, while the machine takes over the task of gathering and processing materials, carrying out the calculations, assembling references, and presenting data in a form convenient for analysis.

Being a unified theory of control processes, cybernetics embraces three different branches: the information theory, the theory of programming (or methods of control), and the theory of control systems.

Information theory (see Information, theory of) deals with the study of the methods of coding (transformation), transmission, and sensing of information. Transmission of information is accomplished with the aid of signals which are physical processes whose given parameters are in unequivocal correspondence with the information being transmitted. The establishment of such correspondence is called coding (see Code, Coder). Although the transmission of any signal requires an expenditure of energy, the amount of energy expended is not, in the general case, connected with the quantity, and particularly the quality of information transmitted. This constitutes one of the main characteristics of control processes: the control of large streams of energy can be accomplished using signals requiring insignificant amounts of energy for their transmission.

The most thoroughly developed aspect of the information theory is the statistical approach, which is based on the probability characteristics of the message in transmission. The central concept of the information theory is the measure of the information content defined as the change in the degree of uncertainty in the expectation of some attribute of the message before and after the reception of the message. This criterion permits the measurement of the information content in a message in a manner similar to that in which the amount of energy is measured in physics, and an evaluation of the effectiveness of the various methods of coding informatic , as well as the throughput capacity and resistance to interference of various communication channels (8, 9, 10, 13). The mathematical definition of the quantities of information is arrived at in the following manner. In the theory of probability, a full system of occurrences is a group of occurrences $A_1, A_2, \ldots A_n$ in which one, and only one of these occurrences necessarily appears for each trial. For instance, the appearance of 1, 2, 3, 4, 5 or 6 when a die is cast, or the appearance of either heads or tails upon tossing a coin. A simple alternative, i.e., a pair of opposite occurrences, exists in the latter case.

A finite scheme is a full system of occurrences $A_1, A_2, \ldots A_n$, given together with its probabilities: $P_1, P_2, \ldots P_n$:

$$A = \begin{pmatrix} A_1 & A_2 & \ldots & A_n \\ P_1 & P_2 & \ldots & P_n \end{pmatrix}, \qquad (1)$$

where $$\sum_{k=1}^{n} P_k = 1; \; P_k \geq 0.$$

Each terminal scheme has its own given uncertainty; i.e., we know only the probabilities of the possible outcomes, but it is uncertain which particular outcome will appear in reality.

The theory of information introduces the following characteristic for estimating the degree of uncertainty for any given finite system of occurrences:

$$H(P_1, P_2, \ldots, P_n) = -\sum_{k=1}^{n} P_k \log P_k, \qquad (2)$$

where the logarithms are at an arbitrary, but always the same base; when $P_k = 0$, it is assumed that $P_k \log P_k = 0$. The quantity H is called entropy of a given finite scheme of occurrences, and has the following properties:

1. The quantity $H(P_1, P_2, \ldots P_n)$ is continuous with respect to P_k;

2. $H(P_1, P_2, \ldots P_n) = 0$ only when one of the terms $P_1, P_2 \ldots P_n$ equals one, and the remaining ones equal zero, i.e., the entropy equals zero when there is no uncertainty in the finite scheme;

3. $H(P_1, P_2, \ldots P_n)$ has its maximum value when all P_k are equal to each other, i.e., when the finite scheme has the greatest degree of uncertainty. In this case

$$H(P_1, P_2, \ldots, P_n) = -\sum_{k=1}^{n} P_k \log P_k = \log n. \quad (3)$$

Furthermore, entropy has the property of being additive, in that the entropy of two independent finite schemes is equal to the sum of the entropies of these schemes. The above expression for entropy is quite convenient, and it fully characterizes the degree of uncertainty of this or that finite scheme of occurrences. The information theory proves that the above form of equation for entropy is the only one that satisfies the three foregoing properties.

The data concerning the results of the trial whose possible outcomes are determined by a given finite scheme A, represents some information removing the uncertainty existing prior to the trial. The greater the degree of uncertainty of the finite scheme, the greater is the amount of information obtained as a result of conducting the trial and removing the uncertainty. Since the degree of uncertainty of a finite scheme is characterized by its entropy, it is expedient to measure the amount of information obtainable in the trial in terms of this quantity. This means that, in the general case, the amount of information about any given system which has different probabilities of the possible outcomes is determined by the entropy of the finite scheme which characterizes the behavior of that system.

Since a statement of the result of a choice between two equally probable alternatives, which constitutes the simplest form of information, is taken as the unit of information, the base of logarithms in the expression for entropy is usually 2.

Of particular importance is the study of the natural systems of coding hereditary information which secure the storage, in a negligible amount of matter, of an enormous amount of information. Here a single cell contains the characteristics of a fully grown organism.

Of prime importance is the connection, established by cybernetics, between the concept of information and that of the thermodynamic concept of entropy. Thermodynamic entropy characterizes the degree of "disorder" (or chaos) of a given physical system, while information characterises the degree of "disorder" of the source of information. Therefore, from the information point of view, entropy characterises the degree of inadequacy of information about a given physical system. If we regard a laboratory in which a physical experiment is being performed as a closed physical system we can estimate the likely increase in the entropy of this system, and the amount of information which can be obtained as a result of the experiment. For instance, let us study an isolated system in which an adiabatic transformation characterized by constant entropy is taking place. In order to measure the parameters of this system (pressure, temperature, etc.), it is necessary to connect the system to the measuring instruments, which leads to an increase in the entropy of the system, which now consists of the system under study plus the measuring instruments. The amount of information obtained as a result of measurement will always be smaller than the increase in entropy due to the experiment.

The treatment of thermodynamic entropy from the viewpoint of information has a direct bearing on the uncertainty principle in quantum physics. If the process of observation is not to influence its results, it is imperative that the increase in the entropy of the system comprising the object of study and the measuring instruments be negligibly small in comparison with the full entropy of the system under observation. In this case the experiment can be considered undisturbed, or reproducible. Otherwise, the experiment must be considered to be an irreversible process. The methods of the statistical theory of information can be applied in the general planning and organization of physical experiments, evaluation of their results, and in the analysis of the effectiveness of various methods of observation (7).

In addition to the problem of estimating the amount of information and evaluating the reliability of its transmission and storage, of considerable importance is the study of the various forms of its presentation. This problem is virtually untouched in the theory of information. A given amount of information may be more or less accessible to practical use depending on the method of its presentation, and the transformation of information from one form into another is frequently very complicated. For instance, the same information can be presented in the analytical, graphic, or tabular forms. Technically, the three forms contain the same information, but differ in the convenience of its utilization. The new semantic trend now being developed within the theory of information deals with the problem of quantitative expression of the information content, which reduces essentially to the study of the forms of presentation and means of compaction of information, i.e., its transformation into a more economical form. One of the basic aims of this trend is to study the processes of image recognition in living organisms, and to model these processes in artificial systems. The process of image formation is precisely one of transforming information received in the form of a large number of concrete instances into a totality of characteristics and their connotations. A quantitative approach to the question of the value of information to the receiver is also being developed. Assuming that information is gathered for the purpose of achieving a given aim, its value can be measured as the difference of probabilities of attaining this aim before and after the information is received (14).

The theory of programming in its broadest sense represents a science dealing with the study and development of the methods of description and modelling of all information processing and control activities. Here belong primarily the theory of programming the problems for their solution on electronic computers, the theory of algorithmization of various control processes, and the various mathematical methods of finding optimum solutions. Of high theoretical and practical importance is the development of automatic programming of problems for digital computers, aiming at entrusting the machine with increasingly complex forms of statement and preparation of problems. A number of programming devices which prepare working programs for computers has been constructed on the basis of the operator method proposed by A. A. Lyapunov in 1953. An international language of programming (ALGOL) has been developed, whose function is to facilitate the exchange of problem solution algorithms on the international scale.

The methods of automatic programming presently assure the possibility of designing problems for computers using mathematical formulas or verbal expressions which determine the methods of solution without the need for a detailed description of the solution processes in the form of elementary operating sequences. In the long range view, the development of automatic programming and the structure of computers should permit the solution by these computers of computation, logical, and physical problems posed by the conditions alone. The computer should automatically select the optimum method of solution, determine the sequence and the required calculation variants, analyze the results, and present them in a convenient and generalized form. The general theory of programming information processing operations may be deemed to include the mathematical methods of selecting the optimum solutions in the process of controlling complex assemblies. The process of finding a solution in the general case includes the evaluation of the information about the assembly, determination of procedure (strategy) suitable to the purpose of control, and the elaboration of control commands which determine the individual actions of the active elements. The spectrum of processes associated with the finding of solutions is extremely broad, and embraces all possible means of information processing, from the elementary reflex reactions typical of the simplest control systems to the creative thinking processes of man. From the mathematical standpoint, the purposive functioning of control systems (natural and artificial) represents a process of minimizing, at each step of control, some function of the system's state. This function constitutes the criterion of the quality or the purpose of control of a given system. Within the framework of practical cybernetics, a considerable degree of development has been experienced by the mathematical methods of seeking optimum solutions such as linear and automatic programming, as well as the theory of mass service, theory of games, etc. These methods are used not only in the military and economic administration fields, but also in the planning and analysis of physical experiments, construction of mathematical models, and the study of various physical processes and systems (16, 17).

Among important achievements of cybernetics we find the development of a unified approach to the study of various information processing systems by means of breaking down these processes into the elementary acts which, as a rule, represent the alternative choices ("yes" or "no"). A systematic application of this approach permits one to formalize the more complex processes of the intellectual activity of man, and to describe in detail and in a univocal manner (i.e., algorithmize), the working processes of various control systems.

Among the important tasks of this branch of cybernetics is the study of the nature of learning processes and creative thinking in man, and the reproduction of similar processes in electronic machines. Experiments carried out in this direction aim at studying and modelling in the machine of the heuristic and intuitive solutions of problems, as well as analyzing the trial-and-error methods with a division of the overall problem into separate subproblems with automatic scanning of the intermediate stages, together with the means of their attainment. Of great interest to the solution of this problem is the work concerned with reproduction of various associative memory systems which would permit an automatic finding and integration of information content.

The theory of control systems deals with the general informational and physical principles of the structure of control systems of different kinds and purposes. In the broad sense, a control system is any physical object which performs the function of purposive processing of information.

The following main classes of control systems can be distinguished: a) biolgical systems for the storage and transmission of hereditary information; b) control systems in living organisms which secure the organism's reflex activity; c) the brain as the organ of thought; d) automatic information processing systems used in technology; e) economic and other social information processing systems; and f), humanity as a separate system performing the function of information processing in the process of the development of science

The theory of automata, which is a special branch of cybernetics, deals with abstract discrete action systems which reflect the informational properties of various classes of real systems. A conspicuous part in the theory of automata is played by the construction of mathematical models of the brain's neuron networks as a basis for studying the thought mechanism and the structure of the brain, which is capable of sensing and processing a vast amount of information in an organ characterized by small volume, negligible expenditure of energy, and extremely high reliability (2, 3, 15).

An analysis of various control systems shows that their structure has two principles in common: the feedback, and the multistage (hierarchic) principles of control. The presence of feedback from the active to the control elements makes it possible for the control system to take constantly into account the actual state of the whole system, as well as the influence of the environment. The hierarchic principle of control assures an economy of structure and stability of function in the system. It describes the structure of a multistage system in which direct control of the active element is accomplished by a mechanism of a lower order itself subject to control by a mechanism of the second order, which in turn is controlled by a mechanism of the third order, etc.

The manifestations of the above principles in real control systems are extremely complex, forming a large number of interrelated and cross-linked levels of control in which the hierarchic nature of control becomes relative. Here various elements belonging to the lower levels of control may exert a controlling influence on the elements of a higher level of control, while communications between the elements is not clearly defined, but rather have the character of probability. The characteristic property of such systems is their complexity which precludes the possibility of their description and analysis on the sole basis of the knowledge of behavior of its individual elements. The task of cybernetics consists in creating special methods based on the use of integral characteristics (e.g., the degree of organization) and structural characteristics (hierarchy of control, system of feedbacks) for describing complex systems.

The organic union of the principles of feedback and control hierarchy confers upon control systems a property of "ultrastability" which enables them to find automatically the optimum conditions of operation and adaptation to the varying external conditions. These principles constitute the basis of the biological evolution of species, and form the foundation of the development, learning, and acquisition of experience by living organisms in the course of their existence. Gradual development and accumulation of conditioned reflexes represents an increase in the level and complexity of control in primitive living systems.

The aforementioned feedback and hierarchic principles of control are also utilized in construction of complex technological control systems, and in organization of control in society (1,2,3).

Knowledge gained in the study of control systems can be systematized in the form of a general scheme which describes the order of study of these systems in a variety of fields. The process of investigation of control systems is sub-divided into two main stages: macro- and micro- approaches to a given control system. The former is characterized by the fact that the control system is considered from a purely functional point of view. This includes the input and output streams of information, the means of coding this information, and the regularity of action of the control system under given conditions. Following this macroscopic or functional study, a detailed study of the internal structure of the system becomes necessary. Here we learn about its component parts or elements, the ways in which they are interconnected, how the individual elements work, etc. A full description of the system's functioning can be given on the basis of these results. In other words, we can construct an algorithm of the system's work. Algorithmization of the control system itself consists of a description of the order of its work, and the actions performed by its parts are considered as elements. It frequently happens that the microscopic approach is transformed into the macroscopic approach in the process, since the microscopic approach to the study of the system as a whole also embraces the macroscopic aspect of the functioning of its component parts. Frequently the component parts isolated in the course of study represent complex control systems in their own right, and the micro-approach to the study of the whole system is transformed into the macro-approach to the study of one of its parts.

Algorithmization of the control system itself, i.e., a detailed description of the order of its action should not be confused with the disclosure of the algorithm of the system itself. The latter determines the way in which the system processes the information fed into it from outside, and what its output is in any given case. Consequently, we have to distinguish two algorithms: that to which the system is subject, and that which tho system determines itself.

Two types of problems arise in connection with the study of control systems: analysis of their structure, and synthesis, using given elements, of systems capable of carrying out a given algorithm. The common requirements are: attainment of the necessary speed, accuracy, the smallest possible number of elements, and reliability of action. In order to evaluate the degree of organization of complex control mechanisms, use is made of a special quantitative criterion characterized by the amount of information which it is necessary to introduce in order to secure the transition of a control system from the original disordered state into the required organized state.

Of particular interest are self-organizing systems which have the property of spontaneous transition from any given initial state into a given stable state corresponding to the nature of external stimuli. In the general case, the state of such systems changes randomly under the influence of external stimuli. Thanks to the presence of the hierarchic nature of control and of feedback, these systems purposively select stable states corresponding to the external stimuli.

The property of organization can manifest itself only in systems having a redundancy of structural elements and a random character of communication between them, changing as a result of the interaction between the system and the environment. Examples of such systems are seen in the neuron networks of the brain, various types of colonies of living organisms, certain complex self-organizing economic or administrative systems, and some artificial self-organizing devices of the perceptron type, etc. (see Learning machines).

In addition to the information aspects, cybernetics is also concerned with the study of the general physical principles underlying the construction of control systems from the standpoint of their capacity to sense and process information. This includes the studies of the relationship between the size of control systems and their limiting response speeds (limited by the speed of light), the limiting capacities of small control mechanisms to sense information univocally in connection with the appearance on that scale of the laws of quantum physics, etc.

In its methods, cybernetics is a mathematical science which makes an extensive use of a varied mathematical apparatus in order to describe and study control systems. It is characteristic of cybernetics to make use of mathematical modelling methods for modelling various control systems on universal programmed computers. This method, based on a mathematical description of the process under study, also makes it possible to take into account the effect of random factors by means of representing them by random number sequences subject to appropriate laws (the Monte Carlo method).

In addition to mathematical modelling, use is also made of the various forms of physical modelling which consists in substituting the phenomena under study by other isomorphic (i.e., similar) phenomena which it is easier to reproduce and observe under laboratory conditions. The method of modelling, which is based on the cybernetic principle of the uniformity of the laws of control in any given control system, is of great theoretical importance.

Cybernetics, which deals with the general laws of control processes in the machine, the living organism, and the human society, opens up new vistas in the quest for understanding the phenomenon of life, including the nature of the human intellect, and in the construction on that basis of increasingly accomplished cybernetic machines which in turn will assist man in his further penetration into the secrets of nature.

Bibliography

1. N. Wiener, Kibernetika ili Upravleniye i Svyaz' v Zhivotnym i Mashine (Cybernetics, or Control and Communication in the Animal and the Machine), (Transl. from English), M., 1958;

2. Avtomaty (Automata), collection of articles edited by C. E. Shannon and J. McCarthy (Transl. from English), M., 1956;

3. W. R. Ashby, Vvedeniye v Kibernetiku (An Introduction to Cybernetics) (Transl. from English), M., 1959;

4. A. N. Kolmogorov, Kibernetika (Cybernetics), BSE, 2nd ed., Vol 51, M., 1958, pp 149-51;

5. A. A. Lyapunov, "O Nekotorykh Obshchikh Voprosakh Kibernetiki" (Some General Problems of Cybernetics), in the collective work Problemy Kibernetiki (Problems of Cybernetics), No 1, M., 1958;

6. S. A. Pokatayev, Signal (The Signal), M., 1958;

7. L. Brillouin, Nauka I Teoriya Informatsii (Science and Information Theory). (Transl. from English), M., 1960;

8. S. Goldman, Teoriya Informatsii (Information Theory) (Transl. from English), M., 1957.

9. C. Shannon, "Statisticheskaya Teoriya Peredachi Elektricheskikh Signalov (Statistical Theory of Transmission of Electric Signals), in the collective work Teoriya Peredachi Elektricheskikh Signalov pri Nalichii Pomekh (Theory of Transmission of Electric Signals in the Presence of Interference), Collected Translations, M., 1953;

10. A. Ya. Khinchin, Ponyatiye Entropii v Teorii Veroyatnostey (The Concept of Entropy in the Theory of Probabilities), "UMN", 1953, Vol 8, 3rd. ed.;

11. A. N. Kolmogorov, "Teoriya Peredachi Informatsii" (Theory of Trans-

mission of Information), M., 1956 (Dokl. na plenarnom zasedanii sessii AN SSSR po nauchnym problemam avtomatizatsii proizvodstva) (Report on the Plenary Session of the AN SSSR on the Scientific Problems of Automation in Industry);

12. A. N. Kolmogorov, Interpolirovaniye i Ekstrapolirovaniye Statsionarnykh Sluchaynykh Posledovatel'nostey (Interpolation and Extrapolation of Random Stationary Sequences), Izv. AN SSSR ser. mat. 1941, Vol 5, No 1, pp 3-14;

13. A. A. Kharkevich, Ocherki Obshchey Teorii Svyazi (An Outline of the General Thery of Communication), M., 1955;

14. A. A. Kharkevich, "O Tsennosti Informatsii" (On the Value of Information), in the collective work Problemy Kibernetiki (Problems of Cybernetics), No. 4, ., M., 1960;

15. S. Ya. Yablonskiy, "Osnovnye Ponyatiya Kibernetiki" (Basic Concepts of Cybernetics), Ibid., No 2, 1959;

16. D. Blackwell and M. A. Hirshik, Teoriya Igr i Statisticheskikh Resheniì (Theory of Games and Statistical Decisions), (Transl. from English), M., 1958;

17. J. McKenzie, Vvedeniye v Teoriyu Igr (An Introduction into the Thery of Games), (Transl. from English), M., 1960;

18. I. P. Pavlov, "Dvadsatiletniy Opyt Ob'yektivnogo Izucheniya Vysshoy Nervnoy Deyatel'nosti Zhivotnykh" (A Twenty-Year Experiment in Objective Study of the Higher Nervous Activity in Animals), Poln. Sobr. Soch. /Not identified/, Vol 3, Book 1-2, 2nd. ed., M. - L., 1951;

19. I. M. Sechenov, Refleksy Golovnogo Mozga (Reflexes of the Brain), M., 1952;

20. P. K. Anokhin, " Fiziologiya i Kibernetika" (Physiology and Cybernetics), in Filosovskiye Voprosy Kibernetiki (Philosophic Problems of Cybernetics), M., 1961;

21. A. I. Kitov and N. A. Krinitskiy, Elektronnye Tsifrovye Mashiny i Programmovaniye (Digital Electronic Computers and Programming), M., 1959;

22. B. A. Trakhtenbrot, Algoritmy i Mashinnoye Resheniye Zadach (Algorithms and the Solution of Problems by Machine), M., 1960.

2281
CSO: 7413-N

-END-