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Major Developments in the SovBloc Cybernetics Programs in 1965

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MAJOR DEVELOPMENTS IN THE SOVBLOC CYBERNETICS PROGRAMS IN 1965

Project Officer

[redacted] (b)(3)

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CENTRAL INTELLIGENCE AGENCY

DIRECTORATE OF SCIENCE AND TECHNOLOGY

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PREFACE

At the 22nd Party Congress in 1961 the CPSU decided to make cybernetics an instrument of national policies pertaining to management in the Soviet Union. Since that time the field of cybernetics has been undergoing a gradual, multifaceted, and programmed evolution under the immediate supervision of the Cybernetics Council, Academy of Sciences, USSR. This pattern of development has been paralleled by cybernetics programs in some of the Satellites and to a lesser extent in Communist China. In this report, the recent organizational, scientific, technological and philosophical developments in this program are reviewed, discussed, and placed in perspective in the context of related research and political and philosophical activities. Earlier developments were reviewed in *The Features of the Soviet Cybernetics Program Through 1963*, OSI–RA/65–2, 5 January 1965.

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MAJOR DEVELOPMENTS IN THE SOVBLOC CYBERNETICS PROGRAMS IN 1965

PROBLEM

To review and evaluate major events in the development of Sovbloc cybernetics programs during 1965.

SUMMARY AND CONCLUSIONS

The institutional base of the Soviet cybernetics program increased sharply during 1965—the creation of cybernetics institutes at Tashkent, Yerevan, Minsk, Baku, Gorkiy, and Leningrad approximately doubled the number of such institutes. At least four new serial publications appeared during the same period: *Cybernetics; Automatic Measurements; Economics and Mathematical Methods;* and *Questions of Theoretical Cybernetics.*

A computer-based information-management system was established to systematize the results of the cybernetics program and to facilitate the exploitation of Western research. It is based on a well-structured subject index containing 80 main headings which range in subject coverage from "analog computers" and "automatic control" to "stochastic approximation techniques" and "utility theory."

The Council for Cybernetics convened biweekly during 1965 to foster coordination of research and the dissemination of ideas pertinent to the most important problems facing the cybernetics program. It also cooperated in the organization of at least six major conferences: the First All-Union Symposium on Automatic Pattern Recognition; First All-Union Conference on Experiment Planning; Second Symposium on Cybernetics (Tbilisi); All-Union Conference on Cybernetics and the National Economy; Third All-Union Conference on Automatic Control—Technical Cybernetics; and the Second Scientific Conference on Neuro-Cybernetics of the Schools of Higher Education.

The scientific and technological accomplishments revealed during 1965 indicate that the rate of progress of the Soviet Union is accelerating in the fields of theoretical, technical, and applied cybernetics. Exemplifying Soviet progress in theoretical cybernetics is their pattern recognition research, which reached a relatively high plane of accomplishment during 1965. In their multifaceted mass attack on the recognition problem, the Soviets used psycho-biological, bionic, mathematical, and combined approaches which found expression in reports of research on: heuristic programming; the relationships of information theory and learning to the recognition problem; human speech recognition; the algorithmic simulation of human pattern recognition and problem-solving systems; and the hardware simulation of the human pattern recognition apparatus. The last-mentioned research activity has resulted in models of individual neurons, neuron nets, and receptor and analyzer systems which perform information transformation functions analogous to those of the living prototypes after which the hardware is modeled. The most significant Soviet contributions to the solution of the pattern recognition problem during 1965 come from the mathematicians. Especially notable was Ya. L. Tsypkin's discovery that there is a close proximity between problems solvable by the method of potential functions and problems analyzed in the theory of stochastic approximations.

The outstanding technical cybernetics accomplishment revealed by the Soviets during 1965 was the BESM–6 computer. This all-solid-state digital computer represents a considerable advance over previous Soviet machines. It is well-suited to economic, military, and other applications requiring a large volume of calculations. Translation of this advance into widely available machines and associated software will require some years. For the present and near future the URAL series of compatible computers and software will provide major support to the cybernetics and economic data processing programs. As to the more basic aspects of technical cybernetics, the Soviets continued to focus attention on optimal control problems with an unusual emphasis on those encountered in stochastic systems. The large number of papers devoted to problems of optimal control of stochastic systems revealed that the considerable activity on this very difficult subject in optimal control theory has advanced to a somewhat practical statistical design stage.

Soviet progress in applied cybernetics was evidenced by Soviet revelation during 1965 of a number of hierarchical systems for the control of industrial complexes. Among those described are experimental systems with the designations IMPUL'S and PROKAT and an unnamed system in which VNIIEM–3 computers are combined in hierarchical fashion for technological planning and administrative control of a steel mill. These systems rely heavily on self-adaption of the control elements because of the difficulty encountered in accurately knowing the process dynamics of such systems in advance.

The development of new software was revealed during 1965. One is ALGOS (Algorithmic Descriptions of Industrial Cybernetics Systems), a special programming language for the automatic formulation of computer programs for controlling industrial processes. Another is EPSS (Heuristic Program for Self-organization and Self-teaching) which is applicable to self-organized hierarchical man-machine systems. ALGEK and KOBOL-GAYAPEI, programming languages for use in economic decision-making and accounting operations, respectively, were considered for adoption during 1965 by the CEMA Group for Algorithmic Languages for the Processing of Economic Information.

The Unified Information Network was the most significant planned application of cybernetics discussed during 1965. More than 100 new computer centers were observed for the first time in the USSR during the year. Some of these may become, along with several thousand others, part of a nationwide network for collecting, processing, storing, and transmitting information. Plans for this network are assigned perhaps the highest priority in the theoretical and technical aspects on the long-range cybernetics program. The literature reviewed during 1965 reveals that the Soviets are still at an early stage in the ambitious research and development program to institute this management system of unprecedented complexity.

The newly created Council for Problems on Management of Economic and Social Processes of the Academy of Social Sciences under the Central Committee, CPSU, plays a leadership role, especially in the philosophical aspects of this program. A possible guideline for these philosophical endeavors is a concept called the "theory of development." Based on analogies recognized by Sovbloc philosophers between the evolution of species and the development of social systems, the theory of development holds that observed regularities in natural phylogenetic processes can be used as guides in engineering the evolution of social systems toward higher levels of development. This theory incorporates modern mathematical approaches to the modeling of social systems' dynamics with descriptive models of the evolutionary process as it occurred in biological nature. One of its key postulates states that automation is a universal law in the development of species and is, therefore, a prerequisite to the progressive development of social systems.

Recognizing an intimate connection between socio-economic development and security, some Soviets believe that the success of their cybernetics program in providing means for the optimal management of social transition will prove to be the decisive factor in the East-West contest. Aside from what would be gained in terms of the security of the USSR, these Soviets believe that successes in developing techniques for the scientific guidance of social development could furnish an example in this respect for the emerging nations of the world and, hence, influence their paths of future development along lines inimical, perhaps to US policy. The organizational, research, engineering, and philosophical developments within the cybernetics program of the USSR during 1965 indicate a marked acceleration of Soviet efforts to realize the potential offered by that program in terms of their national and international objectives.

Developments transpired in the East European satellites and to a lesser degree in Communist China during 1965 which reflect the programs and aspirations observed in the USSR. A collaborative Bloc-wide program is suggested by reports describing activities in Czechoslovakia, Hungary, Poland, and East Germany which will be in support of national and international (CEMA) research programs devoted to scientific management of society. Parenthetically, even the Chinese Communists began to espouse cybernetics openly during 1965.

DISCUSSION

INTRODUCTION

The Soviet cybernetics program comprehends theoretical, technical, and applied research in a multitude of scientific subjects and problem areas. The success of the program is contingent, therefore, upon Soviet abilities to systematize and interrelate these previously independent fields with reference to the operation of general laws of communication and control. A step to develop further such abilities was taken by the Soviets during 1965 with the establishment of an information-management system for classifying, structuring, and interrelating the subfields included under the heading of cybernetics by the Soviets.

The basis of the system is a subject index with more than 80 main headings each of which is identified by a 4 digit code. Some of the main headings of the subject index are given in the following list.[1]

Differential analyzers
Bionics
Biotechnology (Biotekhnika)
Probability distributions
Probability theory
Computer technology
Computer technology, applications
Computers
Analog computers
Computer units and elements
Functional generators
Mathematical genetics
Decoding
Memory devices
Game theory
Integral functional units
Information processing
Information transmission
Information search
Information theory
Operations research and mathematical economics
Operations research, applications (prilozheniya)
Cybernetics in medicine and biology
Cybernetics and psychology
Cybernetics, applications
Cybernetic problems of the theory of algorithms
Cybernetic control (upravleniye) systems, theory
Cybernetic devices

Coding theory
Codes
Finite automata, theory
Regulation (kontrol')
Correlation between random values, theory
Logical schema
Logical elements
Queueing theory
Mathematical problems of semiotics
Operations research models
Modeling
Mathematical modeling
Reliability theory
Theory of decision functions
Network theory
Automatic control (upravleniye)
Mathematical modeling of thought processes
Electrical modeling
Nonparametric problems. Nonparametric criteria for verifying hypotheses
Perceptrons
Usefulness theory
Sequential analysis
Limit theorems
Converters of analog values into digital
Code converters
Converters of digital values into analog
Verification of hypotheses, evaluation of parameters, goodness-of-fit test
Programming
Automatic programming
Dynamic programming
Linear programming
Nonlinear programming
Programs and algorithms for the solution of problems on computers
Scheduling theory
Pattern recognition
Automatic control (regulirovaniye), theory
Relay circuits, theory
Servo systems
Random processes and random functions
Statistics of dependent observations
Mathematical statistics
Statistical analysis, multivariate
Statistical analysis of random processes
Stochastic approximation, the Monte-Carlo method
Impulse meters
Theoretical-probabilistic and statistical methods in the natural and humanitarian sciences
Theoretical-probabilistic and statistical methods in engineering (tekhnika)
Control of resources, theory
Programmed control
Electrical circuits, theory
Economic models

In the body of the index, subheadings under the main divisions are assigned additional two digit designations. Thus, each subject entry is identifiable by a six digit code.

The first use was made of this subject index by the Soviets in systematically cataloging all the abstracts of cybernetic literature published during 1965 in the *Reference Journal: Cybernetics* issued by the Institute of Scientific Information, Academy of Sciences, USSR. The availability of this index with its thousands of entries and of the source journals makes unnecessary any attempt at an exhaustive recapitulation of Soviet research in cybernetics. However, there is a time-lag between the publication of research and its inclusion in abstract form in the reference system. Thus, the index for 1965 is to literature much of which goes back to 1964 or earlier. Hence a requirement for reviewing and evaluating material published during 1965. The scope of cybernetics depicted in the index demonstrates also the futility of any attempt at substantive completeness in such a review. Therefore an attempt has been made to provide only illustrative examples of developments in theoretical, technical, and applied cybernetics.

A noteworthy attribute of the new, computer-based information-management system beyond its contribution to the systematization of cybernetics is that it amplifies Soviet research and development capabilities. By facilitating access to native and world literature, the information system permits a Soviet scientist to build upon rather than duplicate precedent research.

Illustrative of the capability of an information system for amplifying research and development activities are the findings made in an extremely well-done US review completed during 1965 of Soviet progress in switching theory and logical design.[2] It was obvious to the reviewer that Soviet authors are generally very familiar with nonSoviet work in their field, often with surprising promptness, due mainly to the availability of an information system. As a result of this awareness of non-Soviet work, there has been relatively little duplicated effort by Soviet researchers on problems of switching theory and logical design that have already been adequately treated outside of the Soviet Union. It was noted that there was negligible duplication and overlap of results between publications of different Soviet authors; each contribution is usually related very carefully to the pertinent contributions that precede it.

The status of switching theory and logical design in the USSR measured in terms of the accumulated technical content of past publications and the amount of significant activity in recent publications was found to be behind that in the US. On the other hand, the reviewer reaffirmed the pre-eminence of the Soviet Union in particular aspects of the field, namely, complexity estimates for switching networks, certain minimization problems, the analysis of relay-type circuitry, the selection of logical primitives (building blocks), and the development and use of certain methods for the synthesis of multi-terminal contact networks. It is highly likely that pre-eminence in these particular problems of cybernetics was achievable because Soviet scientists could concentrate on them knowing that international progress in the other aspects of switching theory would be made available through the information system.

The philosophical overview which is the basis for the new information-management system also facilitates more efficient management of personnel, facilities, and projects interrelated in the cybernetics program. The concept of optimal control lends functional unity to the program; the philosophical overview expressed in a "problem-tree" for cybernetics prescribes how the various parts of the program are to interrelate in performing programmed functions. The Soviets reached a new high during 1965 in the use of the information system and other management techniques for the consolidation of the cybernetics program.

ORGANIZATIONAL ACTIVITIES DURING 1965

New Research Facilities

The research base of the Soviet cybernetics program was expanded with the establishment of new institutes at Tashkent, Yerevan, Minsk, Baku, Gorkiy, and Leningrad and with the creation of one "cybernetics center" in Kiev and possibly another in Moscow.* The Institute of Cybernetics at Tashkent, a part of the Uzbek Academy of Science, is the first one of its kind in Central Asia. With its computer center it is to concentrate on the economic planning and management of chemical and other enterprises found in the Uzbek Republic and elsewhere in Central Asia. To a lesser degree the Tashkent institute will engage also in theoretical research in biocybernetics.

The Institute of Cybernetics at Yerevan was created by a reorganization of the Joint Computer Center of the Armenian Academy and of the Yerevan State University. Its efforts are concentrated on the application of cybernetics to the social sciences and especially to economics, mathematical linguistics and machine translation, archeology, and sociology. An Institute of Technical Cybernetics, Byelorussian Academy of Sciences, was created at Minsk during 1965.

The new Institute of Cybernetics at Baku is the result of a reorganization of the Computer Center, Azerbaydzhan Academy of Sciences. According to D. A. Babayev, its deputy director, the new institute has been directed by the Presidium of the Academy of Sciences, USSR, to concentrate on theoretical and applied problems in cybernetics. The special topics of theoretical cybernetics to be pursued include research on the theory of finite automata, the theory of functions, the theory of operators, and other aspects of mathematics applicable to cybernetics. The second main trend involves the application of cybernetics to the solution of major complex problems connected with the development and management of Azerbaydzhan's petrochemistry-based industry. The institute will have 14 laboratories. One will deal with development of methods of research and control of processes occurring in petroleum-bearing rock strata. Another laboratory will develop devices for storing and processing scientific and technical information for petroleum-refining and petro-chemical enterprises. A third lab-

* Research facilities at established cybernetics institutes are being expanded also. For example, construction began during 1965 of an eleven-story laboratory for the Institute of Cybernetics in Tbilisi.

oratory will be concerned with the use of currently available computers and their modernization.

The facility at Gorkiy is the Scientific Research Institute of Applied Mathematics and Cybernetics, Gorkiy State University. Research there has been concerned with the synthesis of nonlinear control systems.[3-5]

The research facility opened at Leningrad during 1965 is the Institute for Complex Social Research. It is the first scientific institution in the USSR in which mathematical and classical sociological methods are applied "on an equal footing" in approaching the problems of "man and society." * It has nine laboratories to cover a wide field of research in problem areas such as economic control, engineering psychology, work physiology, programmed instruction, and the "comprehensive study of the individual." [6]

The plans for the first of several "cybernetic centers" were completed by the Ukrainian Academy of Sciences on 17 September 1965. The Institute of Cybernetics in Kiev will be the nucleus of the center which will include departments for theoretical and economic cybernetics, a computing center, a biocybernetics department, a design bureau, and an experimental factory. The center will be used also to train cybernetics specialists in planning and management of the national economy, computer manufacturing, industrial automation, theoretical economics, and in biology and medicine. Housing plans for the center call for accommodations for 6,000 people.[7] What is possibly the second "cybernetics center" is under construction in southeast Moscow. It will probably have as its nucleus the new and considerably expanded facility for the Institute of Automatics and Telemechanics (Engineering Cybernetics).[8]

* Many proposals have been made to US foundations to establish a "Rand-type" institution for the study of social system dynamics and for the formulation of mathematical models of the transition processes of societies. As yet there is no such establishment in the US. Recent US Government awareness of the vital importance of the social reconstruction dimension of the Vietnam conflict is motivating systems-oriented companies such as those in the aerospace industry to move into the field of social systems research.

New Soviet Publications

The most significant of the four cybernetics-related journals which began publication in the USSR during 1965 is *Kibernetika* (Cybernetics), an organ of the Ukrainian Academy of Sciences. V. M. Glushkov* is chief of an editorial board which includes such outstanding Soviet Bloc scientists as A. A. Lyapunov, A. A. Dorodnitsyn, S. L. Sobolev, and A. A. Stogniy. Issues received to date have emphasized automata and algorithm theory, computer theory, the theory of models, techniques for simulation of human thought processes, information systems, and mathematical linguistics.

The new journal, *Avtometriya* (Automeasuring), focuses on the theory and engineering of elements and systems for automated measurement procedures and for the transmission of the resulting information. Its chief editor, K. B. Karandeyev, is Director of the Institute of Automatics and Electromeasuring at Novosibirsk and the deputy editor is M. P. Tsapenko of the same institute. Karandeyev and Tsapenko are chairman and deputy chairman, respectively, of the Section for Measurement Information Systems of the Cybernetics Council which recommended establishment of such a journal in September 1964.

A third new journal, *Ekonomika i Matematicheskiye Metody* (Economics and Mathematical Methods), is edited by N. P. Federenko of the Economics Section of the Cybernetics Council. The publication of *Voprosy Teoreticheskoy Kibernetiki* (Problems of Theoretical Cybernetics) began during 1965 under the editorship of V. M. Glushkov. It complements the journal, *Technical Cybernetics*, which appeared during 1963.**

* Glushkov is director of the Kiev Institute of Cybernetics, vice-president of the Ukrainian Academy of Sciences, a member of the Cybernetics Council, Academy of Sciences, USSR, and an official of the State Committee for Science and Technology.

** Soviet scientists also serve as editors of new serial publications for 1965 issued by Satellite organizations. One of these is *EIK: Elektronische Informations veranbeitung und Kybernetik* (Electronic Information Processing and Cybernetics) published in East Germany.

Major Meetings

Conferences are used by the Cybernetics Council as a management tool for organizing, integrating, and monitoring research programs on specialized as well as on more general problems of cybernetics.[9]

The First All-Union Symposium on Automatic Pattern Recognition was held in June 1965.* The more than 60 papers presented dealt with such problems as the automation of data input to computers, methods for recognizing petroliferous strata, how to incorporate pattern recognition in universal automata capable of self-orientation in their environments, construction of machine analogs of the sensory organs of living organisms, and how to automate medical diagnosis procedures.[10]

The First All-Union Conference on Experiment Planning** was devoted to the use of modern techniques for planning and managing scientific and engineering research projects. It recommended the following: (i) Creation of a scientific research and consultation center for the study of experiment planning operations; (ii) conversion of the Problem Laboratory of Automation and Telemechanics of the Moscow Power Engineering Institute into a problem laboratory for the VUZ system; (iii) organization of courses for training research planning specialists in the application of mathematical statistics; and (iv) provision in the plans of the State Committee of the Chemical Industry in association with Gosplan USSR for scientific research toward the broad introduction of mathematical methods of experiment planning in laboratory, pilot, and full-scale installations.[11] [12]

The Second Symposium on Cybernetics was held at Tbilisi during November 1965 with Chairman of the Cybernetics Council, A. I. Berg, presiding. Approximately 130 papers were presented by scientists representing the many scientific centers located in Moscow, Leningrad, Novosibirsk, Minsk, Tallin, Kiev, Baku, Yerevan and in other cities. The problems designated by the Cybernetics Council for consideration by the symposium were: (i) Analysis and synthesis of cybernetic systems; (ii) operations research; (iii) problems of heuristics and artificial intelligence; and (iv) programming languages and logical structures.[13–15]

The Third All-Union Conference on Automatic Control (Technical Cybernetics) opened in the Odessa Opera House on 20 September 1965 and continued for five days aboard the steamship *Admiral Nakhimov* on the Black Sea. Two important technical addresses were delivered at the opening session, the first by V. A. Trapeznikov, chief organizer of the conference, and the second by Ya. Z. Tsypkin.

Trapeznikov's talk on the subject of "Automatic Control and Economics" emphasized the importance of a logical hierarchy of control in large industrial systems, starting with a well-regulated and dependable lower-level control which functions according to references set by higher-level controllers, but which can function well without constant corrections from the higher level. Trapeznikov emphasized the importance of the proper development of computer control of large-scale processes and in particular the use of a hierarchical control structure for maximum efficiency and reliability. Because of the difficulty in knowing accurately the process dynamics in advance, he also stressed the importance of developing self-adaptive systems.

Professor Tsypkin presented a rather speculative paper on a unified theory of cybernetics. He referred to three models for control systems: deterministic, stochastic, and self-adaptive, and to the diverse methods of analysis, synthesis, and optimization which have been applied to these models. He then spoke about a new method he has developed which embodies mathematical programming, stochastic approximation, and optimization theory. This method is claimed to allow the study of control systems, learning systems, and pattern recognition systems from a uni-

* As early as 1963 it had been reported that classified research an automatic pattern recognition systems was being conducted under the direction of M. V. Keldysh at "his institute." According to a Soviet scientist, this research was "not in the plan." The symposium reports may have included some of the heretofore classified information.

** This conference sponsored by the Cybernetics Council was held in December 1964 but was not reported until July 1965.

fied point of view. Although he had, at that time, only succeeded in solving problems which have already been solved by other methods, he seemed confident that his new method could be useful in attacking unsolved general problems of cybernetics.

Substantive topics discussed included optimal systems, where the emphasis still seemed to be concentrated on the restricted class of problems amenable to analytical synthesis, although there were two papers which dealt with computational aspects of optimization. Optimal control of distributed parameter systems also was discussed in two presentations.

The two sessions on the theory of nonlinear systems were devoted to two major topics: stability conditions for nonlinear systems and the theory and design of control systems with variable structure. This latter topic, which has been extensively studied by Emel'yanov and his co-workers at the Institute of Automatics and Telemechanics, deals mainly with switching feedback structures which can cause the overall system to operate in the so-called "sliding mode," i.e., a regime where the feedback structure is switched rapidly and the system state "slides" toward equilibrium along the switching boundary. One of the advantageous aspects of such a design is the fact that while in the "sliding mode" the overall system response is insensitive to variable or unknown plant parameters, and is determined entirely by controllable feedback parameters. Much of the research on such systems has been concerned with extending the analysis to higher order systems, designing the proper switching hyperplanes for such systems, and obtaining theoretical conditions for the existence of sliding modes.

In the three sessions devoted to statistical methods in control theory there were an unusually large number of papers on the problem of optimal control of stochastic systems indicating considerable research activity on this very difficult subject in optimal control theory. To US observers at the meeting, the formulation and approach seemed to be on a somewhat more practical statistical design basis than the work being done in the US.

Stochastic control is an extremely important subject. It is involved in handling the complexities of the control of large systems characterized by uncertainties. The theory used in approaching such systems realistically is the theory of probability, of which the theory of stochastic processes is a chapter. The uncertainties arise because of errors in measurement, in data processing, in control, and in formulation. In order to take these into account, a theory of stochastic processes is required. Although this theory was created in the US, the most significant work is now being done in the USSR by I. V. Romanovsky, L. I. Rozonoev, R. L. Stratonovich, N. N. Krasovsky, and A. A. Fel'dbaum.

The theory of stochastic processes introduces random variables with known probability distributions to simulate some of the features of uncertainty in actual processes. In connection with the interception problem, for example, it is necessary to determine a number of unknown parameters, e.g., what is it?, where did it come from? This can be done on the basis of sequential estimation, "learning," at the same time decisions are made. These are particular cases at the juncture of stochastic control theory and adaptive processes, to which Fel'dbaum gave the name "dual control processes" which have great relevance to military operations.

In addition to the regular sessions of the Technical Cybernetics Conference there were special discussions devoted to the adjunct fields of automata theory, learning systems, pattern recognition, and to applications of cybernetics to large-scale systems. The general impression formed by US attendees was that most of the computer control work in the Soviet Union is still in the planning stage, or in the limited application stage where the computer is used as a data processing and display unit for the improvement of manual control, but not in the closed-loop control stage.[17]

Following the technical cybernetics conference by five days was the Second Scientific Conference on Neuro-Cybernetics of the Schools of Higher Education at Rostov-on-

Don. Cosponsors of this conference with the Cybernetics Council were the Ministry of Higher and Secondary Specialized Education of the USSR; the Ministry of Higher and Secondary Specialized Education of the RSFSR; the Scientific Council on the Problems of Physiology, USSR Academy of Sciences; and the Rostov State University.

The bureaucratic stature and multiplicity of the conference sponsors, the academic stature of many members of its organizing committee, and the comprehensiveness of its agenda all testify to the rapidly increasing significance attached by the Soviets to neurocybernetics. Sections were devoted to the organization of functional brain systems; electrophysiological correlates of behavior; models of psychophysiological structures and behavioral processes; and heuristic programming.

That there was a section on heuristic programming is of significance; the Soviets are late-comers to this field. Most of the papers dealing with heuristic programming were presented by personnel of the Laboratory of Information Processes of the Brain, Moscow State University (MGU). Since 1959 the MGU group has been analyzing those parameters that are present in the structure of informational situations and which provide possibilities for use in the formulation of search strategies (algorithms or heuristics) for problem solving or pattern recognition. The reports reveal that, in general, the Soviet approaches to heuristic programming are similar to and based upon US work. Somewhat distinctive is the obvious Soviet attempt to identify the neurological and psycho-physiological bases of heuristic modes of behavior.

Napalkov described the development of EPSS (Heuristic Program for Self-Organization and Self-Teaching). It consists of a system of intercoordinated subroutines of various levels, each of which organizes and monitors the program of a lower level. He claims that EPSS is well suited to self-organization in cases of complex, multilevel bounded environments where the applicability of other programs of different types is shown to be impossible.

In analyzing the heuristics used by man in chess playing, O. K. Tikhomirov and his associates made movies of players' eye movements and cyclographic recordings of touch-and-feel movements of blind players. The research indicated that one of these motor functions (eye and hand movements) consists of "recall" of particular configuration possibilities at different stages, and that there is a direct reflection in motor functions of those alternatives which the person has specifically studied. Subjects were found to fix attention to some "zone of operations" which changes constantly in accordance with the game situation and forecasts of progress based upon a heuristic of the player. A comparison with a verbal account shows that there is reflected in the subjects' motor activity a much larger number of playback moves than the subjects' verbal account indicates. This suggests two interacting levels of play selection based upon reducing search possibilities which are unduplicated in any existing machine programs for chess playing.

Emotional states were also considered by Tikhomirov as a component of heuristics. He continuously monitored galvanic skin resistance (GSR) of subjects in problem solving situations and found that an abrupt and sharply expressed drop in skin resistance occurred when the subject "had a new idea" or "found the solution." These emotional responses precede the conscious evaluation of the "idea" which are made afterwards. These results suggest that evaluation of the emotional component define and limit the zone of the subsequent search and thereby serve as heuristics.

Speakers discussed the problem of defining the characteristics of and the relationships between conscious and unconscious activity in problem solving activity as these relate to heuristic programming. The solution to this problem according to V. N. Pushkin is connected with neurocybernetics applications of the concept of internal or brain models of objects and the realities of the external world. Man's ideas or images can be examined as informational cognitive models of reality, each of which represents a complex cognitive system that embraces verbal, motor, and graphic components. Dynamic information models of the problem situation are created in man's brain during the definition stages of problem-solving. However, even in this case there remains an unresolved question: why are some manifestations of the operation of a dynamic model perceived, while others remain unperceivable? This question leads to a wider problem: just how is man's conscious activity a unique psycho-physiological process of the brain? Studies of problem-solving and of creative activity in science and technology by Pushkin lead to his formulation of a cybernetic scheme in which intra-gray-matter self-regulation is considered an internal mechanism for such activity. From the viewpoint of this scheme, the totality of the information models in the brain of man, with their oral, visual, and motor components, represents control systems, the functioning of which is regulated by a control block in the brain (a gray-matter regulator). The problem confronting the person is represented in this regulator from the viewpoint of some existing model in the person's brain. There is a basis for thinking that the gray-matter regulator in turn represents a complex system, and, thus, that the control of the problem-solving process is carried out at several different levels.

The forward part of the frontal lobe is hypothecated to be a higher-order regulator of gray-matter modeling activity. The following anatomical and clinical phenomena lend support to this proposition: (i) the afferent and efferent fibers which connect this portion of the brain with the other regions of the cortex; (ii) the specific mental aberrations of frontal lobe diseases, the essential feature of which is an inability to come to grips with a problem and the absence of intellectual awareness; (iii) the impairment of control over one's thinking processes in schizophrenia and the characteristic alterations in the behavior of patients after a lobotomy.

Thus, the cortex, as a regulator for the organism and its behavior in the surrounding world, can itself be thought of as a unique self-controlling system, consisting of a regulator for controlling an object and of feedback channels between them. The conscious activity of a man in the process of solving a creative problem is a function of the interaction of the gray-matter regulator with the brain's information models. When the process of modeling items from the external world finds a match in the gray-matter regulator, the problem solution is perceived. In those cases where the components of the problem solution are not perceived, the dynamic models in the brain function autonomously.

The vital element of any control process is the image of the object in the regulator. Therefore, the explication of the structure of the language of intra-gray-matter regulation, by means of which an image of the information control models is maintained in the regulator, is one of the important tasks facing contemporary neurocybernetic research into the mechanisms of heuristic activity. It can be presumed that this same language is utilized for encoding a problem situation presented to a person, the resultant solution to which is a function of creative (heuristic) activity. Another important problem here is that of investigating the different levels of the regulation process in the major cortical hemispheres during problem-solving.

The experiments of Pushkin's group leads them to the conclusion that research on the role of the brain's design of informational models in effective self-regulation is the path to solution of a whole series of practical questions of heuristic programming which US investigators have left unanswered.* Abstracts of the proceedings of the Neurocybernetics Conference reveal that the Soviets left unanswered the basic problem to which the meeting was addressed: how to create "an artificial intellect." The proceedings do testify, however, to the fact that mathematicians, psychologists, engineers, and physicians from major cities of the USSR and from Poland, East Germany, Hungary, Czechoslovakia, and Yugoslavia are at least talking about the problem.[18]

* M. Gaaze-Rapaport, a member of the Cybernetics Council, reported at the Second All-Union Symposium on Cybernetics (Tbilisi, 24–27 November 1965) that the Soviets are trying to construct complex machine modeling units based on Pushkin's hypothesis about the formation in the human brain of some approximate model of the outside world.

Regular meetings of the Cybernetics Council were convened during 1965 on a bi-weekly basis. The proceedings of these sessions are not published. But accounts of Soviet activities in specialized fields occasionally refer in retrospect to the role of council meetings in the development of programs in those research areas. An ad hoc council meeting on teaching machines and programmed instruction is a case in point. During 1961 when Soviet research on these teaching aids was nil, a group of Soviet educators and psychologists attended a UNESCO meeting on programmed instruction and other modern approaches to the tutorial process. They came away convinced that adoption of these new methodologies was urgently needed by the USSR. This conviction was communicated to the Psychology Section of the Cybernetics Council which then convened a meeting on the matter which subsequently passed on its favorable recommendations to the Council for Coordination of Science and Technology. There, after additional and broader discussions, a decision was made to adopt the new techniques, and the recommendation was passed on to the Minister of Higher and Secondary Specialized Education of the RSFSR. He in turn issued a directive to establish research programs to provide a scientific basis for improving the educational methodology of the USSR. Similar chronologies could be described for the adoption of heuristic programming, PERT, and for various other tools of scientific management about which recommendations were transmitted via this channel.

THEORETICAL CYBERNETICS DEVELOPMENTS (PATTERN RECOGNITION)*

General

The most significant tendency of the Soviet cybernetics program observed during 1965 was toward collaborative research involving some of the best mathematicians, biologists, engineers, and psychologists of the USSR. Representative of these efforts is research on pattern recognition, a field in which the interdisciplinary approach has helped the Soviets to reach a high plane of accomplishment. Soviet work in pattern recognition was selected as an exemplar of the interdisciplinary research reviewed during 1965 because of its centrality to a number of the cybernetics program's facets. The development of heuristic programming, adaptive systems, and other building blocks for cybernetic systems share a common dependence on pattern recognition. As is true in heuristics, the methods used to distinguish patterns involve essentially the use of rules of thumb selected by a computer over a series of trials on the sole basis that they seemed to work; that is, they made discriminations of the sort desired by the computer programmer. The tie of pattern recognition devices to the design of self-adaptive control systems is slightly more involved. When unpredictable or excessively rapid changes occur in the environment of a control system such that ordinary system identification (measurement and interpretation) and subsequent optimal control based on it, become difficult, one must resort to statistical assumptions as to most likely values, i.e., a probability distribution. On this basis a decision has then to be made on the proper control for optimization; this indicates that a control policy or law has to be set up. "Decision-adaptive" is the name given to controllers of this sort by some US scientists. Where the probability distribution is not known at the outset, the use of a learning decision-adaptive controller is invoked. Measurements are classified into a series of control situations and suitable control policy is decided on both the immediate control situation and also on past control situations. In this respect the decision-adaptive control system is a pattern recognition device and a control situation is a particular pattern of the plant environment. It is the aim of the control to recognize the pattern and from it to decide the control law which will give an optimum.

Pattern recognition is related also to information theory. A collection of scientific works devoted to this aspect of pattern recog-

* Because this report is a general survey of events in the cybernetics program and not a comprehensive account of Soviet cybernetics research activities, only one sample of the significant trends observed during the year is discussed.

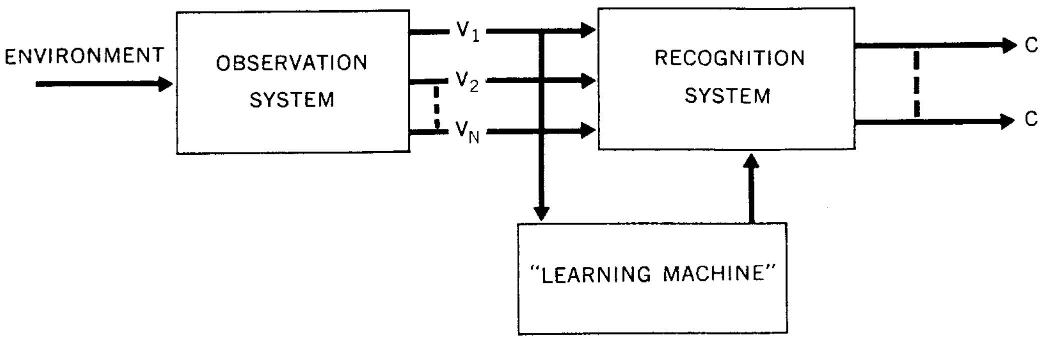
nition associated with noiseproof coding of information and allied problems was published during the year by the Institute of Information Transmission Problems, Academy of Sciences, USSR.[19]

The study of man, the archetypical pattern recognition system, is at the root of this research problem. Even untrained human beings are credited with the ability to recognize a person's identity from the pattern of his handwriting, of his voice, or of his writing or singing style. Early work in pattern recognition stemmed from an admiration of the facility of humans to learn with ease these common patterns, and from an admiration of their high degree of accuracy in recognizing the patterns in different handwriting and thereby to identify the authors.

The scientific field of automatic pattern recognition grew from the vague notions of looking for the common patterns and from attempts to construct machines that can recognize patterns to approximate, in performance, the ability of humans to do the same. Its two major problems, namely, "machine learning" and "recognition" or classification were distinguished several years earlier in the US than in the Soviet Union. Some scientists in pattern recognition argue that if humans (or even simple biological systems) can do pattern recognition with ease, then one ought to model biological systems by a partial simulation of their internal structures and perhaps similar performance might result. The term "bionics" is applied to work based on this premise.

Another group of pattern recognition workers considers that "learning" and "recognition" problems of pattern recognition can be formulated in mathematical terms as problems of recognition of membership in classes, and that some solutions can be obtained through the application of one of the mathematical disciplines such as group theory, set theory, Boolean algebra, integral geometry, communication theory, statistical decision theory, and others. The common starting point of each of these methods is to represent an input by a set of measurements, variously called features, receptors, parameters, coordinate dimensions, clues, properties or attributes. Each input that belongs to a given class can be regarded as a vector in a vector space and is located at a point defined by the set of measurements. A class is a collection of points scattered in some manner in the vector space (often referred to as observation or measurement space). Members of two different classes, A and B, are distributed, in general, in different manners in the space. Machine learning (or learning what the pattern is) is regarded by all of the above disciplines as the problem of determining the best shape and location of regions in the vector space so that A's and B's should become separated into regions called A and B. Pattern recognition or classification is the act of naming the region (A or B) in which the measurements made on a new input are contained.

The three parts of pattern recognition systems are illustrated by the block diagram in figure 1. This shows the observation system that represents the input by a set of measurements. The methods used to process inputs of known classification to discover their common pattern and thus to develop a good partition of the vector space is referred to as "learning." The act of evaluating a new input to decide in which partition of the space it is contained is performed by the classification or recognition system. In the final analysis all recognition systems can be regarded as table look-ups for they all associate a previously stored decision with each possible input and for the same input they always render the same decision. Of course, there are major differences in the manner in which different recognition systems store the decisions that should be made at any one of an infinite number of points in the vector space while they possess only a finite capacity of information storage. The important difference between different pattern recognition techniques, however, is not in the recognition system but in the learning system where the way in which partitions are obtained from the learning samples and where the restrictions on the type of obtainable partitions are determined.



54325 6-66 Figure 1. General pattern recognition system

A comprehensive discussion of these and other fundamental aspects of the theory of pattern recognition and its application to the design of reading automata was published during the year by the Laboratory of Reading Automata, Institute of Cybernetics, Academy of Sciences, Ukrainian SSR.[20] A wide circle of problems related to the theory of pattern recognition, modeling of various algorithms and discriminating systems on electronic computers, and to the design of reading automata are examined in this handbook. In addition, reading automata and their components which were developed and manufactured in the Institute of Cybernetics, Academy of Sciences, Ukrainian SSR are discussed. Although this handbook was published during 1965, it describes work done in the 1963–64 period by V. A. Kovalevskiy, M. I. Shlezinger, L. A. Svyatogor, V. K. Yeliseyev and others. Its value lies in its usefulness as a source of background data to complement the 1965 research in pattern recognition.

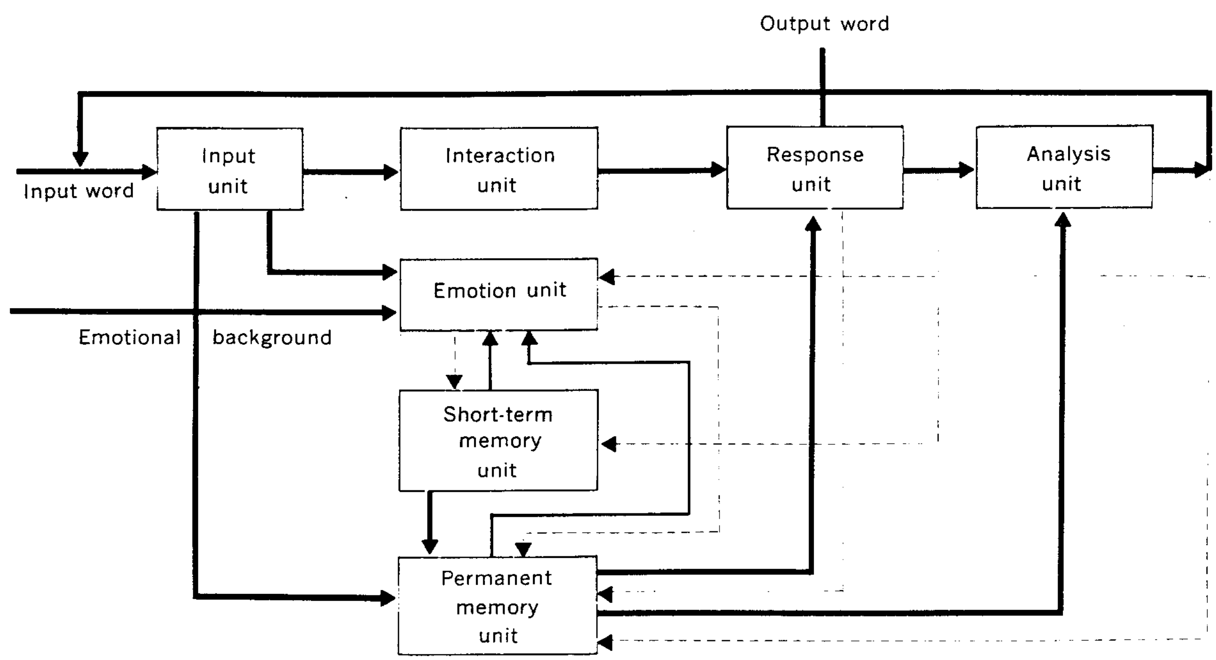
Psychobiological Approaches

An algorithm for pattern recognition described by A. G. Frantsuz is said to simulate certain features of the human pattern recognition system.[21] It is made up of minimization of the description (reduction to separation without selection of a subspace which is optimal in some sense), and construction in this subspace of a local decision rule. Frantsuz notes that there are some analogies between this algorithm and the functional algorithm for recognition of shapes by biological analyzers. Although the limitations of the possible analogies are not established, Frantsuz is apparently working along those lines; a paper on the subject by him and his colleagues at the Military Medical Academy imeni S. M. Kirov was presented at a symposium there on cybernetics and clinical medicine during 1964.

Pattern recognition as it relates to problem solving by humans has been a concern of I. M. Gel'fand, a mathematician, and of M. L. Tsetlin, an engineer, since at least 1962. In developing mathematical programming methods for finding a minimum of a function of many variables and for searching for minima, they chose to study the way men and animals solve such problems. This approach was taken for the reason discussed below. In general, a perfect model of a complex technical system which one might wish to control is unsatisfactory because it is too complex. It is necessary to have some measures of what control variables are important and of the effectiveness of the system. Animal operations in natural environments involve a massive number of variables but only certain ones are chosen as being of importance. Gel'fand and Tsetlin are trying to model this selection procedure in what is tantamount to a general model of how the brain finds a local region of control in phase space. Although this problem may be amenable to analysis, solution algorithms are too complex. Therefore, oblique algorithms are sought such as one for finding the minimum of a function of many variables. Now the problem of finding the extremum of a function of more than five variables is probably an impossible task even on computers unless help is forthcoming from insights into the patterns or organization procedures used by man. Gel'fand, head of the research group: Regulatory Mechanisms of the Central Nervous System at the Institute of Neurosurgery imeni N. N. Burdenko, is trying to gain such insights into physiological control mechanisms for subsequent improvement of mathematical programming for use in artificial control systems. He also continues his association with the Mathematics Institute of Moscow State University and the Institute of Biological Physics of the Academy of Sciences, USSR.

From his analyses of organisms as if they were optimizing automata exposed to a changeable environment, and from detailed investigations of what types of functions of available inputs are used for optimization of overall criteria, Gel'fand's group is developing new mathematical programming methods. Decision makers in the Soviet economy may use these methods in situations such as the following: the computation of a global extremum in nonconvex programming problems faced by economists requires a determination of all local extrema and a comparison at the corresponding values of objective functions. Gel'fand's group is contributing approximate methods for the computer solution of special classes of nonconvex extremal problems as a result of their neurocybernetic research. That they have not yet developed general methods for the computer solution of nonconvex nonlinear problems is probably attributable in part to the incompleteness of their hypothesis about the computational and pattern recognition systems employed by the brain.[22-25]

The influence of emotional factors on pattern recognition and other psychic factors was incorporated in a model developed at the Kiev Institute of Cybernetics.[26] It is a simple, simulated model (see figure 2) for information processing based on the interaction of two types of programs, "intellectual" and "emotional." The intellectual program is developed to reflect certain logical principles, and



NOTE: Arrows show path of information transmission.
Heavy solid lines indicate "intellectual" program.
Thin lines indicate "emotional" program.
Dotted lines show feedbacks.

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Figure 2. Block Diagram of Amosov's model of the Psyche

the emotional program is developed to reflect the relation of reality to the needs and motives underlying emotional behavior. The emotional program is based on the behavior of a given person. The intellectual program of the model under consideration is designed to recognize words and phrases, and the emotional program takes into account certain features of behavior and memory organization. The emotional program on the basis of input word analysis, that is, "harmful-useful" or "pleasant-unpleasant," affects or even changes the intellectual program, and the latter in turn affects emotion development. The intellectual program is capable of improving its solutions on the basis of changes in the permanent memory unit.

Bionics Approaches

The Cybernetics Council's Bionics Section published the first comprehensive Soviet collection of articles on bionics during 1965.[27] The bionics effort as revealed therein is concerned mostly with the construction of machines which can perform those information processing functions which are the bases of pattern recognition and related activities in a manner analogous to the way living systems perform such activities. Interrelated in such research are scientists who study natural phenomena and mathematicians and engineers who use the results of these studies as the bases for the construction of machine analogies of the natural information transformation functions. Thus, for example, studies of the pattern recognition apparatus in living systems become the bases for the construction of self-teaching, adaptive machines. An experimental model of one such machine is shown in figure 3. This automaton which learns to recognize visual patterns was designed by Ye. K. Aleksandrov and his associates.

In a similar vein, research on natural neurons, neuron nets, receptors, and analyzors has been translated into hardware models which carry out the information transformation functions of the living prototypes after which the hardware is modeled. To cite a few examples of these research and engineering activities, E. K. Kazimirov has created a mathematical model of a neuron and using transistors constructed a working hardware model on the basis of the mathematical scheme. V. G. Totsenko and B. M. Yegorov constructed networks from artificial neurons and are now concerned with increasing the

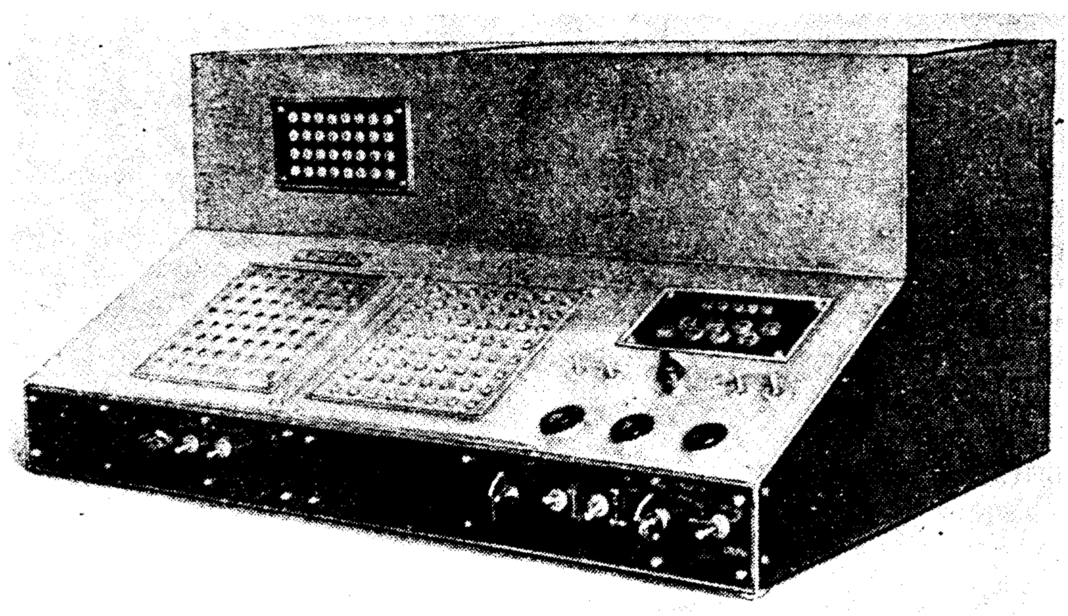

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Figure 3. Experimental model of a self-teaching automaton for visual pattern recognition

reliability of such assemblies. The studies by I. B. Gutchin and A. S. Kuzichev on the reliability of natural neuron nets are contributing to efforts to improve the reliability of artificial nets. A more ambitious project to model the human psyche has arrived at the stage at which a rather gross block diagram of the information transformation functions of the human brain has been formulated.[28-32]

Mathematical Approaches

Ya. I. Khurgin and V. I. Loginov have reported on a number of algorithms for dividing objects into classes in a manner analogous to the way the brain learns to process a series of representative of these classes. They view the problem of division of objects into classes as equivalent to the problem of selection of a class of functionals like $M = (f)$, separating the forms into the corresponding space, and subsequent selection in class M of the functional f_m which minimizes the defined conditions, such as the probability of error. The selection of functional f_m is performed on the basis of the available data by use of a teaching sequence. The problem of form recognition, from the probability theory point of view, therefore amounts to development of a deciding rule for differentiation of hypotheses under conditions when only the empirical distribution is known. An algorithm of recognition is presented by Khurgin and Loginov which realizes the minimum probability of error.[33]

The problem of pattern recognition is expressed by V. A. Kovalevskiy as a statistical statement. It is formed in terms of the minimization of risk with production of experimental data characterizing unknown parameters of some laws of probability distribution. This statement of the problem allows production of evaluations of the minimal length of a teaching sequence. The evaluations produced for the length of teaching lead to the conclusion of the importance of the role of *a priori* limitations applied to the results of teaching before the beginning of the experiment. The use of a hierarchy of rules for solution, ordered as to complexity, allows production of an algorithm which will provide for a certain result with a period of teaching as short as needed. Although Kovalevskiy agrees that this approach cannot solve the problems involved in creating what he calls a "universal learning automaton," he believes that by integrating his ideas with the perception approach of certain US scientists, a practical, applied method for construction of teaching and self-teaching machines is feasible.[34]

Heuristic rules are judged by F. D. Petrovsky to be a good approach to the form identification problem. He finds that the identification rules based on successive determinations of the membership in some class of forms of one of the forms in the set produced do not allow production of potentially effective identification algorithms. He suggests a potentially effective identification rule for the set of forms produced with sets of forms defined on the basis of learning and analyzes heuristic modifications of the optimal rule which are convenient for realization of identification algorithms on computers.[35]

The use of a pattern recognition system as a self-organizing system—a corrector with feedback—in systems for the control of multidimensional processes is recommended by A. G. Ivakhnenko. In an analysis of the problem of extremal control of a multidimensional object under the influence of perturbation matrix λ and control action matrix μ, the quality index ϕ is measured continuously, but can take on only two values—"satisfactory" and "control." Technological considerations of set-correlation (regressive) analysis can produce the optimal astatic characteristic of the object, determining the maximum of the quality index $\mu = \phi\ (\lambda)$ where $\phi = \phi\ \max'$.

The closed (determined) portion of the system is calculated according to this characteristic. However, due to inexact determination of the characteristics of the object and change of its parameters in the process of operation, it is necessary to join a self-organizing portion to the closed portion of the system. For this purpose Ivakhnenko suggests a recognition system similar to those used for differentiation of letters or speech sounds. The system does not require design and is based on very little initial information on the object. It is sufficient to know that there is a single extreme and that the line of the "poles" of the recognition system intersects the astatic characteristic. This information is contained with an excess in the data produced for design of the closed portion.

With the expansion of the matrices into lines, the spatial problem is reduced to a problem on the plane $\mu'-\lambda'$ (generalized regulating action—generalized perturbation). The order of the expansion of the matrices into lines is selected so that the astatic characteristic of the object is produced with a steady increase. In the process of operation of the object, this type of curve may be disrupted, but only to such an extent that the extreme peak can still be divided into a series of "situations" with straight or broken lines.

Algorithms are used for self-teaching of the recognition system after which it functions as a self-tuning model of the object for correction of the characteristics of the closed portion. Ivakhnenko presented results of such modeling of processes of self-teaching or recognition systems at the Third All-Union Conference on Automatic Control: Technical Cybernetics.[36]

Like Ivakhnenko, Yu. N. Chekhovoy and I. P. Kerekesner conisder the place of pattern recognition systems in control systems. They suggest a combined self-teaching automatic control system for transient objects consisting of a multidimensional connection with perturbing actions $\overline{M}_0 = f(I)$ [*] and teaching feedback, which connects the functional dependence [*] in the memory of the system. Here $\overline{M}_0$ is the optimal value of the control actions vector, $\overline{L}$ is the perturbing actions vector. The formation of the connections [*] is accomplished by a recognition system which learns to divide space $\overline{L}$ into areas within whose limits there is no need to change the control actions vector. These areas are called situations.

The algorithm for recognition of situations and the algorithms for teaching the system suggested by the authors are analyzed. It is shown that teaching the recognition of situations is a simple Markovian process. The Markovian process theory apparatus is used for analysis of the convergence of the process of teaching. The investigations of convergence are illustrated with examples. Experimental dependencies of the probability of error in recognition on the number of steps in the teaching process and on the parameters of the algorithms analyzed are produced as a result of the modeling of the suggested algorithms. It is shown that the fixed terminal value of probability of error in recognition does not depend on the initial state of the system.[37]

A significant result in pattern classification was derived in a recent article by Ayzerman, Braverman, and Rozonoer.[39] The result is essentially as follows. Consider the variables x_i forming a pattern vector $\times$. The vector $\times$ can belong to either one of the two classes A or B. Let the probability that $\times$ belongs to A be denoted by $D(\times)$ and assume that $D(\times) = \sum_{i=1}^{N} C^*_i \xi_i(\times)$ where the $\xi_i(\times)$ are members of a known orthonormal set of functions. The Ayzerman-Braverman-Rozonoer algorithm says that $D(\times)$ can be computed recursively by successive approximations through the use of the Novikoff training procedure with a randomized correction feature.

The application of the method of potential functions to the pattern recognition problem as first outlined by M. A. Ayzerman is probably the major mathematical contribution of the Soviets to the problem of teaching automata to separate input situations into classes. During 1965, Ya. L. Tsypkin[40] discovered the proximity between problems which are solvable by the method of potential functions and the problems analyzed in the theory of stochastic approximations. Ayzerman and his coworkers responding to Tsypkin's discovery carried out a detailed analysis of the interconnection between the method of potential functions and the Robbins-Monro process but not the other methods of the theory of stochastic approximations. In addition to their other results, they found that the method of potential functions can be realized by means of a computer or a perceptron, while the Robbins-Monro procedure can be realized only by a perceptron. From these analyses Ayzerman also concluded that Tsypkin's discovery forms a basis for believing that a more general theory covering a wide range of such problems will be developed.[41]

The Soviets have designed pattern recognition devices which embody such form-recognition algorithms. One such special purpose computer was noted as an achievement at the year-end review of activities of the Department of Mechanics and Control Processes, Academy of Sciences, USSR. This department, administered by B. V. Petrov, also head of the Technical Cybernetics Section, Cybernetics Council, is reported to have designed a computer capable of recognizing and distinguishing squares, circles, and triangles. The department announced in a recent broadcast that they hope for a machine able to scan complex blueprints and then control machines manufacturing the components set out in these blueprints.[42]

A second example taken from the many discussed in a 1965 Soviet book on reading devices [43] is a character reader built by the Vilnius Computing Machinery Plant for scanning alphanumeric text. At the beginning of 1963, the Computer Center of the Lithuanian Academy of Sciences commissioned a "BESM–2M" computer which made possible the elimination of punched cards and the direct coupling of the reader with the computer. Similar work was performed at the Institute of Cybernetics, Ukrainian Academy of Sciences, where the reader was connected to a "Kiev"-type computer (a BESM–2M). These experiences suggest that the best method for inputing masses of data into a computer is by such direct couplings of reader and computer.

Soviet approaches to the pattern recognition problem are, therefore, via the mathematical programming of psychological operations on the one hand and, on the other, the simulation of brain structures involved in pattern recognition systems, thereby simulating the integrated physical and psychical apparatuses involved in human pattern recognition activity. Pattern recognition research is illustrative of the Soviet trend observed during 1965 toward interdisciplinary research. But it is only part of a larger program for the realization of "universal automata" destined for use in the optimal control of complex, purposeful, and dynamic systems. Figure 4 illustrates (with broken lines) the problem which must be resolved if the over-all cybernetics program is to accomplish its goal.

TECHNICAL CYBERNETICS DEVELOPMENTS

Computer Technology

In May 1965 the Soviets revealed their largest known computer, the BESM–6. This machine has been evaluated as a marked advance in the Soviet computer-engineering art, incorporating all-solid-state construction, speeds more commensurate with special application demands than in any previously known Soviet machine (up to 1,000,000 opns/sec), input-output units on a par with equivalent US equipment which has been available for 6 years, time sharing design capabilities and other interesting features.

The machine's instruction repertoire includes a very efficient approach to address selection, some special instructions for handling real-time data, facility for doing "significant arithmetic" and so on. In addition to being a valuable asset for general purpose use in solving scientific and engineering problems, it should be well-suited to specialized applications requiring a large volume of calculations (e.g., in economics, telemetry, tracking, etc.) and for work in pattern recognition and pictorial-data smoothing.[45–48]

The URAL class of computers was expanded with the introduction of models with the designations 11, 12, 14, and 16. These machines are members of a series of compatible computers out of Penza. The compatibility feature and their availability makes these new machines suitable for incorporation into the networks, parallel systems and in the other types of multi-machine configurations under consideration by Soviet systems designers.

Coupled to native Soviet capabilities in computer technology is an intensive program for exploitation and publication of Western research and development. This is indicated in

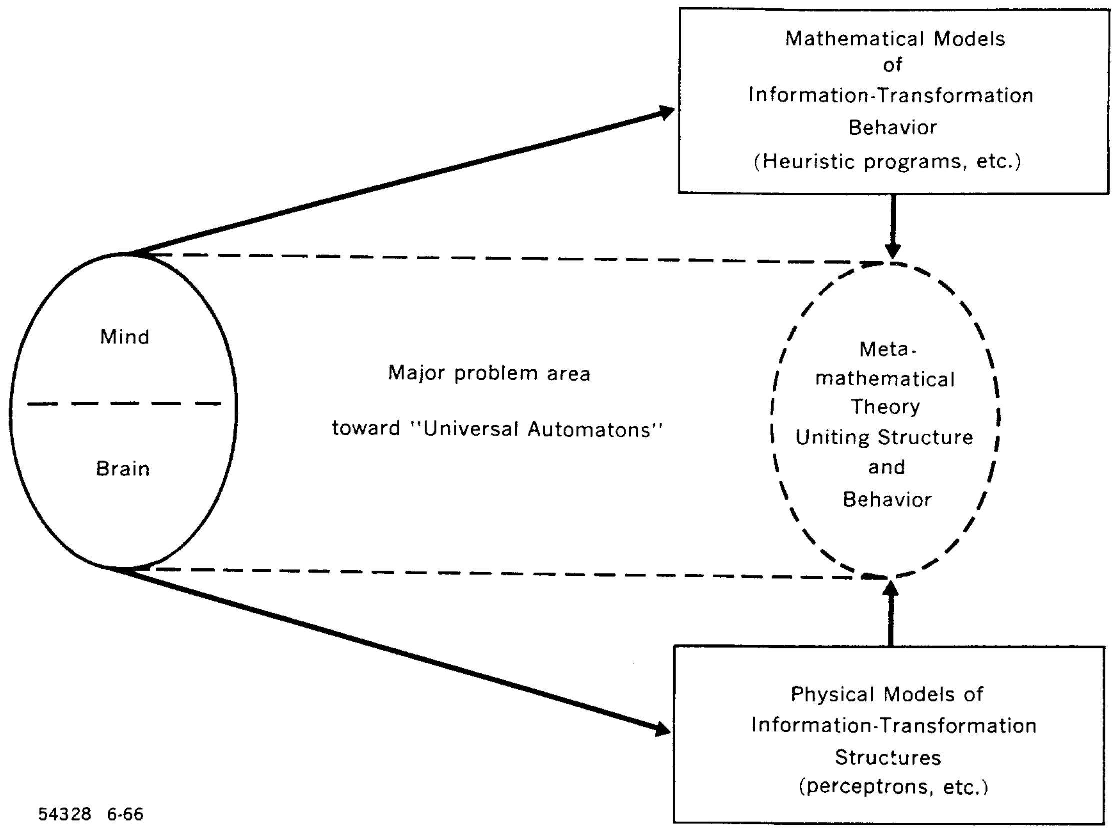

Figure 4. Schematic illustration of a major problem area in cybernetics

a recent volume which contains articles on the architecture and serviceability of the IBM/360 and a discussion of automation of solid-state logic design in the US computer industry.[49] Even more representative of the scope of Soviet exploitation of US computer know-how is the section in the *Referativnyy Zhurnal*: *Kibernetika* devoted to computers. This source is replete every month with references to the world's stock of computer theory and technology. Assuming that (1) Soviet scientific and technical talents are exemplified in the BESM–6 computer described above, (2) the intensive program for exploitation of theory and machines produced elsewhere is digested by Soviet theorists and engineers; and that (3) an importation program of increasing size is underway, leads to the conclusion that the present Soviet data processing and computer weaknesses are due to inadequacies in production technology at the industry level rather than to a lack of scientific know-how.

Systems Research and Engineering

Technological progress involving the utilization of computers depends in great measure upon the solution of very fundamental problems in the area of systems science and engineering. The speed, compactness, memory-size and speed of access to memories and other characteristics of computers are increasing rapidly in the USSR. The Soviet industrial sector will gradually but certainly improve its capabilities for producing newer types of machines which will incorporate advanced characteristics. But a more difficult problem remains: how to employ these machines in information and control modes in complexly organized systems? Soviet system scientists, during 1965, presented solutions to a number of such problems as they are encountered at various levels of the production process. In a more theoretical manner they have also studied larger-scale problems at the level of large regions and at the level of the national economy as a whole. Addressing themselves to systems problems of the foregoing types have been experts in mathematical modeling and programming, systems optimization, statistics and probability theory and in computer theory and engineering.

The most valuable source of information about these activities was published during 1965 in a compilation of papers presented originally in November 1963 at a conference on Automatic Operational Management of of Production Processes.* This conference which typifies the cybernetic approach was held to coordinate research on scientific and technological problems connected with the development of systems irrespective of the branch of industry involved and of the industrial manufacturing peculiarities of individual production facilities. Such problems involve: (a) the construction of mathematical models of complexes of production processes on the basis of analyses of existing flows of information in actual complexes; (b) the study of the characteristics both of the individual elements and of the connections between those elements in systems; (c) methods and algorithms for the processing of primary data which assure a monitoring of events in a real complex of production processes and a refinement of their mathematical model; (d) algorithms for finding optimal solutions in the form of production graphs of the distribution of power and material flows according to their quantitative and qualitative indicators among production sectors, solutions which satisfy some predesignated criteria of optimality; (e) methods and programs for finding optimal solutions on general purpose and special purpose computers; (f) technical means for the collection, transmission and preliminary processing of information, means of presenting generalized information to a human operator and means of communication with automatic actuating devices; and (g) methods of compilation of technical tasks on special purpose control computers and ancillary equipments.

* This conference was sponsored by the Section of Technical Cybernetics of the Council on Cybernetics, Academy of Sciences, USSR, and the Section of Control Systems of Industrial Enterprises of the Interdepartmental Scientific Council on the Introduction of Computer Techniques into the National Economy under the State Committee for Coordination of Scientific Research Work.

The foregoing approaches are the building blocks which go to make up what the Soviets call the theory of large systems control. In its content and methods this research trend is connected with mathematics, the theory of automatic control, computer technology, economics, biology, psychology and a number of other scientific disciplines. On account of the variety of problems and methods for solving them, the theory of large systems control is regarded by the Soviets as a division of cybernetics. The structure of the theory of large systems control and its basic concepts and terminology have not yet been established in the USSR, just as systems theory in the West remains at an embryonic level.[50]

Among the systems which the Soviets revealed during the year were the "IMPUL'S" System, the PROKAT System, and a rolling mill control system. All of these are either operational or scheduled to become operational in the near future in concrete situations.

The "IMPUL'S" System was designed by the Central Scientific Research Institute for Overall Automation for the operative control of a section of a metallurgical combine. A control computer developed for this purpose is made up of components used in the RAZDAN-2 computer. Control problems put to the system are classified, and methods for their solution are developed, according to a method based on the principle of optimality developed by Richard Bellman of the Rand Corporation. An algorithm for control of the system is worked out, consisting of a set of algorithmic sequences determining the reaction of the system as it moves from one state to another. The suggested principles for construction of the system have been investigated on a statistical model by the Monte Carlo method. Synthesis was performed for the control system; its structural plan, information flows, functions, and technical data for the main parts of the system have been worked out; and a control computer has been developed to serve as the main link in the control system.

At the present time, according to the Soviets, the "IMPUL'S" System is being introduced at an undesignated metallurgical combine somewhere in the USSR. Due to the introduction of this system, the combine itself has undergone considerable reconstruction, including its rail yard, and the installation of means for electrical centralization of signals, locomotive communications, and of a control dispatcher point supplied with modern communications equipment where the control computer will be installed.[51]

The PROKAT (rolling mill) computer control complex was slated to be installed in late 1965 in another of the large metallurgical combines. Structurally, the PROKAT computer control complex consists of three interrelated automatic subsystems of control which are united via a centralized data system and by a centralized over-all controlling computer. The local automatic systems containing STAL–1 and STAL–2 computers control the work of individual production sections. The centralized data system with its computer, possibly a TsUM–1, provides for the collection, accumulation and processing of information with the issuance of operational and technical documentation. The centralized controlling computer regulates the interaction of the local automatic control systems and monitors and records inputs and outputs by the section mill. The over-all control computer is a general purpose machine with a speed on the order of 5,000 operations per second.[52]

A comparable system for computer control of a "1300" automatic blooming mill provides automatic operational planning; automatic optimization and realization of the operating programs of individual groups of mechanisms; optimal automatic tuning of the individual controlling devices according to feedback of the results of rolling; provision of high-echelon control and coordination of the mechanisms of the mill; introduction of the sets of orders; calculation and production of a "no-waste cutting program;" automation of production accounting of the mill; and determination of the production-economic indicators of its operation. These tasks are solved by a multi-machine, two-stage hierarchical system of VNIIEM–3 control computers which are combined into an over-all cybernetic control system for direct automatic control of technological processes and of the subsystem for economic planning and operative-dispatcher information.[53]

Soviet interest in applying computer control systems for industrial management was highlighted in March 1965 when V. D. Lebedev, then Deputy Chairman of the USSR Sovnarkhoz, announced plans to modernize management techniques by installing computers at 119 plants and combines during 1965 and 1966. These plans are a natural consequence of the recently intensified interest of the Soviet leaders in improving the efficiency of operational control of industries.

At industrial levels above individual shop operations there are efforts underway to develop broader-scale systems of control involving the use of computers. Thus for example, one of the most rapidly growing uses of computers in the USSR is in the construction industry, where they have been tried and found effective in the planning and management of large-scale industrial and housing construction projects. The computers are used in conjunction with SPU (System of Planning and Management) methods, the Soviet counterpart of US-developed PERT (Program Evaluation and Review Technique). In Moscow, a special communications system is being built for the State Committee for Construction (Gosstroy, USSR) which will permit direct inputs of information on the progress of construction into Gosstroy's computer center, where it will be used to process and update PERT networks.[54]

Software Developments

A computer input language for engineering calculations is under development by V. M. Glushkov and his assistants at the Institute of Cybernetics in Kiev.[55] Information is read into the machine, element by element, with the help of a printed unit (keyboard) provided with all the symbols of the input language. Depressing a key of this unit inserts one symbol into the location of the store, the same symbol simultaneously being printed on a sheet of paper. Results are read out of the machine by means of the same printing unit and recorded on the same sheet of paper, just after the recording of the program previously read into the machine.

Limitations imposed by the size of the storage unit may make it impossible to read in the whole program at once. In this case the problem has to be divided into sections and solved in stages. The results of the initial data of preceding stages may be used in the next stage. To avoid repeated input of the same information it is possible to partially renew the programming while preserving the results of the preceding stages. The Input Language has much in common with ALGOL-60 but at the same time differs from it in having a simple program structure and a modified syntax of declarations. Details of the semantics and method of writing programs will be provided soon in a special manual for machine users.

ALGOS, another software development, has been described by V. T. Kulik and his associates from the Institute of Automation and the Kiev Polytechnical Institute.[56] ALGOS (Algorithmic Description of Industrial Cybernetic Systems) is a special programming language for automatic formation of computer programs for controlling industrial processes.

ALGOS permits description of information on complex industrial processes in a form comprehensible to the engineer. The goal of analysis of control of the production process is written in the same language. If the initial data are insufficient for solution of the problem, the machine will output a list of the information needed. When *a priori* data are insufficient, a program may be formulated to produce the necessary information by experimentation. If the initial information is sufficient, the machine will produce the solution and output the data from digital modeling of the operation of the production process in the desired regime and with the desired control machine characteristics. If the machine is supplied with information on available series-produced control machines, it will automatically select from the possibilities supplied the most suitable machines for performing the control function. Algorithms of the system constructed by the heuristic programming method have been tested for complex systems in the chemical, metallurgical and power industries. Kulik recommends ALGOS for use as a unified language oriented toward production processes in the CEMA countries.

The quest for Bloc-wide approaches to programming languages extends beyond the types oriented toward production processes to include languages for economic problems. In Berlin, during March 1965, two Bloc-wide groups on algorithmic languages held meetings: GAMS (Group for the Automation of Programming of Intermediate Machines) and GAYAPEI (Group for Algorithmic Languages for the Processing of Economic Information). GAMS is trying to establish a modified ALGOL-60 language (ALGAMS). GAYAPEI is considering two languages, KOBOL-GAYAPEI and ALGEK, for accounting and economic decision-making purposes, respectively.[57]

CONTRIBUTORY EUROPEAN SATELLITE ACTIVITIES

Czechoslovakia

Cybernetic groups in the European Satellites were actively engaged during 1965 with programs to develop improved systems for the guidance of social processes. In Czechoslovakia the Cybernetics Commission of the Academy of Sciences completed the first phase of a long-range research and development program by holding the First Scientific Symposium on Cybernetics at Smolenice.* The program's second stage which began in 1965 calls for establishment of a Czech Cybernetics Society; standardization of terminology; inclusion of cybernetics projects in the long-range research and development programs of ministries, schools, and institutes; an increase in the volume of cybernetic publications; and for the inclusion of curricula for cybernetics in educational establishments. A new Institute of Labor of the Slovak Academy of Sci-

* This meeting was held in October 1964 but reports were not received until 1965.

ences was created in Bratislava to study human factors in relation to problems of scientific management and organization of the national economy.[58]

Hungary

The Hungarians established a Cybernetics Committee under the Presidium of the Academy of Sciences and an Inter-institute Complex Committee for Research on Automation and for the Advancement of Cybernetics. Hungarian emphasis seems to be on the biomedical aspects of cybernetics. A joint cybernetics center was established by Medicor Muvek, a medical instrument factory, with the Budapest Medical University. The Scientific Society of Measurement Technology and Automation devoted a conference to diagnostic computers and neurocybernetics. Budapest was chosen by UNESCO for the neurocybernetics conference sponsored in the spring of 1965 by the International Brain Research Organization. The Hungarian Academy of Sciences established a well-equipped neurocybernetics laboratory headed by Kalman Lissak, an active campaigner for interdisciplinary cooperation between the academy's institutes.* New cybernetics laboratories for industrial research also were established during 1965 at the Bolyai Institute of Szeged University and at the Jozef-Attila University, Szeged.[59–62]

Some Hungarians began to show interest also in the social management aspects of cybernetics during 1965. Concern with "guidance systems for society" became evident with the March 1965 issue of *Valosag*, Hungary's sociology journal, which announced the beginning of a debate in that journal concerning such problems. Andras Hegedus, chairman of the editorial committee of *Valosag*, came out for a radical recasting of social guidance systems along scientific organizational-management lines. "Almost overnight," he says, "the social scientists were given freedom to examine critically the operational effectiveness of the state administrative system and orders to carry out such investigations." The aim of empirical social research in the view of Hegedus is to develop a guidance system which seeks to optimize social and economic decisions at every level of the system through the use of information systems and mathematical techniques in selecting those variants most favorable for society. Research on techniques for selecting leaders trained in modern systems management was also listed as a must.

* One example of Lissak's success is the adaptation for use in the neurocybernetics laboratory of a transistorized 128-channel analyzer designed originally for nuclear physics research by the Central Physics Research Institute.

Poland

Poland's Cybernetics Commission, directed until his death in 1965 by Oskar Lange, has been concerned mostly with the introduction of computers into the economic and management fields. Reports received during 1965 on the content of Poland's 1966–70 Plan reveal that the larger cities of Poland are to get 27 computing centers with a total of 57 computers. Educational institutions are to be allocated 48 computers to meet scientific, industrial, and educational requirements. Fifty industrial centers for design and production control machines are planned, and mining and power engineering industries are to be assigned 18 computers. Seventy-eight additional computers are to be assigned to a variety of other, but as yet unspecified, activities. To lend manpower support to these planned establishments, a special center is to be created which will train 1,200 people a year for electronic data processing, and five new technical schools for training service and maintenance personnel are to be set up. The first of these new technical schools opened during 1965.[63 64]

The National Management Development Center in Warsaw is the key organization for developing techniques for using the computer centers as part of a cybernetic system of national economic management. This internationally-subsidized center is involved in the cybernetics of planning according to Greniewski in a primer on the subject for Western readers.[65]

East Germany

While continuing to emphasize cybernetics as the basis of modern technology, the East German Cybernetics Commission also began during 1965 to concern itself with problems of social management. The author of one article in *Einheit* emphasized the hope that cybernetics will be able to overcome bureaucracy in East Germany if the social scientists improve their qualifications in cybernetics, mathematics, and mathematical logic enough to help the new economic system of planning and management of the social system to succeed. The leadership of the SED (Soziolistische Einheitspartei Deutschlands) hopes, according to one source, to develop cybernetics as "the theoretical basis for scientific management and organization of production and of the whole comprehensive socialist reconstructions." [66] [67]

Some cyberneticians seem to be fostering this movement in East Germany and in the other Satellites. Soviet articles in the East German publications, for example, extol the social science which is resulting from the merging of hitherto separate disciplines and involving the application of cybernetics to the management of social development systems. The most recent article of this type entitled "The Control of Social Processes and Cybernetics" was written by the Soviets L. B. Khalperin and P. N. Lebedev and published in the East German journal, *Statt und Recht* (State and Law).[68]

Parenthetically, it is worth noting that one Chinese Communist showed signs during 1965 that he was openly espousing cybernetics. The author of what is probably the first report received in the West from China on the development of cybernetics, claims that the course of this new science has followed the pattern described by Mao Tse-Tung for the progress of human knowledge. Only the philosophy of Marx, Lenin, and, especially, of Mao Tse-Tung is able, the author claims, to properly guide the future course of progress in cybernetics. Contrasted to the somewhat ludicrous and largely historical and tutorial content of this article is an account of the contribution of H. S. Ch'ien* to the establishment of engineering cybernetics as a discipline likely to result in practical applications of the science of information and control.[69]

PHILOSOPHICAL ACTIVITIES

"Large Systems" and Social Guidance

The marked increase during 1965 in Soviet interest in optimal control procedures for use in the management of multidimensional, multilevel, man-machine systems as such systems interact with complicated environments has found expression as a separate discipline devoted to "large systems." ** Members of such classes of systems are made up of the totality of interconnected controlled subsystems united by a common control system. One example, which is the most comprehensive system of this class known to be under construction in the USSR, is the so-called Unified Information Network which is destined to become the "nervous system" of the Soviet Government. The number of identified computer centers which might become nodes in this network when it eventually is tied together, increased during 1965 from 240 to 350. ***

During the same period, Soviet concern with the problem of "social guidance systems" became as evident in Soviet literature as it was in that of the Satellites. Furthermore, measures were taken to reify some of these ideas in practical terms. An example of an organizational measure was the creation at mid-year by the Academy of Sciences of a social science information group to furnish

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* In 1954 while he was working at the Jet Propulsion Center of the California Institute of Technology, H. S. Ch'ien was the author of the first book published on engineering cybernetics. This book was translated into Chinese in 1958. Ch'ien returned to Communist China in the late 1950's and became a key figure in a number of important scientific projects.

** The subject of "large systems" is being developed especially by the Division for Large Systems of the Institute of Automatics and Telemechanics (Technical Cybernetics) and it is not elaborated on in this report. A separate report on this subject is in preparation.

*** See OSI-SR/65-16, 29 April 1965, OUO. The lower figure is the count of computer centers as of December 1964; the higher figure is the count for December 1965. Thus the number of computer centers built or identified during 1965 is 110.

the inputs necessary for the design of control processes for social systems. Its tasks include determination of social science information requirements and formats; coordination of social science information activities throughout the USSR; methodological and technical assistance to social science organizations dealing with information; and development of international contacts with social science institutions involved in the collection, storage, processing, and transmission of information.

Of the many research projects underway, the experimental mathematical model of a city-scale development plan for Tallin is an interesting illustration completed by the Kiev Institute of Cybernetics.* This comprehensive model of the reconstruction process for the capital city of Estonia offers solutions, according to the Soviets, of the economic, social, architectural and other interrelated problems involved in engineering the transformation of a societal system of city dimensions which has been growing in random fashion since the year 1219.[70] [71]

The Communist Party is supporting—if not fostering—such developments involving the application of exact mathematical methods to social phenomena. Part of the Party's concern is with the long-range need for development of a new generation of cybernetics-oriented social science students. To meet this need, social science teachers are being exposed to cybernetics. A discussion of the role of cybernetics in modern social science is the lead article in a collection of materials for use in teaching dialectical materialism. It was originally presented by A. I. Berg, Chairman of the Cybernetics Council to the Pan-Russian Seminar of Social Science Teachers on the Philosophical Problems of Contemporary Natural History.[72]

There is some evidence that the Party is also concerned about the apparent reluctance of social scientists to adopt cybernetic methods either for reasons of inability or of fear based on the earlier negative official view of cybernetics. A recent article in the Party's journal, *Kommunist*, was aimed at reduction of the latter factor.[73] Entitled "Cybernetic Methods in Sociology," the article rejects as incorrect the earlier Soviet position which held that there existed some sort of division between the natural sciences and the social sciences because the latter "could only roughly evaluate social phenomena which were not subject to control." But now, the article continues, social scientists are applying exact mathematical methods mainly in the field of mathematical modeling of social phenomena.

In order to apply the science of information transmission and processing and control (cybernetics) the author believes that it is necessary to define the many channels through which information is passed in a society, and to define the quantity of information (not the number of words) contained in such "messages." The development of methods of analyzing the quantity of information in messages and the impact (in the cybernetic sense) of these messages on the social phenomena under study is a primary problem in contemporary application of cybernetic methods to sociological study. Looking upon society as a whole, a unified structure, and the process of control of the social "organism" as that of transfer of information directed at subordination of the individual sectors, when necessary, for the good of the whole (society), it is possible to apply cybernetic methods to study and control of sociological phenomena. For example, the "foresight" of certain information processes, the degree to which they serve the long range needs of the society, can be determined. The author states, however, that the Soviet goal is to use the regularities learned from such a study not to "control" the lives of citizens with a centralized "super-brain" but to use the information to produce effects on the motivation and sociological phenomena concerning its citizens so that scientific planning of their activity (on the basis of what the theory says they will do, not on the basis of interference with the functioning of the information channels to make them act as desired) can be more efficient.

* Descriptive models interrelating the same type of factors are providing the operational bases for the construction of several new towns in the US. Reston, Virginia, is a case in point. But we are unaware of examples in the US in which mathematical models are providing the basis for reconstruction of cities, like Syracuse, N.Y., which has approximately the same population as Tallin.

This *Kommunist* article is excerpted to further illustrate a point, i.e., that the changes in the Soviet Bloc observed during 1965 were not confined to the scientific and technological aspects of cybernetics. These together constitute but one dimension of a transition process in which new social institutions are also going to be produced in response to the new technology. The social institutions to be created in the future will in turn produce further changes in technology. Soviet planners, aware of the enormous complexity involved in these social interrelations and of the difficulties entailed in interrelating changes in both of these aspects of human life, are looking to social cybernetics for techniques for the conscious control of social development.[74]

The most significant development during 1965 involving the Party's role in the application of cybernetics to social guidance was the creation of a Council for Problems of Management of Economic and Social Processes in the Academy of Social Sciences of the Central Committee, CPSU. Because of the intimate relationship of social development processes and the maintenance of security in the contemporary world, the facilitation by the Council of the application of cybernetics to the management of society could enhance the internal security stature and the capabilities of the USSR for influencing the developmental paths of the emerging nations.

The new Council resulted from a meeting of representatives of the Cybernetics Council, the philosophy departments of universities and of other organizations which took place at the Academy of Social Sciences probably sometime late in 1965. The initiators of the meeting—the chairs of "scientific communism" and economic sciences—tabled for discussion an illustrative set of topics on the theoretical problems of the scientific management of society. Speakers at the meeting included O. Deyneko (Section for Theoretical Problems of Organization of the Scientific Council for the Complex Problem "Cybernetics," AS USSR); G. Bryanskiy (Moscow Engineering-Economics Institute); G. Slezinger (Scientific Research Institute of Labor); and others.

They described the scientific work in the field of organization of management of society being done in their respective establishments, made a number of suggestions for improving this work, and emphasized the necessity for uniting the efforts of scientists and practical workers concerned with the guidance of society.

The new Council is the answer of the Academy of Social Sciences and of its parent organization, the Central Committee, CPSU, to this recognized need. The following scientific research topics have been approved for investigation by the Council: general problems of scientific management; structure and function of management systems; management technology; information systems in management; and other aspects of cybernetics along with the development of means by which workers may participate in social control practices.[75]

The Theory of Development

The observed trends in technical and applied cybernetics involving the management of large systems and social guidance, respectively, came together this year in a number of publications that discussed various elements of a philosophical construct which is called the "theory of development." This literary bridge between technology and the social sciences has been in the process of formulation since, at least, 1958, but still only its silhouette was observable during 1965.

Formulation of this theory began with an article during 1958 entitled "Applications of Cybernetics in the Social Sciences." The author presented a somewhat naive argument in support of the thesis that cybernetics can be a boon to applied sociology in socialistically organized societies but a bane to sociologists in the capitalistic world. The manner of presentation suggested that this position was advanced merely as a necessary accompaniment to the real message the author wished to convey, i.e., that Soviet planners had a crying need for the development of a quantitative sociology and that computers and their associated methodologies were indispensable for meeting that requirement.[76]

A brochure giving clearer outlines of the evolving theory of development was published in Poland by Oskar Lange in 1960 under the title "Totality, Development, and Dialectics in the Light of Cybernetics." Three years later, the State Publishing House for Political Literature, Moscow, released the first Soviet brochure on the subject: "Cybernetics: Philosophical and Sociological Problems" by I. Novik. Also during 1963 a number of articles by Soviet authors outlined their views on the relationship of cybernetics to social progress. This collection, authored by Academicians, S. G. Strumilin, V. A. Trapeznikov, and V. S. Nemchinov, reiterated much of what had been said by them in many places: (1) An essentially new type of social organization will result from the application of science to society and cybernetics. This will be the best illustration of the relationship between science and the activity of people, a relationship to which the future belongs; (2) the industry of the future will undoubtedly be a complex of production processes united by a single automatic control and guidance system with cybernated devices doing most of the work for man; and (3) when society passes over from the basically primitive forms of control to automated systems based on scientific methods of research and electronic techniques, definite changes will result in the socio-economic structure of society. These phrases have a familiar ring but are significant, nevertheless, because of their publication for the first time in an international Communist journal. In retrospect, it seems that the purpose of the authors of this collection was to furnish approbation for creative, mathematically oriented social scientists.[77]

Also, during 1963, two relatively unknown Leningrad authors published a brochure, "Miracle of Our Time—Cybernetics and Problems of Development," which closely parallels the work of Lange which had been published three years earlier. The authors, B. V. Akhlibininskiy and N. I. Khralenko, analyze the reasons for the appearance of cybernetics as an independent branch of science; the role of cybernetics in the creation of the material-technical base of communism; and the contributions of cybernetics to understanding the essence of life and especially of social dynamics. These threads are woven together in a popular style into what they and other Soviet writers designate as the "theory of development or progress."

In the spring of 1964 at the Novosti Press Agency in Moscow the first large-scale, public discussion of cybernetics which had implications for the problem of development was held. It was a conference on Cybernetics, Planning and Social Progress sponsored by the editors of *USSR, Ekonomicheskaya Gazeta,* and *Voprosy Ekonomiki.* The participants included leading Soviet mathematicians; philosphers; economists, chairmen of State committees, departments, and planning and statistical bodies; directors of research institutes; and heads of educational instiutions. The theme of the meeting was that a socialist society can make use of cybernetics in ways "inconceivable" under other types of systems, and the result of the conference was to remove ideological bars to the application of some elements of cybernetics to the guidance of social processes. Foremost among the participants were V. M. Glushkov, Trapeznikov, Nemchinov and other scientists intimately associated with the Cybernetics Council.[78]

Concurrent with the publication and meeting activity seminars were initiated to develop cybernetic methodologies for the social sciences based on computer-based models of socio-economic processes. One such seminar was created in conjunction with the Cybernetic Council at the Department of Dialectical and Historical Materialism of Moscow University. The latest contribution in this chronology of the genesis of the cybernetics-related theory of development is the book *Kybernetika ve Spolesenskych Vedach* (Cybernetics in Sociology Research) published by the Czech Academy of Sciences. Among its authors are Arab-Ogly who wrote the first Soviet article dealing with cybernetics and society and others from the Soviet Bloc and Western Europe who pioneered the movement to relate cybernetics and social dynamics. At least in Arab-Ogly's case this effort has been going on quietly for at least eight years.

The following summary of the basic assumptions of the theory of development is derived from the previously cited sources:

1. Social change can be described in terms of biological evolution, a process which entailed the reorganization of successful species in adaptively responding to environmental changes. The mechanisms by which biological species so maintain levels of "dynamic stability" can be explained by cybernetics. Because biological evolution and the transition processes of social systems are analogous, cybernetics is also the key to understanding social change.

2. Biological evolution is the predominant tendency toward increased levels of systems' complexity made possible by the adaptive occurrence of automatic physiological feedback systems. As in biological evolution, each succeeding state in the progressive development of social systems is characterized by a more complex form of organization and commensurate automatic control resulting in the increased orderliness and decreased chaos of societies which adapt "to the times."

3. The development of man and social systems is not through the simple processes of adaptation to external conditions but through the creation by science and technology of new forms of external conditions which are more propitious for survival. Man and society must adapt therefore, not to nature directly but to nature as it is being transformed by science and technology, i.e., by making his ideas and social institutions harmonious with the man-made environment.

4. The process of development, the complication of organizational forms, which permits the maintenance of system-environment stability is explicable in terms of game theory, a tool of cybernetics. Stability is achieved if a system can counter each strategy of the environment (opponent) with a new and more appropriate corresponding strategy. The responses of men and advanced societies to the environment are qualitative. Quantitative responses characterize lower animal forms and primitive societies. The struggle for stability will be successful, therefore, in direct proportion to the number of different strategies that the transition system has at its disposal. Those systems which possess the greater variety of methods of behaving in response to varied natural and man-made environmental influences are thusly preserved.

5. The variety of methods of behaving is equal to the system's store of information or negentropy. In this manner the process of development is linked in Soviet theory to the concept of organization, information, and negentropy. The theory says that for a system to possess a variety of strategies (a greater choice of possible responses to opponents) and thus to develop it must have a complex inner structure; that is, a high level of organization. The more complex the system, the greater the choice of possible responses to external influences it has at its disposal. There are no upper limits to the level of complexity a system of organization may attain—as shown in the history of the development of living systems and of societies—if the process of complication is accompanied by the development of mechanisms that simplify or "automate" its operations. Automation, which creates that simplification without which further development would be impossible, is, therefore, a universal law of development. Because the problem of automatic control in its most general sense is one of the central problems of cybernetics, it is the key to the progressive development of society.

The foregoing paragraphs approximate as much as is possible at the present time the evolving theory of development. From this outline it is clear why mathematicians, engineers, mathematical economists, biologists, and other specialists and a new breed of social philosophers are interacting in the Soviet cybernetics program. Such interactions are viewed as a necessary condition for the automation of control systems and such automation is requisite in the theory of development for the progress of the USSR toward a higher stage of social organization. Cybernetics, as suggested by I. V. Novik, is, therefore, a vantage point around which scientists can generalize their activities and social philosophers can make their ideas more concrete.[79]

That cybernetics is playing such a role is evident in publications in which, on one hand, for example, a study of ergodic development processes is used by a mathematician to illustrate the universality of control laws as evidenced by a characteristic property common to biological, physical, social, and economic processes and computing machines. Philosophers, on the other hand, are not just talking about "dialectic development"; under the impetus of cybernetics they are discussing the necessity for clarification of the "purpose" of social systems; the creation of probabilistic models of social dynamics; and the need for computer-based information models as an aid to management. The evidence about the cybernetics program collected during 1965 indicates that at least some elements of the theory of development are the bases for the policies of current leaders. However, there is no evidence that all elements of the theory of development have been accepted by the leadership as the basis for all socio-economic policies.[80-84]

International Ramifications

Although applications of Soviet ideas about societal cybernetics and the theory of development were described by one author as decisive factors in the world revolution, they found expression during 1965 in only one major collection of papers authored by representatives of the scientific communities of the USSR, the Satellites, Israel, and of Western Europe. It was a compilation of articles on cybernetics and the social sciences and was dedicated to the memory of Norbert Wiener. Other more ambitious plans for promulgating Soviet notions about cybernetics and social progress during 1965 did not materialize. Some of those plans were included in the USSR National Commission recommendations for the 1965–66 Program for UNESCO to provide means for a "great study" on teaching methods based on cybernetics; a brain research program with special emphasis on neurocybernetics; and, of special significance, an international meeting on "Cybernetics and Computers in the Service of Social Progress." [85-87]

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