The Chair of Mathematical Theory of Intelligent Systems

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The article describes the process of the Chair creation, the main research areas and results, and Chair members.

Introduction

The role of hi-tech in civilization progress is constantly increasing. Intelligent systems represent one of the main areas of hi-tech, because such systems facilitates the major component of civilization progress - the intelligent component.

The above reasons were taken into consideration in the Faculty of Mechanics and Mathematics in Moscow State University in 1986, and a new branch devoted to applied research in the areas of mechanics and mathematics was founded. This branch contained the new Laboratory of Intelligent systems founded on the basis of the Chair of Discrete Mathematics. Later this laboratory was renamed into the Laboratory of Problems of Theoretical Cybernetics. The Laboratory is targeted at solving problems coming from the industry. Students and post-graduate students also take part in research process.

In 1991 the new Chair of Mathematical Theory of Intelligent Systems was founded on the basis of the Laboratory of Problems of Theoretical Cybernetics and the Chair of Discrete Mathematics.

The article is devoted to the above events. It describes the history, the essence, the main problems and the main results of the research in the area of intelligent systems as a part of the research in the area of mathematical cybernetics in Moscow State University. We also describes other activities of the Chair of Mathematical Theory of Intelligent Systems and the Laboratory of Problems of Theoretical Cybernetics.

We pay special attention to the member of the Chair and the Laboratory and present the graph describing these teams.

We give a number of references, however the list of references may be incomplete.

1 Cybernetics

People are interested in shifting their various but often routine jobs upon the shoulders of machines. It allows to make life easier and to spend more time solving new, more sophisticated problems, and, as the result, leads to the progress of civilization. Recently this trend started to embrace the area of intellectual activities.

The approach to modeling of "thinking"systems was first presented by A. Turing in late 1930-s. The Second Word War made many scientists switch to solving practical problems some of which were connected to designing thinking systems, e.g. for message decryption, target following, efficient computations, etc. The results in this field lead to the creation of a new area of science - cybernetics. The main starting contributions were made by C. Shannon [1] and A. Turing [2]. The development process was guided by the contributions of J. von Newman [3], A.A. Lyapunov [4], S.V. Yablonskiy [5], O.B. Lupanov [10], A.A. Kolmogorov [6], N. Wiener [7], V.M. Glushkov [8], Y.I. Juravlev [9], and other scientists.

Research of thinking systems became one of the main areas of cybernetics. Such research was called intelligent system theory.

In 1950-s and 1960-s a more detailed description of and intelligent system started to emerge. New system characteristics lead to the creation of new research fields, such as formal languages, pattern recognition, memorization, decision making, teaching and learning, reasonable behavior. Another field of research was devoted to structures capable of modeling the above characteristics, e.g. logical and neural nets, programs, automata, computers, etc.

The progress in the major part of research fields was significant but not uniform. Automata theory, formal language theory and pattern recognition became the most advanced fields. There are several reasons explaining why it was so. Mathematics turned out to be not ready for solving the major part of problems. Researchers suffered from the lack of computing facilities and did not have sufficient resources to perform adequate and efficient modeling of the objects and processes being studied. There was too little cooperation between researchers from different fields, especially too little cooperation with mathematicians (it was probably caused by the fact that many researchers did not get sufficient mathematical background). However many mathematicians exposed certain inertness and switched to new problems unwillingly.

As the result the development of several fields was slow, and hopes to design machines capable of creative processes such as translating texts in natural languages, composing poems and music, medical treatment, etc. are still only hopes.

It took years to overcome these difficulties. During the latest forty years the new apparatus of analytical and discrete mathematics was created, and during the latest twenty years a breakthrough in the area of hardware and software was performed. Even twenty years ago the capabilities of modern computers looked fantastic. Mathematical background of the researchers was significantly improved, and the scale of cooperation grew up.

As the result the intensity of research of intelligent systems increased. Many areas, such as formal and natural language theory, recognition of visual, audio and abstract patterns, databases and knowledge bases, fast information extraction and processing algorithms, theories of teaching and learning systems, automata, machines, machine nets, computer modeling, etc. became mature.

Many countries studied to produce expert systems replacing humans in various areas from accounting to scientific research. The need of such systems nowadays is one of the main driving forces in intelligent system theory.

The demand for specialists in intelligent system theory is much higher than the supply provided by universities.

The creation of the Chair of Mathematical Theory of Intelligent Systems was logically prepared by the works in this area; actually it could be reasonable to create the Chair even earlier.

Faculty of Mechanics and Mathematics became the center of research in the area of cybernetics; it was the cradle and the leading scientific center of cybernetics in Soviet Union.

Faculty of Mechanics and Mathematics, a relatively young Faculty of Computational Mathematics and Cybernetics and a number of scientific centers of Russian Academy of Science and universities are nowadays the main scientific force in the area of cybernetics.

The first seminar on cybernetics in the Soviet Union was founded in early 1950-s in the Faculty of Mechanics and Mathematics. The seminar was headed by A.A. Lyapunov and S.V. Yablonskiy. The participants of the seminar included such well-known scientists as A.I. Berg [11], L.V. Krushinskiy [12], N.V. Timofeev-Resovskiy [13], A.N. Kolmogorov, P.S. Novikov [14], A.P. Yershov [15], A.A. Markov [16], O.B. Lupanov, Y.I. Juravlev, and V.Y. Kozlov.

The seminar is connected to development of almost every field of cybernetics, including intelligent systems.

Later there emerged new seminars on control system theory, complexity theory, algorithms, automata, pattern recognition, languages, databases and knowledge bases, decision making, intelligent systems, etc.

These seminars and corresponding lecture courses were first organized by the Chair of Computational Mathematics headed by S.L. Sobolev and later by A.N. Tihonov.

In 1959, when the Chair of Mathematical Logic headed by A.A. Markov and later by A.N. Kolmogorov was founded, the seminars and the courses moved to the new Chair.

In 1980 the new Chair of Discrete Mathematics headed by O.B. Lupanov was founded, and the seminars and the courses moved to the new Chair.

In 1991, when the Chair of Mathematical Theory of Intelligent Systems headed by V.B. Kudryavtsev was founded, the seminars and the courses connected to intelligent systems moved to the new Chair.

In 1970s the Faculty of Computational Mathematics and Cybernetics was created on the basis of the Faculty of Mechanics and Mathematics and the Faculty of Physics. The new Faculty contained the Chair of Mathematical Cybernetics headed by S.V. Yablonskiy. In 1998 the new Chair of Mathematical Methods of Forecasting headed by Y.I. Juravlev was founded. This Chair also performs research in the area of cybernetics.

The main research in the area of cybernetics in Moscow State University was carried out by researchers and students of the listed chairs.

The important role in uniting seemingly different areas of cybernetics into a solid theory was played by the well-known work of S.V. Yablonskiy [5] carried out in 1950-s and 1960-s. This work introduced one of the main notions of cybernetics - control system, guided the research directions and solved some problems in these directions. As the result, a significant part of cybernetics could be considered as the theory of control systems.

The main results in the area of cybernetics in Soviet Union were published in periodical transactions "Problems of Cybernetics"later called "Mathematical Issues of Cybernetics". The transactions were first edited by A.A. Lyapunov, then - by S.V. Yablonskiy. Now the editor in chief is O.B. Lupanov.

In 1960 the journal "Cybernetics"edited by V.M. Glushkov was founded.

In 1989 the journal "Discrete Mathematics"edited by V.Y. Kozlov was founded.

The publications of foreign authors devoted to cybernetics were published since 1970 in "Transactions on Cybernetics"edited by O.B. Lupanov. These publications helped to teach several generations of researchers.

Articles on pattern recognition are published in the journal "Pattern recognition and image analysis"founded in 1995 and edited by Y.I. Juravlev.

Articles on intelligent system theory are published in journal "Intelligent systems"founded in 1996 on the basis of the Chair of Mathematical Theory of Intelligent Systems an edited by V.B. Kudryavtsev.

2 Intelligent systems

The control system is defined by the following notions: element, element scheme, scheme functioning, and scheme environment.

Elements have input and output channels used for interactions. A scheme can be created by connecting inputs of elements to outputs of other elements. Such schemes implement a recurrent process of interaction with environment in time (time is considered to be discrete). These processes are defined by a number of assumptions.

Elements have internal states that change in time depending on the current input values and previous state value. Input and state values determine output values. Hence, given the current state and input values, one can compute the output values and the states at the next moment. Hence, given the initial state values, the environment defines current outputs and next states. This interaction cycle can be repeated, and we get scheme functioning.

A control system is the above scheme interacting with the environment.

Scheme functioning is also called control system behavior in the environment.

It is important to point out that all material and abstract information processors are control systems and therefore can be studied by the means of control system theory. The examples of such objects include formulae, automata, electrical chains, biological cells, etc.

Automata is probably the most complete example of control system among the real examples of control systems, because in fact automata can be obtained by limiting value sets to finite sets and limiting scheme types to element compositions (that can be later reswitched). Automata generally works infinite time.

In approximative approach to control systems, when all value sets are considered to be finite, we in essence come to the model of automata which becomes a universal model and hence plays a special role in cybernetics.

Studies in the area of automata theory became the main research direction for the team formed by the author and his current and former students. As the result, the team had managed to select and study the main environments, automata types, types of automata behavior in various environments, to create methods for optimal synthesis of fault-tolerant automata, to research modeling capabilities of infinite automata (called cellular automata), etc.

These results together with the results by A. Moore, S. Kleene, D. McNotton form the classical contents of automata theory.

One of the main directions of automata theory is studying the behavior of automata in various environments. The ideology of this direction comes close to intelligent system theory.

E.g. automata analysis of geometrical environments is connected to pattern recognition; automata analysis of language environments is connected to languages, logical reasoning and problem solving; analysis of mixed geometrical and language environments is connected to collective behavior and decision making; the synthesis of automata with the given behavior is connected to database and knowledge base architectures and information extraction, etc.

During the research in the area of automata theory the author and the members of his research team constantly increased the sphere of interpretations of automata using models and problems from various fields such as mathematics, physics, biology, psychology, sociology, technology, etc. As the result, automata theory was sufficiently enriched, and its applicability was essentially widened.

Intelligent systems were also studied as the objects connected to automata models.

Let us describe in general a popular type of an intelligent system (called Turing type intelligent system) shown in the figure.

Let us consider an object **O** interconnected with the environment **C**. The object can input information from the environment and affect the environment (this process is depicted by the corresponding arrows).

Input information from **C** comes into **O** and is placed into a recognition block **P**, then moved into the memory block Π for the purpose of analysis. The process of analysis is based on a block **DK** containing database and knowledge base (long-term memory); the process is controlled by the control block **Y** and depends on a number of parameters describing internal object properties and environment state.

Database and knowledge base together with the control block form the system "brain". Imitation capabilities of the system depend on internal operator efficiency and sufficientness of information stored in the "brain".

Object is functioning in time stepwise. Functioning is graded by a number of internal and external functionals.

The sequence of functionals values is considered to be the characteristic on object and environment interaction. It is used to estimate the "reasonability"of object behavior, including the conclusion whether the object has completed its task or not.

Concrete interpretations of various intelligent system components lead to concrete intelligent system implementations.

A solver of mathematical problems is a good example of such an intelligent system. The environment is a set of problems on elementary algebra, geometry and calculus. Functioning is looking for the solution of the input problem, and the result is the solution and the description of the solution process, or rejection, if the solver fails to solve the problem.

Databases and knowledge bases of the solver include the list of standard techniques of identical transformations of algebraic expressions, basic theorems, and logical inference operations.

Control block is the most sophisticated block for the solver. The idea behind it is to provide optimality of technique selection from database and knowledge base by the means of heuristics to reduce inference complexity as much as possible.

The idea behind such a construction is a new one; it allows to overcome the shortcomings of logical and axiomatic approach used e.g. in such tools as General Problem Solver and Mathematika.

This system was created by A.S. Podkolzin. It showed high efficiency by solving the major part of problems from various textbooks in a few seconds.

The solver was exposed at an International exhibition in Hannover (Germany), at Russian and International conferences and seminars.

The list of the existing intelligent systems is long.

Research in the area of intelligent systems in the Faculty of Mechanics and Mathematics of Moscow State University was stimulated in 1986, when the Department of Applied Research in Mathematics and Mechanics headed by V.A. Sadovnichiy was founded. The Department provided a framework where specialists in mechanics and mathematics worked together solving problems lying on the boundary between various areas of science. The results of the Department include the research in the area of space implemented in industry and awarded a number of domestic and international prizes.

The main area of research of the Laboratory of Problems of Theoretical Cybernetics, a part of this Department, was intelligent systems theory and its applications.

As it was pointed out earlier, in 1991 the Laboratory of Problems of Theoretical Cybernetics and the Chair of Discrete Mathematics served as the basis for the new Chair of Mathematical Theory of Intelligent Systems (MaTIS). The couple Chair - Laboratory sufficiently consolidated the research in the area of intelligent systems in Moscow State University.

Research and teaching in the area of intelligent systems are performed together by the members of MaTIS Chair and Laboratory. The joint team consists of ten doctors of science, twelve Ph.D.'s, and ten young researchers and embraces not only intelligent system theory and discrete mathematics and cybernetics, but also some areas of algebra, geometry, theory of functions, etc.

Such team allows to perform complex research in the area of intelligent system theory which itself is a complex discipline.

The main areas of research are the following.

a) Recognition of audio, visual and abstract images.

b) Information storage, search and extraction.

c) Solvers of intelligent problems in various spheres.
d) Teaching and learning systems.
e) Discrete structures and processes.
f) Automata and algorithms.
g) Computer modeling in natural science, technology and humanities.
h) Information security.

Let us describe the above areas in more detail.

3 Pattern recognition

The research is focused in several directions: combinatorial and logical approach based on tests; discrete geometrical approach based on internal figure encoding; dynamical based on automata ideology.

3.1 Combinatorial and logical approach

This approach emerged in 1960-s under the influence of testing methods of fault detection in technical devices proposed by S.V. Yablonskiy and I.Chegis [17].

A test for a given matrix is a set of columns such that every row in the set is distinct. A test is called final if it does not contain other tests. A test is called minimal if it contains the minimal number of columns. These notions can be extended to matrices with equivalence relation on rows. The lines should be distinct with the respect to the equivalence relation.

If we consider equivalence classes as states of a device, tests can recognize the corresponding state, i.e. the pattern of the state. The paper [17] contains definitions of tests, final and minimal tests, and procedures obtaining final and minimal tests.

Later Y.I. Juravlev, F,P, Krendelev and A.N. Dmitriev [18] introduced the notion of informative column weight - the frequency of occurrence of the column in tests. This weight was used to create a linear functional determining the process of selecting the equivalence class of a row, i.e. recognizing the corresponding pattern.

The generalization in comparison with [17] was in the fact that the initial matrix served only as the "teaching"material and did not describe the whole state set of a device. This approach worked well for a number of applications including the problems of geology and medicine.

However, the situations where linear functionals were inefficient emerged very quickly.

V.B. Kudryavtsev [19] proposed a different functional for row classification. It was defined in the following way: for an arbitrary test and a given line is classified, a set of tests is considered, and "voting"procedure is performed. Voting result is the normalized vector of classification results for every test in the set. Final classification is performed according to the voting results. The test set could contain all tests, all final tests, or all minimal tests. Column weights could be taken into consideration. It turned out that the described procedure is particularly efficient when the matrix is a qualitative description.

"Voting"procedure worked well in such problems as geological search, medicine, economical efficiency estimation, etc.

Efficiency of voting test procedures in applied pattern recognition problems stimulated the creation of theory of pattern recognition based on tests.

The main questions of the theory included combinatorial tests characterization and efficient generation of testing procedures providing the given recognition precision.

The team consisting of V.E. Kuznetsov [20], E.V. Dukova [21], A.E. Andreev [22] and A.A. Kibkalo [23] and headed by V.B. Kudryavtsev performed research and obtained the results that currently are the contents of theory of pattern recognition based on tests.

It is important to point out that the first linear recognition procedures based on tests allowed to process relatively small data arrays represented by matrices with approximately thirty rows and columns.

The first step in increasing matrix sizes was performed by V.E. Kuznetsov who designed a stochastic procedure for building tests and calculating their attributes including informative weights. The procedure had polynomial complexity and was capable of processing matrices up to a hundred rows and columns. This procedure became one of the main components of recognition procedures based on test voting.

E.V. Dukova designed an algorithm of asymptotically efficient test creation for narrow matrices (the number of columns is sufficiently more than the number of rows). For almost all narrow matrices the asymptotic number of tests was expressed explicitly, as well as the values of informative weights and their correlations.

These narrow matrix procedures of E.V. Dukova with built-in modules of V.E. Kuznetsov provide the solution with polynomial complexity. So matrix sizes increased up to a hundred rows and a thousand columns. These results formed E.V. Dukova's Ph.D. thesis.

E.V. Dukova's results were improved by A.E. Andreev. He considered arbitrary matrices with the given submartix comparison graph. The main result was characterization of matrix families sets with constant, polynomially and exponentially growing number of tests and final tests, and the description of informative weights and minimal test length for these families. As the result, asymptotically optimal procedures for generating the most important test classes were constructed.

A.E. Andreev's procedures with built-in modules of V.E. Kuznetsov provide polynomial algorithms for arbitrary matrices, and the number of rows and columns can be increased up to two thousand.

Research of E.V. Dukova and A.E. Andreev showed that for almost all matrices voting against all tests or all final tests discard informative weights, and test families are unstable for small matrix variations, i.e. when two matrices differ insignificantly, test sets for these matrices can be quite different.

However matrices emerging from applied problems (unlikely almost all matrices) as a rule do not satisfy the above undesirable properties.

Hence it was reasonable to construct test sets that could treat informative weights according to their substantial importance for almost all matrices. It was desirable that these sets did not differ significantly for similar matrices.

This problem was solved by A.A. Kibkalo. The resulting construction consisted of "short"tests with length not greater than the logarithm of the number of rows in matrix. A.A. Kibkalo also proposed an asymptotically optimal algorithm for generating "short"tests.

A.A. Kibkalo's procedure with built-in modules of V.E. Kuznetsov provide polynomial algorithms for almost all matrices and can efficiently process matrices with thousands rows and columns.

A.A. Kibkalo's results and procedures are currently the core of pattern recognition on the basis of tests.

The results of M.V. Nosov [24] under scientific supervision of

A.S. Aleshin are also worth mentioning. M.V. Nosov solved the problem of functional description of test sets for tables.

Linear test procedures were studied by students of V.B. Kudryavtsev and A.A. Bolotov A.Shaeb [25] (Syria) and by students of S.V. Aleshin V.V. Pereslavskiy [26] and B.V. Getsko [27]. As the result pattern classes that can be efficiently recognized by linear procedures were described, as well as cases that can not be efficiently processed by linear procedures.

3.2 Discrete geometrical approach

This approach was developed in works of V.N. Kozlov [115] under scientific supervision of V.B. Kudryavtsev. The research was targeted at designing procedures for recognitions of geometrical figures formed by a finite number of points on a plane or in space. Such recognition is connected to overcoming many technical difficulties. It has to utilize various assumptions and mathematical technologies. The main reason for these difficulties is the necessity to consider such transformations as rotations, symmetry, stretching and local distortions.

The new approach was based upon internal figure encoding invariant to the above transformations.

The encoding is performed in the following way. Figure points are enumerated, then for every simplex its measure is evaluated.

Figure encoding consists of all triples containing a pair of simplexes and relation of their non-zero measures.

It is proved that for arbitrary number of dimensions two figures have the same encodings (up to point reenumeration) if and only if the figures are affine equivalent. It is also shown that small code modification leads to a small figure transformation from affine point of view. On the basis of these results polynomial algorithms that check figure similarities up to the given precision were designed. The approach was extended to restoring the figure by a pair of its projections. These results formed Doctor of Science thesis of V.N. Kozlov.

3.3 Automata recognition

This approach is based on using automata as the recognition tool.

There are two directions connected to automata recognition - connected to recognition of visual and audio patterns.

S.V. Aleshin [116] considered visual recognition in case when the pattern being recognized can be rescaled. So a pattern is transformed into a hierarchical structure that serves as the environment for an automaton. Automaton traverses the hierarchy and determines the corresponding pattern class. For several pattern classes recognizing automata were constructed, and the properties of these automata were studied.

These results with their applications in industry formed S.V. Aleshin's Doctor of Science thesis.

The research of I.L Mazurenko [28] under the scientific supervision of D.N. Babin used automata approach for speech recognition. Natural language fragments are represented by regular languages, and regular languages are recognized by corresponding automata. As the result a practical implementation was performed. Experiments showed that the efficiency of the implementation enriched by articulation consideration was higher than the efficiency of known recognizers of Russian language.

4 Information storage, search and extraction

This direction is closely connected to the development and needs of computing technology in the second half of the XX-th century. During the fifty years of history of this direction there emerged a number of concrete information storage forms, key problems of information search and extraction and algorithms solving these problems. So there existed a number of separate components serving as model objects. There was no general model, no unified problems, unified notion of complexity or unified algorithms.

The unified information storage and search theory was created by E.E. Gasanov [29] under scientific supervision of V.B. Kudryavtsev and A.S. Podkolzin.

The theory is based upon an information graph model of data storage and search. The model is a graph with selected input and output vertices. Input vertices get input data, and output vertices provide reaction to input data. Graph edges pass information throughout the graph. Graph vertices are loaded with computing automata processing information from input edges and passing processed data to output edges. As the result there emerges a computing process originated by input data and finished by providing output data. The graph stores data and allows to compute answers to various queries. The graph is constructed based on a concrete data block and a set of possible queries. Search complexity is the time required to process a query. Data blocks can be characterized by parameter determining block sizes, so we get mass problems with the corresponding Shannon complexity functions. As an example of mass problems one can consider "basic"problems solved separately for various database types, e.g. for lexicographical, trees, relational databases, etc.

Examples of basic problems include "problems with short answers", "problems for partially ordered sets", "interval search", etc. For such problems two types of solutions were obtained - Shannon function estimation and optimal information graph synthesis. Shannon function asymptotics were expressed explicitly, and it was shown that Shannon function is unstable to graph parameter variation but stable to input data variation.

Information graph theory embraces all solutions for concrete database types and provides new algorithms and synthesis technologies that are much more efficient than known solutions.

Information graph theory was the core of E.E. Gasanov's Doctor of Science thesis.

B. Thalheim [30] from Germany, the former student of V.B. Kudryavtsev, developed the logical approach to database analysis. One of the main results here is the functionality criterion allowing to determine whether a database can be decomposed. An important case here is when a database can be described as a deductive closure of a set of axioms. B. Thalheim also proposed corresponding algorithms, and the results were used in creating real databases connected to ecological information.

Logical approach to database analysis formed the core of B. Thalheim's Doctor of Science thesis.

M.N.Nazarov, the former student of A.E. Andreev, researched the problem of parallel data extraction from databases implemented in several external carriers, with several independent queries in case when only one query to every carrier is allowed [119]. As the result the complexity of the solution was estimated.

5 Intelligent problem solvers

Designing intelligent problem solvers is the main direction of intelligent system theory. In MaTIS Chair this area is researched by A.S. Podkolzin [31] who developed a new original approach to solver synthesis. It is obvious that this problem can be solved evolutionary, moving from concrete solvers to general theory. A.S. Podkolzin used elementary algebra and calculus as the environment for his solver, because this ares has accumulated a lot of exercises that can be used as teaching material. The solver itself was already mentioned earlier.

From general point of views a solver is a deductive system that tries to deduce the given statement from the given axiom set, so the area is closely connected to mathematical logic. However mathematical logic is not focus on deduction process itself - it either considers situations when it is known that deduction is possible or uses assumptions sufficient for deduction existence.

In solver deduction the possibility of deduction is the main problem. How can deduction be found?

The proposed solution is the following. The language for expressing propositions and questions is considered to be fixed. First a bank of elementary transformations of words and phrases in this language should be created. We suppose that it is possible to measure the efficiency of applying the given transformation to the given text. The problem is to construct deduction (if it is possible) as a sequence of elementary transformations that uses the set of axioms to answer the given question about the given text. A.S. Podkolzin has developed a powerful and sophisticated technology for creating such solvers. The technology imitates logical calculus, but inference is performed on the basis of an internal guide that selects the optimal plan at every step. It turned out that the solver of mathematical problems built with the help of this technology imitates the reasoning of an advanced student and tends to finding the shortest solution.

Self-teaching is not implemented adequately yet.

Self-teaching for solvers is the problem of the future, and the solution of this problem will become a breakthrough in cognition modeling.

Solver creation was the core of A.S. Podkolzin's Doctor of Science thesis.

6 Teaching systems

This area was covered by the team headed by V.B. Kudryavtsev. Team members include A.S. Strogalov, P.A. Aliseichik and V.V. Peretrukhin [32]. Research is based on the following idea. A teaching system consists of three main components: a teacher, a student and a database with knowledge. The input is data about a student and a target problem that needs to be solved at the end of teaching process (e.g. the student should achieve a certain level of knowledge). The teacher starts teaching by forming the model of student by estimating various parameters, such as knowledge perception rate, ability to concentrate, ability to remember material, etc. The model allows to optimize teaching process for a concrete student. Model parameters depend on the area of knowledge. One of the main results was creation of an environment for creating expert teaching systems. One of the key contributors to this solution was K. Vachik from Germany.

With the help of the above environment over twenty teaching systems for arts, computer science, medicine, history, literature, economics, etc. were created. These systems are actually being used in education process.

7 Automata

Automata can be considered as a formal model of an intelligent system or as a control system of general type.

An automaton is determined by the internal logic, structure or behavior in the environment. Interconnections of these components in various interpretations is the subject of automata theory.

Automata theory can be divided into three parts: abstract automata theory, structural automata theory, and cellular automata theory.

Abstract automata theory studies properties of fixed automata in concrete environments. Structural automata theory studies the ability of concrete automata sets to generate new automata compositions and the properties of these compositions. Cellular automata theory studies the properties of infinite automata compositions.

7.1 Abstract automata theory

The main problems of this field of automata theory are automata analysis and automata synthesis.

Automata analysis is describing the behavior of concrete automata. Automata synthesis is describing automata with the given behavior.

Automata behavior types come from practice. The main types include transformation, acception, enumeration, evaluation, etc.

Historically the first problem to be researched was studying automata as transforming devices. The actual problem was to reconstruct an automaton and its states by fragments of the behavior defined as correspondence sets for inputs and outputs (these sets are called experiments), e.g. to solve synthesis problem.

Automata reconstruction problem was first set by A. Moore [30]. A. Moore was the first researcher to achieve concrete results in automata reconstruction for simple and multiple experiments.

Automata reconstruction can be viewed in a broader context.

A. Moore considered experiments that emerge when one inputs the given set of words to an automaton with the fixed initial state. This set forms an "output"neighborhood of the automaton state. An important generalization is the situation when one knows experiment set emerging when an automaton transits from other states to the given state. The latter set forms an "input"neighborhood of the automaton state.

Now let us consider the problem of state reconstruction in an assumption that only fragments of these neighborhoods are known for different states, and an automata class containing the automaton being reconstructed is fixed.

This problem was formulated by V.B. Kudryavtsev for I.S. Grunskiy [34]. I.S. Grunskiy obtained a number of important results, including the description of the simplest neighborhoods allowing state reconstruction and automaton reconstruction for both finite and infinite automata classes, description of the whole system of such neighborhoods, and nearly optimal reconstruction procedures for practically important automata classes. These results formed I.S. Grunskiy's Doctor of Science thesis.

G.G. Ponomarenko [35] studied the problem of automata reconstruction under an assumption that only fragments of output neighborhoods are known, and these neighborhoods are limited by some constant **r**. The research was performed under scientific supervision of V.B. Kudryavtsev and I.S. Grunskiy. Automata comparison according to such neighborhoods generates the relation of **r**-equivalence for automata.

G.G. Ponomarenko researched the structure of **r**-equivalent automata classes, and the superstructure of such classes. As the result procedures for automata reconstruction were created.

S.A. Bogomolov [36] supervised by V.B. Kudryavtsev and V.A. Buevich researched the possibility of reconstruction of simplest automata on the basis of a finite set of finite output neighborhood fragments represented by a union of simple experiments. The results included complete description of such automata and reconstruction algorithms.

A.V. Kluchnikov [37] supervised by V.A. Buevich researched complexity aspects of automata reconstruction.

V.A. Kozlovskiy [38] supervised by V.B. Kudryavtsev and I.S. Grunskiy researched the influence of automata class on the problem of reconstruction. Let us describe the results of V.A. Kozlovskiy in more detail.

Real automata construction is performed step-by-step according to the Moore diagram. At every step the transitions from the given state to other states under every input letter are implemented. This is the place where errors like incorrect transitions can occur. After the iterations are complete, a class generated by the initial automaton is created on the basis of certain fragments of the output neighborhoods. The structure of this class and algorithms for reconstruction in this class were obtained. The complexity of these algorithms was polynomial. In general case the complexity of reconstruction is exponential.

L.V. Kalyanov [39] supervised by V.B. Kudryavtsev and A.M. Bogomolov studied the influence of symmetry on automata reconstruction with multidimensional input. L.V. Kalyanov described inertia groups for automata working on words with fixed length, classified temporal chains of these groups and estimated chain length. L.V. Kalyanov also showed how knowing the chains affects automata reconstruction.

The problem of automata reconstruction is not only interesting by itself, it also plays an important role in practice, e.g. for real automata diagnostics.

Automata diagnostics problem can be stated in the following way. Let us consider the original automaton and a set of automata considered to be "descendants"of the original automaton. It is required, if possible, to establish for an arbitrary automaton from the set whether it is the original automaton or not.

V.G. Skobelev [40] supervised by V.B. Kudryavtsev and A.M. Bogomolov studied the complexity aspects of reconstruction problem; A.A. Sytnik supervised by V.B. Kudryavtsev and A.M. Bogomolov studied this problem when automata class consists of subautomata of a single universal automaton.

G.P. Pogosyan [41] and O.A. Dolotova [42] supervised by V.B. Kudryavtsev researched automata without memory with input errors like shortcuts, wire cuts, wire swapping, etc.

O.A. Dolotova considered Post classes [43, 44] of Boolean functions. Foe every class Shannon function defined by the minimal sufficient number of inputs determining the correctness of automata functioning. It turned out that Shannon functions grow only for conjunctions and disjunctions classes, and the growth is linear. For all other classes the value of Shannon function is constant. This effect remains for almost all functions from Post classes.

G.P. Pogosyan considered **k**-valued logics. In this case Shannon functions grow when the number of variables grows. The asymptotic behavior of Shannon functions was found explicitly.

All results from this subsection, like results of O.A. Dolotova and G.P. Pogosyan were adopted for solving automata diagnostics problem in practice.

Accepting automata were also studied. The problem here is to describe the possible classifications of external events defined by sets of input words by the means of internal automata logic.

The problem of event classification by the means of automata was first stated by S. Kleene [45]. S. Kleene found the complete solution of this problem. It was shown that events recognized by automata form a special algebra equivalent to so called regular word sets. The results of S. Kleene marked the way of creating formal languages approximating real languages. After regular languages were discovered, a hierarchy of regular languages generalizations represented by Turing machines with various limitations was created.

For every such machine class the problem of correspondence between machines and languages can be stated.

After the results of S. Kleene it became important to create formulas of regular events represented by the given automaton and to create representing automata on the basis of the given regular expressions. Practically important algorithms of this kind were presented by V.M. Glushkov [46].

S. Uscumlich [47] from Yugoslavia supervised by A.S. Podkolzin solved the correspondence problems connected to V.M. Glushkov's algorithms in a chain "analysis-synthesis-analysis". S. Uscumlich developed special methods for operating regular expressions and Moore diagrams to establish the correspondence. As the result, it became possible to describe the objects transformed to each other in the above chain at a qualitative, metrical and algorithmical levels. The complexity estimations for the simplest regular expressions and automata corresponding to each other are close to final. The estimations are exponential and are determined constructively. Algorithmical part is close to optimal. These results formed the core of S. Uscumlich Doctor of

Science thesis.

Computational abilities are another interesting facet of automata behavior. Automata computations can be presented by the following interpretations. Let an automata have several input channels and one output channel. The inputs are random independent sequences. Hence the frequencies of concrete symbols in the output sequences are defined by the probabilities of input symbols. As the result it becomes possible to assign a numerical function to the automaton. The function has several input variables. Input and output values are defined in a segment [0, 1].

A.V. Ryabinin [48] supervised by V.B. Kudryavtsev and A.S. Podkolzin studied such modeling of real functions. A.V. Ryabinin solved the problem of analysis for automata computers by describing the set of functions that can be modeled by automata. It turned out that this set in essence consists of relations of uniform polynomials with natural coefficients. It was shown how the polynomials are computed and how functions computed by automata superpositions can be expressed in terms of such polynomials. A.V. Ryabinin also obtained a nearly final estimation of the number of states required to model an arbitrary continuous function from the class of the given smoothness with the given precision.

The constructed model is one of the simplest models for computing complex real functions.

There exists an important class of technical automata called generators. An automaton is a generator if the set of its outputs consists of all output words. The generating property is usually checked by analyzing the set of output words of growing length. A.S. Podkolzin [49] supervised by V.B. Kudryavtsev found out that Shannon function of the length of such output words is equal to $2^n - 1$, where n is the number of states. The solution was obtained constructively by designing the corresponding example. The publication of these results became the winner of the nation-wide contest of students' scientific projects.

The described automata behavior types were not based on any additional interpretations of input and output words.

If such interpretations are added, the applicability of automata to practical problems will increase.

One of the most studied interpretations is interpreting words as trajectories in a discrete space.

Let us consider an integral grid in space. The grid nodes are "colored"into colors from the given list. An automaton is placed into the given node. The automaton can view the neighborhood of the given size. Coloring of this neighborhood of the input letter. Output is either movement into the neighbor node or staying in the same node. So the automaton starts moving around the grid. The problem is to describe the movement and the zones the automaton travels through.

Let us consider a connected grid zone colored by colors from a fixed subset. Let the remaining grid part be colored into a fixed color not belonging to the selected subset. The zone is called a maze (finite or infinite). Let automata move only in the maze.

The problem is to determine whether there exists an automata capable of traveling through all finite mazes. The negative answer was first given by L. Budach [50]. However the proof was clumsy and contained some logical flaws. A.S. Podkolzin provided a simple and clear proof of this fact [51]. It is interesting to point out that a collection of two automata is capable of traveling through all finite mazes. For three-dimensional mazes the negative answer can be obtained much simpler.

G. Kilibarda [52] from Yugoslavia supervised by V.B. Kudryavtsev studied the problem of automata traveling through mazes.

G. Kilibarda gave and inductive and logically simple proof of Budach-Podkolzin theorem.

G. Kilibarda constructed the simplest automata collections capable of traveling through all planar mazes. The collections consist of a regular automaton and stone automata. Stone automata can move only with the regular automata. The time required to travel through mazes was estimated. The order of time is equal to the order of maze area.

G. Kilibarda constructed universal traps for planar case. A universal trap is an infinite maze such that for any given number of states there exists a neighborhood radius such that any automaton with the corresponding number of states is unable to leave this neighborhood for any starting position. The construction was generalized for a three-dimensional case and automata collections.

These results formed the core of G. Kilibarda's Doctor of Science thesis [78].

G.U. Kudryavtsev [53] supervised by A.S. Podkolzin considered the problem of Moore diagram analysis automation for automata. This problem is connected to traveling through mazes and investigating mazes' properties. For an arbitrary Moore diagram the automaton traveling through this diagram in optimal time was constructed, and the number of states was estimated. For an arbitrary Moore diagram the automaton checking whether two states are distinguishable, and the number of states, solving time and experiment length were estimated.

Automata in mazes were studied by A.N. Zyrichev [54], A.A.Zolotykh [55], A.Z. Nasyrov [56], V.I. Grunskaya [57], B. Stomatovich from Yugoslavia, etc.

A.N. Zyrichev found out that there exists an automaton capable of traveling through all finite mazes with limited holes. A.A.Zolotykh improved this result and showed that there exists an automaton capable of traveling through all finite mazes with holes limited in a fixed direction.

A.Z. Nasyrov supervised by V.A. Buevich showed that there exists an automata with two marks, one of which is unremovable, capable of traveling through any finite multi-dimensional maze.

V.I. Grunskaya supervised by V.B. Kudryavtsev started to research the problem of characterization of automata trajectories in mazes. V.I. Grunskaya found when automata are equivalent from the viewpoint of trajectories. It turned out that trajectories as a language are context-dependent with a number of important solvable properties.

B. Stomatovich supervised by V.B. Kudryavtsev researched the problem of letter recognition by automata. The notion of a letter was formalized, and for the formalization the problem of existence of recognizing automata was solved. For solvable case the corresponding automata were constructed, and the solution complexity was estimated. It turned out that complexity is a square function of letter area.

J. Schtorm [58] from Germany supervised by V.B. Kudryavtsev studied automata behavior in automata environment. Let us consider an automaton and select a subset of state set. The sets from this subset are called acceptable. An automaton is called δ-optimal in an environment for $\delta > 0$ if the frequency of acceptable states is at least $1 - \delta$ for growing functioning time. For the given δ and the environment J. Schtorm described δ-optimal automata, and for the given automaton and δ J. Schtorm described the corresponding environments. He also studied the hierarchies of automata and environments and constructed synthesis procedures for them.

7.2 Structural automata theory

As it was already noted, structural automata theory studies the properties of automata algebras. These algebras can be divided into two classes - algebras of automata without memory and algebras of automata with memory.

Algebras of automata without memory are known as logical functions algebras, algebras of automata with memory are usually called automata algebras. Both classes are also called functional systems.

The main problems in this area include completeness, expressibility, basis, subalgebra lattice structure, etc.

Completeness problem is to describe all algebra subsets that form the whole algebra under closure against all algebra operations. Such subsets are called complete subsets.

Expressibility problem is describing all algebra subset pairs $_{\mathbf{1}}$ and $_{\mathbf{2}}$ such that $_{\mathbf{1}}$ closure against all algebra operations contains $_{\mathbf{2}}$.

Basis problem is describing all complete irreducible algebra subsets.

Automata without memory

Historically algebras of logical functions with superposition operation was the first objects to be studied.

E. Post constructed the whole lattice of subalgebras of $\mathbf{P_2}$ - the algebra of logical functions. As the result, the problem of completeness, expressibility and basis for all $\mathbf{P_2}$ subalgebras was solved.

U.I. Yanov and A.A. Muchnik [59] found a principal difference of $\mathbf{P_2}$ and $\mathbf{P_k}$ with $\mathbf{k} > 2$. Not all $\mathbf{P_k}$ subalgebras are finitely generated, and subalgebra lattice becomes continual.

A.V. Kuznetsov [60] showed that all finitely generated $\mathbf{P_k}$ subalgebras contain a finite system of maximal subalgebras, i.e. precomplete classes. This system can be constructed efficiently and is criterial, i.e. a set of functions is complete if and only if it is not contained in any precomplete class. Hence the problem of completeness and expressibility for finite sets is algorithmically solvable and is equivalent to constructing all precomplete classes.

An explicit description of precomplete classes was first obtained for $\mathbf{P_3}$ by S.V. Yablonskiy [60] and for $\mathbf{P_4}$ by A.I. Maltsev [61]. I. Rosenberg [62] used methods of predicate description of precomplete classes originally borrowed from A.V. Kuznetsov and further developed by I. Rosenberg to describe all precomplete classes for $\mathbf{P_k}$ with arbitrary $\mathbf{k}$.

V.B. Kudryavtsev with S.V. Yablonskiy and E.U. Zaharova [63] constructed the asymptotics of the precomplete class number for $\mathbf{P_k}$ (Kuznetsov's problem). The asymptotics was double exponential, so applicability of precomplete classes criteria in practice turned out to be quite limited.

V.B. Kudryavtsev [64] gave an explicit description of the minimal Sheffer system of precomplete classes, i.e. a criterial system for a single function in $\mathbf{P_k}$ (Sheffer problem). It turned out that such system is unique.

V.B. Kudryavtsev also described all fundamental subgroups of a symmetrical group of all permutations of $\mathbf{k}$ elements. Such subgroups are defined by the property of forming a complete set with any essential function (Solomaa problem).

V.B. Kudryavtsev [64] described the minimal criterial system for functions from $\mathbf{P_k}$ with image equal to the set of all $\mathbf{k}$ values.

D. Lau [65] from Germany supervised by V.B. Kudryavtsev researched the problem of finite generation of monotonous functions in $\mathbf{P_k}$. As the result classes with finite basis were described, as well as classes without a finite basis.

V. Harnau [66] from Germany supervised by V.B. Kudryavtsev considered a sublattice of closed sets in $\mathbf{P_k}$ formed by all functions commutative with the given function with one argument. V. Harnau found out when such classes coincide, what are the minimal subalgebras in the sublattice, what is the sublattice cardinality, width, depth, minimal and maximal chain length. The results were generalized for the whole $\mathbf{P_k}$. He also studied the Galois-type correspondences including closed sets that do not contain selectors.

These results formed the core of V. Harnau's Doctor of Science thesis [67].

The notion of logical functions was extended by V.B. Kudryavtsev to heterogeneous logical functions depending on variables with different value sets. For algebras of form $\mathbf{P}_\Sigma$ V.B. Kudryavtsev obtained embeddability and finite-generateness criteria, and solved at an algorithmic level and in terms of precomplete classes the problems of completeness and expressibility. For small numbers of variable values and variable types precomplete class systems were constructed explicitly. It was shown that $\mathbf{P_2}$ is the only algebra with a finite subalgebra lattice.

L Arutunyan supervised by V.B. Kudryavtsev studied the subalgebra lattice of $\mathbf{P}_{\Sigma_1}$ - the simplest algebra of heterogeneous functions. Knowing $\mathbf{P_2}$ lattice proved to be helpful for researching $\mathbf{P}_{\Sigma_1}$ subalgebras. These subalgebras were stratified according to a "trace", i.e. the intersection with $\mathbf{P_2}$. It was shown what layers have finite, countable of continual cardinality. The latter layers are essentially equivalent to a set of all subsets, because superposition generates only singular functions.

An approximative approach to studying $\mathbf{P_2}$ lattice properties was developed by R.M. Djavadov [69] supervised by V.B. Kudryavtsev and A.S. Podkolzin.

The idea is to introduce the measure of likeness of functions as the share of difference for all possible input values.

R.M. Djavadov considered problems of metrical completeness and expressibility for the whole $\mathbf{P_2}$ and $\mathbf{P_2}$ subsets with the given precision $\epsilon > 0$. The problem was solved for all Post classes. The proof was based on a special logically simple r representation of functions that ϵ-approximate the given function.

P.A. Aliseichik [70] supervised by V.B. Kudryavtsev found the asymptotics of the length of the longest $\mathbf{P_k}$ basis and constructed such basises for small values of $\mathbf{k}$.

S.I. Kartashev [71] supervised by V.B. Kudryavtsev considered algebras of $\mathbf{P_2}$ functions with operations formed by close $\mathbf{P_2}$ function sets. Post lattice was stratified into classes that produce algebras with finite, countable and continual cardinality of closed set lattices. In the latter case algebras are close to the set of all subsets.

These constructions were improved by Dow Ju Zyn [72] from China supervised by V.B. Kudryavtsev. Dow Ju Zyn considered algebras of predicated in $\mathbf{P_k}$ with operations from $\mathbf{P_k}$ and solved the problem of classification of such algebras with finite, countable and continual cardinality of subalgebras. The problem of completeness and expressibility was also solved by explicit algorithm descriptions and precomplete class systems constructions.

A.V. Makarov [73] supervised by S.V. Aleshin continued studying $\mathbf{P_k}$ homomorphisms started by A.I. Maltsev [61].

V.V. Kudryavtsev [74] supervised by A.S. Podkolzin considered a new class of functional objects - finite collections of functions from $\mathbf{P_k}$. These collections can be viewed as a generalized automaton description that includes only functions implemented in various states. The problems of completeness and expressibility of finitely-generated algebras of such collections were solved at algorithmical level. V.V. Kudryavtsev proposed algorithms for constructing precomplete classes in these algebras, though the apparatus of predicates and classes of predicate preservation plays a limited role in the model.

V.S. Darsalia [75] supervised by V.B. Kudryavtsev considered algebras of polynomials with superposition operation. For polynomials with natural coefficients V.S. Darsalia explicitly constructed all precomplete classes. The number of precomplete classes is finite. It was shown that the problems of completeness and expressibility are algorithmically solvable. For polynomials with integral or rational coefficients completeness and expressibility are unsolvable, and the set of precomplete classes is continual, though it does form a criterial system. In cases of natural and integral coefficients basises are finite, and it is algorithmically possible to select a basis from an arbitrary complete system. In case of rational coefficients complete systems are infinite. V.S. Darsalia obtained the depth of the above algebras in each other.

Limit logics are another generalization of $\mathbf{P_k}$ algebra. A countable set of functions with variables and functions taking natural values and superposition operation form an algebra called limit logic if for any $\mathbf{k}$ it contains a subalgebra that can be homomorphically mapped on $\mathbf{P_k}$. The set of limit logics is continual.

Y. Demetrovich [76] from Hungary supervised by S.V. Yablonskiy and V.B. Kudryavtsev studied the possibility of limiting the set of limit logics by modeling limit logics by other limit logics. As the result a set of partial preorders was constructed. These preorders contain equivalence classes that could swallow "similar logics". However it turned out that the cardinality of these classes is still continual for a wide interpretations of modeling. Still minimal and maximal classes have a number of important properties, such as explicit construction of basis, precomplete classes, functions forming the classes, etc.

V.B. Kudryavtsev proposed a general constructive model of a functional system [64]. This model has two implementations. The first implementation is generated by functions of finite or countable logic, the second one is generated by functional sequences, i.e. dictionary functions implemented by finite or infinite automata. In both cases operations are automata computable operations that generate automata closure in functional systems. All existing functional systems are covered by this model. Moreover, one can expect that in future new algebras with finitary operations and hence algebraic closure will emerge. The proposed model can implement an arbitrary operator of such type. V.B. Kudryavtsev described the variety of automata closures, properties of partial order of these closures, variety depth and width, and behavior of finite automata closures. V.B. Kudryavtsev also created the theory of finitely-generated finite functional systems over $\mathbf{P_k}$. This theory gives solutions to the above problems for functional algebras. In particular it was established how closed class lattices in $\mathbf{P_k}$ transform from continual cardinality to finite cardinality when closure operators vary over the set of finite closure operators. The latter problem was also solved for countable valued logic.

These results and the results on automata without memory mentioned earlier formed the core of V.B. Kudryavtsev's Doctor of Science thesis.

V. Lashhia [77] supervised by S.V. Aleshin considered a functional system example over $\mathbf{P_k}$ with concrete types of automata computable operations. V. Lashhia studied some basic functional system problems for this example.

G. Kilibarda [78] supervised by V.B. Kudryavtsev studied automata closures for computable functions. For a classical functional system of computable functions with superposition, primitive recursion and minimization operations the basic functional system problems are algorithmically undecidable. The question is how does one need to facilitate automata closure to come to constructive properties of such algebras. G. Kilibarda constructed chains of automata closure facilitations that lead to decidability of both separate basic problems and groups of basic problems of functional system theory.

Automata with memory

Algebras of automata with memory form a more sophisticated object than algebras of automata without memory, with new important properties.

The first algebra of that kind to be considered was the functional system of automata called $\mathbf{k}$ logic functions with delays with the operation of synchronous superposition. This system was studied by V.B. Kudryavtsev [79] supervised by O.B. Lupanov. Such automata compute $\mathbf{P_k}$-functions in some time (with a delay). If the output of one automaton is connected to the input of another automaton, it is required that the delays of these automata are equal (synchronous connection). Such functional system $\overline{P_k}$ is a model of computer chip synthesis.

The problem was to consider various interpretations of completeness. An automata system is complete if its closure contains any function with any delay; any function with a limited delay; any function with any delay starting from some value; etc.

For every of the above cases there exist criterial closed class systems consisting of a countable efficiently defined family of precomplete classes and chains of closed classed not contained in any precomplete class.

This event is a sufficient difference between automata algebras with memory and automata algebras without memory.

It turned out that there always exists an algorithm verifying whether a system is complete in the above senses. The algorithm is based on criterial systems.

M. Milichich [127] from Yugoslavia supervised by V.B. Kudryavtsev and A.A. Bolotov researched Galois correspondence for functions with delays and described both known facts and new results in this language.

A transition from the above algebra to $\mathbf{P_a}$ - all finite automata with superposition and back propagation (composition) leads to a number of new effects. Though $\mathbf{P_a}$ is finitely-generated, it contains a continual set of precomplete classes, as it was shown by V.B. Kudryavtsev [79] supervised by O.B. Lupanov, and the problems of expressibility and completeness are algorithmically undecidable, as it was shown by M.I. Kratko [80] supervised by B.A. Trahtenbrot.

These facts stimulated studying the phenomenon of inefficiency of basic problems solutions for $\mathbf{P_a}$. Research was performed in two main directions.

The first direction was based on limitations of the notions of expressibility and completeness. The second direction was based on narrowing automata classes where the problems of completeness and expressibility are solved.

The first direction was pursued under supervision of V.B. Kudryavtsev by V.A. Buevich [81], B. Thalheim [82] from Germany, U. Dassow [83] from Germany, A.S. Strogalov [84], I. Hazbun [85] from Jordan (the second supervisor in the latter case was D.N. Babin), etc.

The second direction was pursued under supervision of V.B. Kudryavtsev by K.V. Kolyada [86], D.N. Babin [87], etc., and under supervision of S.V. Aleshin by A.A. Chasovskih [88].

Let us describe some results in more detail. V.A. Buevich and

B. Thalheim considered the problem of completeness under an assumption that an automata system is complete if its closure under composition operation for the given input length τ models the behavior of every automaton (τ-completeness). If a system is τ-complete for any τ, it is called **A**-complete.

It is obvious that for any fixed τ and number **k** of input values studying $\mathbf{P_a}$ can be limited to considering $\mathbf{P_a}$ only with superposition operation and, moreover, $\mathbf{P_a}$ can be substituted by a special finitely-generated subclass **R** of $\mathbf{k}^{\tau}$-valued logic. As it was noticed earlier, in this case there exists an algorithm for solving completeness and expressibility problems and constructing all precomplete classes, and the number of precomplete classes is finite.

An explicit description of all precomplete classes was given by V.A. Buevich in his Doctor of Science thesis.

Mohammed al Naef [124] from Lebanon supervised by V.A. Buevich considered the relations of completeness and **A**-completeness for automata with a limited arity.

B. Thalheim studied the properties of the class $\mathbf{R_1}$ containing all unary functions from **R**. B. Thalheim found the cardinality of this class and its closed subclass lattice, the width and the depth of the lattice, described precomplete classes, solved problems of completeness and expressibility for $\mathbf{R_1}$. He also found sufficient conditions of τ-completeness in **R** of systems containing the whole $\mathbf{R_1}$.

V.A. Buevich showed that the problems of **A**-completeness and **A**-expressibility for automata are algorithmically undecidable.

Another completeness limitation is the requirement to automata system closures for any regular event to contain an automaton representing this event. Such completeness is called Kleene-completeness or **K**- completeness.

U. Dassow proved that **K**-completeness and **K**-expressibility are algorithmically undecidable.

Another attempt to limit the notion of completeness was performed by A.S. Strogalov. He introduce the metrics on words and superwords analogous to Baire metrics. The metrics is spread on automata, and for a given precision ϵ the notions of ϵ-completeness and ϵ-expressibility as ϵ-neighborhoods of the corresponding closures are considered. It was shown that ϵ-completeness and ϵ-expressibility are algorithmically undecidable, though the whole automata class does contain an efficiently constructible ϵ-complete subclass of strongly connected automata.

I. Hazbun considered a similar problem. He made an assumption that the states of automata composition are a Cartesian product of the states of automata taking part in composition. Such an assumption allows to constructively solve the main functional system problems.

Limiting automata classes can be performed in two directions.

First of all, completeness and expressibility problems can be studied in $\mathbf{P_a}$ subclasses.

One can also remain in $\mathbf{P_a}$ but study completeness and expressibility of special automata families.

In the first case, as it was noted earlier, V.B. Kudryavtsev proved that completeness and expressibility can be checked constructively for functions with delays.

Another limitation of $\mathbf{P_a}$ is the class of linear automata. In this case A.A. Chasovskih proved that completeness and expressibility are algorithmically undecidable and gave an explicit description of all precomplete classes. The cardinality of precomplete classes was countable.

In the second case K.V. Kolyada studied the properties of Kleene algebra subalgebras, i.e. of regular functions with union, concatenation, iteration and adjunction operations. It was shown that these subalgebras can be stratified into families with undecidable completeness and expressibility problems and families with decidable completeness and expressibility problems.

An important advancement in understanding the nature of undecidability of completeness and expressibility problems for $\mathbf{P_a}$ was performed by D.N. Babin [87].

The idea of D.N. Babin's approach was to stratify finite automata systems into classes so that all systems inside one class behave in the same way with the respect to completeness decidability, and comparable classes inherit the properties of completeness decidability or undecidability depending on the fact whether one class is "weaker"or "stronger", correspondingly.

The stratification also should consider the essence of automaton which is in fact a combination of logic and memory.

It makes sense to consider an automata system as two parts - a logical part and a memory part. As it was already noted, E. Post computed the whole closed class lattice for $\mathbf{P_2}$. So it makes sense to stratify finite automata systems according to coincidence of their logical parts with fixed Post classes.

The stratification with the above properties is studied instead of arbitrary finite automata systems. For every class the problem of completeness decidability is solved.

The major problem is to determine the boundary in Post lattice such that the classes above the boundary are decidable and the classes under the boundary are undecidable from the point of view of completeness.

This problem was solved. It turned out that only a finite number of Post classes are decidable from the point of view of completeness. Decidability is proved by designing a scheme of efficiently limited complexity, and undecidability is proved by modeling an undecidable Post combinatorial problem. D.N. Babin also proved that the case of **A**-completeness is totally similar to the above case. These results formed the core of D.N.Babin's Doctor of Science thesis.

The methodology of researching the boundary was formed by considering concrete cases. One of the most important cases was proving completeness against superposition operation of a system of all unary automata and an automaton without memory implementing Sheffer function.

It is important to note that D.N. Babin considered only automata with binary inputs and outputs. The problem for $\mathbf{k}$-valued inputs with $\mathbf{k} > 2$ is still open.

The results presented in this section are the major results for the two ways of studying inefficiency of basic problems solutions for $\mathbf{P_a}$ with composition operations.

Automata algebra with superposition operation have a weaker closure operator, hence its properties are even less constructive than for composition operations.

For such algebras S.V. Aleshin [89] studied the problem of basis when input, output and state sets cardinalities vary. S.V. Aleshin described algebras with a basis and without a basis. The methodology developed by S.V. Aleshin allowed to construct an automata group modeling the weak unlimited Bernside problem. The first solution of this problem was found by E. Golod and I.R. Shafarevich [90]. Construction of such a group was of significant methodological importance, because it exposed rich modeling capabilities of automata algebras. The research was performed under supervision of V.B. Kudryavtsev.

Modeling in automata groups was later considered by V.I. Malygin under supervision of S.V. Aleshin. V.I. Malygin studied modeling via internal automata states and constructed the examples of groups representable in the above sense.

V.V. Makarov [125] supervised by S.V. Aleshin studied the conditions of finiteness of element orders for the Bernside-type automata group mentioned above.

D.N. Babin supervised by S.V. Aleshin considered the influence of internal automata semigroups on solving the completeness problem for superposition operation. D.N. Babin constructed the completeness criterion in terms of precomplete classes for so called verbal automata [119].

7.3 Cellular automata

Cellular automata are infinite nets of automata with outputs connected to inputs of other automata. An important cellular automata class is formed by homogeneous structures. Often notions of cellular automata and homogeneous structures are synonyms. Homogeneous structures are constructed in the following way. The integral grid in n-dimensional space is considered. Every grid node is loaded with the same automaton with **m** inputs and **p** outputs. For a fixed automaton inputs are connected to some outputs of other automata, and some inputs of other automata are connected to the outputs. Hence the neighborhood scheme is defined. The scheme is replicated to cover the whole infinite net.

If all automata inputs and outputs are connected to some outputs and inputs, the structure is autonomous. If there are free inputs and outputs, they are considered to be net inputs and outputs, and the net is called a net with inputs and outputs.

Let us consider only Moore automata, i.e. automata outputs are defined by automata states. Let us introduce a special state 0 called rest state and impose the additional condition: if an automaton is in "rest"state and all inputs are equal to 0, the state must remain 0.

The research is focused on autonomous homogeneous structures (AHS) and homogeneous structures with inputs and outputs (HSIO).

If AHS has all automata in state 0 at the initial moment, informational process will only reproduce the initial situation.

If some AHS automata are in non-zero initial states, they form some non-trivial configuration and give birth to a non-trivial informational process. Such processes are the focus of AHS theory.

The basic directions of AHS research include:

1. Moore diagrams of AHS and the correspondence with structural AHS implementations.

2. Modeling configurations in AHS.
3. Modeling computational processes in AHS.
4. Mutual AHS modeling.

The first direction plays the role of research apparatus and provides the technical language for AHS properties description. This apparatus is well-developed, so is was utilized to study directions 2–4.

For direction 2 it was shown that any recursive sequence of finite configurations can be reproduced in some AHS, i.e. every fixed period of time AHS states will be equal to the corresponding sequence element.

It was shown that almost all AHS have configurations that grow infinitely.

It was shown that verifying whether a configuration will disappear in finite period of time is algorithmically undecidable for AHS where configuration growth is faster than $4\log_2 t$, but becomes decidable when growth is slower than $(1/4)\log_2 t$. The boundary between solvable and unsolvable cases was found with a very good precision.

The above results were obtained by A.S. Podkolzin [91] supervised by V.B. Kudryavtsev.

An interesting problem is to wrap a configuration up to a single automaton and then to reproduce the initial configuration. One can also impose additional "noise"affecting the growth process. A.V. Dumov [92] supervised by V.B. Kudryavtsev found the fastest possible solutions of these problems and constructed asymptotics for automata complexity and growth time.

Direction 3 studies computations in AHS. The model is parallel, so basic arithmetic operations like multiplication, division, exponentiation, linear system solution, natural numbers properties verification, etc. can be implemented efficiently.

It turned out [91] that linear systems can be solved in linear time, as well as primality tests for natural numbers.

A.V. Galatenko supervised by V.B. Kudryavtsev developed the methodology for nearly optimal graph placement to a set of parallel plains in AHS. A.V. Galatenko constructed the characterization of placement metrical properties in terms of precise assertions and approximations. All algorithms have polynomial complexity.

In direction 4 one AHS can be considered as an AHS family in the following interpretation. Let us consider a larger grid, so automata in grid cells compose a new automaton. We get a new AHS modeled by the original AHS. It was shown that there exist universal AHSs, i.e. structures that can model arbitrary AHSs. The simplest universal AHSs in terms of states number and neighborhood were constructed, though universality is an algorithmically undecidable property. For an arbitrary AHS pair the conditions when the first AHS can model the second AHS in real time or with a delay were found. These results were obtained by A.S. Podkolzin supervised by V.B. Kudryavtsev.

Major result in HSIO research were obtained by A.A. Bolotov [91] supervised by V.B. Kudryavtsev.

A.A. Bolotov proved that state distinction in HSIO is algorithmically undecidable. He showed that the main HSIO parameters, such as the number of states, neighborhood scheme, inputs and outputs number, are logically independent. A.A. Bolotov obtained the modeling criterion for HSIO in other HSIO, proved that completeness and expressibility for HSIO with composition operations are undecidable, though the algebra itself is finitely-generated. He also found the complexity of HSIOs computing the given sequence of algebraic operators.

AHS and HSIO due to their universality have many applications in natural sciences, technology and humanities, because this model unites space, time, logic, definition finiteness, and the process.

8 Algorithms

Algorithms are applied to two main objects: finite sets and infinite sets.

In the former case researchers as a rule deal with scheme computations, in the latter case - with Turing or operational computations.

Scheme computations deal with **k**-valued logical functions. There exists a number of concrete schemes, such as formulas, contact schemes, functional elements schemes, etc. The value of k is usually 2.

For a Boolean function the problem is to find the simplest scheme from the point of view of element number. This problem can be formulated in the following way. The goal is to find the minimal number of element $\mathbf{L}(\mathbf{n})$ sufficient for constructing the scheme computing the given Boolean function with $\mathbf{n}$ variables.

The number $\mathbf{L}(\mathbf{n})$ is called Shannon complexity. Shannon complexity and scheme construction algorithms for various classes of Boolean functions are the main objects of computing schemes complexity theory.

Additional challenge is introduced by considering errors in schemes that should not affect computations correctness. Such schemes are called self-correcting.

The main results in studying $\mathbf{L}(\mathbf{n})$ belong to C. Shannon [1], O.B. Lupanov [10], S.V. Yablonskiy [93] and the members of their scientific schools. As a rule $\mathbf{L}(\mathbf{n})$ obtaining and optimal algorithm construction depended on scheme types.

O.B. Lupanov found the universal approach to solving the problems of the above type. The approach was based on local encoding method introduced by O.B. Lupanov. Local encoding method allowed to solve optimal synthesis problems for many functional classes with the appropriate adaptation to the concrete schemes.

The method of O.B. Lupanov is one of the most significant mathematical ideas; it influenced probably every specialist in synthesis theory.

A.E. Andreev [94] supervised by V.B. Kudryavtsev managed to create a new approach to the problem, though the approach correlated with Lupanov's method.

The idea in A.E. Andreev's work was to represent Boolean functions via functional nets similar to automata operations introduced by V.B. Kudryavtsev, and then to reconstruct nets into schemes. A.E. Andreev considered combinatorial properties of the nets and the imposed properties of Boolean functions. As the result he managed to create a universal method for constructing optimal schemes of different types for various classes of Boolean functions and for obtaining Shannon functions.

The method was generalized for the case when the number of errors in scheme is almost exponential, and Shannon function asymptotics remain the same as in case when there are no errors.

A.E. Andreev's method covered formulas, contact π-schemes, binary programs without computational commands, contact schemes, contact and gate schemes, contact and relay schemes, functional element schemes, formulas with partial memory, multifunctional element schemes, binary programs of general type, etc.

Classes of Boolean functions covered by A.E. Andreev's method included partial functions with the given domain cardinality, functions with the given number of ones, functions with limited entropy, non-zero invariant Yablonskiy classes, Post classes except linear functions and logical sums and multiplications, etc.

A.E. Andreev created the "industrial"method of optimal synthesis that currently does not have any analogs.

These results formed the core of A.E. Andreev's Doctor of Science thesis written when A.E. Andreev was 29 years of age.

Deep understanding of Boolean functions construction nature and an outstanding synthesis method allowed A.E. Andreev [95] to be the first researcher to construct an example of a Boolean function with an almost exponential complexity in monotonous functional elements scheme and thus to solve Shannon's problem that remained unsolved for over fifty years. All earlier examples had linear complexity.

Automata computations lie in the middle between scheme and Turing computations. The main complexity characteristic of automata computations is automaton memory.

A.E. Andreev, A.A. Chasovskih and A.A. Kudrin [96, 97] considered the problem of determining complexity of automata computation of Boolean function terms. As the result the algebra was stratified into layers corresponding to constant, logarithmic and linear number of delays in automata representation depending on the term length. Stratification is defined majorly by iterative functions properties like belonging to some Post classes. The complexity turned out to be linear for almost all basises.

I.A. Vikhlyantsev [123] supervised by A.E. Andreev developed asymptotically optimal methods for synthesis of contact schemes and functional element schemes implementing systems of elementary conjunctions.

O.A. Sherbina [98] supervised by V.B. Kudryavtsev studied the efficiency in operational sense of U.I. Juravlev's local algorithms applied to quasiblock discrete programming problems. O.A. Sherbina showed that in this case local algorithms have smaller average and Shannon complexity than discrete programming. Complexity estimations for optimal resource reservation were constructed explicitly.

G.N. Arkabaeva [99] supervised by V.B. Kudryavtsev and E.E. Gasanov research a group of sorting algorithms. G.N. Arkabaeva found upper complexity estimations in terms of standard operations and showed logical independence of these algorithms, i.e. for every pair of algorithms she constructed an example when the first algorithm solved the problem simpler that the second algorithm.

K. Weber [100] from Germany supervised by V.B. Kudryavtsev, Nguen Kim An [101] from Vietnam supervised by V.B. Kudryavtsev and A.S. Podkolzin, and T. Igamberdyev [102] supervised by V.B. Kudryavtsev and A.E. Andreev worked on normal forms of Boolean functions.

K. Weber studied DNF complexity measures defined by sums of numbers of weighted conjunctions and disjunctions. K. Weber showed that the measures are logically independent when weights vary, and determined the minimal number of variables when this independence start to express. K. Weber also evaluated Shannon function for these measures.

Nguen Kim An studied the nature of PDNF transformations graph. She considered swallowing of elementary conjunctions by other conjunctions. Nguen Kim An described types of such graphs, cardinality characteristics, branching, width, depth, number of leafs. She showed the dependency of the number of function's variables on transformation graph generated by this function. Nguen Kim An showed how constructing minimal DNF is simplified when transformation graph has a simple structure, e.g limited width or branching, etc.

T. Igamberdyev considered the problem of finding solutions of systems of Boolean equations. He obtained the precise formula of average number of Boolean equations system where equations are defined by DNF. For some general assumptions about system metrical parameters T. Igamberdyev found asymptotics of the number of solutions of almost every system with the given parameter growth. He obtained the exact formula of the average number of solutions for Boolean systems where equations are sums of elementary conjunctions, and an asymptotic estimation of the number of solutions for almost all systems with the given parameter growth. T. Igamberdyev showed that in some cases complex DNFs can be approximated by simpler DNFs, and designed the algorithms for such approximation and for solving approximate solutions of equations with simplified DNFs.

Ranko Scepanovic [103] from Yugoslavia supervised by S.V. Aleshin researched scheme complexity for flat pattern recognition. The results allowed to design procedures for optimal synthesis of such schemes.

A.E. Andreev [104] developed a gradient method for building DNFs close to minimal for almost all Boolean functions. This method has logarithmic complexity in comparison with the traditional methods.

A.A. Irmatov [105] researched the number of threshold functions of 2-valued and **k**-valued logics. The new combinatorial and topological methodology allowed to improve all known results and to get the best known upper and lower estimations close to asymptotics.

J. Kovianich from Yugoslavia supervised by A.A. Irmatov improved the combinatorial lemma of Littlewood and Offord. The improved result was used by A.A. Irmatov in his estimations.

K. Wagner [106] from Germany supervised by V.B. Kudryavtsev compared computations in Turing machines and cellular automata of arbitrary finite dimension. As the result a computational hierarchy of computational efficiency was created, and efficiency advancements for various classes were estimated.

Abdul Sattar from Iraq supervised by A.S. Podkolzin and E.E. Gasanov studied the complexity of implementing a group of sequential operators in automata schemes [120]. An important aspect of research was estimating functional complexity of automata schemes, i.e. how scheme delay depends on the number of elements in the scheme.

9 Applications

The research team of MaTIS Chair and PTC Laboratory perform applied research in areas connected to natural sciences, humanities, industry, management, etc.

One of the most important projects of such kind was inspired by the Institute of Machinery and was entitled "Spark". The goal was to create a mathematical model of a self-organizing distributed space-and-ground system capable of functioning in ground-controlled mode and in autonomous mode and studying Earth and space. The system contains information input units, information processing units, decision-making units, and decision-implementing units. It was necessary to develop synthesis methods for such systems, to study the system properties and to learn how to control system so that its parameters are kept in a fixed domain. The ultimate goal was to produce a software implementation of the system. The problem was solved with the help of dynamic net of hybrid automata. The net consisted of a recognition block, thinking block and reacting block. System goals were formalized, functionals for estimating functioning quality were designed, and optimal control methods were discovered.

The research team of this project was headed by V.B. Kudryavtsev and consisted of three subteams headed by A.S. Podkolzin, S.V. Aleshin and V.A. Buevich. The first subteam consisted of A.S. Strogalov, P.A. Aliseichik, E.E. Gasanov and V.V. Peretrukhin. They worked on the thinking part of the system.

The second subteam consisted of A.A. Irmatov, M.V. Nosov, V.I.Malygin and N.F. Anisimov. They worked on pattern recognition.

Unfortunately V.I.Malygin and N.F. Anisimov died at a young age.

The third subteam consisted of D.N. Babin, A.A. Zolotykh, A. Zyrichev and D. Zamyatin. They worked on system control.

This project stimulated advancements in all directions of intelligent system theory.

The new pattern recognition algorithms based on logical and combinatorial approach, algebraic and geometrical approach and automata approach were designed. These algorithms were successfully applied to other practical areas, such as geological research. The results can be found in publications by V.B. Kudryavtsev, A.E. Andreev, E.V. Dukova, A.A. Kibkalo, etc.

The new approach to databases called information graph model of information storage and search was developed by E.E. Gasanov and his students.

This model allowed to create databases containing large amount of information, e.g. dealing with arts.

The innovative computer intelligent system for solving mathematical problems based on controlled logical inference was designed by A.S. Podkolzin.

The ideas of the solver were utilized in a joint project with LSI Logic Corp. As the result of this project a new mathematical and computer system for design automation was created. This system is a software package that allows to speed up the design process, increase speed and decrease sizes of chips designed. The package is protected by over a hundred US patents. The research team included V.B. Kudryavtsev, A.E. Andreev, A.S. Podkolzin, S.V. Aleshin, E.E. Gasanov, A.A. Bolotov, A.A. Zolotykh, N.F. Anisimov, A.A. Galatenko, E.E. Egorov, Y. Kalinin, S.B. Rodin, P.A. Panteleev, etc.

The results of studying system teaching in "Spark"project were later generalized to computer teaching. A new approach to teaching with the help of computers was developed.

The idea of the approach was to design the teaching system in such a way that it reflected all components of the real teaching process, i.e. teaching data, student model, and the model of the teacher implementing the optimal teaching strategy. The environment for creating such systems was created. The environment was used to design teaching systems for computer science, foreign languages, arts, history, etc. These systems are issued on CDs and are currently available in the market.

Teaching systems were developed by V.B. Kudryavtsev, A.S. Strogalov, P.A. Aliseichik, V.V. Peretrukhin and K.V. Harin.

E.V. Timofeev supervised by A.S. Strogalov designed an imitation model for estimating the correspondence of psychological conditions and mimicry. These results can be used in computer teaching systems [126].

Situation modifications monitoring was an essential component of "Spark"project. Later it was considered as a separate problem. As the result a monitoring intelligent system targeted at nuclear technology level estimation by observing indirect data was designed. This system is currently used in IAEA. The research was performed by V.B. Kudryavtsev, A.P. Ryjov and A.G. Belenkiy.

Applied Problem Department of Russian Academy of Science initiated the research targeted at speech formalization for the purpose of speech recognition and synthesis. The new approaches to these problems were created. As the result computer speech recognition systems were designed.

The research of speech recognition when additional mimic data is available were later financed by Intel. The research was performed by D.N. Babin, I.L Mazurenko and A.B. Kholodenko.

NATO finances research targeted at automata modeling of plant genetic mechanism. The results allowed to forecast the progressing variability. The research team consists of V.B. Kudryavtsev, V.N. Kozlov, M.V. Nosov, D.V. Alekseev and a number of biologists.

For a number of years V.B. Kudryavtsev and S.V. Yablonskiy researched modeling of social processes by the means of discrete mathematics. A number of problems of current state, dynamics and steadiness of development for Slovenian society were solved. Slovenian specialists S. Saksid and J. Knap also took part in research.

Applied research stimulates the creation of the new mathematical apparatus suitable for solving new problems by mathematical methods up to Ph.D. level. Let us list some examples of such new ideas.

V.N. Kozlov [107] supervised by V.B. Kudryavtsev and L.V. Krushinskiy studied reflex activities of biological systems. V.N. Kozlov constructed a model of perception evolution for and object interacting with an environment. The model included formalization of memory, operational mechanisms, encoding, pattern recognition, decision-making and parameter dynamic of interior objects. The model allowed to explain conditional, unconditional and extrapolational reflexes.

R. Lukanova [108] from Bulgaria supervised by V.B. Kudryavtsev developed the formal apparatus for semantic analysis of natural-language texts. The apparatus is a formal grammar with two components - syntactic and semantic. Semantic rules allow to extract contents and perform interpretations of phrases generated by syntactic rules. The apparatus is targeted at automated translation, text abstracting, etc.

A.A. Shakirov [109] supervised by A.A. Gasanov researched applicability of logical language for geometrical figure description. A.A. Shakirov showed that predicate logic with the limited number of variables has a finite complete set of identities. He proposed an efficient criterion of figures identity based on formula representation. A.A. Shakirov showed that it takes linear time to transit from a formula representation to an analytical representation. He also proposed a new procedure for formula minimization.

A.P. Ryjov [110] supervised by V.B. Kudryavtsev and V.N. Kozlov developed a fuzzy logic apparatus for information process monitoring. A.P. Ryjov proposed formalizations for elementary steps of such processes and operations over the steps, and procedures for computing compositions of steps and processes. This algebra was used to create a mathematical and computer system of nuclear technology monitoring.

L. Minchich [122] from Czech Republic supervised by V.N. Kozlov proposed a model of reconstructing a two-dimensional picture by one-dimensional projection with additional noise.

F.N. Nefidov [111] supervised by V.B. Kudryavtsev created an automata model of a person suffering from acute enteric impassability. The model included an automated diagnostics system, system for forecasting disease outcome and possible complications, and a system for selecting the optimal treatment strategy. The model was implemented in a software package and is currently used in medical institutions.

Z.E. Koroleva [112], I.A. Chijova [113] and V.O. Krasavchikov [114] supervised by V.B. Kudryavtsev studied test procedures for geological search and mineral volume estimation. The results allowed to discover new mineral fields worth millions of dollars.

N.U. Demin [121] supervised by E.E. Gasanov studied reengineering of secure message passing protocols. Though in general the problem has exponential complexity, for some protocol classes N.U. Demin constructed algorithms with polynomial complexity up to second degree.

10 Teaching process

Specialized lecture courses and seminars of MaTIS Chair cover all main areas of intelligent system theory.

Some courses are obligatory for all students of MaTIS Chair, some are optional.

"Discrete Mathematics"and "Intelligent System Theory"are the basic courses.

"Discrete Mathematics"is taught by V.B. Kudryavtsev and A.S. Strogalov. The course includes the general concept of discrete mathematics and the main results of discrete mathematics areas. The areas are discrete functions, automata, algorithms, combinations theory, graphs, encoding, discrete optimization. Lectures follow the requirements of the Faculty of Mechanics and Mathematics: strictness, clarity, depth and width.

"Intelligent System Theory"is taught by V.B. Kudryavtsev, A.S. Podkolzin, E.E. Gasanov, A.A. Chasovskih and V.A. Nosov. This course is new; its contents is still forming. The main areas covered by the course include pattern recognition, databases, decision-making, expert systems and solvers, logics, modeling, complexity theory.

The courses are accompanied by seminars.

"Automata Theory"and "Algorithm Theory"courses play a special role in education process.

"Automata Theory"is taught by V.B. Kudryavtsev, V.A. Buevich, A.S. Podkolzin, S.V. Aleshin and D.N. Babin. This course contains the main result of automata theory. The major part of the results was discovered by the researchers of MaTIS Chair.

The course consists of three parts.

The first part is devoted to abstract automata theory. It describes various automata behavior types, such as computations, representations, traveling, etc.

The second part is devoted to structural automata theory. It describes the problems of completeness, expressibility and automata modeling.

The third part is devoted to cellular automata. It describes the abilities of cellular automata to model discrete processes.

"Algorithm Theory"is taught by V.A. Buevich, I.A. Lavrov and V.A. Nosov is a traditional one; however due to the fact that education in the Faculty of Mechanics and Mathematics is focused on continuous mathematics, this course plays an important role, because it allows students to master one of the main mathematical tools — algorithms.

"Pattern Recognition"taught by S.V. Aleshin and M.V. Nosov describes the main approaches to pattern recognition. The course core is formed by combinatorial and logical procedures that are especially efficient when patterns have qualitative attributes; algebraic and geometrical methods when patterns have appropriate natures; stochastic operators, when patterns are characterized by stochastic attributes; structural procedures, when patterns are combinations of several objects.

The course contains theoretical results, heuristic methods and various examples.

"Database Theory"taught by E.E. Gasanov is an original course. It does list traditional approaches to information storage and search, but the focus is on informational graph approach. The course describes the most general data model facilitated by internal operators. The model allows to process queries in parallel mode. Informational graphs unite diverse problems for various data models and allow to obtain general solutions and to compare different data models.

"Intelligent Problem Solvers"taught by A.S. Podkolzin is a new course. It describes the principles of intelligent functioning of biological systems with formalizations of all components. It is shown how intelligent solvers can be constructed for elementary mathematics, calculus and logics. The major part of results listed in the course belong to the researchers of MaTIS Chair.

"Mathematical Cybernetics"taught by E.E. Gasanov is a course for post-graduate students. Its contents is based on the program of post-graduate examinations. It includes scheme complexity, algorithm complexity, discrete function algebras, identical transformations, optimization, etc.

"Introduction to the Algebraic Theory of Encoding"taught by A.A. Irmatov gives a wide view on problems and results in error-resistant encoding theory.

"Information Security"taught by V.A. Nosov lists the main results in theoretical and applied aspects of information security.

"Homogeneous Structure Theory"taught by A.S. Podkolzin is devoted to cellular automata — infinite automata schemes with homogeneous local structure. This object is a perfect modeling tool, because it unites space, local logic, time and processes. It can be applied to natural sciences, technology and humanities. The course is devoted to fundamental theoretical results and application examples.

"VLSI Synthesis Methods"taught by A.A. Chasovskih is an applied course. It is devoted to the procedures currently used in VLSI synthesis, the complexity of these procedures and to whole synthesis cycle.

"Mathematical Economics"taught by U.N. Cheremnyh is devoted to modeling economical processes at a high level of abstraction by the means of classical mathematics. The course is obligatory for students majoring in mathematical economics.

"Mathematical Models of Economical Calculations"taught by A.A. Irmatov is a new course. It is devoted to mathematical models and acceptable formalizations used for making decisions in microeconomics and macroeconomics.

"Mathematical Biology"taught by V.B. Kudryavtsev and V.N. Kozlov is obligatory for the students of Mathematical Cybernetics Chair of the Faculty of Computational Mathematics and Cybernetics. The course consists of several layers corresponding to modeling of cells, organs, organisms, and populations. For every layer modeling methods and main mathematical results are described..

"Fuzzy Logic"taught by A.P. Ryjov is devoted to a relatively new approach to events and processes that do not allow precise description. The approach was first proposed by L. Zadeh and was developed by many researchers. The current state of the art allows to work with fuzzy data and processes with the help of the corresponding computer models.

The courses are accompanied by the specialized seminars.

"Automata Theory"is the main seminar of MaTIS Chair. It was founded in 1960-s. It is devoted to the major scientific results in the main areas of research pursued by MaTIS Chair.

"Computer Science"taught by P.A. Aliseichik is held in computer class. It is devoted to improving programming skills and to creating real expert systems.

The students enter the Chair when they are third-year students. The average number of students that enter the Chair every year is around forty. The scientific work is started since the student enters the Chair. Third-year work forms the first course paper, fourth-year work forms the second course paper, and fifth-year work forms the diploma paper. As a rule, scientific work is continuous, i.e. the second course paper continues the first course paper, and the diploma paper continues the second course paper. Every year nearly 20 scientific articles by the Chair students are published in scientific magazines. Around one-fourth of all student who have only good and excellent grades and significant scientific results enter post-graduate school. The total number of post-graduate students is over thirty.

As a rule the students have good computer skills, and it helps in theoretical and applied research.

In new environment in Russia, when due to economical reasons the chain "fundamental science — applied science — technology — market"is separated into several chains at the national level it is important to every Chair graduate and researcher to take part in as many chains as possible.

The higher the dimension in the above sense of the Chair graduate is, the easier it will be to adopt to the new environment.

The above ideas affect the Chair teaching strategy. The Chair tries to give a good basic education in discrete mathematics and mathematical cybernetics, to teach to solve applied problems and to master computer science as a way to convert mathematical knowledge used to solve applied problems into a software package.

The Chair is focused on providing up-to-date education to its students.

The leading role in this process belongs to scientific supervisors, who select areas of research for students, formulate concrete problems, and help to determine solution strategies.

An important factor in providing good education is the fact that MaTIS Chair works together with PTC Laboratory primarily focused on applied research. As the result, students have a chance to work in complex projects initiated by Russian and foreign organizations.

The examples of such projects are "Design Automation"(with

LSI Logic Corp.), "Teaching Systems—IDEA project (with Ruhr University, Bochum, Germany), "Nuclear Technology Monitoring"(with IAEA), "Speech Analysis and Synthesis"(with Intel), "Distance Computer Diagnostics"(with Pittsburgh University), "Modeling of Plant Genetic Mechanism"(with NATO), "Reasonable Behavior of Device Systems"(with Central Research Institute for Machine Building).

The Chair graduates work in Russian, joint and foreign corporations that require specialists in high technology.

The best graduates enter post-graduate school. The best post-graduate students enter MaTIS Chair and PTC Laboratory. 80% of the Chair and the Laboratory researchers are graduates of MaTIS Chair, and 20% are graduates of other chairs of the Faculty of Mechanics and Mathematics. Such structure allows the research team to study complex problems covering both discrete and continuous properties.

Many Chair graduates work outside Russia. The major part of these graduates are foreigners. 10 researchers work in Germany, 7 — in USA, 7 — in Canada, 6 — in Yugoslavia, 6 — in Vietnam, 2 — in Japan, 2 — in China, 2 — in Hungary, 2 — in Czech Republic, 2 — in Slovenia, 2 — in Bulgaria, 1 — in Netherlands, 1 — in France, 1 — in Jordan, 1 — in Syria, 1 — in Iraq. There are also many researchers in the former Soviet republics.

The major part of the graduates mentioned above became well-known scientists, others work in industry and management.

So, Dr. R. Scepanovic is a vice-president of LSI Logic Corp. and heads the Advanced Development Laboratory, Prof. B. Thalheim is the head of Computer Science Faculty of Cottbus University, Prof. G. Pogosyan is the head of the Applied Mathematics Faculty of Tokyo University, Acad. Y. Demetrovich is the head of department of Budapest Scientific Institute, Prof. S. Uscumlich heads the Applied Mathematics Chair of Beograd University.

Connections with the Chair graduates support international contacts. The most active scientific contacts are with universities of Tokyo, Pittsburgh, Bochum, Cottbus, Beograd, Ljubljana, Podgorica, Damasus, etc., and with corporations "LSI Logic Corp.", "Intel", "Mirantis", "Cadence Design Systems, Inc. Elbrus, Int", etc.

11 Other activities

Currently a scientific school in Russia can survive only because of the activities of the school itself. MaTIS Chair works hard in this direction.

Three scientific centers were created on the basis of the Chair and the Laboratory.

Russian-American Center was founded with LSI Logic Corp. It is targeted at the research in the area of design automation.

Russian-German Center was founded with Bochum University. It is targeted at the research of teaching systems.

Scientific and Teaching Center "Intelligent Systems and Fuzzy Technology"was founded with Computing Center of Russian Academy of Science and Russian State Humanitarian University. It is targeted at preparing new specialized courses and research in the area of fuzzy logic.

These Centers allow to stay in touch with industrial and research organizations and to organize joint projects.

The Centers provide new rooms, new computers and software packages, thus allowing to improve research results. It is important to note that new rooms are not taken away from other chairs of the Faculty — in fact, they increase the Faculty.

Cooperation with industrial and research organizations allows the Chair to have up-to-date computing facilities, software packages, network connections and additional financing. E.g. computing facilities were donated by Central Research Institute for Machine Building, Bochum University, LSI Logic Corp., AMD Corp., etc.

Scientific meetings are another form of scientific consolidation. MaTIS Chair organizes the International Conference "Intelligent Systems and Computer Science". In 2006 the conference will be conducted for the ninth time. The conference is staged at the Faculty of Mechanics and Mathematics, and many undergraduate and post-graduate students take part in it. As a rule, over 200 researchers from all over the world take part in the conference. The subjects of talks cover the main areas of intelligent system theory and adjoining areas of computer science.

Conference proceedings are published in "Intelligent Systems"magazine issued by the Chair. The magazine is also published in the Chair's web site `http://www.intsys.msu.ru`, so the Proceedings are available to a wide group of researchers.

"Intelligent Systems"magazine is issued since 1996. It consists of three main blocks.

The first block contains surveys on the most important intelligent system problems.

The second block contains publications on specialized intelligent system synthesis and testing.

The third block contains mathematical articles that form the basis for the second and partially the first block.

Depending on funding the magazine is issued 1 or 2 times a year. The main funding comes from LSI Logic Corp., Mirantis and Cadence Design Systems, Inc. Some funding comes from Russian Foundation for Basic Research. The magazine contains articles by leading researchers as well as by young scientists. It is an official magazine of the Russian Attestation Commission, so the articles can be included into Ph.D. and Doctor of Science thesis.

Articles and books by the Chair researchers play a significant role in intelligent system theory. The number of such articles is several hundred, the number of books including monographs and textbooks is over 20.

The main monographs include "Logic Algebra Functions and Post Classes"by S.V. Yablonskiy, G.P. Gavrilov and V.B. Kudryavtsev [44], "Introduction to Automata Theory"by V.B. Kudryavtsev, S.V. Aleshin and A.S. Podkolzin, "Homogeneous Structures Foundations"by V.B. Kudryavtsev, A.S. Podkolzin and A.A. Bolotov [91], "Information Storage and Search Theory"by E.E. Gasanov and V.B. Kudryavtsev [29] published by Nauka, and a number of books published by Moscow State University, including "Functional Systems"by V.B. Kudryavtsev, "Introduction to Abstract Automata Theory"by V.B. Kudryavtsev, A.S. Podkolzin and S. Uscumlich, etc.

Besides teaching mathematics it is important to tell the students about the contributions made by Russian scientists. Such contributions are well-known and make students proud of their Motherland.

Nowadays historical foundations of Russian society are subjected to ungrounded questions and doubts, so it is important to show young people that Russia is still mighty, and in some time it will again take the appropriate place in history.

This aspect of education is covered by the seminar "Science and Culture"headed by V.B. Kudryavtsev. This seminar is functioning since 1991. Seminar members include V.A. Buevich, V.N. Kozlov, A.S. Strogalov, A.A. Irmatov, well-known scientists from the Faculties of Mechanics and Mathematics, Physics, Philology, Computational Mathematics and Cybernetics. Leading persons of science and culture give talks devoted to acute problems of the society. The speakers that focused on science include academicians A.A. Logunov, A.A. Samarskiy, Y.L. Ershov, O.T. Bogomolov, V.L. Makarov, N.N. Moiseev, A.Y. Ishlinskiy, B.A. Rybakov, A.G. Chuchalin, S.P. Kurdumov, etc. Speech topics included elementary particle theory, energetics, politics, economy, sociology, medicine, etc. The speakers that focused on culture include writers V.G. Rasputin, V.I. Belov, V.S. Rosov, V.V. Karpov, V.V. Kojinov, Y.P. Vlasov, A.I. Kazintsev, directors N.N. Gubenko, Y.M. Solomin, S.S. Govoruhin, N.P. Burlyaev, actress J.A. Bolotova, ballerinas E.S. Maksimova, A.Y. Volochkova, painter I.S. Glazunov, sculptor V.M. Klykov, metropolitans Kirill and Pitirim, chess player M.M. Botvinnik, etc. The third category of speakers consists of public figures, such as A.A. Zinoviev, V.N. Kara-Murza, A.N. Krutov, N.S. Leonov, A.N. Baburin, P. Shkundrich, S. Uscumlich, N.G. Ivashov, etc.

MaTIS Chair has a web-site `http://www.intsys.msu.ru`

12 Chair members

The Chair consists of ten professors - Doctors of Science, eleven associate professors and leading researchers - Doctors of Philosophy, and ten junior researchers.

Chair and Laboratory foundation was influenced by the traditions of Faculty of Mechanics and Mathematics targeted at research and teaching. These traditions were based on wide availability of education, so talented students entered the Faculty from all regions. As the result of competition of talented students, about seventy percent of Faculty members came from periphery of the country. However this number started to decrease. Since 2000 the number of young scientists from periphery is around twenty percent. Yet around sixty percent of Chair members represent the main regions of the Soviet Union. As the result of such diversity, the spectrum of research directions covered by the Chair is quite wide.

Chair foundation was significantly influenced by such leading scientists as V.A. Sadovnichiy, S.V. Yablonskiy, O.B. Lupanov, Y.L. Ershov, Y.I. Juravlev, V.A. Ilyin, E.V. Moiseev. Scientific and organizational contacts with these people allow the Chair to solve strategic and tactical problems.

The Chair is headed by V.B. Kudryavtsev. His scientific interests include discrete mathematics, mathematical cybernetics and computer science.

V.B. Kudryavtsev is the author of over 150 scientific publications, including 14 monographs and over 30 US patents on chip synthesis. V.B. Kudryavtsev supervised around 60 Doctors of Philosophy and over 20 Doctors of Science.

V.B. Kudryavtsev is the academician of the Russian Academy of Technical Sciences and Russian Academy of Natural Sciences, the Distinguished Scientist of Russian Federation, Honored Doctor of Belgrade University, Honored Member of International Bibliographic Center Council in Cambridge, Honored Professor of Moscow State University.

V.B. Kudryavtsev graduated from Moscow State University and entered the Chair of Mathematical Logic of the Faculty of Mechanics and Mathematics. In 1964 he completed his Ph.D. thesis, in 1972 — Doctor of Science thesis. In 1982 he became the Professor of the Chair of Discrete Mathematics. Since 1986 V.B. Kudryavtsev is the head of the Laboratory of Problems of Theoretical Cybernetics.

Since 1991 V.B. Kudryavtsev is the head of MaTIS Chair. He is the editor in chief of "Intelligent Systems"magazine and a vice editor in chief of "Discrete Mathematics"magazine. V.B. Kudryavtsev teaches obligatory and specialized courses in the Faculties of Mechanics and Mathematics, Computational Mathematics and Cybernetics, Physics, Economy, Biology, Chemistry and Philology. He is the author of new courses "Automata Theory", "Pattern Recognition", "Cellular Automata", "Functional Systems", "Intelligent Systems", "Logical Functions Theory", etc. V.B. Kudryavtsev is the head of the International Conference "Intelligent Systems and Computer Science"and of the seminar "Science and Culture". He is often invited to scientific centers of Americas, Europe and Asia. Most of the Chair researchers were taught by V.B. Kudryavtsev.

Professor S.V. Aleshin graduated from the Chair of Mathematical Logic of the Faculty of Mechanics and Mathematics. After graduation S.V. Aleshin became assistant professor, then, after completing Ph.D. thesis on pattern recognition — associate professor, then, after completing Doctor of Science thesis — professor.

Scientific interests of S.V. Aleshin include automata theory, pattern recognition and applied research. He is the author of over 60 scientific publications including monographs and US patents in the area of microelectronics.

S.V. Aleshin supervised 10 Doctors of Philosophy.

S.V. Aleshin teaches specialized courses and seminars on pattern recognition and automata theory. He is also involved into organizational activities. S.V. Aleshin was the head of Russian-German Institute of Science and Culture. He is the advisor of the Rector of Moscow State University.

Professor A.E. Andreev also graduated from the Chair of Mathematical Logic of the Faculty of Mechanics and Mathematics. After graduation A.E. Andreev became assistant professor, then, after completing Ph.D. thesis on pattern recognition — associate professor, then, after completing Doctor of Science thesis — professor. For several years A.E. Andreev worked in Volgograd State University — as the head of Chair of Discrete Mathematics, dean of Faculty of Mathematics, and pro-rector.

The scientific interests of A.E. Andreev include pattern recognition, complexity theory and mathematical and computer methods of chip synthesis. A.E. Andreev is the author of over 40 scientific publications and over 100 US patents on chip synthesis.

A.E. Andreev supervised four Doctors of Philosophy.

Professor D.N. Babin graduated from the Chair of Mathematical Logic of the Faculty of Mechanics and Mathematics. His Ph.D. thesis was devoted to automata theory. He became a researcher at the Laboratory of Problems of Theoretical Cybernetics, then moved to MaTIS Chair. After completing Doctor of Science thesis D.N. Babin became the professor. He is also the deputy head of the Laboratory.

The scientific interests of D.N. Babin include automata theory, pattern recognition and computer modeling. He is the author of 40 scientific publications.

D.N. Babin supervised two Doctors of Philosophy.

D.N. Babin teaches specialized courses and seminars on automata theory and computer modeling.

Professor V.A. Buevich graduated from the Chair of Mathematical Logic of the Faculty of Mechanics and Mathematics. He graduated from post-graduate school of Academical Computational Center, entered the Chair of Discrete Mathematics, and then moved to MaTIS Chair. After completing Doctor of Science thesis on automata theory V.A. Buevich became the professor. He is a specialist in automata theory. V.A. Buevich is the author of over 40 scientific publications.

V.A. Buevich supervised four Doctors of Philosophy.

V.A. Buevich teaches specialized courses and seminars on automata theory and algorithm theory.

Professor E.E. Gasanov graduated from the Chair of Mathematical Cybernetics of the Faculty of Computational Mathematics and Cybernetics. His Ph.D. thesis was devoted to database theory. He became the researcher of the Laboratory of Problems of Theoretical Cybernetics, then, after completing Doctor of Science thesis, he became the professor of MaTIS Chair and the deputy head of the Chair.

The scientific interests of E.E. Gasanov include information storage and search. He is the author of over 90 scientific publications including over 20 US patents on chip synthesis.

E.E. Gasanov supervised four Doctors of Philosophy.

E.E. Gasanov teaches specialized courses and seminars on cybernetics and information theory.

Professor V.N. Kozlov graduated from the Chair of Biophysics of the Faculty of Physics and post-graduate school of the Chair of Mathematical Cybernetics of the Faculty of Computational Mathematics and Cybernetics. He became an assistant professor of the Chair of Mathematical Cybernetics, then, after completing Ph.D. thesis on neural activities modeling, he became an associate professor. After completing Doctor of Science thesis on pattern recognition V.N. Kozlov became the professor of MaTIS Chair. V.N. Kozlov is the deputy head of the Laboratory of Problems of Theoretical Cybernetics.

The scientific interests of V.N. Kozlov include modeling of reasonable behavior of biological systems. He is the author of over 40 scientific publications.

V.N. Kozlov supervised two Doctors of Philosophy.

V.N. Kozlov teaches courses and seminars on mathematical biology.

Professor A.S. Podkolzin graduated from the Chair of Mathematical Logic of the Faculty of Mechanics and Mathematics. After completing Ph.D. thesis on cellular automata theory A.S. Podkolzin became assistant professor, and then associate professor of the Chair of Mathematical Logic. After completing Doctor of Science thesis on mathematical problem solver theory A.S. Podkolzin became the professor of MaTIS Chair.

The scientific interests of A.S. Podkolzin include automata theory, intelligent problem solver theory and chip synthesis theory. He is the author of over 70 scientific publications including monographs and over 20 US patents on microelectronics.

A.S. Podkolzin supervised two Doctors of Science and eight Doctors of Philosophy.

A.S. Podkolzin teaches courses and seminars on automata theory, intelligent problem solver theory and computer modeling.

Professor Y.N. Cheremnyh graduated from the Chair of Differential Equations of the Faculty of Mechanics and Mathematics. He became an assistant professor, and then, after completing Ph.D. thesis, associate professor of the Faculty of Economy. After completing Doctor of Science thesis on macroeconomics Y.N. Cheremnyh became the professor of MaTIS Chair.

The scientific interests of Y.N. Cheremnyh include mathematical economics and economical dynamic modeling. He is the author of over 80 scientific publications including monographs and textbooks.

Y.N. Cheremnyh supervised 12 Doctors of Philosophy.

Y.N. Cheremnyh is a member of International Management Academy.

Y.N. Cheremnyh teaches courses and seminars on mathematical economics for students of MaTIS Chair.

Professor A.V. Chechkin graduated from the Chair of Function Theory and Functional Analysis of the Faculty of Mechanics and Mathematics and from post-graduate school of the Chair of Computational Mathematics of the Faculty of Mechanics and Mathematics. After completing his Ph.D. thesis A.V. Chechkin worked as an assistant professor and associate professor in military universities in Moscow. After completing Doctor of Science thesis on radiating system synthesis A.V. Chechkin became a professor.

The scientific interests of A.V. Chechkin include intelligent systems. He is the author of over 100 scientific publications, including 7 monographs and 7 textbooks.

A.V. Chechkin is the winner of the National Premium of USSR. He is a corresponding member of Russian Academy of Technical Science.

A.V. Chechkin supervised 10 Doctors of Science and over 20 Doctors of Philosophy.

A.V. Chechkin teaches specialized courses and seminars on computer science and intelligent systems.

Associate professor A.A. Irmatov graduated from the Chair of Higher Geometry and Topology of the Faculty of Mechanics and Mathematics. After completing Ph.D. thesis on algebraic topology

A.A. Irmatov became a researcher of the Laboratory of Problems of Theoretical Cybernetics. For a long time A.A. Irmatov was the scientific secretary of the Laboratory. Later A.A. Irmatov became the associate professor of MaTIS Chair. A.A. Irmatov was the scientific secretary of the Chair. Currently he is the deputy head of the Chair.

The scientific interests of A.A. Irmatov include algebraic topology, functional analysis, combinations theory, information security and mathematical economics. He is the author of 12 scientific publications.

A.A. Irmatov studied economics, management and finance in IEDC-Bled School of Management in Slovenia and became MBA.

A.A. Irmatov is the winner of Young Scientist Contest of Moscow State University. He supervised one Doctor of Philosophy.

A.A. Irmatov is involved into organizational activities. He is the scientific secretary of the International Conference "Intelligent Systems and Computer Science"and of "Intelligent Systems"magazine. He is the responsible secretary of the seminar "Science and Culture"and the head of Russian-German Center.

A.A. Irmatov teaches courses and seminars on mathematical economics, combinations theory and information security.

Associate professor A.S. Strogalov graduated from the Chair of Mathematical Cybernetics of the Faculty of Computational Mathematics and Cybernetics. He worked as an assistant professor, then, after completing Ph.D. thesis on automata theory, became an associate professor of Moscow Institute of Energy. Then he became a researcher of the Laboratory of Problems of Theoretical Cybernetics. When MaTIS Chair was founded, A.S. Strogalov became the associate professor of the Chair. For a long time A.S. Strogalov was a scientific secretary of the Laboratory and the Chair. Currently he is the deputy head of the Chair.

The scientific interests of A.S. Strogalov include automata theory, expert system theory, computer teaching system theory. He is the author of 45 scientific publications.

A.S. Strogalov supervised one Doctor of Philosophy.

A.S. Strogalov is involved into organizational activities. He was the deputy of Moscow Soviet, he is the member of Methodical Council of Russian Ministry of Education, Methodical Council of Moscow State University. He is the deputy head of the International Conference "Intelligent Systems and Computer Science"and a vice editor in chief of "Intelligent

Systems"magazine. A.S. Strogalov is the head of Moscow Scientific Center on Culture and Information Technology.

A.S. Strogalov teaches courses and seminars on discrete mathematics, mathematical modeling and expert systems.

Associate professor A.P. Ryjov graduated from the Chair of Mathematical Cybernetics of the Faculty of Computational Mathematics and Cybernetics. He completed Ph.D. thesis on fuzzy logic and became an assistant professor of MaTIS Chair, and then became associate professor. His scientific interests include fuzzy sets and their applications and mathematical economics. He is the author of over 50 scientific publications.

A.P. Ryjov studied economics, management and finance in IEDC-Bled School of Management in Slovenia and became MBA.

A.P. Ryjov is involved into organizational activities. He is a member of a number of international organizations on fuzzy mathematics, the scientific secretary of "Intelligent Systems"magazine, the head of Scientific and Educational Center "Intelligent Systems and Fuzzy technology in Moscow State University, RAS Computational Center and Russian State Humanitarian University".

A.P. Ryjov teaches courses and seminars on fuzzy mathematics.

Associate professor A.A. Chasovskih graduated from the Chair of Discrete Mathematics of the Faculty of Mechanics and Mathematics. He became an assistant professor of the Chair of Discrete Mathematics. After completing Ph.D. on automata theory A.A. Chasovskih became the associate professor of MaTIS Chair.

The scientific interests of A.A. Chasovskih include automata theory, pattern recognition and computer science. He is the author of 15 scientific publications.

A.A. Chasovskih is the winner of Young Scientist Contest of Moscow State University.

A.A. Chasovskih supervised one Doctor of Philosophy.

A.A. Chasovskih is involved into organizational activities. For a long time he was the vice dean of the Faculty of Mechanics and Mathematics. Currently A.A. Chasovskih is the head of Kolmogorov school.

A.A. Chasovskih teaches courses and seminars on automata theory, pattern recognition and complexity theory.

Leading researcher V.A. Nosov graduated from the Chair of Probability Theory of the Faculty of Mechanics and Mathematics and completed Ph.D. thesis. He is the deputy head of MaTIS Chair. He also works in university administration on organization of information security research and teaching process.

The scientific interests of V.A. Nosov include combinations theory, information theory and information security. He is the author of over 100 scientific publications. He supervised 10 Doctors of Philosophy.

V.A. Nosov teaches courses and seminars on information security.

Leading researcher P.A. Aliseichik graduated from the Chair of Discrete Mathematics of the Faculty of Mechanics and Mathematics. After completing Ph.D. thesis devoted to finite-valued logic theory P.A. Aliseichik became a researcher of the Laboratory of Problems of Theoretical Cybernetics. His scientific interests include functional systems, expert systems and computer science. He is the author of 17 scientific publications and 10 computer teaching systems. P.A. Aliseichik teaches discrete mathematics and computer science. He is the deputy head of the Laboratory of Problems of Theoretical Cybernetics.

Leading researcher A.A. Zolotykh graduated from the Chair of Higher Algebra of the Faculty of Mechanics and Mathematics. He became a researcher of the Laboratory of Problems of Theoretical Cybernetics. His Ph.D. thesis was devoted to algebra. His scientific interests include algebra, automata theory and computer science. He is the author of over 70 scientific publications including a monograph and US patents on microelectronics. A.A. Zolotykh is the scientific secretary of the Laboratory of Problems of Theoretical Cybernetics.

Leading researcher M.V. Nosov graduated from the Chair of Higher Algebra of the Faculty of Mechanics and Mathematics. After completing Ph.D. thesis on pattern recognition M.V. Nosov became a researcher of the Laboratory of Problems of Theoretical Cybernetics. His scientific interests include pattern recognition and computer science. He is the author of 12 scientific publications. M.V. Nosov teaches courses and seminars on cybernetics.

Researcher A.G. Belenkiy graduated from Moscow Institute of Radioelectronics and post-graduate school of RAS Computational Center. He is a specialist in information technology. A.G. Belenkiy is the author of 23 scientific publications. He teaches seminars on computer science technology.

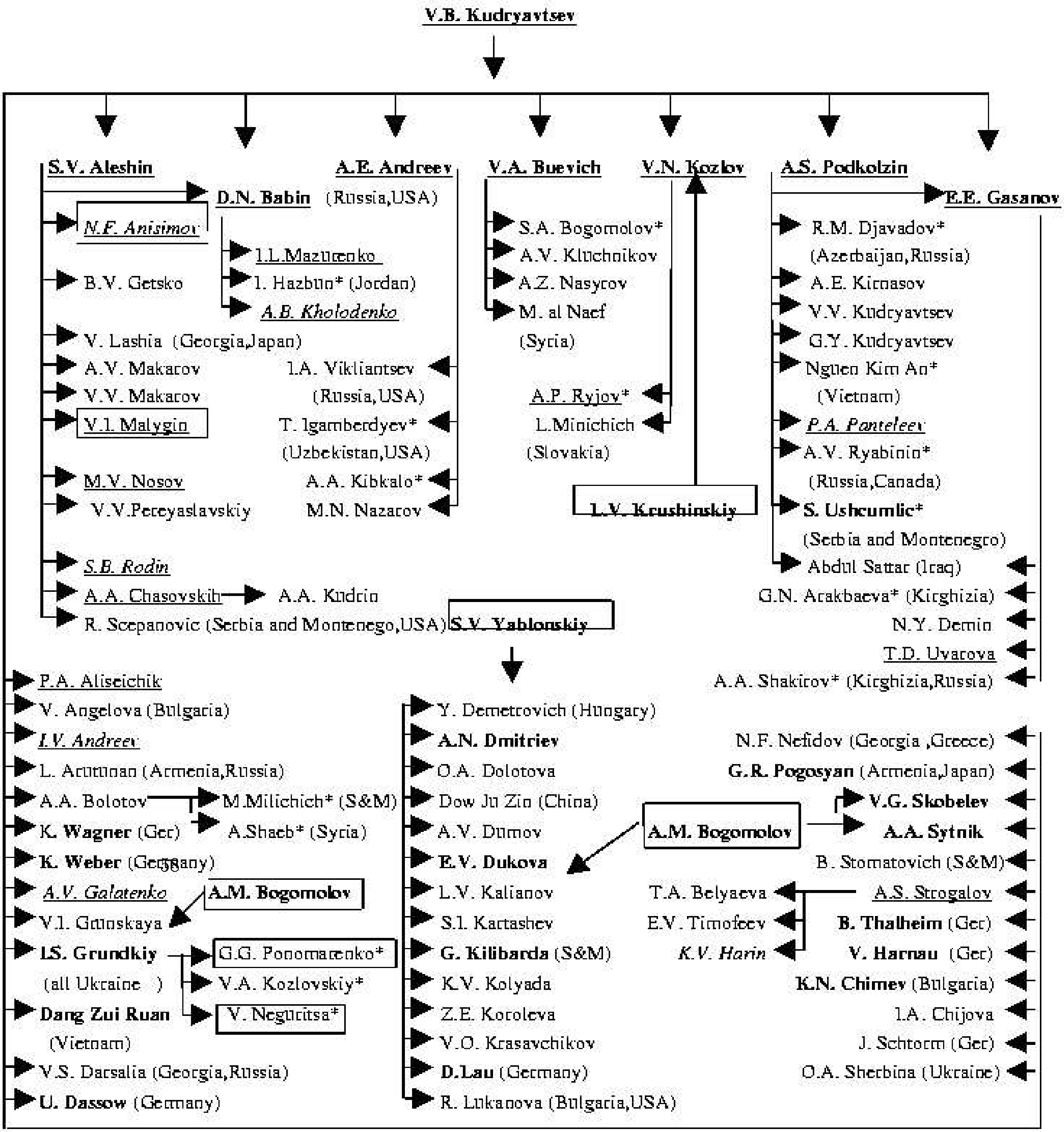
Researcher I.L. Mazurenko graduated from the MaTIS Chair the Faculty of Mechanics and Mathematics. His Ph.D. thesis s devoted to automata speech recognition methods. He is the thor of 10 scientific publications including two Russian patents speech recognition. I.L. Mazurenko is the scientific secretary the Laboratory of Problems of Theoretical Cybernetics and of ntelligent Systems"magazine. He is the web master of sites of e Chair and the Laboratory. I.L. Mazurenko teaches courses d seminars on speech synthesis and analysis.

Researcher A.E. Pankratiev graduated from the Chair of gher Algebra of the Faculty of Mechanics and Mathematics. s Ph.D. thesis was devoted to algebra. The scientific interests A.E. Pankratiev include algebra and computer security. He the author of 7 scientific publications. A.E. Pankratiev is e scientific secretary of MaTIS Chair. He teaches seminars on crete mathematics and information security.

Junior researcher A.A. Kudrin graduated from the MaTIS air of the Faculty of Mechanics and Mathematics. His Ph.D. esis was devoted to automata term evaluation. He is the author three scientific publications. A.A. Kudrin teaches seminars on ural networks.

Junior researchers A.V. Galatenko, A.Kirnasov, S.B. Rodin, N. Safiullin and A.B. Kholodenko graduated from MaTIS air. Junior researcher D.V. Alekseev graduated from the Chair Function Theory and Functional Analysis. Junior researcher A. Panteleev graduated from Moscow Automobile Institute. All ese researchers graduated from the corresponding post-graduate ools. Now they are completing their Ph.D. works and take rt in research and teaching process. A.V. Galatenko works information security and cellular automata. A.Kirnasov and A. Panteleev research automata testing complexity issues. A.N. fiullin studies automata models of market. A.B. Kholodenko rks on approximation of natural languages by formal languages. B. Rodin focuses on automata methods of image synthesis. V. Alekseev studies real function approximation and computer deling of biological problems. All these researchers also work the area of computer science.

A.B. Kholodenko is the scientific secretary of the Chair.



D.V. Alekseev

A.G. Belenkiy

A.A. Zolotykh

A.A. Irmatov → J. Kovianchich (Serbia and Montenergo)

V.A. Nosov → 10 Doctors of Philosophy and 1 Doctor of Science

A.E. Pankratiev

Y.N. Cheremnyh → 13 Doctors of Philosophy

Notes: Names of researchers of MaTIS Chair and PTC Laboratory are underlined. Manes of Doctors of Science are in bold, names of researchers without Ph.D. degree are in italic. Cosupervision of V.B. Kudryavtsev is marked by a * symbol. Arrows are directed from scientific supervisors to researchers supervised. If the country is not indicated, the researcher is Russian. S&M means Serbia and Montenegro, Ger means Germany.

Bibliography

1. C. Shannon. "Publications on information theory and cybernetics". "Mir"publishers, Moscow, 1963, pp. 1–830 (in Russian).

2. A. Turing. "Can machines think?". "Mir"publishers, Moscow, 1962, pp. 1–81 (in Russian).

3. J. von Newman. "Theory of self-reproducing automata". "Mir"publishers, Moscow, 1971, pp. 1–384 (in Russian).

4. A.A. Lyapunov. "On some aspects of cybernetics". "Problems of Cybernetics"transactions, №1, "Nauka"publishers, Moscow, 1958, pp. 5–22 (in Russian).

5. S.V. Yablonskiy. "Basic notions of cybernetics". "Problems of Cybernetics"transactions, №2, "Nauka"publishers, Moscow, 1959, pp. 7–38 (in Russian).

6. A.N. Kolmogorov. "Basic notions of probability theory". "Nauka"publishers, Moscow, 1974 (in Russian).

7. N. Winer. Cybernetics. J. Wiley, N. Y., 1948.

8. V.M. Glushkov. "Introduction to cybernetics". Ukrainian Academy of Science publishers, Kiev, 1964, pp. 1–324 (in Russian).

9. Y.I. Juravlev. "Articles on mathematical cybernetics". "Nauka"publishers, Moscow, 2000 (in Russian).

10. O.B. Lupanov. "On one approach to control system synthesis — local encoding principle". "Problems of Cybernetics"transactions, №14, "Nauka"publishers, Moscow, 1965, pp. 31-110 (in Russian).

11. A.I. Berg, A.I. Kitov, A.A. Lyapunov. "On possibility of industry management automation". "Problems of Cybernetics"transactions, №6, "Nauka"publishers, Moscow, 1961, pp. 83–110 (in Russian).

12. L.V. Krushinskiy. "Studying extrapolation reflexes of animals.Problems of Cybernetics"transactions, №2,

"Nauka"publishers, Moscow, 1959, pp. 213–228 (in Russian).
13. N.V. Timofeev-Resovskiy, "Microevolutions."Botanical Journal, 43, №3, 1958, "Nauka"publishers, Moscow (in Russian).
14. P.S. Novikov. "Elements of mathematical logic. Nauka"publishers, Moscow, 1959, pp. 1–400 (in Russian).
15. A.P. Ershov. "Operator algorithms.Problems of Cybernetics"transactions, №3, "Nauka"publishers, Moscow, 1960, pp. 5–48 (in Russian).
16. A.A. Markov. "Algorithm theory."Transactions of Institute of Mathematics, 42, Moscow, 1954, pp. 1–374 (in Russian).
17. I.A. Chegis, S.V. Yablonskiy. "Logical methods of electrical scheme control."Transactions of Institute of Mathematics, 1958, pp. 270–360 (in Russian).
18. A.N. Dmitriev, Y.I. Juravlev, F.P. Krendelev. "On mathematical principles of object end event classification.Discrete Analysis"transactions, №7, 1966, "Nauka"publishers, Novosibirsk (in Russian).
19. R.M. Konstantinov, Z.E. Koroleva, V.B. Kudryavtsev. "Combinatorial and logical approach to mineral estimation problems.Problems of Cybernetics"transactions, №31, "Nauka"publishers, Moscow, 1976, pp. 25–41 (in Russian).
20. V.E. Kuznetsov. "On one stochastic algorithm of test table informative characteristic evaluation.Discrete Analysis"transactions, №23, 1973, "Nauka"publishers, Novosibirsk, pp. 8–23 (in Russian).
21. E.V. Dukova. "Asymptotically optimal test algorithms in pattern recognition."Ph.D. thesis, 1979, Computational Center of Academy of Science, pp. 1–127 (in Russian).
22. A.E. Andreev. "On qualitative and metrical properties of test algorithms."Ph.D. thesis, Faculty of Mechanics and Mathematics, Moscow State University, 1981, pp. 1–145 (in Russian).
23. A.A. Kibkalo. "On **T**-algorithms for recognitions by short tests."Ph.D. thesis, Faculty of Mechanics and Mathematics, Moscow State University, 1988, pp. 1–153 (in Russian).
24. M.V. Nosov. "Functional characteristics of test algorithms of pattern recognition."Ph.D. thesis, Faculty of Mechanics and Mathematics, Moscow State University, 1989, pp. 1–80 (in Russian).
25. A. Shaeb. "Investigation of linear metrical recognition algorithms."Ph.D. thesis, Faculty of Mechanics and Mathematics,

Moscow State University, 1985, pp. 1–126 (in Russian).

26. V.V. Pereyaslavskiy, Ph.D. thesis, Faculty of Mechanics and Mathematics, Moscow State University, 1985, pp. 1–80 (in Russian).

27. B.V. Getsko. Ph.D. thesis, Faculty of Mechanics and Mathematics, Moscow State University, 1989, pp. 1–70 (in Russian).

28. I.L. Mazurenko. "Automata methods of speech recognition."Ph.D. thesis, Faculty of Mechanics and Mathematics, Moscow State University, 2001, pp. 1–119.

29. E.E. Gasanov, V.B. Kudryavtsev. "Information storage and search theory."2002, Fizmatgiz publishers, Moscow, pp. 1–288 (in Russian).

30. B. Thalheim Abhangigkeiten in Relationen. Dissertation fur doctor B. Uni Dresden, 1985, p. 1–205 (in German).

31. A.S. Podkolzin. "On mathematical problem solving processes modeling."Doctor of Science thesis, 1994, RAS Computational Center, pp. 1–304 (in Russian).

32. V. B. Kudryavtsev, K. Vashik, A. S. Strogalov, P. A. Aliseichik, V. V. Peretrukhin. On the automation model of the learning process. Discrete mathematics and applications, VSP, Utrecht, the Netherlangs, Tokyo, Japan, Vol. 6, № 6, 1996, 533–539.

33. A. Moore. "Speculative experiments with sequential machines.Automata"transactions, 1956, "Mir"publishers, Moscow, pp. 179–210 (in Russian).

34. I.S. Grunskiy. "Automata behavior in state neighborhoods and automata recognition."Ph.D. thesis, 1975, Computational Center of Academy of Science, pp. 1–110 (in Russian).

35. G.G. Ponomarenko. "On **r**-indistinguishability of finite automata."Ph.D. thesis, Applied Mathematics and Mechanics Institute, Donetsk, 1983, pp. 1–75 (in Russian).

36. S.A. Bogomolov. Ph.D. thesis, 1987, Computational Center of Academy of Science, pp. 1–90 (in Russian).

37. A.V. Kluchnikov. "On automata synthesis on the basis of finite behavior fragments". Ph.D. thesis, Faculty of Mechanics and Mathematics, Moscow State University, 1993, pp. 1–80 (in Russian).

38. V.A. Kozlovskiy. "On local automata fault detection."Ph.D. thesis, Applied Mathematics and Mechanics Institute, Donetsk, 1981, pp. 1–104 (in Russian).

39. L.V. Kalyanov. "Automata behavior steadiness."Ph.D.

thesis, Saratov State University, 1993, pp. 1–115 (in Russian).

40. V.G. Skobelev. "Algorithms and complexity of internal state recognition for finite automata."Ph.D. thesis, Applied Mathematics and Mechanics Institute, Donetsk, 1980, pp. 1–120 (in Russian).

41. G.R. Pogosyan. "On diagnostic test complexity for logical devices."Ph.D. thesis, 1982, Computational Center of Academy of Science, pp. 1–73 (in Russian).

42. O.A. Dolotova. "On Post-type logical schemes control complexity."Ph.D. thesis, Faculty of Mechanics and Mathematics, Moscow State University, 1991, pp. 1–101 (in Russian).

43. E. Post. Two-valued iterative systems of mathematical logic. Prinston, 1941, p. 1–145.

44. S.V. Yablonskiy, G.P. Gavrilov, V.B. Kudryavtsev "Logical algebra functions and Post classes.Nauka"publishers, Moscow, 1966, pp. 1–90 (in Russian).

45. S. Kleene. "Event representation in neural networks and finite automata.Automata"transactions, "Mir"publishers, Moscow, 1956, pp. 15–67 (in Russian).

46. V.M. Glushkov. "Digital automata synthesis. Fizmatgiz"publishers, Moscow, 1962, pp. 1–320 (in Russian).

47. S. Uscumlich. O kvalitativnim i metrickim svojstvima algoritama analize i sinteze koacnih automata. Doktorska disertacija, 1979, Universitet Beograda Jugoslavija, p. 1–100 (in Serbian).

48. A.V. Ryabinin. "Automata implementation of real functions."Ph.D. thesis, Faculty of Mechanics and Mathematics, Moscow State University, 1988, pp. 1–102 (in Russian).

49. A.S. Podkolzin. "On generator automata recognition complexity.Discrete Analysis"transactions, №21, 1972, "Nauka"publishers, Novosibirsk, pp. 31–61 (in Russian).

50. L. Budach. Automata and labyrinth. Mathematische Nachrichten, 1978, v. 86, p. 195–282 (in German).

51. V.B. Kudryavtsev, S.V. Aleshin, A.S. Podkolzin. "Introduction to automata theory.Nauka"publishers, Moscow, 1985, pp. 1–320 (in Russian).

52. V.B. Kudryavtsev, S. Uscumlich, G. Kilibarda. "On automata behavior in mazes.Discrete mathematics"magazine, vol. 4, №3, 1992, pp. 3–28 (in Russian).

53. G.Y. Kudryavtsev, "On temporal complexity of solving tasks in mazes by finite automata."Ph.D. thesis, Faculty of Mechanics and Mathematics, Moscow State University, 1991, pp.

1–127 (in Russian).

54. A.N. Zyrichev. "On synthesis of the automaton traveling through all planar mazes with bounded holes.Discrete Mathematics"magazine, vol. 3, №1, 1991, pp. 105–113 (in Russian).

55. A.A. Zolotykh. "Traveling through mazes with holes bounded in a fixed direction.Discrete Mathematics"magazine, vol. 5, №1, 1993, pp.59–69.

56. A.Z. Nasyrov. "On behavior of marking automata in mazes."Ph.D. thesis, Faculty of Mechanics and Mathematics, Moscow State University, 2001, pp. 1–77 (in Russian).

57. V.I. Grunskaya. "On some properties of automata paths in mazes."Ph.D. thesis, Faculty of Computational Mathematics and Cybernetics, Moscow State University, 1994, pp. 1–190 (in Russian).

58. J. Storm. Uber Verhalten von endlichen Automaten in determinierten Umgebungen. Dissertation der Doktor, 1978, Uni Rostock, p. 1–140 (in German).

59. Y.I. Yanov, A.A. Muchnik. "On existence of **k**-valued closed classed without a finite basis."Transactions of Academy of Science, vol. 127, №1, 1959, pp. 144–146 (in Russian).

60. S.V. Yablonskiy. "Functional constructions in **k**-valued logic.", Transactions of Institute of Mathematics, vol. 51, "Nauka"publishers, Moscow, 1958, pp. 5–142 (in Russian).

61. A.I. Maltsev. "Iterative Post Algebras."Novosibirsk State University publishers, 1976, pp.1–100 (in Russian).

62. I. Rosenberg. Uber die functionale Vollstandigkeit in dem mehrwertigen Logiker. Rozpravy Cs. Akademie Ved. Ser. Math. Nat. Sci., 80, 4, 1970, 3–93.

63. E.Y. Zaharova, V.B. Kudryavtsev, S.V. Yablonskiy. "On precomplete classes in **k**-valued logic". Academy of Science transactions, vol. 186, №3, 1969, pp. 509-512 (in Russian).

64. V.B. Kudryavtsev. "Functional systems."Moscow State University publishers, Moscow, 1982, pp. 1–159 (in Russian).

65. D. Lau. Eigenschaften gewisser abgeschlossener Klassen in Postschen Algebren. Dissertation fur Doktor, 1977, Uni. Rostock, Germany, p. 1–147 (in German).

66. W. Harnau. Die Struktur Vertauschbarketsmengen der **k**-wertigen Logik. Dissertation A, 1973, Uni. Rostock, Germany, p. 1–115 (in German).

67. W. Harnau. "A generalized relation notion and modified superposition for multivalued logic algebra."Doctor of Science

thesis, 1983, Dresden University, Germany, pp. 1–180 (in German).

68. L.A. Arutunyan. "On depth of closed classes for nonuniform functions."Ph.D. thesis, Faculty of Mechanics and Mathematics, Moscow State University, 1993, pp. 1–120 (in Russian).

69. R.M. Djavadov. "On ϵ-completeness of sets of logical algebra functions."Ph.D. thesis, 1982, Computational Center of Academy of Science, pp. 1–145 (in Russian).

70. P.A. Aliseichik. "On maximal basis length in finitely generated closed classes of **k**-valued logic."Ph.D. thesis, Faculty of Mechanics and Mathematics, Moscow State University, 1988, pp. 1–121 (in Russian).

71. S.I. Kartashev. "Expressibility issues for functional Post-type systems."Ph.D. thesis, Faculty of Mechanics and Mathematics, Moscow State University, 1987, pp. 1–126 (in Russian).

72. Dow Ju Zin. "On functional Post-type systems."Ph.D. thesis, Faculty of Mechanics and Mathematics, Moscow State University, 1990, pp. 1–137 (in Russian).

73. A.V. Makarov. Ph.D. thesis, Faculty of Mechanics and Mathematics, Moscow State University, 1988, pp. 1–80 (in Russian).

74. V.V. Kudryavtsev. "Expressibility and completeness conditions for functional systems of bundles of **k**-valued logical functions."Ph.D. thesis, Faculty of Mechanics and Mathematics, Moscow State University, 1997, pp. 1–51 (in Russian).

75. V.S. Darsalia. "On polynomial functional system completeness problem."Ph.D. thesis, Faculty of Mechanics and Mathematics, Moscow State University, 1998, pp. 1–116 (in Russian).

76. Y.Demetrovich "On some homomorphisms and relations for limitary logics.Problems of Cybernetics"transactions, №30, "Nauka"publishers, Moscow, 1975, pp. 5–42 (in Russian).

77. V.V. Lashhia. "On completeness conditions for **k**-valued logics."Ph.D. thesis, Faculty of Mechanics and Mathematics, Moscow State University, 1995, pp. 1–80 (in Russian).

78. G. Kilibarda. "On two typical functional models of automata with closure operator."Doctor of Science thesis, 1989, Belgrade University, Yugoslavia, pp. 1–127 (in Serbian).

79. V.B. Kudryavtsev. "Completeness issues for some functional systems connected to automata."Ph.D. thesis, Faculty

of Mechanics and Mathematics, Moscow State University, 1963, pp. 1–110 (in Russian).

80. M.I. Kratko. "Algorithmical undecidability of completeness recognition for finite automata."Academy of Science transactions, vol. 155, №1, 1964, pp. 35–37 (in Russian).

81. V.A. Buevich. "The solution of τ-completeness problem for automata."Doctor of Science thesis, Faculty of Mechanics and Mathematics, Moscow State University, 1992, pp. 1–329 (in Russian).

82. B. Thalheim . "Completeness and expressibility conditions for steady automata."Ph.D. thesis, Faculty of Computational Mathematics and Cybernetics, Moscow State University, 1979, pp. 1–167 (in Russian).

83. J. Dassow. Ein modifizierter Vollstandigkeitsbegriff in einer Algebra von Automatenabbildungen. Dissertation fur Doktor B. Uni Rostock, Germany, 1978, p. 81–120 (in German).

84. A.S. Strogalov. "On ϵ-modeling of finite automata behavior."Ph.D. thesis, Faculty of Computational Mathematics and Cybernetics, Moscow State University, 1985, pp. 1–122 (in Russian).

85. I. Hazbun. "On completeness and expressibility conditions in precise automata algebra."Ph.D. thesis, Faculty of Mechanics and Mathematics, Moscow State University, 1992, pp. 1–60 (in Russian).

86. K.V. Kolyada. "Issues of completeness for regular mappings."Ph.D. thesis, Faculty of Mechanics and Mathematics, Moscow State University, 1987, pp. 1–84 (in Russian).

87. D.N. Babin. "The solution of the problem of automata Post basis classification according to decidability of completeness and **A**-completeness."Doctor of Science thesis, 1999, Faculty of Mechanics and Mathematics, Moscow State University, pp. 1–244 (in Russian).

88. A.A. Chasovskih. "Completeness conditions for linear automata."Ph.D. thesis, Faculty of Mechanics and Mathematics, Moscow State University, 1993 (in Russian).

89. S.V. Aleshin. "On automata mapping superpositions."Ph.D. thesis, 1973, Faculty of Mechanics and Mathematics, Moscow State University, pp. 1–60 (in Russian).

90. E. Golod, I.R. Shafarevich. in "Proceedings of the International Mathematical Congress", Moscow, 1968, pp. 248–289 (in Russian).

91. V.B. Kudryavtsev, A.S. Podkolzin, A.A. Bolotov.

"Homogeneous structure theory foundations.Nauka"publishers, Moscow, 1990, pp. 1–296 (in Russian).

92. A.V. Dumov. "On configuration growth in homogeneous structures."Ph.D. thesis, Faculty of Computational Mathematics and Cybernetics, Moscow State University, 1997, pp. 1–102 (in Russian).

93. S.V. Yablonskiy. "Introduction to discrete mathematics. Nauka"publishers, Moscow, 1975, pp. 1–320 (in Russian).

94. A.E. Andreev. "On functional network synthesis."Doctor of Science thesis, 1985, Faculty of Mechanics and Mathematics, Moscow State University, pp. 1–250 (in Russian).

95. A.E. Andreev. "On one method of obtaining lower estimations for individual monotonous functions complexity."Academy of Science transactions, vol. 282, №5, 1985, pp. 1033–1037 (in Russian).

96. A.E. Andreev, A.A. Chasovskih. "Automata complexity of formula evaluation."Moscow State University bulletin, series 1, Mathematics, Mechanics, 1996, №4, pp. 22–24 (in Russian).

97. A.A. Kudrin. "Automata complexity of formula evaluation."Ph.D. thesis, Faculty of Mechanics and Mathematics, Moscow State University, 2000, pp. 1–99 (in Russian).

98. O.A. Sherbina. "Investigating some local algorithms for quasiblock discrete programming problems."Ph.D. thesis, Computational Center of Academy of Science, 1979, pp. 1–127 (in Russian).

99. G.N. Arkabaeva. "Data sorting methods complexity estimation."Ph.D. thesis, Faculty of Mechanics and Mathematics, Moscow State University, 1996, pp. 1–103 (in Russian).

100. K. Weber. Uber verschiedene Komlizirtheitmate bei Alternativen Normalformen. Dissertation B. Uni Rostock, Germany, 1975, pp. 1–75 (in German).

101. Nguen Kim An. "On some properties of Boolean function minimization algorithms."Ph.D. thesis, Faculty of Mechanics and Mathematics, Moscow State University, 1982, pp. 1–147 (in Russian).

102. T.M. Igamberdyev. "On the number of solutions of Boolean equation systems and solution search methods."Ph.D. thesis, Faculty of Mechanics and Mathematics, Moscow State University, 1988, pp. 1–102 (in Russian).

103. R. Scepanovic. Ph.D. thesis, Belgrade University, Yugoslavia, 1987, pp. 1–70 (in Serbian).

104. A.E. Andreev. "On one gradient algorithm

modification."Moscow State University bulletin, series 1, Mathematics, Mechanics, №3, 1985, pp. 29–35 (in Russian).

105. A. A. Irmatov. Arrangements of Hyperplanes and the Number of Threshold Functions, Acta Applicandae Mathematicae, V. 68, Nos. 1–3, 2001, p. 211–226.

106. K. Wagner. Berechenbare Funktionen uber n-dimensionalen Worten. Dissertation fur Doktor, Uni Jena, Germany, 1973, p. 1–171 (in German).

107. V.N. Kozlov. "On mathematical modeling on some control processes connected to biological behavior."Ph.D. thesis, Faculty of Computational Mathematics and Cybernetics, Moscow State University, 1978, pp. 1–91 (in Russian).

108. R. Lukanova. "Situational and semantic analysis of a natural language."Ph.D. thesis, Faculty of Computational Mathematics and Cybernetics, Moscow State University, 1991, pp. 1–154 (in Russian).

109. A.A. Shakirov. "Logical and algebraic methods of geometrical figure description."Ph.D. thesis, Faculty of Mechanics and Mathematics, Moscow State University, 1997, pp. 1–83 (in Russian).

110. A.P. Ryjov. "On qualitative indicator selection for describing objects by fuzzy sets."Ph.D. thesis, Faculty of Computational Mathematics and Cybernetics, Moscow State University, 1992, pp. 1–127 (in Russian).

111. F.N. Nefidov. "Creating a model for treating children from some acute enteric diseases."Ph.D. thesis, Computational Center of Academy of Science, 1977, pp. 1–143 (in Russian).

112. Z.E. Koroleva. "Efficiency analysis of several combinatorial and logical methods of pattern recognition (in connection to solving a geological problem)."Ph.D. thesis, Computational Center of Academy of Science, 1975, pp. 1–102 (in Russian).

113. I.A. Chijova. "Indicator role estimation in combinatorial and logical pattern recognition problems."Ph.D. thesis, Computational Center of Academy of Science, 1988, pp. 1–165 (in Russian).

114. V.O. Krasavchikov. "A modification of test approach to description table analysis on the basis of final table property."Ph.D. thesis, Computational Center of Academy of Science, 1982, pp. 1–163 (in Russian).

115. V.N. Kozlov. "Mathematical modeling of visual perception and recognition."Doctor of Science thesis, Faculty

of Computational Mathematics and Cybernetics, Moscow State University, 1997, pp. 1–211 (in Russian).

116. S.V. Aleshin. "Dynamic pattern recognition."Moscow State University publishers, Moscow, 1996, pp. 1–98 (in Russian).

117. V.B. Kudryavtsev, A.S. Podkolzin, S, Uscumlich. "Introduction to abstract automata theory."Moscow State University publishers, Moscow, 1985, pp. 1–180 (in Russian).

118. D.N. Babin. Ph.D. thesis, Saratov State University, 1987, pp. 1–90 (in Russian).

119. M.N. Nazarov. "Parallel computation of Boolean functions as a model of access to distributed resources."Ph.D. thesis, Volgograd State University, 2003, pp. 1–105 (in Russian).

120. Al-Dovri Abdul Sattar Abdul Jabbar. "Functional measure of computing complexity for automata schemes."Ph.D. thesis, Faculty of Mechanics and Mathematics, Moscow State University, 1994, pp. 1–127 (in Russian).

121. N.Y. Demin. "On secure network protocol reconstruction on the basis of message exchange."Ph.D. thesis, Russian State Humanitarian University, 2003, pp. 1–122 (in Russian).

122. L. Minchich. "On one mathematical model of visual pattern perception."Ph.D. thesis, Faculty of Computational Mathematics and Cybernetics, Moscow State University, 1988, pp. 1–120 (in Russian).

123. I.A. Vikhlyantsev. "On separating scheme synthesis."Ph.D. thesis, Volgograd State University, 1992, pp. 1–104 (in Russian).

124. Mohammed al Naef al Haj Unis. "On **A**-completeness of an automata system implementing the set of all simple experiments."Ph.D. thesis, Faculty of Mechanics and Mathematics, Moscow State University, 1989, pp. 1–107 (in Russian).

125. V.V. Makarov. Ph.D. thesis, Faculty of Mechanics and Mathematics, Moscow State University, pp. 1–75 (in Russian).

126. Е. В. Тимофеев. О моделировании мимической компоненты в обучающих информационных системах. Кандидатская диссертация по техническим наукам, РГГУ, 2002 г., стр. 1–203. 126. E.V. Timofeev. "On mimic component modeling in teaching information systems."Ph.D. thesis, Russian State Humanitarian University, 2002, pp. 1–203.

127. M. Milichich. "On Galois correspondence for algebra of functions with delays."Ph.D. thesis, Belgrade University, 1981, pp. 1–100 (in Serbian).