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Researches in Artificial Intelligence in Republic of Moldova

Yu.Pechersky

Abstract

The article presents a review of researches in the field of Artificial Intelligence in Republic of Moldova concerning pattern recognition and also theory and applications of intellectual knowledge based systems.

1 Introduction

In Republic of Moldova, which was the part of the forwer Soviet Union, since 60th researces in theoretical and applied mathematics have been actively carried out. They are mainly concentrated in the small on a number of workers Institute of Mathematics, belonging to the Academy of Sciences of Moldova and located in the capital of the republic Kishinev. A little later researches and applied works in some fields of computer science have begun. In particular, in the interests of constructing various information systems, specialized algorithms for pattern recognition and classification of multi–attribute objects have been developed. The practical necessety for extending these works has led to establishing in 1983 within the Institute of Mathematics the Laboratory of Mathematical Cybernetics. Later it was renamed to the Laboratory of Artifficial Intelligence Systems (LAIS).

From the very beginning in the field of view were the problems connected with the expert knowledge representation and processing. As the researches were developing and first versions of instrumental expert systems were created the neccesety for automatisation of the knowledge acquisition process for expert systems and for forming knowledge base has arisen. Therefore a part of efforts of the LAIS was directed to solving these problems. Also the problem of situation analysis and decision making in organisational control using expert knowledge and expert estimations werestudied.

All these researches were supported by the following grants.

	Title	Period	Customer
1.	The program of scientific and technical progress of the countries members of SEV. The project "Expert systems in agriculture".	1987–1990	USSR Academy of Sciences
2.	Development and test of exploitation of instrumental diagnostic expert systems for contemporary and perspective personal computers	1988–1990	USSR State Commette on Science and Technology
3.	State program of fundamental researches of AI	1991–1995	USSR Academy of Sciences
3.1	The project "Creating solvers and subsystems for knowledge base debugging based on the classification and analogy ideas"	1991–1995	
3.2	The project "Development of hybrid expert systems building methods for supporting decision making processes"	1991–1994	
4.	Development of knowledge representation techniques and realization on their basis of expert systems for decision making process automatization in concrete domains	1991–1992	USSR Academy of Sciences

Unfortunately, because of adisintegration of the Soviet Union financing projects 3 and 4 was ceased. The project 4 was continued under the support of the Ministry of Economy of the Republic of Moldova.

Main researches on AI in the Republic of Moldova are concentrated in the Institute of Mathematics. The LAIS is a small collective from 10–12 workers (without doctorants and students), including 6 doctors of sciences. Separate researches mainly of applied character are carried out also in other organizations such as Moldavian State University (intellectual systems of programming), Technical University of Moldova (expert systems for electronic circuits diagnosis), factory "Alpha" (expert systems for TV–sets diagnosis), firm "Reut" (expert systems for planning) and others.

Conferences, workshops and schools being carried out in Kishinev and vicinities favoured the development of research on AI in Moldova. The LAIS with the support of the Association for AI of the forwer Soviet Union, USSR Academe of Sciences and Scientifico–Technical Society of Radio–Electronic and Communication of Moldova have organized more than 10 scientific meetings (see Chronicle).

Almost all leading specialists and scientists of the CIS memebers countries took part in them. The permanent assistence in the making scientific elaborations was rendering by Prof. D.Pospelov (Computing Center RAS, Moscow), Prof. A.Zakrevsky (Institute of Technical Cybernetics BAS, Belorussia, Minsk), Prof. N.Zagoruiko (Institute of Mathematics RAS, Novosibirsk), Dr. L.Mikulich (Institute of Control Problems RAS, Moscow) and others.

Research workers of the LAIS published more than 250 scientific papers and about 200 times presented their papers on international, national and republican conferences. Software created in the LAIS was demonstrated on international exhibitions in Polish, Yugoslavia, Russia. It is used to solve practical problems in more than 200 scientific centers, firms and banks in Russia, Latvia, Moldova, Belorussia, Ukraina, Uzbekistan, Kirgizstan, Bulgaria, Slovakia.

2 Pattern recognition and classification

Researches in this field were stimulated by practical tasks in geology, stratigraph, biophysics, agrochemistry, comparative ampelograph. For example, in agrochemistry it is the actual diagnostic problem of finding the degree of plant provision with mineral feed elements on a number of attributes (plant development phase, height, leaf colour alteration, degree of damage); the attributes may be both qualitative and quantitative.

As a rule, to solve classification and pattern recognition problems attribute model of the objects or their sets was used (e.g., rectangular tables of the kind “object/property”). The following problems were formulated on these models:

- finding object attributes coefficients of informativity;
- analysis of tables to find out redundance or abundance of a set of attributes;
- finding mutually independent attributes and their subsets;
- constructing effective decision rules.

To solve these problems in the LAIS logico–combinatorial approach was developed based on using boolean algebra, methods, graph theory, combinatorics and heuristic [1,2]. In its framework effective algorithms of object recognition and classification were developed on the basis of which later recognition programs and information searching systems were created [3,4,5].

Taking into account such properties of boolean functions as their linearity, full and partial symmentry, monotony, self–duality permit in some cases to simplify the synthesis of digital automates. In [1] finding typology of boolean functions was reduced to the recognition of function types on trees, corresponding algorithms were built, and useful estimations were obtained.

In Technical University of Moldova logico–combinatorial method of solving in real time pattern recognition problems for a large number of attributes and under the circumstances of uncertainty concerning distribution law of the values of attributes was developed [6]. The method is based on using flexible table technique for initial object description and special recognition processor, universal for a given class of models.

In 1985 in the LAIS the works on creation of intellectual dialogue data processing systems have begun. In particular, an interactive system of data cluster analysis ISK was developed, allowing effective interaction with the user in defining the tactic of solving multi–attribute object classification problems. Later, in the process of evolution of ISK and realization of new ideas, an intellectual system of data claster analysis ISKAD [7,8] has appeared embodying some properties of expert systems. ISKAD permits to select crisp and fuzzy clasters, in its knowledge base a number of known and original algorithms of object classification is included. For the knowledge representation frames and productions are used, logical inference is based on backward chaining. There is a graphical support of the claster formation process.

In the framework of this project the problem of fuzzy classification (without learning) of compound data described by a finite number of attributes of different type [9]. The result obtained is a generalization on the fuzzy case of the earlier developed by E.Dide the dynamic thickenings methods[1]. The optimization model of the problem considered is built, and an iterative algorithm is proposed to solve it.

A part of above mentioned results is accumulated in the monograph [10]. First in the USSR schools on logico–combinatorial methods in AI and pattern recognition being carried out in Kishinev in 1978, 1979, 1985 favoured the development of these researches.

3 Knowledge representation and processing in expert systems

In 1984–1985 under the supervision of Dr. S.Solowiev an original knowledge representation method had been developed. It is based on using a simple system of alternatives [11-15], in which, as it turned out, an extensional of any notion can be expressed.

The simple system of alternatives (SA-system) is introduced by the triple of sets $\langle S, C, A\rangle$, where S is a set of main facts, C is a set of auxiliary facts ($S \cap C = \emptyset$), A is a number of subsets of the kind $\langle h_1, h_2, \ldots, h_m\rangle$ from $S \cup C$. Members of A are alternatives. United set of statements (facts) is designated by symbol H ($H = S \cup C$). Thus the simple system of alternatives is a set of records consisting of main and auxiliary facts. Main facts correspond to the attributes of problem situations. Auxiliary facts represent ties among alternatives. Only those SA-systems are considered in which each fact is included at

[1]Dide E., Data analysis techniques, Moscow, Finansy i Statistika.

least in one alternative. This allows to represent SA-systems by simply enumerating alternatives.

Let us consider a number of characteristic functions over the set of facts. The function $f : H \rightarrow 0,1$ satisfies the SA-system $R = \langle S, C, A \rangle$ if for any alternative $\langle h_1, h_2, \ldots, h_m \rangle$ from A the condition $f(h_1) + \ldots + f(h_m) = 1$ holds. A set of functions satisfying SA-system R is designated $F(R)$. Logical inference in the system of alternatives $R = \langle S, C, A \rangle$ is considered as a problem of reconstruction of a partially defined function from the class $F(R)$ [11].

An experimental verification of the formalizm of simple systems of alternatives passed in creating empty expert system (ES) FIAKR. This instrument is intended for building expert systems supporting decision making process in recognition and diagnosis problems [12]. It can be used in those problem domains where the descriptions of external attributes, intermediate propositions and goal states can be represented in the form of a collection of one-valued attributes (i.e., in each problem situation attributes which describe it take only one value). Attributes and their values are used for describing declarative knowledge. The representation of procedural knowledge is realized by identifying separate attributes with the names of programs.

Knowledge base of FIAKR-like ES is built in the form of the system of alternatives. At every step some (highly restricted) subset of facts connected by particular dependency is choosen. This subset is identified with a mini-system of alternatives or knowledge module. In the system FIAKR the following knowledge modules are used:

alternative combining a group of mutual exclusive statements in which setting one statement is equivalent to refutation of all others;

incompatibility is which from setting one statement follows refutation of all others;

prohibition representing a group of statements in which setting all statements except one entails refutation the rest statement;

implication which represents an ordinary implicative dependency between groups of statements, i.e., in presence of all premises a consequence is always inferred, and vice virsa, when the consequence is refuted the only premise which is not set is refuted;

production which differs from implication only in that it does not work in back direction.

The system FIAKR is realized in the language Pascal. It supports the dialogue with the user in the form of menu. In difficult situations one can call the help system, give non-unique answer or refuse to answer the system question at all. It is allowed to go back to the beginning of consultation and to change some answers. The dialogue can be postponed in order to be continued the next time.

In 1987 the development of another approach to the knowledge representation and processing started in the interests of solving diagnostic problems. It is based on using finite predicates (including fuzzy ones) and the formalizm of sectional boolean matrices proposed by Prof. A. Zakrevsky from Belorussia[2].

Let $\{a_1, a_2, \ldots, a_n\}$ be a set of problem domain object attributes, and let $A_1, A_2, \ldots, A_n$ be corresponding finite sets of their values. Attributes and their values form the syntactical description of the class of objects to be diagnosed, when each of them is represented simply by a number of values $\langle a_1, a_2, \ldots, a_n \rangle$ from the universe $M = A_1, A_2, \ldots, A_n$. If in M consisting of all combinations of the values of attributes, some subset P is selected, then the class being studied is said to be described semantically. In fact, the subset P of semantically right descriptions represents the problem domain laws which hold always independently of the concrete situation. The subset P can be represented in the form of n-place predicate $\phi(a_1, a_2, \ldots, a_n)$ with the domain of definition M. Its characteristic set, i.e., a collection of elements from M on which ϕ takes the value 1. coincides with P [16,17].

In these terms the problem of diagnosis comes down to the following [17]. There is partial information about, e.g., first m $(m < n)$ attributes

[2]Zakrevsky A.D., Logical inference in finite predicates, Preprint No. 6, Institute of Technical Cybernetics, Belorussia, Minsk, 1989.

of the object from the class P: $a_j \in F_j \subset A_j$ $(j = \overline{1,m})$. It is necessary to find the minimal on the power subsets $B_j \subset A_j$ $(j = \overline{1,m})$ such that for any $a_j \in B_j$ the condition $\phi(a_1, a_2, \ldots, a_n) = 1$ is satisfied. Obviously, the problem of confirmation of the hypotheses about the goal attribute being advanced can be formulated analogically.

Further, boolean vactors broken in sections are put in one-to-one correspondence with the attributes $a_1, a_2, \ldots, a_n$. The values of attributes correspond to the two-valued components of the sections. These vectors are used for the representation of members and subsets of the set M, while the collections of vectors are used for the representation of any finite predicates. Vectors are interpreted as elementary conjunctions of one-place predicates (conjuncts) or as elementary disjunctions (disjuncts). The matrices of conjuncts are defined as dijunctive normal forms (DNF) of finite predicates, and the matrices of disjuncts — as CNF. The finite predicate $\phi(a_1, a_2, \ldots, a_n)$ can be represented in the form of the conjunction of elementary disjunctions $d_1, d_2, \ldots, d_k$. This CNF is represented by the sectional boolean matrix D consisting of line-disjuncts $d_1, d_2, \ldots, d_k$ and is thought of as the system of equations $d_1 = 1, d_2 = 1, \ldots, d_k = 1$. A set of roots of this system is a characteristic set of the predicate ϕ.

The problem of logical inference on the matrix D representing knowledge base comes down to finding prime disjuncts of the predicate represented by the matrix D [18].

In 1990 this approach was generalized on the fuzzy case supposing that semantics or knowledge about the class of objects is fuzzy, while syntax is the same. In other words, a subset of semantically right descriptions is supposed to be fuzzy in the sense of L. Zadeh. In any case semantics can be represented in the form of mapping $\pi_P : M \rightarrow [0, 1]$.

The method of sectional boolean matrices was generalized on the fuzzy case as well [19]. The central moment of the approach is the operation of fuzzy resolution which is applied to two source disjuncts on kth section and results in the third disjunct called resolvent. kth section of resolvent is equal to the conjunction, and the rest of sections — to the disjunction of the corresponding sections from the source disjuncts.

It is important that the content (semantics) of the resolvent in general case depends on the form of premises. It is shown that to obtain the strongest resolvent it is necessary to transform source disjuncts to kth reduced form. Criteria of adjacency of two disjuncts are also formulated allowing us to determine if the resolvent is a consequence of one of two premises without constructing the resolvent itself, proceeding only from the form of premises.

Crisp approach was realized in the instrumental ES EDIP [20]. Fuzzy approach was implemented in the form of the library of functions for MS-Windows called logical kernel EDIP. This library underlies the interactive system Fuzzy Knowledge Manager EDIP for MS-Windows which performs functions of entering and editing knowledge, entering data and goals of consultations, and carrying out logical inference [21]. All these systems perform preliminary compilation of the knowledge base for increasing the speed of the following logical inference during the consultation.

In section 2 we discussed the classification system ISKAD. The shell OBSES for building classification and recognition ES is the generalization of instrumental ideas laid in this system [22]. For the knowledge representation frames and productions are used. Facts, heuristics and meta-knowledge can be stored in the knowledge base. Meta-knowledge serves for controling logical inference and explaining system's behaivor. Problem domain knowledge is packed in clasters that permits to fulfil flexible logical inference by activating clasters during the consultation and to verify the knowledge base by clasters.

The system OBSES includes the following main components: editor for creating frame structures; rule editor; blackboard; sceleton structure of the knowledge base; rule interpreter; consistency maintenance block; explanation block. The architecture of OBSES is close to such systems as EMYCIN and HEARSAY.

The conception of table-oriented ES developed in the Technical University of Moldova [23] is based on the representation of knowledge in the form of decision tables (in one line of the table productions with both similar conditions and similar right parts-decisions are written). The data base is represented by a table "object-property". Entering data is reduced to filling in the input table that cteates “image of goal” by the user. To achive it the questions preliminary divided into groups and characterizing particular sides of the problem are asked. Output table is organized analogically. Warnings and errors in input data are entered into the separate table.

A collection of described tables forms a so called tabular ES. Logical inference in it is realized by searching in the hierarchical system of decision tables. ES of this kind can be built with the help of “electronic tables” and table processors. An experimental version of the tabular ES is built on the basis of the table processor Supercalc with adding a search criteria table.

The knowledge representation procedure proposed by the LAIS aspirants G. Andrienko and N. Andrienko and described in [24] uses modified repertory grids method with the help of which one can acquire knowledge about problem domain object properties from the expert. This knowledge is fixed in tables of the kind “object-property” and then logical inference on a set of tables corresponding to different abstraction levels is carried out. Logical inference is realized with the help of the algorithm of cutting out. If the user answers the question about the object attribute value and this answer is absent in the possible values table for given object, then the column corresponding to the object is cut out of the table. Objects with the columns which are not cut out are considered to be decisions. Depending on the result of consultation on the table, a table of lower abstraction level is called as a parameter of the logical inference block.

On the basis of this procedure an original instrumental ES ESKIZ is developed, which is oriented at the recognition problems and has an effective explanation subsystem.

In 1987–1989 a successful attempt was made to develop a formalizm for semantical networks and productions, and to verify its effectivity in solving AI problems. It is shown that in describing semantical networks three types of relations should be used: intensional, extensional and conceptual relations. Intensional relations are defined as with the help of a predicate formula consisting of binary predicates. Extensional relations are known theoretical set relations. Conceptual relations are defined by the pair consisting of intensional and extensional relations. Algebraic formalizm of conceptual relations is built.

Semantical nerwork is defined as some set of conceptual relations. Production is defined as a relational formula, the left part of which is the product of conceptual relations and the right part is an intensional relation defining conclusion [25].

A method of the description of pseudo–physical logics with the help of the theory constructions as follows: $RT_x = \langle \sum_x, \Delta_x, A_x \rangle$, where $\sum_x$ — theory signature involving names of basic and derivative theory relations; Δ_x — a set of derivative relations definitions through basic ones; A_x — theory axioms defining properties of basic relations. Three types of properties are used: symmetry, transitivity, and also the properties of left and right unity [25,26]. It is shown that the problem of logical inference in pseudo–physical logics in general case comes down to the problem of computing relational expression which is the product of relations. It is developed the method of determining pseudo–physical logic description completeness making use the following criterion: the theory RT_x is complete if its axioms guarante computing the value of any its expression.

4 Forming the knowledge bases of expert systems

The problem of knowledge acquisition remains the bottlneck braking the process of creation and distribution of ES. As its source a specialist–expert ordinary appears. Present methods of the work with experts are imperfect and, in particular, they are not able to maintain the permanent interest by the expert to the difficult knowledge acquisition process.

In 1986 Dr. S.Solowiev and G.Ginkul proposed untraditional approach to the partial automatization of the knowledge acquisition process. The method obtained the name of expert games [27]. The main idea consists in enriching the dialogue with the problem specialist (knowledge engineer) by computer games being immersed in the problem domain and based on the corresponding terminology.

The idea of game approach to the work with the expert underlay the complex of algorithms for the knowledge acquisition KAPRIZ [28–32]. Besides game programs, KAPRIZ includes knowledge base where all acquired information is entered to, a number of program–heuristics performing its processing and forming concrete decision making procedures within problem domain, and editor allowing to control all processes in the program complex. Thus all game programs are closed into the one knowledge base and at the same time they are absolutely independent. It allows free widening available set of games, provided that their input and output parameters are correspondingly arranged.

Program–heuristics realize information processing after carrying out games. By analyzing expert actions in a concrete game situation and proceeding from the formal definition of a rule they put forward hypotheses about the existence in problem domain of objective laws being expressed by these rules. Heuristic programs result in the forming procedure–rules of the following types: implication, prohibition, incombatibility, alternative.

Another developed in the LAIS approach is connected with the modification of known repertory grids method[3] The method of knowledge acquisition developed assumes analysis by the expert of problem domain objects with the simultaneous generation of tables "object–property". From the obtained set of tables relating to different abstraction levels knowledge modules then are acquired [33,34]. The principle described is implemented in the instrumental ES ESKIZ.

Further this technology was enhanced and realized in the instrumental ES AFORIZM [35,36,37]. The feature of the system is its orientation at analysis and formalization of intellectual problems of different types: recognition, selection, control and planning. The technology AFORIZM allows dealing with complex problems with solution process breaking into a number of subproblems. There are modules in the system which reakize different knowledge acquisition methods. For

[3]N.Cooke, I.McDonald, The application of psychological scaling techniques to knowledge elicitation for knowledge–based systems. Int.I. on Man.Machine Studies, Vol.26,1987, 533–556.

each type of problem there is a method of acquisition. At each time the system concentrates the attention of expert at viewing one problem in isolation from others. The hypertext technology is used in the system AFORIZM — mainly as means for showing knowledge base to expert [38].

Game approach to the knowledge acquisition turned out fruitful also in the framework of repertory grids method. The usage of dynamic computer graphics turing a game extends expressive power of the repertory grids method [39].

A system of acquiring knowledge from expereimental data [40] developed in the LAIS is a little aside from the described researches. It uses the method of mapping data table onto the two–valued hypercub wible the dimension depending on the number of table attributes. The hypercub vertex are looked through making use of heuristics and those are found which confirm the logical rule supposed.

one more development of the LAIS is connected with the problem of knowledge base debuging FIAKR–like ES. It is created an iterative method of finding defects and contradictions in knowledge bases working in static and dynamic regimes. The method is based on building and analysis of minimal resulting and conflict descriptions in knowledge bases [41,42].

It is interesting that in 1991–1993 four workers of the LAIS obtained doctor degrees for researches in the field of automatization of ES knowledge base forming processes.

5 Decision making support systems

There exist many decision making problems in ill–structured domains where facts and knowledge about control objects are uncertain and frequently erroneous or inconsistent. The same can be said about criteria which underlie decision making. The problems of kind are badly solved or are not solved at all by traditional methods.

During many yearsin the LAIS techniques of collective expertise have been studying as rather effective means for estimating the state of complex or ill-formalized objects such as, e.g., scientifico-technical programs, economical or ecological projects.

In 1986 SIREX was created — the prototype of an interactive system automating main stages of the collective expertise [43]. Later on more deep conceptual scheme of estimating objects and decision making was developed. The technology proposed in its framework contained new elements.

Arrays of uncertain estimations generated by experts are initial information.

Automatic system of collective expertise have to have an universal collection of operational means providing the flexibility of the system as a whole. This collection includes different methods of initial information analysis, aggregation of estimations, interpretation of results, prognosis of states of the object in time etc.

Entering a scenario of the technological process of the expertise as a whole is provided. Scenaria are constructed with the help of integrated ES determining their structure and the consequence of operations taking into account decision maker preferences, concrete problem formulation, analyzed object pecularities.

Multiaspect interpretation of results should be provided including in addition to the tables of numbers and traditional diagrams, more sophisticated forms. Therefore image graphic facilities were developed and hypertext usage is foreseen.

Where it is possible and worth while, in combination with heuristics application software packages are used realizing methods of multicriteria optimisation.

Research results in the frameworks of the conception proposed are published in [44,45,46]. The collective expertise technology is implemented in the interactive system KIOT [47].

6 Practical Application of Artificial Intelligence Systems

The majority of above described results were applied within Moldova and abroad.

FIAKR is one of the first developed in USSR commercial instrumental ES [48]. With the help of FIAKR a number of ES was created for solving practical diagnostic problems. Let us mention only ES FIAKR-T [49], which determines characteristic types of relations between phitogormons give morphological description of tomates. Diagnoses of such kind are used at the stage of experiment planning in cell engineering. With the use of the system FIAKR the problems of diagnosis of machine tools with digital program control, ecological monitoring, geomorphology, new weapons expertise etc. were solving in different firms of Moldova, Russia, Latvia, Belorussia, Bulgaria, Ukraine.

The system SIREX was applied for processing expertise results in public health, and more advanced system KIOT — for estimation of the quality of scientifico-technical projects in the field of informatics in Moldova.

The interactive systems of cluster analysis ISK and ISKAD are applied for processing data of space research (Moscow, Petersburg), for enhancing water supply control (Moscow), for sorting economical information (Moscow), for processing experimental data in immunology (Serpuhov) etc.

One of the applications of the instrumental ES AFORIZM turned out rather unexpected. It was used in Russian center for training spacemen in creating ES for training to drawing together of spaceship and orbital station[4]. With the help of the instrument AFORIZM ES for controling wire communication lines laying was also developed.

With the help of the instrumental system EDIP and EDIP-F the problem of ecological monitoring of water environment near a power station, determinig vermins of cultured plants, diagnosis of communication equipment, and screening alcoholism [50] were solving.

In the Technical University of Moldova instrumental ES for testing microprocessor devices were created and tested [51].

[4]Snastin A.A., Details of the application of the systems GURU and AFORIZM in developing prototype expert system for monitoring the process of drawing together a spaceship and an orbital station, Proc. III conf. on AI, Vol. 2, Tver, 1992, 12–15 (Russian)

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Yu.Pechersky,
Institute of Mathematics,
Laboratory of Artificial Intelligence Systems,
Academy of Sciences, Moldova
5, Academiei str., Kishinev,
277028, Moldova
Phone: (373+2) 73-81-30
e-mail:23LSII@math.moldova.su

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