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Solving the Problem of Finding Hypothetically Connected Objects by Means of Spatial Multi-Valued Structures

In the work the basic aspects of mathematical modeling of AFP-structures as universal functional converters of spatial type on the basis of decomposition of multiple-valued structures are investigated, also there have been investigated an approach to the implementation of the linear logical transformation finding method for solving the problem of finding hypothetically connected subscribers in the automated system of complex calculations of telecommunication enterprise.

Introduction

Developing and improving computer facilities underline the process of automatizing mental activity, which was the starting point of emergence of concept of artificial intelligence. However, the successes in the field of intellectualizing computer machines are insignificant especially if one compares the achieved results with anticipated ones and forecast. The orientation to the attain of qualitatively new technologies of information processing manifests itself in attempts to realize systems of artificial intelligence (AI) on Neumann computers. Therefore, new requirement of the technology of information processing are caused by need for solving problems, which are badly formalized and the availability of user who is not a professional programmer. Thus, we came to realizing one of the variants of developing AI systems are the way of analyzing modeling and synthesizing a natural language intelligent interface by means of multiple-valued logical systems, in particular by algebra finite predicates as well as the theory of multiple-valued structures and coding. Since the advent of computers facilities research has been carried out and realization at the level of engineering solutions multi-valued structures and coding in view of high information saturation of their signals has been conducted. Structures of data processing means, which are conducted on the basis of multiple-valued logical elements and modules with appropriate links, are called multiple-valued structures. All the objects, which are described by finite structural alphabet: elements, modules, structures, system of computer, measuring and control facilities and natural language information tools are classified among such structures.

At present there exist a great number of uncoordinated approaches and methods of building and applying multiple-valued structures, however, their systematization and classification are not available (i.e. any kind of an ordered system of realization means). At the same time the optimum design and technical realization of computer machines on the base of multi-valued structures are impossible without simultaneous development of entirely new (nontraditional) kinds of mathematical models and their research for various

models of operation and interpretation of the modeling results. All this has resulted in a critical situation, which is caused by absence of the integral theory of constructed highly effective multi-valued structures of spatial type. The analysis done shows that the problem of developing the generalized theory of building highly effective multiple-valued computer structures and coding for language systems can be solved only within the class of intuitive and constructivist theories [1-4].

Today, data processing in intellectual systems is based on the particular knowledge about subject domain. However, knowledge representation systems itself that simulate human activity, are insufficiently formalized. There have been developed a lot of methods of knowledge representation. Herewith, usually, every knowledge representation system has its own advantages and disadvantages, endowed with the specific structure and efficient only in specific subject domains. It is natural that the more general the language character of data representation, the bigger the area of subject domains, where it can be implemented. Such universal language of knowledge representation can be considered the finite predicates logic, owing to through algebraic logic apparatus it became possible to formalize arbitrary ratio. The finite predicate logic and predicate operations are effective and convenient for the description of various information, formation of queries in databases and simulation of human activities.

The purpose of the given work is dedicated to development of adequate algebra and logic systems engineering tools of language phenomena objectification on the basis of their formalization and corresponding approbation.

Choosing the Body of Mathematics

The availability of algebra of finite predicates (AFP) provides an interesting opportunity of realizing a transition from algebraic description of information processes to their description in the form of equation in the language of given algebra and the equations specify relations between its variables [5], [6]. All the variables in the equation possess equal rights and any of them can be both independent and dependent ones. The presence of equations and their advantage over algorithms consist in the fact that there appears an opportunity to calculate the reaction of the system even in case of the incomplete definiteness of initial information, whereas an incompletely developed algorithm is unable to operate. One should note that by means of AFP-structures which realize appropriate finite predicates. The given approach is similar to the process of constructing combinational circuits by the formula of algebra of logic. Depending on the level of functional and structural realization we have AFP-structures of the first, second and third level [6].

The algebra of finite predicates is used as the body of mathematics of the research. We treat AFP as the one which is represented by the set M of all the predicates U^m. Let T be a set of all relations on U^m, Q be a set of all predicates on U^m. The relation T and predicate Q are called corresponding to each other, if for any $x_1, x_2, \ldots, x_m$ we have:

$$Q(x_1, x_2, \ldots, x_m) = \begin{cases} 0, \text{ if } x_1, x_2, \ldots, x_m \notin T; \\ 1, \text{ if } x_1, x_2, \ldots, x_m \in T. \end{cases} \quad (1)$$

In accord with (1) there can be a transition from the arbitrary relation T to predicate Q corresponding to the said relation T. The predicate Q which is found by the expression is called the characteristic function of relation T.

The condition of the form:

$$a(x_i) = x_i^a = \begin{cases} 0, if\ a \neq x_i; \\ 1, if\ a = x_i. \end{cases} \quad (2)$$

is called predicate of recognizing an object $a \in U$ of variable $x_i, i = \overline{(l,m)}$.

The predicate $a(x_i)$ should be considered as the predicate $a(x_1, x_2, \ldots, x_i, \ldots, x_m)$ from $P \subseteq Q$, whose all arguments, except x_i, are negligible. We will replace the expression in the form $a(x_i)$, where $i = \overline{l,m}$, $a \in U$ by x_i^a (here a is called an exponent of the variable x_i. Thus, the set T and basic elements x_i^a ($i = \overline{l,m}$, $a \in U$) and basic operations: disjunction, conjunction and negation is called the algebra of finite predicates over M. Eliminating the operation of negation out of the basis of the given algebra enables to obtain so called disjunction and conjunction algebra of predicates (DCAP). Its completeness is proven [7]. Thus, the given algebra is considered as an instrument of research but not as its subject.

The linear logical transformation (LLT) degree finding method. LLT degree finding method has been presented and proved

$$Q^{(n)}(y) = \bigwedge_{i=1}^{n} K_i Q(y), \text{ where } K_i = K = K(x,y)K(y,x)$$

$$P^{(n)}(x) = \bigwedge_{i=1}^{n} K_i' P(x), \text{ where } K_i' = K' = K(y,x)K(x,y).$$

The developed LLT degree finding method $Q^{(n)}(y)$ can be divided into the following stages. You must first find the matrix K, superposition of kernels of linear LLT from $P(x)$ into $Q(y)$ and, respectively, form $Q(y)$ into $P'(x)$: $K = K(x,y)K(y,x)$.

The next step is to find the conjunction of all *n* kernel LLT superpositions and the input vector.

Thus, we can conclude that *n* is a linear logical transformations ($n \geq 1$) depends on the type of matrix K. It is important that the matrix K depends only on the definition domain of variable *x*. As the step, in which the degree of LLT in the further actions does not change, and directly depends on the dimensionality of the definition domain of variable *x*.

The assertion that if for finding of LLT degree in two successive steps of conversion value is repeated, this value will be repeated also in the following steps [7]. That is, if the finding of *n*-th LLT degree obtained similar results were obtained for *n*-th and *n*-1 steps, this result also will be received on the following *n +1*-th, *n +2*-th, etc. d. steps. Then this linear transformation is desired.

We will continue to use this assertion in solving the problem of finding hypothetically connected subscribers.

Formalizing the Concept of Unification of Spatial Multiple-Valued Structures

A concept of unifying (reducing to uniformity and indissoluble interaction) two-digit and multi-valued means of processing appropriate (symbolic) data semi digital in a natural language. The present approach is based upon a single methodological and special purpose principle by applying the proposed methods of the theory of intelligence [8] for mathematical description and appropriate formalization of the concept of unifying input/output data [9] and their intermediate transformation [10] an appropriate AFP-structure of the third sort [5].

AFP-structure of the third sort is proposed on the basis of the SDF architectural studies presented in the works [5], [6], [9], as well as proceeding from the need for structurizing problems in developing the intuitive and constructivistical theory of constructing multiple-valued structures of spatial type for language systems.

AFP-structure of the third sort based upon a two-input universal multivalued functional converter [5] includes the following components: a recognition element *n*-valued variable which is formed by a parallel analog-to-digital converter together with a spatial decoder, a matrix selector and a matrix switch, a control unit, a parallel digital-to-analogue converter (key switch). After describing the logic of operation of these components by the appropriate equations of the algebra of finite predicates, we will obtain their mathematical models. The use of the concept of unification and the given algebra will ensure boundary parallelism and uniformity of the structure as a whole. Obtaining analytical relations of input /output variables of component will make it possible to formalize and synthesis procedure of multiple-valued structures of spatial type [5], [6].

The research has shown that the application of traditional methods of combinational synthesis in functionally complete bases as disjunction (conjunction) normal forms to multiple-valued structures of spatial type is ineffective from the point of view of retaining the properties of uniformity and parallelism of structural formations [3], [5]. There is a need for seeking objects of research which are the most natural and closest to the inner logic of functioning for a natural language particulary of corresponding structures a variety of algebraic and logical means of modeling and new methods of synthesis of corresponding structures [5], [10].

Solving the Problem of Finding Hypothetically Connected Objects

Currently, the structure, conditions of application, interconnections with other systems and complex problems with each other, modes of operation and automated system of complex calculations functioning principles (CCFP) of integrated informational and computational enterprise system of telecommunication are being developed.

One of the problems that CCFP solves is a hypothetically connected subscribers finding problem (HCSFP) [11]. Input data is presented as a set of all subscribers of the city of Kharkiv, the set of subscribers, with whom the hypothetical connection is required to be set up, as well as phone numbers that were used to call during certain period of time. All subscribers of Kharkiv, that can be hypothetically interconnected must to be found. Hereinafter, “hypothetically connected” should be read as denoting a whole chain of telephone calls, through which the information could be transmitted, rather than not direct connection between objects (subscribers).

In the CCFP system, the HCSFP has not been solved completely. Only few searching cycles were carried out, since there was no known search algorithm termination criterion. In turn, the set of subscribers is big enough to implement a full search. The number of cycles wasn’t big, from 2 to 5. That is why in most cases all solutions could be not found. It can be assumed that this criterion developed, based on the LLT degree finding method, allows the task to be solve.

For example, when receiving a request from certain services on the need acceptance of data on the phone (i.e. phone numbers on which the calls were made from the given telephone number during some period of time). Then again, the obtained results would come in the form of inquiry: who was calling on this telephone numbers and so on few times (cycles). Herewith, all actions were performed by the operator, rather than automatically.

Let us give an example of solving the HCSFP. Data for the problem solving will be taken from the database of the following structure (Fig. 1). Due to some requests there used lookup tables of one-time services and lookup tables of trunking groups.

Automatic international telephone connection

State	Duration of conversation	Date	Beginning of conversation (time)	Outcome telephone number	Income telephone number code	Income telephone number

Subscribers

Telephone	First/Last name	Properties

Directions

Code	Region	City	Country

Figure 1 – Database Scheme

Let the variables x_i, $i = 1,2,...,12,...$ be the numbers of Kharkiv and Kharkiv region. The problem is to find all the subscribers' phone numbers, which subscribers with numbers x_1, x_2, x_4, x_7, x_9 can be connected to. The set of subscribers' numbers to which the income calls are recorded mark y_j. Fig. 2 suggests that subscribers x_1, x_2, x_4, x_7, x_9 are hypothetically connected to subscribers $y_1 - y_{24}$, the solution is found in 3 steps. Usage of the developed LLT degree finding method allowed to minimize the solutions search time.

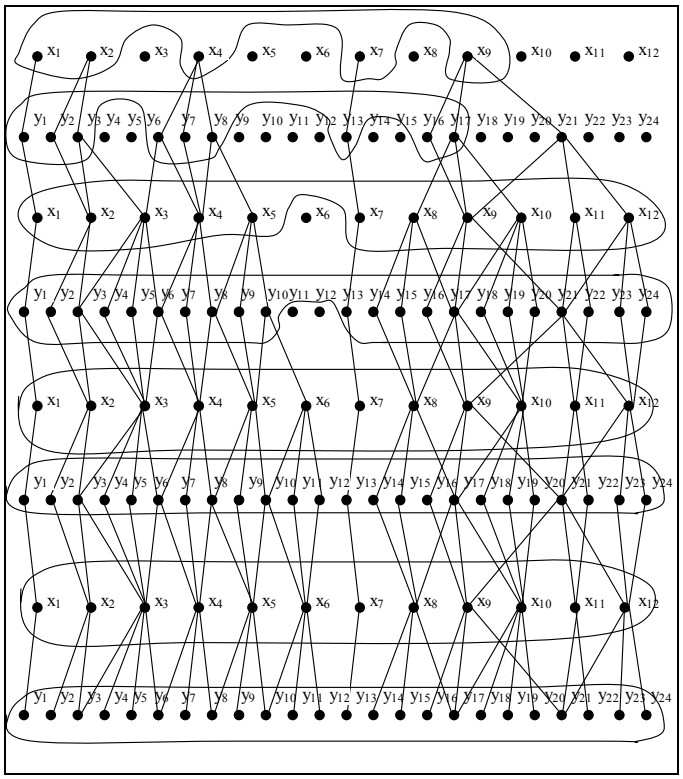

Figure 2 – Finding the HCS

Variables x_i, $i = 1,2,...,12,...$ are Kharkiv and Kharkiv region phone numbers. We must find subscribers' phone numbers which subscribers with numbers $x_1 = 0572230508$, $x_2 = 0572945376$, $x_4 = 0577124387$, $x_7 = 0577774004$, $x_9 = 0577711691$ can be connected to.

Thus, there were found the following Kharkiv and Kharkiv region subscribers' phone numbers: $x_3 = 0577153256$, $x_5 = 0577356578$, $x_6 = 0572995633$, $x_8 = 0577332376$, $x_{10} = 0572278745$, $x_{11} = 0577126534$, $x_{12} = 0572937694$.

Analysis of Used Method

Let us perform further comparison of the method by which previously the HCSFP and the method of *n*-th linear logical transformation was solved. Previously, while searching at the solution for the given states space the search depth was defined. Thus, before beginning the search the MAXSTEP parameter had to be installed, which presets the number of iterations. It was usually limited by 5 steps.

The MAXSTEP parameter also considers solutions search time by finding *n*-th LLT, and it also limits the number of iterations. But the difference is that if the solution satisfies a criterion of method work end before the MAXSTEP step, the program finishes the search.

Let us break the test in a few cases, if a solution is on the 1st, 2nd and *n*-th step.

1. Suppose that there is a set of numbers, which were called not often and not to different phone numbers from. Then the solution is found already on the 2nd step, but because it is not known in advance in how many steps it is found, it could take longer to solve.

According to statistics there are about 35% of such subscribers.

Using the method of *n*-th LLT in any case the solution is found in 2 iterations. According to the method that was previously used, the number of steps depended on set MAXSTEP.

2. By assuming that there is a set of numbers, where the solution is found in 3 steps.

According to statistics there are about 40% of such subscribers.

Using the method of *n*-th LLT in any case the solution is found in 3 iterations. According to the method that was previously used, the number of steps depended on set MAXSTEP. And if we set MAXSTEP = 1, the final solution will not be found at all. In other cases, increasing MAXSTEP, the time is lost on extra steps of the algorithm.

3. Suppose that there is a set of numbers, where the solution is found in n steps.

Using the method of *n*-th LLT in any case the solution is found in *n* steps. According to the method that was previously used, the number of steps depended on set MAXSTEP. In this case, if set parameter is too small, then the final solution will not be found, only an intermediate (in this way not all hypothetically connected objects will be found), and if the set parameter is too large, the search for a solution will take much time.

Thus, the method of *n*-th LLT allows finding the final solution. Using the MAXSTEP parameter, the number of steps is limited and a solution will be found faster in most cases (if the solution is found in 2-6 steps). Using the method previously used, the MAXSTEP parameter cannot be set small (2 or 3) because about 30% of phone numbers do not fit in this space, but if the parameter set more than 3, then for about 75 % of numbers redundant iteration will be made. The method of *n*-th LLT does not have these shortcomings.

Conclusions

Thus, the above listed results make possible the following important conclusion: using new algebraic and logical means of modeling of natural language constructions in the form of a system of equations based on the AFP-language and explicit way of specifying a finite alphabet operator which underlies method of solving these equations, ensures realization the property of reversibility of AFP-structures and a wide paralleling of symbolical information processing. Fundamental research of the algebraic and logical structure of an natural language as well as algebraic and logical means of its modeling in the form of AFP-structures of the first, second and the third sort permits to come close to the solution of the important scientific problem: attain qualitatively new technologies of symbolical information processing on the basis of the concept of unification and methods of synthesizing reversible spatial multivalued structures of language systems.

Suchwise, we have investigated implementation of *n*-th LLT degree finding method for HCSFP. This allowed to increase speed and accuracy of finding problem solutions by reducing the number of steps during information processing, due to the formulation of clear work completion criterion. However, the method allows to stay not bind to a specific subject domain structure, hence in further it makes sense to investigate the work of the method for arbitrary objects, for instance, for problems solving in logistics or some objects of reach transport nodes connecting problems.

In particular, in the works the accent on the concept of neuro-physiologic and neuro-cybernetic aspects of alive brain mechanisms is made. It is connected with the following natural neuron structures from nervous cells, i.e. neurons, essentially are highly effective recognizing systems and, for this reason, is of interest not only for doctors and physiologists, but also for the experts designing artificial intelligence systems. However direct transfer of research results of neuro-physiologists in engineering practice is now impossible because of a lack of an appropriate bioelectronic technology and an element basis, that has led to development and creation of a set of varieties of artificial neurons realized on the elements of the impulse technology.

As the corollary, non-adequacy of used principles of coding and element basis to simulated processes entails a redundancy, complication and non evidence of used mathematical and engineering means of transformations, loss of a micro level of parallelism in handling expected fast acting and flexibility of restructuring without essential modifications of architecture and connections.

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Решение проблемы обнаружения гипотетически связанных объектов на основе пространственных многозначных структур

В работе исследованы основные аспекты математического моделирования АКП-структур как универсальных функциональных преобразователей пространственного типа на основе декомпозиции многозначных структур, а также был рассмотрен подход к выполнению линейного логического метода обнаружения преобразования для того, чтобы решить гипотетически связанную проблему подписчиков в автоматизированной системе сложных вычислений телекоммуникационного предприятия.

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Розв'язання проблеми виявлення гіпотетично пов'язаних об'єктів на основі просторових багатозначних структур

У роботі досліджено основні аспекти математичного моделювання АСП-структур як універсальних функціональних перетворювачів просторового типу на основі декомпозиції багатозначних структур, а також був розглянутий підхід впровадження лінійного логічного методу виявлення перетворення, щоб вирішити гіпотетично зв'язану проблему передплатників в автоматизованій системі складних обчислень телекомунікаційного підприємства.

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