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Current Research and Development in Artificial Intelligence

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ABSTRACT

This study aimed at the modification of the paradigm of artificial intelligence pro-posed in the paper. The basis for this modification is the existence of algorithms that are inductive by construction but unlike the majority of similar algorithms they can be justified. In the framework of this paradigm one can determine the content of the majority of the existing notions (i.e. knowledge, representation and manipulation, knowledge bases,…etc). An example of a working system in the field of medical diagnostics is given. The system may be considered as a prototype of a knowledge base management system.

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INTRODUCTION

Let's consider the state of the art in Artificial Intelligence (AI). The key notion of AI is knowledge which is an object, a mean and an aim of modeling. However, there are still questions concerning the notion of knowledge, its processing and the evaluation of the results of the associated modeling. By way of example, this is apparent when analyzing the current state of expert systems that greatly depend on taking a particular conception of knowledge.

What are the reasons for such a situation? In our opinion, only the following reasons are of fundamental importance, firstly, the fact, knowledge is not specified on a formal level (unlike information and data). Knowledge should become an object of mathematical formalization. The second factor undeniably related to the first one, centers around the level of computer technologies. It is well known that any technology allows to build user-friendly systems when certain conditions are met. For example, solution of problems concerning information representation and manipulation, the provision of the necessary level of information independence (separation) from algorithms of its processing etc. As for knowledge, such conditions do not exist yet.

From the above, it is evident that we can assume the following conclusions. All the necessary notions exist, but they are either inaccurately defined or their systematization is not quite correct. Otherwise the state of AI theory may be thought of as satisfactory. Hence it follows that without modification of AI paradigm it is hardly probable to expect fundamental changes in solving problems of obtaining knowledge from data, knowledge manipulation, etc.

Brief Description of the Existing Paradigm:

Within the existing system of notions in AI. We can identify three levels of construction: theoretical, technological and an applied level. Each level has particular notions. Theoretical level: The starting point of all theoretical constructions is a definition of knowledge. The following conceptions of such definition may be thought of as the best known and logically complete:

- the first conception relates to informal aspects of the notion and is based on the reasoning that knowledge is interpreted data (Shakah,2012).
- the second conception is based on the choice of a certain way to represent the source of information. The most widely used are frames, semantic networks and "axiomatic" means (with the use of languages of propositional calculus, predicate calculus, modal logics, etc.) (Shakah *et al*.,2012 and Thaysa al et,2007).The main reasoning of the conception may be formulated in the following manner: knowledge is all that can be obtained on the basis of the above-mentioned representations with the help of relevant mechanisms of inference.

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- The third conception is the notion of knowledge representation. The choice of representation mechanisms logically follows from the choice of the conception of knowledge. For the first conception, by convention, use is made of representations in the form of formal grammars(Shakah *et al*,2012). Means peculiar to the second conception are practically all enumerated above.

Additionally, the notion of algorithms (mechanisms) of knowledge manipulation is defined. The purpose of manipulation is to solve one of the following interconnected problems: obtaining of new objects, knowledge or inclusion of certain objects, information of which is not given beforehand into a existing knowledge system. The particular realization of algorithms is determined by the choice of previous notions, and the purpose and specialization of the language used for formalization. The content of all algorithms realize a certain inference. As for the form they can be divided into two types: deductive and inductive. If it is considered that deduction is not only a property of an algorithm but a characteristic of objects (information) as well, then almost all algorithms may be called inductive. Hence it is natural to classify algorithms according to the language of formalization. From this point we can determine the following types of algorithms: resolution (most often parameterized) (Shakah *et al*., 2012, Thaysa *et al*, 2007, Krasnoproshin *et al*., 1996), inductive inference (Barwise, 1982), fuzzy inference (including probability algorithms (Shakah, 2012 and Barwis, 1982).

Technological level: The notions of this level (and of the applied level) are not quite settled. Hence we will give some explanations first. The technological level comprises a set of methods and software that are intended for the support of design, realization and functioning of systems based on knowledge. These methods and software require that the objects being processed satisfy certain specifications and the logic of their processing be standardized. If we now disengage ourselves from specifications and standards, then the basic notions of this level will be (Shakah,2012, Thayse *et al*.,2007):knowledge base; interpretation of objects; interface; and knowledge extraction.

The list of notions almost completely determine the meaning and content of the technology for working with knowledge. It can be enlarged taking into account the specialization of means. The means can be universal (all kinds of programming systems for AI), or specialized (expert systems, decision-making support systems, etc.). Here it is possible to single out the following notions:

- language for knowledge description;
- representation scheme;
- allowable operations on knowledge;
- explanation, etc.

The above list of notions are complete without additional comments, because their meaning greatly depends on the content of notions selected on the theoretical level. Besides, now it is more important to determine how these notions form a system.

Applied level. This level is formalized to a lesser extent. Nevertheless, the following notions can be mentioned:

- problem;
- qualitative and quantitative estimates characterizing solvability of a particular problem and the result of its solution.

In answer to the question, why these problems are assigned to the applied level? It is obvious that certain distinctions always exist between an applied problem and its formal model. A theoretical construction provides only the necessary prerequisites which allow to estimate the quality of problem solution. In reality such an estimate depends on many circumstances and can be obtained from an experiment. Although the way of conducting experiments and obtaining estimates is determined on the theoretical level.

Now let’s determine the essence of the existing AI paradigm. We will describe a way of constructing a system on the basis of the notions introduced above as thesis. The theses in a greater extent will have an applied nature. Any theory has sense if at least one problem can be solved with its help. Hence theoretical, technological or any other systematization is a direct consequence of an applied theory. A system should describe interaction and inter conditionality of notions.

Thesis 1. The prime notion is a problem that is formulated on the informal level. For each problem (in case it relates to AI) it is possible to choose the corresponding knowledge rep-resentation model. The choice of a particular way of representation depends on the aims of problem solution, the necessity to estimate the result and other circumstances.

Thesis 2. A certain set of manipulation algorithms is associated with each knowledge representation model. The choice of a particular algorithm is stipulated by a number of restrictions. The major restriction is an algorithm should not be reduced to a simple exhaustion under all allowable conditions imposed on the problem.

Thesis 3. The choice made at the previous stages stipulates a possibility of choice on the technological level. Realization and particular content of notions of this level greatly de-pend on the choice of programming environment or system.

Thesis 4. It is necessary to carry out an estimate of quality of problem solution. In the event that the estimate is unsatisfactory, a correction is possible.

It is obvious that notions themselves do not depend on applied problems. But their ability to form systems is completely determined by a possibility to solve all problems that can be related to the field of AI. In this sense any paradigm is a closed one (notions are more than enough), but it is incomplete. This results in drawbacks of the existing system. Let's enumerate the major ones:

1. Impossibility a priori to say something about the choice of the way of knowledge representation for the problem being solved. This choice is subjective and greatly depends on the man who solves the problem;
2. The necessity to use unjustified algorithms in the majority of problems. From the final volume of the defined knowledge justified inference on new objects can be obtained only in very special cases. The cases, when the body of the defined knowledge is infinite (may be built potentially), are very special in the sense of information. But, then there is a possibility to use justified algorithms;
3. Lack of technology such as used in databases. Hence design and construction of a particular system is basically intuitive rather than technological.

The list can be easily enlarged. But even the enumerated drawbacks are sufficient to say that the existing paradigm calls for a modification.

3. Brief Description of a Possible Modification:

Let's consider the essence of the proposed modification. To do this, we will discuss in more detail knowledge manipulation algorithms. There is a close interdependence between the notion of an algorithm and the notion of knowledge. But algorithms have a property that depends not only on constituents of the notion of knowledge, but on qualitative and quantitative characteristics of the problem as well. This property is called justification.

Notes. Let's explain what is meant by justification (Shakah *et al*.,2012).To do this, we consider one of "axiomatic" systems, that is based on the language of propositional calculus. Its essence is as follows: a language L is chosen with the help of which the system is built. The system consists of axioms A and inference rules R. For such a system, and only for it, it is shown that the system is in a unique fashion (within the accuracy of language L) characterized by the following properties:

* completeness (each object, written with the help of language L, should belong to a truth class, i.e. identically true, identically false or neutral);
* consistency (not a single object and its logic negation can simultaneously belong to the same truth class);
* closure (each object, written with the help of language L after applying R, is always entered in a truth class).

The result of the above-mentioned properties is the existence of a universal algorithm that guarantees entering of any object above language L in a truth class (may be by a countable number of steps). This algorithm is called resolution (let's denote it by R0 for brevity). Thus, the main point of justification of resolution R0 in relation to propositional calculus lies in the fact that the result is guaranteed.

Now let's assume that there is an algorithm R1 that has the following properties:

* it is inductive by construction (i.e. it works with a finite body of input information but allows to construct inference in relation to an infinite set);
* it is justified in a sense;
* it works with universal knowledge representation. In this case it is assumed that a universal representation can be obtained from any existing one without loss of information.

It is easy to see that in this case there is a possibility to avoid at least two draw-backs mentioned above (below we will show how it is possible to get rid of the remaining one). The point is that justification is always associated with properties of algorithm R1, i.e. completeness, consistency and closure. These properties in turn are a firm basis for further realization.

Now we may present the modified paradigm. Let's do it again with the help of theses.

Thesis 1. The prime notion is a problem that is formulated on the informal level. For each problem (in case it relates to AI) a way of transition to a universal knowledge representation model is chosen.

Thesis 2. The choice of an algorithm is absent. For knowledge manipulation use is made of algorithm R1.

Thesis 3. The interrelation of notions of the technological level is provided with the help of a system that can be called knowledge base management system (KBMS). The system contains means allowing to carry out design, realization and functioning of knowledge.

Thesis 4. It is necessary to carry out an estimate of quality of problem solution. In the event that the estimate is unsatisfactory, a correction is possible. In this case only correction of knowledge (information) makes sense.

Let's briefly describe the main notions necessary to formulate the modified paradigm. All missing details one can find in (Shakah *et al*.,2012 and Levesque *et al* ,2012).

Let's start with the justification scheme of algorithm R1. For this purpose we will introduce several classes of problems. Let's denote by X an arbitrary set of objects. Then:

* Z1 are problems in which information about X is given in the following manner. A certain finite subset X0 is known as well as rules R with the help of which the whole set X can be constructed from X0. Algorithm R0 is also known by means of which for any given object xÎ X it is possible to determine whether x can be deduced from X0 with the help of R, cannot be deduced or can be deduced by convention;
* Z2 are problems in which information about X is given like in Z1, but rules R are not known. To determine deducibility use is made of the same algorithm R0;
* Z3 are problems in which information about X is also given through a certain finite sub-set X0. But to determine deducibility use is made of algorithm R1 which differs from R0.

Now let's assume that R0 is justified for problem Z1. Besides, there is a formal representation of objects, any set X0 in all problems Z1 - Z3 can be reduced to this representation without restrictions essential for the solution. Then the proof of justification of algorithm R1 reduces to the proof of the following assertions.
Assertion 1 (local justification)

For any problem Z2 there is such statement Z3 that for any object xÎ X0 solutions in Z2 by algorithm R0 and solutions in the corresponding statement Z3 by algorithm R1 coincide, and for all remaining xÎ X are majorized from the point of view of the extent of belonging.
Assertion 2 (global justification)

For any problem Z1 there is such statement Z3 that for any object xÎ X solutions in Z1 by algorithm R0 and solutions in the corresponding statement Z3 by algorithm R1 coincide.

It is easy to see that algorithm R1 is as much justified as R0. Note that classes of problems Z1 - Z3 are not empty. For example, a well-known problem of propositional calculus belongs to Z1. Most of problems related to AI are formulated and solved in statement Z2. A well-known problem of pattern recognition can be assigned to class Z3. The description of algorithm R1 and its properties one can find in (Pyatnitsyn,2010).

Let's consider now the notion of knowledge (Gutnikov *et al.*,1998). Above we have described two conceptions of such definition. It is easy to enumerate their drawbacks. Hence we proceed from the fact that when constructing a different conception of knowledge it is necessary to try to avoid the above-mentioned drawbacks. In so doing, a new conception as a special case should contain at least the ones mentioned above.

The notion of knowledge can be defined on the basis of the following quite evident points:
* knowledge can be defined on two levels, i.e. informal and formal. The relation between the levels exists and is realized with the help of coding (from the informal level to the formal one) and interpretation (from the formal level to the informal one). As a result it is possible to determine a sequence (in terms of categories) for obtaining and processing knowledge;
* knowledge, as an object, is a part of the notion of information. On the informal level objects that are described by these notions coincide. On the formal level information falls into objects that are described by the notions of knowledge and data. These are different notions and they describe different objects. As a result of interpretation both sets of objects are represented as knowledge on the informal level;
* the difference between data and knowledge on the formal level can be described in terms of connections. In this sense data are defined as objects that are completely characterized by connections of one of the following types (or their combination): absence of connection, connections of order, connections of type (or multiplicity). In terms of allowable operations we can say that all these types of connections are described by relational algebra. Data are a set closed under operations of relational algebra. Knowledge, in its turn, is defined as objects that are characterized by connections of succession (inheritance) and deducibility. The language, in the framework of which it is possible to unite these two sets of objects, is the language of algebraic systems (Shakah *et al*.,2012,and Levesque *et al*.,2012).

It is easy to see that in this case the notion of knowledge representation should satisfy the following conditions:
* to provide support for algorithm R1 and operations used to describe the connection of succession;
* to allow without distortions to pass from representations existing on the formal level to the desired one;
* to have a possibility to describe connections typical for the notion of data.

In (Shakah *et al.*,2012,Gutnikov *et al*.,1998)one can find description of the representation that satisfy all the enumerated conditions. On the whole, if we leave out details, the representation is quite equivalent to the one used in object-oriented programming. Hence the representation is called an object representation.

One component of such universal representation is a set of elements characterized by the generality of structure and the way of construction in the following sense:
object: Π1 ´…´ Πn ® D1 ´…´ Dn
where Πi are signs, Di is a set of possible values of a sign (i=1,…, n). Another component is a certain characteristic of connection or relation between objects. On the formal level relation is a subset of Cartesian powers of the set {object}^{m}. Thus, any object can be identified with a pair <object, relation>, or in the general case with the Cartesian product {<object, relation>}^{m}. The formal sense also has the representation in terms of {<object, connection>}^{m}. As this takes place, all allowable connections, that appear in the definition of knowledge, can be described in terms of the following representations:

F : {<object, connection>} ^{m} → {<object, connection>}^{k} (m, k $\in$N)

Now let's describe briefly the construction of the corresponding notions for the technological level. The key notion here is a knowledge base that must satisfy the following conditions:
* to inherit properties of previous technologies (bases and data structures);
* to ensure support for the whole spectrum of connections mentioned above;
* to provide separation of knowledge (data) from means of manipulation;
* to ensure a design process that in case of knowledge can be based on consistency.

By adding interpretation support for knowledge (obtained on the formal level), interface and other features of developed systems to the system having the enumerated properties, we obtain a knowledge base management system (KBMS).

The realizability of technological problems and formal constructions described in the paper may be proved by an example of an actually existing system. The system is developed for solving a range of problems relating to medical diagnosis. The system is called "ORTHO-EXPERT" (OE) and at the moment it is under approbation. In the functional sense (OE) is oriented towards the complete information provision necessary for orthopedist's practice. It should be noted that the work carried out when solving this particular problem greatly stimulated the development of the conception of knowledge presented in the given paper. An extended description of OE system one can find in (Shakah,2012 and Bergmans *et al*.,1997).

4. Summary:

Let's discuss the essence of the proposed modification of AI paradigm. On the whole, everything is reduced to the use of justified inductive algorithms. Of course, this restricts the choice to some extent, but as a result we receive much more. First, we have a distinct definition of the notion of knowledge. Second, the result is guaranteed. Third, we have separation of knowledge from the means of its manipulation. The last two factors result in a possibility to have a technology for constructing systems based on knowledge.

The justification of algorithms exhibits not only theoretical meaning. In practice, the fact that the result is guaranteed leads to the following. Let's assume that we have managed to obtain an a priori estimate characterizing the relative body of the available knowledge. This, for example, can be the capacity of information or entropy (E. Shannon). Let's denote such estimate by a. It is evident that any quality estimate a' characterizing results of the algorithmic processing of new knowledge cannot be higher than a. The justification of the algorithm guarantees that a'=a. Of course, this does not take off pathological heuristic nature of practical problems that is the consequence of incompleteness of a priori knowledge.

The introduced paradigm somewhat changes the essence of problem solution as well. We can say that the aim of problem solution is not numbers but understanding. Such understanding should lead to the construction of a model justified according to all canons of mathematical rigor. The proposed paradigm is a model allowing to advance towards understanding.

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