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Knowledge in artificial intelligence systems: searching the strategies for application

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Abstract

The studies based on auto-epistemic logic are pointed out as an advanced direction for development of artificial intelligence (AI). Artificial intelligence is taken as a system that imitates the solution of complicated problems by human during the course of life. The structure of symbols and operations, by which intellectual solution is performed, as well as searching the strategic reference points for those solutions, which are caused by certain structures of symbols and operations, – are considered among the main issues in analysis of AI and its applications. Expert systems are interpreted as a kind of intelligent systems; different ways to represent knowledge (such as logical model, frame-based and production systems, semantic networks) are described within the framework of cognitive studies of AI. The presentation of knowledge is stated to be the methodology for modeling and formalization of conceptual knowledge in the field of engineering.

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Keywords: Artificial intelligence, knowledge, meta-knowledge, presentation of knowledge, knowledge processing, singularity.

1. Introduction

The first International Joint Conference on Computer Science was held in Washington in 1969, where the term "artificial intelligence" (AI) was introduced and got the right to live. Intellectual tradition of AI study begins in "Physics" by Aristotle, who saw the difference between matter and form: this difference is the philosophical basis of the ideas of symbolic calculus or data abstraction. "Logic" by Aristotle is close to the ideas of artificial intelligence, because he interpreted the state that the study of thought is the basis of knowledge. Aristotle was the first who turned to the laws of the "correct" thinking, i.e. the processes of forming hard evidence, developed a non-formalized system of syllogisms and used them in design of proof procedure. The ideas of Aristotle, "the master of those who know", were background for studying formal axiomatization of logical reasoning (Russel S., 2014).

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As for the practical application we can mention Raymond Lull, who in the 13th century developed the idea that useful reasoning conductivity by means of mechanical artifacts. He believed that it is possible by various combinations of known concepts to deduce new truths. Then Leonardo da Vinci in 1500 designed mechanical calculator, and about a century later world knew about the first computing machine constructed by Wilhelm Schickard, the arithmetical machine by Blaise Pascal and a mechanical device by Gottfried Wilhelm Leibniz, allowed to operate not numbers, but concepts. Mind began to be interpreted as a physical system.
Today, the field of artificial intelligence plays a key role in various fields of human life and is focused on creation a computer with human-like intelligence. Analysts believe that place of highly specialized artificial intelligence the universal AI system will come. However, to create an advanced intelligent system is necessary to answer several questions first, for example – the question of the role of knowledge in AI systems.

2. Subject and Methods

The answer to the above question is searched in this paper by studying the problems, the set of which constitute a subject field of the paper:

- specificity of knowledge used in expert systems;
- knowledge search and representation as the fundamental problems of AI development;
- ways of representing the knowledge – logical model, semantic networks, are the production and frame-based systems – and their specific features;
- knowledge representation as a methodology for modeling and formalizing the conceptual knowledge in the field of knowledge engineering;
- specificity of knowledge representation in frames, gnoseological potential of this form of representation;
- gnoseological nature of knowledge engineering.

The formulated subject of this study makes necessary to use advantages of such methods as theoretical generalization, empirical observation, as well as epistemological potential of system and integrated approaches. Abilities of logical method of study are also used.

3. Obtained results

Twenty years ago, American mathematician Vernor Vinge presented his report titled "The coming technological singularity: How to survive in the post-human era?" at VISION-21 Symposium carried out by NASA Lewis Research Center (now NASA Glenn Research Center) and the Ohio Aerospace Institute. The key concept in the report was technological singularity, the singular point (lat. *singularis* – separate, special). Prof. V. Vinge wrote about exponential changes in hitech field and about movement to the evolutionary asymptote – a point of singularity in which the indicators of progress will trend to infinity. He linked analysis of singularity symptoms to the ways of forming a superhuman intelligence, for instance – increase the biologic ability of human, human-computer systems and, finally, the very AI systems.
The problem field of philosophical knowledge generated the idea that the brain is like a machine and it uses encoded knowledge; the thought itself is used in selection of effective actions. Mathematics played a huge role in AI development. Mathematicians have created the tools to manipulate logically valid statements (in addition to manipulate probable and unreliable statements). Mathematicians laid also the base of the theory of algorithms.
Modern concepts of thinking and mind are based largely on the "Discourse on the Method" by Rene Descartes, where he tried to find a basis of reality, using the methods of cognitive introspection. This idea of dualism of mind and physical world is the basis of R. Descartes heritage, including discovery of analytic geometry. Studies by Descartes served as connecting link in developing for many centuries the intellectual tradition of research in AI field, because Descartes in his work formulated the state: interaction of *res cogitans* and *res extensa*, – the mind and the physical world – is a necessary condition of being; therefore, it is necessary to find a way to reunite them.
However, what is meaning of artificial intelligence, complex and highly promising technology of digital culture? There are different answers: a computer model of the brain (the concept of "artificial neurons"); a universal

logical machine; an expert system; evolving function of adaptive behavior on the basis of "artificial life". In this paper, we use the definition provided in the "Dictionary of Cybernetics": artificial intelligence is "an artificial system that simulates solution of problems by human during his life," i.e., we emphasize the "secondary" meaning of rules of functioning devices based on principles of "intelligent machines".

Development of AI resulted in understanding the importance so-called expert knowledge, which is specific to every particular subject area ("domain specific"). G.F. Luger in the book "Artificial Intelligence" (Luger G.F., 2004) interprets the expert knowledge as a combination of theoretical understanding of the problem and a set of heuristic rules to solve it – the rules, the effectiveness of which is evident in a particular domain. In this case, the expert knowledge is coded and takes the form applied by computer in solving such problems. Techniques of many modern expert systems used today in the field of design, research, education, business and medicine, have been developed in the framework of projects DENDRAL, MYCIN, PROSPECTOR, INTERNIST, XCON and proved their viability, denoting the development of expert systems as the dominant sphere of AI practical application. However, analysts warn of too much optimism in assessing the potential of expert systems technology. This is due to the limited knowledge available to the expert system, the difficulties in transfer of "deep" knowledge of particular domain, the lack of flexibility, and finally, to the inability to provide meaningful explanations and difficulties in testing expert systems, limitations in practical learning.

G.F. Luger in his book (Luger G.F., 2004) wrote about such feature of intellectual system as not just the subject knowledge, but also the knowledge that it knows the subject. In this case, knowledge is described in specific and generalized terms; intelligent system, describing the knowledge, is learning, interacting with the world. Analysts consider this "awareness of own knowledge" as meta-knowledge, which is the knowledge of higher level (the problem of specificity and formalization of meta-knowledge for the first time was studied in Bertrand Russell's theory of logical types).

Since 1980, the scope of artificial intelligence turned into an industry: DEC (Digital Equipment Corporation) had developed commercial expert system R1. In the 80 years large US corporations already had application-oriented research groups working in AI field. In 1981 Japan started the project to develop a computer of fifth-generation. The project was planned for 10 years and used the language Prolog. At the same time a new research consortium was founded in the United States focused on ensuring the competitiveness of the USA industry. The ideas of AI were used in this strategy applied to chip design and research in the field of human-machine interface. Although these ambitious objectives were not fully reached, it is in the 80s of the past century, the field of artificial intelligence have become a part of industry.

Today, the specialists in AI are interested in two of the most fundamental problems: knowledge representation and search. In the case of knowledge representation we are talking about knowledge acquisition, new in its essence, by referring to abilities of the formal language used in the process of computer manipulation. In the case of search we are taking about such a method to solve the problem, which allows to see problem states (following G.F. Luger (Luger G.F., 2004). As for the main issues of analysis of AI scope and its application fields, we can find among them – the structure of symbols and operations through which the intelligent solution of the problem is performed, and the search of strategic guidelines for those solutions which are caused by certain structures of symbols and operations. The very issues of knowledge representation and search are the basic package of research in the problem field of AI.

The processing of knowledge arrays is now the dominant paradigm of intelligent technologies. The systems usually called "intelligent" is the systems, the dominant basis of which is a knowledge base or domain model described in super-high level language, near to be natural (Luger G.F., 2004). Faced with the problems of high complexity (interpretation of natural language, assistance in difficult decisions making, interpretation of visual message), a man gets help of intelligent systems. These systems are necessary when using low-formalized expert knowledge, practical experience which is large enough, and sometimes priceless. Expert systems are a kind of intelligent systems. Expert systems are very effective in the fields, where huge experience of highly qualified

specialists is accumulated in many subject areas: in these areas difficult decisions making depends on the expertise; the subject areas themselves have got the status of "expert spheres".

Intelligent systems, and expert systems as their subset based on knowledge, are divided into expert systems that solve different classes of problems. Among the problems of analysis (in which a number of solutions can be listed and included in the system) – there are data interpretation, diagnostics, support of decision-making. Among the problems of synthesis (in which a number of solutions cannot be counted and a set of solutions is based on solutions of sub-problems) – there are design, planning and control. Within the range of problems solved by expert systems, we have to point out the combined problems such as learning, predicting and monitoring, on the basis of which the completeness prediction is possible, using a parametric dynamic model.

We would like to emphasize that the development of expert systems is associated with two kinds of difficulties: a) difficulties of knowledge acquisition and b) difficulties of knowledge structuring – that is being studied in the problem field of knowledge engineering as AI issues aiming at development of models, methods and systems for acquisition, structuring and formalizing the experts knowledge to design the knowledge bases. We agree with those analysts (A.P. Chastikov, T.A. Gavrilova and D.L. Belov) who believe that the knowledge engineering is gnoseologic twice due to its triple interpretation: 1) first reality is reflected in mind of an expert, 2) experience of the expert is interpreted by knowledge engineer; 3) we can talk about interpretation in the field of knowledge of the expert system itself (the field of knowledge is an informal description of domain concepts identified from the system of expert knowledge (Chastikov A.P., 2003)).

Getting by knowledge the status of the dominating resource of society, new forms of knowledge, the process of formation of which goes on in the knowledge society – all this naturally requires new forms of knowledge representation, as well as development of their various models. This is largely caused by the fact that in 70th years the development of expert systems is formed within AI subject area. The reason was the necessity of development of expert systems that could be applied in expert assessment. The importance and difficulty of the problem is largely determined by the knowledge structure, which, in turn, is determined by the scope of application of this knowledge. This structure consists of facts of the subject domain and links between these facts, rules of action; moreover, in this structure we have to take into account the knowledge, on which the method of including the knowledge in an expert system itself is based.

Today, the experts discuss the different ways of knowledge representation. They include logical model, frame-based production systems and semantic networks – the most typical model of knowledge representation, applied within cognitive studies of AI. Analysis of theoretical methods of knowledge representation is carried out within the logical studies: for example, a model of knowledge representation, was developed basing on first-order predicate logic. As for other methods of knowledge representation, they are based on mathematical formalization. Specific ways of knowledge representation are related to specific structure of knowledge. Note that today there are models of knowledge representation in which the above methods are integrated.

Knowledge representation systems have the following specific feature: these systems simulate human activity that is carried out in informal way. The same knowledge representation models are focused on the information that comes from the experts; this information is often controversial, but in the end the specifics of its application requires that this kind of information was presented in mono-semantic, formalized form. This can be achieved by turning to ideas of many-valued logic, theory of fuzzy sets and finally, due to use of analytic mathematical models.

Today, we can state that knowledge representation in its status is a methodology for modeling and formalization of conceptual knowledge in the field of knowledge engineering. Many analysts (for example Japanese researchers Haruki Ueno and Izidzuki Mitsuru) consider the history of research in the field of AI (excluding the early stages) as the history of research and interpretation of knowledge representation methods. Application of knowledge is described here as the technology for getting solution according to the form of knowledge representation. Knowledge base as an integral part of knowledge-based system includes not only a description of the knowledge, but also the mechanisms of conclusion, in which this knowledge is applied (Amemiya M., 1986).

One of the typical models of knowledge representation (within cognitive studies of AI) is a model based on frame theory. Frame is an abstract image to represent the stereotype of the object, concept or situation: generalized and simplified model or structure. What is the specificity of knowledge representation by frames? Researchers studied AI began to discuss the theory of frames and its epistemological potential in 1975. Exactly in this year Marvin Minsky (Minsky M., 1975) outlined the theory of frames, gave the concept of basic structure of knowledge representation by frames and control of conclusions, considered specifics of universal frame language. Frames have been interpreted as relatively large units of knowledge representation; their hierarchical structure was revealed, taking into account its degree of abstraction; their ability to present a combination of declarative and procedural knowledge were analyzed. Marvin Minsky in the 1975 work "A Framework for Representing Knowledge" interpreted the core of frame theory as follows: when a human falls into a new situation, radically changing his attitude to the current circumstances, he recalls the frame-structure. A frame is a unit of knowledge representation, filled in the past. However, it is possible to change its details, focusing on the ongoing situation. The frame is a network consisting of several tops and relations: fixed information about the true state of the object, as well as the terminal slots (terminals) to be filled with specific knowledge and data.

Marvin Minsky pointed that the frame theory should be attributed to the theory of goal setting. It is based on facts perception by comparing the received information to specific elements and values, as well as with the framework determined for each conceptual object in our memory. The structure representing this framework is the frame. Since there are analogies between conceptual objects, then a hierarchical structure with classificatory and generalizing properties arises. It shows hierarchical relationship of "abstract-concrete" form. Complex objects are a combination of several frames, it is a frame-based network. The frame itself is one of way to organize knowledge when developing expert systems

Today, we can stay that the most important problems related to the epistemological principles of organizing intelligence as a physical system, are such issues as the representation problem, the problem of the nature of interpretation (the character can only be understood in the context of interpretation), the problem of uncertainty of representations and finally, the problems associated the limitations of the method, the problem of symbol founding in neural networks. These and similar issues require careful attention to the further development of AI; they are important and remain still open. The invention of the digital computer indicated the birth of cognitive science, otherwise known as the science of intelligent systems.

Prerequisites for its generation were created by Aristotle, Descartes, Buhl, the creators of neural network models Turing, McCulloch, Pitts, and besides – J. Von Neumann, who proposed the concept of artificial life. Their research founded a science when computers appeared as an experimental basis. And the main question today is: whether the theory of intelligent systems to assist in the creation of AI?

In conclusion we give citation of Turing Award winners (1975) A. Newell and H.A Simon from their Turing lecture. They defined computer science as "an empirical discipline. We would have called it an experimental science, but like astronomy, economics, and geology, some of its unique forms of observation and experience do not fit a narrow stereotype of the experimental method. None the less, they are experiments. Each new machine that is built is an experiment. Actually constructing the machine poses a question to nature; and we listen for the answer by observing the machine in operation and analyzing it by all analytical and measurement means available, Each new program that is built is an experiment. It poses a question to nature, and its behavior offers clues to an answer. Neither machines nor programs arc black boxes: they are artifacts that have been designed, both hardware and software, and we can open them up and loot inside. We can relate their structure to their behavior and draw many lessons from a single experiment" (Newel A., 1976).

G.F. Luger believes that if to try to develop the study of AI to the level of science by integrating them as a part of the science of intelligent systems, then the process of design, use and analysis of artifacts will require the use of empirical and analytical methods. And here any programs of AI have to be treated as an experiment. G.F. Luger wrote that response of the nature to design and programming principles forms our understanding of formalism, regularities and the very essence of thinking (Luger G.F., 2004). The answer to the this question is in

the problem field of philosophy. Other philosophical questions associated with the idea of AI are: What is intelligence? Is it possible to formalize it and how to fit it into the context of the theory of intelligent systems? What is the role of artificial intelligence in the study of nature and the phenomenon of intelligence? What are the ethical sequences of development of intelligent machines? What is the cognitive architecture of the human brain? The studies based on the use of auto-epistemic logic are one of the promising ways to search for answers to the questions above (Luger G.F., 2004). These systems are able to form automatically the concepts for expert systems. This opens up for these systems the possibility of to carry out such a crucial cognitive operation, as a generalization – the central operation of the whole process of cognition.

4. Conclusions

Pointing out the development of expert systems as an important application field of AI, the authors worn against too much optimism in assessing the potential of expert systems technology, due to the limited knowledge available to the expert system, the difficulties in transfer of "deep knowledge" and a lack of flexibility, as well as due to inability to provide meaningful explanations, difficulties in testing of expert systems and limitations in practical learning. We emphasize the difficulties associated with development of expert systems: difficulty of acquisition structuring and formalization of knowledge. This issue is studied in knowledge engineering, the purpose of which is to develop models, methods and systems for obtaining, structuring and formalization of knowledge of professionals aiming at design of knowledge bases. We agree with those analysts who believe that the knowledge engineering is gnoseologic twice due to its triple interpretation: 1) first reality is reflected in mind of an expert, 2) experience of the expert is interpreted by knowledge engineer; 3) we can talk about interpretation in the field of knowledge of the expert system itself (the field of knowledge is an informal description of domain concepts identified from the system of expert knowledge.

In this paper we also investigated the specifics of methods and models for knowledge representation. We consider logical model and frame-based production systems, semantic networks as the most typical models within cognitive field. Analysis of theoretical methods of knowledge representation is carried out within the logical studies: for example, a model of knowledge representation, was developed basing on first-order predicate logic. As for other methods of knowledge representation, they are based on mathematical formalization.

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