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BUILDING AN EFFECTIVE KNOWLEDGE MANAGEMENT SYSTEM IN THE CONCEPT OF ARTIFICIAL INTELLIGENCE SYSTEM ORGANIZATION

CONSTRUINDO UM SISTEMA EFICAZ DE GESTÃO DO CONHECIMENTO NO CONCEITO DE ORGANIZAÇÃO DE SISTEMAS DE INTELIGÊNCIA ARTIFICIAL

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ABSTRACT

Objective: The study aims to analyze the design and operation of database and knowledge base machines within the concept of artificial intelligence system organization, focusing on creating AI systems to model solutions described by mathematical operations over natural language at logical and hardware levels.

Method: The research utilized a qualitative approach, reviewing scholarly articles from scientific journals to explore the organization of AI systems, particularly through the use of finite predicates and universal functional transformers.

Results: The study identifies that the key challenge in building a management system at the semantic or semantic-pragmatic level lies in constructing information databases (data and knowledge) related to the subject industry and developing output mechanisms for deriving necessary decisions. The mathematical structure of data in declarative languages is grounded in systems of predicate equations.

Conclusion: The paper concludes that building effective AI-based knowledge management systems involves integrating complex data and knowledge structures at

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semantic levels to enhance decision-making processes, highlighting the need for advanced computational architectures to handle the semantic complexity of data.

Keywords: knowledge, data; Knowledge base; Artificial intelligence; Finite predicate; Universal functional transformer; Declarative language.

Objetivo: O estudo visa analisar o design e operação de máquinas de base de dados e de conhecimento dentro do conceito de organização de sistemas de inteligência artificial, focando na criação de sistemas de IA para modelar soluções descritas por operações matemáticas sobre linguagem natural em níveis lógico e de hardware.

Método: A pesquisa utilizou uma abordagem qualitativa, revisando artigos acadêmicos de periódicos científicos para explorar a organização de sistemas de IA, particularmente através do uso de predicados finitos e transformadores funcionais universais.

Resultados: O estudo identifica que o principal desafio na construção de um sistema de gestão nos níveis semântico ou semântico-pragmático reside na construção de bases de dados de informação (dados e conhecimento) relacionadas à indústria do assunto e no desenvolvimento de mecanismos de saída para derivar decisões necessárias. A estrutura matemática dos dados em linguagens declarativas é baseada em sistemas de equações de predicados.

Conclusão: O artigo conclui que construir sistemas eficazes de gestão do conhecimento baseados em IA envolve integrar estruturas complexas de dados e conhecimento em níveis semânticos para aprimorar os processos de tomada de decisão, destacando a necessidade de arquiteturas computacionais avançadas para lidar com a complexidade semântica dos dados.

Palavras-chave: Conhecimento; Dados; Base de conhecimento; Inteligência artificial; Predicado finito; Transformador funcional universal; Linguagem declarativa.

INTRODUCTION

The 20th century was marked by a material-energy and socio-economic crisis of social production, a way out of which was the transition of the economically developed countries from material-energy production and consumption technologies to intelligent-information technologies, whereby material and energy resources are saved by switching from information processing to knowledge processing (Eremeeva et al., 2024). The fastest supercomputers run much slower than they need to deal with the data and knowledge presented by language models describing descriptive sciences. The resolution of this problem depends on the development of appropriate computer systems capable of running 1,000 times faster than the existing major supercomputers (Abdikeev & Kiselev, 2011). The notion of new information

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technologies implies the ability to use modern means and methods of obtaining, processing, and systematizing knowledge (Abdullaev et al., 2023).

There has been a clear positive trend of researchers gradually realizing that the Von Neumann architecture computer, essentially a finite-state machine, cannot serve as a tool to create intelligence systems or control, for it is a context-independent system (Zhdanov, 2012). This fact gave rise to a new direction, which argues that with the transition to higher hierarchical levels, system intelligence increases as its precision drops, and vice versa. These systems are designed to work with uncertain information (that cannot be precisely described mathematically) on the properties and characteristics of system-complex objects and the environment of their operation (Abdullaev et al., 2023; Babkin et al., 2006).

In the context of real systems working with highly uncertain information to build intelligent systems, using new information technology focused on context-dependent information flows, i.e., the highest levels of system complexity, is inevitable (Liu et al., 2023; Telnov et al., 2024). Therefore, to rightfully employ a finite-state machine (computer) as part of an intelligent system, it is necessary to consider the possibility of building abstract constructs to realize objects that are non-computable in the conventional sense.

LITERATURE REVIEW

The difficulty of the concept of knowledge, which is always expressed in a language of relationships, lies in the multitude of opportunities for its realization and inseparability with the concept of data, with the continuous process of its change, which enables context connections between data (Vorobev, 2016).

The areas of subject industries where it is most appropriate to work with the data and knowledge presented by language models are those dominated by empirical knowledge, where the complexity of facts and their descriptions excludes the use of mathematical language — the so-called descriptive sciences (Gataullin et al., 2015). This approach allows for the most accuracy in describing the given system, especially when the formal-logical properties of the linguistic apparatus are changed under the influence of input information flows (Osipov, 2015; Sultonova et al., 2023).

The totality of knowledge, i.e., data, in control problems is represented by a certain semiotic system that usually comprises three aspects: syntactic, semantic, and pragmatic. Based on these three aspects of semiotic systems, we need to identify three

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types of knowledge as three types of relationships between data: syntactic, semantic, and pragmatic (Gavrilova et al., 2016).

Syntactic knowledge characterizes the syntactic structure of the information flow that does not depend on the meaning and content of the concepts used, i.e., does not form an intelligent system (Gavrilova & Khoroshevskii, 2000). Semantic knowledge is a structure that shapes the current context. It contains information that directly concerns the current meaning and general point of the described concepts and defines the state of data connections in the information base (Grakova et al., 2016). Pragmatic knowledge determines the most likely relationships that describe the data in terms of the problem to be solved (generalized or objective context), for example, considering the specific criteria and agreements in force with respect to the task (Shunkevich, 2017). The concept of objectivity corresponds to the interpretation of pragmatism, the pragmatic aspect of the creation of the intellectual system as a purposeful limitation of its free will, the limitation of unnecessary connections for a system that we do not expect to be that intelligent (Vorobev & Dmitrenko, 2015).

From an engineering point of view, the syntactic, semantic, and pragmatic sides of knowledge are different relationships of one or several terms (data) with other records in the information base (Polichka & Vostrikova, 2016).

The most general challenge in creating semantic or semantic-pragmatic interaction control systems relates to the choice of context-dependent data presentation technologies, the construction of information (data and knowledge) bases on the subject area, and the output mechanism to obtain the necessary solutions (Golenkov et al., 2017). Speech is structured through the formation of a basic set of relations (within 200): temporal, spatial, causal, quantifying (binary, ternary), etc. (Luneva, 2007).

The description (representation) of knowledge in artificial intelligence systems is the most convenient with declarative languages of the type described by T.A. Cherniak et al. (2015). The processing of these languages can be divided into two parts: 1. what is declared by the person; 2. what is processed by the computer.

Human preprocessing consists in abstracting a real problem into a physical or mathematical model (Abdullayev et al., 2024). Later, the mathematical model is transformed into a machine-oriented map that is perceived by the computer. Only using semantic processing is it possible to create an appropriate program for the transformation of reporting forms. The computer here only provides support for the

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processing carried out by the human person (Kiseleva et al., 2023; Vasilev & Chernov, 2008).

The foundation of such a machine language consists of basic concepts; semantics (based on the corresponding syntax); procedural images describing semantic units; and corresponding rules for structuring concepts (syntactic rules). Processing mechanisms (their work) are determined by language semantics and syntax (Briukhov et al., 2015).

Procedural languages are description languages based on procedure semantics. The operational mechanisms of these languages correspond to information processing and transformation functions, while the structural elements of the language have nothing in common with real-world objects. Procedural semantics are considered and described in computation theory, allowing one to obtain a full theoretical description of the system of knowledge processing in AI (Briukhov et al., 2015).

A declarative language relies on its corresponding data structure, which includes components defined by the computer's memory structure. In declarative languages, the syntax-semantics ratio is similar to that of natural language — drawings, graphs, spatial images, databases, etc. Databases are abstract models of a limited area of application (branch of knowledge) distinguished into 1) engineering databases; 2) hierarchical; 3) network; 4) relational; and 5) post-relational (Gavrilova et al., 2016).

The models of declarative languages are represented through predicates, drawings, figures, graphs, etc. The mathematical structure of data in declarative languages is based on systems of predicate equations in axiomatic set theory, in which set theory is interpreted as the structure of data (Shunkevich, 2017).

Each attribute of the AI system can itself be a universal functional transformer (UFT), albeit at a different hierarchical level. This suggests that the UFT is a recursive system that has its own language and begins to live and act, realizing its properties, once the programming process is complete, and the computer starts to operate following a specific control debugging algorithm. The UFT can only transform (transition) into a basic AI unit with the computer running (Vorobev & Dmitrenko, 2015).

The initial UFT reactions are full of content and are therefore called the UFT's own representations of controlling influence. However, since the sources of external disturbances to the UFT can be any objects and data, its representations are new information, and the UFT itself is the source of this information (Vorobev & Dmitrenko,

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2015). It can be concluded that the UFT process needs to be managed to optimize its performance.

This work aims to analyze the design and operation of database machines (DBM) and knowledge base machines (KBM) in the framework of AI system organization.

METHODS

In accordance with the specifics of research and design of DBM and KBM in the framework of AI system organization, this study employed a qualitative approach to research.

In the first phase of the study, the sources of information needed to realize the study objective were selected. Data for the study were collected from monographs and articles published in journals indexed by Scopus and Web of Science. A detailed study and generalization of theoretical achievements on the problem of AI systems organization allowed us to conclude that the creation of AI systems is possible by analyzing, modeling, and synthesizing an intelligent speech interface with the help of finite predicates, whose mathematical apparatus is presented in existing research (Bondarenko & Shabanov-Kushnarenko, 2011; Igoshin, 2008; Khairovaet al., 2014; Mamedov & Shabanov-Kushnarenko, 2014), and the corresponding structures and coding methods.

Now, let us introduce the concept of a finite predicate (FP). Let A be a finite alphabet consisting of k letters a1, a2,…, ak, and Σ – a set of two elements denoted by the symbols 0 and 1 and referred to as falsehood and truth, respectively. The variable in set A will be called an alphabetic variable and the variable given in the set Σ — logical. A finite n-place predicate over alphabet A is any function f(x1, x2,…, xn)=t of n alphabetic arguments x1, x2,…, xn, belonging to set A and having logical values t. In principle, each finite predicate f can be specified with a table of its values. In this table, each set of argument values (x1, x2,..., xn) corresponds to the value t of the predicate f.

In the second stage, hardware support for the possibilities of the predicate approach was provided with a KBM oriented on the practical task of perceiving the semantics of information as management with consideration of all the necessary conditions of context analysis and the restructurization of connections in work with knowledge.

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RESULTS

Our proposed hardware support for the possibilities of the predicate approach is a mechanism focused on the practical task of perceiving the semantics of information as management considering the necessary conditions of context analysis and the restructuring of connections in work with knowledge. This mechanism of control over system-complex objects in the theory of intelligent control systems can be provided by KBM, not to be confused with the long-standing DBM.

DBM has been around for a long time and has been considered the basis of the fifth generation of computing systems. The reason for this was the fact that the von Neumann structure does not conform to DBM requirements. The implementation of search, update, data protection, and transaction processing only by software is inefficient in performance and cost. DBM was initially focused on relational data models, which is unacceptable because relational and post-relational bases are not designed to provide a continuous process of relationship restructuring. Accordingly, these machines were not and cannot be tasked with context-dependent languages.

That being noted, let us consider some possibilities offered by KBM.

The conclusion reached in our analysis of the knowledge base realization problem entails a principal opportunity, albeit not an implementation procedure, of work with context-dependent descriptions, even though reduced to the variant of computing predicates with context-variable relationships.

For this, however, we need to have a flexible enough structure that would allow for effective restructurization, which enables behavior (decision-making) that does not boil down to a finite model.

Therefore, let us consider the following KBM architecture (Figure 1). The machine consists of the required number n of individual modules, each of which, after the conversion of the input text parcel into the language of predicates, is fed a triple of type $(ABC)_i$, $i \in 1...n$ for subsequent direct disclosure following relevant laws.

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ABC:	Transformation rules	ABC_{11}	ABC_{12}	ABC_{13}	ABC_{14}	ABC_{15}	$ABCi_{6}$	...ABC_{17}...
ABC_2		ABC_{21}	ABC_{22}	ABC_{23}	ABC_{24}	ABC_{25}	ABC_{26}	
ABC_3		ABC_{31}	ABC_{32}	ABC_{33}	ABC_{34}	ABC_{35}	ABC_{36}	ABC_{37}
ABC_4		ABC_{41}	ABC_{42}	ABC_{43}	ABC_{44}			
ABC_5		ABC_{51}	ABC_{52}	ABC_{53}	ABC_{54}	ABC_{55}	ABC_{56}	ABC_{57}
…		…						
ABC_n		ABC_{n1}	ABC_{n2}	ABC_{n3}	ABC_{n4}	ABC_{n5}	…	

Figure 1. The architecture of knowledge base machines
Source: based on predicate calculus language

Since the number of transformation laws is not that large, an effective path here is to use a dynamically formed matrix of the form presented in Figure 1. The rows of this matrix not only correspond to the order of transformation of the input predicates but make a table of all the formal logical relationships used in the current information package. By each next operation of accepting input information, the machine switches to a state of readiness to accept input signals through individual input channels, with another matrix being formed in the process of information input.

The starting message of each module is a set of predicates extending the input text of the form $(ABC)_{il}$, $i \in 1...n$, $l \in 1...k$, containing all possible logical transformations of the initial predicate. Due to the fact that this process is greatly parallel in nature, it is possible to organize each module in the form of a parallel machine. Such a module is not only a finite automaton but also a neuron with multiple inputs and multiple outputs corresponding to the number of new predicates received from the input package.

It is useful to consider several inputs to draw second-order conclusions arising from the combined assessment of several constituent predicates. The modules get full versatility and, as soon as they finish their work at the first level of transformation, can be used at the second, and if necessary, at the subsequent levels.

DISCUSSION

In KBM the input information is a control and a command for organizing actions for its processing. This is natural enough because we are dealing with an input language of the context-dependent level. If we wish to speak in the terminology of algorithms here, we can say that the algorithm of operation is explicitly specified in the processed context-dependent entry.

However, input information can significantly change the structure of the finite automaton and require all the actions shown to be necessary when considering the

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stability problem (Babkin et al., 2006). Nevertheless, it is possible to introduce a logical termination criterion (for example, by the depth of predicate transformation) and therefore the record processing procedure would be ended. The KBM is a parallel machine with all the useful features for processing data and the links between them.

The KBM externally represented by a finite automaton changes its structure under the influence of the input information flow at each specific moment in time, thus realizing the case of modeling non-recursive objects in the frequency sense under the condition of irreducibility to a finite model, but complete modelability in the frequency sense (Osipov, 2015).

This rather simple thesis encompasses a range of fundamental propositions. It is an implicitly stated position on the existence of engineering or mechanistic intelligence, some pseudo-intelligence capable not only of learning, but also of learning to learn. This is what we wish for today in setting the task of creating a KBM, and the other properties of intelligence, for example, free will, are considered superfluous for such a system.

It is somehow uncomfortable to find oneself dependent on some machine that makes our lives easier, but in exchange for this forces us to recognize that it has its own interpretation of the data it has received, its own understanding of the subject (Burkaltseva et al., 2023; Nikolaeva et al., 2024). By creating the KBM, we want to create something capable of understanding, but we want to save ourselves from the need for mutual understanding a priori.

Next, let us consider the purely engineering aspects of this approach and explicitly formulate what we want from an engineering intelligence and its components. First and foremost, we should highlight the implicit formulations of strong requirements, essentially defining the very possibility of setting the task of creating the KBM.

The formulation of control from data flow suggests that the data flow includes structures, the discovery and proper use of which will give the KBM the ability to self-structure and self-organize.

That is, there is a fundamental difference between the phenomenon of data flow and the flow in the classical understanding of flow systems. In the latter, the flow is assumed by default to be some structureless entity, while structures arise from the interaction of the flow with boundaries, with interfaces between different environments. For example, flow in heat conduction problems is something that is a priori, by definition

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structureless, whereas data flow, on the contrary, implies the presence of some hidden structures, although unknown a priori, which should be identified and utilized.

We also must not overlook the stark arbitrariness of the term "self-structuring", increasingly used in works related to the design of information bases (Shunkevich, 2017), that is, ultimately, to KBM. The question reasonably arises: self-structuring to what model or structure? Some researchers dare to recognize the objectivity of the existence of some natural structure of the problem area, but this is still no more than a desire to find such a structure. However, this wish is far from groundless.

For example, mass chemical formulas partially objectively reflect the properties of chemical compounds, structural formulas are adequate to the topology (but not the geometry) of the arrangement of atoms in molecules, the structure of Newton's mechanics is partially adequate to the entire structure of modern physics, etc. There are sufficient grounds to envisage the existence of general laws of interaction between structures, covering not only physical (energy) but also informational phenomena and the essence that should exist in the Universe.

Finally, there remains a group of problems that can be labeled as the task of finding and designing adequate data models and implementing these models in some physical KBM structures.

Let us try to formulate the requirements for the data model and its implementation as an engineering model in a concrete form, but at the same time without reducing the level of generalization so as not to wipe out the essence of the problem. For this purpose, it is enough to sequentially go through all the requirements both to the generalized data model itself and to the realizability of this model in some physical structures, i.e., the requirements to the possibility of reflecting some abstract KBM structure onto the physical implementation, the architecture of a particular physical machine.

We are interested in cases that are finite modelled, but with an a priori innumerable number of steps, since the condition of existence of the corresponding predicate transformer is written as a set of postulates. In the sense of practical implementation, this automatically means that the abstract data model can be represented in a general way as a virtual structure that is not associated with the physical (numerical) implementation parameters in its organization. Moreover, the whole KBM structure can only be virtual.

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Nevertheless, implementing any application task will still require reflection in the physical address space. Hence the requirement: the structure of the data itself, that is, the methods (possibly one but universal method) of addressing must be invariant to the displayed abstract data model. Given physical realization, this means that the cost of implementing the addressing method should almost always (except for the zero-degree set cases) not rise faster than the amount of data. The loss of addressing efficiency is the only so far known cause of self-destruction of information systems. It is cheaper to build a new system than to maintain an inefficient mechanism. This aspect is equated with the problem of cleaning up — identifying and destroying inefficient structures. However, this is not the same, as inefficient structures should appear in any system of this kind if we accept their right to make mistakes.

Another aspect that should be highlighted is not so much as an explicit requirement, but rather a clue for further analysis of the problem. The conditions of frequency-based realization of the predicate transformer, i.e., a KBM that can do more than a traditional DBM, come in the form of lists of second-order predicates, but, importantly, not from an overall perspective but in each finished time frame.

Figure 1 represents only the state of the KBM on some elementary beat of its existence while representing it in a finished time period will require a hierarchy of at least three levels of predicate tables. That is, apart from Figure 1, two more levels of "conditions of use" are needed.

A KBM generally presents a coherent hierarchical system of dynamic processes. The conclusion following from this is that these systems preclude the use of mechanical decomposition, at least with respect to their application in accordance with classical control theory. It is crucial to find a representation that covers the totality of nested dynamic processes.

Let us wrap up the discussion of the feasibility of KBM with the following. For purely computational reasons, address architectures, that is, von Neumannian machines, are probably going to dominate the market for several decades. This means that the issue of representing the KBM structure as an address architecture will remain relevant. Given the non-triviality of the problem, its research will be a separate engineering task. As long as address machines exist, data model development will be a problem that complements the task of finding adequate KBM structures.

For a long time, the agenda in the development of computer architectures has been a focus on KBM. In this regard, let us highlight the following. Today's self-

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developing real information systems (technologies, data models) are referred to as such most likely in anticipation of their future improvement. As of now, self-development ability is nowhere near in sight and the title merely reflects the sufficient flexibility of data models and the availability of tools to manage the development of these models. This sets the task of achieving self-development and creating the next generation of machine architectures.

In setting the goal of creating a machine with the next-generation architecture, we are seeking more, i.e., the ability of a machine to build data structures and its own structure truly independently. We are striving for a transition to living systems, possessing if not free will, then at least survival instinct.

CONCLUSIONS

The areas of subject industries where it is most appropriate to work with the data and knowledge presented by language models are those dominated by empirical knowledge, where the complexity of facts and their descriptions excludes the use of mathematical language and intelligent information technologies. The most common problem in building a control system at the semantic or semantic-pragmatic level of interaction relates to information bases (data and knowledge) on the subject industry and output mechanisms to obtain the necessary solutions. The mathematical structure of data in declarative languages is based on predicate equation systems.

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