https://orcid.org/0000-0003-3478-8417
https://orcid.org/0000-0002-5523-6120

UDC 004.82, 004.89, 004.853, 004.855, 005

I.A. ZHYRIAKOVA*, S.V. HOLUB**

A NEW APPROACH TO THE FORMAL EXPLICIT SPECIFICATION OF KNOWLEDGE ACQUISITION

*Bohdan Khmelnytsky National University of Cherkasy, Cherkasy, Ukraine
**Cherkasy State Technological University, Cherkasy, Ukraine

Анотація. *Процес прийняття рішень у багатьох предметних областях – задача досить нетривіальна. Залучення «розумних систем» для підтримки процесів прийняття рішень вимагає нових підходів до здобування та зберігання знань. Описується нова концепція побудови баз модельних знань. В основі концепції твердження про те, що знання відображаються у формі ієрархічного поєднання багатопараметричних моделей. Передбачаються комплексний аналіз існуючих підходів до роботи зі знаннями та вибір моделі їх подання. Відповідно до запропонованої авторами методології створення баз модельних знань описано новий метод онтологічного моделювання. Даний метод ґрунтується на принципово нових підходах до формування моделі подання знань, до побудови архітектури баз модельних знань та інтелектуальної системи в цілому. Це дозволяє значно розширити функціональні можливості інтелектуальних систем, зокрема, моніторингових інтелектуальних систем, автоматизувати процеси синтезу моделей та глобальних функціональних залежностей, знизити впливовість суб'єктивних оцінок дослідника на результати перетворення даних. Описані результати досліджень засобів онтологічного моделювання, що використовуються для формалізації та систематизації елементів глобальних функціональних залежностей, які поєднують моделі об'єктів спостережень. Ці моделі є розв'язками локальних задач перетворення інформації в окремих предметних областях. У залежності від призначення інтелектуальної системи реалізується поєднання глобальних функціональних залежностей на вищому рівні і таким чином відбувається формування структури бази модельних знань. Використання стратегії координації елементів, яка застосовується моніторинговою інтелектуальною системою, дозволяє сформувати синергетичні зв'язки між окремими локальними моделями у структурі глобальної функціональної залежності та між глобальними функціональними залежностями на вищому рівні бази модельних знань.*

Ключові слова: *інтелектуальні системи, база знань, моделі подання знань, моніторинг.*

Аннотация. *Процесс принятия решений во многих предметных областях – задача достаточно нетривиальная. Привлечение «умных систем» для поддержки процессов принятия решений требует новых подходов к получению и хранению знаний. Описывается новая концепция построения баз модельных знаний. В основе концепции утверждение о том, что знания отражаются в форме иерархического сочетания многопараметрических моделей. Предполагаются комплексный анализ существующих подходов к работе со знаниями и выбор модели их представления. Согласно предложенной авторами методологии создания баз модельных знаний описан новый метод онтологического моделирования. Данный метод основывается на принципиально новых подходах к формированию модели представления знаний, к построению архитектуры баз модельных знаний и интеллектуальной системы в целом. Это позволяет значительно расширить функциональные возможности интеллектуальных систем, в частности, мониторинговых интеллектуальных систем, автоматизировать процессы синтеза моделей и глобальных функциональных зависимостей, снизить влияние субъективных оценок исследователя на результаты преобразования данных. Описаны результаты исследований средств онтологического моделирования, используемые для формализации и систематизации элементов глобальных функциональных зависимостей, которые сочетают модели объектов наблюдений. Эти модели являются решениями локальных задач преобразования информации в отдельных предметных областях. В зависимости от назначения интеллектуальной системы реализуется сочетание глобальных функциональных зависимостей на высшем уровне и таким образом происходит формирование структуры базы модельных знаний. Использование стратегии координации элементов, которая применяется мониторинговой интеллектуальной системой, позволяет сформировать синергетические связи между отдельными локальными*

моделями в структуре глобальной функциональной зависимости и между глобальными функциональными зависимостями на высшем уровне базы модельных знаний.
Ключевые слова: *интеллектуальные системы, база знаний, модели представления знаний, мониторинг.*

Abstract. *The decision-making process in many subject areas is a rather nontrivial problem. The use of "smart systems" to support decision-making processes requires new approaches to knowledge acquisition and storage. A new concept of building models of model knowledge is described. At the heart of the concept is the assertion that knowledge is displayed in the form of a hierarchical combination of multiparametric models. A comprehensive analysis of existing approaches to knowledge work and the choice of their presentation model is envisaged. In accordance with the methodology proposed by the authors for the creation of models of model knowledge, a new method of ontological modeling is described. This method is based on fundamentally new approaches to the formation of a model of presentation of knowledge, to the construction of the architecture of the bases of model knowledge and the intellectual system as a whole. This allows to expand significantly the functionality of intelligent systems, including monitoring intelligent systems, automate the processes of synthesis of models and global functional dependencies, reduce the influence of the subjective judgments of the researcher on the results of data conversion. The results of investigations of ontological modeling methods used for formalization and systematization of elements of global functional dependences, which combine models of objects of observation, are described. These models are solutions to local problems of information transformation in selected subject areas. Depending on the purpose of the intellectual system, a combination of global functional dependencies is realized at the highest level, and thus the formation of the structure of the base model knowledge. Using the strategy of coordination of elements, which is used by the monitoring intellectual system, allows to form synergies between individual local models in the structure of global functional dependence and between the global functional dependencies at the highest level of the model knowledge base.*
Keywords: *intellectual systems, knowledge base, knowledge representation models, monitoring.*

DOI: 10.34121/1028-9763-2019-4-139-145

1. Introduction

Computer scientists have adopted the technical term «ontology» from philosophy and use it as an analogy or metaphor for the formal definition of concepts and their relationships as a basis for a knowledge representation. This is useful for knowledge-based applications. The most common definition of term «ontology» is the definition of T.R. Gruber [1], according to which «ontology is a formal explicit specification of a shared conceptualization». From this point of view, every specification should be built based on some conceptualization for each of the knowledge bases, or knowledge-based systems for the automation of decision-making. Therefore, the actual practical task which solution is proposed in this paper is development a new approach to the formal explicit specification of knowledge acquisition. This approach involves other principles of knowledge saving for inductive modeling that will simplify the procedure of new knowledge acquisition. New approach is based on the main items of the hierarchical multilevel system theory and on the method for complex systems multilevel modeling.

2. Technology of multilevel intellectual monitoring

The term «intelligence» covers many cognitive skills, including the ability to solve problems, learn, understand language, and knowledge working. Therefore in the knowledge engineering, as a branch of artificial intelligence, the interrelated terms those ties together are "knowledge management" and "knowledge modeling" stands out. Knowledge management and knowledge modeling are processes that unfold through several steps and include subprocesses that define them. Such subprocesses usually include: knowledge presentation, knowledge mining and knowledge using. Working with knowledge also requires the implementation of techniques and tools that would promoteclarity of interpretation of them. Also, any of these subprocesses is based on the models of knowledge presentation as a part of the intellectual system knowledge base.

Knowledge is a very specific resource, it is difficult to identify, it is measured poorly both qualitatively and quantitatively and it is difficult to formalize. In addition, knowledge of any subject area can only be formed on the basis of consolidation and the subsequent comprehensive analysis of large data arrays, which becomes possible only by knowledge-oriented models creation, which defined by Newell [2] as a main tool for supporting the intellectualization of decision making systems.

The main disadvantage of existing knowledge models, which applied in the programs that achieve expert-level competence in solving problems in task areas by bringing to bear a body of knowledge about specific tasks, such as expert systems first [3], or later the question answering dialogue systems [4], or, for example, natural language dialogue systems [5] and computer-assisted and control problem solving systems [6] is to don't support the relevance of the knowledge base in accordance with new tasks. Therefore, the creation of a KBM based on a combination of several global functional dependencies, which solves its monitoring tasks in a specific subject area, create a single informative intelligent environment that can comprehensively describe any objects and predict the current of objects states. The KMB created in this way will could correct the deficiencies between existing knowledge-oriented models and simplify the way of maintaining knowledge updating by subject area which will contribute to multilevel modeling for automation of decision-making in the conduct of intellectual monitoring.

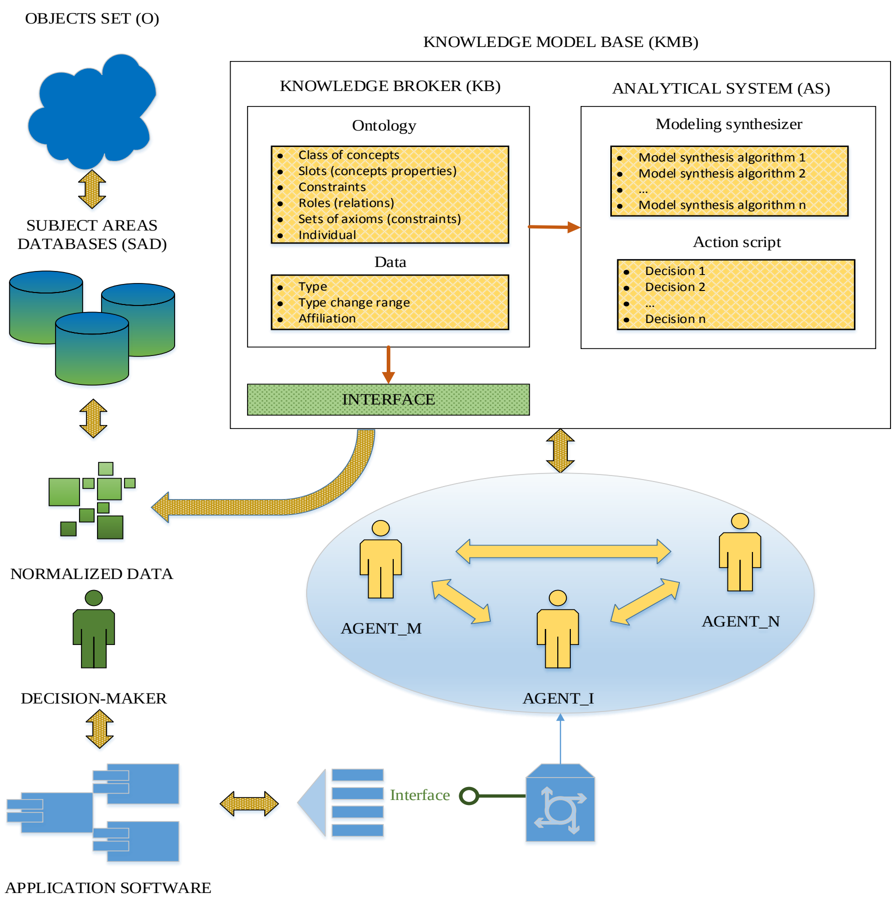

Figure 1 –The architecture of knowledge model base

In fig. 1 presents the architecture of the KMB as a part of the multi-level intellectual system of information processing with hierarchical control that's interacting with multi-agent system by knowledge broker (KB), which in turn interacting with decision-maker by application software. As illustrated in fig. 1, the information is transferred to high-level reasoning modules for knowledge accumulation and progressively compressed (simplified), or for decision making to the situation (action script) in applications based on smart environments for implementation of the intellectual monitoring.

Thus, knowledge sharing and exchange is particularly important in multi-agent systems. An agent is usually described as a persistent entity with some degree of independence or autonomy that carries out some set of operations depending on what he perceives. In multi-agent systems, an agent usually cooperates with other agents. In order to communicate, agents must be able to deliver and receive messages, parse the messages, and understand the messages. An agent is able to communicate only about facts that can be expressed in some ontology. This ontology must be agreed and understood among the agent community (or at least among its part) in order to enable each agent to understand messages from other agents. So, their understanding requires formalize the mechanisms of explicit specification of knowledge acquisition. Therefore, knowledge broker allows transmitting ontological basis to agents.

The focus of this architecture is on the perception role in acquiring knowledge from the environment and events for responsive and reactive adaptive applications which afford the ability to solve the problems of classification of states, forecasting detection, risk exposure, etc., and are a sign of intellectual monitoring.

According to the proposed methodology any characteristics of the object cannot conform to describe only by unique model. Every object, considered as a black box, can to describe by an infinite number of models with different, or identical external manifestations.

The characteristics of the object are a data space, which include observed and latent (dummy) data. Structuring of information from data space for analysis will be considered as an inductive synthesis of knowledge, realized as a result of the automatic generation the classification multiparameter models based on dataset (training samples). Training samples, as a rule, are small sets of data describing known objects.

A set of the object representation (initial feature map) will to produce on every level. On the low-level will to produce a set of the simple object representation based on the observed data. Low-level models are the explicit knowledge about object. Then, the iterative process could to repeat, and on the higher-level building up multidimensional matrix feature map, or r-rank tensors. In this way, not only explicit knowledge about object building up on the higher-level, but specific implicit (tacit) knowledge about object within subject area.

All inductive models look like a set of knowledge samples that identifies a similar object. All models makes possible to its test to determine the indicators of the characteristics influence by object study. After analyzing any model conclusions can be drawn about latent (dummy) characteristics of the object within subject area.

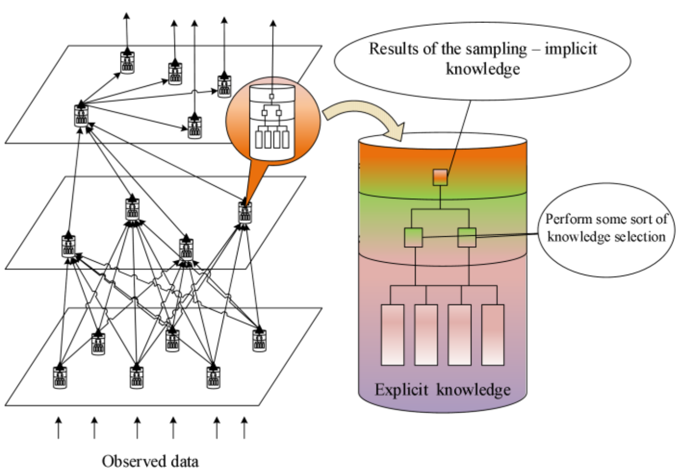

Figure 2 – Global function of the subject area

The complexity of model combinations at each level of information processing has steadily increase, depending on the number of new imaginations of object that are taken into account in the process of the model synthesizing. Model combinations form the hierarchical structures, such as view on fig. 2.

The inductive approach in this particular case is to consider specific models, and step by step complicating them from model including the monitoring data to complex implicit dummy knowledge of the object.

The main goal is to find a knowledge subspace of lower dimensionality than the original knowledge space, on which to project the dataset, while retaining its features. It is useful to reduce the computation time of subsequent data analysis. As a result, on every level there will be a bottom-up synthesis of the new knowledge that will be better than the last one.

Such approach to knowledge modeling is based on the basic principal points of the hierarchical multilevel systems theory [7], conforms the point of view of the individual elements coordination in complex system, and is based on the method of complex systems multilevel modeling of according to observational data in conditions of incompleteness of information [8], that is fully corresponds to the architecture of open, distributed and decentralized smart environments.

3. Formal explicit specification of knowledge acquisition

One of the most important tasks of scientific methodology is the unequivocal explication of its basic concepts. The traditional knowledge hierarchy first appears in knowledge management literature with the work of M. Zeleny in his book [9]. Therefore, let us consider of basic concepts such as data, knowledge, and conceptualization from the authors submission.

Data is an unorganized and unprocessed facts, raw numbers, figures, images, words, sounds, derived from observations or measurements or indicators in qualitative or quantitative forms that are necessary for the initial cursory experience to know object, process or phenomenon at a certain point in time that characterize its condition. Usually data is static in nature, a set of discrete, objective facts about events. Data are not knowledge. Data are the raw material for knowledge creation.

There is no consensus on a definition of knowledge. We should note first of all that the term «knowledge» creates an ambiguity. In most theories of the knowledge society, any explicit, sociologically relevant definition of knowledge is absent. Thus, according to the authors, the knowledge is always based on data, because they represent information about the trends for the observed object, process or phenomenon at a certain time interval, as well as quantitatively or qualitatively reflect its properties and their changes under the influence of external factors. In other words, knowledge characterizes the dynamics of the observed object, process or phenomenon. In addition, knowledge is contextual and it can be re-used.

KMB should be stay updated. Therefore, we must have to describe such representation of terms which can for knowledge updating have to be renewed or maintained. In this way, before conceptualization let’s look at hierarchical typology of explicit knowledge by M. Zack presents in his book [10]. He tells that explicit knowledge is further classified into declarative, procedural, and causal knowledge.

Declarative knowledge, or «knowledge about» or «know what», refers to the concepts, categories and things that are important. It is the ability to recognize and classify concepts, things and states of the world, routine knowledge about which the expert is conscious. It is shallow knowledge that can be readily re-called since it consists of simple and uncomplicated information. This type of knowledge often resides in short term memory.

M. Zeleny defines in [11] procedural knowledge as «knowledge how», represents the understanding of how to carry out a specific procedure and refers to the ability to perform a particular set of actions.

Causal knowledge, or «knowledge why», refers to an understanding of why something occurs. It is description of causal links among a set of factors, or describe how best to achieve some goal.

The KMB contains all knowledge types, such as declarative, procedural, and causal.

The basic concepts that are sufficient and necessary to describe any subject area include: an abstract object and event. A subject matter of abstract object is defined in terms of a components set, for example: category and elements forms, their relative position, means of communication, size distribution, percentages, weight, proportion etc. of different materials; and the states of the object expressed in qualitative or quantitative form, etc. A subject matter of abstract event is defined in terms of technological tools employed, for example: the technological process and its purpose (monitoring, control, etc.), series of procedures in technological process and their sequence, temperature or time profile, set of the physical facilities involved in the process, etc.

Before knowledge structured, we make number of assumptions: knowledge can be represented as set of concepts that are ordered in a certain way; knowledge must be indexed or unique. Therefore, the process of development formal explicit specification of knowledge acquisition is best illustrated from ontology of the any subject area [12], such as view on fig. 3.

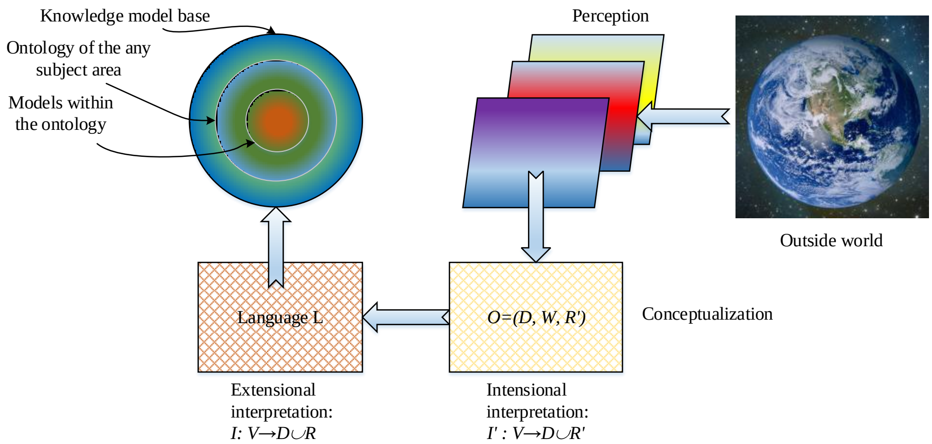

Figure 3 – The process of development formal explicit specification of knowledge acquisition

Let the subject area is made up of many objects O that interacting with each other. Then the tuple $(D,\ R)$ it's an extensional relational structure, where D is an entity type set that we'll call a domain that includes a certain subset of objects O, and R are a wide range of the relationship set on D with different relationship degree.

Under the system S we'll understand the part of the outside world (subject area), which we monitoring try to investigate, which is perceived by an outside agent to the system S. S include a set of variables obtained by monitoring.

The outside world is a linearly ordered set of states W, which describe the evolution of the system S in time. States W are the unique values of observed variables which characterize the system S.

Then the intensional p^n relation with n relationship degree on $(D,\ W)$ is a function $p^n : W \to 2^{D^n}$ of the set W on the set of all extensional relations with n relationship degree on D.

Thus, the intensional relational structure it's a triple $(D,\ W, R^{'})$, where $R^{'}$ is the set of extensional relations between objects O. If we assume that unary relations are unchanged and binary relations changing, that we can specify intensional relations as functions with constraint language.

Thus, the intensional specification it's the choice of language L and constraint of its interpretation by introducing a set of rules (axioms). And ontology is a set of axioms to represent only relevant models of knowledge acquisition in KMB structure.

If the language L it's the first-order language with the vocabulary V and $S = (D, R)$, then the first-order extensional structure (model L) it's the tuple $M = (S, I)$, where I is a function of extensional interpretation $I : V \to D \cup R$, which displays the vocabulary V into D or R.

Consequently, this approach can be successfully used for develop a common concept structure in the decision-making by application software, that are based on a model-based approach. This approach allows to build an abstract metamodel of interconnected concepts (describes the structure and principles of other models in KMB) and to exchange rules between ontology and multiparameter computing models that consolidate knowledge within heterogeneous domains, by combining them in formed global functional dependencies. Also, this approach will make possible to unify the process of structural identification of the global functional dependencies, by checking them to build ontology rules.

4. Conclusion

In this paper we have discussed how to build the formal explicit specification of knowledge acquisition for decision-making in intellectual monitoring process based on the ontology theory, basic principal points of the hierarchical multilevel systems theory, and the method of complex systems multilevel modeling of according to observational data in conditions of incompleteness of information.

A new approach proposed in this paper can be applied to implementation for development of the systems of the intellectual monitoring in any subject area.

Also, in this paper were viewed the principles of ontology modeling and knowledge representation by inductive approach.

RERERENCES

1. Gruber T.R. A Translation Approach to Portable Ontologies. *Knowledge Acquisition.* 1993. Vol. 5, N 2. P. 199–220.
2. Newell A. The Knowledge Level. *Artificial Intelligence.* 1982. Vol. 18, N 1. P. 87–127.
3. Tzafestas S.G., Kokkinaki A.I., Valavanis K.P. An Overview of Expert Systems. *Expert Systems in Engineering Applications* / eds. S. Tzafestas. Springer Science & Business Media, 2012. P. 3–24.
4. Lovely S., Vijay D., Kamaljeet K. Question Answering Dialogue System: A Brief Review. *International Journal of Computer Science & Information Technology*. 2014. Vol. 1. P. 4–11.
5. Holger Q., Robert B. Speech Dialogue Systems and Natural Language Processing. *Computer Speech. Springer Series in Information Sciences*. 2004. Vol. 35. P. 67–106.
6. Rus T. Computer-Based Problem Solving Process. 2015. 368 p. URL: https://is.gd/lz545C (Last accessed: 15.04.2019).
7. Месарович М., Мако Д., Такахара И. Теория иерархических многоуровневых систем. Москва: Мир, 1973. 344 с.
8. Голуб С.В. Багаторівневе моделювання в технологіях моніторингу оточуючого середовища. Черкаси: видавництво ЧНУ імені Богдана Хмельницького, 2007. 220 с.
9. Zeleny M. Management Support Systems: Towards Integrated Knowledge Management. *Human Systems Management.* 1987. Vol. 7, N 1. P. 59–70.
10. Zack M.H. Developing a knowledge strategy. *California Management Review.* 1999. Vol. 41, N 3. P. 125–145.
11. Zeleny Milan Human Systems Management: Integrating Knowledge, Management and Systems. World Scientific Pub Co Inc., 2005. 484 p. URL: https://is.gd/fMa92p (Last accessed: 15.04.2019).
12. Андон Ф.И., Яшунин А.Е., Резниченко В.А. Логические модели интеллектуальных информационных систем. К.: Наукова думка, 1999. 398 с.

Стаття надійшла до редакції 02.07.2019