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ENTERPRISE ENGINEERING AND INTELLECTUAL TECHNOLOGIES FOR LIFECYCLE MANAGEMENT OF INDUSTRIAL PRODUCTION

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Abstract: *The fundamental scientific problem of the development of the mathematical foundations of engineering for industrial enterprises and the development of mathematical methods of production management, as well as the creation of intelligent systems for coordinated management of the life cycles of products and production in the network of enterprises are discussed. The issues in demand in the development of a vast interdisciplinary field of enterprise engineering and the development of modern network enterprises and intelligent production using mathematical modeling methods are discussed.*

Keywords: *artificial intelligence, mathematical management problems, decision making, intelligent manufacturing, enterprise engineering, life cycle management, multi-agent systems.*

Аннотация: *Саноат корхоналари инжинирингининг математик асосларини ишлаб чиқиш ва илаб чиқаришни бошқаришнинг математик усулининг ривожланиши, шунинг дек корхоналар тармоғида ишлаб чиқариш ва маҳсулотнинг ҳаётий цикларини изчил бошқаришнинг интеллектуал тизимларини ишлаб чиқиш каби фундаментал илмий муаммо изоҳланган. Математик моделлаштириш усулларидан фойдаланган ҳолда корхоналар инжинирингининг кенг фанлараро соҳасини ривожлантириш ҳамда замонавий тармоқ корхоналари ва интеллектуал ишлаб чиқаришни ривожлантиришнинг талаби юқори бўлган масалалар муҳокама қилинган.*

Таянч сўзлар: *сунъий интеллект, бошқарувнинг математик муаммолари, қарор қабул қилиш, интеллектуал ишлаб чиқариш, корхона инжинирингини, ҳаётий циклни бошқариш, мульти агентли тизимлар.*

Аннотация: *Трактуется фундаментальная научная проблема разработки математических основ инжиниринга промышленных предприятий и развития математических методов управления производством, а также создания интеллектуальных систем согласованного управления жизненными циклами продукции и производства в сети предприятий. Обсуждаются востребованные вопросы развития обширной междисциплинарной области инжиниринга предприятий и разработки современных сетевых предприятий и интеллектуальных производств с использованием методов математического моделирования.*

Ключевые слова: *искусственный интеллект, математические проблемы управления, принятие решений, интеллектуальное производство, инжиниринг предприятий, управление жизненным циклом, мультиагентные системы.*

Introduction

In the 21st century, the broad interdisciplinary field of Enterprise Engineering is actively developing, aimed at the design and development of modern network enterprises and intelligent production with extensive use of mathematical modeling methods. For more than a decade, there has

been an ever-expanding international CIAO Network that includes universities, research institutes, businesses, and organizations interested in the development of general enterprise design theory and methods. In this case, the concept of "enterprise" is interpreted very broadly: from classical forms of enterprises (corporations and partnerships) to all kinds of associations, alliances, networks of enterprises, supply chains, etc. Here the acronym CIAO, formed from the words Cooperation, Interoperability, Architecture, Ontology, characterizes their close relationship: enterprise cooperation implies interoperability of their information systems, and enterprise architecture is understood as a development standard - a normative constraint on the freedom of enterprise designers, with common ontologies at the core of their joint activities.

Since 2005, the CIAO Network has hosted the annual Advances in Enterprise Engineering Workshops, which became the Enterprise Engineering Working Conference in 2011.

The purpose of enterprise engineering is the study, design and creation of a modern enterprise as an integrated holistic system based on the modeling of its products, resources, processes, operations. In an ever-changing and unpredictable competitive environment, enterprise engineering seeks to answer the fundamental question of how to define, design and improve various elements, properties, processes, structures of an enterprise based on intelligent technologies using analysis, synthesis, decision-making methods. Thus, enterprise engineering involves the use of formal methods and tools for enterprise research and design.

The current state of enterprise engineering

The world level of research in the field of enterprise engineering is determined by the works of such scientists as: F.Vernadat, T.Davenport,Y. Dietz, D.Liles, D.Martin, E.V.Popov, Y.F.Telnov, A.V.Scheer and others .Let us briefly analyze their ideas about the essence of enterprise engineering and its basic disciplines.

According to D. Lyles and co-authors, enterprise engineering encompasses the knowledge, principles, and practical recommendations associated with the analysis, design, creation, and operation of enterprises [1].

According to F. Vernadat, enterprise engineering is the art of understanding, defining and implementing the necessary business processes and business structures throughout the life cycle of an enterprise to achieve its goals, efficiency and competitiveness in the market environment. The two basic disciplines of enterprise engineering are enterprise modeling and enterprise integration [2]

In turn, J. Martin identified seven basic disciplines of enterprise engineering, grouped around the concept of "value", and in the work of Y. Dietz et al. The discipline of enterprise engineering. [3] mentioned the following three main goals of enterprise engineering: intellectualization of enterprise management, improvement of its organization, social orientation.

Enterprise engineering can be based on at least three main assumptions (see monographs by E.V. Popov and Y.F. Telnov on engineering and reengineering of organizations, for example, [4], [5]:

1) the enterprise is a complex open system, functioning in a heterogeneous environment;

2)this system, being dynamic, acts as a set of processes that must be designed to meet organizational goals;

3)it is possible to use engineering approaches to the tasks of creating and transforming (transforming) an enterprise.

In J.L.G. Dietz's monograph [6] the author indicates three levels of enterprise engineering based on modern information technology:1) data systems engineering ; 2) information systems engineering ; 3) enterprise engineering based on their ontological representation. This concept forms the basis of the DEMO (Design and Engineering Methodology for Organizations) enterprise engineering support methodology. In addition to these three levels, in our view, it is advisable to consider item 4) Knowledge-Based Networked Enterprise Engineering.

The modern state of research in this area is also reflected in the works [7] and [8].

According to Y.F. Telnov, the engineering approach to the construction and research of enterprises goes back to business process re-engineering (M. Hammer, J. Champy, E.V. Popov, A.W. Scheer), enterprise architecture modeling (D. Zachman, G.N. Kalyanov, B.A. Pozin), corporate knowledge management (K. Wiig, T.A. Gavrilova, T. Davenport, O Leary, E.V. Popov), ontological modeling (T.A. Gavrilova, T. Gruber, N. Guarino, R. Mizoguchi, A.V. Smirnov, S.V. Smirnov), multi-agent technologies (K. Hewitt, M. Wooldridge, V.I. Gorodetsky, A.V. Smirnov, V.B. Tarasov).

It seems promising to develop the concept of enterprise engineering based on modeling the system of life cycles: product life cycle, production life cycle, the life cycle of the enterprise, etc.

The prerequisites for effective life cycle management are its engineering and modeling.

The concept of lifecycle engineering

At the end of the 20th and beginning of the 21st century, the concept of lifecycle engineering emerged, which involves extensive use of modern information and communication technologies in modeling and integrating its stages.It is developed in the works of L.Alting, P.Bernus, F.L.Krause, E.Kusiak, A.Molina, Kh.M.Sanchez, G.Spur, and others. The main aspects of the engineering of LC are:

1) knowledge engineering and lifecycle knowledge management (LC), in particular based on a visual representation of its structure

2) optimization of time relations between stages and phases of the lifecycle of a complex technical system (for example, reducing the development time and increasing the period of operation of the CTS)

3) accounting and management of uncertainties arising at different stages of the LC, in particular, by granulating the information circulating throughout the LC.

Here, lifecycle engineering is understood as the basis for the integration of various processes and structures in the enterprise.

In recent years, the concept of the lifecycle of products has expanded to include the Recycling stage, which is the basis of the "circulation of the lifecycle" concept proposed by Japanese specialist F. Kimura. Around the same time, V.B. Tarasov introduced a three-dimensional system of life cycles "Product Life Cycle - Process Life Cycle - Enterprise Life Cycle" and proposed variants of its granulation. So the formation of virtual enterprises based on intranet networks is aimed at extending the lifecycle of individual enterprises. This influence is quite complex and ambiguous: for example, the exclusion of a stage from the life cycle does not always mean a reduction in total costs, and on the contrary, the lengthening and more thorough elaboration of individual stages (for example, maintenance and repair) can provide significant savings and lead to a reduction in the total cost of the life cycle.

In terms of product lifecycle engineering, its modeling and the integration of the individual stages of the lifecycle are central.It seems fruitful to analyze circular, sequential, sequential-parallel, incremental models of lifecycles, the expediency of construction, as well as the formal representation and study of spiral models with different values of the step between coils is substantiated.

The concept and models of the life cycle of a complex technical system were considered by Yu.R.Valkman, G.B. Evgenyev, K.D. Juk, V.N. Spitsnadel, J. Stark, A.I. Subetto, and others. The spiral models of the lifecycle were developed by B.Boem, L.A. Kashuba. The analysis of the relations between the time intervals of the LC is based on the works of J. Allen, D.A. Pospelov, A.P. Eeremeev, and G.S. Plesnevich.

The issues of lifecycle engineering and lifecycle management are actively developed by L. Alting, J. Stark, E. Sudov, M. Ovsyannikov, V. Tarasov, N. Yusupbekov, and others. In contrast to the problems of the life cycle of ontologies, on which there are many publications in the literature on ontological engineering, the issues of building a system of ontologies as a basis for knowledge management of the life cycle of complex products remain unresolved; among the first studies in this area we can mention the works of T. Tran, P.Haase, O. Munoz-Garcia, R. Studer.

The founders of ontologies and ontological modeling are T. Gruber and N. Guarino, the authors of classical definitions of ontology as "specification of conceptualization common to some community of agents" or as "logical theory, which defines conceptualization in an explicit form".

The modern world level of researches in the field of application of the ontological approach to knowledge management in organizational networks and virtual enterprises is defined by works of such scientists as M. Gruninger, T. Sandholm, M. Uschold, D. Fensel, M. Fox, M. Fernandez. Among the leading specialists in this field are T.A. Gavrilova, A.S. Kleshchev, V.V. Gribova, G.S. Plesnevich, A.V. Smirnov, S.V. Smirnov, D.V. Kudryavtsev, D.I. Muromtsev.

Problems of information granulation and creation of formal models for its description at the required level of abstraction /detail are considered in the works of L.Zadeh, V.Pedrycz,T.Lin, Y.Yao, I.Z. Batyrshin, S.Butenkov, N.G.Yarushkina and the pioneers of granular ontologies are T.Bittner, B.Smith, A.Varzi, L.Vieu, J.Allen, A.Rao, K.Bettini, A.Montanari, J.Euzenat.

Conclusion

To summarize, it would be like to emphasize the relevance and importance of fundamental scientific problems of developing the mathematical foundations of enterprise engineering and the development of mathematical methods of production management, as well as the creation of an intelligent system of coordinated management of product life cycles and production in a network of enterprises. In this case, in particular, the topicality of the specific scientific task of building intelligent control systems of the family of life cycles increases. Relevant is the development and implementation of the concept of intelligent production, the development of methodology and theory of life cycles for intelligent production. The systematization, construction and development of formal models of life cycles in production, primarily spiral models, when formalized methods and computer models of enterprise engineering will be developed using knowledge management based on ontological modeling, coordinated management of the life cycles of the enterprise, its processes and products, software agents and multi-agent systems. In the same line is the development of an intelligent product lifecycle management system based on the interaction of agents, the mapping of agent-based technologies to a system of lifecycles. There is a demand for planning the construction of a cloud-based support system for the lifecycle of industrial production using methods and technologies of the industrial Internet of things, development of methods and algorithms for intelligent analysis of imprecise, inconsistent, fuzzy and linguistic information circulating at various stages of life cycles based on soft computing (including modern neural networks with deep learning, fuzzy time series, methods of fuzzy clustering, etc.)In modern conditions also increased the urgency of building algorithms for production planning under conditions of fuzzy information and time constraints.

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