Survey of Present System Engineering Multi-Agent Based Methods. Development and Application

Irina A. Spitsina[1], Alexander L. Krochin[1], Konstantin A. Aksyonov[1], and Olga P. Aksyonova[1]

Ural Federal University, Yekaterinburg, Russia
krosha_i@inbox.ru
alkrochin@yandex.ru

Abstract. Multi-agent approach (MAA) to development of systems architecture has many advances over traditional ones. Here, we concern one problem in analysis of business processes (BP) of organizational-technical systems (OTS). That is, influence of the data flow bottlenecks onto reliability level of the man-machine distributed system. In such systems, there is an upper limit on the delay time in data transmission or execution time due to the specifics of business processes. Authors have conducted simulation of the BP dynamics and confirmed advantages of their MAA-based method.

Keywords: Business processes, decision-making, multi-agent resource conversion processes, MRCP, multi-agent systems, information processing system

Introduction

Successful development of information processing system (IPS) is strongly determined by elaboration of the methodological approach used in the design process. This process involves three groups of participants: users, analysts, and developers. The current trend is the automation of all processes of the enterprise: business processes, processes of coordination, and decision-making.

The IPS development method should allow one to:

1. build a unified IPS model understandable to all participants in the development process;
2. comprehensively address issues of formalization and computerization of the decision-making processes;
3. conduct simulation modeling of automated processes of an enterprise with the ability to use the results and knowledge formalization stages of automation.

1 Some present methods of IPS development

Now we consider the methods of IPS development, which provide the features mentioned above.

1.1 Skobelev's method

Skobelev's method is intended for creation of multi-agent systems (MAS) of operative information processing to support decision-making processes. As a model of knowledge representation, he uses ontologies and the networking-company model of the network needs and opportunities (NO-net), as described in his dissertation [1]. Each company is represented as a network of agents of needs and opportunities. The method solves the problem of interaction of these agents in the decision-making process.

By Skobelev P. O., the development methodology includes the following stages:

- description of the subject area MAS;
- description of classes of agents and decision-making rules;
- description of the interaction protocols of the agents;
- types and structure of messages;
- software implementation of the agents.

This method is implemented as a set of components for developing the multi-agent systems MagentaToolkit [2]. To configure the system for specific domain, ontologies used are created by application of a special tool included in the package. The described product is intended for the MAS development planning, and resource allocation. It is not concerned with the analysis and reengineering of business processes of the enterprise.

1.2 Method by Karsaev O.V. and Gorodetsky V. I.

The method by Karsaev and Gorodetsky is based on the Gaia [3] methodology and environment MASDK [4] in support of its use. It is designed for development of the applied multi-agent systems. The coarsening method can be described in five stages [5].

At the first stage, "design software MAS" comprises analysis and description of domain ontology. As the result, it determines the classes of agents and maps them to roles. The distribution of roles between classes of agents determines what classes of agents for further phases of development will provide the solution of certain tasks.

At the second stage, "design of a class of agents" is a description of three components that form the structure of the agent

- the behavior model of the agent;
- service models;
- a mental model.

At this stage, there is only a description of agents using charts by the object-oriented approach. Writing software code (that describes the service function) that occurs at the third stage. Then the automatic generation of source code classes of agents is performed. After that there is the automatic generation of software code classes of agents.

The fourth stage describes the knowledge and rules conduct the agent. The last stage is deployment of the agents in the network.

Thus, the Karsaev and Gorodetsky method does not allow one to describe static and dynamic business processes, and, therefore, is not concerned with their analysis and re-engineering.

1.3 Method by Shvetsov A. N.

The proposed method is related to development of the corporate intellectual systems decision-making support [6]. At the initial stage, much attention is paid to structural, logical, and behavioural aspects of automated enterprise. At the stage of formalization, of the logical model, knowledge base, topological and object model are constructed. Then a prototype system and its industrial version are developed. The main focus of this method is put on the extraction and formalization of knowledge about the subject.

The Shvetsov method is implemented as a software package DISIT (Distributed Intellectual System Integrated Toolkit) [7]. It is designed to develop MAS, based on the following principles:

- description of the domain model, using the frame concepts;
- description of the behaviour of agents in the form of products.

In this tool the package consistently performs the following method steps.

1. Describes the domain model: the logic relationship of a frame of concepts and their attributes.
2. Intelligent agents are distinguished and defined by their behavior with respect to the system limits.
3. Received a conceptual domain model is translated to logical model MAS.
4. Intelligent components and agents reside in the corporate network.

The study shows that the method Shvetsov A. N. not dealing with issues of analysis and re-engineering static and dynamic business processes.

1.4 Method by Alexandrov D. V.

The Alexandrov method is aimed to modeling the distributed systems management of business processes of the enterprise [8]. The analysis of a subject in the Alexandrov method uses the structural functional approach. A simulation model is developed based on the apparatus of colored Petri nets. The simulation results give recommendations for improvement of the business processes. If necessary,

it is proposed to conduct a tactical re-engineering. It includes adding/removing functions, staff, redistribution of functions between the employees, transfer of employees from one structural unit to another, etc. The next step is implementation of the agent-based applications to automate business processes. Also, the method involves the use of simulation modeling for monitoring business processes of the enterprise.

2 New proposed method

The Authors of the paper proposed a new method for development of IPS [9, 10] as a model of knowledge representation that uses a model of multi-agent resource conversion processes (MRCP) and the frame-based approach [11]. The new method based on multi agent analysis [12–14] and software design [15, 16].

At the beginning of the process of development a model of the MRCP of the enterprise is built and simulation is carried out to identify the bottlenecks. Then the model is transformed into the model of IPS, which is a diagram of functional and object-oriented approaches. The developers modify the model of the system and design the user interface that is followed by automatic generation of source code of the future IPS.

For comparative evaluation of methods for information systems development, the following set of criteria where used.

1. The process model of the enterprise (A), which describes static (B), dynamic (C) business processes, and models of decision makers (D). Thus, we can describe all processes of organizational-technical system.
2. Tools of processes (E) including organizational re-engineering and analysis of the "bottlenecks". This feature of the method provides creation of a process model OTS "as-is", which eliminates the existing problems of enterprises.
3. Possibility of using data from a company model in the development of the IPS (H): part of dynamic business processes and the model of decision-makers. This allows one to automate the development process and reduce errors in the transition time between models.
4. Using the structural (K) and object-oriented (L) approaches. The combination of these approaches allow one to build a more complete model of the information system understandable to users, analysts, and developers.
5. The results of the automation (M): business processes, decision coordination, and the decision-making processes, i.e., the use of logical inference machine.

Results of comparison of the methods in the IPS development of show the following

1. For (A):
   - Skobelev's method uses ON-nets;
   - Shvetsov method and Karsaev and Gorodetsky method do not need any model;

   - Alexandrov method uses coloured Petri-net; our suggested method uses MRCP.
2. For (B):
   - Shvetsov method and Karsaev and Gorodetsky method do not use this opportunity;
   - Skobelev's method, Alexandrov method and our suggested method use this opportunity.
3. For (C) only our method describes dynamic business processes.
4. For (D) all methods with the exception of Alexandrov method describe models of decision makers.
5. For (E):
   - only Alexandrov method Of D. V. makes organizational reengineering;
   - only our method includes analysis of the "bottlenecks".
6. For (H):
   - only our method uses data about dynamic part of business processes;
   - all methods with the exception of Alexandrov method use data from the model of decision-makers.
7. For (K) and (L):
   - only our method uses combination of structural and object-oriented approaches;
   - all methods with the exception of Alexandrov method use object-oriented approach;
   - Alexandrov method uses structural approach.
8. For (M):
   - all methods automate business processes;
   - Skobelev's method, Shvetsov method and our method automate decision coordination;
   - only Shvetsov method and our method automate the decision-making.

The above analysis shows that the new method provides more complete solution to the problem of automation for all OTS-processes.

The new method involves solution of the problem of locating instances of concepts of the subject area in the knowledge bases of the agents. Its formulation is presented below.

Find

$$\min z = \sum_{i=1}^{m} \sum_{j=1}^{n} c_{ij} x_{ij}, \tag{1}$$

with limitations

$$\sum_{j=1}^{n} a_{ij} x_{ij} \geq 1, \quad j = 1, \ldots, m, \tag{2}$$

$$x_{ij} = (0,\, 1),\, i = 1, \ldots,\, m;\; j = 1,\, \ldots,\, n, \tag{3}$$

$$T_{\text{BP}} \leq T_{\text{BP}}^{\max}, \tag{4}$$

where n is the number of agents; m is the number of subject area concept samples; c_{ij} is the factor that valued expenditure for putting the i-th concept sample near the j-th agent;

$$x_{ij} = \begin{cases} 1, \, i\text{-th concept sample near } j\text{-th agent;} \\ 0, \text{ other.} \end{cases}$$

a_{ij} is the factor that evaluated j-th agent's need i-th concept sample;

$$a_{ij} = \begin{cases} 1, \, j\text{-th agent needs } i\text{-th concept sample;} \\ 0, \text{ other.} \end{cases}$$

Relations (1) – (4) were implemented in the BPsim products family (BPsim.MAS, multi-agent system dynamic simulation, and the BPsim.SD, the CASE-tool).

The application of this approach to production and logistics is described in [17–21]. There is a significant reduction in the transition time between the stages of IP development. The average effect in the design of the IP model was 42% [9]. Some of its advantages over existing models are also briefly listed in Conclusion.

3 Conclusion

Existing methods do not completly solve the problem of development IPS affecting the analysis of the processes of the OTS. They do not take into account the dynamics of BP, do not pay attention to analysis of the "bottlenecks", and do not use information from the process model OTS in the dynamic BP for the development of IPS. The new proposed method solves these problems. In addition, the method deals with the question of reliability of human-machine distributed system in terms of limits of executing the business processes.

Acknowledgement

The work was supported by Act 211 Government of the Russian Federation, contract 02.A03.21.0006.

References

1. Skobelev, P. O.: Open multi-agent system for operative processing of information in the decision-making processes: Avtoref. dis. on competition of a scientific degree. Kazan.step. Ph. D.(in Russian), Samara (2003)
2. Andreev, V. V., Batishchev, V. C., Ivkosic, K. V., Aquarina, T. V., Skobelev, P. O.: Tools for developing multi-agent systems in industrial scale [Electronic resource](in Russian) http://www.ssc.smr.ru/media/ipuss_conf/06/5_01.pdf
3. Zambonelli, F., Jennings, N., Wooldridge, M.: Developing Multiagent systems: The GAIA methodology. ACM Transactions on Software Engineering and Methodology, 12(3), 417-470 (2003)
4. Gorodetsky, V., Karsaev, O., Samoylov, V., Konushy, V.: Support for Analysis, Design and Implementation Stages with MASDK. LNCS 5386, 272-287 (2009)
5. Gorodetsky, V., Karsaev, O., Konushy, V., Samoylov, V.: Design and Implementation Stages with MASDK (in Russian). Trudi SPIIRAN www.proceedings.spiiras.nw.ru
6. Shvetsov, A. N.: Models and methods of corporate intellectual systems of support of decision-making: dis. dr. tech. nauk (in Russian) St. Petersburg (2004)
7. Shvetsov, A. N., Sergushicheva, M. A.: Design of applied multiagent systems using package DISIT (in Russian). Informatsionnie technologii (Information technology). 8, 54–60 (2009)
8. Alexandrov, D. V., , Fadin D. N.: Consulting in organizations (in Russian), Vladimir, Publishing house Vladim. state University (2006)
9. Spitsina, I. A.: Method of decision support in the development of information systems based on multi-agent approach: dis. Cand. tech (in Russian). Ekaterinburg (2015)
10. Aksyonov, K. A., Bykov, E.A., Aksyonova, O. P. : Development and application of software engineering solution BPsim.SD. In Proceedings - UKSim-AMSS 7th European Modelling Symposium on Computer Modelling and Simulation, EMS. Manchester; United Kingdom 6779866, 321-325 (2013)
11. Aksyonov, K. A., Bykov, E. A., Antonova, A. S., Aksyonova, O. P., Sufrygina, E. M., Goncharova, N. V.: Tools and Methodologies for Business Processes Formalization: Application to Multi-agent Systems. In Proceedings of the IEEE 2011 UKSim 5th European Symposium on Computer Modeling and Simulation, 16-18 November, Madrid, Spain, 113-118 (2011)
12. Zadorozhnyi, V. N., Yudin, E. B.: Dynamic equations of node degrees in growing networks with connection losses. 2016 Dynamics of Systems, Mechanisms and Machines, Dynamics 2016. Proceedings, 2017. p. 7819111. DOI: 10.1109/Dynamics.2016.7819111.
13. Zadorozhnyi, V. N., Yudin, E. B.: "Growing network: models following nonlinear preferential attachment rule". Physica A: Statistical Mechanics and its Applications. **428**, 111-132 (2015)
14. Yudin, E. B., Yudina, M. N.: Calculation of number of motifs on three nodes using random sampling of frames in networks with directed links. 2017 Siberian Symposium on Data Science and Engineering (SSDSE), 23–26. DOI: 10.1109/SSDSE.2017.8071957
15. Kuleshov, S, V., Aksenov, A. J., Zaytseva A. A.: Software-Defined Data Formats in Telecommunication Systems. Series: Advances in Intelligent Systems and Computing. **575** , 326–330 (2017)

16. Alexandrov, V. V., Kuleshov, S. V., Zaytseva, A. A.: Active Data in Digital Software Defined Systems Based on SEMS Structures. Logical Analysis of Data and Knowledge with Uncertainties in SEMS – Smart Electromechanical Systems, Studies in Systems, Decision and Control. Gorodetskiy, A. E. (ed.). **49**, 61–69 (2016)
17. Aksyonov, K., Bykov, E., Sysoletin, E., Aksyonova, O., Nevolina, A.: Integration of the Real-time Simulation Systems with the Automated Control System of an Enterprise. In International Conference on Social Science, Management and Economics (SSME 2015) Guangzhou, China, May 09-10, 871-875 (2015)
18. Aksyonov, K., Bykov, E., Sysoletin, E., Aksyonova, O., Goncharova, N.: Perspectives of Modeling in Metallurgical Production/ In International Conference on Social Science, Management and Economics, Guangzhou, China, 876-880 (2015)
19. Aksyonov, K., Bykov, E., Aksyonova, O.: Real time simulation models integrated into the corporate information systems. In 33rd Chinese Control Conference, Nanjing; China, 6810-6813 (2014)
20. Aksyonov, K. A., Spitsina, I. A., Sysoletin, E. G., Aksyonova, O. P., Smoliy, E. F.: Multi-agent approach for the metallurgical enterprise information system development (in Russian). In 24th Int. Crimean Conference "Microwave & Telecommunication Technology" (CriMiCo'2014). 7 – 13 September, Sevastopol, 1, 437-438 (2014)
21. Aksyonov, K. A., Spitsina, I. A., Aksyonova, O. P., Schaible, Ph.: The state analysis of intelligent tools of computer aided software engineering (in Russian). In 24th Int. Crimean Conference Microwave & Telecommunication Technology (CriMiCo'2014). 7 – 13 September, Sevastopol. 1, 421-422 (2014)