Simulation of intelligent service-oriented systems in conditions of uncertainty

Larisa K. Ptitsyna[1], Nidal El Sabayar Shevchenko[2]
The Bonch-Bruevich Saint-Petersburg State University of Telecommunications
[1]ptitsina_lk@inbox.ru, [2]nzs.vus@gmail.com

Mikhail P. Belov
Saint Petersburg Electrotechnical University "*LETI*"
milesa58@mail.ru

Aleksey V. Ptitsyn
Saint Petersburg National Research University of Information Technologies, Mechanics and Optics
pticin@inbox.ru

***Abstract*—The reasons for the urgency of the development of the technological basis of service-oriented systems are examined. Prospective directions of intellectualization of service-oriented systems are outlined. The techniques of integration of technologies of intellectualization of service-oriented systems are described. New conceptual models of intellectual service-oriented systems are proposed. The basic components of the intellectualization of service-oriented systems are presented. Methods for generating base components are disclosed. An analytical method for overcoming a priori uncertainty regarding the configuration of a service-oriented system is developed in the analysis of its quality. Techniques for advanced object-oriented modeling of the basic components of the intellectualization of service-oriented systems are formed.**

Keywords— intellectual technologies; service-oriented system; method; generation; model; integration; methodology; object-oriented modeling

I. INTRODUCTION

The current stage of economic development is characterized by the association of regional economic systems into a single global ecosystem in which the knowledge plays the main role and its generation is a major source of growth. The development of the world ecosystem is associated with the fifth technological order, characterized by the integration and convergence of information and communication technologies.

In the world ecosystem, competencies for the research of markets and industries of the economy are formed on platforms with hyper-technological content. Ecosystem platforms are the basic components of environments in which favorable conditions for effective interaction of subjects of the markets and branches of economy are created.

The research of environments is carried out on the basis of the construction of complex hierarchical information and telecommunication systems that widely use virtualization, remote clouds and high-performance computing resources.

As the environment improves, the world market is segmented, competition becomes tougher, market relations are computerized, and the interdependencies of producers are deepened. In such conditions, the strategy of creating and maintaining multicomponent software products in the form of service-oriented systems is rapidly developed [1, 2], providing for a flexible and prompt response to changing market conditions and increasing customer requirements for the quality of products and services [3].

The strategy is defined according to the service-oriented architecture paradigm, in which loosely coupled heterogeneous services interact on standardized protocols using a scalable network information space.

In general, the multifaceted nature of ecosystem factors that affect the functional specifications of service-oriented systems and the requirements made on them becomes one of the main reasons for finding effective solutions for their intellectualization.

The scientific basis for the intellectualization of service-oriented systems refers to the field of artificial intelligence, in which intellectual tasks are defined, systematized, solved, analyzed, optimized and automated.

By the use of intelligent service-oriented systems, three categories of intellectual tasks are solved:

- The task of reproducing human abilities.
- The task of ensuring rationality, when all the actions pertaining to a certain system are carried out correctly, being a ware of what is right.

- The tasks of recreating the environment for objects and/or subjects and their interaction.

By analogy with artificial intelligence, the following categories can be distinguished in the life cycle of intelligent service-oriented systems:

- Systems with reproduction of thought processes.
- Systems with reproduction of rational reasoning.
- Systems for implementing functions that require intelligence being implemented by people.
- Systems for implementing rational actions.

The implementation of intelligent service-oriented systems can be based on one of the possible approaches or combinations:

- An approach based on cognitive modeling.
- An approach based on the application of laws of thought.
- An approach based on the use of the Turing test.
- An approach based on the formation of model-analytical intelligence.
- An approach based on the creation of intelligent agents.

In the functional definition of the intelligence of the service-oriented system according the Turing test, the following is included:

- Text processing services in natural languages.
- Knowledge representation services.
- Services of automatic formation of logical inferences.
- Machine learning services.
- Machine vision services for the perception of objects.
- Robotics services for manipulating objects and moving in space.

Within the framework of the considered approaches, the solution is proposed for the dynamic configuration of a service-oriented system based on the services of artificial intelligence, implementing rational actions for the integration of services, and determining and monitoring the quality of the service-oriented system.

The services of artificial intelligence include planning service and service of model-analytical intelligence.

Realization of rational actions is assigned to the planning service, and the determination and monitoring of the quality of the service-oriented system is based on the service of its model-analytical intelligence providing analysis of the planned integration of the service-oriented system.

The proposed solution is accompanied by the formation of a methodological basis for the generation of formalizations that allow the creation of intelligent dynamically configurable service-oriented systems with quality assurance.

II. METHODOLOGICAL BASIS FOR GENERATION FORMALIZATIONS OF INTELLIGENT DYNAMICALLY CONFIGURABLE SERVICE-ORIENTED SYSTEMS

The methodological basis takes into account the conditions of a priori uncertainty regarding the relationship between the quality criteria for planning and the parameters of the characteristic space of actions performed by the services. Overcoming of a priori uncertainty is carried out by testing alternative hypotheses about the relationship, construction and analysis of regression and neural network models. The main hypothesis is oriented toward the independence of jointly observed random variables. Using the models, the relationships between the quality criteria of planning and the parameters of the characteristic space of performed actions by the services are reflected. Information on factors that affect the quality of planning, is divided into two groups. The first group includes the characteristics of the environment of the service-oriented system, and the second group includes the parameters of the planning task. To test the hypothesis of the independence of jointly observed random variables, the chi-square test is used, which is connected with the construction of the conjugacy table for the characteristics.

Formation of the methodological basis begins with the formation of a system of conceptual models that describe possible variations in the architecture of service-oriented systems with artificial intelligence. Each conceptual model is represented by a tuple

$$\mathbf{Q}_j = \langle \mathbf{C}_j, \mathbf{R}_j \rangle,$$

where $\mathbf{C}_j = \{c_{ji}\}$ is the set of concepts $i=1,2,...,I$ corresponding to the components of the j-th architecture variation;
I – is the number of concepts;
J – is the number of architecture options;
$\mathbf{R}_j$ is the precedence relation, which is determined by matrix of $I \times I$ size.

Among the concepts, there are action services, customer service services, maintenance manager service, a service-dispatcher of service-oriented activity, services of various planning algorithms, a service of model-analytical intelligence, a service of choosing a rational planning algorithm. Introduction to the planning service architecture is treated as the first stage of the intellectualization of a service-oriented system.

The second stage of intellectualization is associated with the connection of the model-analytical intelligence of the system. Integration of the planning service and service of model-analytical intelligence is carried out through the formed plan of actions performed by executing services.

In the possible variations of architecture, both the composition of its components and its topology vary. In the context of possible requirements for professional and leisure activities, the characteristic of the presented modifications of service-oriented architectures is carried out.

The system of conceptual models is supplemented with a functional model of the planning service that is engaged in the formation of a service integration plan. It is assumed that a certain action is implemented by each service.

The solution plan is built by transforming the original partial plan. A partial plan is described by two tuples.

The first tuple is represented by three sets

$$\mathbf{P} = \langle \mathbf{T}, \mathbf{ST}, \mathbf{C} \rangle,$$

where **T** is the set of time steps;
ST: $\mathbf{T} \rightarrow \mathbf{O}$ represents the steps of the plan to the set of basic operators **O**.

The second tuple is formed by three sets of constraints

$$\mathbf{C} = \langle \mathbf{C}_O, \mathbf{C}_B, \mathbf{C}_L \rangle,$$

where $\mathbf{C}_\mathrm{O}$ is the set of partial order relations on the set **T** so that: $t_0 < t_i$ and $t_i < t_\infty$ for any $t_\mathrm{i} \in \mathbf{T}, i > 0$;

$\mathbf{C}_\mathrm{B}$ is the set of binding constraints on the occurrence of variables in the pre- and post-conditions of operators implementing actions;
$\mathbf{C}_\mathrm{L}$ is a set of additional constraints.

The set of considered planning algorithms includes schemes corresponding to autonomous, operational and distributed planning.

This diversity is focused on the distinction between the scale of service-oriented systems and requirements to their functionality. In conceptual terms, the approach based on the formation of model-analytical intelligence can be combined with each of the other basic preferences presented in intellectualization and become a system component of any service-oriented system.

In this regard, the model-analytical intellect is presented with such requirements, which primarily concern the maintenance of the quality of the functioning of service-oriented systems [4]. Profiling the quality of the functioning of service-oriented systems is carried out in the context of their application [5]. With this concept of intellectualization of service-oriented systems, its methodology extends to a methodological basis, which includes:

- Representation of the environment [6].
- Definition of the profiles of intellectualization [7].
- Selection of quality profiles [1-6, 8, 11, 13].
- Justification for selection of the system model class service operation processes and service-oriented system as a whole [1-6, 8, 11, 13].
- Choice of methods for their binding [9, 10, 12].
- Definition of a system of methods for constructing a model series [1-6, 8, 11, 13].
- Development and application of methods for analyzing the model series in a system of selected classes [1-13].
- Situational demarcation of analytical formalizations [1-6, 8, 11, 13].
- The formation of invariants for the verification of analytic formalizations.
- Mapping of analytic formalizations to services.
- Design, creation and maintenance of software [2].
- Management of the quality of works performed by the intellectual system in accordance with the defined requirements.

Formation of invariants for the verification of analytical formalizations for the service of model-analytical intelligence is performed using the theory of graphs, probability theory, the theory of Markov chains, the theory of Markov and semi-Markov processes.

Techniques for generating analytical formalized model for service-oriented analytical intelligence to analyze the integration of services in three situations:

- Passive environment.
- Active environment.
- Aggressive environment.

For each of the above situations, the following is analyzed:

- Integration of a sequence of services.
- Integration of a sequence of services with feedback.
- Integration of parallel services with boolean synchronization logic.
- Integration of parallel services with the majority synchronization logic.
- Integration of parallel services with the majority synchronization logic.
- Integration of parallel services with temporal synchronization logic.
- Integration of parallel services with boolean synchronization logic and feedback.
- Integration of parallel services with majority synchronization logic and feedback.
- Integration of parallel services with majority synchronization logic and feedback.

The influence of feedback is considered in relation to the following situation:

- After some large-granular action inherent in the process of functioning of a multi-component software package of service-oriented architecture, a probable return to its implementation is activated.

When analyzing the influence, probability distribution density of execution time of service tasks in the specified situation is obtained by means of a transition to the description of the action with feedback by the Markov chain:

$$\mathbf{P} = \begin{bmatrix} 0 & f(N) & f(N-1) & f(N-2) & f(N-3) & \dots & f(1) & 0 \\ 0 & 0 & 1 & 0 & 0 & \dots & 0 & 0 \\ 0 & 0 & 0 & 1 & 0 & \dots & 0 & 0 \\ 0 & 0 & 0 & 0 & 1 & \dots & 0 & 0 \\ \dots & \dots & \dots & \dots & \dots & \dots & \dots & \dots \\ 0 & 0 & 0 & 0 & 0 & \dots & 1 & 0 \\ q & 0 & 0 & 0 & 0 & \dots & 0 & (1-q) \\ 0 & 0 & 0 & 0 & 0 & \dots & 0 & 1 \end{bmatrix}$$

where P is the square matrix of (N + 2) × (N + 2)) transitions in the set of discrete states S, | S | = N + 2, where the (N + 2)-th pseudostate is absorbing;

$$f(n) = u(k_{0,1,\dots,i,\dots,I}),\; n = k_{0,1,\dots,i,\dots,I},\; N = K_{0,1,\dots,i,\dots,I},$$

$$\sum_{k_i=0}^{K_{0,1,\dots,i,\dots,I}} u(k_i) = 1 ,$$

where $u(k_{0,1,\dots,i,\dots,I})$ is the probability distribution density of the service execution time without feedback;
$K_{0,1,\dots,i,\dots,I}$ is the maximum possible time for the service execution without feedback;
q is the probability of feedback activation.

The estimation of $u(k_{0,1,\dots,i,\dots,I,(I+1)})$ probability distribution density of service execution time with feedback is determined according to the ratio:

$$u(k_{0,1,\dots,i,\dots,I,(I+1)}) = P_{1,N+2}^{(k_{0,1,\dots,i\dots,I,(I+1)})} - P_{1,N+2}^{(k_{0,1,\dots,i\dots,I,(I+1)-1})},$$

where $P_{1,N+2}^{(k_{0,1,\dots,i\dots,I,(I+1)})}$ is the $(1,(N+2))$-th element of the $k_{0,1,\dots,i,\dots,I,(I+1)}$-th power of the matrix;
$P_{1,N+2}^{(k_{0,1,\dots,i\dots,I,(I+1)-1})}$ is the $(1,(N+2))$-th element of the ($k_{0,1,\dots,i,\dots,I,(I+1)} - 1$) -th power of the matrix.

III. CONCLUSION

The presented methodological outline extends the technological basis for the generation of intelligent service-oriented systems required to ensure effective interaction between market actors and the industries of the economy.

REFERENCES

[1] Ptitsyna L. K., Smirnov N. G. Development and Analysis of Models of Integration of Service-Oriented Agents in Heterogeneous Networks. Scientific and technical statements STU. 2011.No 6.1 (138). pp. 71–81.

[2] Ptitsyna L.K. Software Computer Networks. Managing Large-Granular Processes on the Basis of Language BPEL: Proc. Manual / L. K. Ptitsyna, N. G. Smirnov. SPb. : Univ. Polytechnic. University Press, 2011. 105 p.

[3] Ptitsina L.K., Smirnov N.G. The Analytical Basis of Service Integration in Service-Oriented Systems. *Industrial Automatic Control Systems and controllers*, 2011. no 5. pp. 31–36.

[4] Ptitsyna L.K., Smirnov N.G. Analysis of Model and Analytical Intelligence Control Systems Integration Service-Oriented Funds. *System Research in Science, Management and Education*, 2014. pp. 106–113.

[5] Ptitsyn A. V., Ptitsyna L. K. Object-Oriented Analysis of Integration of Means of Protection of Information. *The Protection of Information*, 2013, no. 1, Pp. 69–76.

[6] Ptitsyna L.K., Veselov V.O. Analysis of integration of service oriented means in active infocommunication mediums. *H&ES RESEARCH*, 2015. no. 2. pp. 42-47.

[7] Ptitsyna L.K., Kondrat'ev D.A., Elsabayar Shevchenko N.N. Intelligent profiles of service-oriented architectures. *Papers of educational institutions of communication,* 2016. vol. 2, no. 2, pp. 72-77.

[8] Ptitsyna L.K., Savlish A.V., Smirnova P.V. Analytical modeling of a service-oriented system with typical configuration of means. *Papers of educational institutions of communication*, 2016. vol. 2, no. 3, pp. 55-59.

[9] Ptitsyna L.K., Kondrat'ev D.A., Elsabayar Shevchenko N. Conceptual models of intellectualization of service-oriented architectures. *Trudy 5 MezhdunarodnoyNauchnoTekhnicheskoyINauchnoMetodicheskoyKonferentsii “Aktual’nyeProblemyInfotelekommunikatsiiVNaukeIObrazovaniya”* [Proc. 5th. Int. Conf. “International conference on advanced infotelecommunication”] St.Petersburg, 2016. pp. 108-113. (In Russian)

[10] Kondrat’ev D.A., Ptitsyna L.K., El Sabayar Shevchenko N. Simulation intelligent service-oriented systems. *Trudy1VserossiyskoyNauchno-PrakticheskoyKonferentsii “InformatsionnyeSistemyITekhnologiiVModelirovaniiIUpravlenii”* [Proc. of the St.Petersburg Electrotechnical University "LETI" 1st. Conf. “Information systems and technologies in modeling and management”] Yalta, 2016, pp. 57-60. Available at: http://istmu2016.csrae.ru/ru/1/publications (Accessed: 14 May 2016). (in Russian)

[11] Ptitsyna L.K. Methodology for generation of model-analytical intelligence for service-oriented systems with quality assurance. *Trudy6MezhdunarodnoyNauchno-TekhnicheskoyINauchno-MetodicheskoyKonferentsii “Aktual’nyeProblemyInfotelekommunikatsiiVNaukeIObrazovaniya”* [Proc. of the Bonch-Bruyevich “SUT” 6th. Int. Conf. “International conference on advanced infotelecommunication”] St.Petersburg, 2017, vol. 3, pp. 351-354. (In Russian)

[12] Ptitsyna L.K., Kondrat'ev D.A., Elsabayar Shevchenko N. Selecting a planning algorithm for intelligent service-oriented systems. *Trudy 6 MezhdunarodnoyNauchno-TekhnicheskoyINauchno-MetodicheskoyKonferentsii “Aktual’nyeProblemyInfotelekommunikatsiiVNaukeIObrazovaniya”* [Proc. of the the Bonch-Bruyevich “SUT” 6th. Int. Conf. “International conference on advanced infotelecommunication”] St.Petersburg, 2017, vol. 3, pp. 277- 282. (In Russian)

[13] Ptitsyna L. K., Smirnova P. V. Method of forming a model of service-oriented systems with temporal logic of service synchronization // *Trudy6MezhdunarodnoyNauchno-TekhnicheskoyINauchno-*

MetodicheskoyKonferentsii “Aktual’nyeProblemyInfotelekommunikatsiiVNaukeIObrazovaniya” [Proc. of the the Bonch-Bruyevich “SUT” 6th. Int. Conf. “International conference on advanced infotelecommunication”] St. Petersburg, 2017. vol.3. pp. 355- 360. (In Russian)