Some aspects of simulation application in dynamic integrated expert systems

Galina Valentinovna Rybina, Viktor Mikhaylovich Rybin, Sergei Sergeevich Parondzhanov, Soe Thi Ha Aung

National Research Nuclear University MEPhI "Moscow Engineering Physics Institute", Kashirskoye shosse, 31, Moscow, 115409, Russian Federation

Abstract. New aspects of simulation application in dynamic integrated expert systems are considered. Modern stage of simulation studies is analyzed. The problems of integration of simulation methods and tools with expert systems technology in dynamic integrated expert systems are investigated. Current version of simulation subsystem is described, including a detailed examination of the basic subsystem components and technology to construct simulation models of complex technical systems by tools of this subsystem, functioning as part of a dynamic version of the AT-TECHNOLOGY system.

[Rybina G.V., Rybin V.M., Parondzhanov S.S., Aung S.T.H. **Some aspects of simulation application in dynamic integrated expert systems.** *Life Sci J* 2014;11(8s):144-149] (ISSN:1097-8135). http://www.lifesciencesite.com. 30

Keywords: dynamic intelligent systems, dynamic integrated expert systems, task-oriented methodology, simulation, complex engineering systems, simulation subsystem, simulation model, AT-TECHNOLOGY system.

Introduction

Today results of research in various classes of dynamic intelligent systems (DIS) are urgently demanded in commercial and industrial applications and software technologies in general. This is due to the fact that in modern conditions of creation and use of high-critical technological complexes and systems of civil and military purpose, traditional technologies can no longer ensure better control and decision-making, especially in terms of increasing information risk and influence of such factors, as unexpected (abnormal) situation controlling systems operation, existing human factor, etc. [1—3]. Therefore, the actual task of a modern post-industrial society is the use of modern DIS in a wide range of applications - from spacecrafts, complex automated manufacturing and robots to technical-organizational (technical - social) systems with uncertain human factor.

It should be noted that the suitable research and implementation objects are, usually, sufficiently complex and weakly or moderately structured dynamic systems with nonlinear unstable connections, the functioning of which may be accompanied by an abundance of abnormal situations and human risks [1—3] . This is evidenced by numerous experience of exploiting different classes of the most developed DIS, such as intelligent control systems [1, 2], intelligent decision support systems [3], dynamic integrated expert system (IES) [4] and a wide range of multi-agent systems [5].

Therefore, the development of efficient models, methods and technologies of implementing complex dynamic systems is one of the most urgent problems, not only in artificial intelligence, but also in related scientific areas, such as simulation modeling, dynamic control of large distributed systems, etc., that it requires joint studies of integration processes between isolated classes of DIS and traditional software systems.

The subject of the present work is application of methods of simulation modeling to automate the process of constructing dynamic IES using task- oriented methodology [4], and supporting software (AT -TECHNOLOGY system). Scientific and practical results achieved in the theory and technology of constructing IES have been published in the monograph G.V. Rybina [4], and repeatedly described in various scientific journals.

A New Stage in the Development of Simulation Modeling

Without claiming to comprehensive and multidimensional analysis on the evolution of simulation modeling and current state of research and development in that field of scientific knowledge, we consider only the basic aspects of simulation modeling (detailed reviews are given in [6-12], and others). As shown in [6], the occurrence of the concept of simulation model (SM) in the beginning of 1990s was caused by the initiation of some terminological confusion and variety of interpretations of this concept. The matter is that the term simulation (Latin. simulation - malingering, assimilation) has entered in the domestic literature as "simulation" (Latin. imitation - imitation, simulation), which has led to the ambiguity of interpretations as it can be translated as a "simulation" in the first case, and in the second – "simulation modeling"

In reality, when it is a question about SM, there is not just modeling, it is modeling of a special kind opposed to analytical modeling in some sense related to the following requirements:

• SM should reconstitute both structure of original object and its functioning with necessary completeness;

• SM is orientated on the knowledge acquisition about a prototype, not by an analytical research or numerical computations, and with the help of “simulation experiments” on these models.

In our country, during the period from the middle of 1960s to the late 1990s numerous scientific schools have been established. They have developed the theoretical and conceptual bases of simulation modeling and created a number of original languages and software tools automating modeling (SLANG, NEDIS, STAM, AnyLogic, etc.), as well as such adapted to the domestic computer hardware modeling languages as a family of GPSS, SIMULA, GASP, CSL and others widely used for solving the applied problems. The SIMULA-67 language compiler for the BESM-6 and ES IBM is created at the Department of “Cybernetics” of the NRNU MEPhI university by using domestic REFAL language and today the SIMULA -67 language is recognized as a leading one of the first programming languages using object-oriented approach [13].

Significant “break” of domestic school of the late 1990s in the field of simulation were the development of RAO- approach (Resource-Action-Operation) led by V.V. Emelyanov [14] and the creation on its basis specialized simulation system RAO-Studio which is now widely used in the real sector of economy and in the learning process of a number of well-known universities (NRNU MEPhI, NIUMEI,MESI, etc.).

It should be pointed out that for a long time researches in the field of simulation modeling have been mainly focused on classical simulation modeling oriented to formal (especially, mathematical models) that do not allow full consideration of variety of possible variants of complex engineering systems (CES) and complex engineering and organizational systems (CEOS) [4, 6] . Therefore, formation of modern computer modeling based on the whole scientific and technological results achieved in the framework of the classical simulation modeling is closely linked with other areas of artificial intelligence, such as knowledge engineering, evolutionary and genetic modeling, integrated models and soft computing, neural networks, etc.

Basing on the analysis of [6, 7, 14] it may be noted in general that the problems of simulation modeling at present time include the following aspects:

- methodological, associated with the development of new approaches and concepts of formalization and structuring of simulated systems, as well as improvement of system modeling frameworks;
- Mathematical, based on the widespread use in simulation modeling, in particular, in procedures of simulation experiments, various statistical methods, optimization methods, decision-making methods and knowledge engineering, etc.;
- Technological (instrumental), based on the creation of specialized software tools, automation of the construction of SMs with the full use of all innovations in the field of information technology and modern programming (advanced graphics and multimedia, object-oriented programming, Web-technology, etc.);
- Applied, related to the so-called “geography" using methods and tools of simulation modeling in variousfields of public, commercial and industrial activities, etc.

Thus, today simulation modeling, experiencing a rebirth, becomes more advanced computer aided modeling technology used in a wide range of new applications related to the control and decision-making of technical, organizational, economic, social and other character in dynamic problem fields. This is evidenced by the significant volume of publications, in which the applications of methods and tools of simulation modeling in new applications such as business information systems [7], organizational and technical systems [12], etc. are described along with the use in traditional fields such as modeling of manufacturing processes [11, 14, 15], aviation [16], logistics [7, 17], and others.

The integration of simulation modeling with data mining technology (DataMining) [4] and decision support systems [18], intelligent agents [5], etc. are actively investigated. The problems of integration of simulation technology with expert systems technology were first investigated in the context of RAO - approach [14], and in the field of CAD [4], but the most complete development has been achieved within the framework of task- oriented methodology constructing dynamic IESs [4].

Features of the use of simulation modeling when constructing the dynamic IESs using the dynamic version of AT-TECHNOLOGY system [4, 19] are considered bellow in more details.

Features of Simulation Modeling the External World in the Construction of Dynamic IESs

Long-term experience of practical use of task-oriented methodology and AT-TECHNOLOGY system [4] has shown, that the applications in the which problem area is dynamic occur very often, and therefore a cycle of researches has begun and led to the creation of theory and software technology constructing dynamic IESs which operates in real time, i.e. IESs using dynamic representation of object domains and solving dynamic problems [19—20].

In the context of the further development of task-oriented methodology for other architectures of DIS, in particular, multi-agent systems also conducted researches related to the creation of simulation systems interaction of intelligent agents (IMVIA), which is currently used as a workbench developing the prototypes of multi-agent systems for dynamic problem fields.

It is important to note that the most common objects using dynamic IES were CES and CEOS, i.e. the following objects of a technical nature [4] : their parameters constantly vary (in real time); they comprise from several hundred to several thousand functionally and structurally interrelated components, subsystems, modules, units, etc.; the diagnostics of these objects can be considered as a specific control process with the goal of determining the technological state of objects at each current instant (the general task of diagnostics of the object status) and, in addition, the task of fault finding (as a special case of the general diagnostic task); the functioning of these objects is a complex technological process accompanied by a multitude of abnormal conditions, rapid changes in the environment, and the lack of time for decision-making in response to abnormal conditions; a high price is paid for errors made by operators. Therefore, the dynamic IESs for discrete and continuous-discrete CES must ensure, in the general case, support for the execution of the following tasks: the dynamic modeling of all processes of functioning the of CES; monitoring the CES operation, detection of deviations from the prescribed regime, pre-failure alerting and abnormal condition warning, emergency cut-out, etc.; studying the actions of the operators who control CES and training of personnel; a convenient graphic user interface for monitoring variations in the basic parameters characterizing CES operation, etc.

In this connection, the architecture of dynamic IES undergoes substantial changes as all basic components of static IES are practically modified, especially, knowledge base and reasoning tools, and two new subsystems are added—subsystem modeling the external world (environment) and subsystem interfacing with the physical equipment, as well as the technology of constructing dynamic IESs is significantly changed [4]. The subsystem interfacing with the external environment is necessary to obtain a constant data stream from external equipment and sensors, and the subsystem modeling the external world (environment) is intended to simulate the data stream at all stages of the life cycle of dynamic IES development.

In the context of this work, the most interest is represented by the subsystem modeling the external world, because the data it ensures uses temporal solver of the AT- TECHNOLOGY system to realize a deduction in time [20]. As the behavior of CES is necessary to consider in time in the development of IES (i.e., to establish the relationship between the parameters at different times), the essential step of the construction of IES is the testing of the components of created system at SM, that it ensures the evaluation of the availability of dynamic IES, without resorting the costly system implementation.

Basing on these objectives the most attention has attracted the concept of simulation modeling using RAO-method [14] which implements the process-oriented approach to construct SMs, that seems to be justified and appropriate in terms of the expansion of AT-TECHNOLOGY system architecture by specialized tools as subsystem simulation modeling the external world and organization of combined operation of that system with the temporal solver and other basic components of the dynamic version of AT- TECHNOLOGY system [19—20].

Main Principles and Features of the Construction of Simulation Subsystem

As shown in works [4, 19], in the architecture of the simulation subsystem, the functionality of the developed tools is divided between two global modules – the “SM development module” whose tasks are to support the development and debugging of SM and other functions requiring the visual interface, and the “SM computation module” ensuring the computation of the conditions of SM in each time step (cycle) of modeling time during a simulation experiment.

The development of a powerful full-featured high-level language to describe the SM and the creation of a corresponding compiler for that language are the unifying conceptual framework for the two basic modules. To implement this approach, at the first stage of the researches, formalism RAO is used as a language to describe the SM, the basic version of which is given in [14], but in the future, based on the analysis of current requirements to design models of the external world to create dynamic IESs developed a special language “RAO^{AT}” including new conceptual changes associated with object -oriented language and significant technological expansions due to the addition of new instructions and data storage structures [19—20].

The basic concept of the creation of RAO^{AT} language is its full object orientation, and therefore, such basic principles of object-oriented language, as encapsulation, inheritance and polymorphism are implemented. From the standpoint of encapsulation should be noted that into the language were entered modifiers for resource types that allow to describe the internal logic of resource types that change the state of the resource attributes according to some conditions (logical or temporary). Also entered the internal attributes of the resource types that are not available for changing by operation templates, that it significantly reduces the effort required in the design and development of SM containing a set of resource types that are represented by sets of an arbitrary number of instances by transferring the description of variation of resource conditions from the operation templates to the state modifiers of resource types.

Inheritance and polymorphism in the RAO^{AT} language are represented with the ability to inherit one type of a resource from another and override the implementation of the state modifiers of a resource in the process of inheritance that can largely simplify the SM containing the sets of structurally similar resources.

Basic principles and implementation features of the several versions of simulation subsystem in the context of the proposed approach have been repeatedly described in different papers, in particular [19—20]. In general, it should be noted that such basic requirements, as the ability to create new objects and resource types on the basis of finished, the ability of developing model base through the development of resource types library, the efficiency in developing and maintaining complex SM (hundreds or thousands of objects and resource types, well-developed logic), the description language of SM allowing to construct SM by specialists on simulation modeling rather than programmers and the efficient ways to integrate with third party software, were considered when developing the subsystem.

Another important feature is related to the "SM development module" ensuring the user (knowledge engineer and / or specialist on simulation modeling) by convenient visual editor that allows to operate graphical objects and relationships between them within the concept of RAO-method. Meanwhile, a code generation of the model in RAO^{AT} language occurs (established resource types, resource templates operations, etc.). Result of the visual design of the model is the description of the model in RAO^{AT} language. The tools of this module allow you to construct a model of the outside world for dynamic IES using visual, flexible, extensible, repeated-used objects (resource types). The ability to increase the life cycle of SM by rapid adjustment to changing conditions, when solving of which require both high and low levels of abstraction, is achieved due to an unlimited nesting of resource types and inheritance .

Composition and structure of the "SM development module" and the "SM computation module" functioning in the structure of the current version of simulation subsystem (dynamic version of the AT-TECHNOLOGY system) are briefly considered bellow.

Composition and Structure of the Basic Components of Simulation Subsystem

General architecture, composition and structure of the basic components of the current version of simulation subsystem are shown in (Fig.1), detailed description of which is given below.

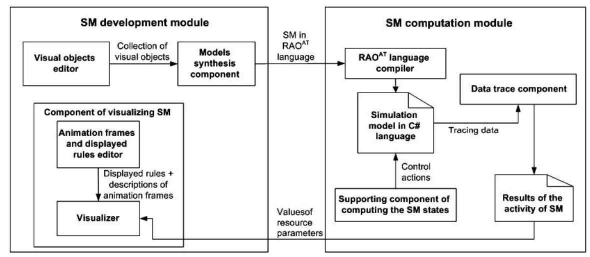

Fig. 1: General Architecture, Composition and Structure of the Basic Components of the Current Version of Simulation Subsystem

Visual Objects Editor

The component "Visual objects editor" allows you to create objects, setting their properties and attributes, as well as establish relationships between the model objects in graphical mode. Knowledge engineer and / or specialist on simulation modeling, operating with the models editor, designs SM on graphic canvas containing a predetermined number of various objects, at that the ability to create, delete, copy objects and set relationships between them is ensured. The values of a particular set of properties are able to change for each object. The created visual representation of SM and properties of all objects are stored in the memory of the editor, as well as in a separate text file, which is further processed by the RAO^{AT} language compiler. This visual tool allows you to load a saved SM to update the visual presentation and insert the changes manually to obtained code which is described in RAO^{AT} language.

Models Synthesis Component

The models synthesis component, interacting with the visual objects editor by processing the stored collections of objects, generates a description of SM in RAO^{AT} language in XML format which is passed to the RAO^{AT} language compiler.

Component of Visualizing SM

Knowledge engineer, if necessary, with the support of the "Animation frames and displayed rules editor" selects the description of the model in RAO^{AT} language and makes animation frames for corresponding objects, and the tool "Visualizer" based on the values of resource parameters, descriptions of animation frames and displayed rules ensures drawing the animation frames.

RAO^{AT} Language Compiler

The obtained description of SM in RAO^{AT} language is passed to the input of the "SM computation module" where the compilation from RAO^{AT} language to C# language occurs and the further interpretation and run the developed model (Fig. 1). The kernel of the "SM computation module" is the "RAO^{AT} language compiler" which structure has a standard form for the syntax-driven three-pass compiler. This compiler consists of an analyzer which includes components of the lexical, syntactic and semantic analysis, and synthesis component including a generation component of output code. Features of the implementation of several versions of the RAO^{AT} language compiler are described in detail in [20]. It should be noted that the availability of such objects in the RAO^{AT} language, as irregular events and temporary resources, requires the time coordination with each object of the model. Each object has its own internal timer showing within the modeling time scale, how much time obtains an object. In addition, this timer is associated with the total time of an activity of the SM for a corresponding pause during transferring and obtaining the data from the working memory of the temporal solver.

Supporting Component of Computing the SM States: The "Supporting component of computing the SM states" ensures the generation of a discrete modeling time, as well as the generation of the control actions used to start or stop the activity of SM in the form of messages on each discrete time step. Computation of the new state of SM is based on the state at the previous time step and an allowance of executed operations.

It is important to note that the achieved version SM in the form of .dll is intended for further application in the process of prototyping of dynamic IESs [20]. Single-purpose component "Timer" of AT-TECHNOLOGY system which obtains an input SM in the form of ".dll" ensures the synchronization of the processes of interaction between simulation subsystem and reasoning tools (temporal solver and AT-solver).

As the temporal solver, as well as the SM, operates on time step, the interaction is realized through the exchange of data and commands in asynchronous mode [20]. At the end of each time step of the activity of SM, data transferring to the solver through the working memory is realized. The obtained data initializes a new reasoning cycle. From now the solver has a certain time quantum allowing the deduction for urgent situations. The resulting urgent commands (the deduction of which had time to execute within the time limit) are used at the next time step of SM. Not considered urgent and common situations are processed before the end of the next time step and used through a time step of the activity of SM. In case of obtaining new data from SM a deduction is processed and delivered an interim solution. The next time step of the activity of temporal solver does not depend on the place where the deduction of previous time step has broken down.

Conclusion

Thus, the further development and deep integration of the methods of simulation modeling with the methods of constructing dynamic IESs in the context of task- oriented methodology as a unified framework ensuring the complex decision for scientific and applied problems related to the construction of different classes of dynamic IESs, allowed to create an approach that does not have analogues today. This approach has been successfully implemented in the framework of the dynamic version of AT- TECHNOLOGY system and has already proven its efficiency in the implementation of the prototypes of applied dynamic IESs.

Acknowledgment

This work was supported by the Russian Foundation for Basic Research, project no. 12-01-00467.

Corresponding Author:
Dr.Rybina Galina Valentinovna
National Research Nuclear University MEPhI "Moscow Engineering Physics Institute"
Kashirskoye shosse, 31, Moscow, 115409, Russian Federation

References

1. Makarov, I.M., V.M. Lohin, S.V. Manko and M.P. Romanov, 2006. Artificial intelligence and intelligent control systems. Moscow: Publishing house "Science ", pp: 333.
2. Rybin, V.M., 2011. Intelligent control based on dynamic integrated expert systems.

Information-measuring and control systems, 6: 16-19.
3. Bashlykov A.A. and A.P. Eremeev, 2013. Semiotic systems for real-time intelligent decision support in the management of complex technological objects. Information-measuring and control systems, 5: 49-57.
4. Rybina, G.V., 2008. Theory and technology of integrated expert systems. Monograph. Moscow: Publishing house "Nauchtehlitizdat", pp: 482.
5. Tarasov, V.B., 2002. Of multi-agent systems for intelligent organizations: philosophy, psychology, computer science. Moscow: Publishing house "Editorial URSS", pp: 352.
6. Plotnikov, A.M., Ju.I. Ryzhikov and B.V. Sokolov, 2011. Current state and development trends of simulation in the Russian Federation. Fifth All-Russian Scientific and Practical Conference on simulation and its application in science and industry "Simulation. Theory and practice". Collection of reports. (issue 1), Saint Petersburg: Publishing house "JSC Center for Technology and shipbuilding", pp: 55-61.
7. Lychkina N.N., 2012. Innovative simulation paradigms and their application in the field of management consulting, logistics and strategic management. Modern control technology logistics infrastructure - III: Collected articles. Moscow: Publishing house "S-C-M Consulting", pp: 9-28.
8. Averill, M. and W. Kelton, 2000. Simulation modeling and analysis. 3rd ed. McGraw-Hill,Inc., pp: 760.
9. Banks, J., 1998. Handbook of Simulation: Principles, Methodology, Advances, Applicationsand Practice. Wiley, pp: 864.
10. Pidd, M., 2004. Computer simulation in Management Science. 5th ed. Chichester: Wiley, pp: 328.
11. Seidel, S., U. Donath and J. Haufe, 2012. Towards an integrated simulation and virtual commissioning environment for controls of material handling systems. Proceedings of the 2012 Winter Simulation Conference. Published in Simulation Conference (WSC), pp: 2852 - 2863.
12. Fougères, A., 2011. Modelling and simulation of complex systems: an approach based on multi-level agents. IJCSI International Journal of Computer Science Issues, 1: 8-17.
13. Kibernetika: gody, ljudi, sobynija. Cybernetics: the years, people, events. collective monograph. Ed. GV Rybina., 2013. Moscow: Publishing house "Radiotechnics", pp: 376.
14. Emel'janov, V.V. and S.I. Jasinovskij, 1998. Introduction to intelligent simulation of complex discrete systems and processes. RDO language. Moscow: Publishing house "Anvik", pp: 533.
15. Rath, G., M.L. Jürgen and W. Waldhauser, 2012. Embedded simulation for automation of material manipulators in a PVD coating process. Proceedings of the 2012 Winter Simulation Conference. Published in Simulation Conference (WSC), pp: 2842 -2851.
16. Vishnjakova, L.V., O.V. Degtjarev and A.B. Slatin, 2011. Simulation modeling of the operational functioning of complex aircraft systems and facilities management. Fifth All-Russian Scientific and Practical Conference on simulation and its application in science and industry "Simulation.Theory and practice". Collection of reports. (issue 1), Saint Petersburg:JSC "Center for Technology and shipbuilding ", pp: 30-41.
17. Toluev, Ju.I., 2008. Simulation modeling of logistics networks. Logistics and Supply Chain Management, 2(25): 53-63.
18. Trahtengerc, J.A., 1998. Computer decision support. Moscow: Publishing house "SINTEG", pp: 376.
19. Rybina, G.V., 2010. Tools for constructing dynamic integrated expert systems: the development of AT-TECHNOLOGY complex. Artificial intelligence and decision making, 1: 41—48.
20. Rybina, G.V., A.V. Mozgachev, S.S. Parondzhanov and S. Aung, 2013. Dynamic integrated expert systems: methods of representation and processing of temporal knowledge. Instruments and Systems. Management, monitoring, diagnostics, 6: 63-73.

5/12/2014