Methods and Algorithms of Integrated Modeling of Complex Technical Objects in Dynamically Changing Conditions

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***Abstract*— The paper analyzes the main problems and features of complex modeling of composite objects and regards existing and future methods and approach for the implementation of this type of modeling. Examples of practical implementation of complex modeling technologies in relation to the problems of synthesis proactive spacecraft control systems, as well as multi-criteria evaluation and analysis of production plans of shipbuilding enterprises are given.**

Keywords*— *complex modeling; complex objects; coordination of models; simulation systems; hybrid modeling

I. INTRODUCTION

At present, the limited capabilities of existing tools for modeling composite objects (CMO), including composite technical objects (CTO), have contributed for the joint application of traditional and new (intelligent) models and relevant modeling technologies, i.e. the transition to the concept of integrated (system) modeling [1, 7, 15]. At the very beginning of its existence in our country and abroad (70-80-ies of the last century), the key concepts and technologies of complex modeling were best implemented within the so-called imitation systems (IMS), which achieved a deep combination of simulation and analytical approaches to modeling, full use of the mathematical apparatus, computers and creative thinking of man [1, 14, 19].

Currently, the term **IMS** is disclosed as a specially organized modeling complex consisting of the following elements: a) simulation model (SM) (hierarchy of simulation models), reflecting a certain problem area; b) analytical models (AM) (hierarchy of analytical models), giving a simplified (aggregated) description of the various aspects of the simulated phenomena; c) information subsystem, including the database of data (data bank), and in the future – knowledge base, relying on the ideas of artificial intelligence; d) control and interface system, which provides interaction of all components of the system and work with the user (decision maker) in the interactive dialogue mode [1, 15]. Let us consider the main features of the organization and implementation of complex modeling of CMO in comparison with the existing traditional approaches to modeling.

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II. PECULIARITIES OF COMPLEX MODELING

The first and, perhaps, **the most important feature** of complex modeling (CM) is the essence of coordination at conceptual, model-algorithmic, information and software layers of the models, methods and algorithms used. At the same time in general along with the actual model agreement in solving the problems of analysis and synthesis of CTO intermodel and (or) intramodel coordination of criteria functions (performance indicators, quality indicators, objective functions, etc.), providing basis for comparison and selection of alternative solutions [10, 13, 22] should be carried out. Speaking about such a widespread type of CM as analytical-simulation modeling (ASI) the choice of principles, methods, models and algorithms for matching these models in each case is determined by the research objectives. For example, when solving some problems, it is advisable to use analytical modeling (at the algorithmic level) inside simulation modeling to find acceptable options for changing exogenous variables [11, 15].

In another case, on the contrary, IM is used to clarify the relaxed solutions obtained on AM. The mentioned inclusion of one class of models as a block in the composition of another class of models can be used at a high frequency of numerical implementations of relatively small-dimension problems, which, due to the smoothness of procedures, do not require participance of decision making person (DMP) and are carried out automatically.

The paper [19] contains examples implementing multi-criteria analytical-simulation inter-model coordination, carried out by defining the Pareto set using the fundamental large-size multi-criteria model of discrete optimization, narrowing this set based on machine analysis of its properties and the introduction of relevant information during the interactive procedure performed by the DMP, the person justifying the solution (PJS) with a computer, as well as by using additional mathematical models, providing further refinement and narrowing of the Pareto set up to the adoption of a single decision. The Pareto matching principle, provided that it is supplemented with provisions on the narrowing of the Pareto set, provides the most favourable opportunities for making fully justified decisions based on the analysis of the behavior of various performance indicators within this set. It is important to develop a proper strategy of narrowing with the involvement of competent professionals and analytical and simulation mathematical models.

The paper [23] suggests the methodological approach of removing the criteria uncertainty in the evaluation of the efficiency of production plans of shipbuilding enterprises, caused by the variety of linguistically specified performance indicators. The additional DMP is represented by production models and processed using parametric fuzzy measures and methods of the experiment planning theory. Implication of the proposed approach allows to fully consider the logics behind decision maker's preference on criteria for achievement of the goal and calculate comprehensive performance evaluations that flexibly take into account the advantages and disadvantages of compared production plans.

The advantages of joint use of AM and IM in the complex study of CTO are manifested not only in the planning stage of machine experiments and their complex models, but also in the processing and analysis of the results of machine experiments. E.g., correlation between the results of simulations on a simplified AM and the exact AM allows to apply a significant reduction in the number of IM implementations can be achieved to obtain a given accuracy of estimates of endogenous variables. Therefore, combined (analytical and simulation) methods for determining the probability characteristics of systems are being intensively developed.

The analysis shows that each of the listed options of methods of organization of CM based on AM and IM has advantages and disadvantages, and their choice is determined by the peculiarities of specific subject area where the CTO operates, its limitations, as well as the research objectives. A more detailed analysis of the coordination of the composite object AIM is discussed in papers [18, 22] within the developed theory of quality evaluation (qualimetry of models and polymodel complexes).

Speaking about the possible specific ways of coordination of mathematical (analytical-simulation) models of decision-making with their logical-algebraic and logical-linguistic analogues (models), built on the basis of IIT, it is advisable to focus on the results obtained to date in the field of hybrid modeling (HM), which is one of the varieties of CM. Speaking about the type of modeling we should emphasize that it is based on the combined use of such modern information technology as expert systems or systems based on knowledge (Knowledge-Based Systems); technologies of fuzzy logic (Fuzzy Logic); technologies of artificial neural networks (Artificial Neural Networks); technology of the conclusion based on precedents (Case Based Reasoning, CBR); technologies of natural language systems and ontology; associative memory technologies; cognitive mapping and operational coding technologies; evolutionary modeling technologies; multi-agent modeling technologies [5, 6, 8, 9].

The existing technological gap between the bionic intelligence of artificial neural networks (ANNs) and the intelligence of logical inference systems is being reduced through the creation of fuzzy-neuro-genetic information technologies and tools. Along with hybrid intelligent technologies (HIT), the brella term "soft computing" is widely used, which was introduced in 1994 by Professor L. Zadeh and is interpreted by the following formula: Soft computing = fuzzy systems + neural networks + genetic algorithms.

This soft computing is implemented by the corresponding soft intellectual system, which should be coordinated with the technology of uncertainty management, learning technology and self-organization. The typical procedure of functioning of the latter system includes [6,8]: transformation of input parameters (situations) into a fuzzy representation; extraction of the knowledge presented in the form of productions IF-THAT from fuzzy training sample by means of a neural network; optimization of production rules by means of genetic algorithm. Thus, due to the integration of the listed IIT, fuzzy neural networks are trained as neural networks, but their results are explained as in fuzzy inference systems. There are also options for training neural networks to adjust already trained networks using genetic algorithms (GA). The advantage of such interaction of IIT is that unlike the method of back propagation, GA errors are not sensitive to the network architecture. In general, according to the results of studies carried out in the field of hybrid intelligent systems, several directions of integration of the methods and technologies are discussed, which are presented in the table. 1.

It is important to emphasize [5, 19] that the integration of the proposed models, methods and technologies within the CM is carried out at the ***deep*** and not at the ***external*** layer, where different system components implement a single method of solving intellectual problems and interact with each other. The deep level of association involves the creation of new methods that use the constructive (formal) level of description of the concepts and relationships of the combined simple methods.

The second feature of CTO complex modeling is the mandatory assessment of the correctness of the coordination of different types of models, as well as a preliminary analysis of the existence of solutions to the relevant problems of modeling. The essence of studying this problem is a kind of payment for the completeness and adequacy of the representation of the layer by a polymodel complex.

It is necessary to note one more complex modeling feature, which implies the demand for modern modeling automation tecniques on each modeling stage. In other case the CM will become impossible because of very large expenses of time, money and other resources which need to be allocated each time. At present more than 400 languages of automation model and corresponding automation systems model exist [18, 20, 21]. The advantages and disadvantages of national and foreign tools and modeling automation environment (MAE) were repeatedly discussed at the previous IMMOD conferences. GPSS, AnyLogic, BpSIM, PowerSim, simplex, module vision Triad.Net, CINCH, ESimL, Simulab, NetStar, Piligrim, BRIDGE, KOGNITRON, etc. are the most often discussed MAE tools during previous conferences.

Speaking of the means of automation of complex modeling, it should be noted that, unfortunately, they are either focused on the solution of narrowly specialized classes of applied problems with the wide functionality of the services provided [14], or they are rather universal means of modeling automation, in which the coordination of different types of models, methods and algorithms for analysis and synthesis of CTO is carried out not at the deep (model-algorithmic) level of description, but through the DMP in an interactive mode at the level of software and information support [20]. In other words, in the latter case there is interactive, but not integrative interaction, which does not provide the appearance of synergetic effects in the form of the emergence of new knowledge obtained in integrative complex modeling.

III. Conclusion

The conducted research has shown that the required level of adequacy, reliability and accuracy of modeling CTO demands implication of modern methods and technologies of complex modeling. The main advantage of this type of modeling is that due to the polymodel (multi-model) description of each specific subject area under study and the corresponding coordination of different types of models, methods and algorithms of analysis and synthesis of CTO at the formalized (deep) level of description, it is possible, firstly, to compensate the shortcomings and limitations inherent in each particular class of models, methods and algorithms, and, secondly, to obtain a synergetic effect from their integrative use, expressed in the formation of new knowledge about CTO and its behavior.

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