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Multiple models of information fusion processes: Quality definition and estimation

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ABSTRACT

Now problems of a multi-criteria quality estimation of models as well as a justified selection of task-oriented models are still not investigated thoroughly enough. The importance of the problems increases when a research object is described not via a single model, but with a set or a complex of multiple models including models from different classes or combined models such as combined analytical-simulation models, logical-algebraic ones, etc. The aforementioned problems are being investigated within the theory of model quality control. The description of main elements of this theory and its applications is the primary goal of the paper.

1. Introduction

In the last decades, the problems connected with product quality testing have become the subject of intensive investigations in a new scientific field, quality science. One of the main branches of this science is qualimetry that develops methodological backgrounds for the quantitative estimation of product quality [4].

The central concept of both quality science and qualimetry is the concept of quality. The concept involves, according to the ISO 8402-2000 international standard, a totality of characteristics of an object that determine its capability to satisfy the established or supposed requirements [3,4]. In the field of designing and applying new information technologies, the investigations devoted to estimation of the product quality have been conducted for a long time; their results have been reflected in the international standards and GOST [8,15]. For example, the international standard ISO 9126:1991 “Information technology. Evaluation of software products. Quality characteristics and a manual for their application” [4,7] and the subsequent standards (ISO 9126:1–4, ISO 14598-1–6: 1998–2000) contain models, indices, criteria and metrics of the quality of software tools and products [8,15].

Currently methodological tools of quality evaluation are carefully specified for computer models and programs [7,8,15]. Due to that, the development of tools for evaluating the quality of methods, models, algorithms and methodologies is very topical, especially at early stages of modeling original objects.

It is worth noting that, in the field of investigating the quality of models, many scientific and practical results connected with both qualitative and quantitative estimation and analysis of model properties [6,16,28] and the choice (synthesis) of models have already been obtained [13,25,29]. For different application domains, specific theories and technologies of modeling have been designed. In addition, a large number of bases of typical models and poly-model systems have been developed and are widely used in practical investigations [1,9,30,35,37].

At the same time, even though a large number of various models exist, the problems of substantiated choice of models, their comparison, arrangement and comparative analysis of different modeling technologies are still unsolved [1].

Moreover, at present there is an urgent need for ready-to-use information technologies similar to programming-free software products [34]. To solve all the specified problems, theoretical backgrounds for evaluating and analyzing the quality of models and poly-model systems have to be developed.

The results of investigations in the field of model quality control are very important for substantiated choice of structure and contents defining multiple-model complexes in different

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areas. In our case we use these results for structure-functional synthesis of multimodal interfaces in man-machine systems [1,9,13,21,25,29,30,32,34,35,38]. The main problem of these systems is connected with information fusion from different types of input devices (e.g., an eye-gaze, a gaze-speech and manual-gaze-speech input devices). This paper proposes the methodological backgrounds for qualimetry of models to be used in integration of data and knowledge from multi-model interfaces in man-machine systems.

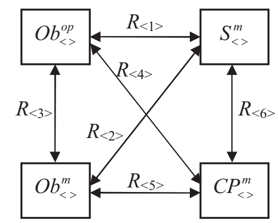

Fig. 1. All possible interrelations of objects and subjects of modeling.

2. The main tasks and results of investigation

2.1. Problem A. Investigation overview and related work

The presented considerations show that the problems of estimating the quality of models, analyzing, ranking their classes, reliably synthesizing new models, or choosing existing models for particular tasks are still unsolved. Besides, their topicality grows when the investigated object is described by a poly-model system, containing diverse and combined structures estimated by their own indices [1,2,18,21,30,33]. Additional complexity arises when the *time factor* should be taken into account. This is mainly true for original objects that, due to some reasons (objective, subjective, internal, external, etc.), have structural dynamics [20]. To ensure model adequacy, its parameters and structures have to be adapted to changeable conditions [1,18,19,21,30,33]. For this purpose, in advance, at the stage of model synthesizing, it is necessary to add additional elements in the composition of its parameters and structures to provide redundancy. In the further application, these elements will allow controlling the model quality and reducing the model sensitivity to variations in the composition, structure and content of the source data. However, in the authors' opinion, to constructively solve the general problem of evaluating and controlling the quality of models, the following groups of problems have to be investigated: *to describe, classify and choose a system of indices that evaluates the quality of models and poly-model systems; to develop a generalized description (macrodescription) of various classes of models (macromodels) that allow one, first, to establish interrelations and correspondences between the types and kinds of models and, second, to compare and rank them, using various metrics; to develop combined methods for estimating model quality indices of numerical and non-numerical (nominal and ordinal) scales; to develop methods and algorithms for solving problems of multicriteria analysis, ordering, choice of the most preferable models (poly-model systems) and control of their quality; and to develop the methodological backgrounds for multicriteria analysis and synthesis of technologies for integrated (system) modeling of complex objects.*

In the authors' opinion, the specified problems and the methodological backgrounds for their solution, supplemented by the development of the conceptual and methodological basis, can be regarded as components of a new applied theory, which will be called herein *qualimetry of models (modelmetry)* [20]. Let us consider in detail the most important aspects characteristic of the qualimetry of models and poly-model systems.

The concept of model is widely applicable in natural human languages and is a general scientific term. It is characterized by polysemy that is brightly expressed and reflects different meanings of this concept depending on applications and contexts. At present, there are several hundred definitions of the concept of a model and modeling [6,22]. Let us present some of them [6,19,21,26–28,30,33]. For example, a model is a system whose investigation is a tool for obtaining information about another system; a model is a method of knowledge existence; a model is a multiple-system map describing the original object and including together with absolutely true content conditionally true and false content, which reveals itself in the process of its creation and practical use; modeling is one of the stages of cognitive activity of a subject, involving the development (choice) of a model, conduction of investigations with its help, obtaining and analyzing the results, production of recommendations on the further activity of the subject and estimation of the quality of the model itself as applied to the solved problem and taking into account specific conditions.

The analysis of the listed definitions implies that each correctly designed model contains objective truth (i.e., to some extent, it correctly reflects the original object) [22,26]. At the same time, due to the finiteness of the designed (applied) model (a limited number of elements and relations that describe objects belonging to infinitely diverse reality) and limited resources (temporal, financial and material) supplied for modeling, the model always reflects the original object in a simplified and approximate way. However, the human experience testifies that these specific features of a model are admissible and do not oppose the practical solution of problems. In the course of modeling, it is advisable to distinguish the following basic elements and relations: first, a subject or subjects ($S^{m}_{<>}$), an original object ($Ob^{op}_{<>}$), model-object ($Ob^{m}_{<>}$), an environment ($CP^{m}_{<>}$) in which the modeling is performed; and, second, binary relations between the listed elements $R_{<1>}(Ob^{op}_{<>}, S^{m}_{<>})$, $R_{<2>}(S^{m}_{<>}, Ob^{m}_{<>})$, $R_{<3>}(Ob^{op}_{<>}, Ob^{m}_{<>})$, $R_{<4>}(CP^{m}_{<>}, Ob^{op}_{<>})$, $R_{<5>}(CP^{m}_{<>}, Ob^{m}_{<>})$ and $R_{<6>}(CP^{m}_{<>}, S^{m}_{<>})$. The subscripts "< >" mean the personal names of objects (subjects) and relations [27]. The authors assume that subjects of modeling belong to these classes of social subjects: decision makers (DM); persons that substantiate the decisions (PSD); experts; persons who use the models; and persons who design the models, (for reading convenience, the complete list of denotations is given in Appendix A). Fig. 1 shows possible variants of the interrelation between the listed elements and relations between them.

One of the main specific features of original objects (real or abstract) is their complexity [1,25] that reveals itself in the form of *structural complexity, complexity of functioning, complexity of the choice of behavior* and *complexity of development*. Therefore, to describe such objects, several models should be used, rather than a unique model. In other words, we should perform *system modeling* (poly-model description of the application domain) [1]. Another specific feature of the state-of-the-art modeling consists in considerable intensification of works in automation of modeling process and, first of all, in the phase connected with the design of a computer model [1,8,13,30]. Moreover, within the framework of new information technologies based on the concepts of knowledge bases, the concept of "model" has considerably extended the limits of its application - from the field of passive informational resources to the field of active ones. Under these conditions, algorithms that are elements of procedural knowledge turn into operating environments providing the problem solution in the language of models. The most important components of the conceptual basis for qualimetry of models and poly-model systems are their properties. Due to that, in what follows the main properties of models that should first be evaluated in their comparison and choice are outlined.