METHODS OF COMPUTER-AIDED DESIGN OF SPACE SYSTEMS

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Abstract: This article reviews the basic statements of using apparatus of mathematic Category Theory in the theory of Computer-Aided Design of space systems and conceptual mathematical models (categories) for the phase of conceptual modeling. We present a formal description of a general conceptual representation, which specifies the structure of the system knowledge at different levels of abstraction, and the conceptual view of the subject task, which is determined by the construction of a system of knowledge for a specific subject area.

Keywords: Computer-Aided Design, Category Theory, Conceptual modeling.

Introduction

Main trends of scientific and technological progress require improvement in the qualitative and quantitative characteristics of the projected space systems with an increase in the productivity of a designer and it is one of the main reasons why the theory and methods of Computer-Aided Design (CAD) of space systems have reached a completely new level. It should be noted that the basis for this is the theory of Computer-Aided Design Systems (CAD/CAM) [1–3].

The experience of development and exploitation of CAD/CAM of space systems showed that despite the big costs, connected with the creation of object-oriented CAD/CAM, these systems pay off fairly quickly. This is primarily due to a sharp increase in the productivity of designers and increased quality of projects.

The theoretical basis provides ideological unity, the completeness of solved tasks, the optimality of the separation of functions. The difficulty of its development is explained by the impossibility of solving the problem by simple translating into the "machine language" of traditional methods and design techniques that are focused on the creative, heuristic nature of human work. It is necessary to develop a formalized theory of CAD and operation of space systems, their mathematical models (MM), which play the role of objects of Computer-Aided Design, processing methods of these models focused on machinery, numerical processing and using possibilities of modern applied mathematics. MM and developed techniques must satisfy incompatible requirements of accuracy, versatility, efficiency and simplicity.

It follows that the problem of development of theoretical provisions and development of methods of the theory of computer-aided design object-oriented CAD/CAM is relevant.

Direction of development of the theory of Computer-Aided Design

Nowadays one of the directions of the development of the theory of CAD is the addition methods of mathematical Category Theory (CT) to the theory of CAD [4, 5]. The application of CT makes it possible to present explicitly and compactly all the main points of the theory of CAD. For example, objects of a specific category (formal MM) correspond to technology artifacts. Many technological processes are represented in the form of morphism.

The possibility of generation of sequences of mappings into formal MM was taken as the basic position of the methodology of automation of intellectual labor. These mappings were created in advance and have three levels of abstraction (abstract, object, concrete) of conceptual models.

In this article the results that correspond to the stage of conceptual modeling are presented.

Conceptual modeling

The development of conceptual and mathematical models (CMM), or categories for the stage of conceptual modeling, which serves as the basis for representation of the system knowledge design task included the following tasks [6]:

- detection of theoretical, methodological and practical grounds;
- evaluation of the structure and composition of the CMM;
- detection of dependencies that arise during the formation and integration of the CMM.

As a result of the analysis, it was shown that the base of methodological justifications consists of:

- methodology of creation of CAD/CAM, the basis of this is that the quality of automated design of a complex system directly depends on the quality and interaction of design, technological and production environments;
- the structure of the abstract problem of the projected complex system, which is a construction that enables the presentation of any process of Computer-Aided Design with a specified degree of detail;
- knowledge theory.

As a result of the research, the base of theoretical justification was determined:

- mathematical Category Theory
- artificial intelligence theory
- concepts theory.

The results of conceptual modeling of complex systems contain three levels of abstraction— abstract, objective and concrete.

At the abstract level, a general representation of knowledge systems is provided.

At the object level, the subject area is provided by representations of the specificity of knowledge systems.

At a particular level, the factographic information is used.

In this research, the model at any level of abstraction is the main primary information. The models are presented as mathematical categories.

The set of representations of conceptual models consists of two parts: a common conceptual representation (CCR) and the conceptual representation of the subject task (SRST). The structure of the knowledge system at different levels of abstraction is set using the CCR, and the construction of a knowledge system for a particular subject area is determined using the CRST. Conceptual models of all 3 levels of abstraction, which are interconnected by component, belong to the CCR. Conceptual models of the object and concrete levels of abstraction, which are also interconnected by component, belong to the CRST. Each of the representations is considered in more detail below in the article.

CCR can be expressed as

$$CCR = \left(CCR_1, CCR_2, CCR_3\right) \quad (1)$$

Here, CCR_1 – abstract level, CCR_2 – object level, CCR_3 – concrete level.

CCR_i at the i-th level of abstraction can be expressed as

$$CCR_i = \left(Ob\_CCR_i, Mor\_CCR_i\right) \quad (2)$$

Where, Ob_CCR_i – the set of models at the i-th level;
Mor_CCR_i – the set of morphisms at the i-th level;
$Mor\_CCR_i = S\_CCR_i \cup D\_CCR_i$;
$S\_CCR_i = \left(B\_CCR_i, P\_CCR_i, B\_CCR_i\right)$ – static relations at the i-th level; $B\_CCR_i \subset Ob\_CCR_i \times Ob\_CCR_i$ – binary relations on Ob_CCR_i;
P_CCR_i – scheme on Ob_CCR_i;
$BP\_CCR_i \subset P\_CCR_i \times P\_CCR_i$ – binary relations on P_CCR_i; $D\_CCR_i = \left(V\_CCR_i, BV\_CCR_i\right)$ – dynamic relations on objects;
V_CCR_i – restrictions of the i-th level of abstraction;
$BV\_CCR_i \subset V\_CCR_i \times V\_CCR_i$ – binary relations on V_CCR_i.

Restrictions reflect the existence of mappings (morphisms):

$$f : Ob\_CCR_i \to V\_CCR_i \quad (3)$$

The presence of a non-empty ensemble of dependencies for the formation of models is based on the following fundamental positions:

– the directions of the processes of cognition, from specific observations to abstract thinking, from general to selected, from abstract to particular;
– the law of the negation of negation, analysis of specific, synthesis of a single;
– the law of cyclicality of scientific knowledge.

The abstraction mechanism is the base for the existence of relations between the cmm on the ccr of different levels of abstraction.

The transition from the general level to the particular one can be expressed as

$$CCR_i \to CCR_{i+1} \quad (i = 1,2) \text{ i. e.} \tag{4}$$

$Ob\_CCR_i \to Ob\_CCR_{i+1}$, $B\_CCR_i \to B\_CCR_{i+1}$, $P\_CCR_i \to P\_CCR_{i+1}$,

$BP\_CCR_i \to BP\_CCR_{i+1}$, $V\_CCR_i \to V\_CCR_{i+1}$, $BV\_CCR_i \to BV\_CCR_{i+1}$.

The methods of relational algebra are the justification of the interconnection of categories at different levels.

A procedure called a "natural connection" is expressed for any objects A_1 and A_2 as $A = A_1 \bullet A_2$. The use of this operation makes it possible to obtain new information from the initial relations.

From these facts, one may conclude that

$B\_CCR_{i+1} = Ob\_CCR_i \bullet Ob\_CCR_{i+1} \bullet B\_CCR_i$,

$S\_CCR_{i+1} = S\_CCR_i \bullet B\_CCR_i \bullet B\_CCR_{i+1}$ – for a set of static operations,

$BV\_CCR_{i+1} = V\_CCR_i \bullet V\_CCR_{i+1} \bullet BV\_CCR_i$ – for a set of dynamic operations.

On this basis, one can define laws of transition from the CMM that belong to the abstract level to the CMM that belong to the object level, and the CMM that belong to the object-level to CMM that belong to a concrete level.

CRST for the n-th task is represented in the following form:

$$CRST(n) = (CRST_2(n), \{CRST_3(n)\}) \tag{5}$$

Here, $CRST_2(n)$ – CMM n-th substantive tasks at the object level of abstraction;

$\{CRST_3(n)\} = (CRST_{31}(n), CRST_{32}(n), ..., CRST_{3k}(n))$ – CMM for the k-th realization of the n-th subject of the task;

$$CRST_2(n) = Ob\_CRST_2(n) \cup Mor\_CRST_2(n) \qquad (6)$$

Where, $Ob\_CRST_2(n)$ – subject entities;

$Mor\_CRST_2(n) = S\_CRST_2(n) \cup D\_CRST_2(n)$ – set of morphisms;

$S\_CRST_2(n) = (B\_CRST_2(n), P\_CRST_2(n), BP\_CRST_2(n))$ – set of static relations on objects;

$B\_CRST_2(n) \subset Ob\_CRST_2(n) \times Ob\_CRST_2(n)$ – set of binary relations on $Ob\_CRST_2(n)$;

$P\_CRST_2(n)$ – -set of schemes on $Ob\_CRST_2(n)$;

$BP\_CRST_2(n) \subset P\_CRST_2(n) \times P\_CRST_2(n)$ – set of binary relations on $P\_CRST_2(n)$;

$D\_CRST_2(n) = V\_CRST_2(n) \cup BV\_CRST_2(n)$ – set of dynamic relations on objects;

$V\_CRST_2(n)$ – set of restrictions of object level of abstraction;

$BV\_CRST_2(n) \subset V\_CRST_2(n) \times V\_CRST_2(n)$ – set of binary relations on $V\_CRST_2(n)$.

$$CRST_{3i}(n) = Ob\_CRST_{3i}(n) \cup Mor\_CRST_{3i}(n) \qquad (7)$$

Where, $Ob\_CRST_{3i}(n)$ – representatives of subject entities;

$Mor\_CRST_{3i}(n) = S\_CRST_{3i}(n) \cup D\_CRST_{3i}(n)$ – set of morphisms;

$S\_CRST_{3i}(n) = (B\_CRST_{3i}(n), P\_CRST_{3i}(n), BP\_CRST_{3i}(n))$ – set of static relations on objects;

$B\_CRST_{3i}(n) \subset Ob\_CRST_{3i}(n) \times Ob\_CRST_{3i}(n)$ – set of binary relations on $Ob\_CRST_{3i}(n)$;

$P\_CRST_{3i}(n)$ – set of schemes on $Ob\_CRST_{3i}(n)$;

$BP\_CRST_{3i}(n) \subset P\_CRST_{3i}(n) \times P\_CRST_{3i}(n)$ – set of binary relations on $P\_CRST_{3i}(n)$;

$D\_CRST_{3i}(n) = V\_CRST_{3i}(n) \cup BV\_CRST_{3i}(n)$ – set of dynamic relations on objects;

$V\_CRST_{3i}(n)$ – set of restrictions of object level of abstraction, which are representatives of subject dependency;

$BV\_CRST_{3i}(n) \subset V\_CRST_{3i}(n) \times V\_CRST_{3i}(n)$ – binary relations on $V\_CRST_{3i}(n)$.

Dependence of the models can be represented as

$$V\_CRST_2(n) \to \{V\_CRST_3(n)\} \text{ i.e.} \quad (8)$$

$$Ob\_CRST_2(n) \to \{Ob\_CRST_3(n)\},$$

$$P\_CRST_2(n) \to \{P\_CRST_3(n)\},$$

$$BP\_CRST_2(n) \to \{BP\_CRST_3(n)\},$$

$$V\_CRST_2(n) \to \{V\_CRST_3(n)\},$$

$$BV\_CRST_2(n) \to \{BV\_CRST_3(n)\}.$$

The substantiation of the connection between models at different levels is performed using the relational algebra:

$B\_CRST_{3j}(n) = Ob\_CRST_2(n) \bullet Ob\_CRST_{3j}(n) \bullet B\_CRST_2(n)$,

$S\_CRST_{3j}(n) = S\_CRST_2(n) \bullet B\_CRST_2(n) \bullet B\_CRST_{3j}(n)$ – static relations,

$BV\_CRST_{3j}(n) = V\_CRST_2(n) \bullet V\_CRST_{3j}(n) \bullet BV\_CRST_2(n)$ – dynamic relations.

Integration at the object level is represented as

$$Ob\_CRST_2^0 = \bigcup_n Ob\_CRST_2(n),$$

$$B\_CRST_2^0 = \bigcup_n B\_CRST_2(n),$$

$$P\_CRST_2^0 = \bigcup_n P\_CRST_2(n),$$

$$BP\_CRST_2^0 = \bigcup_n BP\_CRST_2(n),$$

$$V\_CRST_2^0 = \bigcup_n V\_CRST_2(n),$$

$$BV\_CRST_2^0 = \bigcup_n BV\_CRST_2(n)$$

Integration at the concrete level is represented as

$$Ob\_CRST_3^0 = \bigcup_{n,m} Ob\_CRST_{3m}(n),$$

$$B\_CRST_3^0 = \bigcup_{n,m} B\_CRST_{3m}(n),$$

$$P\_CRST_3^0 = \bigcup_{n,m} P\_CRST_{3m}(n),$$

$$BP\_CRST_3^0 = \bigcup_{n,m} BP\_CRST_{3m}(n),$$

$$V\_CRST_3^0 = \bigcup_{n,m} V\_CRST_{3m}(n),$$

$$BV\_CRST_3^0 = \bigcup_{n,m} BV\_CRST_{3m}(n).$$

Conclusions

The regularities of the mappings are based on the identity of the use of abstractions during the process of forming links at the CMM at the same level of abstraction.

Description of the CCR and CRST allows us to solve the problems of systematization and description of models as specific design tasks, and integration of data representations into a single whole.

Description of the relationships between CMM CCR and CRST on the basis of the revealed regularities of the display provides the ability to:

- limit many kinds of connections and dependencies, if there is a verbal symbolic representation;
- apply semantic addition to formalized symbolic presentation of subject tasks, and make it full.

In the process of research, the modeling methods discussed in this article were implemented in the MATLAB and Maple systems

[7–10]. The developed software was used to solve various problems related to the design of systems with which space is explored [11–13].

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AN ANALYSIS OF SOME WAVELET FUNCTIONS IN TERMS OF BROADBAND SYSTEMS SYNTHESIS

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Abstract: This article deals with the issues of application of some wavelet functions for a wideband signal design on the basis of matrices of particular form of the autocorrelation function. The elements of such matrices are complex numbers with the module equal to one. The research objects are wavelet functions and wideband signals obtained on the basis of wavelet analysis. Numerous studies have displayed that rather explicit results of wideband signal design allow to receive following continuously differentiable wavelet functions: the b-spline wavelet, Morlet wavelet.

Keywords: wireless broadband connectivity, digital signal processing, wavelet functions.

Introduction

Methods and broadband radio communication systems in comparison with a set of modern technologies have a rather long history. The first receptions and transmissions were carried out for the wideband signals being of spark nature, and meet the criteria of the