Integration of descriptions of conceptual model representations at automation of design tasks

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Abstract. This paper investigates integrating model representation descriptions in the form of charts and specifications at the stage of automated systems conceptual modeling, developed in order to solve design tasks on the methodology for automating intellectual labor (MAIL). In the process of creating the applied automated system on the basis of MAIL there were developed the following model representations of design tasks: initial, conceptual, infological and datalogical. The description of conceptual model representation includes the following forms (specifications) and charts: for a static component - F1 and F2, the chart of conceptual structure; for a dynamic component - F3 and F4, the chart depicting a system of subject dependences; F6 and the matrix chart showing the model as a whole including static and dynamic components coordination. There was investigated the process creating charts and specifications as a basis of the method and technique to integrate descriptions of dynamic and static components for the problems solving carried out at designing mechanical engineering objects. Integration of models is performed separately for each component of model on each type of description. Integrating descriptions in the form of charts and specifications for dynamic components of conceptual model representations is given in this paper.

1. Introduction
Automating design-technology tasks solving (further - design tasks) [1, 2] at mechanical engineering objects designing assumes application of modeling methods allowing to describe information multi-level structure and complex algorithms.

One of them is the methodology for automating intellectual labor (MAIL) [3, 4]. Methodology is developed in Russia at Department of Information Technologies and Computing Systems in MSUT “STANKIN”. It suggests industrial process for designing automated systems, and includes methods for describing complicated information and well-organized algorithms.

Automated systems designing on MAIL includes several stages: initial, conceptual, infological and datalogical modeling. Models have universal representation (conceptual, infological, datalogical) and representation of subject tasks (initial, conceptual, infological, datalogical). Universal representation is formed at three levels of abstraction – abstract, object, specific; representation of subject tasks at two levels of abstraction – object and specific ones. In this paper representation of subject tasks at a stage of conceptual modeling will be considered [3, 5].

At the stage of initial modeling, process solving of design task is analyzed, and there formed the model simulating its decision process from the point of view of an expert. At a stage of conceptual modeling, the system of subject domain knowledge is described. It defines conceptual structure and the
system of restrictions for the automated task. At a stage of infological modeling, there is formed the project of the automated system invariant to the program and technical environment and implementers.

Each model includes the description of informational or static, functional or/and dynamic components, model as a whole. Informational (or static) component describes structure of the model static elements. A functional component presents an algorithm of the operations performed within a subject task. A dynamic component presents a structure of restrictions for a static structure and access to it. The model of a whole defines coordination of functional or/and dynamic and informational or static components. Herewith for initial model - functional and informational components, for conceptual model - dynamic and static components, for infological model – functional, dynamic and informational ones. The description for each of the components is formed as special charts and specifications.

Designing the automated system, complicated design tasks are decomposed into simpler ones. When forming model representation for a complex of tasks, initially design of separate tasks is carried out, further their descriptions are integrated into uniform representation.

2. Method for integrating descriptions of conceptual models

Rules for integrating descriptions of model representations include the following issues:

1. Integration of subject tasks model representations is carried out separately for models of each level and at each level – on each component (figure 1).

2. Integration is carried out for each type of the description separately – for charts and specifications.

3. The process of integration includes identifying subtasks merge point, executing integration algorithms and code converting elements of dynamic and static structures.

4. Representing the result of integration in the form of charts and specifications for each component for the gained integrated model representation.

Figure 1. Process of integrating model representations at each stage of creating the automated systems.

At a design stage of automated systems, the integration of conceptual model representations on the object level for n-subject task is defined as follows [3, 5]:

\[
KP_2(n) = \bigcup_{i=1}^{n} KP_2(i)
\]
and includes a number of the sets obtained as a result of integrating sets of the subject categories (equation 2), the static relations (equation 3), the dynamic relations (equation 4) and the relations describing interrelations of static and dynamic components (equation 5).

\[
M_2 (n) = \bigcup_{i=1}^{m} M_2_i(n)
\]  
(2)

\[
TH_2 (n) = \bigcup_{i=1}^{m} TH_2_i(n)
\]  
(3)

\[
FU_2 (n) = \bigcup_{i=1}^{m} FU_2_i(n)
\]  
(4)

\[
R^{SP}_2 (n) = \bigcup_{i=1}^{m} R^{SP}_2_i(n)
\]  
(5)

Let's consider the process integrating the dynamic components of conceptual model representation, given in the form of charts and specifications \[6, 7, 8\].

Let's make integration of diagrams in the form of the systems of subject dependences \(W_n, W_m\), where \(W_m\) – the system of subject dependences defining an algorithm of the solution of a subtask from a system \(W_n\) \[6, 7\]. As a result of systems merging the new system of subject dependences \(W_2\) with uniform coding, turns out, it includes \(W_n, W_m\) (equation 6).

\[
W(n) \bigcup W(m) = W_2
\]  
(6)

As there is a merger of different diagrams of subject dependences, we will input indexes \(n, m\), defining belonging of dependences to the corresponding system of subject dependences. It turns out \(w_{ps}^{n}\) – subject dependence, \(p\) - level of decomposition \(n\) - a subject task, \(w_{cv}^{m}\) – subject dependence \(c\) - level of decomposition \(m\) - a subject task. In the place of joining charts, the integrated subject dependence accepts indexes of initial dependence (herewith they are semantically similar) (equation 7).

\[
\overline{w_{vi}^{m}} = \overline{w_{zi}^{l}}
\]  
(7)

Further merging charts of subject dependences happens according to one of the following options:

- when the subset of subject dependences of \(k\)-th decomposition level has no subject dependence having a relationship of the "composition" kind;
- when the subset of subject dependences of \(k\)-th decomposition level has at least one subject dependence having a relationship of the "composition " kind and which is located before the place of joining of charts;
- when the subset of subject dependences of \(k\)-th decomposition level has the subject dependences having a relationship of the "composition " kind and which are located before and after the charts joints.

Let's consider option of merging subject dependences charts when the subset of subject dependences of \(k\)-th decomposition level has no subject dependence, having a relationship of the "composition " kind (figure 2).

If \(A^{k+1} \subseteq Lw_i w_{(k+1)}, w_{(1)}, w_{(2)} \), where \(i = l - p, p = 1, 2, ..., l - 1\), then \(w_{zi}^{w} = w_{zi}^{w} \), where \(z = c + 1; a = b + g, q = k + 1, w = l + g, g = 0, 1, 2, ...\).
That is \( w_{(c+1)(b+0)}^\mu \equiv w_{(k+1)(b+1)}^\mu \) etc.

\[
\begin{align*}
\text{Figure 2. Integration of subject dependences charts according to option 1.}
\end{align*}
\]

The description of conceptual model representation includes a set of tables (specifications) \( R(n) \). Therefore for the formal description of specifications it is necessary to input indexation:

\[
R(n) = \bigcup_t R^t(n), R^t(n) = \bigcup_e R^e(n), R^e(n) = \{ r^e_j \}
\]

where \( R^t(n) \) – subset of the specifications, where \( t \) - the type of a component ( \( t = 1 \) – static, \( 2 \) – dynamic, \( 3 \) – linking the model as a whole), \( R^e(n) \) – subset of the specifications, where \( t \) - the type of a component \( e \) – the number of specification of certain type \( (e = 1, 2, \ldots, m) \), \( r^e_j \) – \( j \) - tuple of the specification of type \( t \), number \( e \).

Formation of specifications for structural diagrams includes display of the received coded structure of subject dependences in a tabular view (for a task or for a complex of tasks).

In F3 specification the structure of a subject dependences system is fixed, F4 specification allows to record the orderliness simple dependences for each difficult subject dependence. The construction type of difficult subject dependence can be basic or standard. The basic type includes a sequence, an iteration, a choice; the standard type includes a cycle, a switch. On Figure 3 the description of F3 specification is submitted.

Thus it turns out that domains \( D_1^{21}, D_2^{21}, D_3^{21}, D_4^{21}, D_5^{21}, D_6^{21} \) contain the description of composition a subject dependences system (the list of subject dependences).

Using the indexation introduced above for the formal description of specifications, we will describe \( R(n) \) – a set of specifications of conceptual model representation for design task \( n \):

\[
R(n) = \{ R^1(n), R^2(n), R^3(n) \}
\]

where \( R^1(n) \) – subset of descriptions of a static component in the form of specifications (forms F1, F2) (equation 10); \( R^2(n) \) – subset of descriptions of a dynamic component in the form of specifications (forms F3, F4) (equation 11); \( R^3(n) \) – subset of descriptions of coordination of model as a whole in the form of specifications (form F6) (equation 12).
$R^{21}(n)$ (Specification F3)

| Code | Name of subject dependence | Degree of formalization | Status of subject dependence | Structural property | Note |
|------|-----------------------------|-------------------------|-----------------------------|---------------------|------|
| $r_1^{21}$ | $z_{11}$ Design calculation of all cylindrical gears with straight teeth (CGwST) | analytical | | | |
| $r_2^{21}$ | $z_{21}$ Design calculation of cylindrical gear with straight teeth | intermediate | $!$ $[$ $!$ number of gears $!$ | $]$ standard module $!$ | $[$ array of modules $!$ |
| $r_k^{21}$ | $z_{32}$ Definition of design parameters of the current transfer | algorithmic | intermediate | $[$ standard module $|$ |
| $r_n^{21}$ | $z_{33}$ Calculation of the module with internal gearing | analytical | elementary | $/$ type of gearing $|$ |

**Figure 3.** The fragment of specification F3.

\[
R^1(n) = \langle R^{11}(n), R^{12}(n) \rangle
\]  
(10)

where $R^{11}(n)$ – the description of a static component in the form of the first specification of this type (form F1); $R^{12}(n)$ – the description of a static component in the form of the second specification of this type (form F2).

\[
R^2(n) = \langle R^{21}(n), R^{22}(n) \rangle
\]  
(11)

where $R^{21}(n)$ – the description of a dynamic component in the form of the first specification of this type (form F3); $R^{22}(n)$ – the description of a dynamic component in the form of the second specification of this type (form F4).

\[
R^3(n) = \langle R^{31}(n) \rangle
\]  
(12)

where $R^{31}(n)$ – the description of model as a whole (coordinating static and dynamic components) in the form of the first specification of this type (form F6).

The integrated specifications represent integration of two specifications for the design tasks $n$ and $m$, describing identical components the same type of forms where the subject task $m$ is a subtask of a complex of tasks $n$ [8]:

\[
R^{11}(n)^* = R^{11}(n) \cup R^{11}(m),
\]

\[
R^{12}(n)^* = R^{12}(n) \cup R^{12}(m),
\]

\[
R^{21}(n)^* = R^{21}(n) \cup R^{21}(m),
\]

\[
R^{22}(n)^* = R^{22}(n) \cup R^{22}(m),
\]

\[
R^{31}(n)^* = R^{31}(n) \cup R^{31}(m).
\]  
(13)
3. Conclusions

1. Automating design-technology tasks in designing mechanical engineering objects involves modeling the structure of information, the structure of the task performing process and their mutual coordination.

2. The methodology of automating intellectual labor is one of the ways to create the automated systems and to allow projecting the automated systems in the form of model representations, to describe their components in a graphic and matrix type (chart) and in the form of specifications.

3. Conceptual model representation defines the system of knowledge of subject domain (the system of concepts and restrictions for the automated task). This stage of conceptual modeling is very important as the correctness of interpretation of infological and datalogical model representations depends on correctness of the constructed model.

4. The developed method of integrating conceptual models descriptions allows to form uniform conceptual representation for a complex of design tasks. It helps to define points to development the automated system for a dynamic component, to avoid redundancy of information for a static component.

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