Integration of descriptions of infological 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 infological modeling, developed in order to solve design tasks on the methodology for automating intellectual labor (MAIL). In the process of creating the 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 infological model representation includes the following forms (specifications) and charts: for a static component – P1 and P2, the chart of infological structure; for a dynamic component – P3 and P4, the chart depicting a system of subject accesses; for a functional component – P5 and P6, the chart depicting a system of subject manipulations; P8 and the matrix chart showing the model as a whole including static, functional 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, functional and static components for the models of automated systems that perform design tasks in the design of mechanical engineering objects. Integrating descriptions in the form of charts and specifications for functional components of infological model representations is given in this paper.

1. Introduction
To date, a number of technologies for the development of automated systems (AS) have been formed. As a rule, the creation of AS is not a one-time action and the process consists in gradually improving and supplementing the originally developed prototype with new functions. Due to the increase in the volume and complexity of AS, the need to ensure their quality, the emergence of groups of specialists for each stage of creation, methods and methodologies for modeling subject tasks and means for their automation have appeared.

One of them is the methodology for automating intellectual labor (MAIL) [1, 2]. Methodology is developed in Russia at Department of Information Technologies and Computing Systems in MSUT “STANKIN”. This methodology is based on the cognitive and semiotic approaches, and the development of the semiotic approach. MAIT offers an industrial way to create automated systems and allows you to describe a multi-level information structure and complex formalized algorithms. The design and engineering tasks (hereinafter design tasks) refers to this type of tasks. [3, 4, 5, 6].

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.
As the automated system is created at each stage, the following model representations are formed:
the initial model representation that reflects the process of solving the task from the point of view of the
expert; a conceptual model representation that defines the conceptual structure and system of constraints
for an automated task; infological model representation, which describes the project of the automated
system invariant to program and technical environment and implementers.
In this paper representation of subject tasks at a stage of infological modeling will be considered [1, 7].

The model presentation includes a set of components:
• informational (or static) component describes the composition and structure of the model static
elements;
• functional component presents an algorithm of actions performed as part of subject task;
• dynamic component describes the composition and structure of restrictions on the static
structure and access to it;
• the model as a whole defines the coordination of the functional and / or 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. To
obtain a uniform description of the system that solves the design task, the process of integrating model
representations of subtasks into the description of the AS complex of tasks is performed.

2. Method for integrating descriptions of infological 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 merge point of subtasks, executing integration
algorithms and code converting elements of dynamic and static structures.
4. Representing (visualization) the result of integration in the form of charts and specifications for
each component for the gained integrated model representation.
Figure 1. The integration of descriptions of infological model representations.

At a design stage of automated systems, the integration of infological model representations on the object level for n-subject task is defined as follows [8]:

\[ ILP(n) = \bigcup_{i=1}^{m} ILP_i(n) \]  

(1)

and includes a number of the sets obtained as a result of integrating sets of the structural units (equation 2), the static relations (equation 3), the functional relations (equation 4), the dynamic relations (equation 5) and the relations describing interrelations of static, functional and dynamic components (equation 6).

\[ L(n) = \bigcup_{i=1}^{m} L_i(n) \]  

(2)

\[ DE(n) = \bigcup_{i=1}^{m} DE_i(n) \]  

(3)

\[ ZJ(n) = \bigcup_{i=1}^{m} ZJ_i(n) \]  

(4)

\[ QI(n) = \bigcup_{i=1}^{m} QI_i(n) \]  

(5)

\[ R^{IP}(n) = \bigcup_{i=1}^{m} R^{IP}_i(n) \]  

(6)

Let's consider the process integrating the functional components of infological model representation, given in the form of charts and specifications [8, 9, 10].
Let's make integration of diagrams of the systems of subject manipulations $X^2(n)$, $X^2(m)$, where $X^2(m)$ – the system of subject manipulations defining an algorithm of the solution of a subtask from a system $X^2(n)$ [9]. As a result of the systems merger, a new system of subject manipulations $X^2(n)^*$, with a single coding, is obtained, it includes $X^2(n)$, $X^2(m)$ (equation 7).

$$X^2(n) \cup X^2(m) = X^2(n)^*$$

As there is a merger of different diagrams of subject manipulations, we will input indexes $n$, $m$, defining belonging of manipulations to the corresponding system of subject manipulations. It turns out $x^s_{ps}$ – $s$ - subject manipulation, $p$ - level of decomposition $n$ - a subject task, $x^v_{cm}$ – $v$ - subject manipulation $c$ - level of decomposition $m$ - a subject task. In the place of joining charts, the integrated subject manipulation accepts indexes of initial manipulation (herewith they are semantically similar) (equation 8)

$$x^m = x^v$$

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

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

Let's consider option of merging subject manipulations charts when the subset of subject manipulations of $k$-th decomposition level has at least one subject manipulation having a relationship of the "composition" kind and which is located before the place of joining of charts (figure 2).

If $\exists x^m_{(k+1)j} : \left( x^m_{(k+1)(j+1)} \right) \in LX_kX_{k+1}$, then

$$x^m_{(k+1)(j+1)} \equiv x^m_{ps}$$

That is $x^m_{(c+1)(l+g)} = x^m_{(k+1)(j+1)0}$, $x^m_{(c+1)(l+g)} = x^m_{(k+1)(j+1)1}$ etc.

![Diagram](image-url)

**Figure 2.** Integration of subject manipulations charts according to option 2.
The description of infological model representation includes a set of tables (specifications) [10]. Therefore for the formal description of specifications it is necessary to input indexation (equation 9):

\[ S(n) = \bigcup_{i} S_{i}(n), S'(n) = \bigcup_{e} S_{e}(n), S_{e}(n) = \{ s_{e}^{n} \} \]  \hspace{1cm} (9)

where \( S'(n) \) – subset of the specifications, where \( t \) - the type of a component \((t = 1 \text{ – static, } 2 \text{ – dynamic, } 3 \text{ – functional, } 4 \text{ – linking the model as a whole})\), \( S_{e}(n) \) – subset of the specifications, where \( t \) - the type of a component \( e \) – the number of specification of certain type \((e = 1, 2, \ldots, m\)), \( s_{e}^{n} \) – \( j \) - tuple of the specification of type \( t \), number \( e \).

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

In P5 specification the structure of a subject manipulations system is fixed, P6 specification allows to record the orderliness simple manipulations for each difficult subject manipulation. The construction type of difficult subject manipulation 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 P6 specification is submitted.

\[ S^{32}(n) \text{ (Specification P6)} \]

| \( D_{1}^{32} \) | \( D_{2}^{32} \) | \( D_{3}^{32} \) | \( D_{4}^{32} \) | \( D_{5}^{32} \) | \( D_{6}^{32} \) |
|----------------|----------------|----------------|----------------|----------------|----------------|
| subject manipulation code 1 | subject manipulation code 2 | subject manipulation code 3 | evaluation of the relationship | code of the relationship | type of relationship |
| z 11.1 | z 21.1 | - | cycle | z11z21.1 | S |
| z 21.1 | z 31.1 | z 32.1 | sequence | z21z31z32.1 | C |
| z 21.1 | z 32.1 | z 33.1 | sequence | z21z32z33.1 | C |
| ... | ... | ... | ... | ... | ... |
| z 43.1 | z 55.1 | z 56.1 | sequence | z43z55z56.1 | C |

Figure 3. The fragment of specification P6.

Thus it turns out that domains \( D_{1}^{32}, D_{2}^{32}, D_{3}^{32}, D_{4}^{32}, D_{5}^{32}, D_{6}^{32} \) contain the description of structure a subject manipulations system.

Using the indexation introduced above for the formal description of specifications, we will describe \( S(n) \) – a set of specifications of infological model representation for design task \( n \) (equation 10):

\[ S(n) = \{ S_{i}(n), S_{2}(n), S_{3}(n), S_{4}(n) \} \]  \hspace{1cm} (10)

where \( S_{i}(n) \) – subset of descriptions of a static component in the form of specifications (forms P1, P2 – this is description of the elements of the infological structure and their binary relationships) (equation 11); \( S_{2}(n) \) – subset of descriptions of a dynamic component in the form of specifications (forms P3, P4 – this is a description of subject accesses and their structure) (equation 12); \( S_{3}(n) \) – subset of descriptions of a functional component in the form of specifications (forms P5, P6 – this is a description of subject manipulations and their structure) (equation 13); \( S_{4}(n) \) – subset of descriptions of coordination of model as a whole in the form of specifications (form P8) (equation 14).

\[ S_{i}(n) = \{ S_{i}^{1}(n), S_{i}^{2}(n) \} \]  \hspace{1cm} (11)
where $S^{11}(n)$ – the description of a static component in the form of the first specification of this type (form P1); $S^{12}(n)$ – the description of a static component in the form of the second specification of this type (form P2).

$$S^2(n) = \{S^{21}(n), S^{22}(n)\}$$ (12)

where $S^{21}(n)$ – the description of a dynamic component in the form of the first specification of this type (form P3); $S^{22}(n)$ – the description of a dynamic component in the form of the second specification of this type (form P4).

$$S^3(n) = \{S^{31}(n), S^{32}(n)\}$$ (13)

where $S^{31}(n)$ – the description of a functional component in the form of the first specification of this type (form P5); $S^{32}(n)$ – the description of a functional component in the form of the second specification of this type (form P6).

$$S^4(n) = \{S^{41}(n)\}$$ (14)

where $S^{41}(n)$ – the description of model as a whole (coordinating static, dynamic and functional components) in the form of the first specification of this type (form P8).

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 $n$ (equation 15):

$$S^{11}(n^*) = S^{11}(n) \bigcup S^{11}(m),$$

$$S^{12}(n^*) = S^{12}(n) \bigcup S^{12}(m),$$

$$S^{21}(n^*) = S^{21}(n) \bigcup S^{21}(m),$$

$$S^{22}(n^*) = S^{22}(n) \bigcup S^{22}(m),$$

$$S^{31}(n^*) = S^{31}(n) \bigcup S^{31}(m),$$

$$S^{32}(n^*) = S^{32}(n) \bigcup S^{32}(m),$$

$$S^{41}(n^*) = S^{41}(n) \bigcup S^{41}(m).$$ (15)

3. **Conclusion**

1. To automate the design-technology tasks, which performed during the design of mechanical engineering objects, it is necessary to model the structure of information, the structure of the task performing process, and their mutual coordination. At the same time, it is necessary to take into account the presence of the following features of design tasks - a complex formalized algorithm and a multi-level structure of information.

2. The methodology of automating intellectual labor offers an industrial way 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. The infological model representation describes the project of an automated system, independent of the software and hardware environment and the means of its implementation. The stage of infological modeling is very important, since at this stage a rational organization of information and an algorithm for solving a design task problem in a computing environment is determined.

4. The developed method of integrating infological models descriptions allows to form uniform representation for the project of automated system that performs a complex of design tasks. It helps to define points to development the automated system for a functional component, to avoid redundancy of information for a static component, organize a system of access to the infological structure for the dynamic component.

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