Development of Requirements for The Content of a Digital Passport and Design Solutions

Julia V. Donetskaya* and Yuriy A. Gatchin
Faculty of Information Technology Security, ITMO University, 197002, 9 Lomonosov st., St. Petersburg, Russia

Abstract. The work presents the results of the development of requirements for the content of a digital passport and design solutions. The composition of each of them is listed, taking into account the specifics of the activities of a particular enterprise and the design tasks to be solved. On this basis, an execution sequence for creating and using a digital passport is proposed.

1. Introduction

At present, the development and delivery of high-tech electronic products is performed with direct interaction of various organizations in accordance with the positions of agreements and work schedules. At the same time, problems arise associated with access and exchange of up-to-date product data, coordination of lists and versions of operating systems, as well as structures and formats of exchange files [1,2]. One of the solution methods is to generalize approaches to the automated management of product data and design and production procedures using ERP, PDM, MES and / or QMS systems at various enterprises.

The results obtained at the same time allow us to conclude that the list of procedures depends on the characteristics of the activity of a particular enterprise and is of the same type, and the list of generated data depends on the implemented and operated systems and is represented by meaningful and / or requisite parts of information objects. Thus, a complete electronic definition of a product or its digital passport is formed, the analysis of the content of which can be used to solve various design problems [3-5].

The works [6-8] show the results of the creation and use of elements of the passport of an electronic product at the stages of development, preproduction and production. On this basis, the task was set to develop a basis for the creation and use of a digital product passport in the instrumentation industry, which requires to:

- Describe the principles of forming the content of a digital passport for an electronic product at the stages of its life cycle.
- Formulate the requirements for the content of a digital passport.
- Formulate the requirements for design solutions based on the content of a digital passport.
- Develop an execution sequence for creating and using a digital product passport in the instrumentation industry.

This work focuses on the solution of the listed problems.

2. Formation of the Digital Passport Content of an Electronic Product at the Enterprise
It is known that when forming the content of a digital passport of products, enterprises take into account the experience gained by other enterprises. In other words, they know which product data and design and manufacturing procedures have been previously automated and which types of systems have been used.

If we imagine that the creation of a digital passport is a project task, then the company has formed many design alternatives, such that the pairs “information object - design and production procedure”, “content part of the object - type of system” and “requisite part of the object - system” are set. Moreover, the first of them is called the component of the digital passport, and the second and third determine the parameters of the component [5].

Then, to form the digital passport content of the product, the following steps need to be performed:

- determination of the lists of systems (operated and implemented at the enterprise) and their types, on the basis of which a digital passport will be created.
- determination of the stages of the product life cycle, the management of which should be automated.
- formation of design and production procedures lists, the management of which is automated at each stage of the life cycle.
- formation of data lists of an electronic product, formed as a result of the implementation of design and production procedures.

The result of this is a set of values of the elements of the digital passport content models [9]:

Model of components $R(C)$ whose elements are specified by pairs “information object - design and production procedure”.

Model of the parameters of the components of the digital passport $U = (u_1, u_2, ..., u_p)$, which vary depending on the types of systems used and stages of the life cycle, and also include:

- parameters of the stage of concluding an agreement, formed by means of the EDMS;
- parameters of the stage of concluding an agreement, formed by means of the ERP system;
- parameters of the stage of concluding an agreement, formed by means of the PDM system;
- parameters of the development stage, formed by means of the ERP system;
- parameters of the development stage, formed by means of the PDM system;
- parameters of the stage of preparation of production, formed by means of the ERP system;
- parameters of the production preparation stage, formed by means of the PDM system;
- parameters of the production stage, formed by means of the ERP system;
- parameters of the production stage, formed by means of the PDM system;
- parameters of the stage of operation and repair, formed by means of the EDMS;
- parameters of the stages of operation and repair, formed by means of the ERP system;
- parameters of the stages of operation and repair, formed by means of the PDM system;
- parameters of the stages of operation and repair, formed by means of the QMS system.

Model of descriptions $G(C)$ of the components of a digital passport, each element of which is formed by components and their corresponding parameters, formed at a specific stage of the life cycle.

Interaction model

$$
X(C) = \begin{pmatrix}
1 & X_{12}(C_1, C_2) & \cdots & X_{1l}(C_1, C_l) \\
X_{21}(C_2, C_1) & 1 & \cdots & X_{2l}(C_2, C_l) \\
\vdots & \vdots & \ddots & \vdots \\
X_{k1}(C_k, C_1) & X_{k2}(C_k, C_2) & \cdots & 1
\end{pmatrix},
$$

where
\[ X_{ij}(C_i, C_j) = \begin{cases} 0, & G_i(C_i) \neq G_j(C_j) \\ 1, & G_i(C_i) = G_j(C_j) \end{cases}, \]  

(1)

at \( i, j = 1, k \).

Thus, the task of creating a digital passport is reduced to the formation of an element of the matrix \( G(C) \) based on the component model \( R(C) \) and the model of parameters \( U \), and the task of using a digital passport is reduced to the matrix \( X(C) \), each element of which satisfies condition (1).

This also takes into account the requirements for the content of the passport and design solutions.

2. Requirements for the Content of a Digital Passport

The performed research made it possible to formulate such types of requirements for the content of a digital passport (\( RS \)), such as:

• Stages of the life cycle of an electronic product at which the enterprise operates - \( RS_1 \).

• Project-manufacturing procedures performed at stages of the life cycle - \( RS_2 \).

• Types of product data to be stored in the digital passport - \( RS_3 \).

In other words, we have a set \( RS = RS_1 \cup RS_2 \cup RS_3 \).

2.1. Stages of the Life Cycle of an Electronic Product

It is known that enterprises in the instrumentation industry, in general, implement their activities at the stages of concluding an agreement, development, preparation of production, production, operation and repair. Then we represent the requirement \( RS_1 \) in the form

\[ RS_1 = (rs_{11}, rs_{12}, ..., rs_{1a}), \]

where \( rs_{1i}, i = 1, a \) correspond to the listed stages and are elements of a fuzzy set, the membership function of which takes one of two values:

"1" - if the activity of the enterprise at a given stage is recorded in the digital passport;

"0" - if otherwise.

Design and production procedures performed at stages of the life cycle

Analysis of the activities of enterprises made it possible to identify and summarize design and production procedures at the stages of the life cycle \([\). It can be formulated as:

\[ RS_2 = (rs_{21}, rs_{22}, ..., rs_{2b}), \]

where \( rs_{2i}, i = 1, b \) correspond to the identified list of design and production procedures and are elements of a fuzzy set, the membership function of which takes one of two values:

"1" - if the specified design and production procedure must be taken into account in the digital passport;

"0" - if the specified procedure or stage of the life cycle is not taken into account in the digital passport.

2.2. Types of Product Data to Be Stored in A Digital Passport

In addition to the procedures, as a result of the analysis of the activities of enterprises, the types of generated data about the product, represented by the information objects of ERP, PDM, MES and/or QMS systems, have been established. We can write down that

\[ RS_3 = (rs_{31}, rs_{32}, ..., rs_{3c}), \]

where \( rs_{3i}, i = 1, c \) correspond to the identified list of product data types and are elements of a fuzzy set, the membership function of which takes one of two values:
"1" - if the specified type of data on the product must be taken into account in the digital passport;
"0" - if otherwise.

The values of the formulated requirements can be used in the analysis of design alternatives to create a digital passport for an electronic product at a specific enterprise.

3. The Execution Sequence for Creating A Digital Passport for An Electronic Product
The execution sequence includes:

- Formation of a variety of design alternatives in accordance with the analysis of the experience of industry enterprises. In fact, this means obtaining pairs "information object - design and production procedure".
- Formation of a set $RS = RS_1 \cup RS_2 \cup RS_3$, the elements of which are the values of the types of requirements given above.
- Obtaining elements of the component model $R(C)$ in the form of pairs "information object - design and production procedure", such that:

  \[ c_i = 1; i = 1, k; j = 1, n_k \] if a given type of product data is formed by a given design and production procedure (in addition, the corresponding elements of the sets $RS_2$ and $RS_3$ are equal to 1);

  \[ c_i = 0; i = 1, k; j = 1, n_k \] if a given type of product data is not formed by a given design and production procedure (in addition, the corresponding elements of the sets $RS_2$ or $RS_3$ are equal to 1).

- Formation of the component model in the form of lists of content and requisite parts of information objects. In this case, the attributes used are determined on the basis of the lists of requisite parts.

As a result, a digital passport is created, the content of which can be used when making design decisions in accordance with the requirements for them.

4. Requirements for Design Solutions
The performed research made it possible to formulate such types of requirements for design solutions ($RP$), such as:

- Performed design and production procedure - $RP_1$.
- Design solutions for managing product data - $RP_2$.
- Design solutions to manage design procedures - $RP_3$.
- Design solutions for managing production procedures - $RP_4$.

In other words, we have a verbally defined set $RP = (RP_1 \cup RP_2) \cap (RP_1 \cup RP_3) \cap (RP_1 \cup RP_4)$.

4.1. Performed Design and Production Procedure
The set forming the considered type of requirements is a subset of the set $RS_2$, i.e. $RP_1 \subseteq RS_2$.

Analysis of the activities of enterprises, performed by the authors, made it possible to form a list of procedures, the implementation of which is accompanied by the adoption of a design decision, referred to one of three classes of design tasks [5,9]: product data management; management of design or manufacturing procedures. Then the requirement $RP_1$ can be represented in the following form

\[ RP_1 = (rp_{i1}, rp_{i2}, \ldots, rp_{id}), \]

where $rp_{i} \in RS_2; i = 1, d; d < b$, correspond to the list of design and production procedures requiring the solution of design problems, and are elements of a fuzzy set, the membership function of which takes one of two values:
"1" - if the specified design and production procedure is performed;
"0" – if otherwise.

4.2. Design Solutions for Product Data Management
The considered type of requirements is associated with design tasks:
• search for developed and adjusted components of the product and products of co-contractors;
• search for previously developed products and their components;
• search for replaceable components;
• search for products of co-contractors, materials, components and their suppliers;
• search for products of third-party suppliers, materials and components allowed for use;
• formation of design and software documentation presented in tabular form;
• search for documentation to be corrected.

When solving any of them, it is necessary to take into account:
$$RP_i = (p_{i1}, p_{i2}, \ldots, p_{ie}),$$
where $p_{ij}, i = 1, e$, correspond to the list [5,9], the values of each of the elements of which are specified by information objects. In this case, if the value of any element of the set should not be taken into account when solving a specific problem, then instead of its value, "0" is put; "1" – if otherwise.

4.3. Design Solutions for Managing Design Procedures
The considered type of requirements is associated with design tasks:
• search for developed and adjusted components of the product and products of co-contractors;
• search for previously developed products and their components;
• search for replaceable components;
• search for products of third-party suppliers, materials, components and their suppliers;
• search for products of third-party suppliers, materials and components allowed for use;
• search for documentation to be corrected;
• control of the results of control over the fulfillment of work schedule items;
• search for components to be produced;
• control over the execution of production operations.

When solving any of them, it is necessary to consider:
$$RP_i = (p_{i3}, p_{i4}, \ldots, p_{if}),$$
where $p_{ij}, i = 1, f$, correspond to the list [5,9], the values of each of the elements of which are specified by information objects and parameters of set $U$. In this case, if the value of any element of the set should not be taken into account when solving a specific problem, then instead of its value, "0" is put; "1" – if otherwise.

4.4. Design Solutions for Managing Production Procedures
The type of requirements under consideration is associated with the formation of design and production procedures when interacting with the customer, for which one should take into account:
$$RP_i = (p_{i4}, p_{i5}, \ldots, p_{ig}),$$
where $p_{ij}, i = 1, g$, corresponds to the list [5,9], where the values of each of whose elements are specified by design and production procedures.

5. Execution Sequence for Using A Digital Passport of An Electronic Product
The execution sequence includes [9]:

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• Analysis of the components of the digital passport and the parameters describing them, required to form a design solution that meets the requirements for it. As a result, the elements of the component model $R(\overline{C}) \subset R(C)$ and the parameter model $\overline{U}$ are obtained.

• Development of rules for the selection of descriptions of digital passport components for the formation of design solutions using the apparatus of the theory of fuzzy sets. As a result, the elements of the description model $G(\overline{C})$ are obtained.

• Development of rules for choosing descriptions of components of a digital passport for the formation of design solutions using the principle Takagi-Sugeno-Kanga of building a fuzzy network.

• Formation of a similarity criterion based on the least squares method, as well as determination of the upper and lower boundaries of the intervals of the desired values.

As a result, the elements of the matrix are formed $X(C)$, satisfying the condition (1), which is the desired design solution, regardless of its type.

6. Conclusion
Thus, two types of requirements have been developed for the content of a digital passport and for design solutions. The first of them takes into account the peculiarities of the activity of a certain enterprise, and the second - the specifics of the project task. This made it possible to develop a sequence of actions describing the creation and use of a digital passport, which, in its turn, is the basis of the namesake method used in the instrument-making industry.

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