RULES FOR CHOOSING COMPONENTS OF A SINGLE DIGITAL PASSPORT FOR THE GENERATION OF CAD DESIGN SOLUTIONS

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Abstract: *In previous articles, it was shown that for "Industry 4.0" production one of the important tasks is the collection, storage, analysis and processing of product data and related design and production procedures. This determines the implementation of PDM, ERP, MES and/ or EAM systems at enterprises and the construction of a metasystem based on them - a single digital passport. Its content allows to automate the generation of design decisions for timely management decisions, as well as to propose an approach to solve the problem of minimizing the impact of the human factor for the tasks of Industry 4.0. Therefore, the work presents the results of the development of the rules for choosing the components of a single digital passport for the generation of design solutions based on the principle of building a fuzzy Takagi-Sugeno-Kang network. The results obtained will allow to formulate a criterion for the similarity of the production object and the design and production procedure in the digital environment to the given requirements based on linear approximation methods.*
KEYWORDS: *SINGLE DIGITAL PASSPORT, CHOICE OF DIGITAL PASSPORT COMPONENTS, CAD DESIGN SOLUTIONS.*

Introduction

Current trends in the development of engineering and technology contribute to the automation of various production processes based on the implementation of a new paradigm - Industry 4.0. Its main idea is to minimize (up to an exception) the influence of the human factor [1]. In this case, one of the important tasks is the organization of the collection, storage, analysis and processing of data and related design and production procedures [2] at all stages of the life cycle of an electronic product (LCP) due to:

- Implementation of ERP, PDM, MES and/or EAM management systems at enterprises;
- Integration of these systems to organize timely access to information for each participant in the product's life cycle;
- Determining the types of product data that should be generated and stored using the previously mentioned systems;
- Organization of the uniqueness of the input points of various types of product data indicating the types of systems by which it is implemented;
- Determining the sequences of design and production procedures at each stage of the product's life cycle.

The implementation of this is ensured by the construction of a single digital passport at the enterprise, which is reflected in the eponymously named methodology [3], proposed by one of the authors of this article. The single digital passport is a metasystem containing information about the electronic product, as well as design and production procedures indicating the types of control systems used to implement them, based on the ontological approach. This allows to automate the generation of design solutions that provide a similar representation of production facilities and procedures in a digital environment, and also offers an approach to solve the problem of minimizing the influence of the human factor for the tasks of Industry 4.0. Thus, the following methods were developed: a methodology for generating design solutions for CAD, CAD mathematical apparatus [4] and rules for choosing descriptions of the components of a single digital passport [5].

The results obtained were used to develop the rules for choosing descriptions of the components of a single digital passport based on the principle of constructing a fuzzy Takagi-Sugeno-Kang network [6], on which this article focuses on.

The task of selecting components descriptions of a single digital passport for the generation of CAD design solutions

Thus, the idea of developing rules for choosing descriptions of the components of a single digital passport is based on the fact that, parameters characterizing the electronic product at the stages of its life cycle are determined. That is to say:

$$Request\_Process = (RP_1, RP_2, \dots, RP_P),$$

where RP_i – parameters of the life cycle stage of an electronic product ($i \leq P$).

In addition, descriptions of the components of a single digital passport are known,

$$G(C) = \left(G_1(C_1), G_2(C_2), \dots, G_K(C_K)\right),$$

which allows to present an electronic product, the design and production procedures in a digital environment based on lists of components of a digital passport and corresponding lists of parameters.

Moreover, the components of a digital passport are formed according to information about the electronic product at the stages of its life cycle $R(C) = (C_1, C_2, \dots C_k)$ and the requirements for the passport $Reques\_System = (RS_1, RS_2, \dots, RS_S)$ presented at a particular enterprise [4,5].

Then, in accordance with the Takagi-Sugeno-Kang principle, the rules shaping for choosing components descriptions of a single digital passport consists of the following stages:

1. Shaping the rules for verifying the proximity of the option to describe the components of a single digital passport to the parameters of the stages of the life cycle of an electronic product.
2. Verification of the implementation of each generated rule.
3. The choice of descriptions of the components of a single digital passport that satisfy the parameters.
4. Verification of the compliance with the Gauss-Markov conditions.

Rules development for choosing components descriptions of a single digital passport

Stage 1. Since the descriptions of the components of a single digital passport are given by fuzzy variables, it is possible to formulate rules that verify the proximity of the description variant of a digital passport component to the parameters of the life cycle stage. That is to say, the following set is formed as follows:

$$R_1: \{\left(RP_1 \text{ есть } g_{11}(\overrightarrow{C_1})\right) AND \left(RP_2 \text{ есть } g_{12}(\overrightarrow{C_1})\right) AND \dots AND \left(RP_P \text{ есть } g_{1P}(\overrightarrow{C_1})\right)\};$$

$$R_2: \{\left(RP_1 \text{ есть } g_{21}(\overrightarrow{C_2})\right) AND \left(RP_2 \text{ есть } g_{22}(\overrightarrow{C_2})\right) AND \dots AND \left(RP_P \text{ есть } g_{2P}(\overrightarrow{C_2})\right)\};$$

$$\dots$$

$$R_K: \{\left(RP_1 \text{ есть } g_{K1}(\overrightarrow{C_K})\right) AND \left(RP_2 \text{ есть } g_{K2}(\overrightarrow{C_K})\right) AND \dots AND \left(RP_P \text{ есть } g_{KP}(\overrightarrow{C_K})\right)\}.$$

Stage 2. Each of the presented rules is intended to verify whether a particular requirement specified by 0 or 1 corresponds to the description contained in the digital passport. Regarding this, checks of the following form are performed:

$$IF\ (R_1)\ THEN\ G_1(\overrightarrow{C_1}) = a + \sum_{j=1}^{P} b_j \cdot RP_j \cdot g_{1j}(\overrightarrow{C_1});$$
$$IF\ (R_2)\ THEN\ G_2(\overrightarrow{C_2}) = a + \sum_{j=1}^{P} b_j \cdot RP_j \cdot g_{2j}(\overrightarrow{C_2});$$
$$IF\ (R_K)\ THEN\ G_K(\overrightarrow{C_K}) = a + \sum_{j=1}^{P} b_j \cdot RP_j \cdot g_{Kj}(\overrightarrow{C_K}).$$

Therefore, verification of compliance with the rules allows to formulate a linear dependance between the requirement - the input parameter - and the description taking into account the coefficients a and $b_j, j = \overline{1, P}$.

Stage 3. Then, the choice of components descriptions of a single digital passport should satisfy the formula:

$$G^*(\vec{C}) = \beta \cdot X + \varepsilon,$$

where X – deterministic matrix of dimension $K \times P$, such that $X = RP \cdot G$;

β – column vector containing elements $\beta = (a, b_1, b_2, \dots, b_K)$.

That is to say, the choice of components descriptions of a single digital passport comes down to searching the elements of the column vector β.

Stage 4. To verify the legitimacy of the submitted statement, verification of several Gauss-Markov conditions should be performed [7]:

1) the model is set in the form defined at the stage 2;
2) $G^*(\vec{C})$ – matrix in the form defined in step 3;
3) $E(\varepsilon) = 0$; $E(\varepsilon^2) = \sigma_\varepsilon^2$.

Therefore, it is possible to generate CAD design decisions based on the similarity criterion specified, using the least squares method.

Conclusion

Thus, the rules for choosing components descriptions of a single digital passport have been developed, which allow to generate CAD design solutions, which correspond to the search for elements of the column vector β.

Compliance with the Gauss-Markov conditions allows to formulate a criterion for the similarity of the production object and the design-production procedure in a digital environment to specified requirements based on linear approximation methods.

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