

The ontological model and the hybrid expert system for products and processes quality identification involving the approach based on system analysis and quality function deployment

Aleksandr Dmitriev^{1,2} and Tatyana Mitroshkina^{1,a}

¹Samara State Aerospace University named after academician S.P. Korolev (National Research University), 443086 Samara, Russia

²Samara Region State Academy (Nayanova), 443010 Samara, Russia

Abstract. Discussed model of quality of identification has improved mathematical tools and allows you to use a variety of additional information. The proposed robust method is a matrix MTQFD (Matrix Technique Quality Function Deployment) allows you to determine not only the priorities but also the assessment of the target values of the product characteristics and process parameters, with the possible use of the information on the negative relationship. Designed ontological model, method and model of expert system versatile and can be used to identify the quality of services.

1 Introduction

Effective design of quality products based on the ontological approach, the requirements of the standards, the use of knowledge bases, ontology and methods of quality management is an important way to increase the competitiveness of products [1].

Design of quality products is the development of products based on consumer expectations, knowledge and parametric identification of the characteristics of quality.

The problem of quality parametric identification (identifying priorities and performance targets) on the basis of consumer expectations and the developer of knowledge is a key task [2–4]. There are difficulties in identifying the quality of new and complex products. The problem of parametric identification, in fact, is the reverse. It is necessary to determine the characteristics of the designed products or services (the cause of) satisfaction of identified (effect). The problem of parametric identification of quality products and services, as well as the majority of inverse problems is incorrect. Incorrectness is shown in a high variability of the requirements in time, the ambiguity of unspoken expectations, etc.

The aim is to improve the quality and competitiveness of products. It is proposed to design and develop products to be based on the use of various types of information (knowledge), the identification of the target values of the product characteristics and process parameters and the effective application of the QFD [5, 6].

2 System ontological approach and QFD

Modern international management system standards, including standards for quality management system ISO 9001 developed using a common approach and require a knowledge management organizations [7]. So, the new

version of ISO 9001 (ISO 9001: 2015) has been developed in accordance with the Annex to the Directive ISO Annex SL (ISO / IEC Directives, Part 1 Consolidated ISO Supplement - Procedures specific to ISO). The directive establishes a new, uniform standard for management systems (based on ISO 9001, ISO 14001, ISO 50001, ISO 22000, ISO / IEC 27001, and others.), According to which all management systems standards will be given to a single structure.

Paragraph 7.1.5 ISO 9001:2015 "Knowledge" is specifies requirements for knowledge management [7]:

- The organization shall determine the knowledge necessary for the operation of the quality management system and its processes and to assure conformity of goods and services and customer satisfaction.
- This knowledge shall be maintained, protected and made available as necessary.
- Where addressing changing needs and trends the organization shall take into account its current knowledge base and determine how to acquire or access the necessary additional knowledge.

Integration with the requirements of ISO 9001 in the field of knowledge management and implementation of risk management are the main directions of the update of the standard and bring it to the modern level of management science.

Design and development of ontology (ontological engineering) - basis for the concept of knowledge management - currently the most promising approach to managing complex "content" systems. The development of knowledge management system includes several phases: accumulation, retrieval, structuring, formalization and software implementation and maintenance.

The main objective of the ontological approach - ordering of knowledge by their ordering, create a single hierarchy of concepts, harmonization of terms and rules of interpretation - has the general objective of improving

^a Corresponding author : t.mitroshkina@gmail.com

the efficiency of product design in accordance with the requirements and expectations of customers. The methodology of ontological engineering will optimize the product design process, taking into account not only the needs and expectations of consumers, but also the knowledge base developer.

The key objective is to define the quality assurance (identification) characteristics of product quality. From this task depend on further steps of the product life cycle and, ultimately, the competitiveness of the organization. In theory, under the control of the system to understand the definition of identity structure of the system and its parameters by analyzing the inputs and outputs of the system [2, 3, 4, 8]. The structural and parametric identification of commercial products using modern methods of quality management.

Modern methods of transformation of customer requirements in the immediate characteristics of the new (or upgraded) product quality identification method is QFD. The aim of the method is the conversion request (needs and expectations) in product specifications and work instructions, visualization, documentation and planning quality. The main element of QFD is precisely the deployment of customer requirements in the production and the attainment of the relevant specifications to meet consumer expectations. That is, in this case we are talking about the pre-production to the production of new products.

In the expanded implementation of QFD process includes four levels, and each of them built a house of quality (House of Quality, HoQ).

At the consumer level I converted into technical specifications. Then the last components are converted into characteristics (level II), then - in process parameters (level III), and then performance requirements operations (IV level).

The result of the application of QFD is to set priorities and identify the product characteristics, characteristics of the components, process parameters and auxiliary operations, the greatest impact on meeting customer requirements.

Thus, the absolute value of the priority of the j -th generalized characteristics of the product by 1 level QFD is calculated using the formula:

$$qI_j = \sum_{i=1}^n (pI_i \cdot hI_{ij}) = pI_1 hI_{1j} + pI_2 hI_{2j} + \dots + pI_n hI_{nj} \quad (1)$$

where hI_{ij} - the coefficient of the relationship j -th generalized characteristics of the product and the i -th requirements; pI_i - the relative importance of the value of the i -th requirements for the consumer; n - number of consumer requirements.

Methods of identifying quality evolve simultaneously with the development of the concept of "quality". At the same time a significant role in the development of QFD play mathematical approaches that are used in computer parts (matrix calculus, the solution of the inverse problem), and in terms of integration with other methods, such as a table of voice user (VOCT) [4, 5, 9], the theory of solutions Inventive Problem Solving (TRIZ) [10], analysis of the types and consequences of potential

inconsistencies (FMEA) projects to improve the "Six Sigma" and others [11, 12].

The effective application of the method proposed structuring of knowledge and use of the ontological approach. The traditional approach to designing products means choosing the concept and definition of the technical characteristics of products. This is often the author of a technical project is the developer. Taken into account the knowledge base in the class "concept products" and attributes "Product Features". The ontological model of design quality on the basis of QFD, in contrast to the traditional approach to the design in the first place takes into account the class of "user requirements".

Customer requirements are determined by analyzing the voice of consumers and are described by a list of requirements (in accordance with the model N. Kano [9] consists of the basic requirements, contractual requirements and expectations of customers), the importance of the requirements (for example, on a 10-point scale) and evaluation competitiveness of products / customer satisfaction (including benchmarking data). The result of the design on the first level are the QFD concept (structure) of products and product characteristics, which are described by a list of specifications, interconnection and value characteristics. This design goal is not only the "development" or "modification" of products, and the development or modification of the product, taking into account the characteristics of the relationship and data benchmarking so as to achieve the necessary level of competitiveness. In the case of product design consisting of individual components, great care must be taken the design quality of the components, which is defined not only by their technical characteristics, but also the quality of manufacturing processes and the production conditions. The ontological model of design quality on the basis of QFD is implemented using the tool Protégé. The structure of the ontology is similar to the hierarchical directory structure.

3 Implementation of the ontological model of design quality on the basis of sustainable matrix method MTQFD

It is proposed to use the method of approximate solution of sustainable method of approximate solution of the following matrix equation (hereinafter - linear mathematical model LMM):

$$H \cdot \delta\Theta = \delta P, \quad (2)$$

where $\delta\Theta$ - n -dimensional vector of relative deviations of parameters of state (estimates of the target values of the product characteristics for level 1 QFD), δP - k -dimensional vector of relative deviations signs of state (the importance of the requirements and expectations of customers (for level 1 QFD), H - matrix of size $(k \times n)$ the coefficients of the requirements and characteristics of the relationship (for level 1 QFD).

The developed algorithm matrix method MTQFD includes both the conventional calculation of vectors of

priorities, and the parametric identification of the characteristics of the products / components (1, 2 levels QFD) and parameters of technological processes and auxiliary operations (3, 4 levels QFD), is widely used in engineering sciences.

Using matrix transformations and known method of least squares (OLS) using the formula (3), we obtain not only adopted in the evaluation of QFD priorities change specifications, but other assessment areas for further improvement.

$$\hat{\delta\Theta} = (H^T P H)^{-1} H^T P \delta P \quad (3)$$

where P - is the weight matrix of error requirements and expectations.

In addition, the conditions of existence of the real possibility of serious errors in the measurements of the state of signs (for first-level error QFD marketing data can be 10..50% for small samples) use OLS requires the use of special methods of preliminary rejection of initial data [13].

It is proposed to use OLS, in limited cases, only if the number of requests is greater than the number of features / parameters involved in the model.

If the number of performance exceeds the number of claims, it is advisable to use an algorithm robust parametric identification of the mathematical model, taking into account information about the error model (matrix interconnection requirements and specifications), and features state (needs and expectations), as well as additional information about the possible values of the relative changes in the parameters state (characteristics), taking into account the risks, the characteristics of correlations ("roof» HoQ).

All sustainable scheme for estimating linear models are based on the functions of impact and sustainability assessment. Particular attention is paid to the assessment of sustainable Huber. To find a sustainable assessment Huber used an iterative procedure that converges to robust estimates for finite number of iterations [13].

Solution of the problem in this formulation allows to obtain estimates of the parameters of state (the relative change in performance), both agreed with the results of marketing research and benchmarking, and more information and knowledge about the inaccuracy of the data and the developer.

It is proposed to conduct parametric identification based on regularization theory, can reasonably take into account a wide range of different additional information. Upon receipt of regularized estimates take into account the best pilot and the additional information, the choice of the regularization parameter α carried c considering the measurement error and uncertainty factors (matrix H) LMM [1].

The developed method MTQFD regularized solution of the problem of parametric identification of the mathematical model is defined as follows:

$$\hat{\delta\Theta}^\alpha = \arg \min_{\delta\Theta} M^\alpha[\delta\Theta] \quad (4)$$

where

$$M^\alpha[\delta\Theta] = \sum_{i=1}^k F_1(c_1, \Delta_i, p_i) + \alpha \sum_{j=1}^n F_2(c_2, \delta\Theta_j - \delta\Theta_j^0, q_i),$$

where F_1 and F_2 - function of the special form [1, 13], Δ - residual, p, q - weight discrepancy, c - setting Huber.

In the case of the quadratic norm equation (4) takes the following form:

$$M_1^\alpha[\delta\Theta] = \|H\delta\Theta - \delta P\|_p^2 + \alpha \left\| \delta\Theta - \delta\Theta^0 \right\|_q^2,$$

where $\|\cdot\|_p = (\cdot)^T P (\cdot)$ - quadratic norm with weights.

It is evident that the decision on the one hand, depends on the use of information and benchmarking LMM, prisoners in the first term $\|H\delta\Theta - \delta P\|_p^2$ smoothing functional M_1^α , on the other hand - on the information about the possible values of the parameters of state concluded in the second term $\|\delta\Theta - \delta\Theta^0\|_q^2$. Ratio between benchmarking and additional information is determined by the regularization parameter α .

Selecting the iteration step, which determines the desired value of the relative deviations of parameters of the state and the corresponding regularization parameter α , is carried out at the value of the regularization function $f(\alpha)$ closest to zero:

$$f(\alpha) = \left\| H\hat{\delta\Theta} - \delta P \right\|_p^2 - \alpha (\delta + h \left\| \hat{\delta\Theta}^\alpha - \delta\Theta^0 \right\|_q)^2 \quad (5)$$

here: $\left\| \delta P - \delta \bar{P} \right\|_p \leq \delta$, $\left\| H - \bar{H} \right\| \leq h$, $\left\| \hat{\delta\Theta}^\alpha - \delta\Theta^0 \right\|_q$

defined differently for each task.

To implement the method presented MTQFD developed a software module in the system MathCAD. To simplify the implementation of the method in the development of software module provides the use of the original data in the form of standard tables, MS Excel, which allows researchers and experts not to spend resources for technical training data and focus on the issues of "quality" of the original data and the additional information.

The purpose of the expert system of design quality on the basis of MTQFD is to improve the quality of products due to: the automated storage ways to improve product competitiveness and customer satisfaction; the development of a mathematical model of the process of identification of product quality; formalizing the knowledge representation of experts; creation modes advice, training and the acquisition of new knowledge.

Expert system is the standard structure of the knowledge base (description pro-problem areas, procedural knowledge, declarative knowledge, attributes and source data consulted) and shall take into account the experience of experts in the design of products and time-processing technology and manufacturing processes. The knowledge base in addition to the specific information requirements of consumers and characteristics of products includes models of the problem domain for components, technology and production processes, including proper description of the area and knowledge of the problem solving procedure (consultation scenario). The expert system provides a solution to problems on the basis of knowledge, including knowledge of different classifications, as well as experience experts in product design and development processes. The expert system is

focused on the identification of product quality throughout the development of products, components, technology and production processes (all 4 levels QFD).

4 Discussion

The proposed objective ontology design quality is based on the ontological approach, developed in the systems management and enshrined in international standards, which, in fact, form a meta-ontology. Developed ontology MTQFD method can significantly alleviate the designers, engineers and experts to solve practical problems of identification and further planning of quality, as well as improve the accuracy and robustness of the results to the initial data errors. Ontology is implemented on the example of the problem of designing automotive wire taking into account additional information, including the results of failure mode and effect analysis (FMEA) [11]. Application of the ontological approach and method MTQFD allowed reducing design period, to improve the quality and competitiveness of automotive wire due to the calculation of new priorities, clarify product specifications and parameters of technological and manufacturing processes.

Advance understanding of the ontological paradigm and design of quality products based on parametric identification of models, customer requirements, knowledge can achieve to improve product quality and competitiveness in various industries.

References

1. A.Ya. Dmitriev and T.A. Mitroshkina. Ontology of designing, **5**, 313-327 (2015) [In Russian]
2. K.J. Astrom and P. Eykhoff, *Automatica*. **7**, 123 (1971)
3. L. Ljung, *System identification. Theory for the User*, (Prentice Hall, 1999)
4. E.V. Nikulchev, *2014 International Conference on Computer Technologies in Physical and Engineering Applications (ICCTPEA)*, pp. 129 (2014)
5. Y. Akao and G.H. Mazur, *International Journal of Quality & Reliability Management*, **20**, 20 (2003)
6. G. Mazur. *12th Symposium on QFD/6th International Symposium on QFD2000*, pp. 305-317 (2000)
7. ISO 9001:2015 (2015)
8. G.N. Rogachev, *Automatic control and computer sciences*, **48**, 249 (2014)
9. N. Kano, N.Seraku, F.Takahashi and S.Tsuji, *Journal of Japanese Society for Quality Control*, **14**, 39 (1984)
10. H. Yamashina, T. Ito and H. Kawada, *International Journal of Production Research*, **40**, 1031 (2002)
11. V.N. Rodionov, T.V. Popova, A.Ya. Dmitriev and T.A. Mitroshkina. *Metodyi menedzhmenta kachestva*. **8**, 30 (2011) [In Russian]
12. T.M. Fehlmann, *Int. J. of Quality & Reliability Management*, **22**, 83 (2005)
13. Peter Huber. *Robust Statistics* (Wiley, 1981)