Parametric Models of the Product Novelty Assessment Through the Basic Structures Approach

G I Korshunov¹,², S A Nazarevich¹

¹Innovation and Integrated quality systems dept., Saint-Petersburg State University of Airspace Instrumentation, 67, Bolshaya Morskaya St., Saint-Petersburg, 190000, Russia
²Ciberphisic systems and control high school, Peter the Great St.Petersburg Polytechnic University, 29, Polytechnicheskaya St., Saint-Petersburg, 195251, Russia

E-mail: kgi@pantes.ru

Abstract. The achievement of essential consumer parameter values or the implementation of new functionality determines the degree of novelty of the product. However, issues related to the evaluation of technical and scientific novelty of experimental products remain open. This is due to different approaches in the formulation of the problem in terms of many parameters. One of the known approaches to quality assessment is the formation of options based on the basic structures. This approach is consistent with the practice of creating a new product based on a retrospective analysis of the basic structures in the selected problem area. Known, for example, models of functionally necessary and functionally sufficient structures, basic structures represented by the point of the multidimensional parameter space. An important complement to this approach is to take into account the constraints required to manage the quality of an innovation project. The process of improving the parameters of new products is halted by the existing limitations, both in scientific and technological progress and in the social environment. The paper proposes to determine the degree of change in the technical characteristics of new products in relation to the current analogue or adopted prototype. The set of technical and social requirements established for the product by the terms of technical requirements and normative documents determine the functional significance of new products. Models and methods of estimation of a product novelty achievability in the conditions of not completely clear requirements of the market are offered. The analysis of the degree of change of parameter values is performed using fuzzy logic and flexible calculations. The parametric model application allows, taking into account the existing limitations, to determine the required level of perspective novelty of products.

1. Introduction

The novelty of the product is the object of analysis from different points of view of innovation and quality theory. The novelty of a product can be determined by the level of sales during the life cycle, when, upon reaching the limit of novelty, it becomes traditional and obsolete. However, along with such a utilitarian approach, it is important to determine the set of properties characterizing novelty, as well as to reveal the origin of the new product. The sources for the appearance of a new product may be the current analog or the accepted prototype. More in-depth studies lead to fundamental innovations, defined as basic technologies [1]. Applied importance of fundamental innovations shows
itself in the form of new generations of products and trends in the development of technology. Corresponding phenomena and new knowledge are formed in the form of subject and problem areas and as a knowledge base, where it is possible to trace the development of the product under consideration, represented by the structure of basic indicators (parameters). Formation and selection of a variant of a new product is performed on the basis of a parametric model and one or many criteria.

2. Kinds of basic structures
The idea of creating a new product based on the basic structure is not new and is reduced to the tasks of forming options and choosing the optimal ones. The intuitive "structural" approach to creating a new product is presented in [2] as the selection of some basic minimum set of tools for the subsequent enhancement of functionality in order to perform increasingly complex tasks. The received basic structures are proposed to be subdivided into functionally necessary and functionally sufficient ones and a game approach is proposed for solving the problem of choosing optimal base structures in the parameter space. The presented model is constructed taking into account Pareto consistency and Nash balance.

The task of forming and selecting variants is proposed in [3] to be performed in the morphological parameter space, where the base points are formed. Formation of morphological variants is carried out in some neighborhood of the base point taking into account the limitations, and the advantage of the chosen variant is determined by the proximity to this point on the basis of the accepted metric.

Existing models and methods for the formation and selection of options are the theoretical basis for assessing the novelty of the product. However, the answer to the question whether it is always possible to consider a new product as the best is not unambiguous. The article is devoted to the problem of ensuring the functional significance of the projected products, represented by a set of technical and social requirements, with limitations of social significance and the current state of the technique and technology.

3. Parametric models and limitations
The development and achievement of novelty on the basis of basic structures is carried out in conditions of incomplete certainty. Reducing the level of uncertainty is provided by the decomposition of the goal and the creation of a system of parameters. The parameters of the basic structure describe its primary properties and are the initial data in the study and choice of options.

The parametric model can include a working range of parameters that are meaningful to the customer or the implementation of new functional parameters on the current product line. For a clear definition, market research is carried out, the result of which is the first indicator of the competitiveness of the chosen enterprise strategy. The conducted researches based on the data of the retrospective analysis, allow to draw a conclusion that in many cases there is no absolutely new product, and there is a degree of difference from the basic structure of the sample.

As an example, the project "Technology of year-round production in cultivation facilities of high-quality ecologically safe plant products" is considered (Fig. 1). The innovation was realized using a light-vegetation plant for growing plants under the project "NOV". An improved innovation for obtaining product versions is the hydroponic plant growing plant, performed in the project to select the basic structure of "BS" [6].

The project implementation corresponded to the planned development, laid in accordance with the principles of advanced standardization. In such conditions it is rather difficult to predict future prospective characteristics without taking into account real social standards such as market requirements (Fig. 2). The increase in the number (Fig. 1) of the functionally necessary and functionally sufficient characteristics of the "BS" project has undergone an adjustment. Taking into account actual social requirements, the demand curve for the technical product was prolonged. There was a need for preventive management of the development of complex technical products.
Iterative development of basic structures of functionally necessary and functionally-sufficient complex technical products is hampered by existing limitations in scientific and technical progress and in the social and consumer environment. These limitations are related to problems of replication and diversification of available technologies [7], applicable for large-scale production.

The initial set of parametric models $Z_n (Y_n; X_n)$ is subject to the dichotomy of iterative development, which is affected by a set of limitations in the development of the level of technology (M) and existing social standards (S). The principles of continuous successive improvement [2] laid by advanced standardization create the conditions for the appearance of a second kind of error - the adoption of a false hypothesis about the market demand in the parametric model $Z_3 (Y_3; X_3)$. With the real possibility of creating new or updated social standards by adopting the parametric model $Z_2 (Y_2'; X_2')$, production processes are stimulated. This is appeared in the increasing demand for typical solutions from the product line represented by the parametric series.
Figure 3. Fragment of the choice of the parametric model.

A retrospective analysis of the development of functionally necessary and functionally sufficient technical products has shown that the adoption of an invariant parametric model based on the results of analysis of the basic structure ensures the growth of market demand for such products, thereby creating new social standards. Therefore, such a decision as the best practice was used to improve the "NOV" project based on the application of the methodology for assessing the novelty of the parametric model of the basic structure.

4. The method of evaluating novelty

The determination of the degree of change in the requirements for the technical characteristics of the new product in relation to the basic structure is expressed in the form of a technical requirements, where a correspondence is established between the adopted parametric model of the projected product and the current limitations of S, M. The practical solution consists in applying the analysis of the basic structure of products (Table I).

Table 1. Method for analysis of the basic structure - changes in consumer characteristics.

| Name of product characteristics changes | Degree of change in consumer characteristics (I_{12}) |
|----------------------------------------|------------------------------------------------------|
|                                        | I_{12} = \frac{P_{\text{improved consumer characteristics}}}{P_{\text{total number of consumer characteristics}}} |

Degree of technical performance change (I_{11})

| Degree of technical performance change (I_{11}) | I_{11} = \frac{P_{\text{number of improved specifications}}}{P_{\text{total number of technical characteristics}}} |

The consumer characteristics and characteristics of the results of changes describe the secondary properties of the product and are defined as a function of the parameters. Formula (1) is used to evaluate the degree of novelty of a parametric model of functionally-necessary and functionally-sufficient complex technical products. The obtained quantitative ratio of the requirements to the
degree of change in the technical characteristics of the product to the total number of technical characteristics of the basic structure makes it possible to obtain the result of the degree of change (Table II) and the interpretation according to the forms of innovation activity (Table III).

\[ Q = \frac{P_{\text{improved consumer characteristics}}}{P_{\text{total number of consumer characteristics}}} + \frac{P_{\text{numb}}}{P_{\text{total numb}}} \] 

### Table 2. Method for analyzing the basic structure – the results of changes in consumer characteristic.

| Value | Characteristic of the results of changes | Degree of progressiveness of innovation (I_{13}) | The created social effect (I_{14}) |
|-------|------------------------------------------|-----------------------------------------------|----------------------------------|
| 0,2   | Improving the secondary characteristics of the innovation object | Not the achievement of social requirements (standards) | Providing separate social requirements |
| 0,4   | Improving the basic characteristics of the innovation object | A significant excess of the main characteristics of the object | Ensuring social requirements (standards) |
| 0,7   | Significant excess of the main characteristics of the innovation object | Improvement of the individual social requirements | Improvement of the whole complex of norms |
| 0,8   | Achievement of qualitatively new characteristics | Significant excess of social requirements | Exceeding the world level of social requirements |
| 1     | Receiving new products, first mastered in the national economy | | |
| 2     | | | |

The normative documentation for the operation of products adopted for the basic structure and the results obtained from consumers should be used for a comprehensive analysis of the requirements for the degree of change in the significant characteristics of the product.

### Table 3. Scale of results of application of the method.

| Value | Notation | Name of membership of the basic structure |
|-------|----------|-----------------------------------------|
| 0,2   | Q1       | Modification                            |
| 0,4   | Q2       | Surface improvement                     |
| 0,6   |          |                                        |
| 0,8   | Q3       | Deep improvement                        |
| 1,0   |          |                                        |
| 1,2   | Q4       | Modernization                           |
| 1,4   |          |                                        |
| 1,6   | Q5       | Innovation                              |
| 1,8   |          |                                        |
| 2,0   |          |                                        |
The main difficulty in applying the methodology is to determine consumer characteristics that are set by social standards with unclear requirements. A fuzzy logic method is used for the analysis of consumer characteristics for an example [6], [7], [8], [9].

\[ \begin{align*}
\mu_{g_1} & = \begin{cases} 
0, & \text{if } x < 0,1 \\
0,1 & \text{if } 0,1 < x < 0,2 \\
0,2 & \text{if } 0,2 < x < 0,6 \\
0,6 & \text{if } x > 0,7 \\
0 & \text{if } x > 1,0 \\
\end{cases} \\
\mu_{g_2} & = \begin{cases} 
0,1 & \text{if } x < 0,6 \\
0,2 & \text{if } 0,6 < x < 0,7 \\
0,8 & \text{if } 0,8 < x < 1,0 \\
1 & \text{if } x > 1,1 \\
\end{cases} 
\end{align*} \]

**Figure 4.** Functions of belonging to basic structures.

The mathematical equations for the membership functions based on the trapezoid, with a well-defined nucleus of the set of basic structures are given in the formulas below:
\[
\mu_{(1)} = \begin{cases} 
  y = 0, & \text{if } x < 1.0 \\
  x - 0.1, & \text{if } 1.0 < x < 1.1 \\
  0.2 - 0.1, & \text{if } 1.1 < x < 1.4 \\
  0.6 - 0.2, & \text{if } 1.4 < x < 1.5 \\
  y = 0, & \text{if } x > 1.5 
\end{cases}
\]

\[
\mu_{(2)} = \begin{cases} 
  y = 0, & \text{if } x < 1.2 \\
  x - 0.1, & \text{if } 1.2 < x < 1.4 \\
  0.2 - x, & \text{if } 1.4 < x < 1.8 \\
  0.6 - 0.2, & \text{if } 1.8 < x < 1.9 \\
  y = 0, & \text{if } x > 1.9 
\end{cases}
\]

\[
\mu_{(3)} = \begin{cases} 
  y = 0, & \text{if } x < 1.6 \\
  x - 0.1, & \text{if } 1.6 < x < 1.8 \\
  0.2 - x, & \text{if } 1.8 < x < 2.0 \\
  0.6 - 0.2, & \text{if } 1.9 < x < 2.0 
\end{cases}
\]

5. Conclusion

The article proposes to determine the degree of change of technical parameters of new products in relation to the current analogue or the accepted prototype, represented as the basic structures. The proposed approaches allow the formation of invariant parametric models based on the results of analysis of the basic structure of functionally necessary and functionally sufficient technical products.

The use of such models ensures the fulfillment of the requirements established to change the degree of novelty. This allows us to take into account the needs of the market in products, thereby creating new social standards. At the same time, the set of limitations in the development of the state of the art and the existing social standards necessary to manage the quality of the innovation project are envisaged. Analysis of consumer characteristics of new products is carried out in conditions of incomplete certainty. Uncertain logic and flexible computing are used to uncover uncertainties, as well as other models and methods used to manage innovative projects, their risks and opportunities.

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