Compositional Method of Geometric Modeling: Basic Principles

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Abstract

The article presents the origins and systematizes the basic properties of the compositional method of geometric modeling in the context of modeling of complex multifactorial systems. The method is based on the means of the point calculation of Baliuba-Naidysh and has its advantages in geometric formalization of a large number of input factors of different nature. The approaches to parameterization of a point, a plane and an n-dimensional figure are shown. The possibility of transformation of geometric figures in local simplices without the use of the global coordinate system is proved. The invariance of the BN-coordinates in projecting on each of the axes allows us to break the complex multi-parameter n-dimensional problem into n simple, one-dimensional problems. This can significantly simplify the calculation process and reduce the system requirements for the used computer equipment. Based on the methods of BN-calculus, the method of BN-interpolation for a B-curve passing through three points uses a parametric connection. The searched current point is defined as the sum of the shares of participation of all outgoing points, therefore, there is no need to use systems of algebraic equations. This prevents composite method of geometric modeling from oscillations.

Keywords: compositional method of geometric modeling, point calculation of Baliba-Naidsh (BN-calculus), BN-coordinates, BN-interpolation.

Problem setting. Formulation of the problem. Daily management activities, in particular, in the field of selection and implementation of energy saving projects, require the adoption of appropriate decisions. Typically, such decisions are made by the manager on the basis of their own experience, based on the calculations provided by the relevant experts and analyzing a large number of heterogeneous factors. The subjective part of such decisions may result in incomplete use of existing energy saving potential.

Improving the quality and reasonableness of such decisions by reducing the subjective component is achieved through the introduction of information systems supporting management decisions. These systems are implemented on the basis of relevant models. However, given the complexity and multifunctionality of real (economic) objects for modeling, such models are rather complex. In the case of changes in input factors reconfiguration of labor models and requires highly qualified personnel. This prevents the widespread distribution of such systems, especially among small businesses.

Thus, the development of a modeling method that will allow us to create an easy-to-use and easy-to-read information system that can take into account the unlimited number of input factors of any nature, analyze factors in different combinations and at different levels of the hierarchy, and visualize the results, is relevant .

Analysis of recent research. Based on the analysis of recent studies, the expediency of using Baliuba-Naidysh point calculation methods [1] has been determined, taking into account such advantages: convenient formalization of initial data; the absence of a need to solve systems of algebraic equations [2]; the absence of an attachment of point equations to a global coordinate system. Taking into account the available research results and the development of the compositional method of geometric modeling [3, 4, 5], it was possible to systematize the properties of this method in the context of multifactorial systems modeling.

The purpose of the article. Identify and systematize the basic properties of the compositional method of geometric modeling, which is based on the means of the point calculation of Baluba-Naidysh, in the context of its application for the geometric modeling of multifactorial systems.

Main part.

In view of the fact that the developed compositional method of geometric modeling is based on the principles of the calculus of the Baliuba-Naidysh (BN-calculus), we will explain the basic principles of BN-calculus.

Let given points A, B, C in the global coordinate system X, Y, Z (Fig. 1).

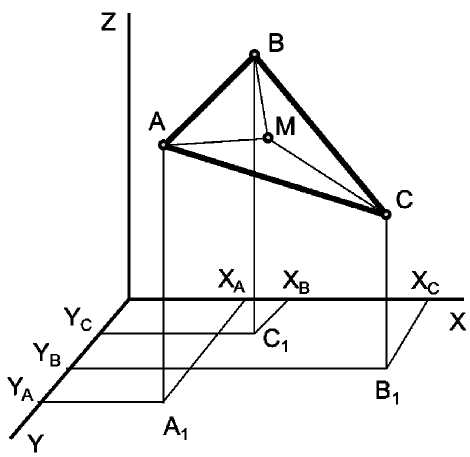

Fig. 1. Determination of the current point M.

Then the point coordinates can be denoted as $A(X_A, Y_A, Z_A)$; $B(X_B, Y_B, Z_B)$; $C(X_C, Y_C, Z_C)$.

Let us arbitrarily take the current point M in the plane ABC. According to the principles of the point calculation, the point M can be determined relative to the basic points A, B, C through the corresponding parameters (which are called BN-coordinates), that is: $M(p_M, q_M, r_M)$, where p_M, q_M, r_M – BN-coordinates . In this case, the sum of all BN coordinates should be equal to one, that is, p + q + r = 1.

BN-coordinates are defined as the ratio of the area of the corresponding triangle to the area of the entire triangle ABC, namely:

$$p = \frac{S_{MBC}}{S_{ABC}} \quad q = \frac{S_{AMC}}{S_{ABC}} \quad r = \frac{S_{ABM}}{S_{ABC}}.$$

Thus, the point M is given in simplex A, B, C [6]. This made it possible to perform operations on points without using the global coordinate system. This is one of the most important principles of BN-calculus.

Using the BN-coordinates, the parameterization of the plane relative to the vertices of the simplex A, B, C:

$$M_2 = Ap_A + Bp_B + Cp_C;$$

where p_A; p_B; p_C is the BN-coordinate, with $p_A + p_B + p_C = 1$;

M_2 is a B-figure.

Similarly, the parameterization of the n-dimensional space relative to (n + 1) of the vertex of the simplex A_0, A_1, ... A_n:

$$M_n = A_0a_0 + A_1a_1 + \ldots + A_na_n; \quad a_0 + a_1 + \ldots + a_{n-1} + a_n = 1,$$

where a_0; a_1; ... a_{n-1}; a_n – BN-coordinates.

From this it is possible to formulate the following provisions:

- Parametrization can be generalized to n-dimensional space.
- The values of BN-coordinates determine the share of the participation of each of the input points A_i in the formation of the current point of M_i.
- Each current point is defined as the sum of the shares of all ingoing points. Proceeding from this, on B-curves there is no oscillation.

- The appearance of points of bend on the B-curves may be due to the incorrect selection of output points. Applying the methods of Variable discrete geometric modeling, you can easily get rid of unnecessary points of inflection.

The formation of the point equation of the B-segment of surface can be represented as follows (Fig. 2):

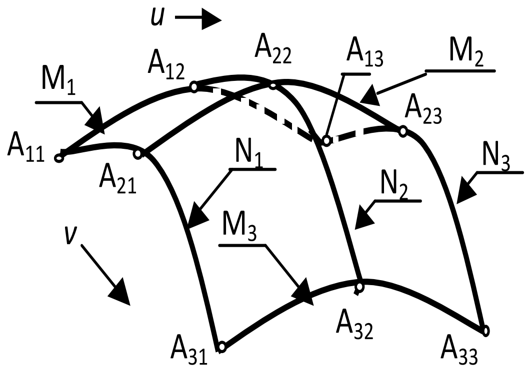

Fig. 2. The scheme of formation of the point equation of the B-surface.

From the above scheme you can make the equation of the edges along the parameter u:

$$M_i = A_{i1} p_1 + A_{i2} q_1 + A_{i3} r_1;$$

as well as the equation of edges along the parameter v:

$$N_j = A_{1j} p_2 + A_{2j} q_2 + A_{3j} r_2;$$

where p_1, q_1, r_1, p_2, q_2, r_2 are the parameters that determine the properties of the B-figure.

B-surface is formed when in the same equation, instead of points, the second equation is substituted - the method of a moving simplex (the method of Baliuba).

Taking into account the above, we can formulate the basic principles of the compositional method of geometric modeling:

1. The method is based on a point BN-calculus;

2. The method uses local simplexes;

3. Determines the BN-coordinates relative to the vertices of the original geometric figure;

4. Solves tasks in space whose dimension determines the number of parameters of the factor under consideration;

5. Because of the application of the simple ratio of three points, the spatial solution is projected onto the axis of the corresponding parameters with the preservation of certain BN-coordinates;

6. The spatial solution of the problem is given by a parametric point form, for the segment B-surface as a whole, without dividing it into separate cells;

7. The model of a geometric figure with a constant number of ingoing points is constant due to the fact that it is constructed on the properties of the geometric figure and the interconnections between the points forming it;

8. Any qualitative change in the starting points of a geometric figure does not change the model;

9. The current point is defined as the sum of the shares of participation of all nodal points in the original geometric figure, while the value of the participation share is equal to the corresponding BN-coordinate;

10. The obtained solution in a local simplex, whose vertices are defined in the global coordinate system, can easily be translated into the original global coordinate system and determine the parameters of the position of the geometric figure relative to it.

11. An analysis of a multidimensional problem can be carried out by designing a solution separately for each axis of multidimensional space. That is, dividing a multidimensional problem into a corresponding number of one-dimensional ones.

12. Having one-dimensional solutions, all connected by a common $0 \le t \le 1$ parameter, with further unification, in different variants, projections on the axes, it is possible to more thoroughly analyze the processes through the use of computer simulation.

Conclusion.

Based on the properties of the point calculus of Baliuba-Nidysh, the properties of the compositional method of geometric modeling (CMGM) are determined and systematized. Determination of the immutability of the BN-coordinates when designing for each axis gives the opportunity to consider each factor separately. This allows you to vary the values of any source factors without changing the model itself, which opens wide prospects for researching a real object in different operating modes.

Based on the developed approach to the geometric interpretation of factors, a monofactorial analytical principle is proposed and an algorithm for constructing a multilevel model for multi-factor systems is proposed. Using this algorithm, using the principle of combining several B-surfaces with the help of the B-curve, it is possible to analyze the object of modeling at any desired level of the hierarchy.

Based on the methods of BN-calculus, the method of BN-interpolation for a B-curve passing through three points, uses a parametric connection. The searched current point is defined as the sum of the shares of participation of all outgoing points, therefore, there is no need to use systems of algebraic equations. This prevents CMGM from oscillations. Oscillation is possible only if one or more output points are misplaced, which can be eliminated by using known methods.

An important feature of CMGM is the possibility of breaking a complex n-dimensional problem into n simple one-dimensional problems with the subsequent combining of results; easy algorithmization and reduced system requirements for computer during calculations.

Due to the convenience of software implementation and reduced system requirements for computer during the calculations, ease of use, it is promising to implement the method in the daily work of the head of the company, including using on mobile devices.

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