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DESCRIPTION OF THE TRANSFORMATION OF GEOMETRIC FORMS IN A FOUR-DIMENSIONAL SPACE

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Abstract

The article deals with the construction of a new method for representing geometric figures in four-dimensional space, the problem of interpreting a function of many variables through its parameters. The task of transforming the geometric shapes of three-dimensional objects into four-dimensional space is relevant in the practice of designing shells of floors of civil and industrial structures. The design of shells based on 3D modeling methods is insufficient in the design of building structures.

Keywords: hyper networks, finite difference method, boundary conditions, polihedron, nodes, substitutions in n-dimensional space

Observation of technical, building objects, especially technological processes in most cases when conducting research work, multivariate function testing requires that the goal is to find optimal (extreme) function values or to test optimal values around infinitely large values.

Naturally, such observations require the use of linear or non-linear programming to find optimal values, check the perimeter of optimal values, solve differential equations, or perform this process automatically. To automatically solve the problem, that is, when solving the issue of implementing a linear program, in turn, creates the need to approximate the objective function. Taking into account that the objective function is multiparametric, it becomes necessary to represent the poles in a multidimensional space. The description of geometric figures in multidimensional space, especially E^4, E^6, E^n [1-4], was carried out by various research works.

It is known that N.S. Gumen [5] managed to solve the problem of representation of basic geometric shapes and images in multidimensional space (En), the main properties and characteristics of their representation. He has conducted a number of scientific studies in this area. But in his work the relationship between axonometric projections was not clarified and the laws for choosing the angles of the coordinate axes were not revealed.

Therefore, in this study, we want to talk about our scientific research on the relationship between coordinate axes in a multidimensional space.

Let us present the algorithms for taking into account substitutions in the En-dimensional space:

1) To use the Monge apparatus in the space E^n $OX^I X^{II} X^{III} \dots . X^n$ arrows are taken in the order $OX^{n-2} X^{n-1} X^n$, $n \in d$;

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2) Each replacement is made at least (n-3) times.
3) The axes of X^{n-1} and X^n are always taken vertically and rotated 90° clockwise (n-3).
4) Since the diagrams obtained in the above order comply with all the rules of the Monge apparatus, it is possible to represent the image of the main geometric figures for any dimension in mutually perpendicular coordinate axes, i.e. $X^{n-2} \perp X^{n-1} \perp X^n$.

Let's move on to the presentation of several geometric shapes.

It is known that:

$$(x^I - a)^2 + (x^{II} - b)^2 + (x^{III} - c)^2 + (x^{IV} - d)^2 = R^2 . \qquad (1)$$

Expression (1) denotes a sphere of radius R with center O (a; b; c; d) in the space E^4. The ways to depict it in the drawing are as follows:

P.V. Filippov's method and his students are shown in Figure 1 [4]:

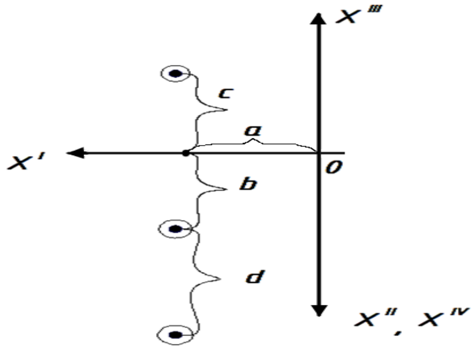
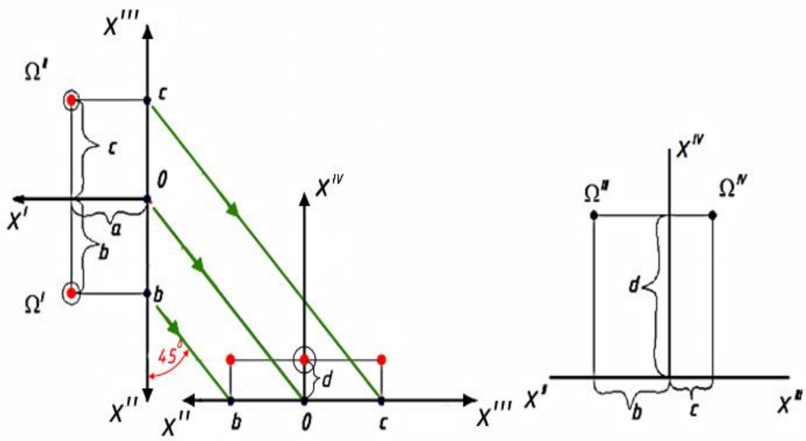


Fig. 1: Filippov's method

This method is sometimes called the Radishchev method, since both scientists are representatives of the same scientific school. [6].

Let's display equation (1) in a new way we have developed (Fig. 2) [7-10].



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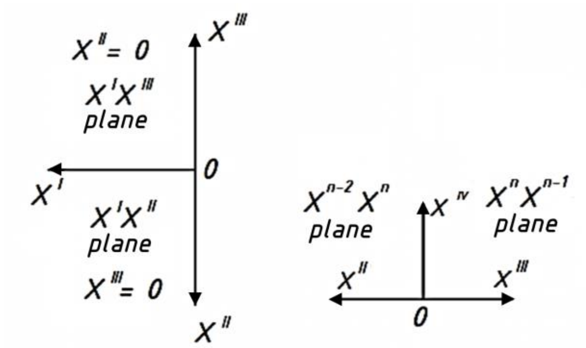

Fig. 2: Proposed new method of coordinate transformation

the space $X^{I}\perp X^{II}\perp X^{III}$ goes into the space $\rightarrow X^{II}\perp X^{III}\perp X^{IV}$.

If we generalize $X^{n-2}\perp X^{n-1}\perp X^{n}$ is converted to $X^{n-2}\perp X^{n-1}\perp X^{n}$. On each transition $X^{n-2}X^{n-1}X^{n}$ is converted to $X^{n-1}X^{n-2}X^{n}$ and rotated 90°. The space $X^{n-3}\perp X^{n-2}\perp X^{n-1}$ transformed into the space$X^{n-2}\perp X^{n-1}\perp X^{n}$.

The algorithm for transforming the space E^6 end E^n is shown in Fig.3.

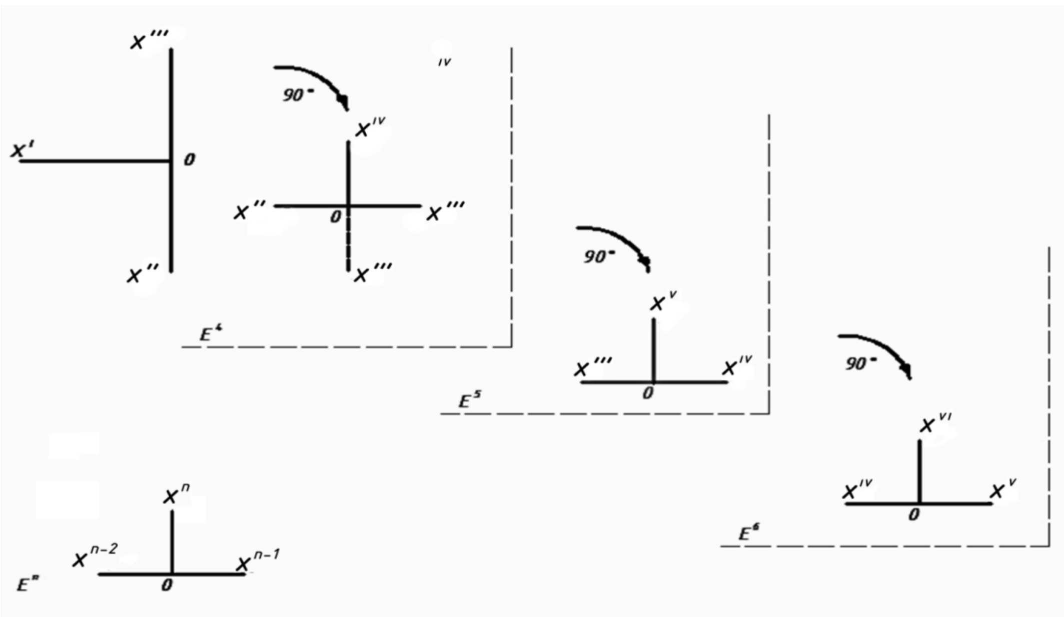

Fig. 3: Algorithm for transforming the space E⁶ end Eⁿ

Note:

1. X^{n-2} and X^{n-1} are positioned horizontally after a 90° rotation of the vertical axes around origin 0.
2. In each transformation, the same 0 is always taken as the origin.

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3. When the X^{n-2}, X^{n-1} axes are rotated by 90°, the origin 0 also rotates, and the X^{n} axis passes through the origin and is perpendicular to X^{n-2}, X^{n-1}.

Basic concepts. Types of axonometric projections. To create orthogonal projections of an object, each of the projections in the H, V and W planes, usually located parallel to their main dimensions (height, width, length), represents the two-dimensionality of an imaginary object. Therefore, drawings based on orthogonal projections can be easily made and the dimensions of the objects depicted on them can be quickly determined. However, such drawings are not illustrative. To overcome this difficulty, a drawing based on orthogonal projections of an object is supplemented by its axonometric projection.

Let us project point A, located in the first octant of the space with coordinate axes onto the plane P in the direction S. The plane P is called the axonometric plane. The projections of the coordinate axes on the planes *OpXp*, *OpYp*, *OpZp* are called axonometric axes (Fig. 4).

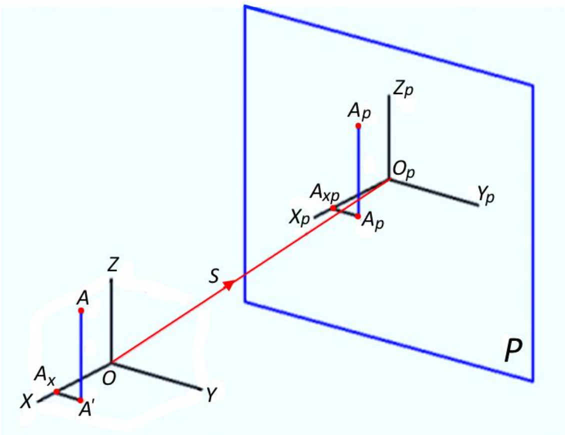

Fig. 4: Projection of the coordinate axes of space onto the axonometric plane P

The direction S (vector) can be oblique or perpendicular to the axonometric plane. Direction (vector) coordinates should not be taken parallel to any of the planes so that the image is clear.

The unit of length of an object of space, on the basis of which an axonometric image is made, is called a natural unit of measurement.

Suppose that each of the axes OX, OY, OZ has a segment e equal to some natural scale unit, described as ex, ey, ez.

The segments ex, ey, ez are called axonometric scales. The ratio of axonometric scales to the natural scale – $e_x e^{-1}$; $e_y e^{-1}$; $e_z e^{-1}$ are the coefficients of variation along the axonometric axes.

Let's m be the coefficient of variation along the $O_P\ X_P$, and n be the coefficient of variation along the $O_P\ Z_P$ axis.

So $m = \frac{e_x}{e}$; $n = \frac{e_y}{e}$. A three-part spatial broken line $OA_X\ A'\ A$ is projected onto the axonometric plane as a two-dimensional broken line $O_P\ A_{XP}\ \ A_P^I\ A$ (see Fig. 4). The point Ap is called the axonometry of the spatial point A, and the point A'p is called the axonometry of the point A'.

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Based on the properties of parallel projection:

Since $OA_X \in OX$, $A_X\ A' \parallel OY$; $A'\ A \parallel OZ$ then $A_{XP}\ A'_P \parallel O_P$, $A'_P\ A_P \parallel O_P Z_P$P.

We derive the regularity $\frac{A_{XP}\ A_P^I}{e_y} = \frac{A_X\ A^I}{e}$ or $\frac{A_{XP}\ A_P^I}{e_y} = \frac{e_y}{e} = m$, also $\frac{e_x}{e} = e_x * + e^{-1} = k$; $\frac{e_z}{e} = e_z * e^{-1} = n$.

Each node of the spatial polyline defines one of the coordinates of the right angle of the point ($OA_X = X$; $A^I\ A_X = y$ $A^I A = Z$).

The nodes of the polyline in the plane P are called the axonometric coordinates of the point and are denoted X_P, Y_P, Z_P. ($X_P = O_P\ A_{XP}$; $Y_P = A_{XP} A_P^I$; $A_P^I A = Z_P$).

If the coefficients of variation along the axonometric axes (k, m, n) are known, then you can go from the rectangular coordinates of a point to its axonometric coordinate system as follows: $X_P = kx$; $Y_P = my$; $Z_P = nz$.

Theorem 1. If the coefficients of change along the axes are equal to each other (m = n = k), such an axonometry is isometric.

Theorem 2. If two coefficients of change are equal to each other (k = n ≠ m; n = m ≠ k…), then the axonometry is dimetric.

Theorem 3. If the coefficients of change are not equal to each other, i.e. m ≠ n ≠ k, then such an axonometry is a trimetric.

The main theorem of axonometry, Polke's theorem, was discovered in 1953.

Theorem. Any three lines emanating from a point on the plane will be a parallel projection of three mutually equal lines perpendicular to each other in space. Let OX, OY, OZ straight lines emanating from the point O be mutually perpendicular in space and the segments OA, OB, OC lying on them (OA = OB = OC = e) are mutually equal (Fig. 5).

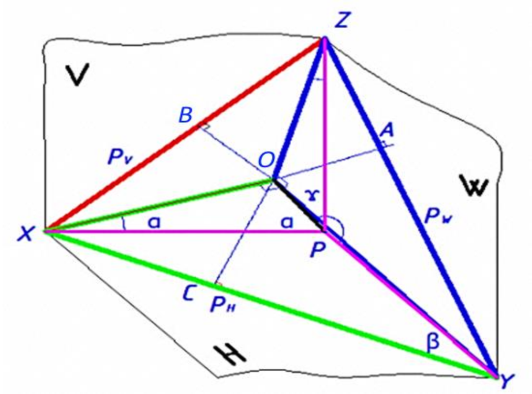

Fig.5: Scale tetrahedron

If we connect the points O, A, B, C in space, then we form a trihedral rectangular tetrahedron, the end of which is at the point O. This tetrahedron is called a scale tetrahedron. The term scale

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tetrahedron was proposed by Professor N.F. Chetverukhin.

Polke–Schwarz theorem: An arbitrary rectangle displayed on a plane can be considered as a parallel projection of a tetrahedron. In other words, the adjacent angles of the axonometric axes and the coefficients of change along them can be chosen arbitrarily.

Следовательно, теоретические основы трехмерного аксонометрического проектирования также справедливы в четырехмерном аксонометрическом проектировании.

Based on the study of the theoretical foundations of four-dimensional axonometric design of objects in three-dimensional space, a number of problems of complex multifactorial processes were solved. The main properties of E4, E6 and also En space contributed to the solution of a number of engineering problems of geoinformation technologies [11-14].

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