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CONSTRUCTION OF A HYPERNET WITH USE FINITE DIFFERENCE METHOD IN E4 SPACE

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ABSTRACT:

This article discusses the design of a hypernet using the finite difference method in four-dimensional space. Problems of interpolation of a function of many variables by its individual values are presented.

KEYWORDS: Hypernet, finite difference method, boundary conditions, affiliation, bypass points, nodes.

INTRODUCTION:

In practice, the problem often arises of interpolating a function of many variables from its individual values obtained experimentally. If the experimental values are taken as boundary conditions, then the interpolation of many variables can be carried out by the method of finite differences. The finite difference equation in this case can be written as a multidimensional generalization of the relationship between coordinate groups of adjacent elements of an elastic network [1,2].

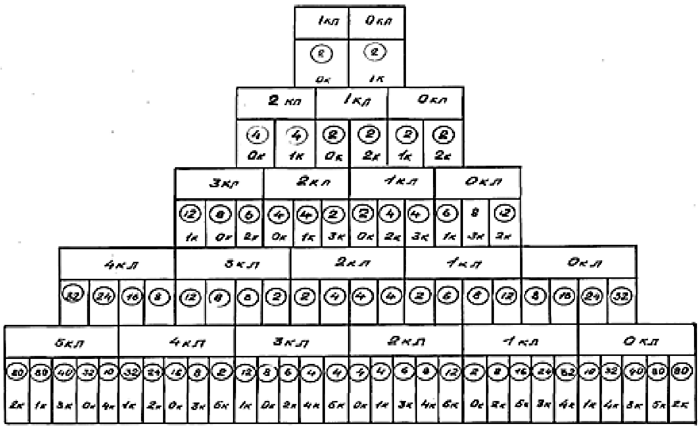
When compiling the finite-difference equation of the relationship between the coordinates of the hypernet nodes, it is necessary to take into account the numerical dependence of the mutual belonging of the hypernet elements. The dependence of the mutual belonging of *i*-dimensional cells of dimension *n*, where $2 \leq i \leq n$, described in the first paragraph, allow us to determine the numerical characteristics of the belonging of *q*-dimensional cells to *p*-dimensional cells in E^n space and vice versa, i.e. $N_q^n \in 6' \; N_0^n$ where 6 is the coefficient. So, in accordance with the formulas, the number of cells of dimension *q*; belonging to one *m*-cell: is defined as follows:

$$6_q^n = \frac{2^{m-q}\prod_{k=0}^{m-q-1}(m-k)}{(m-q)!} \qquad (1)$$

in *En* space, one m-dimensional cell belongs to cells of dimension (*m-1*) and 2(*n-m-1*) cells of dimension (*m + 1*). In particular, in the E^6 space, each *0*-dimensional cell contains ten one-dimensional cells (Table 1).

The set of nodes and links of an elastic n-dimensional hypernet, between which a functional dependence is established in the form of a finite-difference equation, is the star of an elastic hypernet. Such a star can be obtained as a set $6\,{}_1^n = \frac{1}{2}(n-1)$ broken, consisting of *0*-dimensional cells and one-dimensional cells, where n is the dimension of space.

Table 1.



Let us consider the representation of the finite-difference dependence between the coordinates of the nodes of a star in an n-dimensional hypernet as a set of finite-difference equations for i-dimensional polygonal lines in E^n space, where [1, n] ϵi.

Let a broken line $ABCDE \in \zeta$ be given in the E^3 space (Fig. 1.a).

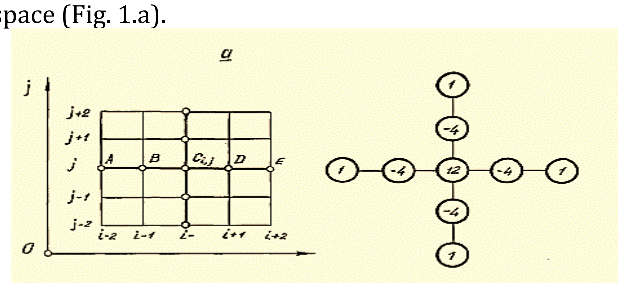


Fig. 1 Dependence between the coordinates of the nodes of the star.

It is required to determine the coordinates of these points of the bypass with a predetermined step.

The coordinates of the nodes (*0*-cells) are determined by solving the system of linear equations [1] in the E3 space in the direction

$$\begin{cases} Z_i = \frac{1}{6}\left(4Z_{i-1} + 4Z_{i+1} - Z_{i-2} - 4Z_{i+2}\right): \\ Y_i = \frac{1}{6}\left(4Y_{i-1} + 4Y_{i+1} - Y_{i-2} - 4Y_{i+2}\right) \\ X_i = \frac{1}{6}\left(4X_{i-1} + 4X_{i+1} - X_{i-2} - 4X_{i+2}\right) \end{cases} \quad (2)$$

towards

$$\begin{cases} Z_j = \frac{1}{6}\left(4Z_{j-1} + 4Z_{j+1} - Z_{j-2} - 4Z_{j+2}\right): \\ Y_j = \frac{1}{6}\left(4Y_{j-1} + 4Y_{j+1} - Y_{j-2} - 4Y_{j+2}\right) \\ X_j = \frac{1}{6}\left(4X_{j-1} + 4X_{j+1} - X_{j-2} - 4X_{j+2}\right) \end{cases} \quad (3)$$

If a discrete surface frame is represented as two families broken with common nodes located in vertical planes, then a discrete geometric model of an elastic network with a quadrangular cell can be built.

To obtain the coordinates of an arbitrary node *Ci,j* of a network with a quadrangular cell (Fig. 2b) in E^3 space, it is necessary to determine the arithmetic mean of the coordinates of the corresponding nodes of the polygonal lines in directions *i* and *j*, i.e.

$$Z_{i,j} = \frac{Z_i + Z_j}{2}; \; Y_{i,j} = \frac{Y_i + Y_j}{2}; \; X_{i,j} = \frac{X_j + X_i}{2}. \qquad (4)$$

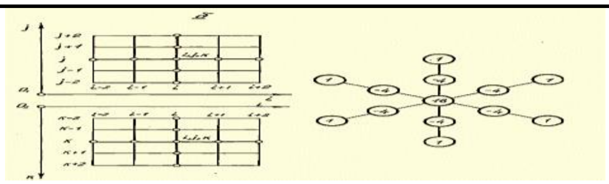


Fig.2b. The relationship between the coordinates of the nodes of the star.

Then, in accordance with (2) and (3), the coordinates of an arbitrary node Ci, j, a network with a quadrangular cell are determined by solving the following system of equations:

$$\begin{bmatrix} Z_{i,j} = 12^{-1}\begin{bmatrix} 4\left(Z_{i-1,j} + Z_{i+1,j} + Z_{i-1,j} + Z_{i,j-1} + Z_{i,j+1}\right) - \\ -Z_{i-2,j} - Z_{i+2,j} - Z_{i+2,j} - Z_{i,j-2} - Z_{i,j+2} \end{bmatrix} \\ Y_{i,j} = 12^{-1}\begin{bmatrix} 4\left(Y_{i-1,j} + Y_{i+1,j} + Y_{i-1,j} + Y_{i,j-1} + Y_{i,j+1}\right) - \\ -Y_{i-2,j} - Y_{i+2,j} - Y_{i+2,j} - Y_{i,j-2} - Y_{i,j+2} \end{bmatrix} \\ X_{i,j} = 12^{-1}\begin{bmatrix} 4\left(X_{i-1,j} + X_{i+1,j} + X_{i-1,j} + X_{i,j-1} + X_{i,j+1}\right) - \\ -X_{i-2,j} - X_{i+2,j} - X_{i+2,j} - X_{i,j-2} - X_{i,j+2} \end{bmatrix} \end{bmatrix} \quad (5)$$

If the broken line ς is represented in E^4 space, then in accordance with (1) it is possible to calculate the number 6_1^n directions passing through the central node of the star. For example, in E^4 the space $6_1^n = 3$. These directions are denoted by indices i, j к. The arithmetic mean values of coordinates along the directions *i,j,k* are determined by the following formulas:

$$X^I_{j_1,j_{2,j_3}} = \frac{1}{3}\sum_{i=1}^{3} x^I_{j_i}; \quad X^{II}_{j_1,j_{2,j_3}} = \frac{1}{3}\sum_{i=1}^{3} x^{II}_{j_i}; \quad X^{III}_{j_1,j_{2,j_3}} = \frac{1}{3}\sum_{i=1}^{3} x^{III}_{j_i}; \quad X^{IV}_{j_1,j_{2,j_3}} = \frac{1}{3}\sum_{i=1}^{3} x^{IV}_{j_i}; \quad (6)$$

where x:= x^I; y:= y^{II}; $z := z^{III}$; $t := t^{IV}$; $i := j_1$, $j := j_2$; and by indices $k := j_2$.

To determine the coordinates of an arbitrary node $C_{j_1,j_{2,j_3}}$ of a hypernetwork in E^4 space with a quadrangular cell, it is necessary to solve the following system of equations:

$$\begin{cases} X^I_{j_1,j_2,j_3} = 18^{-1}[4(X^I_{j_1-1,j_2,j_3} + X^I_{j_1+1,j_2,j_3} + X^I_{j_1,j_2-1,j_3} + X^I_{j_1,j_2+1,j_3} + X^I_{j_1,j_2,j_3+1} + X^I_{j_1,j_2,j_3-1}) - \\ - X^I_{j_1-2,j_2,j_3} - X^I_{j_1+2,j_2,j_3} - X^I_{j_1,j_2-2,j_3} - X^I_{j_1,j_2+2,j_3} - X^I_{j_1,j_2,j_3-2} - X^I_{j_1,j_2,j_3+2}] \\ X^{II}_{j_1,j_2,j_3} = 18^{-1}[4(X^{II}_{j_1-1,j_2,j_3} + X^{II}_{j_1+1,j_2,j_3} + X^{II}_{j_1,j_2-1,j_3} + X^{II}_{j_1,j_2+1,j_3} + X^{II}_{j_1,j_2,j_3+1} + X^{II}_{j_1,j_2,j_3-1}) - \\ - X^{II}_{j_1-2,j_2,j_3} - X^{II}_{j_1+2,j_2,j_3} - X^{II}_{j_1,j_2-2,j_3} - X^{II}_{j_1,j_2+2,j_3} - X^{II}_{j_1,j_2,j_3-2} - X^{II}_{j_1,j_2,j_3+2}] \\ X^{III}_{j_1,j_2,j_3} = 18^{-1}[4(X^{III}_{j_1-1,j_2,j_3} + X^{III}_{j_1+1,j_2,j_3} + X^{III}_{j_1,j_2-1,j_3} + X^{III}_{j_1,j_2+1,j_3} + X^{III}_{j_1,j_2,j_3+1} + X^{III}_{j_1,j_2,j_3-1}) - \\ - X^{III}_{j_1-2,j_2,j_3} - X^{III}_{j_1+2,j_2,j_3} - X^{III}_{j_1,j_2-2,j_3} - X^{III}_{j_1,j_2+2,j_3} - X^{III}_{j_1,j_2,j_3-2} - X^{III}_{j_1,j_2,j_3+2}] \\ X^{IV}_{j_1,j_2,j_3} = 18^{-1}[4(X^{IV}_{j_1-1,j_2,j_3} + X^{IV}_{j_1+1,j_2,j_3} + X^{IV}_{j_1,j_2-1,j_3} + X^{IV}_{j_1,j_2+1,j_3} + X^{IV}_{j_1,j_2,j_3+1} + X^{IV}_{j_1,j_2,j_3-1}) - \\ - X^{IV}_{j_1-2,j_2,j_3} - X^{IV}_{j_1+2,j_2,j_3} - X^{IV}_{j_1,j_2-2,j_3} - X^{IV}_{j_1,j_2+2,j_3} - X^{IV}_{j_1,j_2,j_3-2} - X^{IV}_{j_1,j_2,j_3+2}] \end{cases} \quad (7)$$

In the future, we will consider the construction of a hypernet using the finite difference method in E^5, E^6 spaces.

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