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MODERN RELIEF MODELING METHODS

Isamiddin Fattievich Buranov

Soli Nazhmiddinovich Badriddinov

Bukhara Engineering Technological Institute (Uzbekistan)

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ABSTRACT

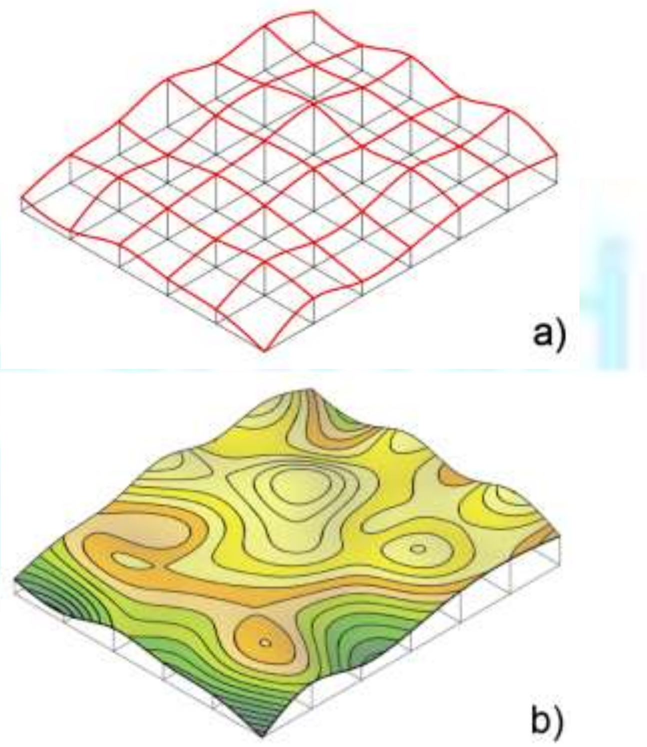
The article discusses various methods of modeling the relief used in the practice of engineering and design work. In particular, the geometrical, mathematical and digital representation of the relief is considered.

Keywords: *geometric model of relief, isolines, mathematic model of relief, digital elevation models (DEM).*

Introduction

Currently, relief modeling and its subsequent study using the obtained models are becoming an integral part of theoretical and experimental research in various fields of earth science (geology, tectonics, hydrology, etc.), in ecology, land cadastre and engineering surveys. Computer processing of spatial data is widely used in the analysis of the distribution of contaminated sites, in the modeling of deposits, as well as in many projects for the sustainable development of territories [1,2].

The geometric model of the topographic surface represents the visualization of the geometric data of the object - the relief in the form of constructing wireframe lines - which characterize the geometric shape of the relief (Fig. 1.3-a, b). One should take into account the primacy of such a model in relation to other types of modeling [3]. It is essentially applicable in the initial collection of information about an object. For example, in geodesy, when compiling triangulation networks, identifying high-altitude points of the selected terrain on the map, the contours of the terrain are also built in parallel, for more informational content about the data on the formation of the relief [4].



a - in the form of profile sections; b - in the form of isolines.

Fig. 1.3. Geometric (frame) model relief

One of the main ways of depicting unambiguous and continuous surfaces is the method of isolines. This method implies the choice in space of a plane perpendicular to the axis of the applicate $z = z' = const$. The intersection of this plane with the depicted surface will be a plane curve, the orthogonal projection of which on the *x0y* plane is called a level line or isoline. If we take a system of such planes parallel to each other, then the set of all isolines will clearly characterize the geometric shape of the surface (Fig. 1.4).

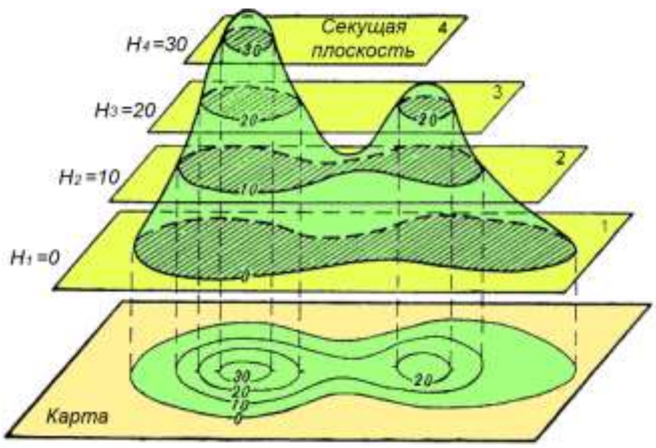


Fig. 1.4. Formation of relief isolines

Usually, when constructing isolines on plans, the value of the cross-section h of the surface is set, the value of which is equal to the distance between two adjacent secant horizontal planes. In the *x0y* plane, the value of *h* characterizes the difference between the marks of two adjacent isolines. Let $z = z0$ be a securing plane with a minimal *z0* mark. Then, with a given value of the section *h*, the equation of the *k*-th section of the plane is:

$$z = z_0 + (k-1)h; \quad k = 1,2,...,n \quad (1.2)$$

Thus, the problem of graphical mapping of the surface $z = f\ (x,y)$ is to construct, inside the domain of existence, curves described by equation (1.2).

The mathematical model represents a certain class of undefined (abstract, symbolic) mathematical objects and the relationship between these objects [5]. It should be noted that a mathematical model of the relief implies the study of qualitative and quantitative relief data. Geometrically, a function of two variables in space is a surface $z = f\ (x, y)$.

The task of the mathematical model of the relief *F* is to obtain some conceivable surface *H* sufficiently close to *F*. From a more general point of view, this problem can be defined as replacing a point set *F* with another point set *H*. Unlike *F*, which is a surface, the point set *H*, in general speaking, it may not be a surface, being, for example, a discrete set. The set *H* should be close in some sense to the surface *F* and can be used to construct in one way or another a surface, again close to *F* [6].

Mathematical connections between the initial points of digital models are described by linear or nonlinear (power) dependences. In the first case, the relationship between adjacent points of the model is described by the equations of the planes passing through every three adjacent points of the model, in the second - by curved surfaces of different orders, and, thus, the terrain is set either by a set of intersecting planes or surfaces of different curvature orders.

Most digital elevation models (DEM) assume in the subsequent mathematical modeling linear interpolation of heights between adjacent points of the model [7; p-5,]. The main task of the mathematical model of the relief is reduced to determining the heights of points on any arbitrary section of the geometric model using known discrete points (nodes). Further, between three adjacent points between which the corresponding desired point falls, the coefficients of the equation of the plane passing through these three points are found. The desired point will belong to this plane (Fig. 1.4-a).

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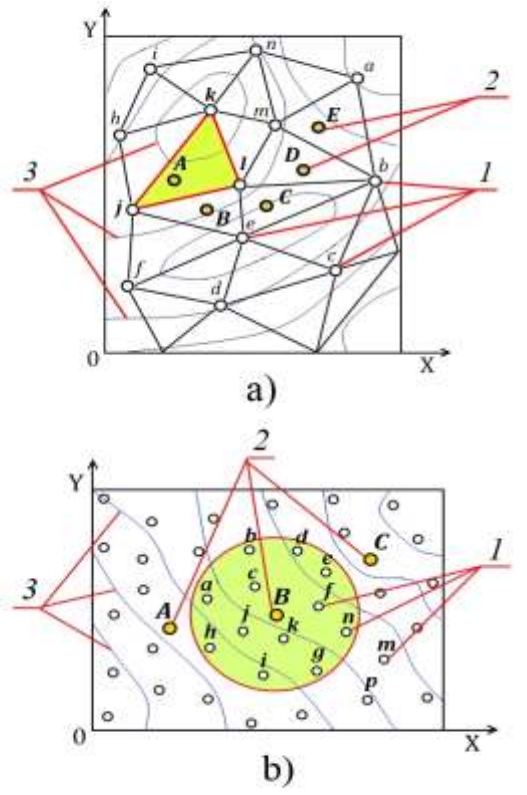

Fig. 1.4. Representation of mathematical relief models:
a) linear; b) nonlinear; 1 - known points; 2 - points to be determined; 3 - isolines.

If the desired point falls between the adjacent initial points of the digital terrain model (DTM) with numbers j, k and l (Figure 1.4-a), then the equation of the desired plane in general form can be represented:

$$H = AX + BY + C. \tag{1.3}$$

In equation (1.3), the design coordinates X and Y of the desired point are known, the height of which must be determined, but the coefficient *A*, *B* and *C* of the equation of the plane passing through the initial points j, k and l of the digital model are not known.

If we substitute the known coordinates of the three initial points of the digital model into equation (1.3), then we get three equations in which only three coefficients *A*, *B* and *C* are not known:

$$\begin{cases} H_j = AX_j + BY_j + C; \\ H_k = AX_k + BY_k + C; \\ H_l = AX_l + BY_l + C; \end{cases} \tag{1.4}$$

The system of equations (1.4) is solved in matrix form or by the "sweep" method, as a result of which unknown coefficients *A*, *B* and *C* are determined. Substituting the design coordinates *X* and *Y* of the desired point, determine its height H.

The main idea of the "floating" approximation is that a circle or square is moved from one determined point to another in such a way that each point, the height of which needs to be determined, is located in its center (Fig. 1.4-b). The radius of the circle or the dimensions of the side of the square are automatically set to include at least 10 model origin points.

Since the coefficients *A*, *B*, *C*, *D*, *E*, *F* in the approximating equation (1.5) are not known, then for each point of the model that falls within the circle or square, write the equations:

$$\begin{cases} H_j = Ax_j^2 + Bx_j y_j + Cy_j^2 + Dx_j + Ey_j + F; \\ H_k = Ax_k^2 + Bx_k y_k + Cy_k^2 + Dx_k + Ey_k + F; \\ \dots\dots\dots\dots\dots\dots\dots\dots\dots\dots \\ H_n = Ax_n^2 + Bx_n y_n + Cy_n^2 + Dx_n + Ey_n + F. \end{cases} \tag{1.6}$$

where: A, B, C, D, E, F - unknown coefficients of the equation of the approximated surface; H_j, x_j, y_j, … , H_n, x_n, y_n are the known coordinates of the points of the model that fall within the circle or square.

Since the number of unknowns in system (1.6) is less than the number of equations (of which there are at least 10), the system is solved by the "least squares" method. Thus, the unknown coefficients of the approximating equation (1.5) are determined, substituting in which the known design coordinates *X* and *Y* of the determined point, determine its height *H*.

Next, the center of the circle or square is mixed to the next determined point, and the procedure is repeated. At the same time, if the density of the initial points of the model in the vicinity of the next point has decreased, then the dimensions of the circle or square will automatically increase, and if the density has increased, on the contrary, it will decrease.

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