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Graphic-Analytical Method of Relief Plane Definition

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Abstract: The graphic-analytic method of plane definition of general landform slope for engineering problems of vertical leveling is offered in article. It is possible to choose an optimum surface project, with the series of conservation measures of a natural landform, particulary, in problems of vertical leveling of ameliorative earth on the basis of the plane of general slope.

Keywords: Vertical Levelling, Input Data, Digital Relief Model (DMR), Line of General Inclination, Relief Plane

1. Introduction

As it is known, the problems of vertical levelling of industrial and civil buildings, road and rail communications, the construction of airfields and sport-governmental structures, etc. originally the project surface is developed on the basis of which is carried out by the transformation of landform. Selection of the optimal design of surface comes from the conditions, imposed on the project as a whole and taken into account the balance of earth masses. Vertical levelling involves: improving performance of aerodromes [1]; creating the necessary conditions for the construction of buildings and with the diversion of surface water from the territories [2]. Road communications projects impose other conditions - the dependence of the longitudinal and cross inclination from the velocity of traffic and not exceeding 20-30 ‰ longitudinal inclination [3]. As seen from the above, listed engineering tasks require a special approach to the choice of optimum solution. Of course, preparation of territories in engineering is accounted geomorphological, geological, hydrogeological, hydrological factors [4], but the question is how reasonable factors are considered. If we consider all new aspect- cost effectiveness will arise.

In practice, the design engineers are guided mainly on the basis of resolution diversion of surface water and the account balance of earth masses (cut = embankment). This is the main task of optimization in the design of the construction of the pain-majority of industrial and civil buildings. It is important to emphasize that this approach is not acceptable, for example, for a vertical levelling design of reclamation of land, where choice of design surface is required taking into account the conservation of topsoil, a special inclination for irrigation and the balance of earth mass [5, 6].

The present level of development of techniques and technologies can be used for development various territories and regions, but the neglect of the natural conditions, the violation of the biological balance often leads to man-made, irreversible disasters with which we often encounter in practice.

Today, energy and resource-saving technologies are demanded as in other fields of science and industry as well as in engineering design problems. On-time practice of engineering preparation and land improvement are becoming more aimed at the preservation and unity of natural and biological balance, regardless of the capital costs. Development of theoretical bases of geometric modeling the relief for the problems of engineering preparation of the territories, which have the opportunity in a set of measures of analysis and synthesis of the topographic surface relief are popular.

Today, methodology of determining the natural slope of the terrain on the quantitative characteristics - input data of the relief is little known. This issue is solved in practice by the analysis of topographic maps of the area, based on the structural lines of relief such as: horizontals, watersheds, thalwegs etc. Nevertheless, the development of a uniform scientific-theoretical method of counting and analysis of the relief is claimed.

2. Materials and Methods

In modern practice, the engineering design of a vertical levelling on the basis of a digital relief model (DRM) is built from discrete data. These discrete data are the three numbers x,y,z - coordinates of points belonging to the surface of relief. A pair of numbers x,y will display a rectangular grid. Grid nodes characterize values of altitudes z (Figure 1). On the basis of these data, in practice, variety of carcass models are built (Figure 2), made visualization of relief and selected design surface.

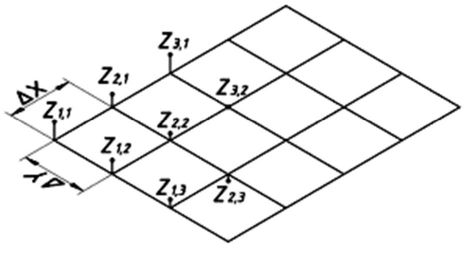


Figure 1. *Input data for digital relief models.*

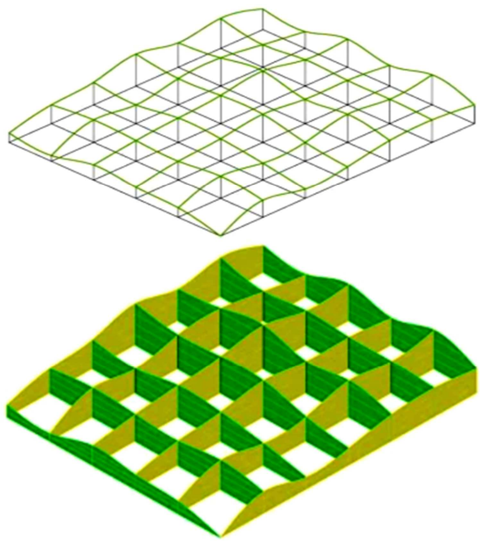


Figure 2. *Carcass models of relief.*

From the above it becomes clear that for any tasks of vertical levelling by using DRM is required manipulation of the input data.

3. Discussion

There are theoretical approaches to determination of a general inclination line of a plane curve operating with input data [7-9]. Since the input data is discrete, finite difference method is used [4]. It is worth mentioning that the line of general inclination is a direct at the average value of the height of a plane curve (which is the line of profile section of the relief). It has been established that the method of determining the general inclination line of plane curve for the even and odd quantity of discrete data are quite different [9].

If we have the matrix of high-altitude values Z (Figure 1):

$$A \equiv \begin{pmatrix} Z_{11} & Z_{12} & \dots & Z_{1n} \\ Z_{21} & Z_{22} & \dots & Z_{2n} \\ \dots & \dots & \dots & \dots \\ Z_{m1} & Z_{m2} & \dots & Z_{mn} \end{pmatrix} \equiv (Z_{ik}) \tag{1}$$

where each row or column of the matrix has a plane curve - profile cross section of the relief, while the average value of the line of general inclination of a plane curve or a section ΔZn or ΔZm in general ΔZ_H will be:

$$\delta Z = \frac{Z_1 + Z_2 + \dots Z_{n-1} + Z_n}{n}; \text{ or } \delta Z = \frac{\sum_{i=1}^{n} Z_i}{n}; \tag{2}$$

For conducting of a straight line it is enough to define a position of one more point N or M. The following point N or M of the line of the general inclination for even amount Z will be (Figure 3):

$$N = \frac{Z_1 + Z_2 + \dots + \lim \delta Z}{n/2}; \text{ or } M = \frac{\lim \delta Z + \dots + Z_{n-1} + Z_n}{n/2}. \tag{3}$$

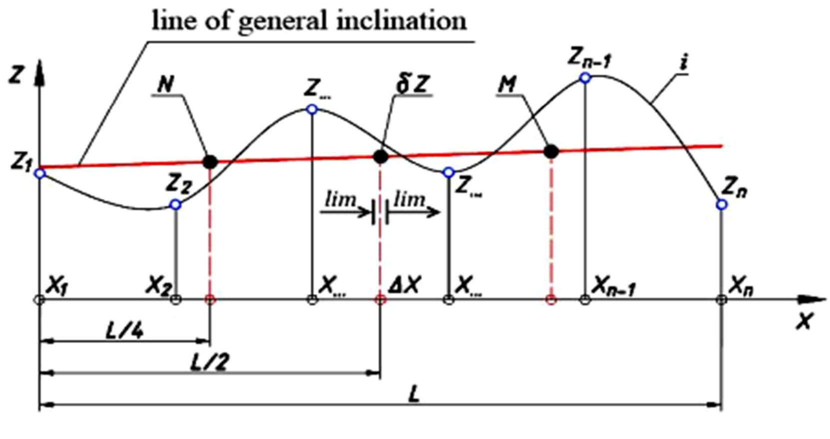


Figure 3. *Line of a general inclination with an even number of data.*

For the points N or M of the line of general inclination with odd number will be Z (Figure 4):

$$N = \frac{Z_1 + Z_2 + ... + \delta Z_k}{(n+1)/2}; \text{ or } M = \frac{\delta Z_k + ... + Z_{n-1} + Z_n}{(n+1)/2}. \quad (4)$$

where:

$$\delta Z_k = \frac{\delta Z + Z_k}{2};$$

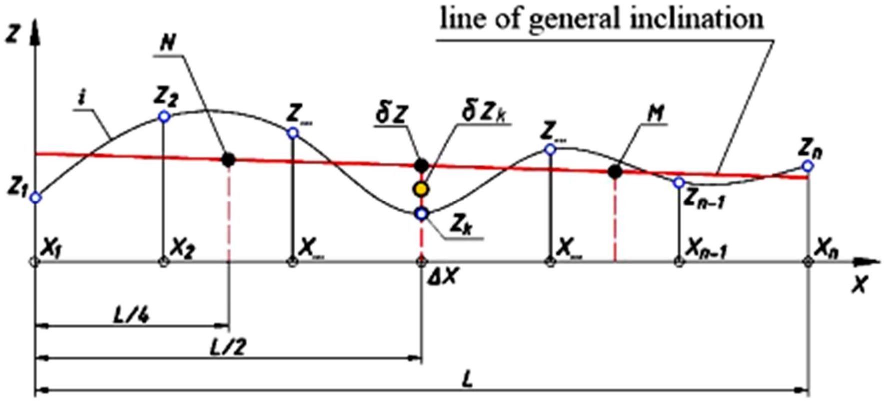


Figure 4. *Line of a general inclination with an odd number of data.*

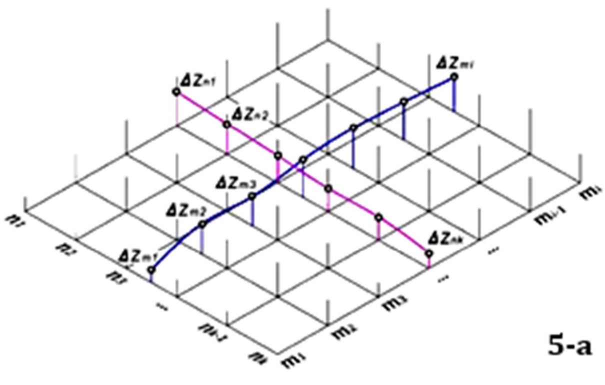
Any pair of found points *N*, *δZ* or *δZ*, *M* will be owned by a single straight line.

The plane is carried out on mean values of high-altitude points of a relief, it can be named as a relief plane. It is known that two mutually intersecting straight lines define a unique plane. To determine the geometric position of relief plane should define two intersecting straight lines and what is the general inclination of the longitudinal and cross-sections of relief.

The average value for each row and column of the matrix also forms two planar curves (Figure 5-a):

$$\Delta Zn = \left| \Delta Z_{n1}; \Delta Z_{n2}; ... \Delta Z_{ni} \right|$$
$$\Delta Zm = \left| \Delta Z_{m1}; \Delta Z_{m2}; ... \Delta Z_{mk} \right| \quad (5)$$

Defining the line of general inclination formed of two planar curves can be build the relief plane (Figure 5-b).



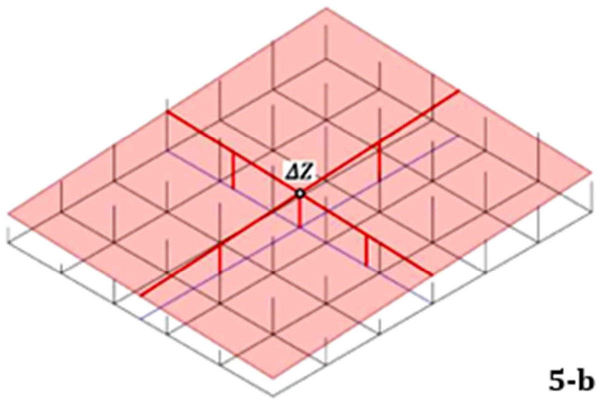


Figure 5. *Definition of the relief plane.*

Determination of relief complexity degree is the most important factor for decision of implementation of different engineering tasks and at the same time the least studied. It shall be noted that the degree of complexity or roughness has a word description as a flat or undulating terrain, rugged topography, smooth relief, etc. and has not numerical characteristics, that, obviously, presents a basic difficulty of their practical use.

In writings [10] there is a description of determination of geometrical model TS complexity degree, where accumulated absolute intrinsic and extrinsic curvatures of crests determine the degree of model complexity. There is also a definition that the simplest surface – plane – has complexity degree equal to “0” irrespective of number of considered crests.

There is no a unified methodology of determination of relief complexity or roughness degree in the engineering practice. There is an approach to this task by methods of probability theory and mathematical statistics based on data of topographic location plan in writings [11]. The work is based on ratio of isolines concentration to dm^2 and takes into consideration indications of water parting lines, baffle-walls thalwegs, bases, etc. This approach is not applicable to DMR (Digital Model of Relief) as modern DMR is based on regular or irregular data grid. Consequently, the relief complexity degree is directly related to these data and may be determined by correlation of these data.

If surface migh be considered as aggregate of consecutive positions of line moving in space according to definite law, let us determine some degree of complexity for plane curve as interpolation of regular grid points by the least distance along X or Y is a plane curve.

Let us consider the complexity of line given by minimal quantity of points:

Two points of the right line simply determine for which degree of curvature will be “0”.

Three points on the plane may lie either on the line, or outside the direct trajectory. Thus, the degree of curvature – complexity of line may be defined through location of three points on the plane.

Further, let us consider a surface with minimum number of points. Three points in the space shall monotypically determine the plane, for which is determined the degree of complexity equal to «0». Four points in the space may determine either a plane, or skew plane, but cannot determine closed convexity or concavity. Intersection of two or three planes given on the rectangular regular mesokurtic form a truncated unclosed vertex. Thus, for rectangular regular mesokurtic is fair the consideration of four intercrossing planes, which shall determine in particular case, both the plane, and the character of convexity or concavity of the considered surface (Figure 6).

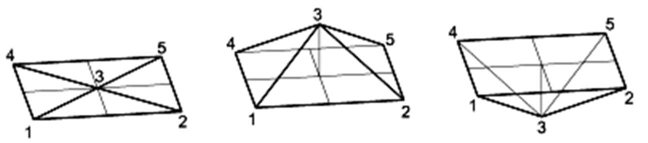


Figure 6. *Intercrossing of four planes.*

On the rectangular regular mesokurtic, the considered four planes may be given by five points. By connecting of intermediate four points it is possible to increase the number of planes to eight. Hence, nine points of regular mesokurtic (3×3) form a square of four cells (quadrants).

$$[A]=\begin{bmatrix} Z_{11} & Z_{12} & Z_{13} \\ Z_{21} & Z_{22} & Z_{23} \\ Z_{31} & Z_{32} & Z_{33} \end{bmatrix} \quad (6)$$

Let us establish some correlation between nine terms of matrix by the finite difference method:

1. Let us take an absolute value of the sum of row elements difference and differentiate:

$$m=\frac{\left|(Z_{11}-2Z_{12}+Z_{13})\right|+\left|(Z_{21}-2Z_{22}+Z_{23})\right|+\left|(Z_{31}-2Z_{32}+Z_{33})\right|}{\Delta X} \quad (7)$$

where ***ΔX*** is an interval of rectangular regular mesokurtic along the rows.

2. Let us take an absolute value of the sum of column element difference and differentiate:

$$n=\frac{\left|(Z_{11}-2Z_{21}+Z_{31})\right|+\left|(Z_{12}-2Z_{22}+Z_{32})\right|+\left|(Z_{13}-2Z_{23}+Z_{33})\right|}{\Delta Y} \quad (8)$$

where ***ΔY*** is an interval of rectangular regular mesokurtic along the columns.

3. Let us summarize the absolute value of diagonal elements difference and differentiate in the same manner:

$$d=\frac{\left|(Z_{11}-2Z_{22}+Z_{33})\right|+\left|(Z_{13}-2Z_{22}+Z_{31})\right|}{\sqrt{\Delta X^2+\Delta Y^2}} \quad (9)$$

Equations (7–9) shall be summarized and so we obtain some value known as ξ for the square of the surface:

$$\xi=m+n+d \quad (10)$$

This equation satisfies to the definition of degree of complexity of the surface $\xi=0$ and gives us different values, if the considered surface is not a plane.

The degree of complexity of irregular (topographic) surface may be also defined by considering the TS as a population of adjacent regular surfaces, and the sum of degree of complexity of squares gives a rough idea of the degree of complexity of TS in total. Thus, the degree of complexity of the whole section of the surface will be:

$$\xi=\xi_1+\xi_2+\xi_3+\ldots+\xi_n \quad (11)$$

4. Conclusion

The graphic-analytical method of the relief plane definition promotes automation of process of designing in CAD taking into account theoretically well-founded alternatives of sampling of optimum solutions. The relief plane is the optimum solution for definition of the general inclination of territory. By varying the plane along a *Z-axis* can lead the balance of earth masses.

The numerical value of complexity of project surface gives an option possibility of project realization, economical accounting of energy resources, bringing in some factors of complexity of realization of the project and etc.

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