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Research on Modeling of Land Leveling Problem

Xue Yao
Shandong University of Technology, Zibo, Shandong 255049, China.
Corresponding author email id: 1023442757@qq.com

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***Abstract* — In this paper, how to choose the appropriate position and excavation depth in a piece of mountain was studied, so that the total amount of earth and stone was the smallest when the total cost of filling and excavation was saved as much as possible. The idea of grid method and limit differential was used, and more advanced data was obtained by interpolation from adjacent elevation points by using MATLAB software. According to the elevation of the design site in the actual elevation of the mountain area, the filling depth or the excavation height is calculated. According to the rectangular volume formula, the earthwork volume of the filling and excavating area in each grid could be obtained. The sum of the two was the total filling amount and the total excavation amount. When solving the problem of the position of the plane of the site, the position coordinates were represented by the points in the matrix, and then each point was traversed in turn by the enumeration method until the point with the smallest amount of earth and stone was found in consideration of the minimum total cost of filling and boring, thereby the area and altitude of the entire site were determined.**

***Keywords* — The Smallest Amount of Earth and Stone; Square Grid Method; Enumeration Method; Linear Programming.**

I. Introduction

For mountainous cities, the mountainous place is an inevitable choice for the development of mountainous cities. How to choose the appropriate oosition [1] and excavation depth in a mountainous area, so that the total amount of earth and rock can be minimized, is a problem worth exploring. In this paper, a 800 m×600 m flat continuous rectangular block is excavated in a mountain with a length of 1500 m and a width of 1000 m as an example of the factory foundation to probe into the optimal filling and digging method to minimize the amount of earth and rock [2].

According to the data given, the 3D drawing function of MATLAB 2016a software was used, and the 3D graphics of the land of the factory was drawn as shown in Figure 1.1 and Figure 1.2:

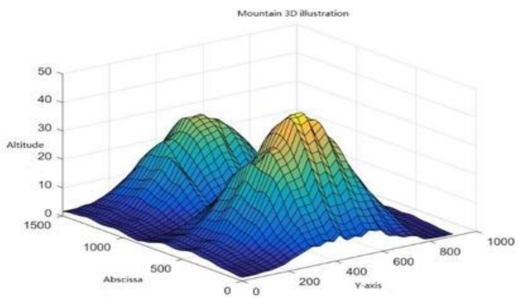

Fig. 1.1. Mountain three-dimensional map.

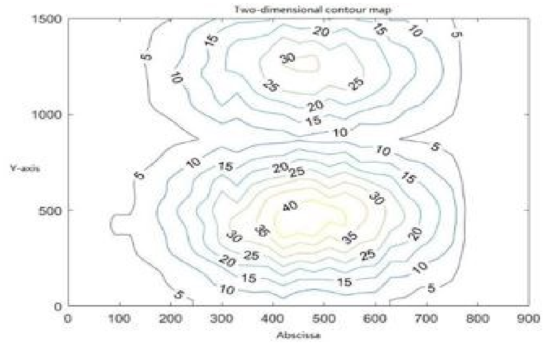

Fig. 1.2. Mountain two-dimensional contour map.

II. Model Establishment

A. *Problem Assumption*

(1) It was assumed that the cost per cubic meter of the fill was 1/3 of the cost per cubic meter of earth and stone for digging the mountain;
(2) Assume that the error caused by the limited division of the land was negligible when calculating the volume.
(3) Assume that the elevations within each design unit block were equal.

B. *Determination of plane altitude*

The bottom area corresponding to the plane was set as D, a rectangular area of 800 m × 600 m. The top altitude was set as $H(x, y)$□ $(x, y) \subset D$. The area was meshed, and the projected area of the corresponding area of each square is ΔD_i ($i = 1.2.3\ldots n$), and the side length was selected as 30 cm. The average of the altitudes of the four vertices of each grid was taken as the altitude of the small area, which is recorded as H_i. And the minimum altitude corresponding to the area in which all squares are located is $h_{\min}$, and the maximum altitude is $h_{\max}$.

Then,

$$H_i = \frac{h_1 + h_2 + h_3 + h_4}{4} \tag{1}$$

The foundation of the factory building is at an altitude, and then:

$$\begin{cases} V_{W_i} = (H_i - h_0)\Delta s_i \square H_i > h_0 \\ V_{f_i} = (h_0 - H_i)\Delta s_i \square H_i < h_0 \end{cases} \tag{2}$$

The total amount of excavation:

$$V_W = \sum_{i=1}^{k_1} V_{W_i} = \sum_{i=1}^{k_1} (H_i - h_0)\Delta s_i \tag{3}$$

And the total fill is:

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$$\mathrm{V}_f = \sum_{i=1}^{k_2}(V_{f_i}) = \sum_{i=1}^{k_2}(h_0 - H_i)\Delta s_i \quad (4)$$

Where k_i is the number of small regions that satisfy the condition $H_i < h_0$.
Then,

$$\omega = \begin{cases} \sum_{i=1}^{k_1}(H_i - h_0)\Delta s_i + \frac{1}{3}\sum_{i=1}^{k_2}(h_0 - H_i)\Delta s_i, V_W \geq V_f \square V_w \geq V_f \\ \frac{4}{3}\sum_{i=1}^{k_2}(h_0 - H_i)\Delta s_i, V_W < V_f \square V_w < V_f \end{cases} \quad (5)$$

The enumeration method was used, the plane area was taken over all possible values in all areas, excavated according to the area corresponding to the minimum cost and the altitude of the excavation [3], and the obtained plane area enables the total excavation and filling of earthwork under the premise of cost saving. The smallest amount.

C. *Determination of the Basement Area of the Plant Floor*

The flat block area was, projected to the bottom surface (plane xoy). The land area with all the square lines was considered as a matrix of points with rows and columns. The intersection of the square lines is the matrix element. There are two specific scenarios [4] based on the assumption that the large area and the selected area are related, as shown in Figures 4 and 5:

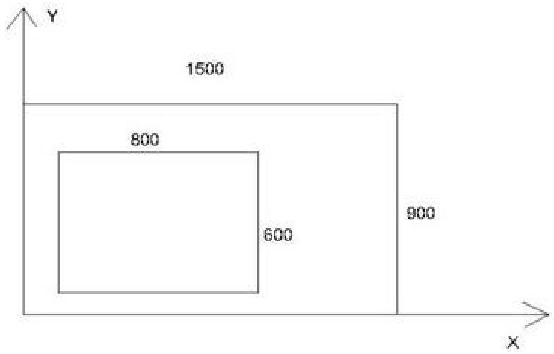

Fig. 2.1 Horizontal plane position.

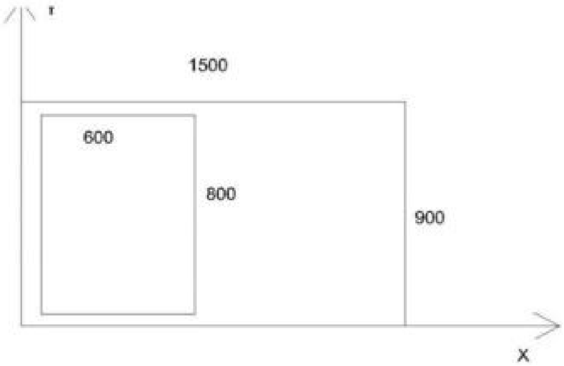

Fig. 2.2 Vertical plane position.

The objective function [5] aiming at the amount of earthwork and the total earthwork cost function can constitute the target planning function as shown:

$$\begin{cases} h_i = \dfrac{h_{ij} + h_{i+1,j} + h_{i+1,j+1} + h_{i,j+1}}{4} (1 \leq i \leq 30, 1 \leq j \leq 50) \\ H_0 = \dfrac{\sum_i^n h_i (i = 1,2,......n)}{n} \\ V_W = \sum_{i=1}^{k_1}(H_i - h_0)\Delta s_i \\ V_f = \sum_{i=1}^{k_2}(h_0 - H_i)\Delta s_i \end{cases} \quad (6)$$

The condition that the points in the coordinate matrix satisfy is that $(x_{ij}, x_{i\pm 20, j\pm 30})$, the enumeration method was used to traverse the check of each point in the region. [6] Assuming that the first point in the lower left corner of the entire rectangular area is x_{11}, and enumeration starts from that point, the condition in the 800×600 rectangular area is satisfied $(x_{ij}, x_{i+20, j+30})$. Assuming that the first point in the upper right corner of the entire rectangular area is 1500×1000, then enumeration starts from the first point called x_{11}, and the condition in the desired rectangular area is satisfied $(x_{ij}, x_{i-20, j-20})$. The dot matrix model was shown in Figure 2.3.

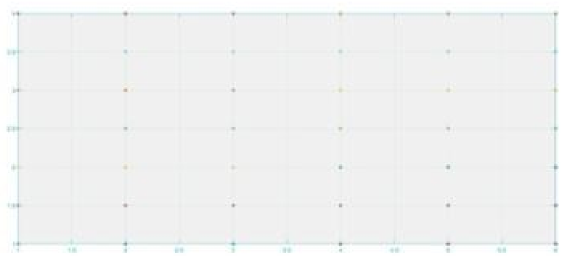

Fig. 2.3 Dot matrix model.

III. Model Solving and Results

According to the mathematical model established above, the coordinates of the four points calculated by MATLAB2016a software are as Figure 7 shows: $A(160, 0), B(160, 800), C(760, 800), D(760, 0)$. That is $h_a = 15.345, V_{\min} = 2787756$, in such a structured area, the total amount of earth and stone of the contiguous land whose bottom surface is $800m \times 600m$, flat at the elevation is $14.259m$, and the minimum value is $2787756m^3$. The calculated position of the leveled land could be shown in Figure 7 and Figure 8:

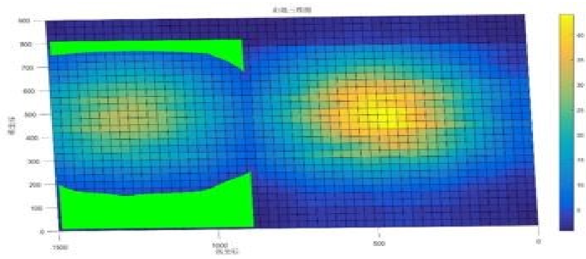

Fig. 3.1 Top view of a layer of horizontally flattened land.

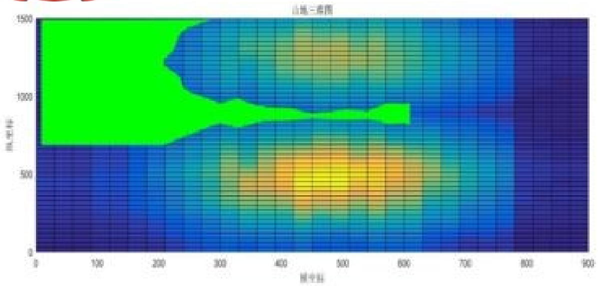

Fig. 3.2 Top view of a layer of stairs longitudinally leveling the land.

IV. Conclusion

In summary, in this paper the grid method and the enumeration [7] method were used, and the calculation software such as MATLAB was combined to find the best location for the site construction when the amount of earth and stone is minimum and the cost is saved. The grid filling method and the differential idea are used to calculate the filling volume, which is convenient and concise.

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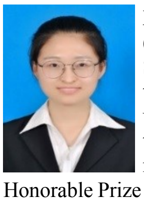
Author's Profile



Xue Yao
(1995-), female, the Han nationality, native place: Shandong Province, China. Undergraduate, specializes in transportation planning and management. Interested in urban transportation system design and intelligent transportation. Excellent mathematical analysis and modeling skills and good at teamwork. Awards: Honorable Prize in COMAP's Mathematical Contest in Modeling (MCM), the Third Prize of the National Road Traffic Science and Technology Contest for the National University Students of Shanghai Lugang Cup, the National Scholarship, etc.