The Estimation of Battlefield Target Area based on Infinitesimal Method

Chunmei Chen[a], Ping Yang[b]

Department of Basic Courses, Rocket Force University of Engineering, Xi'an 710025, China

[a]362437655@qq.com, [b]CCM1977@sohu.com

Abstract

This paper focuses on the method of estimating the target area of the battlefield based on the infinitesimal method. With the help of matlab software, on the basis of pre-processing the initial data, firstly, the surface is fitted to the equation of the surface using the curve fitting toolbox; secondly, the surface is divided into several small triangles using the idea of the infinitesimal method, and the area of each small triangle is calculated to obtain an approximation of each small surface; finally, the area of these small surfaces is summed to calculate an approximation of the whole surface and obtain the results are calculated. In addition to this, the paper also introduces parameters such as the step length of the mesh, the average slope angle and the average wavelength to analyse the errors in the area calculation and to verify the validity of the solution to the problem.

Keywords

Infinitesimal Method; The Battlefield Target; The Curve Fitting; Matlab.

1. Introduction

In the conditions of information warfare, in order to achieve precision strikes by surprise, and gain the initiative in warfare, accurate estimation of important battlefield targets is one of the basic tasks in the development of battle plans and an important guarantee of achieving precision strikes. In actuality, it is necessary to estimate the geographical area of the combat target. The estimation method and accuracy requirements are related to the purpose of the operation and the shape of the target area. For example, if the target area contains a valley, it is necessary to calculate the surface area of the mountain; if the target area is a relatively flat and not very large area, it can be treated as an approximate flat area; if the target area is a large area, it can be approximated as part of the sphere (the Earth is approximated as a sphere) to deal with. Of course, if more detailed information about the regional geomorphology is available, more accurate battlefield target estimation should be performed based on the surface characteristics of the territory.

2. Modeling and Solving based on Infinitesimal Method

According to the needs of the operation, the combat target is a rectangular area of 4000 meters in length and 3000 meters in width. The elevation value corresponding to the grid node with a step of 5 meters in the area is known. The task here is to estimate the surface area of the part of the given target area with an elevation above 12 meters and analyze the accuracy of the calculation.

2.1 Data Preprocessing

According to the grid elevation data given in the problem, use Matlab to get the 3D graph as Figure 1.
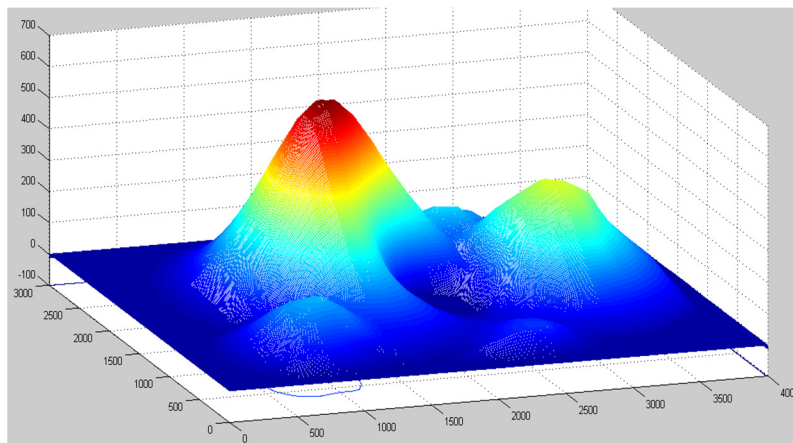
Fig 1. The 3D graph of operational targets

The 3D graph of the combat target shows that the width of each grid on this rectangular area is 5 meters. The height value of each grid is the matrix value at the corresponding position in the known conditions. Because the height value at any point in this target area is changing, we view the surface of the target area as a smooth surface. Firstly, we use the curve fitting toolbox to fit the equations of the surface, secondly, we use the idea of the micro-element method to divide the surface into several small triangles, calculate the area of each small triangle Ai, get the approximate value of the area of each small surface, and finally add the areas of these small surfaces to calculate the approximate value of the area of the whole surface .

2.2   The Battlefield Target Area Estimation Model

The specific modeling process is as follows.

Step1: Use the curve fitting toolbox "cftool"to fit the surface equations and plot the surface image, data points and contours

Although we have a rough idea of the 3D image of the combat target area from Figure 1, we cannot determine the coordinates of any point on each grid area. MATLAB has a curve fitting toolbox, which is not only powerful but also easy to use. It can realize the curve and surface fitting, and also can estimate the accuracy. The specific use process is as follows.

First save the elevation data of the target area in an excel sheet, and then enter the data in the MATLAB command line:

>>x=0:5:2995;

>>y=1:5:3995;

>>z=xlsread(zhanchangmubiaoquyudata.xls);

After data entry is complete, the curve fitting toolbox is launched:

>>cftool

In the upper left corner of the curve fitting toolbox, select the input x, y, and z data, and in the upper right corner, select "polynomialas" the fitting method, and "4" as the number of times to get the fitted surface equation.

Step2: The entire surface is blocked according to the infinitesimal method using 601 × 801 points in the given combat target area. It is stipulated that every four adjacent points (any three of which are not on a straight line) form a small area (spatial quadrilateral), so these 481401 spatial points can be divided into 480,000 small block areas. As shown in Figure 2, when the coordinates of the (i, j) planar grid ($M_1M_2M_3M_4$) are known, the area of the corresponding surface ABCD on the space quadrilateral is approximated by the area of the two space triangles ABD and BCD. The vertical coordinates of the four vertices can be determined from the surface equations in STEP1, and the corresponding spatial coordinates of each small mesh can all be

obtained as A($x_{i,j}, y_{i,j}, z_{i,j}$), B($x_{i,j+1}, y_{i,j+1}, z_{i,j+1}$), C($x_{i+1,j+1}, y_{i+1,j+1}, z_{i+1,j+1}$), D($x_{i+1,j}, y_{i+1,j}, z_{i+1,j}$), respectively, as in Figure 3. Eventually the whole surface can be divided into a number of small triangles.
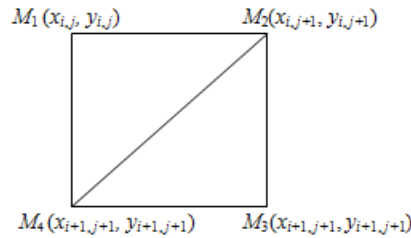

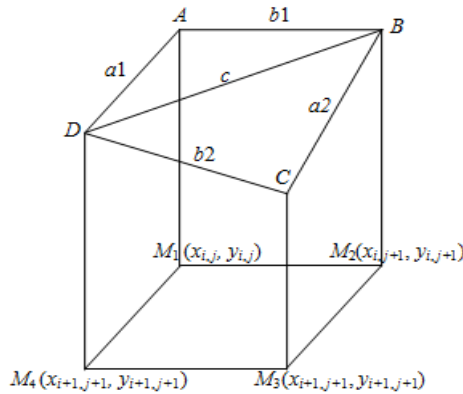**Fig 2.** The graph of planar grid coordinates

Fig 3. The graph of triangular partition of a curved surface

Step 3: Use Heron's formula to calculate the area of each small triangle and add them together to get the total area.

From Helen's formula, let a, b and c be the lengths of the sides of the triangle. The area of the triangle can be obtained.

$$S = \sqrt{s \cdot (s-a) \cdot (s-b) \cdot (s-c)} \tag{1}$$

where is:

$$s = \frac{(a+b+c)}{2} \tag{2}$$

The ABCD in Fig. 3 is a quadrilateral in space whose projection on the horizontal plane is a square of side length 5. The lengths of the three sides of triangle ABD are , , and , and the lengths of the three sides of triangle BCD are , and , where are the common sides of two triangles.

$$a1_{i,j} = \sqrt{5^2 + (z_{i+1,j} - z_{i,j})^2} \tag{3}$$

$$b1_{i,j} = \sqrt{5^2 + (z_{i,j+1} - z_{i,j})^2} \tag{4}$$

$$a2_{i,j} = \sqrt{5^2 + (z_{i+1,j+1} - z_{i,j+1})^2} \tag{5}$$

$$b2_{i,j} = \sqrt{5^2 + (z_{i+1,j+1} - z_{i+1,j})^2} \tag{6}$$

$$c_{i,j} = \sqrt{(5\sqrt{2})^2 + (z_{i+1,j} - z_{i,j+1})^2} \tag{7}$$

After the side lengths of the triangle have been determined, the area A_1 and A_2 of the two triangles is calculated separately from equation (1):

$$A1_{i,j} = \sqrt{d1_{i,j} \cdot (d1_{i,j} - a1_{i,j}) \cdot (d1_{i,j} - b1_{i,j}) \cdot (d1_{i,j} - c_{i,j})} \tag{8}$$

$$A2_{i,j} = \sqrt{d2_{i,j} \cdot (d2_{i,j} - a2_{i,j}) \cdot (d2_{i,j} - b2_{i,j}) \cdot (d2_{i,j} - c_{i,j})} \tag{9}$$

where is:

$$d1_{i,j} = \frac{(a1_{i,j} + b1_{i,j} + c_{i,j})}{2} \tag{10}$$

$$d2_{i,j} = \frac{(a2_{i,j} + b2_{i,j} + c_{i,j})}{2} \tag{11}$$

Adding A_1 and A_2, the approximation of the area of each small curved-sided trapezoid ABCD is gotted. Finally, all the areas are summed to obtain an approximation of the whole surface area.

$$A = \sum_{i=1}^{600}\sum_{j=1}^{800} A1_{i,j} + \sum_{i=1}^{600}\sum_{j=1}^{800} A2_{i,j} \tag{12}$$

3. Model Solution

Consider the effect of the altitude limit given in this question on the target area, all areas less than 12m above sea level is ignored. The data needs to be filtered and processed, which can be solved using Matlab software.

The Matlab assigns a value of 0 to the area below 12. However, for the very few spatial quadrangles that lie in the middle of the two classifications, they can be largely ignored. The area of the surface above 12 metres above sea level can thus be found as $9.7692 \times 10^6 m^2$.

Following the idea of model building above, the results were obtained using MATLAB programming.

4. Conclusion

The error on the DEM surface is a combination of the various errors propagated during the digital ground modelling process. It is mainly influenced by the following aspects: the feature

values of the terrain surface, the three attributes of the DEM surface data, the method of modelling the DEM surface, and the characteristics of the DEM surface itself.

$$\sigma = \frac{d \cdot \tan\alpha}{4k}(1+\frac{4d}{\lambda}) \tag{13}$$

d is the step length of the grid, α is the mean slope angle, λ is the mean wavelength, and k is a constant, and k=4.

$$\lambda = 2H\cot\alpha \tag{14}$$

H is the average relative elevation of the area.

Based on the regional data, the average relative deviation in elevation can be found to be 1.34 using excel calculations, and the regional average slope formula is

$$\alpha = (\sum_{i=1}^{i=600}\sum_{i=1}^{i=799} z(i,j+1)-z(i,j))\Big/5\times599\times799 \tag{15}$$

The final calculation shows that $\sigma = 0.05m$.

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