Research and application of solid waste dumping calculation method in criminal cases of environmental pollution caused by illegal dumping of solid waste based on Arcgis

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Abstract. The determination of the amount of solid waste dumping is one of the important links in handling of criminal cases of environmental pollution of illegal dumping of solid waste, and one of the important basis for sentencing of the crime of environmental pollution. This article is based on ArcGIS technology, referring to the commonly used visualization method of earthwork calculation, taking a criminal case of environmental pollution of illegal dumping of solid waste as an example, an irregular triangulation network (TIN) is used to establish a digital elevation model (DEM) of solid waste piles, in order to discuss the application of ArcGIS in the establishment of solid waste heap model, and calculate the amount of solid waste dumping. The results show that using ArcGIS to build a solid waste heap model and calculate the solid waste dumping principle is simple, fast, and can achieve three-dimensional visualization, which is feasible.

1. Introduction
In recent years, criminal cases of illegal dumping of solid waste and environmental pollution have emerged in an endless stream. The Interpretation of The Supreme People’s Procuratorate and The Supreme People's Court on Several Issues Concerning the Application of Laws in Handling Criminal Cases of Environmental Pollution recognizes the situation of “illegal discharge, dumping, and disposal of more than three tons of hazardous waste” as “severely polluted environment”. It can be seen that in the process of handling environmental pollution criminal cases of illegal dumping of solid waste, the determination of the amount of solid waste dumping is related to the sentencing of environmental pollution crime, investigation and confirmation of ecological and environmental damage, solid waste disposal program and cost confirmation, and is one of the indispensable links. There has been little research on the amount of solid waste dumped. In an actual case, the amount of solid waste dumped is based on the amount of removal and transportation. This method requires the dumping amount to be known only after the clearing and transportation, and the timeliness is low. It is impossible to determine the penalty for environmental pollution crime, ecological environment damage investigation and confirmation, solid waste disposal plan and costs in a short time, and it cannot meet the time point of case handling claim. Therefore, it is extremely important to quickly and accurately predict the amount of solid waste dumped. Considering that the illegal dumping of solid waste heap model is similar to the construction of the earthwork model during the construction process, referring to the commonly used visualization method of earthwork calculation-ArcGIS technology, taking a criminal case of environmental pollution of illegal dumping solid waste as an example to discuss the
establishment of the solid waste heap model, and the prediction of the amount of solid waste dumping, to demonstrate its feasibility.

2. ArcGIS technical principle
ArcGIS is one of the most advanced platforms of GIS technology. The calculation of the amount of solid waste dumped by ArcGIS is based on the DEM method, which mainly includes the establishment of the model and the use of the model to achieve the calculation of the dumped amount. From these two aspects, the principle of the calculation of solid waste dumped based on ArcGIS is briefly introduced.

2.1. Digital Elevation Model (DEM)
The Digital Terrain Model (DTM) describes the surface morphology using the plane coordinates and elevation information of a group of ground points [1]. It is used to describe the elevation, slope, aspect, slope shape, surface undulation and other various geomorphic factors. Digital elevation model (DEM) is a kind of digital ground model. It is a spatial distribution model that uses a set of ordered numerical arrays in the form of X, Y, and Z coordinates to represent the actual terrain height fluctuations and changes, which is in the form of miniaturization. Representing the surface undulations, with the characteristics of image, intuition and precision [2], can be used for elevation information expression, earthwork calculation, perspective analysis, slope research, etc. It is widely used in land leveling, urban planning, architectural design and other fields [3].

2.2. The principle of using DEM to calculate the dumping amount of solid waste
According to the different data structures, the methods of using DEM to calculate the dumping amount of solid waste can be divided into regular grid method, irregular triangle method and contour method [4].

The regular grid method is to divide the research area at equal distances in the X (Y) direction, use the elevation Z of the divided grid points to represent the terrain, form a set of regular rectangular grid DEM, and calculate the model volume by the method of the quadrangular prism [5]. Since the rectangular grid DEM has the smallest storage capacity and can be compressed and stored, it is very easy to use and easy to manage, so it is currently the most widely used data structure form. However, it cannot accurately represent the structure of the terrain. In the case of a certain grid size, it cannot represent the details of the terrain.

The irregular triangulation method is based on the measured ground point coordinates (X, Y, Z), by generating a connected triangulation network, calculating the volume of each triangular pyramid, and finally accumulating the model volume [6]. The irregular triangulation method can optimally organize the original data, connect the discrete points into triangles that cover the entire area without overlapping each other, and have the best structure, and establish the spatial relationship between the discrete points, which can overcome difficulty of using discrete points to calculate the elevation at any point on the surface of the earth.

At present, the irregular triangulation method is the most widely used calculation method of digital elevation model. Compared with other methods, the irregular triangulation method reproduces the fluctuation characteristics of the surface morphology in the form of microcosm, which can more truly reflect the topography of the site. The accuracy is relatively high [7], which has the characteristics of image, intuitiveness and precision.

To calculate the dumping amount of solid waste by the irregular triangle network method, two DEM models (surface DEM and bottom DEM of the solid waste stack) must be constructed first, and the distance between the surface DEM elevation and the bottom DEM elevation is used as the integration height. The two DEM models are divided into several triangles, and the area of these triangles is the integration unit. Through integral calculation, the volume between the two DEMs can be obtained [8], that is, the amount of solid waste dumped. The mathematical expression of the calculation method can be expressed as follows:
In the above formula, \( h(X,Y) \) is the height difference, \( Z_D(X,Y) \) is the surface TIN elevation, \( Z_D(X,Y) \) is the bottom TIN elevation, and \( v \) is the DEM volume.

3. Steps to realize the calculation of solid waste dumping based on ArcGIS

Refer to the basic principle of calculating the amount of excavation and fill based on ArcGIS, and use ArcGIS to calculate the amount of solid waste dumped. The specific work can be summarized as the following steps.

Firstly, preparing data. Calculation of solid waste dumping based on ArcGIS requires source data such as the boundary of the dumping area and elevation points. Load the Polyline layer where the boundary line is located in the dwg format topographic map and the Point layer where the elevation point is located into ArcGIS, and then export the boundary line and the elevation point as shapefile format data. The first paragraph after a heading is not indented (Bodytext style).

Secondly, checking datas. Use ArcMap to open the Shapefile data of the boundary lines and elevation points, and check whether the relevant elevation values are correct. For example, check if the Elevation field is empty.

Thirdly, generate DEM. Use the 3DAnalyst module in ArcMap for DEM construction. First, use the boundary line and elevation point data to generate the survey area TIN. Create a TIN by 3DAnalystTools→CreateTIN in the ArcToolBox tool. Then use TIN to generate the DEM of the survey area, that is, use 3DAnalyst→Convert→TINtoRaster. Use the Extractbymask tool to extract the DEM in the area.

Finally, calculating volume. Import DEM into ArcScene, use the tool to build a 3D model, and use the 3DAnalyst→SurfaceAnalysis→AreaandVolume tool to calculate the volume above or below the specified elevation surface. In the dialog window, inputsurface: select the DEM data in the finally extracted area; the height of the plane in the input area of the heightofplane: select Calculatestatisticsbelowplane, which means calculating the volume below a certain plane; select Calculatestatisticsaboveplane, which means calculating the volume above a certain plane. Finally, click Calculatestatistics to complete the volume calculation [9].

4. An application

In order to verify the advantages and feasibility of ArcGIS to calculate the dumping amount of solid waste, ArcGIS is used to calculate the dumping amount of solid waste in an environmental pollution case of illegal dumping of solid waste occurred in Zhongshan City, Guangdong Province in August, 2019.

The area of the dumping area involved in the illegal dumping of solid waste environmental pollution case is 21928.9 square meters. The dumped solid waste includes waste glass slag, waste plastic bags, waste rags and other domestic garbage, partly exposed on the surface and partly buried underground.

Got the borderline of the area where illegal solid waste is dumped. Selected 16 discrete points evenly distributed in this area. Imported the boundary line and the coordinates of 16 discrete points (Table 1) into the ArcGIS software platform. Using the relevant tools of the 3DAnalyst module, the surface TIN and the bottom TIN were established through spatial interpolation, and then converted into the surface DEM (Figure 1) and the bottom DEM (Figure 2). Superimposing the surface DEM and the bottom DEM, a new grid map was generated, which was a solid waste heap model (Figure 3). In addition, the top view of the model can reflect the depth distribution of the solid waste heap in the entire dumping area (Figure 4). Using the 3DAnalyst module fill and dig tool, the volume of solid waste heap was calculated as 32278.78 cubic meters. The density of domestic waste was calculated at 320 kg/m³, and the total amount of solid waste dumped was 10329.2 tons.
### Table 1. Latitude, longitude and elevation information for 16 points.

| Discrete point | Longitude (x) | Latitude (Y) | Surface Elevation (Z1) | Ground Elevation (Z2) |
|----------------|---------------|--------------|------------------------|-----------------------|
| 1              | 113.36562     | 22.63608     | 2.03                   | -0.77                 |
| 2              | 113.36565     | 22.63636     | 2.24                   | 0.04                  |
| 3              | 113.36557     | 22.63657     | 2.16                   | 0.36                  |
| 4              | 113.36519     | 22.63681     | 2.23                   | -0.17                 |
| 5              | 113.36555     | 22.63699     | 2.06                   | 0.86                  |
| 6              | 113.36502     | 22.63712     | 2.34                   | -0.06                 |
| 7              | 113.36476     | 22.63715     | 2.01                   | -0.49                 |
| 8              | 113.36565     | 22.63736     | 2.57                   | 0.97                  |
| 9              | 113.36507     | 22.6374      | 2.09                   | -0.91                 |
| 10             | 113.36472     | 22.63743     | 1.60                   | -0.70                 |
| 11             | 113.36568     | 22.63772     | 1.98                   | 1.98                  |
| 12             | 113.3652      | 22.63779     | 2.30                   | 0.50                  |
| 13             | 113.36485     | 22.63771     | 2.16                   | 2.16                  |
| 14             | 113.36564     | 22.63808     | 2.03                   | 2.03                  |
| 15             | 113.36525     | 22.63803     | 1.92                   | 1.12                  |
| 16             | 113.36494     | 22.63808     | 1.63                   | 1.63                  |

**Figure 1.** Surface DEM of solid waste stack.
Figure 2. Bottom DEM of solid waste heap.

Figure 3. 3D model of solid waste heap.
In this case, the amount of solid waste obtained through removal is was 10327.8 tons, which was 1.4 tons different from the total amount of solid waste calculated based on ArcGIS, with an error of 0.01%, and the error was small. The amount of solid waste dumped based on ArcGIS had a certain amount of accuracy.

5. Conclusion

This paper discusses the calculation of solid waste dumping volume based on ArcGIS, establishes DEM from the source data, calculates the volume difference of each area of the DEM model to calculate the solid waste volume of each area, and finally statistically summarizes the solid waste volume of the entire dumping area.

Through the relevant function modules of ArcGIS, the terrain information of the solid waste stack can be truly reflected to achieve visualization. While ensuring the true reflection of the dumping situation and dumping amount of solid waste, calculating the dumping amount of solid waste based on ArcGIS is simple, fast, and convenient, which can save a lot of manpower and material resources, and improve the efficiency of handling criminal cases of illegal dumping of solid waste and environmental pollution.

However, for the DEM generated using the elevation information of the topographic map, the error of the DEM mainly stems from the accuracy of the original topographic map, the field measurement error, and the control point conversion error. Therefore, the accuracy of basic maps and basic data is particularly important, which is also an issue requiring special attention when calculating the volume of solid waste dumping based on ArcGIS.

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