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Analysis of Microterrain Data Based on GIS and Applied to Power Grid Layout

Nai Wei, Wei Wang

Wuhan University, Wuhan, 430072, China

Abstract: With the rapid development of economy and electronic information industry, the demand for electricity is getting higher. As a basic project, the reasonable point layout of power grid is becoming more and more important. Topographic elements are the key factors affecting power grid layout. However, the actual terrain is complex and changeable, so it is urgent to quantify all kinds of topographic factors to provide reference for power grid layout. Based on three-dimensional GIS technology, this paper provides a terrain factor algorithm with controllable variables for power grid layout project, obtains terrain factors such as slope, aspect, slope position, underlying surface type and surface roughness with different accuracy according to the actual terrain, and outputs the data format in accordance with the specification to provide decision support for power grid layout. At the same time, this study can also provide a reference for other decision-making works that rely on topographic elements.

Keywords: Three-dimensional GIS, Tiny terrain.

1. Introduction

Terrain is an important factor affecting environmental change, hydrological process, biological distribution, geomorphic features, etc., and the spatial distribution characteristics of terrain attributes are important indicators to describe these spatial change processes[1].The micro-topography formed by the combination of regional large terrain and local topographic terrain topography has a significant impact on local meteorological factors, and even leads to the special enhancement of some meteorological factors (such as ice and wind).Therefore, micro-topography is directly related to the selection of grid layout points and the maintenance of poles and towers. For example, the formation of debris flow and landslide is closely related to the slope and surface roughness, and the slope aspect and elevation will affect the sunlight irradiation intensity, thus affecting the ice-covered melting speed of transmission lines in winter [2].Therefore, digitization and visualization of complex micro-terrain factors can provide reference for power grid layout and effectively improve the quality of electricity consumption. The early power line projects in China are mainly based on the geographical data of manual field survey to design power grid layout scheme. However, this way has the disadvantages of high cost, long cycle and large error. With the continuous integration of computer science and cartography, geographic information system has shown a good application prospect in the electric power industry. By using GIS spatial analysis method based on DEM data to calculate topographic, geomorphic and hydrological information, the problem of tower selection and maintenance in power grid layout can be solved. In this paper, Guangdong Province is taken as the case area to design and develop the power grid layout GIS. The micro-terrain factor algorithm module is added into the power grid layout GIS to realize the calculation of slope, aspect and slope position based on DEM data, and obtain the terrain factor data to provide strong support for power grid layout.

2. Research Data and Methodology

2.1. Overview of Study Area

The terrain of Guangdong Province is complex and diverse. The terrain is high in the north and low in the south. It gradually descends from the mountains in the north to the coastal areas in the south, forming a landform pattern dominated by mountains in the north, hills in the middle, and plain platforms in the south. Therefore, the deployment and maintenance of power grids in Guangdong Province are faced with great difficulties [3].

2.2. Data Sources and Preprocessing

The data in this study include DEM data of 30m×30m resolution, soil type data, and Excel spreadsheet data containing information about the height of surrounding trees. First of all, Excel data were associated with "bar segment" as the key field to obtain the surface roughness factor data set, including rod segment, coordinate information and the vertical distance between the log and log of the traverse. The research data of this paper are shown in table 1.

Table 1. Description of research data

Contains the fields	Contains the fields	data format
DEM	elevation	shp
Soil type	soil type	shp
Hidden Danger File - List of tall plant hidden danger	bar segment, tree species, horizontal distance between traverse and log, vertical distance between traverse and tree	excel
The province line	bar segment, Vertical distance of rod coordinates and wires to trees	excel

2.3. The research methods

2.3.1. Slope aspect calculation

Slope refers to the ratio of vertical height and horizontal distance of slope surface, usually including two parts: slope and slope aspect. Slope refers to the maximum ratio of slope height change; Slope aspect is the direction reflecting the maximum value of slope surface change ratio[4].According to the actual needs of topographical features of Guangdong province and the grid layout, is proposed in this paper in view of the Guangdong power grid layout the gradient of slope to the classification standards (table 2 and table 3), because of ArcGIS can't direct output grade level and tilt, recommendations for layout grid, in order to solve the problem, based on DEM data computing slope and aspect to the information and classification, directly output the information needed for power grid layout, without secondary processing of ArcGIS data:

Table 2. Slope classification

Slope Grade	Slope Degree	Slope /(°)	Suitable for power grid deployment
Grade 1	flat	0~5	Yes
Grade 2	gentle	6~15	Yes
Grade 3	normal	16~25	Not recommended if it is not necessary
Grade 4	steep	26~35	No
Grade 5	Sharp	36~40	No
Grade 6	dangerous	41~45	No
Grade 7	Risk	Above 46	No

Table 3. Aspect classification

Aspect classification	Aspect/(°)	Whether the power grid is properly laid
shady	0~45	No
Half-shady	45~135	Yes
Sunny	135~225	Yes
Half-sunny	225~315	Yes
shady	315~360	No

In this study, the fitting surface method was used to solve the slope aspect under the micro-terrain, as shown in Fig. 1. Based on the 3x3 window, the local function of the quadric surface was constructed for calculation.

e5	e2	e6
e1	e	e3
e8	e4	e7

Figure 1. 3×3 Moving window

Through the surface fitting algorithm to get slope in the direction of X-axis ($slope_{we}$) and Y-axis ($slope_{sn}$):

$$slope_{sn} = \frac{(e_7+2e_4+e_8)-(e_6+2e_2+e_5)}{8cellsize} \quad (1)$$

$$slope_{we} = \frac{(e_8+2e_1+e_5)-(e_7+2e_3+e_6)}{8cellsize}$$

Calculate the slope and aspect of the center point e:

$$\text{slope} = \arctan\sqrt{slope_{we}^2 + slope_{sn}^2} \quad (2)$$

$$aspect = 270° + \arctan\frac{slope_{sn}}{slope_{we}} - 90°slope_{we}/|slope_{we}|$$

cellsize is the resolution of the grid, and e_i is the elevation value of each grid dot.

After the slope aspect value is calculated by the above formula, it can be classified according to the classification table, and the slope aspect data required for grid layout can be output.

2.3.2. Calculate slope positions

Aspect refers to the geomorphic position of the slope surface. For example, on positive or negative terrain. The core work of slope position extraction is the division of geomorphic parts and geomorphic types [5].In this study, the fuzzy inference method of slope position gradient information is used to calculate the slope position information. According to the typical positions of various slope positions in space, the similarity between other positions and typical positions is calculated, so as to systematically and quantitatively describe the spatial gradient information of slope position. The gradient information of important slope position types such as ridge, slope shoulder, back slope, slope foot and valley can be reasonably described [6].

The algorithm mainly involves four terrain parameters: slope, profile curvature, horizontal curvature and other local terrain attributes, and a regional terrain feature RPI.RPI is defined as the sum of the shortest Euclidean distances from the point to the valley and the shortest Euclidean distances from the point to the ridge and the valley. The RPI value calculated based on ridge and valley can better reflect the relative position information of the terrain. Profile curvature is a measure of the change rate of ground elevation along the direction of maximum slope of the ground slope, and horizontal curvature is the curvature value of the curve at a point on the terrain surface obtained by cutting the terrain surface along the horizontal direction, that is, the curvature degree of the ground contour at the point. Since profile curvature and horizontal curvature have similar signs and functions, and horizontal curvature can effectively avoid the unreasonable extreme value of contour curvature, horizontal curvature is used to replace contour curvature in this study. Douglas-Peuker algorithm was used to extract feature points for ridge, and different elevation thresholds could be set based on different study areas as the lower limit of ridge existence, so as to eliminate unreasonable ridge extraction results.

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The algorithm principle of Douglas-Peuker method is as follows (Fig. 2) :

Connect the first and last points of the curve to be processed with a straight line, find the distance between all intermediate points and the straight line, and find the maximum distance value dmax, and compare dmax with threshold:

If dmax < threshold, all the middle points on this curve are dropped;

If dmax≥threshold, the curve is divided into two parts by taking this point as the boundary, and the above process is repeated for these two parts of the curve until all points are processed.

Due to the coexistence of multiple landforms in Guangdong Province in this study area, the lower limit of ridge elevation was set as 950 meters, and a relatively obvious ridge line was extracted.

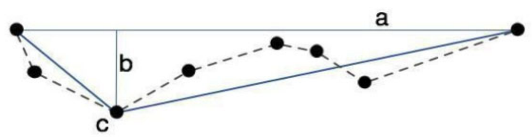

Figure 2. Feature points extracted by Douglas-Peuker method

The valley line adopts O'Callaghan algorithm, which is also known as D8 algorithm. Its basic idea is to use a moving 3x3 window to traverse the DEM data from the upper left corner of the input image to calculate the distance weight drop p between the center pixel and other eight neighboring raster cells. Assume that the position of the center pixel of the raster window is (i, j).Its elevation value is hi, and the elevation value of its domain grid is hk. k starts from east and is taken from 1 to 8 clockwise:

$$p = \begin{cases} h_i - h_k & (k = 1,3,5,7) \\ \frac{h_i - h_k}{\sqrt{2}} & (k = 2,4,6,8) \end{cases} \tag{3}$$

Then take the maximum value of P, mark the k value of the cell where max of p is located, and finally get the flow direction dir of the center pixel:

$$dir = 2^{k-1} \tag{4}$$

DEM elevation value and flow direction value of one of the operation Windows are taken, as shown in Fig. 3 [7]:

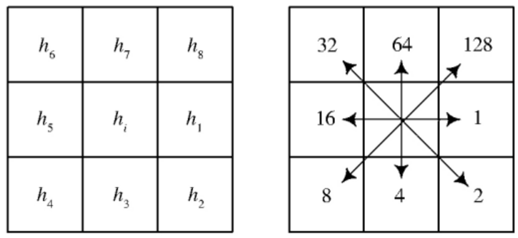

Figure 3. DEM elevation value and stream direction coding value

D8 algorithm is used to calculate each pixel of the upstream catchment area, the catchment area is greater than the given threshold pixel identification as the valleys, the algorithm can produce continuous, the reasonable channel, can set different threshold values according to different research areas, generate realistic topography of river network as a result, in this study, the Guangdong province has complex and varied water networks. The threshold of the upstream catchment area was set as 2km², and a relatively obvious valley line was extracted.

Based on the deterministic classification algorithm of slope position [6], and the limitation of RPI value, rules can be generated to automatically extract the typical positions of various slope positions in the region (table 4). These rules can be applied to extract the typical positions of various slope positions, and the rules can also be set according to the geomorphological conditions of different regions.

Table 4. Parameter Settings for typical positions of slope position extraction

	ridge	Slope shoulder	Back slope	Slope foot	valleys
RPI	≥0.99	[0.9, 0.95]	[0.5, 0.7]	[0.2, 0.3]	≤0.1
Section curvature($\times10^{-3}m^{-1}$)	≥1	≥1	[-0.1, 0.1]	≤-1	[-0.5, 0.5]
Horizontal curvature($\times10^{-3}m^{-1}$)			[-0.1, 0.1]	≥0	
elevation	＞950m				
slope(°)	≤1		≥6		≤1

2.3.3. Surface roughness and surface type algorithms

Surface roughness reflects the undulation of the land surface and is the main influencing factor of many land surface processes[8].There are two kinds of understanding of ground roughness. One is from the perspective of aerodynamics. Due to the uneven surface or the geometric shape of ground objects, the position where wind speed is 0 is not at the surface, but at a certain height from the surface, which is defined as ground roughness, also known as aerodynamic roughness. Another kind of understanding is mainly from the perspective of topography, and defines the degree of ground roughness as roughness, also known as surface microtopography [9].In this paper, the surface roughness mainly refers to the degree of uneven ground.

The extraction of surface roughness factor is mainly based on the corresponding vertical distance data between wires and trees provided by Guangdong Electric Power Bureau. The surface roughness factor data is divided by a 30m×30m grid, and the mean value of the vertical distance between wires and vegetation in each grid is the surface roughness of the grid. At the same time, according to the corresponding relationship between the surface roughness and different vegetation types provided by Guangdong Electric Power Bureau (table 5), the surface type of each grid can be obtained.

Table 5. Correspondence between surface roughness and surface type

ground type	Corresponding surface roughness (m)
Paddy field	0
The dry land	1
forestland	15
bush	8
Land with few trees	10
Other woodland	10
High coverage grassland	0.6
Medium coverage grassland	0.4
Low coverage grassland	0.2
grass	0
lakes	0
Reservoir pits	0
Permanent glacial snow	0
Tidal flats	0
beaches	0
Urban land	30
Rural settlement area	10
Other construction land	10
sand	0.2
Gobi area	0.2
Saline-alkali land	0.5
marsh	0.5
Bare land	0.2
Bare rock stony ground	0.2
other	0.1

3. Results and Analysis

Based on the 30mx30m DEM data of Guangdong Province, the quadric surface fitting algorithm is used to obtain the classification data of slope and aspect, the ArcGIS module is used to calculate the profile curvature and horizontal curvature, and the ridges and valleys are calculated according to Douglas-Peuker algorithm and O'Callaghan algorithm. And then you get RPI. Based on table 4, the slope, curvature, RPI value and elevation value were judged to obtain the slope position data. Based on the surface roughness factor preprocessing results and DEM data partitioning, the surface roughness data are obtained. The underlying surface data were obtained based on "Soil Type Data of Guangdong Province". Then, the data are output in accordance with the standard format. Flowchart of system algorithm implementation is showed in Fig. 4.

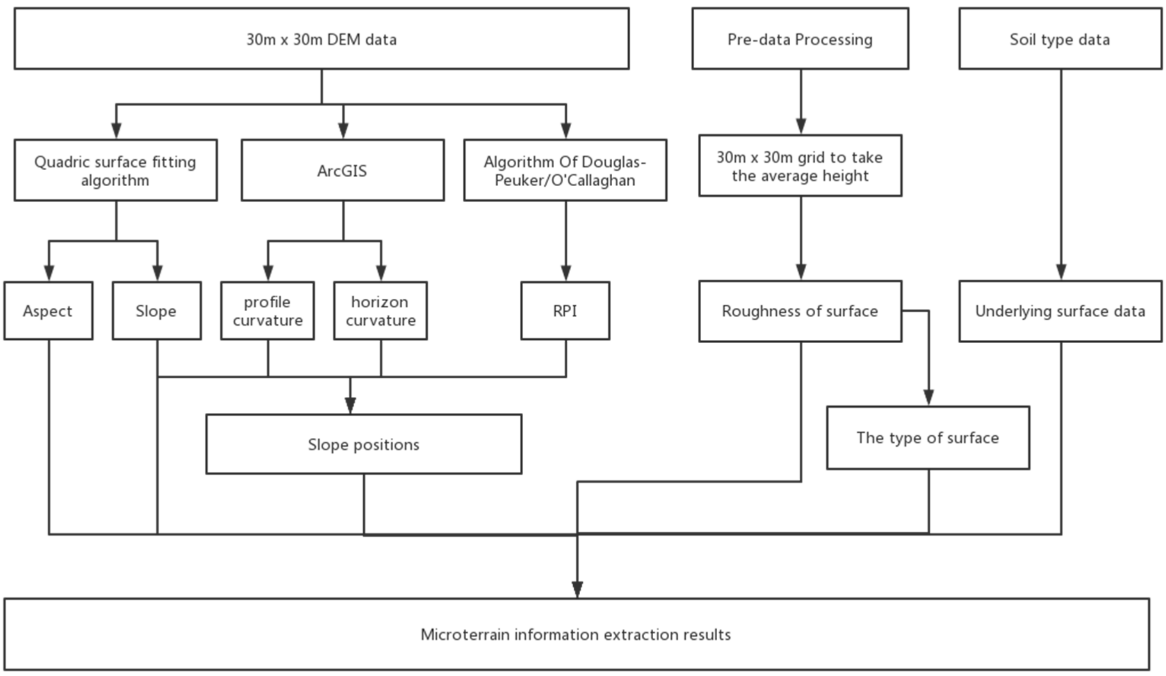

Figure 4. Flowchart of system algorithm implementation

The output result is shown in Fig. 5-Fig. 6:

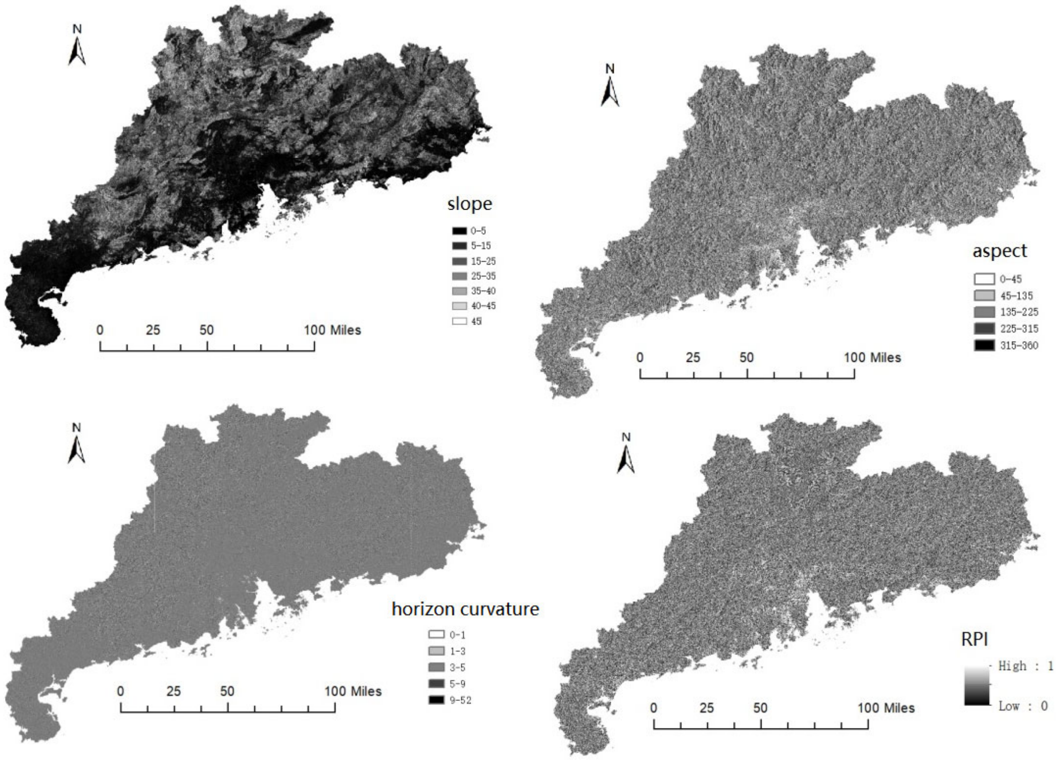

Figure 5. Microterrain data output

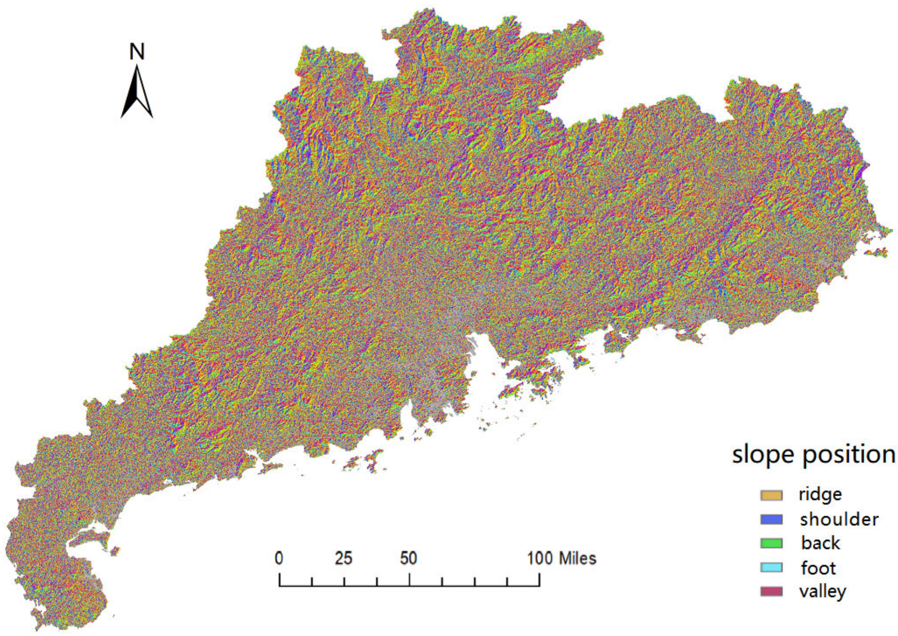

Figure 6. Slope position data output

In order to improve the efficiency of data output, a 512×512 one-dimensional array of BigGrid was established to read data. The numbering method was consistent with the grid numbering rule of each image, and the raster values were read from the lower left corner, line by line. Generate the data format required by the grid (table 6) and store it in the database:

Table 6. Microtopographic information extraction results

Serial number	Central latitude	Center longitude	Altitude	Aspect	Slope	Slope position	Underlying	Surface	Roughness
004614-01	20.38	109.87	0	-1	0	0	255	127	127

4. Conclusion and Prospect

Topographic elements play an indispensable role in all kinds of construction work. How to extract different topographic factors flexibly according to the needs of the project is very important. This paper provides an algorithm for extracting terrain factors such as slope, aspect, position, surface roughness, surface type and underlying surface type based on DEM data and other types of data provided by the project. A variety of standards and variable parameters are provided in the algorithm to make reasonable Settings according to different projects. Finally, the data of different terrain factors are stored in the database according to the prescribed format, which is convenient for the staff to access at any time, and provides an important reference basis for the maintenance and planning of the power grid tower.

However, there are not only six types of micro-terrain factors involved in this study, but also different micro-terrain factors required in different projects. This study will continue to deepen the flexible setting and on-demand extraction of micro-terrain factors, with the ultimate goal of including all the terrain factors in the system. In addition, the parameters and classification standards of various micro-terrain factors can be flexibly set according to different landform types, providing construction workers with more convenient micro-terrain factor data as a reference for project decision-making.

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