Identification of Peak Type Based on DEM

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Abstract. Geomorphologic characteristic of peak is one of the foundations of mountain position indicator and orientation identification. In this paper, the characteristics of three types of peak, pointed peak, flat peak and round peak, are described. After an introduction of the expression of peak geomorphology based on mathematic model and identification method, its limitation in application is pointed out. On a basis of extraction peak point based on DEM, a method of identifying peak type based on DEM is brought forward. According to the mean elevation of peak region, the peak region is divided into three parts. By comparing the mean slopes of them and region searching, the identification of peak type is implemented. An experiment proves the feasibility and practicality of the method. At the same time, the issues to be researched further are mentioned.

Keywords: Peak, Peak Geomorphology, Type Identification

1. Introduction

Peak, the highest part of a mountain or mountain range, is the control skeleton of terrain, influencing the environment change, life distribution and hydrology process. Its geomorphologic characteristic is one of the foundations of mountain position indicator and orientation identification. The factors causing various peak features include rock features, structures and the quality and strength of geological external force. Due to the differences in their formation and the geomorphology, peak can be classified into pointed peak, flat peak and round peak, as shown in figure 1. The pointed peak covers a small area and gradually forms a point. Its profile shows an acute triangle. Round peak is rather wide and circular. Its profile is in a form of parabolic curve. Flat peak has a level terrain. Its profile appears to be a door. These differences make peak a good position indicator in mountainous areas. Extracting peak point and indentifying the type of peak based on certain rule and method are of great practical value to digital terrain analysis.

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(a)Pointed peak (b)Round peak （c）Flat peak

Figure 1.Types of peak

2. The expression of peak geomorphology based on mathematic model

In 2002, utilizing the contour model and the analytic expression of terrain, Zhong Yexun[1] mathematically defines the geomorphic morphology of peak based on the topological rule. Suppose the terrain surface is T, then the mathematic expression of T is:

$$T = f(x,y) = \sum_{i,j=0}^{n} a_{ij} x_i y_j = a_{00} + a_{10}x + a_{01}y + a_{11}xy + a_{20}x^2 + a_{02}y^2 + \dots \qquad (1)$$

When the random point $P(x,y)$ on the surface T satisfies the following conditions, the point $P(x,y)$ is the peak point. β is the slope of point $P(x,y)$, $C_{\max}$ is the maximum curvature, and $C_{\min}$ is the minimum curvature, namely,

$$\begin{cases} \beta = 0 \\ C_{\max} > 0 \\ C_{\min} > 0 \end{cases} \qquad (2)$$

Suppose a and b are the random two points on the surface T and their elevation are respectively H_a and H_b, if a random point i on the surface T satisfies the following formula (3), then T is the surface of slope land and b is the peak point.

$$H_a \le H_i \le H_b \ \ \& \ \ b \in \operatorname{int} CM_i = B_i \bigcap T \qquad (3)$$

In formula (3), B_i is a surface where the point i is on, CM_i is a contour where the point i is also on. If $CM_a = B_a \bigcap T$, CM_a will be the contour of mountain foot. If $TM = \{CM_i, i \in [a,b]\}$, then TM will be the slope land.

When $CM \in ES$ or $CM \in CVS$, T will be a pointed peak. When $CM \in CNS$, T will be a round peak. When $b \in S \in T$ and $H_b = c$ (c is a constant), then T will be a flat peak. ES, CVS and CNS are respectively uniform slope land, concave slope land and convex slope land.

However, since the type of terrain is very complex in the real world, it is very difficult to express the ideal surface T by mathematic polynomial. The coefficients in the formula are difficult to be worked out. It leads to failure of identifying the uniform slope, concave slope or convex slope, so the peak morphology can't be expressed by the mathematic formula (1). As a type of the representation of terrain surface, DEM can implement the terrain analysis quantitatively and automatically. Therefore, extracting the peak and indentifying its morphology become possible by taking DEM as the data source.

3. The extraction of peak point based on DEM

In view of geometric configuration, peak point is the highest point of the mountain. In order to design the extraction method conveniently, the peak point is generally defined as the highest point in the local view window in the extracting process based on DEM. Therefore, in DEM, according to the geometric configuration, the peak point H_P can be considered as the highest point in a certain region S, namely,

$$H_p = MAX\{H_i, i \in S\} \quad (4)$$

Obviously, in view of geometric configuration, the peak point must be the highest point in a local region, but the highest point in a local region isn't necessarily the peak point. There are two methods to extract the peak point, local height difference comparison method and section elevation extremum method[2]. The efficiency of the local height difference comparison method, which takes the raster window analysis as the basic arithmetic, is higher. But it fails to consider the whole diversification of the terrain and to remove the noise, there is much uncertainty. The section elevation extremum method can conveniently extract parts of the terrain feature points from the DEM data, but it is likely to miss some key feature points. Zhong Teng[3] and el. firstly brought forward the concept of reverse terrain DEM. They combined the hydrologic analysis and window analysis based on DEM to implement the effective extraction of peak point. In their method, the amount of the peak points is related to that of the raster cells in the widow. The less the amount of the raster cells is, the more the amount of the peak points extracted is. But when the amount of the raster cells is up to a fixed value, the amount of the peak points extracted doesn't vary much.

It is held in the reference[4] that the peak point must be the highest point in a local region. Firstly in an appointed region, through raster neighbor statistic analysis[5], the highest points which satisfy some preconditions in the region are searched. There are false points in those highest points. Next, taking the contour interval as height difference threshold, the contours are extracted from the DEM, and then they are transferred to the area elevation zone. The peak point can only be located in the self-closed elevation zone. If the outer contour line of the self-closed elevation zone does not include any self-closed elevation zone, the self-closed elevation zone will be extracted and overlapped with the highest points extracted, thus the peak points can be obtained. It can be seen from the method that the extraction of the peak point involves the scale issue in GIS analysis. Namely, given different elevation threshold and different sizes of the neighborhood analysis window, the amount and the location of peak points extracted from DEM are different

The research of the above theory and method of extracting peak point lays a basis for the identification of peak type.

4. The identification of peak type based on DEM

Adopting the method described in reference [4] to extract the peak point, we can identify the morphology of the peak. Since the variation of the terrain slope can reflect the whole terrain geomorphology to a certain extent[6], the peak type can be identified by the variation of the slope of peak region. The scope of the peak region is the self-closed zone where the peak point is located with a certain elevation interval. The elevation intervals are as *Table* 1[7]. From the reference table of natural area of slope characteristic analysis in reference [8], it can be seen that different slope is located in different terrain representation. When the slope of a certain cell of DEM is less than 5°, the surface where the cell is located is plane. Similarly, when the mean slope difference between two neighbor regions is less than 5°, the region consisting of the two regions is comparatively plane, and it is in the same trend of elevation change. As far as the identification of peak type is concerned, if the change trend of elevation is consistent, the peak becomes higher gradually and the ratio is basically the same, then the peak must be pointed. In our method, firstly, the peak can be classified into two types, one is pointed peak, and the other is round peak or flat peak. The difference between round peak and flat peak is that the highest part of flat peak is in the form of mesa, the elevation of each cell does not vary much and the slopes differ little. We can adopt the automatic SRC based region method [9] to find the cells which are on the highest part. If they can form a connective region with certain acreage, then the peak is flat peak. Otherwise, it is round peak. The identification workflow of peak type is as the following *Figure 2*.

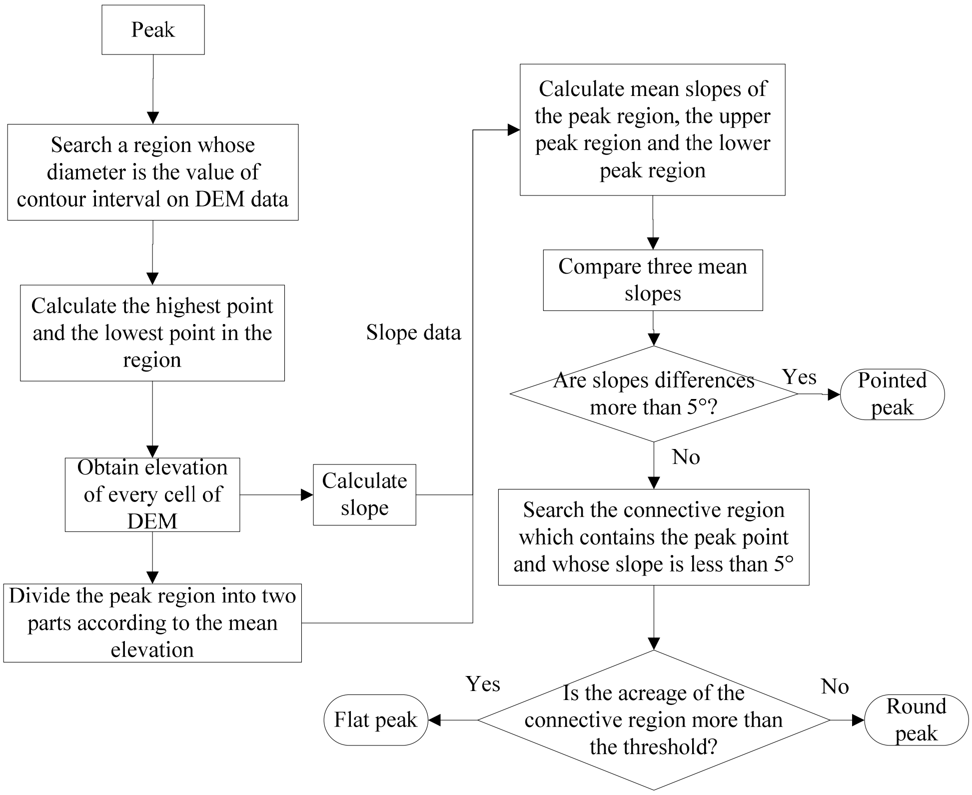

Figure 2. Identification workflow of peak type

Table 1 . Parameters of contour intervals

Sale	Common district	Special district
1:10,000	2.5 meter	1 or 5 meter
1:25,000	5 meter	10 meter
1:50,000	10 meter	20 meter
1:100,000	20 meter	40 meter
1:250,000	50 meter	100 meter

Table 2. Distribution of natural district of slope analysis

Slope index	Terrain representation district
<3°	Plain terrain、center part of basin, Bottom of wide and shallow valley、mesa
3°~5°	Front belt of mountain、front tilt plain of mountain、alluvium、diluvial fan、tableland、valley and so on
5°~15°	piedmont、circumambience of basin、hill
15°~25°	mountainous terrain whose elevation is 200~1500m

25°~30°	the upper of mountainous terrain whose elevation is more than 1000m
30°~45°	the upper of mountain body whose elevation is more than 1500m.
>45°	vertical plane

First, taking the peak point as seed point, a region whose diameter is the value of contour intervals is searched. Through the elevation of DEM in the region, the slope of each cell is calculated by three-order inverse distance square weight difference method[10]. The elevation H of the highest point and the elevation L of the lowest point in the region are searched, and then the middle elevation M of the region is $(L+M)/2$.

Next, the region is divided into two parts according to the elevation of each cell. One part is the cell collection $Part1$ whose elevation is more than M, and the other is the cell collection $Part2$ whose elevation is less than M. Thus we can get three parts: peak region, $Part1$ and $Part2$. The mean slopes of the three parts are calculated. The differences of the three mean slopes are worked out. If the three differences are more than 5°, then the region is a pointed peak. Otherwise, we should further identify whether it is a round peak or a flat peak.

Finally, taking the peak point as the seed cell, according to its slope, some cells are searched. The slope difference between these cells searched and the seed cell is not more than 5°. If the cells can form a connective region which is up to a fixed acreage, then the peak is a flat peak. Otherwise, it is a round peak.

5. Experimental result and analysis

The feasibility and practicality of this method are tested by DEM data with a scale of 1:250,000 from a middle mountainous region in our experiment. The size of DEM is 757×1037. It covers acreage of 625m^2. The maximum elevation and the minimum elevation are 3555m and 547m respectively. Its mean elevation is 1750. In the process of identifying the peak type, the maximum acreage is 1250 m^2 and the contour interval is 50m. In the identification process of whether the connective region is a flat peak or a round peak, the acreage threshold is also 1250 m^2. The peak points are plotted in black manually on the relief map shown in *Figure 3*. The peak type maps achieved by the method in the experiment are plotted as *Figures 4, 5 and 6*. In them, the pointed peak, round peak and flat peak are respectively plotted in red, green and blue.

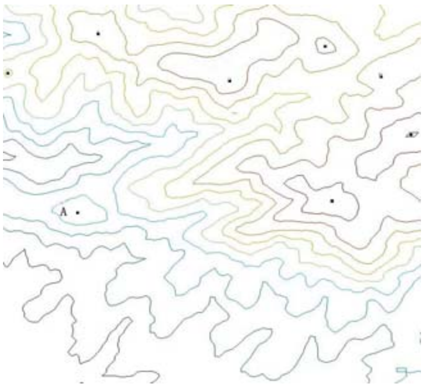

Figure 3. Peaks plotted on the relief map

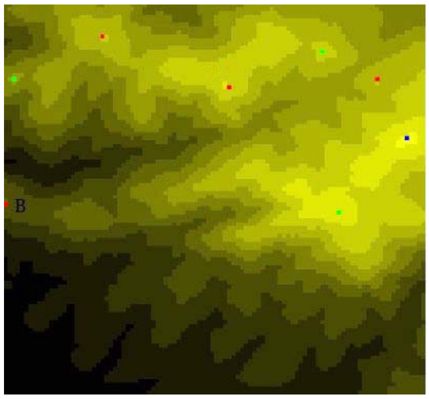

Figure 4. Peak types extracted based on DEM

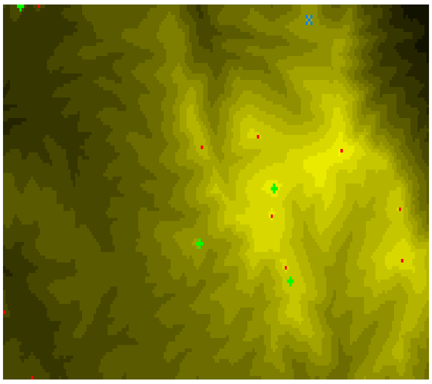

Figure 5. Peak types extracted with the contour interval of 50m

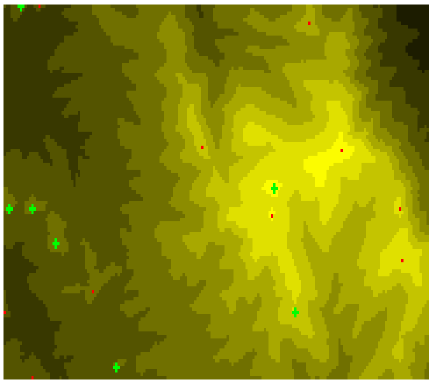

Figure 6. Peak types extracted with the contour interval of 75m

From *Figure 3* and *Figure 4*, it can be seen that the peak type identified by our method accords with its physical meaning and the terrain actuality. In the process of identifying peak type, with different thresholds such as the contour interval, the acreage of connective region, the results of peak type obtained are different. By comparing *Figure 5* with *Figure 6*, the peak type differs much. Therefore, in practice, the thresholds should be adjusted according to the practical terrain. This method is only a beneficial try and reference. The threshold adjustment and the effect of threshold on the peak type should be further researched.

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