Substation Sower Supply Area Division Based on Voronoi Diagram and Road Grid

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Abstract. On the basis of studying the application of Voronoi diagram, considering the influence of geographical factors such as roads and rivers on the power supply area, the method of substation power supply partitioning combined with weighted Voronoi diagram and road grid is proposed. Firstly, according to the urban road network, the power supply area is divided into several grids, and then the substation is taken as the center. Considering the main capacity of the substation, a weighted Voronoi diagram is generated, which makes the result of the power supply area division more scientific and reasonable. Finally, the actual example proves that the method has certain validity and rationality.

1. Introduction

Substation power supply area division is a key issue in power grid planning. Power supply area division directly affects the economics of power grid operation and power supply reliability. There have been many related research results at home and abroad on this issue. Reference [1], the clustering method is applied to establish the index system of distribution network regionalization from the aspects of politics, economy and load. Reference [2], the establishment of the power supply area division standard is established by establishing an evaluation index system for power supply area division and cluster analysis.

Reference [3] used the Voronoi diagram to divide the power distribution area of the distribution transformer, but did not consider the problem of uneven load and geographical obstacles such as roads and rivers. Reference [4], under the assumption that the load density of the power supply area is the same, a method for determining the power supply area of the substation based on the weight of the main transformer of the substation is proposed. Reference [5], the difference between the electrical distance and the Euclidean distance is described by obstacles. Under the premise that the load density of the power supply area is uniform, the Voronoi diagram is used to divide the power supply area.

Based on the application of the basic Voronoi diagram in the power supply area division, this paper proposes a method based on the Voronoi diagram and the road grid to divide the power supply area of the substation based on the road barriers showing the geographical conditions, which better solves the administrative division and road. The impact of traffic on the distribution grid division.
2. Regional Road Grid

From the outline of the figure, human vision can recognize a large amount of object information. Similarly, in the study of computer vision, edges and line segments contain features of the image, and the contour recognition algorithm can extract the boundary of the object in the image. In this study, by identifying the contour of the block in the road image, the ordered block boundary information can be extracted, thereby completing the division of the basic unit of the region.

In this study, the Sobel operator algorithm in the contour recognition algorithm is used to process the image.

(1) First, the image to be processed is read into Python, converted into digital information of image, and the image is filtered by Gaussian filter \( G(x, y) \) to remove noise, and the image \( g(x, y) \) after de-drying is obtained. The filter is as follows:

\[
G(x, y) = \frac{1}{2\pi\sigma} e^{-\frac{x^2+y^2}{2\sigma^2}}
\]

(1)

(2) Gradient calculation: The first derivative \( G_x \) and \( G_y \) of the horizontal direction and the vertical direction, that is, the image gradient, is calculated for the Gaussian processed image. Calculated as follows:

\[
G_x = \begin{bmatrix} -1 & 0 & +1 \\ -2 & 0 & +2 \\ -1 & 0 & +1 \end{bmatrix} \ast I
\]

(2)

\[
G_y = \begin{bmatrix} -1 & -2 & -1 \\ 0 & 0 & 0 \\ +1 & +2 & +1 \end{bmatrix} \ast I
\]

(3)

Then calculate the size and direction of the gradient by the following formula:

\[
\theta = \arctan \frac{G_x}{G_y}
\]

(4)

(3) Non-maximum value suppression: The entire image is scanned to find the local maximum of all the pixels, and the pixels of the non-local maximum are zero-processed. Through this, you can get the initial contour edge points.

(4) Double threshold value processing: first set two high and low thresholds \( t_1 \) and \( t_2 \). When the gray value of the image pixel is higher than \( t_2 \), the pixel is considered to be the contour boundary point; conversely, if the image pixel gray value is lower than \( t_1 \), the pixel is considered to be a non-contour point. When the pixel value of the image pixel is between \( t_1 \) and \( t_2 \), if the pixel is connected to the pixel point directly determined as the contour point, the pixel point is considered to be the image contour boundary point; otherwise, if the pixel point is directly If the pixel point determined to be the contour point is not directly connected, the pixel point is considered to be a non-image contour point.
3. Voronoi Diagram

3.1. Basic Voronoi Diagram
Definition: let \( S = \{p_1, p_2, \ldots, p_n\} \) be the set of points on the plane, which will be
\[
V(p_i) = \bigcap_{i \neq j} \{p \mid d(p, p_i) < (d(p, p_j)) \} (i = 1,2,\ldots,n)
\]
The given segmentation of the plane is called Voronoi diagram with \( p_i (i = 1,2,\ldots,n) \) as the generator (or mother point) (Fig. 1, the dot in the figure is the generator), and \( d(p, p_i) \) is the Euclidean distance between \( p \) and \( p_i \).

![Figure 1. Basic Voronoi diagram](image-url)

The Voronoi diagram on the plane can be regarded as a graph formed by expanding each of the generators \( p \) in the point set \( S \) at the same speed until they meet each other. This has great similarity with the division of the power supply area and can reflect the substation's location in the load center and its spatial influence.

3.2. Weighted Voronoi diagram
Definition: Let \( S = \{p_1, p_2, \ldots, p_n\} \) be the set of points on the plane, and give each vertex a non-negative real weight \( w_i (i = 1,2,\ldots,n) \), called \( D(p, p_i) \) is the weighted distance between points \( p \) and \( p_i \), then \( D(p, p_i) = d(p, p_i) / w_i \), the Voronoi area of point \( p_i \) when the weight is \( w_i \) is:
\[
V(p_i, w_i) = \bigcap_{i \neq j} \{p \mid D(p, p_i) < (D(p, p_j)) \} (i = 1,2,\ldots,n)
\]
Let \( V(p_i, w_i) \) and its boundary be a weighted Voronoi diagram with \( p_i (i = 1,2,\ldots,n) \) as the generator (or mother point) and \( w_i \) as the weight.

3.3. Determining the weight of the weighted Voronoi diagram
The weighted Voronoi diagram mainly considers the magnitude of the force of the generator and its effect on the effective range. In the power system, the power supply area of each substation is not only related to the distance from the load, but also related to the main transformer capacity of the substation. Substation's main transformer capacity is different, and its ability to influence the surrounding power supply area is different. Therefore, under the premise that the load density of the entire area is the same, different weights are given according to the magnitude of the main transformer capacity of the substation.

Since the size of the power supply area is proportional to the main variable capacity, the weight is the weight of the distance, so the weight should be proportional to the square root value of the main variable capacity.

Let the substation \( p_i \) main transformer capacity be \( c_i \), and the weight is \( w_i \) then it can be calculated:
In the above formula, $\bar{r}$ is the mean of all substation capacity, $\bar{r} = \frac{1}{n} \sum_{i=1}^{n} r_i$ ($i = 1, 2, \ldots, n$)

4. Steps for dividing the power supply area

According to the known regional substation capacity and location, the specific steps of applying the weighted V map to divide the power supply area are as follows:

1. Firstly, according to the regional road network, it is divided into several basic units by OpenCV contour recognition.
2. Abstract the substation in the area as a point set, which is the generator.
3. With the generator as the center and the substation capacity as the weight, apply the search strategy to spread in all directions.
4. It is judged whether the partition boundary of each diffusion direction of the generator element meets the adjacent partition, and if it meets, the diffusion of the two partitions in the direction is suspended.
5. If all the road grids are searched, the search ends, and the polygon Voronoi area formed by each generator is the substation power supply area.

Considering that a large number of substations may be concentrated in a high-load area, the area of the power supply area obtained by applying the V map will be small. Therefore, for a substation that is in the same street grid or a very close distance, combine them into one generator, and then use the Voronoi diagram to divide the power supply area.

5. Examples

Taking a county power grid as an example, the substation power supply area division based on the basic Voronoi diagram and the weighted Voronoi diagram is shown in FIG. 2 and FIG. 3.

| Substation       | ChengDong | ChengXi | HuangCun | LiuZhuang | GanHe | ChengBei |
|------------------|-----------|---------|----------|-----------|-------|----------|
| Capacity/MVA     | 60        | 110     | 80       | 90        | 60    | 50       |
| Weight           | 0.89      | 1.21    | 1.03     | 1.10      | 0.89  | 0.82     |

The results of dividing the power supply area by the basic Voronoi diagram are shown in Fig. 2. It can be seen that the partition result has the phenomenon of crossing the river and the main road because the influence of the geographical obstacle is not considered.

Figure 2. Power district partition result of a certain county based on basic Voronoi diagram
The results of using the weighted V map and the road grid to divide the power supply area are shown in Figure 3. Compared with Figure 2, not only the influence of the main capacity of the substation on the power supply radius is considered, but also the relationship between geographical obstacles and substation power supply partitions is well handled.

![Figure 3. Power district partition result based on weighted Voronoi diagram and road grids](image)

6. Conclusion
Based on the road grid and weighted Voronoi diagram, the substation power supply area division method takes into account the main capacity of the substation and the geographical barrier. It can adjust the generation of the element according to the main capacity of the substation to ensure the purchase radius is more reasonable and avoids Crossing the rivers and rivers and the main roads makes the zoning results closer to actual needs.

References
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