Research on Power Network Data Management Based on Convolutional Neural Network

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Abstract. Faced with huge business data, collecting and statistics of these data can be easily achieved through the system. However, during data analysis and result output, there is a large amount of data that cannot be intuitively accepted at a glance, resulting in disorder and inefficient work. Therefore, the grid load thermal map is scaled with cubic convolution interpolation in the paper, which requires the offset distance determination of the floating point in the horizontal and vertical directions. Moreover, based on the operating data of transformer and line, the analysis and verification of the load thermal map in power grid is realized. Besides, problem equipment can be clearly displayed on the map, which is convenient for staffs to identify and analyze.

1. Introduction

The explosive development of data and information transmission have prompted the power industry to adopt new methods to integrate and analyze grid business data, and thermal map can be understood as an intuitive data map, which uses a map to visually display multi-dimensional indicators and supports interactive charts. Besides, as an intuitive data management tool, thermal maps can map massive data through differentiated colors to describe changes in load data. Moreover, visualization management view of load information with thermal map as window can help field staff to grasp related business data such as equipment operating status, load information and load distribution within the shortest time. In addition, combining the collected geographic information and business data with maps, which will be displayed in image mode, makes the analysis results clear at a glance so that equipment operating status information can be easier retrieved and analyzed[1-2].

2. Convolution Interpolation Algorithm

Interpolation algorithms are widely used in image processing, and the quality of interpolation directly affects the effect of image processing. What’s more, during image interpolation calculation, the most important is the quality and complexity of the calculation. Additionally, the interpolation algorithms commonly used in engineering applications are neighbor sampling interpolation, quadratic linear interpolation and cubic convolution interpolation. Moreover, the nearest-neighbor interpolation method has the smallest amount of calculation and the fastest speed, but the accuracy is not high. Meanwhile, bi-linear interpolation has the characteristics of a low-pass filter, which damages high-frequency signals and blurs the outline of the image, but simultaneously the transition at the edges is also more natural. The disadvantage is that the operation speed is slower than that of the nearest neighbor interpolation. Besides, the cubic convolution interpolation method has a large amount of calculation and the speed is the slowest, but it is still ideal for image processing with high requirements.
The 16 neighboring points around a floating-point coordinate \((i + u, j + v)\) is shown below, and the destination pixel value \(f(i + u, j + v)\) can be obtained by the following interpolation formula.

\[
f(i + u, j + v) = [A] \times [B] \times [C]
\]

(1)

\[
[A] = \begin{bmatrix}
S(u+1)S(u+0)S(u-1)S(u-2)
\end{bmatrix}
\]

(2)

\[
[B] = \begin{bmatrix}
f(i-1, j-1)f(i-1, j+0)f(i-1, j+1)f(i-1, j+2) \\
f(i+0, j-1)f(i+0, j+0)f(i+0, j+1)f(i+0, j+2) \\
f(i+1, j-1)f(i+1, j+0)f(i+1, j+1)f(i+1, j+2) \\
f(i+2, j-1)f(i+2, j+0)f(i+2, j+1)f(i+2, j+2)
\end{bmatrix}
\]

(3)

\[
[C] = S(v+1)S(v+0)S(v-1)S(v-2)
\]

(4)

\[
S(x) = \begin{cases} 
1-2^*|x|^2+|x|^3, & 0 \leq |x| < 1 \\
4-8^*|x|+5^*|x|^2-|x|^3, & 1 \leq |x| < 2 \\
0, & |x| \geq 2
\end{cases}
\]

(5)

\(S(x)\) is an approximation to \(\sin(x\pi)/x\).

Compared with the result of bi-linear interpolation, the effect of the image after interpolation is greatly improved, and the accuracy is higher. However, since the value of sixteen pixels is considered and the interpolation kernel function is a third-order function, the amount of calculation is also increased[3-4].

3. Thermal Analysis of Power Network Load Based on Neural Network

Based on the load carried by the transformer, the change in its load factor is calculated. Moreover, reasonable grid load distribution scheme is formulated for heavy overload and light load of transformers to improve the utilization efficiency of transformers, so that grid asset losses can be reduced. What’s more, the thermal map provides a visual interface for load analysis, which can directly lock the problem equipment with the help of the thermal map to determine the weak link of the power grid, so that the deep mining of the power grid data, visual display and interactive analysis can be realized.

3.1. Analysis of Transformer Operation Status

According to the classification of the transformer's operating status, the maximum load rate of the transformer can be defined as (0 ~ 20%) is light load, (20% ~ 70%) is normal state, (70% ~ 100%) is heavy load, and greater than 100% is overload. Besides, the maximum load rate of the transformer indicates the degree to which the maximum load of a certain transformer in that place reaches the rated capacity of the transformer under the maximum operating mode of the certain place. In addition, for a total of \(N\) transformers at a certain voltage level in that place, the maximum load rate of a transformer at the voltage level in the place is as follows[5].

\[
\eta_{\text{max}} = \frac{p_{\text{max}}}{S_i \times 100\%}, i = 1, 2, \ldots, N
\]

(6)

In formula (6), \(\eta_{\text{max}}\) represents the maximum load rate of the \(i^{th}\) transformer, \(p_{\text{max}}\) refers to the maximum load of the \(i^{th}\) transformer, and \(S_i\) is rated as the rated capacity of the \(i^{th}\) transformer.

Substation is taken as the research object in the paper. It is assumed that there are only \(M\) transformers in a substation, and the maximum load rate of the substation is shown below.
In Equation (7), $\delta_{j_{\text{max}}}$ is the maximum load factor of the $j^{th}$ substation.

3.2. Thermal Map Based on Convolution Interpolation

Thermal map is used in the paper to show the operation status of the transformer. The color identification range of the transformer including the color and RGB values is first defined according to the operation status of the transformer. The specific process of the thermal map analysis is as follows.

1. According to the geographic information of the substation, such as longitude and latitude, and the relationship between the line and the substation, geographic wiring diagram of the power grid is drawn on the map.

2. In line with the voltage level and pixel relationship of the power grid, the layer of the map is set to establish the corresponding relationship between the voltage level and the layer, which is shown in Table 1[6-8].

| Voltage level / kV | Layer   |
|-------------------|---------|
| 500               | First layer |
| 220               | Second layer |
| 110               | Third layer |
| 35                | Fourth layer |

3. The maximum load rate of the substation is calculated according to formula (6) and formula (7), then the calculation results are normalized. The normalization method used in the paper is Min-Max Normalization known as dispersion standardization, which is a linear transformation of the original data to map the resulting value to [0,1]. The conversion function is as follows.

$$\delta_j^* = \frac{\delta_j - \delta_{\text{min}}}{\delta_{\text{max}} - \delta_{\text{min}}}$$

In formula (8), $\delta_{\text{max}}$ refers to the maximum load rate of the substation under a certain voltage level, and $\delta_{\text{min}}$ is the minimum load rate of the substation under a certain voltage level.

4. Case Analysis

In order to verify the effectiveness and feasibility of the method, power grid equipment can be analyzed by two classification methods. One is to view the analysis results of operating status in the device under different pixels according to the layer relationship of the map, and the other is to view the operating status of all devices in a certain state based on the device operating status. In addition, according to the
data of a provincial power grid company, the operation of the provincial power grid equipment in a certain year is analyzed in the paper.

4.1. Hierarchical Visual Analysis

4 layers are mainly divided in the paper to implement equipment operation status analysis. Since the number of devices and voltage levels corresponding to different layers are different, multi-angle analysis from global to local and from high voltage to low voltage can be achieved.

(1) Only 500kV equipment can be seen in the first layer, as shown in Figure 1a. From the perspective of the thermal map effect, the load rate of the overall device is large, and the interface is mainly highlighted in red. Due to the low pixels of the map, low-voltage devices cannot be displayed under the pixel. Looking at the overall situation, the province's power grid has a large load, and the operation of power grid equipment is in a heavy state. In order to better lock heavy overload equipment, further analysis is needed.

(2) 220kV equipment can be analyzed in the second layer, as shown in Figure 1b. From this layer, it can be seen that the grid equipment basically exists at independent points, and the grid structure diagram can be clearly seen.

(3) 110kV equipment can be analyzed in the third layer, as shown in Figure 1c. The pixels of the third layer have already been relatively high, and the name of the device can be displayed on the map. Therefore, the heavy overload device can be directly clicked to view its specific operating data to determine whether the area needs to increase or decrease the transformer.

(4) The fourth layer can be extended to 35kV devices, as shown in Figure 1d. Moreover, the fourth layer reaches the maximum pixels, and the grid structure is relatively clear, which can be clear at a glance for the problem equipment.

4.2. Analysis of Different Operating States

In order to better lock the problem equipment, the thermal map is used in the paper to separately analyze the heavy-load equipment and light-load equipment.

Analysis of heavy-duty equipment is as follows. As shown in the thermal map of Figure 2, it can be seen that most of the transformers with larger loads are concentrated in urban centers, and there are almost no heavy-duty equipment in urban fringe areas. In addition, the heavy-duty equipment of each city company is relatively concentrated. For the areas where the problem is serious, the load rate of its equipment can be checked in detail, including operation details of transformer and lines.
Analysis of light-load equipment is as follows. As shown in the thermal map of Figure 2, it can be seen that there is less equipment for a certain power grid equipment, and from the entire map, the light-load equipment is scattered. Similarly, for the areas where the problem is serious, the load rate of its equipment can be checked in detail, including operation details of transformer and lines.

5. Conclusion
Based on big data technology, data are extracted, processed and analyzed in the paper from a certain province's power grid. Then, data analysis model is established in line with the operating status of the equipment. Moreover, cubic convolution interpolation algorithm is used to complete the visualization of the thermal map. Therefore, the thermal map in the paper can show the load distribution of the equipment from a macro perspective. Meanwhile, the operating status of the equipment is identified based on its operating data, so that potential hidden dangers of equipment can be explored to prevent equipment failures in advance, and avoid loss of power grid resources.

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