Outdoor Motion Positioning Based on Collaborative Relation Aerial Image

Xin Sheng

Physical Education Department, Wuxi Institute of Technology, Wuxi 214000, China

Abstract

Outdoor motion positioning technology is an effective method to obtain the distribution information of outdoor personnel in outdoor space. This paper has proposed a method for outdoor motion positioning based on collaborative relation function of aerial image hidden layer topological structure. Compared with the traditional method of outdoor motion positioning based on the hidden layer topological structure, this method makes use of the collaborative relation function Nairo to constrain the positioning result at the single image level, with the results that are more consistent with the spatial correlation hypothesis. The experimental results show that, this method is superior to the traditional method of outdoor motion positioning based on the hidden layer topological structure, and has higher positioning accuracy.

Key words: Aerial Image, Outdoor Motion Positioning, Autocorrelation, Nairo.

1. INTRODUCTION

Aerial image is the phenomenon prevalent in the outdoor space. Soft classification technology, such as outdoor spatial decomposition technology (Charles, 1996; Zhang and Zhang, 2005), can obtain the abundance corresponding to each outdoor personnel category in the pixel, and acquire the abundance image equal to the number of categories, so as to effectively solve the problem of pixel mixing. However, the outdoor spatial decomposition can only obtain the abundance of the end member, but cannot determine the specific positioning of the outdoor personnel in the pixel space, which will still result in the loss of the detailed spatial information of the aerial image.

In view of this problem, literature (Atkinson, Cutler and Lewis, 1997) proposed the concept of outdoor motion positioning. Outdoor motion positioning is a hard classification technology that converts the soft classification into the higher spatial scale (Ke, Li and Zhang, 2007). Many studies have been carried out at home and abroad (Verhoeye and Wulf, 2002; Ke, 2009; Mertens, Verbeke, Ducheyne and Wulf, 2003; Koen C. Mertens, Bernard de Baets, Lieven P. C. Verbeke and Robert R. de Wulf, 2006). Among them, the outdoor motion positioning method based on the hidden layer topological structure (Zhang, Wu, Zhong and Li, 2008; Mertens, Verbeke and Wulf, 2003) can obtain relatively high accuracy of outdoor motion positioning by the application of the non-linear fitting characteristic of the hidden layer topological structure.

However, the traditional outdoor motion positioning method based on the hidden layer topological structure only takes into account the spatial relationship of outdoor personnel at the pixel level (Zhang, Wu, Zhong and Li, 2008; Mertens, Verbeke and Wulf, 2003), but does not take the spatial relationship of the outdoor personnel at outdoor motion level into consideration; therefore, the result is not completely consistent with spatial correlation assumption. In order to better perform the outdoor motion positioning, this paper proposes a hidden layer topological structure model for outdoor motion positioning method based on the collaborative relation coefficient Nairo. The experiments prove that, this method can obtain higher accuracy of outdoor motion positioning.

2. OUTDOOR MOTION POSITIONING METHOD BASED ON HIDDEN LAYER TOPOLOGICAL STRUCTURE

2.1. Basic Theory of Outdoor Motion Positioning

The premise of the outdoor motion poisoning is through the outdoor spatial decomposition of hyperspectral images to obtain the proportion of different outdoor personnel categories in each pixel, then to obtain the spatial distribution of different end members in the outdoor space according to the spatial correlation hypothesis theory.

The spatial correlation hypothesis theory believes that, the outdoor motion with long distance, compared with outdoor motion with relatively short distance, is more likely falling under the same category; and this theory has been verified to be established in most cases (Zhang and Zhang, 2005. As shown in Figure 1, it is a simple schematic diagram of the spatial distribution of the pixels, which contains two different categories of
outdoor personnel, expressed in black and white, respectively, and the enlarged scale $S=5$. Figure 1 (b) and (c) represent two different spatial distribution states, according to the aforementioned theory, the spatial correlation of Figure 1 (c) is greater, therefore, the outdoor distribution is more likely to be Figure 1 (c).

<table>
<thead>
<tr>
<th>32%</th>
<th>100%</th>
<th>40%</th>
</tr>
</thead>
<tbody>
<tr>
<td>12%</td>
<td>40%</td>
<td>16%</td>
</tr>
<tr>
<td>0%</td>
<td>0%</td>
<td>0%</td>
</tr>
</tbody>
</table>

(a) End Member in the Original Image  (b) Inferior Spatial Distribution of Outdoor Motion

(c) Superior Spatial Distribution of Outdoor Motion

Figure 1. Spatial Distribution Diagram of Outdoor Motion

2.2. Outdoor Motion Positioning Method Based on Hidden Layer Topological Structure

The standard hidden layer topological structure algorithm is an error back propagation feedforward network learning algorithm. The network model not only has the input layer nodes, output layer nodes, it also has the hidden layer nodes. For the input signal, it will first be forward propagated to the hidden layer nodes, through the role of activation function, and then propagate the hidden layer node output information to the output nodes, and finally gives the output result. If the desired output result cannot be obtained at the output layer, it goes backwards and returns the error signal along the original connection path, so that the error signal is minimized by modifying the weights of the neurons in each layer. The hidden layer topological model for outdoor motion positioning consists of two modules: model correction (training) and simulation. The two modules apply the same network model. In the model correction module, the parameters of the model are acquired automatically by the application of the training data: and then the parameters are input to the simulation module for analog operation. The structure of the entire model is very simple, and there is no need to manually define the conversion rules and parameters.

The network model is shown in Figure 2. Take the spatial scale $S=2$ as an example, the input layer is the abundance value of an outdoor person in the low resolution target pixel and its eight neighborhood pixels, and the output layer is $S \times S$ pixels that the low resolution target pixel corresponds to at the high resolution reconstructed image. And the value of each node in the output layer indicates the probability that the cell belongs to the outdoor personnel. As the proportion of a certain class in the outdoor space is fixed, for this category, it is necessary to sort each kind of outdoor motion probability value from the largest to the smallest in order to determine the target type until the total number of the category is met. In this way, the spatial distribution of outdoor motion can be determined.

Although the hidden layer topological model for outdoor motion positioning method can obtain high accuracy of outdoor motion positioning (Zhang, Wu, Zhong and Li, 2008; Mertens, Verbeke and Wulf, 2003), the result of the hidden-layer topological structure model positioning has great relationship with the selection of the initial training data. Once the selected training data is not accurate enough or when the network training is not sufficient, the final result of both the accuracy or detail information will be more limited, and at the same time, there are a number of extreme points existing in the global cost function of the network, making the output
prone to the local minimum, and resulting in the “Zigzag” phenomenon, which will cause the outdoor motion positioning not completely consistent with the spatial correlation hypothesis, and these errors are difficult to resolve from the network itself.

3. OUTDOOR MOTION POSITIONING METHOD BASED ON COLLABORATIVE RELATION HIDDEN LAYER TOPOLOGICAL STRUCTURE

The collaborative relation function Nairo can detect the degree of correlation and association of the same attribute value in different spatial positions (Ellison and Glaeser, 1994; Hilbert and Arabie, 1991; C L1FF A D ORD J K, 1973; Get1s, 1992). In order to improve the outdoor motion positioning accuracy of the hidden layer topological structure, Nairo function is adopted to make adjustment to the results of the hidden layer topological structure positioning, and an outdoor motion positioning method based on collaborative relation hidden layer topological structure is proposed.

3.1 Collaborative Relation Function Nairo

Nairo calculation method is derived from the covariance relation based on the statistical correlation coefficient, and its formula is as the following

$$I = \frac{n \sum_i \sum_j W_{ij} (x_i - \bar{x})(x_j - \bar{x})}{\left( \sum_i \sum_j W_{ij} \sum_i (x_i - \bar{x})^2 \right)} \quad (1)$$

In the equation, the value taken for $i$, $j$ is 1 to $n$, $i \neq j$, $n$ is the number of the spatial units involved in the analysis; $x_i$ and $x_j$ stand for the observation value of a certain attribute character $x$ on the spatial unit $i$ and $j$; $\bar{x}$ is the mean of the attribute character $x$; $W_{ij}$ is the element in the spatial weight matrix, and it represents the neighborhood relation of the region $i$ and $j$, which can be measured according to the adjacency criterion or the distance criterion, and the adjacency criterion $W_{ij}$ expression is shown as the following

$$W_{ij} = \begin{cases} 1 & \text{The } i-th \text{ and } j-th \text{ units are adjacent} \\ 0 & \text{The } i-th \text{ and } j-th \text{ units are not adjacent} \\ 0 & i = j \end{cases} \quad (2)$$
In the equation, \( W_i \) is the sum of the spatial weight matrix row \( i \); and \( W_j \) is the sum of the spatial weight matrix column \( j \). Nairo statistics value taking ranges from \(-1\) to \(1\), if \( I \) is greater than \(0\), it is positive correlation, and if \( I \) is less than \(0\), it is negative correlation, and the larger the value is, the greater the spatial distribution correlation is, that is, there is distribution clustering phenomenon in the space, as shown in Figure 3 (a). On the contrary, the smaller the value is, it represents that the smaller the spatial distribution correlation is, as shown in Figure 3 (b). When the value approaches \(0\), it indicates that at this point, the spatial distribution shows random distribution, as shown in Figure 3 (c). Among them, Figure 3 (c) is generated by ENVI software in a random way. It can be seen that the calculation that the Nairo value under this distribution approaches zero, therefore, the Nairo statistics can truly reflect the degree of interrelation and correlation of the same attribute value in different spatial positions.

![Figure 3. Collaborative Relation Results Diagram](image)

**3.2 Hidden Layer Topological Structure Model for outdoor motion positioning Method Based on Nairo**

The specific steps of the Nairo based hidden layer topological structure model for outdoor motion positioning are as the following:

1. Obtain the processing results of the outdoor personnel by the hidden layer topological structure model method, and the pixel value indicates the probability of the pixel falling under the outdoor personnel category.

2. Normalize the positioning results of each outdoor personnel so as to avoid the difference in the process of consolidation. The normalization processing method is
   \[
   n_{ij} = \frac{X_{ij}}{\sum_{i=1}^{N} x_i S^2 - \sum_{j=1}^{N} n_j X_j},
   \]
   In which, \( x_i \) is the abundance value of the \(i\)-th category of the outdoor personnel in the initial input pixels; \( N \) is the number of outdoor motion falling under the \(i\)-th category; \( n_{ij} \) is the probability value of the outdoor personnel with the outdoor motion \(j\) falling under the \(i\)-th category; \( N \) is the number of categories: \( X_{ij} \) is the probability value of the outdoor personnel with the outdoor motion \(j\) falling under the \(i\)-th category; \( n_{ij} \) is the result after normalization.

3. According to the number of outdoor motion corresponding to the low-resolution abundance image and the probability results of each outdoor motion that falls under each category, the classification of each outdoor motion is determined.

4. Adopt Nairo method to compute the spatial distribution correlation of \(S \times S\) (\(S\) stands for the reconstruction scale) pixels on the high resolution classification image corresponding to each original low resolution image pixel, and the maximum correlation can be achieved by exchanging the outdoor motion category value. The method of the outdoor motion category value exchange is: Calculate the number \(k\) of outdoor motion which is different from the central outdoor motion category in the four neighborhoods or eight neighborhoods of the outdoor motion respectively, and record the positioning of the outdoor motion with the highest value of \(k\). Conduct exchange for the outdoor motion with other outdoor motion category value, and recalculate Nairo, if the recalculated Nairo maximum value is greater than the original Nairo value, the category exchange is completed.

5. Repeat step (4) until the value of Nairo no longer changes.

**4. EXPERIMENTS AND THE COMPARISON**

In order to avoid the error introduced by the spatial decomposition and the influence on the accuracy of the classification, the data adopted in this paper is the low-resolution abundance image obtained through descrambling the original high-resolution image. Therefore, the experiment only reflects the performance of the outdoor motion positioning method, while at the same time, the high-resolution classification images can also be applied to assess the accuracy of outdoor motion positioning results.
4.1. Experimental Image 1

Wuhan TM image in September 1999 was selected as the experimental data. The image has 6 wave bands with the resolution of 30m, as shown in Fig.4 (a). In the images, the outdoor personnel can be classified into four categories, that is: Yangtze River, Lake, Residential Area and Vegetation, the water quality of the lake is quite different from that of the Yangtze River; therefore, it is classified as a separate category. Similar to the analog data processing method, the aboriginal abundance image of different outdoor personnel can be obtained through downsampling for the original classification image (Figure 4 (b)), and the number of abundance images is equal to the number of outdoor personnel. The size of the original image is $200 \times 200$ pixel, scale factor is $S = 4$, and each end member abundance image size is $50 \times 50$ pixel, that is: Each low-resolution image pixels correspond to the original image pixel $4 \times 4$. The original hidden layer topological structure model and the Nairo-based hidden layer topological structure model are applied to carry out the outdoor motion positioning experiments on the low resolution images. The positioning results are shown in Figure 4 (c) and Figure (d), respectively.

4.2. Experimental Images 2

As shown in Fig. 5 (a), the actual data is the real TM image located in 6 wave bands in Wuhan area with the resolution of 30m. It contains four different categories including Yangtze River, Lake, Vegetation and Residential Area. The original images are classified by the maximum likelihood method, and the classification results are shown in Fig. 5 (b) as the real reference images. The size of the original image is $200 \times 200$ pixel, and the processing method is the same as the one applied for the Experimental Image 1. The original hidden layer topological structure model and the Nairo-based hidden layer topological structure model are applied to carry out the outdoor motion positioning experiments on the low-resolution images. The results are shown in Figure 5 (c) and Figure 5 (d), respectively.

![Figure 4. Image Positioning Results](image-url)
4.3. Comparison of Experimental Results

From the visual point of view, the original hidden layer topological structure network model results in a certain zigzag positioning effect, while the Nairo based hidden layer topological structure network positioning results are smoother, compared with the reference image, its results are more in line with the actual outdoor personnel distribution. In order to make quantitative analysis of the results of outdoor motion positioning, this paper evaluates the results by the application of the quantitative analysis indexes such as PCC (percent correctly classified), kappa coefficient and confusion matrix, etc. In order to highlight the evaluation performance of the method, two new indexes PCC' (Ke and Ping-Xiang, 2009) and kappa' are introduced. These two indexes are only calculation in view of the outdoor space, which can better evaluate the outdoor motion positioning results.

The experimental results are shown in Table 1. For experiment 1, it can be seen from the comparison of the accuracy results in Table 1 that the PCC value and the kappa coefficient of the Nairo-based hidden layer topological structure method are improved by 1.587% and 2.49%, respectively, compared with the original hidden layer topological structure method. In order to more accurately compare the positioning accuracy of these two methods in the outdoor space, the PCC' value and Kappa' coefficients are calculated respectively. As can be seen from Table 1, the method has improved PCC' and kappa' by 5.385% and 8.38%, respectively. For Experiment 2, it can be seen from Table 1 that the accuracy of PCC' and Kappa' has been improved from 71.666% and 0.5072 to 76.713% and 0.5950, respectively, therefore, and the accuracy of this method is better than that of the traditional hidden layer topological structure outdoor motion positioning.
Table 1. Experimental Image Accuracy Statistics Table

<table>
<thead>
<tr>
<th></th>
<th>Experimental Image 1</th>
<th>Experimental Image 2</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Original Hidden</td>
<td>Nairo-based Hidden</td>
</tr>
<tr>
<td></td>
<td>Layer Topological</td>
<td>Layer Topological</td>
</tr>
<tr>
<td></td>
<td>Structure Model</td>
<td>Structure Model</td>
</tr>
<tr>
<td>PCC</td>
<td>91.713%</td>
<td>93.300%</td>
</tr>
<tr>
<td>kappa</td>
<td>0.8701</td>
<td>0.8950</td>
</tr>
<tr>
<td>PCC</td>
<td>71.888%</td>
<td>77.273%</td>
</tr>
<tr>
<td>kappa</td>
<td>0.5622</td>
<td>0.6460</td>
</tr>
<tr>
<td></td>
<td>86.932%</td>
<td>89260%</td>
</tr>
<tr>
<td></td>
<td>0.7809</td>
<td>0.8199</td>
</tr>
<tr>
<td></td>
<td>71666%</td>
<td>76713%</td>
</tr>
<tr>
<td></td>
<td>0.5072</td>
<td>0.5950</td>
</tr>
</tbody>
</table>

In order to further illustrate the specific differences, Table 2 lists the results of the evaluation on the confusion matrix in Experiment 1 with the application of the two methods. As can be seen from Table 2, for the Nairo-based hidden layer topological structure method, the classification accuracy of all the four categories of outdoor personnel has been increased, especially in the junction area of the vegetation and residential area and lake, which are the areas where the outdoor personnel are relatively complicated, while for the original hidden layer topological structure model, due to the lack of consideration of the relationship between the outdoor motions, it results in decline in the accuracy. From the above analysis and comparison, we can see that the method proposed in this paper takes the information of outdoor motion level into account, and thus can effectively improve the accuracy of outdoor motion positioning results compared with the traditional hidden layer topological structure outdoor motion positioning method.

Table 2. Experimental Image 1 Positioning Result Confusion Matrix Contrast (PCC)

<table>
<thead>
<tr>
<th>Method</th>
<th>Category</th>
<th>Yangtze River</th>
<th>Lake</th>
<th>Residential Area</th>
<th>Vegetation</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>Original Hidden Layer Topological Structure</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Outdoor Motion Positioning Method</td>
<td></td>
<td>5903</td>
<td>80</td>
<td>173</td>
<td>5</td>
<td>6161</td>
</tr>
<tr>
<td></td>
<td></td>
<td>77</td>
<td>686</td>
<td>166</td>
<td>70</td>
<td>999</td>
</tr>
<tr>
<td></td>
<td></td>
<td>168</td>
<td>165</td>
<td>14 319</td>
<td>1 168</td>
<td>15</td>
</tr>
<tr>
<td></td>
<td></td>
<td>13</td>
<td>68</td>
<td>1 162</td>
<td>15 777</td>
<td>20</td>
</tr>
<tr>
<td></td>
<td></td>
<td>6 161</td>
<td>999</td>
<td>15 820</td>
<td>17 020</td>
<td>685</td>
</tr>
<tr>
<td>Nairo-based Hidden Layer Topological</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Structure Outdoor Motion Positioning Method</td>
<td></td>
<td>6 016</td>
<td>59</td>
<td>86</td>
<td>0</td>
<td>6161</td>
</tr>
<tr>
<td></td>
<td></td>
<td>59</td>
<td>773</td>
<td>121</td>
<td>46</td>
<td>15</td>
</tr>
<tr>
<td></td>
<td></td>
<td>86</td>
<td>127</td>
<td>14 582</td>
<td>1 025</td>
<td>17</td>
</tr>
<tr>
<td></td>
<td></td>
<td>0</td>
<td>40</td>
<td>1 031</td>
<td>15 949</td>
<td>37</td>
</tr>
<tr>
<td></td>
<td></td>
<td>6161</td>
<td>999</td>
<td>15 820</td>
<td>17 020</td>
<td>320</td>
</tr>
</tbody>
</table>

Complicated, while for the original hidden layer topological structure model, due to the lack of consideration of the relationship between the outdoor motions, it results in decline in the accuracy. From the above analysis and comparison, we can see that the method proposed in this paper takes the information of outdoor motion level into account, and thus can effectively improve the accuracy of outdoor motion positioning results compared with the traditional hidden layer topological structure outdoor motion positioning method.

5. CONCLUSION

As the traditional hidden layer topological structure outdoor motion positioning method does not take the relationship between the outdoor motions into consideration, its results cannot meet the requirements of the spatial correlation hypothesis very well. In this paper, the hidden layer topological structure model based on the collaborative relation function Nairo is applied to carry out the outdoor motion positioning, so as to comply with the spatial correlation hypothesis theory, and improve the accuracy of outdoor motion positioning. The experimental results show that, the method proposed in this paper, compared with the original hidden layer
topological structure outdoor motion positioning method, can obtain results that are more in compliance with the distribution situation of the outdoor personnel, and can improve the positioning accuracy of outdoor motion. In addition, the collaborative relation function Nairo applied in this paper is also applicable to the ARTMAP neural network model as well as the attraction model and other outdoor motion positioning methods.

REFERENCES


