Land Evaluation Supported by MDS

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Abstract

GIS-MCE is the main method in land evaluation, but it is a linear method and neglects multidimensional complexity of factors used in land evaluation, which leads to information loss. Multidimensional scaling (MDS) originates from psychoanalysis, which is used to describe multidimensional data in higher dimensions by transforming data in higher dimensions into geometry structure in Lower dimensions. In the Land evaluation model supported by MDS, the data is transformed into a similar space and land evaluation is completed according to the spatial clustering based on the data’s spatial similarity, which is a method driven by data and not dependent on others priori assumption. Taking expropriation division in Xuzhou city as an example, it shows that the land evaluation based on MDS meets the requirements of land classification.

Keywords: Land Evaluation  MDS  Spatial Cluster  model

1. Introduction

Land evaluation involves factors of soil, climate, vegetation, topographic and hydrology, which is an analysis integrating spatial information.

In analysis of integrating spatial information, spatial data of different types and different sources can be taken as attribute of spatial cells, which have different spatial resolution and different spatial scale. So land evaluation can be taken as integrating spatial information of different sources and different spatial scales in specific information space.

GIS-MCE is the main method in land evaluation, but it is a linear method and neglects Multidimensional complexity of factors used in land evaluation, which leads to information loss.

Multidimensional scaling (MDS) originated from psychoanalysis, and it is used to describe multidimensional data in higher dimensions by transforming data of higher dimensions into geometry structure in Lower Dimensions. Based on this, Land evaluation supported by MDS is a method driven by data and not dependent on others priori assumption.

2. The principles of MDS

Set the Attribute measurement matrix $C = (d_{ij})_{n \times n}$ of n objects has been given in r-dimensional space, said C is the similarity matrix for the n objects. MDS using C to obtain $p \leq r$-dimensional vector $Z = (z_{(1)}, z_{(2)}, ..., z_{(n)})$, and n objects can be expressed by vector Z, said that Z is a Mimetic Structure of C. Set $\hat{D}$ is Attribute measurement matrix Obtained from the Z, and said $\hat{D}$ is Mimetic distance matrix of C. MDS's target is both to make the n objects to achieve $p \leq r$-dimensional expression, but also to make $\hat{D}$ as close as possible to C, and the process achieves the classification of n objects, where only n-matrix C is available.

Young-Household theorem approaches creating p-dimensional vector Z from the matrix C. For the matrix
\[ C = (d_{ij})_{n \times n}, \text{ set } B = (b_{ij})_{n \times n}, \text{ where} \]
\[ b_{ij} = \frac{1}{2} \left( -d_{ij}^2 + \frac{1}{n} \sum_{j=1}^{n} d_{ij}^2 + \frac{1}{n} \sum_{i=1}^{n} d_{ij}^2 - \frac{1}{n^2} \sum_{i=1}^{n} \sum_{j=1}^{n} d_{ij}^2 \right) \]  

Set \( \lambda_1 \geq \lambda_2 \geq \cdots \geq \lambda_r \) is positive characteristic roots of \( B \), \( e_1, e_2, \cdots, e_r \) is eigenvector corresponding to \( \lambda_1 \geq \lambda_2 \geq \cdots \geq \lambda_r \), take \( Z = (e_1, e_2, \cdots, e_r) = (x_i)_{n \times r} \), each row of \( Z \) matrix corresponds to a mimetic spatial coordinate of object. Take \( Z \) dimension \( p < r \) to realize the classification of \( n \) objects in low-dimensional space.

3. Land evaluation model based on MDS

In the process of anglicizing land information for different types of factors, there is big difference in data preprocessing, such as data quality control, data registration, space unit and so forth, but through a certain mode after pretreatment different sources, different scales, different elements of the land factor in the sampling data can be integrated in an information space, which can study the characteristics of spatial information.

Set \( X_i (i = 1 \ldots N) \) is the space evaluation unit of land, and the spatial coordinates is \((x_i, y_j)\). land evaluation factors subordinate to \( X_i (i = 1 \ldots N) \) constitute a \( r \)-dimensional sampled data information space. \( C \) is the the spatial similarity matrix of \( X_i (i = 1 \ldots N) \) based on sampled data of land evaluation factors. \( Z \) is a Mimetic Structure of \( X_i (i = 1 \ldots N) \); in this mimetic Structure, \( X_i \)'s spatial coordinates is \((u_i, v_i)\).

\[
C = t \{ X_i \} \quad (i=1\ldots n): \quad t \text{ is the similarity measure matrix constructor;} \\
Z = H \{ C \}: \quad H \text{ is constructor to form Mimetic Structure;} \\
F^* = E \{ (u_i, v_i) \}: \quad \text{is spatial clustering for } X_i \text{ Based on } (u_i, v_i) \text{ the, } E \text{ is the analysis process;} \\
F = Q \{ F^* \}: \quad F \text{ is cluster expression of the land evaluation space unit based on } (x_i, y_j), \quad Q \text{ is the transformation process of } F^* \text{ to } F.
\]

4. Realizing Model

Taking expropriation division in Xuzhou city as an example, Realizing the Model of land evaluation based on MDS as follows.

3.1 Establishing multi-dimensional information space

Taking village-level administrative areas as the basic spatial unit, and Taking Annual output value of unit land area (PV), affect degree of central city (CD), accessibility to roads (RD), external transport facilitation degree (TD) status of land use (LU), land supply and demand (LS), the local economic development (EL) as the information dimension, establish multi-dimensional information space:

\[ y_1 (pv_i, cd_i, rd_i, td_i, lu_i, ls_i, el_i) \]

Where \( pv_i, cd_i, rd_i, td_i, lu_i, ls_i, el_i \) is the regular, standardized property value of annual output value per unit area (PV), center city degree (CD), accessibility to roads (RD), external transport facilities degrees (TD) land-use conditions (LU), land supply and demand (LS), the local economic development (EL).

3.2 The similarity structure of spatial cells

Taking \( pv_i, cd_i, rd_i, td_i, lu_i, ls_i, el_i \) as distance measure, establish Euclidean distance similarity measure between spatial unit \( i, j \):

\[
s_{ij} = \sqrt{(pv_j - pv_i)^2 + (cd_j - cd_i)^2 + (rd_j - rd_i)^2 + (td_j - td_i)^2 + (lu_j - lu_i)^2 + (ls_j - ls_i)^2 + (el_j - el_i)^2}
\]

taking \( s_{ij} \) as a similarity measure to establish spatial attribute similarity matrix of Expropriation Division as a table1 (Local)
3.3 Coordinates calculation of mimetic structure

Using ALSCAL in MATLAB to calculate the space coordinates \((u, v)\) in mimetic structure for each spatial unit as shown in Table 2:

**Tab.2 Spatial Cells’ Coordinate in Common Mimetic Structure**

<table>
<thead>
<tr>
<th>Village Name</th>
<th>Coordinate</th>
<th>Village Name</th>
<th>Coordinate</th>
<th>Village Name</th>
<th>Coordinate</th>
</tr>
</thead>
<tbody>
<tr>
<td>qianpantao</td>
<td>-0.072</td>
<td>0.741</td>
<td>zhaowu</td>
<td>-0.478</td>
<td>-0.184</td>
</tr>
<tr>
<td>jingshan</td>
<td>-0.23</td>
<td>-0.134</td>
<td>zhangtun</td>
<td>-0.223</td>
<td>-0.226</td>
</tr>
<tr>
<td>dahuangshan</td>
<td>-0.418</td>
<td>-0.029</td>
<td>dahan</td>
<td>-0.384</td>
<td>-0.125</td>
</tr>
<tr>
<td>keliangzhuang</td>
<td>-0.54</td>
<td>-0.066</td>
<td>lizhuang</td>
<td>-0.564</td>
<td>-0.039</td>
</tr>
<tr>
<td>wangkele</td>
<td>-0.73</td>
<td>-0.144</td>
<td>mazhuang</td>
<td>-0.517</td>
<td>-0.044</td>
</tr>
<tr>
<td>langgudun</td>
<td>-0.825</td>
<td>-0.265</td>
<td>dingzhuang</td>
<td>0.344</td>
<td>1.241</td>
</tr>
<tr>
<td>xiaohuangzhu</td>
<td>-0.765</td>
<td>-0.294</td>
<td>shanghetou</td>
<td>-0.097</td>
<td>-0.384</td>
</tr>
<tr>
<td>xizhuji</td>
<td>-0.739</td>
<td>-0.259</td>
<td>dawangmiao</td>
<td>0.108</td>
<td>0.555</td>
</tr>
<tr>
<td>qianwangjia</td>
<td>-0.866</td>
<td>-0.083</td>
<td>chengzhuang</td>
<td>-0.208</td>
<td>0.566</td>
</tr>
<tr>
<td>poli</td>
<td>-0.784</td>
<td>-0.138</td>
<td>liupu</td>
<td>-0.509</td>
<td>-0.254</td>
</tr>
<tr>
<td>damiao</td>
<td>-0.777</td>
<td>0.41</td>
<td>chaan</td>
<td>-0.229</td>
<td>0.908</td>
</tr>
<tr>
<td>anran</td>
<td>-0.589</td>
<td>0.365</td>
<td>liujii</td>
<td>-0.365</td>
<td>-0.752</td>
</tr>
<tr>
<td>gushan</td>
<td>-0.474</td>
<td>0.443</td>
<td>zhaodian</td>
<td>-0.285</td>
<td>0.083</td>
</tr>
<tr>
<td>zhangzhuang</td>
<td>-0.653</td>
<td>-0.04</td>
<td>sundian</td>
<td>-0.258</td>
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</tr>
<tr>
<td>houyi</td>
<td>-0.66</td>
<td>-0.161</td>
<td>pantang</td>
<td>-0.518</td>
<td>-0.009</td>
</tr>
<tr>
<td>houyi</td>
<td>-0.575</td>
<td>0.303</td>
<td>jianglou</td>
<td>-0.557</td>
<td>-0.197</td>
</tr>
<tr>
<td>qianyao</td>
<td>-0.562</td>
<td>0.169</td>
<td>tangfang</td>
<td>0.078</td>
<td>0.147</td>
</tr>
<tr>
<td>hetao</td>
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<td>0.483</td>
<td>cuiuzhuang</td>
<td>0.535</td>
<td>0.922</td>
</tr>
<tr>
<td>dongcun</td>
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<td>0.205</td>
<td>duanzhan</td>
<td>0.129</td>
<td>-0.108</td>
</tr>
<tr>
<td>houha</td>
<td>-0.688</td>
<td>-0.077</td>
<td>caoshan</td>
<td>-0.135</td>
<td>-0.229</td>
</tr>
</tbody>
</table>
3.4 Spatial clustering in mimetic structure

Realizing spatial visualization of mimetic structure according to coordinates \((u_i, v_i)\) as shown in Figure 1 and realizing spatial cells aggregation according to spatial relations in mimetic structure as shown in Figure 2.

![Fig. 1 Mimetic Structure of Spatial Cells](image1.png)

![Fig. 2 Partitioning Mimetic Structure](image2.png)

3.5 Implementation of expropriation division

Transform the classification of spatial cells in mimetic structure into real space to achieve expropriation division, results of the division shown in Figure 4. Figure 5 is the map of actual expropriation distribution, in Xuzhou city. Comparison of Figures 4 and 5, Comparison of Figures 4 and 5, both the spatial distribution between the two is consistent. Indicating the land evaluation method based on MDS meets the requirements of land classification.
Summary

Land evaluation based on MDS does not rely on priori assumptions, the basic approach is to transform the data into a similar space and complete spatial clustering according to the spatial similarity of the data. The example of expropriation division in Xuzhou city shows that the land evaluation based on MDS meets the requirements of land classification.

References