QUANTITATIVELY OPTIMIZED SELECTION OF PROPER SCALE IN LAND USE CARTOGRAPHIC GENERALIZATION

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Abstract: This paper quantitatively analyzs the map information of different scales in the range of the mapping scale by making use of landscape pattern index, and constructs an evaluation index system by the standard of cartographic generalization evaluation. It takes land use cartographic generalization in Da Xing agricultural region of Beijing for an example, evaluates on the map quality between the scale interval of 10 thousand and 100 thousand, and selects the appropriate scale so as to meet the need of land use cartographic generalization.

Keywords: scale interval, quantitatively analysis, evaluation index system, landscape pattern index, map quality

1. INRODUCTION

Spatial data has a quality of multi-scale,many scholars have mentioned how to select proper scale to express geograghical object in cartographic generalization and graphic display(Tate N et al., 2001;Sheppard E et al., 2004;WANG Jia-yao et al.,2004;AI Ting-hua et al.,2005;Li Zhi-lin,2005). In the quantitative researches of cartographic generalization, many of them aim at given the integrated index of mapping and visible standard. And they will evaluate on many aspects;the precision, position and figure of spatial data, map load , map tidiness and changes of semantic information(Dijk, S.F. van, et al,2002; Longin jan Latecki et al.,2000; Philip N Klein et al, 2001; Sylvain Bard,2002; Zhilin Li et al.,2002; WANG Qing-guo,2006; ZHANG Fa, 2006),but all of these are short of scale rules of map the strict corresponding relations of particular scales. Thus, it is very necessary to have a discussion on the best scale expression of map information, that is to say that we should discuss on the selection of the most appropriate scale that can meet the needs of cartographic generalization evaluation standard.

Categorical map cartographic generalization has become a hot point, following topographic map cartographic generalization. Martin Galanda(2003),Moritz Neun and Stefan Steiniger(2005)brought forward a series of technique levels from microcosmic and medium perspective in researches of topographic map cartographic generalization, but the evaluation level emphasized particularly on map restriction. Nevertheless, solely depending on the microcosmic and using the medium perspective in researches and having no guidance of macroscopic law in mapping information, it is impossible to choose a proper threshold which can engender restriction.

Land use data is a typical type of polygon categorical map , it is fully covering, non-overlapping and seamless. In the aspect of semantic information, this kind of data is hierarchical (Bader M et al., 1997).Land use data cartographic generalization is to develop rules of cartographic generalization so that it can express the data mining process of the information of land use which has a particular scale. And the expressed land use information is decorated though some vision means such as exaggeration and position change on the basis of data scale rules. Thus, scale rules of land use data is the background of cartographic generalization. The adjustment of visible expressions needs to be based on the macroscopic rules. In order to reflect scale rules of land use data, the research should be started followed by three steps. First step is to study the changes of mapping information of the main land category after cartographic generalization, in the background of space pattern of them which has important semantic significance. The second step is to select the most appropriate scale to express land use information on the map by making use of evaluation index system constructed by using the principle of cartographic generalization evaluation.The third step is to make visible adjustment of map information to meet the need of visible and tidiness.The second step is the research point of this paper.

2. RESEARCH APPROACH

The author evaluates the pattern index of series scale maps in mapping scales so as to select the most appropriate scale to express the information onthe map. Specifically, this paper on the basis of the integration of the database and the rules of cartographic generalization, integrates the area polygons of the main type of used land and forms the series scale map in research scope. And this paper builds an evaluation index system by quantitatively analyzing the map information of area polygon by using the landscape pattern index, and chooses a scale which can best meet the need of mapping from series scale maps.

3. SELECTION OF LANDSCAPE PATTERN INDEX

The evaluation index of land use cartographic generalization traditionally used principles to take place of quantitative standards. In researches of cartographic generalization, the mapping information of area polygons is measured by means of landscape pattern index measurement. No matter what kind of the index is, it can be changed or directly cited from landscape pattern index (Bjørke,1996,2001;Beat Peter, 2001). Stefan Steiniger and Robert Weibel(2005)pointed out, the majority of statistic and the measurement of density relation in field of cartographic generalization came from landscape ecology index.

According to principles of land use cartographic generalization evaluation, we can make a connection to landscape pattern index, and construct a mapping information evaluation system of land use cartographic generalization. As shown in Table 1, we choose indices which can reflect area changes, quantity changes, shape rule degree and geometrical complexity degree of different land types as those of mapping information quality evaluation in mapping scale.

Table 1 The index system for scale change

Types of index	Names of index	Explanation
Area index	Percentage of Landscape(PLAND)	Changes of land type area proportion in experimental area
Density index	Polygon Density(PD)	Quantity changes of land
Shape index	Area Weighted Mean Shape Index(AWMSI)	Reflecting the global shape regularity of one type of land
Fractal dimension index	Area Weighted Mean Fractal Dimension (AWMPFD)	Reflecting the geometrical complexity degree of one land type

These indices put more emphases on ecological significant in the study of landscape ecology. But here, these indices emphasized particularly on reflecting changes of mapping information in cartographic generalization mapping scale. Among them, PLAND means information quantity changes of all land types, in evaluation index it reflects the differences between the present area of all kinds of land and the primary area of them after integration; PD reflects changes of the quantity of polygons, the distribution of it and integrated compression ratio of data in cartographic generalization; Shape index reflects changes of polygon regularity in cartographic generalization; Fractal dimension index reflects the geometrical complexity degree changes of figures in cartographic generalization. In this research, shape index and area index take area weighted mean measurement to reflect the changing rules of global mapping information.

The selected index calculation formulaes are shown as the following (1)~(4).

$$\text{Polygon Density:} PD_i = N_i * 100 / A \quad (1)$$

$$\text{PLAND}(P_i) = \sum_{j=1}^{n} B_{ij} \Big/ A * 100\% \quad (2)$$

$$\text{AWMSI} = \sum_{i=1}^{m} \sum_{j=1}^{n} \left[\left(\frac{0.25 P_{ij}}{\sqrt{B_{ij}}} \right) \left(\frac{B_{ij}}{A} \right) \right] \quad (3)$$

$$\text{AWMPFD} = \sum_{i=1}^{m} \sum_{j=1}^{n} \left[\left(\frac{2 \ln(0.25 B_{ij})}{\ln(B_{ij})} \right) \left(\frac{B_{ij}}{A} \right) \right] \quad (4)$$

In these formulaes: PD_i is the average number of the i^{th} land type polygons in every 100 hm^2 of experimental area, PD>0 and no upper limit. N_i is the number of i^{th} land type polygons. A is the total area of all types of lands in the experimental area. PLAND(P_i) is the percentage of landscape of the i^{th} land type in experimental area. B_{ij} is area of the j^{th} polygon of the i^{th} land type. n is the number of i^{th} land type polygons. AWMSI,no upper limit. AWMSI becomes bigger with the increase of polygon shape's irregularity; When the polygons are all squares, AWMSI=1. m is the number of land types. 0.25 is square emendation constant. AWMPFD is the weighted mean of a single polygon's fractal dimension, and $1 \leq \text{AWMPFD} \leq 2$.

In this study, the mapping information changes degree in mapping scale reflected by the indices mentioned before can be divided into two levels:the land type and the experimental area, corresponding to type level and the mosaic structure of the lands level in study of ecological pattern.In experimental area level, changing rules of mapping information can be synthetically reflected. The change on this level is the important point in this research.

4. THE CONSTRUCTION OF EVALUATION INDEX SYSTEM

Quality of mapping information in cartographic generalization is determined by proportion of land type area, polygon density, shape index and fractal dimension index. Different index occupies different position in this research and the weighting factor reflects the status of them. And all of these indices should be evaluated with quantitative methods. In this paper, we evaluated by using extreme value. It is to mark the best index with 100 scores, the worst one with 0, and the mean ones are obtained by means of linear interpolation.

Thus, we construct a map quality evaluation system by making use of the four indices and α_1,α_2,α_3 and α_4 standing for their weights. These weighing values are made with Delphi Model, α_1=0.4,α_2=0.4,α_3=0.1,α_4=0.1. Map quality VALUE(X) can be calculated in formula (5).

$$\mathrm{VALUE(X)}=\alpha_1 * \mathrm{VALUE(PD)}+\alpha_2 * \mathrm{VALUE(PLAND)}+\alpha_3 * \mathrm{VALUE(AWMSI)} +\alpha_4 * \mathrm{VALUE(AWMPFD)} \quad (5)$$

5. EXPERIMENT

5.1 The experimental area

Da Xing agricultural region of Beijing is the research region, the traffic and waters land type take 2% of the total area. Because of its relatively simple land use pattern, the cartographic generalization majors in combination and integration and the polymerization operation, displacement and exaggeration are fewer in this research. All of these give prominence to the leading role of macroscopic rules in mapping information scale.

5.2 The classification and the statistic of lands

According to current three grades of lands classification system, in cartographic generalization many of the third type of lands are faced with problems such as deletion and transitional consumption, and in the statistic of pattern indices there are many differences; at the same time, if we use this system directly, in the process of database integration, the combination of many land blocks will engender excessive deletion of information about and use. In this research, we choose 1:10,000 land use data in 2004 of the experimental area as the experimental data, and the three types classification system in transitional period as the classification system. On the basis of the experimental proposes and the land use features in this area, we take measures of three types classification, the corresponding code of land type is the third grade. We consider the original fourth land type code as the third one, or we combine the lower one to the higher one. Because the span of the scale experiment is long, in order to avoid the influences on the experimental area analysis by the disappearance of some land types which take up low area proportion, we take statistic measures which are similar to the original 8 type's classification system. The advantage is that it can avoid the excessive outburst of the experimental area's individuality and the decrease of its representativeness. Meantime, 8 type's classification can have semantic functions on the integration of small area polygon. The three grades classification can help maintain these qualities such as large quantity of land blocks and complicated relations of land use cartographic generalization.

5.3 The application of semantic significance

In this research, the grades of land types based on their importance levels are: cultivated lands, habitations, industrial and mining sites, garden plots, forest lands, grassplots, unutilized lands.

5.4 The selection of operators in cartographic generalization

To operated factors, the important ground objects can be exaggerated and displaced when their area is less than their mapping area, and it can be maintained and not canceled. To those important ground objects, the area proportion of them is less than 3%. Thus, we omit the method of exaggeration and displacement and use combination and polymerization in cartographic generalization.

5.5 The determination of integrated threshold

According to Beijing Land Use Present Situation Investigation Implementing Regulations (Beijing Bureau of Land Resources,1984) and Land Use Updating Investigation Technical Stipulation (Ministry of Land and Resources,2005), the areas of the minimum polygons of land type drawing mapping are:habitations 4.0mm^2,cultivated lands, garden plots, and waters 6.0mm^2,forest lands, grassplots, unutilized lands 15.0mm^2. On the basis of the regulations and the knowledge of scale and visual effects, we can make out the experimental standards and get the minimum mapping area and the minimum distance of polygons, as Table 2 show.

Table.2 The minimum of area and distance in map generalization

No.	Scale Denom inator (10^{-4})	Habitations (m^2)	Cultivated Lands,Garder Plots, Waters (m^2)	Forest Lands, Grassplots, Unutilized Lands (m^2)	The Minimum Distance of Polygons (10m)
1	1	400	600	1500	1
2	1.4	560	840	2100	1.4
3	1.8	720	1080	2700	1.8
4	2.2	880	1320	3300	2.2
5	2.6	1040	1560	3900	2.6
6	3	1200	1800	4500	3
7	3.4	1360	2040	5100	3.4
8	3.8	1520	2280	5700	3.8
9	4.2	1680	2520	6300	4.2
10	4.6	1840	2760	6900	4.6
11	5	2000	3000	7500	5
12	5.4	2160	3240	8100	5.4
13	5.8	2320	3480	8700	5.8
14	6.2	2480	3720	9300	6.2
15	6.6	2640	3960	9900	6.6
16	7	2800	4200	10500	7
17	7.4	2960	4440	11100	7.4
18	7.8	3120	4680	11700	7.8
19	8.2	3280	4920	12300	8.2
20	8.6	3440	5160	12900	8.6
21	9	3600	5400	13500	9
22	9.4	3760	5640	14100	9.4
23	9.8	3920	5880	14700	9.8
24	10.2	4080	6120	15300	10.2

5.6 Results of the experiment

Based on the calculation of model and data process, the mapping quality evaluation scores in the scale of 1:10,000 to 1:100,000 can be obtained, as shown in Table 3.

6. Analysis and Discussion

It is feasible that quantitatively analysis of the map information by making use of landscape pattern index. Through the model, the evaluation scores can be offer. According to the curve of scores, there are some significant turning points whose amplitude is not high, as Figure 1 shows.

Table.3 The scores of mapping quality evaluation

No.	Scale Denominator (10^{-4})	PD Score	PLAND Score	AWMSI score	AWMDFD score	Mapping score
1	1	0	92.50	0	100	47.00
2	1.4	26.04	38.07	42.86	83.33	38.26
3	1.8	28.47	37.92	57.14	83.33	40.60
4	2.2	31.17	37.01	57.14	83.33	41.32
5	2.6	32.79	37.12	57.14	83.33	42.01
6	3	37.57	36.99	42.86	66.67	40.77
7	3.4	39.91	36.33	57.14	66.67	42.88
8	3.8	42.70	44.34	57.14	66.67	47.20
9	4.2	35.23	52.13	57.14	66.67	47.32
10	4.6	35.23	45.89	57.14	66.67	44.83
11	5	52.16	44.321	42.86	66.67	49.55
12	5.4	57.30	42.52	57.14	66.67	52.31
13	5.8	61.261	43.04	57.14	66.67	54.10
14	6.2	65.59	43.53	71.43	66.67	57.46
15	6.6	71.08	42.77	85.71	66.67	60.78
16	7	73.51	38.02	85.71	66.67	59.85
17	7.4	77.84	31.89	100	50	58.89
18	7.8	77.84	31.89	100	50	58.89
19	8.2	84.14	24.09	85.71	33.33	55.20
20	8.6	87.30	19.38	57.14	16.67	50.05
21	9	91.71	17.29	71.43	0	50.74
22	9.4	98.02	13.70	42.86	0	48.97
23	9.8	100	13.84	42.86	0	49.82
24	10.2	100	13.84	42.86	0	49.82

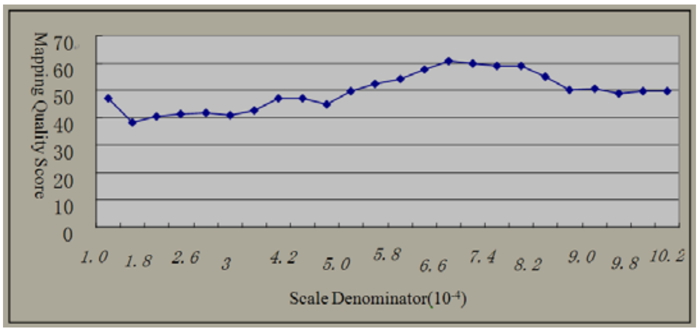

Figure 2 The curve of mapping quality evaluation score

These anomalous points are related to the scale rules of land use data and modeling. According to the distribution of curve, the mapping information in the scale of 1:66,000 is the best. Linking to the dimension chart, integrating all index scores, there is an obvious turning point in the scale of 1:66000, which can indicate the reasonableness of selecting this point.

This experiment proves it can help select an appropriate mapping scale so as to meet the needs of cartographic generalization through constructing an evaluation index system by the standard of cartographic generalization evaluation. This method can provide cartographic generalization with a big rudiment. Based on it, important ground objects can be exaggerated and displaced according to requirements and vision needs.

Certainly, two items should to be considered; the first one is the method of indices weighted value and interpolation; the second one is the complexity and uncertainty of scale rules.Besides, the interpolation between the minimum and maximum is linear, but there are some complicated nonlinear relations of mapping information in cartographic generalization. Thus, it is worth to be studied one step further.

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