QUALITY INSPECTION AND EVALUATION OF SATELLITE ORTHOPHOTOS IN CHINA'S THIRD NATIONAL LAND SURVEY

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ABSTRACT:

Satellite orthophotos are important data sources and results of China's third national land survey, and their quality profoundly affects the accuracy of the survey results. This article reviews the quality requirements and quality models of satellite orthophotos for the purpose of land survey in conjunction with the quality inspection and evaluation of satellite orthophotos covering the entire land area of China, and analyzes the shortcomings of current orthophotos quality evaluation methods. On the basis of this method, a multi-level fuzzy comprehensive evaluation method was introduced to test the orthophotos quality evaluation, and the concepts of maximum membership effectiveness index and evaluation grade probability were used to constrain the evaluation results. The results prove that the method is more effective than the current method true and accurate.

1. GENERAL INSTRUCTIONS

1.1 Satellite Orthophotos

The China's third national land survey used remote sensing, surveying and mapping, geographic information, and the internet to investigate the ownership and use rights of various types of land nationwide. Satellite orthophotos are important data sources and results of China's third national land survey. They are the positioning reference and statistical basis for land survey. They determine the accuracy of the third land survey and the progress of subsequent operations. Therefore, to analyze and evaluate the quality of the orthophotos according to the content of the third land survey work, on the one hand, it can be improved and controlled in a targeted manner during the data processing to improve the orthophotos quality; on the other hand, it can be selected according to the needs of the third land survey work High-quality data sources and reducing unnecessary data processing workload are of great significance for improving the work efficiency and quality level of the results.

This paper analyzes the quality of satellite orthophotos covering the entire land area of China, and conducts corresponding research on the methods of inspection and evaluation the quality of satellite orthophotos for the application of land survey.

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1.2 Quality Requirements

In order to meet the needs of the China's third national land survey, coordinate domestic and foreign satellite data sources, such as GF-2, BJ-2, GJ-1, JL-1A, YG series, WorldView-2 / 3/4, GeoEye-1, KOMPSAT-3 / 3A, Pleiade-1A / 1B, DEIMOS-2 etc. The resolution of satellite orthophotos must better than 1 meter. The plane position accuracy of the orthophotos should generally meet the 1: 10,000 mapping accuracy requirement, the amount of cloud (snow, fog) should not exceed 20%, no large area noise and bands, no deformation of the ground caused by terrain changes, natural colors and clear textures , moderate contrast, layered, no graininess, to avoid overexposure of buildings, roads and other features, the sides of the mosaic line and adjacent images should be basically the same color, which is beneficial to cultivated land, garden land, forest land, grassland Interpretation.

1.3 Check content

The core inspection contents of satellite orthophotos include 14 items such as coordinate system, projection parameters, position accuracy, image edge, sharpness, etc., and a model of quality characteristics and inspection items is formed according to the hierarchical relationship, see table 1 for inspection contents.

Quality characteristics	Check item	Inspection contents
Spatial reference	coordinate system	Accuracy of the coordinate system definition parameters.
	Projection parameters	Correctness of Gaussian projection band and central meridian.
Position accuracy	Position accuracy	Feature point location errors and errors in statistics.
	Edge	Edge errors between

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	accuracy	different images and errors in statistics.
Logical consistency	Image organization	Correctness of organization.
	Image format	Correctness of format and version.
Time accuracy	Original image	Correctness of the original image selection.
Image quality	Image resolution	Correctness of resolution.
	Image range	Correctness of range.
	Color mode	Accuracy of image color mode and pixel bit.
	Texture feature	The color is natural, the color tone is uniform, the details are clear, and the level is clear.
	Image noise	The effect of image noise.
	Information loss	Clouds, snow, fog, and shadows cover the ground, and overexposure or spectral overflow.

Table 1. Quality characteristics and inspection contents

1.4 Inspection Method

Coordinate system, projection parameters, image organization, image format, image range, color mode, etc. can be automatically checked by writing programs, and image resolution, texture features, image noise, and information loss seriously affect the application effect. All inspections are carried out. After all the inspections are passed, the inspection batch is composed of county-level units in the provincial administrative region, and the position accuracy and the edge of the image are sampled for sampling. See table 2 for the sample size (Luo F.J. , 2017).

Lot size	Sample size	Lot size	Sample size
20	3	101-120	11
21-40	5	1121-140	12
41-60	7	141-160	13
61-80	9	161-180	14
81-100	10	181-200	15

Table 2. Lot size and sample size

2. CURRENT QUALITY EVALUATION

2.1 Quality Classification

Following the idea of the barrel theory and Chinese national standard " GB/T 18316-2008 Specifications for inspection and acceptance of quality of digital surveying and mapping achievements", the lowest score of each item is taken as the upper-level score, and the county-level unit quality score is finally obtained, and the corresponding Evaluation level, the corresponding relationship is shown in table 3 (Deng G.Q., 2008).

Score	Quality level	Score	Quality level
[90,100]	excellent	[60,75)	qualified
[75,90)	good	＜60	disqualified

Table 3. Quality classification

2.2 Problem

This method is easy to operate but rough. The processing of the lowest score is essentially a fuzzy processing of each inspection item and quality characteristic weight, and cannot fully reflect the importance of image quality.

Evaluation problems in nature are mostly ambiguous. The meaning of the evaluation level is relatively vague, and the division boundary is even more subjective. For example, a score of 75.1 is good according to this method, but it may be closer to the qualified, so it is more reasonable to describe the "intermediate state" with the degree of belonging instead of not belonging.

Introduce fuzzy comprehensive evaluation method in the evaluation instead of other evaluation methods. Using membership to describe the fuzzy quality grading boundary can overcome the shortcomings of the discontinuity of quality grading in the past (He Y.L., Dai B.L., Tao X.F., 2011). Too large will result in a lower comprehensive evaluation level, making the evaluation results more reasonable.

3. FUZZY COMPREHENSIVE EVALUATION MODEL

3.1 Ideas

There are a lot of fuzzy concepts and phenomena in the objective world. For example, what are "heavy snow", "medium snow", and "small snow", and what are "tall" and "short"?

In order to clarify the fuzzy concept mathematically, Zadeh introduced fuzzy sets. The fuzzy comprehensive evaluation method is to apply the membership theory of fuzzy mathematics to quantify some factors with unclear boundaries and difficult to quantify, and make an overall evaluation of objects subject to multiple factors.

3.2 Principle

First determine the factor set and evaluation level set of the evaluated object, and then determine the weight and membership vector of each factor to obtain the fuzzy evaluation matrix (Jin, J. L. , Wei, Y. M. , Ding, J., 2004). Finally, the fuzzy vector and the weight vector of the factor are fuzzy-calculated and classified. Normalization, the fuzzy comprehensive evaluation results are obtained (Chen, J. , 2015).

3.3 Factor Set, Evaluation Set, Weight Set

The factor set of satellite orthophotos is $U = \{U_1, U_2, ..., U_5\}$, where U_i is spatial reference, position accuracy, logical consistency, time accuracy, and image quality. U_i can also have a subset.

The evaluation set of satellite orthophotos is V = {excellent, good, qualified, unqualified}. The corresponding score interval is shown in table 3.

The impact of each inspection item on image quality is different. Judging the image quality based on individual indicators is incomplete, and the quality requirements of images for different purposes are different (Li Y.L ,Gao Z.G. , Han Y.L., 2006). In order to reflect the importance of each factor, the weight of each factor is determined. The weight vector $W = \{W_1, W_2, ..., W_5\}$ corresponding to factor U and the m check items of factor

U_i can form a sub weight vector $W_i = \{w_{i1}, w_{i2}, \ldots, w_{im}\}$, as shown in table 4.

3.4 Membership Calculation

In order to facilitate the calculation, the linear membership function is used to calculate the membership, as shown in figure 1.

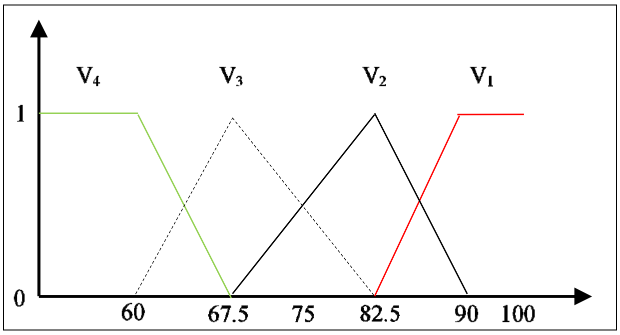

Figure 1. Linear membership function

No.	Quality characteristic	Weight	Check content	Weight	Score
1	Spatial reference	0.2	coordinate system	0.5	100
			Projection parameters	0.5	100
2	Position accuracy	0.2	Position accuracy	0.5	74
			Edge accuracy	0.5	90
3	Logical consistency	0.1	Image organizatio n	0.5	100
			Image format	0.5	100
4	Time accuracy	0.1	Original image	1.0	100
5	Image quality	0.4	Image resolution	0.1	100
			Image range	0.1	100
			Color mode	0.1	100
			Texture feature	0.4	80
			Image noise	0.1	88
			Information loss	0.2	95

Table 4. Weight and quality score

According to the inspection results, calculate and calculate the quality score of each inspection item of the sample $X = \{X_1, X_2, \ldots, X_5\}$, see Table 4, determine the evaluation level of each inspection item from this value, and finally according to the fuzzy from U to V Map the relationship, get the evaluation matrix of each factor, and get the evaluation level of the sample, and the evaluation level of the sample, the weight of the sample can be determined by the area and length (Ying, L.U. , 2007). The mapping relationship is given by equations (1) to (4).

$$V_1 = \begin{cases} 0 & X \le 82.5 \\ (X - 82.5)/7.5 & 82.5 < X < 90 \\ 1 & 90 \le X \le 100 \end{cases} \quad (1)$$

$$V_2 = \begin{cases} (X - 67.5)/15 & 67.5 < X \le 82.5 \\ (90 - X)/7.5 & 82.5 < X < 90 \\ 0 & others \end{cases} \quad (2)$$

$$V_3 = \begin{cases} (X - 60)/7.5 & 60 < X \le 67.5 \\ (82.5 - X)/15 & 67.5 < X < 82.5 \\ 0 & others \end{cases} \quad (3)$$

$$V_4 = \begin{cases} 1 & X \le 60 \\ (67.5 - X)/7.5 & 60 < X < 67.5 \\ 0 & others \end{cases} \quad (4)$$

A fuzzy operator $M(\circ, \oplus)$ with a large clear domain is used.

$$R_1 = [0.5 \ \ 0.5]\begin{bmatrix} 1 & 0 & 0 & 0 \\ 1 & 0 & 0 & 0 \end{bmatrix} = [1 \ 0 \ 0 \ 0] \quad (5)$$

$$R_2 = [0.5 \ \ 0.5]\begin{bmatrix} 0 & 0.43 & 0.57 & 0 \\ 1 & 0 & 0 & 0 \end{bmatrix} = [0.5 \ 0.215 \ 0.285 \ 0] \quad (6)$$

$$R_3 = [0.5 \ \ 0.5]\begin{bmatrix} 1 & 0 & 0 & 0 \\ 1 & 0 & 0 & 0 \end{bmatrix} = [1 \ 0 \ 0 \ 0] \quad (7)$$

$$R_4 = [1 \ 0 \ 0 \ 0] \quad (8)$$

$$R_5 = [0.1 \ \ 0.1 \ \ 0.1 \ \ 0.4 \ \ 0.1 \ \ 0.2]\begin{bmatrix} 1 & 0 & 0 & 0 \\ 1 & 0 & 0 & 0 \\ 1 & 0 & 0 & 0 \\ 0 & 0.83 & 0.17 & 0 \\ 0.73 & 0.27 & 0 & 0 \\ 1 & 0 & 0 & 0 \end{bmatrix} \quad (9)$$

$$= [0.57 \ \ 0.36 \ \ 0.07 \ \ 0]$$

$$B = W \circ R = [0.2 \ \ 0.2 \ \ 0.1 \ \ 0.1 \ \ 0.4]\begin{bmatrix} 1 & 0 & 0 & 0 \\ 0.5 & 0.215 & 0.285 & 0 \\ 1 & 0 & 0 & 0 \\ 1 & 0 & 0 & 0 \\ 0.57 & 0.36 & 0.07 & 0 \end{bmatrix} \quad (10)$$

$$= [0.728 \ \ 0.187 \ \ 0.085 \ \ 0]$$

3.5 Effectiveness index

The relative index of validity of the principle of maximum membership is defined as (Qiu D., 1991):

$$\alpha = \frac{n\beta - 1}{2\gamma(n-1)} \quad (11)$$

where $\beta = \max_{1 \le i \le n} V_i$

$\gamma = \sec_{1 \le i \le n} V_i$

n is the number of factors

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When α≥1, the principle of maximum membership was very effective. When 0.5≤α < 1, the principle of maximum membership was more effective. When 0<α<0.5, the principle of maximum membership was inefficient. When α=0, the principle of maximum membership was completely invalid.

Calculate the highest and lowest scores corresponding to the evaluation set, and calculate the probability of the evaluation results at each quality level according to the distribution ratio of the highest and lowest score intervals in each quality level interval (Bresenham JE., 1965), See Figure 2.

$$S_H = \begin{bmatrix} 0.728 & 0.187 & 0.085 & 0 \end{bmatrix} \begin{bmatrix} 100 \\ 90 \\ 75 \\ 60 \end{bmatrix} = 96.005 \qquad (12)$$

$$S_L = \begin{bmatrix} 0.728 & 0.187 & 0.085 & 0 \end{bmatrix} \begin{bmatrix} 90 \\ 75 \\ 60 \\ 0 \end{bmatrix} = 84.645 \qquad (13)$$

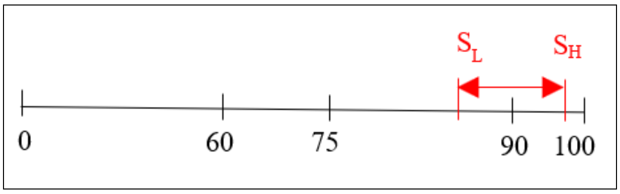

Figure 2. Quality level distribution probability

The component deviation between (β-γ) and the ratio of $\sum_{i=1}^{n} \left| b_i - \bar{b} \right|$ can reflect the effectiveness of the principle of maximum membership. $Cv = (\beta\text{-}\gamma) / \sum_{i=1}^{n} \left| b_i - \bar{b} \right|$, $Cv \in (0, \frac{n}{2(n-1)})$, the larger the Cv, the more effective the principle of maximum membership. Taking the evaluation vector is *B=(0.728,0.187,0.085,0)* as an example, *Cv*=0.566. At this time, the principle of maximum membership is valid, and the object C can be evaluated as a superior product with a high probability.

4. EXPERIMENT

Taking the China's third national land survey satellite orthophotos quality evaluation as an example (table 5 is Anhui province inspection results), a fuzzy comprehensive evaluation was carried out and compared with the evaluation results using the GB/T18316 method, see table 6. The results show that the weight setting not only fully reflects the special requirements for the image quality of the project application, but also takes into account the need for location accuracy; the fuzzy comprehensive evaluation method is generally upgraded by a level compared with the evaluation results of the GB/T 18316 method. The minimum score system will be subject to evaluation bias due to the abnormal influence of indicators of general factors; the deviation ratio, single-valued distribution probability method, and relative validity index can effectively evaluate the principle of maximum membership; the overall quality of the orthographic image of the third national land survey satellite is Excellent to meet the quality requirements of project design.

Sample	Spatial reference		Position accuracy		Logical consistency		Time accuracy	Image quality					
	Coordinate system	Projection parameters	Position accuracy	Edge accuracy	Image organization	Image format	Original image	Image resolution	Image range	Color mode	Color mode	Image noise	Information loss
A	100	100	79	85	100	100	100	100	100	100	92	96	97
B	100	100	81	90	100	100	100	100	100	100	90	95	91
C	100	100	79	83	100	100	100	100	100	100	87	95	94
D	100	100	85	96	100	100	100	100	100	100	94	98	99
E	100	100	86	96	100	100	100	100	100	100	83	89	90
F	100	100	86	98	100	100	100	100	100	100	90	97	96
G	100	100	77	85	100	100	100	100	100	100	90	92	92
H	100	100	69	78	100	100	100	100	100	100	92	94	97
I	100	100	85	94	100	100	100	100	100	100	89	93	91
J	100	100	79	89	100	100	100	100	100	100	84	86	93
K	100	100	74	88	100	100	100	100	100	100	92	95	91

Table 5. Partial inspection results of the third national land survey satellite orthophotos quality (Anhui Province)

Sample	Fuzzy comprehensive								GB/T 18316
	B	*α*	S_H	S_L	*P*		*Cv*	Quality level	
					Excellent	Good			
A	(0.83,0.14,0.02,0)	2.76	97.98	87.15	0.74	0.26	0.59	excellent	good
B	(0.90,0.09,0.01,0)	4.81	98.85	88.35	0.84	0.16	0.62	excellent	good
C	(0.74,0.23,0.02,0)	1.42	97.08	85.79	0.63	0.37	0.52	excellent	good

Sample	Fuzzy comprehensive								GB/T 18316
	B	*α*	S_H	S_L	*P*		*Cv*	Quality level	
					Excellent	Good			
D	(0.93,0.07,0,0)	6.48	99.33	89.00	0.90	0.10	0.63	excellent	good
E	(0.79,0.21,0,0)	1.71	97.92	86.88	0.72	0.28	0.54	excellent	good
F	(0.95,0.05,0,0)	9.33	99.47	89.20	0.92	0.08	0.64	excellent	good
G	(0.83,0.13.0.04,0)	2.97	97.78	86.95	0.72	0.28	0.63	excellent	good
H	(0.80,0.08,0.12,0)	3.06	96.20	85.20	0.56	0.44	0.62	excellent	qualified
I	(0.91,0.09,0,0)	4.89	99.12	88.68	0.87	0.13	0.62	excellent	good
J	(0.74,0.24,0.02,0)	1.36	97.02	85.71	0.62	0.38	0.51	excellent	good
K	(0.80,0.12,0.08,0)	3.06	96.80	85.80	0.62	0.38	0.62	excellent	qualified

Table.6 Comparative results of fuzzy comprehensive and GB/T 18316

5. CONCLUSION

The result of fuzzy comprehensive evaluation is a vector, which reflects the fuzzy attributes of quality itself, and avoids the errors caused by rigid quality evaluation. Fuzzy comprehensive evaluation is generally performed on an object-by-object basis. As long as the evaluation index weights and composition operators are the same for the same object, the evaluation results are unique and have nothing to do with the set of objects. This method can be applied to the quality evaluation of DLG, DEM and other products after reforming the quality factors and weights.

The fuzzy comprehensive evaluation process itself cannot solve the problem of duplication of evaluation information caused by correlation between evaluation factors. Each component of the evaluation vector is weighted by various factors, which reflects how much factors belong to a certain level. If no factor has a membership relationship to a certain evaluation level, the degree of membership of the level must be zero after synthesis. Therefore, the information of the evaluation vector is divergent rather than comprehensive. At the same time, the extraction of quality factors, the determination of weights, the division of evaluation levels, the design of membership functions, and the selection of synthetic operators all need to be verified to ensure the reliability and rationality of the evaluation results.

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