Research on method of remote sensing data quality contrast among different quantization levels

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***Abstract*—Quantization must be taken in the process of data digitization and storage. Remote sensing data use different quantization levels in the process of gathering and storage. Remote sensing data is always compared with other data to decide whether its quality is good or bad, using many quality indexes. But these quality indexes cannot be used directly when the data is compared with other data using different quantization levels. This paper analyses how data quality indexes are affected when quantization level changes, then tests and verifies the result using some experimental data, and puts forward a method remote sensing data quality contrast between different quantization levels based on conversion of quantization level.**

***Key words*—Remote sensing data quality, quantization level, quality contrast**

I. INTRODUCTION

Evaluation methods of the remote sensing data quality are generally classified into two types: the subjective evaluation and the objective evaluation. Metrics on objective evaluation include information entropy, radiometric accuracy, signal-to-noise ratio (SNR), resolution and modulation transfer function (MTF) and so on. Remote sensing data are stored in different bit lengths to obtain different quantization levels, typical cases are 8-bit or 16-digit storage. According to [3], different quantization levels have different impacts on SNR, MTF and the dynamic range of data, thus metrics on objective evaluation cannot be directly put to comparison among different quantization levels. In this paper, effects of quantization levels on objective metrics are discussed, and a method is proposed to compare the data quality on the basis of conversion of quantization levels.

II. REMOTE SENSING DATA QUALITY OBJECTIVE EVALUATION INDEXES

A Information quantity

Information quantity can show richness of image information. It is always expressed by information entropy. Information entropy is defined in many ways, such as shannon-wiener entropy, conditional entropy, square entropy, cubic entropy, and so on. Among these definitions, shannon-wiener entropy is most frequently used, and its formula is shown as follows according to [4].

$$H = -\sum_{i=1}^{M}(P_i \log \mathrm{P}_i) \qquad 1$$

In this formula, i stands for image's grey value, and P_i stands for the probability of grey value i.

B Accuracy of radiation

This index includes six parameters according to [2]: mean value, variance, skewness, gradient, edge radiation distortion and gain adjustment distortion. All these parameters reflect image radiation condition, and their calculation method is showed in table 1.

Table 1 Six parameters of accuracy of radiation

parameters	meaning	Calculation formula
Mean value	Reflects general radiation condition of image	$\mathrm{M}=\sum \ \mathrm{i} \times \mathrm{p(i)}$
Variance	Reflects richness of image information	$\mathrm{D}=\sum(\mathrm{i}-\mathrm{m})^2\mathrm{p(i)}$
Skewness	Reflects the degree of how distribution shape is deviated from symmetrical shape around mean value in image histogram.	$\mathrm{S}=\sum(\mathrm{i}-\mathrm{m})^3\mathrm{p(i)}/\mathrm{d}^3$
Gradient	Reflects gradient of image histogram.	$\mathrm{K}=\sum(\mathrm{i}-\mathrm{m})^4\mathrm{p(i)}/\mathrm{d}^4$
Edge radiation distortion	Reflects radiation irregularity degree in row direction	Mean value and variance of mean value vector in row direction
Gain adjustment distortion	Reflects radiation irregularity degree in column direction	Mean value and variance of mean value vector in column direction

Note: The i stands for image's grey value, and P_i stands for the probability of grey value i.

C Definition

The definition reflects acuity of image edge details changes. Around the edge of surface feature in image, the faster grey value changes as location changes, the more clear details of edge is and the higher resolution is. It's commonly calculated using point sharpness algorithm[2]. This index is calculated using the following formula:

$$\mathrm{EAV}=\frac{\sum_{i=1}^{M\times N}\sum_{a=1}^{8}|\frac{df}{dx}|}{M\times N} \quad 2$$

In the formula, EAV stands for this index, M and N stand for row amount and column amount, "df" stands for how much grey value changes, "dx" is distance increment between two pixels. "a" is the number of pixel around pixel i.

D Signal to noise ration(SNR)

Sensors' SNRs are accessible from the SNRs of imageries. Currently, SNR of remote sensing images are mainly assessed by variance, geographic statistics, local variance, decorrelation method, or neural networks.

SNR of an image is defined as the power spectrum ratio between signal and noise. However, the power spectrum is difficult to be computed, because signal and noise are unknown subsets of the observed data and the restoration process is an illness problem. The variance method was then proposed to use variance ratio of signal and noise to approximate the SNR, which selects a large and uniform area of images and calculates the mean value and standard variance.

The Geographic statistics method found that the DN (digital number) value of ground pixels demonstrate some self-correlation with the change of distances, which showed a certain continuity and relevance of the land surface parameters. This to some extent reflects the spatial structure characteristics of remote sensing metrics. The Geographic statistics method then utilizes the changes of pixels correlation in the spatial domain to measure the power of the noise.

Variance method is not flexible in that it needs manually selected uniform regions, so is improved by the local variance method, which divides an image into many 4x4 or 8x8 blocks. Each block is assumed to be uniform and calculated to get the mean value and standard variance, and the latter is an approximation of the noise. After all the blocks are calculated, arrange of the largest mode is selected according to all the standard variances, and its mean standard variance is set as the noise value of the whole image. This method demonstrates good assessment on the plain images. To achieve a reliable result, the uniformity of the image needs to be evaluated before the local variance method is used.

The local variance method is improved from variance method. How local variance method is calculated is shown in [1]. According to comparison among different methods by Bo Zhu(2010) and experimental result of each method according to [5], local variance method performances well in calculation speed, reliability, correctness and applicability.

III. HOW QUANTIZATION LEVEL CHANGING AFFECTS QUALITY INDEX

We assume that quantization level of data A is a, and quantization level of data B is b, and a<b. We also assume that both grey value is integer. So if they are transformed to each other, their grey value of B is 2^{b-a} times of that of A, but quality indexes of one is not that times of that of the other. Here we analysis the relationship of quality indexes between A and B when transformed with each other from the perspective of qualitative analysis in the following part.

A Information quantity

H_A stands for information entropy of data A, and H_B stands for that of B. When B is transformed to A, quantization level decreases, data richness must also decreases. So $H_A < H_B$; When A is transformed to B, quantization level will not change. So $H_A = H_B$。

B Radiation accuracy

a) mean value. M stands for mean value of data. When B is transformed to A , grey value of B will be divided by 2^{b-a}. Some value may be decimal and when it is transformed to integer the value will be smaller. So $M_A < M_B/2^{b-a}$. When A is transformed to B, grey value of A will be multiplied by 2^{b-a}. No value will be decimal, and value of B is 2^{b-a} times of that of A. So $M_A = M_B/2^{b-a}$.

b) variance. D stands for variance of data. When B is transformed to A , quantization level decreases , value of A will be smaller than value of B divided by 2^{b-a}. In the formula whether the value of (i-m) decreases or increases cannot be confirmed. $D_A \neq D_B/2^{2(b-a)}$. When A is transformed to B, value of A is equal to value of B divided by 2^{b-a}. So $D_A = D_B/2^{2(b-a)}$.

c) skweness. S_A stands for skewness of data. As it's discussed before, when B is transformed to data A, grey value of A is smaller than that of B divided by 2^{b-a}, from the formula we can see relationship between S_A and S_B cannot be confirmed. $S_A \neq S_A \times 2^{3(b-a)}$. Otherwise when A is transformed to B, $S_A = S_A \times 2^{3(b-a)}$.

d) gradient. K_A stands for gradient of data. When B is transformed to A, the relationship between K_A and $K_B \times 2^{4(b-a)}$ cannot be confirmed. $K_A \neq K_B \times 2^{4(b-a)}$, when A is transformed to B, $K_A = K_B \times 2^{4(b-a)}$.

e) radiation distortion. Edge radiation distortion is expressed by mean value and variance of mean value vector in row direction. Rd stands for variance of mean value vector in row direction. Rd is analyzed as that of variance. Gain radiation distortion is expressed by mean value and variance of mean value vector in column direction. Pd stands for variance of mean value vector in column direction. Pd is analyzed as that of variance.

C Signal to noise ration(SNR)

For the benefits of local variance method, here we choose it to calculated SNR. Ps stands for local standard deviation, m stands for mean value .So $\mathrm{SNR} = \frac{m}{Ps}$. When B is transformed to A, m decreased and Ps cannot be so sure. $SNR_A \neq SNR_B$. Otherwise, when A is transformed to B, value m is multiplied by 2^{b-a} and Ps is also multiplied by 2^{b-a}, so SNR is not changed. So $SNR_A = SNR_B$.

D Definition

Definition is calculated by following formula:

$$EAV=\frac{\sum_{i=1}^{M\times N}\sum_{a=1}^{8}|\frac{df}{dx}|}{M\times N} \qquad 3$$

When data B is transformed to data A, M and N is not changed. In the formula df=a-i. We assume that original value of a, i and df in data B is Ba, Bi and Bdf. So

$$a<=Ba/2^{b-a}$$

$$Ba-a*2^{b-a}=0, \text{ or } 1.$$

$$Bi-i*2^{b-a}=0, \text{ or } 1.$$

$$\text{so } |Bdf|-|df|*2^{b-a}=0, 1, \text{ or } -1$$

$$EAV_B-EAV_a*2^{b-a}=\frac{\sum_{i=1}^{M\times N}\sum_{a=1}^{8}\frac{\{-1,0,1\}}{dx}}{M\times N} \qquad 4$$

when A is transformed to B

$$EAV_B=EAV_A*2^{b-a}$$

IV. EXPERIMENTAL DATA ANALYSIS

We choose one panchromatic data whose quantization level is 10, and one panchromatic data whose series is 8.

a) Firstly, quantization level 10 is transformed to 8, meaning data value ranges from 0 to 1023 is compressed to 0 to 255. Assume that data B has quantization level 10, and data A has quantization level 8. Data quality result of B and A is showed in table 1 and table 2 below. From the last column of table 1, we can see that decreasing quantization level can cause significant effect on information quantity and SNR, less effect on other quality indexes. The error of information quantity is more than 25%. The error of SNR is -22.2341%. The error of other index is little.

Table 1PANCHROMATIC DATA

Quality index	**Data B**	**Data A**	**Multiple**	**A multiply by muliple**	**Compared with data B （%）**
Information quantity	7.82576	5.82136	null	5.82136	25.61285
Mean value	311.288	77. 4469	4	309.7876	0.481997
Variance	3742.77	234.002	16	3744.032	-0.03372
Skewness	2.64498e-006	0.000169112	1/64	2.6424e-006	0.097543
Gradient	1.92513e-007	4.92542e-005	1/256	1.92400e-007	0.058697
Edge radiation distortion variance	857.48	53.3761	16	854.0176	0.403788
Gain adjustment variance	34.2465	2.12648	16	34.02368	0.650636
SNR	61.2842	74.9102	NULL	74.9102	-22.2341
Definition	26.2378	6.57457	4	26.29828	-0.23051

b) Secondly： quantization level 8 is transformed to 10, meaning grey value ranging from 0~255 is expanded to 0~1023. It's done by multiplying each grey value by 4. The result of each index is showed in table2. From the last column of table3, it can be seen that every index changes very little when quantization level changes from 8 to 10.

Table 2 QUALITY INDEX VALUE WHEN QUANTIZATION LEVEL CHANGES FROM 8 TO 10

Quality index	**Data B**	**Data A**	**Multiple**	**A multiply by muliple**	**Compared with B （%）**
Information quantity	7.32058	7.32058	null	7.32058	0
Mean value	333.071	83.2677	4	333.0708	6E-05
Variance	56105	3506.56	16	56104.96	7.13E-05
Skewness	7.01471e-008	4.48941e-006	1/64	7.0147e-008	0.000143
Gradient	8.58572e-010	2.19794e-007	1/256	8.5857e-010	0.000233
Edge radiation distortion variance	5923.53	369.995	16	5919.92	0.060943
Gain adjustment variance	257.769	16.0968	16	257.5488	0.085425
SNR	100.375	100.893	1	100.893	-0.51606
Definition	185.782	46.4454	4	185.7816	0.000215

V. QUALITY CONTRAST METHOD BETWEEN DIFFERENT QUANTIZATION LEVELS

According to data showed in chapter 4, we conclude some quality index will change greatly when quantization level decreases, all quality indexes will not change when quantization level increases. So when different quantization levels data are compared with each other, data with less quantization level should be transformed to higher level, to make sure both data quantization levels are in the same level. Figure 1 shows the flow chart of quality contrast between different quantization levels.

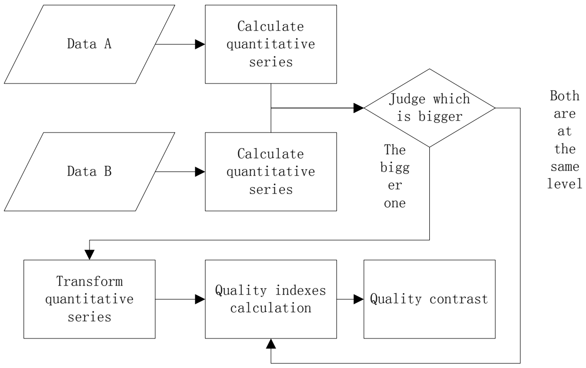

Figure 1 Flow chart of quality contrast between different quantization levels

a) calculate quantization level. It is calculated by investigating a lot of A data's max value, and then decide quantization level. For example, if the max value of A data is between 512 to 1024, then quantization level is 10.
b) transform quantization level. Firstly, decide which quantization level is bigger. Then transform smaller one to higher one, through multiplying the smaller one's grey value by 2^(b-a). If both data quantization levels are the same. There's no need to transform.
c) calculate quality indexes. Calculate each quality index according to what introduced before.
d) quality contrast. Output the result of both data in form of table.

VI. CONCLUSION

This paper analyses how much quality indexes can be influenced when quantization level is changed. Then test and verify the analysis result by experimenting on experimental data. And the result is that when quantization level decreases, indexes like information quantity decreases greatly, index like SNR is affected, and some other indexes are affected very little. When quantization level is transformed to higher level, quality indexes are not affected.

According to the experimental result, when remote sensing data with different quantization levels are compared with each other in quality, quantization level in lower level should be transformed to higher lever to make sure both data are in the same level. This makes both data comparable, and quality indexes result more reliable.

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