QUANTITATIVE METHOD BY INFORMATION THEORY FOR EVALUATING IMAGE ENHANCEMENT BENEFIT OF IPOS

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ABSTRACT:
According to the method of Informatiom Theory and many practical statistical image enhancement examples of the geological lineament, this paper has made quantitative analysis to the enhancement effect of the Image Processing Operation System and its functions, thus solving a current problem that enhancement effect can only be evaluated subjectively and qualitatively. Quantitative parameter calculated by the Information Theory, or Information Level, has definite directive action in the dynamic policy-making course of image processing, and can decide correctly the practical effect of new functions or methods.On the basis of quantitative analysis, the IPOS can make the most of image enhancement benefit quickly and effectively by series-parallel connection programs.

KEY WORDS:
Information, Processing, Enhancement, Signal, Evaluation, Entropy, Function, Probability.

1.INTRODUCTION

Photogrammetry and Remote Sensing are concerned with informaton input-output and its being processed, in this image information domain, Information theory should have certain applied potential. This paper first applies Information Theory analysis method for evaluating enhancement effect of the digital image processing.

To counter wanted fixed enhanced contents of image, this paper regards IPOS function as a information translator, analyzes original image actualities signal Y at input end, processed image gain signal X at output end (Fig. 1) and both composite signal C. On the basis of statistics, 14 kinds of composite probabilities are calculated from respective composite signals. To apply the Channel Mutual Information Theory , we can calculate that function Information Level IL from composite probabilities, which can reflect Y signals in X ones.

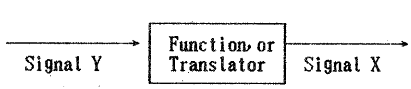

Fig.1, Image information transform

Original image , or total of processed images, can be regarded as information source producing information or signal sequence. Owing to the variety of physical features and whose seasonal dynamic variation , the display degree of actualities signal Y should have that randomness, after being transformed by function, which should also be existential with respect to gain signal X, because of that image processing itself is a random experiment. The randomness of input-output signals is a theoretical premise of calculating IL. IL of function, or probability of its obtaining information, can be used for evaluating degree of its actually reflecting the orginal image information. The calculation of IL is concerned with statistics, in order to attaining the firm statistics purpose, a Feedback Dynamic Recognition Pattern by progressively calculating is applied.In the circulative calculation process,the statistics is incremental. Owing to the mutual causality between input statistics and output calculated value, through observing the dynamic variation of calculated value IL in various process, the IL value can be obtained with higher accuracy in stable state of variation.

IPOS enhancement potential is reflected by carrying out series-parallel connection programs of functions.This paper presents IL budget formula for series-parallel connection, which can be used for calculating and analyzing IL value of system. under conditions of applying this budget formula, various function IL values related to enhanced contents can be used for determining series-parallel connection programs, fixed functions and applicable function number participating in programs, that helps system to obtain deserved information contents with 100/100 reliability approximately.

2. THE PROBABILITY DISTRIBUTION COMPOSITION FORM OF COMPOSITE SIGNALS I(C)J

The information received or processed by men generally is fuzzy one for the most part. After processing to the designated target (such as lineament) with some one system function , the enhanced result in image, or gain signal X, may be decided fuzzily according to the following display grades:

1(it represents distinct); 2(obvious); 3(darkish); 4(obscure); 0(not have result).

On the image processed by a certain function, a result represented by signal I(C)J is obtained,in which :

J is divided into above-mentioned 1,2,3,4,0 grade, it represents the grade of gain signal X enhanced by this function;

I is divided into above-mentioned 1,2,3,4 grade.It represents the grade of actualities signal Y. With respect to same target concerned with signal X,the original image should contain hidden actualities signal Y which can be enhanced by system. I is the attainable enhanced grade processed by system, namely is the maximal grade selected in a number of X signals processed by various system functions and responding to same target. I(C)J is composed of signal Y and X.every designated target (such as lineament)should have a result I(C)J, according to a certain number of targets, to count the respective number of various I(C)J produced by this function, can obtain following I(P)J probability distribution composition form composed of various I(P)J:

$$\left| \begin{array}{llll} 1(p)1 & 2(p)2 & 3(p)3 & 4(p)4 \\ 1(p)2 & 2(p)3 & 3(p)4 & 4(p)0 \\ 1(p)3 & 2(p)4 & 3(p)0 & \\ 1(p)4 & 2(p)0 & & \\ 1(p)0 & & & \end{array} \right| ,$$

$$\text{and} \quad \sum_{I=1}^{4} \sum_{J=1}^{0} I(P)J = 1 .$$

In which, the sub-composition form (1(p)1 2(p)2 3(p)3 4(p)4) represents probability distribution subspace of first class enhanced results, which can fully reflect the grade of actualities signals hidden in original image. (1(p)2 2(p)3 3(p)4 4(p)0),...and so on respectively represents various probability distribution subspaces responding to those enhanced results reduced to a lower class orderly, in which , enhanced result responding to (1(p)0) is low class.

3. THE CALCULATION OF ENTROPY H(α) AND INFORMATION LEVEL IL.

Entropy H(α) is a indeterminateness measure of random experiment α. If α has n mutually incompatible results having respective probability Pi, then according to the entropy definition, the entropy value whose unit is bit can be obtained by following formula:

$$H(\alpha)=-\sum_{i=1}^{n} Pi \cdot \log Pi, \qquad \sum Pi=1. \qquad (1)$$

Where, the logarithm base number is 2, in results of equal pobability (Pi distribution is uniform), the indeterminateness is maximum, its value is logn; when some one Pi equals 1 (Pi distribution is highly concentrated) , the decisivity is maximum, its entropy H(α)=0.
Placing composite probabilities I(p)j into formula (1) respectively, can obtain the combined entropy H(Y,X) of experiment Y and X.
In respect to the actualities signal Y at input end, its probability distribution composition form can be written by its grade I as follows:

$$Y: \left| \begin{array}{cccc} 1 & 2 & 3 & 4 \\ Py(1) & Py(2) & Py(3) & Py(4) \end{array} \right|$$

Py(I) are probabilities corresponding to mutually incompatible results I (I=1, 2, 3, 4), which can be obtained by composite probabilities I(p)J:

$$\begin{array}{l} Py(1)=1(p)1+1(p)2+1(p)3+1(p)4+1(p)0 \\ Py(2)=2(p)2+2(p)3+2(p)4+2(p)0 \\ Py(3)=3(p)3+3(p)4+3(p)0 \\ Py(4)=4(p)4+4(p)0 \end{array} \qquad (2)$$

To place Py(I) into formula (1) respectively, the a-priori indeterminateness of experiment Y, or entropy H(y), can be obtained.
In respect to the gain signal X transformed by a certain function at output end, the following probability composition form can be written by grade J as follows:

$$X: \left| \begin{array}{ccccc} 1 & 2 & 3 & 4 & 0 \\ Px(1) & Px(2) & Px(3) & Px(4) & Px(0) \end{array} \right|$$

Probabilities Px(J) can be obtained by following a set of formulas:

$$\begin{array}{l} Px(1)=1(p)1 \\ Px(2)=1(p)2+2(P)2 \\ Px(3)=1(p)3+2(p)3+3(p)3 \\ Px(4)=1(p)4+2(p)4+3(p)4+4(p)4 \\ Px(0)=1(p)0+2(p)0+3(p)0+4(p)0 \end{array} \qquad (3)$$

To place Px(J) into formula (1), can obtain entropy H(X) of experiment X .
Under conditions of understanding random experiment X at output end, the posterior indeterminateness of experiment Y, or conditional entropy H(Y/X), can be obtained. the indeterminateness H(Y,X) combined by random experiment Y with X, should be sum of X experiment one H(X) and Y experiment posterior one H(Y/X), thus:

$$H(Y/X)=H(Y,X)-H(X)$$

The transform from H(Y) to H(Y/X) explains that the Y signals indeterminateness is reduced as a result of function transform, from the information theory definition, this absolute reduced content is just information content (I)concerned with such signals Y which are contained by signals X, thus:

$$(I)=H(Y)-H(Y/X)=H(X)+H(Y)-H(Y/X)$$

Function Information Level IL, or probability of its obtaining information in the Y signals a-prior indeterminateness, can be obtained by following formula:

$$IL=(I)/H(Y)=[H(X)+H(Y)-H(Y/X)]/H(Y) \qquad (4)$$

IL reflects total enhancement benefit of function, and will not vary with different information source , thus it represents function reliability, should be used as a reliable basis for evaluating enhancement effect.

4. ANALYSIS OF THE IL CALCULATION FORMULA.

With respect to the IL calculation formulas (1)---(4) , whose theoretical base is reliable. From analysis of formula (4) , H(Y) represents a-prior indeterminateness, which does not relate to funcfion transforming, any function having higher IL value must embody that its H(Y, X) wants small and H(X) wants large. those I(P)J concentrating in any range of probability space all can send H(Y,X) becoming small, but H(X)can not necessarily become large. the composition of formula (3) has limited concentrative ranges of I(P)J destribution, only such I(P)J distribution concentrating in (1(p)1 2(p)2 3(p)3 4(p)4)and (1(p)2 2(p)3 3(p)4 4(p)0) subspaces mostly can send Px(J) distribution trending toward uniformization and cause H(X) to become large. It may be seen , that any function having higher IL value can actually or approximately reflect the attainable enhanced grade of signal Y hidden in original image.

5. THE CALCULATION PATTERN FOR FIRM STATISTICS

I(P)J distribution is concentrated in probability space for the function self enhancement feature. When the statistical number N (or probability denominator) reach a certain number, even if adding some I(C)J results into N, the I(P)J total distribution range can not be changed for this reason, in the mean time I(P)J change rate is small, IL calculation places oneself in the firm state. Theoretically N should be infinite, when the N is finite, reducing signal dividual grade or applying Feedback Dynamic Recognition Pattern can attain the purpose of firm statistics.
This pattern is to add statistic number N progressively and quantitatively , to observe the dynamical variation range of calculated IL value for each time, if and when the calculated values oscillate in smaller dynamic range time after

time,then oscillatory mean in this range should be considered as calculated true value in firm state. Through dynamic recognition, some appreciable errors of I(C)J can be checked over, then the IL value can be obtained with higher accuracy.

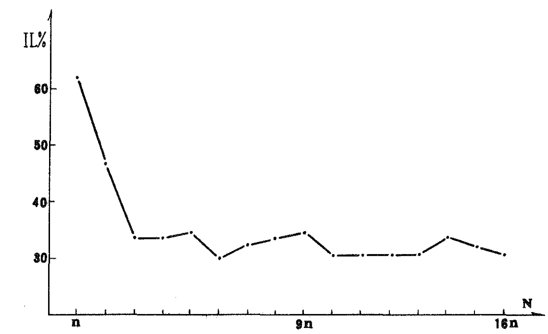

FIG.2, IL calculated process concerned with function-SCALE

The figure 2 shows IL calculated process concerned with function-SCALE in the lower-relief area, the enhanced contents is lineaments.Statistical number N is added progressively according to the progressive calculation ordinal number i, namely N =i n, in which n is 14 (I(P)J has 14 kinds of distribution states) . calculated initial IL value is 62%, when the statistical number is added from 3n,4n---until 16n,IL value is oscillating in 30%-34% range,in which the mean of IL values obtained with 1.7% accuracy is 31%.
When calculating the IL value in strong relief area covered by snow with composite processing program of function-CONVOLVE,initial value is 59%, in 2n--15n statistical interval,the IL oscillation range is 48%-51%, in which the IL mean obtained with 1.1% accuracy is 49%.
When N=14n , the IL had exceeded this firm oscillatory range,through check,that was caused by fuzzily deciding to three underexposure images, thus which were not listed into statistical range. That can be known as above,when statistical number N is more than 3n, the IL value which is available for reference can be obtained , and accurate IL value also needs not above mentioned large statistical number.

6.THE BUDGET FORMULA FOR EVALUATING IPOS ENHANCEMENT EFFECT

Any and all functions are unable to reflect actualities signals hidden in original image all to nothing, thus, for giving full play to system enhancement potential, the series-parallel connection programs of system functions must be established.

6.1 THE BUDGET FORMULA OF ENHANCEMENT EFFECT FOR PARALLEL CONNECTION SYSTEM

The so-called parallel connection program, that is to say , some one image which wants processing is operated by each of all parallel functions respectively, thus obtaining a number of parallel and singular processed results of same image, that can obtain each other's strong points to make up for one's weakness among different results,and can fully reflect actualities signals of original image.
Suppose the reliability of function i obtaining information is IL'i,then unreliability Fi=1-IL'i. In such a case of parallel connection, only when all functions have broken down together, the whole system is regarded as to be out of order. with reference to the probability multiplication theorem, the parallel connection system unreliability Fp is:

$$Fp=F1\cdot F2\cdot\cdots\cdot Fn=\prod_{i=1}^{n} Fi\ .$$

As a result , the reliability of system obtaining information, or
Information Level (IL)p, can be written as follows:

$$(IL)p=1-Fp=1-\prod_{i=1}^{n}Fi=1-\prod_{i=1}^{n}(1-IL'i) \qquad (5)$$

6.2 THE BUDGET FORMULA OF ENHANCEMENT EFFECT FOR SERIES CONNECTION SYSTEM

For giving full play to system potential, some image or other is operated by series orderly functions repeatedly and sequentially, that can concentrate series processed results on a single image, as a result, it is suitable to target interpretation . the series connection program can also participate in parallel connection operation with other programs or functions.
In such a case of series connection , even if only one function has breakdown , the whole system at once breaks down. according to the probability multiplication theorem, the reliability (IL)s of system obtaining information is:

$$(IL)s=\prod_{i=1}^{n} IL'i \qquad (6)$$

It can be known from formula (6), that information content obtained by processing of first function can be reduced progressively with later repeated operations, or even evanesce.In practice the blind series connection of functions can cause result revealed by formula (6).
As to the lineament, the most part of functions concerned with CONTRUST ENHANCEMENT can help to extending dynamical variation range of image gray level distribution field, thus enhancing a part of signals, and keeping a part of non-outstanding actualities signals which help to being enhanced further.
Suppose the original image information content equals 1,and if the series connection operation is composed of three functions having above mentioned property,then it can be known from formula(6),that information content obtained by first function is (I) =1·IL'1=IL'1,that non-outstanding information content kept by first function is(1-IL'1),thus the information content obtained by third function can resolve itself into 3 components: IL'1·IL'2·IL'3, (1-IL'1)·IL'2·IL'3, [(1-IL'1)-(1-IL'1)IL'2] IL'3.It's obvious that information content obtained by third function is insufficient,thus the number of series functions must be limited to 3 at most, for this reason the image processing should consist of pre-main-after processing stages, that would be suitable.
Not all functions can keep non-outstanding actualities singnals in image . This and that functions concerned with pre-after processing stages must help to extending dynamical variation range of image gray level distribution field. In order to making good a loss of information in main processing , a original or pre-processed image

having more information contents, too,may be added into processed result in after-processing.

7.QUANTITATIVE EVALUATION OF SYSTEM ENHANCEMENT EFFECT FOR GEOLOGICAL LINEAMENT.

According to the Feedback Dynamic Recognition Pattern, this paper has calculated respective IL valus of various functions in common use for enhancing lineament. On the basis of total statistics, these values were obtained from 1500 sheet of images concerned with various physical features. Due to lacking statistics to some specific areas, thus in statistics this experiment did not carry out area classification with variety of physical feature. The grade I of signal Y, or selected maximal grade in a number of X signal grades responding to same target,was obtained from respective X signals of 10 functions (or series connection programs). Statistic number of each function was more than ten times number of I(C)J distribution state, about above 140 strips of lineaments.It can be known from examples stated by section 5, that required statistic number need not reach such large value in practice. The percentile IL values of various functions obtained by this experiment can be written in big or small sequence, as follows (percent symbol does not be listed):
HIST'NORMALIZE(43);CONVOLVE(38);LOCAL'ENHANCE(35); HIST'EQ(33);PLIM(32); SCALE(32);SELF-MULTIPLY(31); KL-PRINCIPAL COMPONENT(30); HADMARD(29);FFT1D(28); LOGARITHM(27);KL'TRANSFORM(23);RATIO(19);CLUSTER(17);MSS'BAND-7(26);MSS'BAND-5(22);MSS'BAND-4(18).
These IL values concerned with original single band images reflect visual recognizable and responsive ability to image signals, namely, the visual interpretation is considered as function transform, these differences among IL values are consistent with physical mechanism analysis concerned with band property and geological environment. The IL values of function-CONVOLVE and LOCAL'ENHANCE belong to high level in system, that is concerned with respective property of themselves,and is consistent with most qualitative evaluation conclusions. These quantitative IL values have also revealed difference between theory and practice of some functions, such as function -FFT1D or KL'TRANSFORM.
Putting various functions to participate in parallel connection operation in big or small order of their respective IL value, can obtain parallel connection system (IL)p values from formula (5), as shown in List 7-1.

LIST 7-1, parallel connection system (IL)p values (function).

The parallel function number	1	2	3	4	5	6	7	8	9	10
(IL)p %	43	65	77	85	90	93	95	96	97	97

The formula (5) has larger practicality. In practice, people can usually obtain satisfactory results for lineament only with 4-5 functions,from List 7-1 , it can be known that corresponds to having tapped 90% system gain potential; for some images which are processed difficultly, that often want over five functions to participate in operation, but incremental gain signals are less, that is consistent with retarded appearance of (IL)p increasing velocity in this range shown as List 7-1.
For those series connection programs through practical check, according to name of function participating in main-processing, whose IL values can be arranged in order of big or small, as follows:
COMPOSITION OF KL'COMPONENT WITH ORIGINAL IMAGES (45); CONVOLVE(44); NEGATIVE(42); KL PRINCIPAL COMPONENT(41);LOCAL'ENHANCE(37);KL'TRANSFORM(34); SELF-MULTIPLY (34); RATIO(31).
These respective IL values of above-mentioned main-processing functions, due to their having participated in series connection operation, all have respective improvement over IL value obtained singly by oneself. If these programs sequentially participate in parallel connection operation in big or small order of their respective IL value , those obtained (IL)p values can be listed in List 7-2:

List 7-2 parallel connection system (IL)p values (program).

The parallel program number	1	2	3	4	5	6	7	8
(IL)p %	45	69	82	89	93	96	97	98

That can be known from above, if we put only 4 programs to participate in parallel connection operation, we can tap 90% system gain potential. Series connection programs and functions can also participate in parallel connection operation together.

8.CONCLUSION

For evaluating IPOS enhancement effect, the qualitative evaluation was putted first previously. Except that subjectivity and localization in its weakness , this evaluation hardly considered the actualities information of original image, and only regarded "GOOD" and "BAD" or "HAVING" and "NOTHING" of enhanced results as standard, that is perplexed by surface phenomenon easily. From these composite signals I(C)J, we can carry out quantitative and qualitative evaluation accurately. On the statistic basis of 14 kinds of composite probability distribution results, we can evaluate enhanced effect by single quantitative parameter IL, and can consider all possible cases overall and really.
The IL value represents function or system self enhancement feature, thus can be used as a means checking new functions or programs. Some functions could be a series connection program composed of various procedures, if strict measure leads to increment of procedure number, as formula (6) its enhancement effect could be just the opposite to what one wished.
To use the series-parallel connection programs,can give full play to system enhancement potential.For image enhancement of designated target,we need not employ all system functions, with reference to those respective IL values of various functions or programs which is concerned with designated target, we can compose a subsystem with definite functions, whose effect can represent enhancement potential of the whole system.
To counter the geological lineament,this paper has recounted some quantitative parameters concerned with system and functions, which have definite directive action in the image processing dynamic policy-making course,from which we can obtain many lineaments enhanced results quickly and effectively.

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