Quantitative Approach for Evaluation of Urban Landscape Quality

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ABSTRACT

This paper presents a quantitative approach for outstanding evaluation of the landscape quality, based on the fractal theorem. The analysis uses the box- counting method and the fractal dimension, which may give the quality of the landscape, is determined. The range of good standard value of the fractal dimension is obtained by using commonly acceptable good scenery found in classic landscape paintings, such as of Gogh, Monet or Renoir, and is found within from 1.50 to 1.65. The landscape of which the value of fractal dimension falls into the range can be assumed to be of good quality, while less or greater value may reveal somewhat poor or mismatch in the landscape. In fact, photographs taken in down town and construction site exhibit 1.70 and 1.38, respectively, and thus these two cases can be discriminated as no-good ones from many test samples indicating value almostly within the good standard range of the fractal dimension.

1. INTRODUCTION

In recent years, the social criticism to the total quality of urban landscape including light-up has been rapidly growing up as a sort of socio - cultural assessment. To grade the total quality of the combination between landscape and light - up illuminations is quite ambiguous problem since it strongly depends upon the personal back-ground and subjectivity of the observers whether these are well matched or mismatched.

For treating such problems, the fractal theorem may be invaluable, as used in civil engineering to analyze coast line shape [1] . In this paper, a quantitative approach for outstanding evaluation of the landscape quality is presented based on the fractal theorem. The process analyzes landscape images by using the box-counting method, in which the fractal dimension can be obtained from slope of a curve derived by the image process.

The range of good standard value of fractal dimension may be obtainable from commonly acceptable good scenery in classic landscape paintings, such as of Gogh, Monet or Renoir. By comparing the values of landscape under test with the good standard, its quality can be qualitatively evaluated. The landscape of which the value of fractal dimension falls into the range can be assumed to be of good quality, while less or greater values may reveal somewhat poor quality or mismatch in the landscape.

For demonstrating the method, some sample photo-images are tested using the method. The values of fractal dimension evaluated from the sample photos are all inside of the standard range. However, a photo taken in Sapporo down town exhibits extremely large value than the standard and then we can evaluate the landscape may be poor.

2. BOX - COUNTING METHOD AND FRACTAL DIMENSION

The fractal technique normally requires self-homologous repeating structures in the image to be analyzed. As is often found in recent results of fractal analyses, even a usual landscape of any cases eventually contains plenty of such structures. Here we assume that such condition is almost satisfied in the following descriptions.

In principle, the assumption supports the box-counting method, in which a square box of arbitrary size defined in a test image is successively cut down into a series of smaller homologous squares. Then the relationship between the dividing ratio and resulting number of homologous squares can be written in the form

$$N = 1 / (1/n)^2 \qquad (1)$$

or using logarithmic coordinates, we obtain

$$\log N = -2 \log (1/n) \qquad (2)$$

where N is the count of homologous squares and n is inverse of the dividing ratio.

In order to apply the box-counting method, the test image must be converted into a monochrome and line-drawn image pattern, in advance. We take at first logical product between the box unit and the line-drawn image pattern for each value of the dividing ratio. If no peace of line-drawn image exists in a box, it returns 0, while 1 will be returned for the other cases. The total count of the box that returns 1 is recorded as a function of the dividing ratio. If we denote the total count of the return by N', the fractal dimension,D, is defined as the coefficient of the relationship between $\log N'$ and $\log (1/n)$, as

$$\log N' = -D \log (1/n) \qquad (3)$$

According to the expression of eq.2, the value of D may be distributes within the range, $0 \leqq D \leqq 2$, and the maximum value coincident to the case if line-drawn peaces distribute everywhere in the image. In this paper, it is proposed that the quality of landscapes can be evaluated from the value of the fractal dimension.

Figure1 shows a maximum condition simulated by using a random dot image for various dot density (d_a = 2000~14400 [dots/cm^2]). The slope of the curve is just equal to 2, as expected, within a particular range of $1/n$, depending upon the dot density.

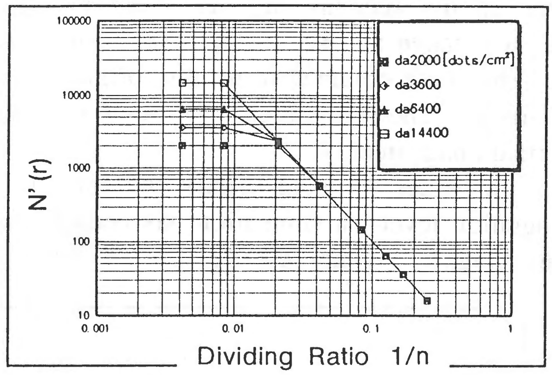


Fig.1 Simulation results obtained by using random dot images

3. EFFECT OF RECOGNITION LEVEL

At the data entry, the image to be tested must be converted to monochrome, if in color, and to line- drawn image in advance. The start square box can be whole image size and is successively divided. The box-counting method gives the number of the boxes where any line parts of the image are found within. The plot of N' as a function of dividing ratio $1/n$ reveals the fractal dimension as the its slope.

The tone of image is digitized from 0 to 255 in level, assigning 0 to black and 255 to white, and the digital image is turned into binary, line-drawn pattern with using a selected recognition level.

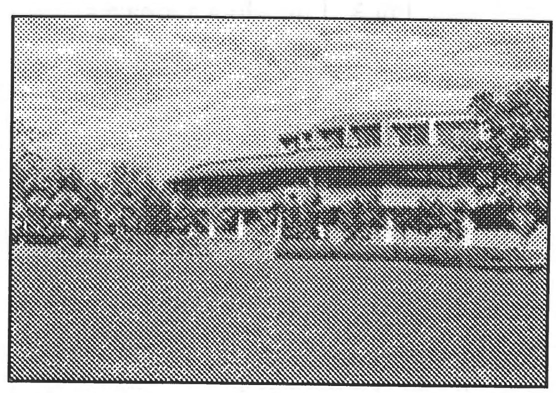


Fig.2 Original image used for the test of recognition level effects.

We must be careful at the image conversion for some dark or fuzzy images, because in the case the distribution of the levels concentrate only in a narrow low level band. Even so, by choosing suited recognition level, the feature of the original image can be clearly transferred in the line-drawn image pattern. Figures 2 and 3 demonstrate the effect of the recognition level selection, i.e. the level was taken at 130 in Fig.3 (a) and at 90 in Fig.3 (b), both obtained from the original image of Fig. 2. The recognition level obviously affects the final image quality.

In order to more clarify the influence of recognition level , a simulation has been made by using Gogh's "Poplar Avenue" . When the recognition level is set at 95, the fractal dimension reaches at the peak (D =1.614), as shown in Fig. 4. while it is selected at 80 resulting D = 1.610. The author can recognize that the later case gives better quality.

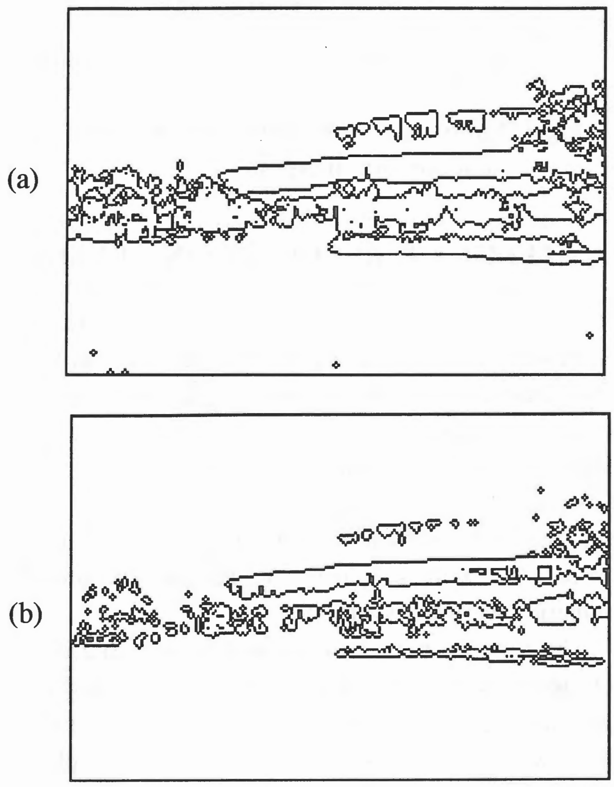


Fig.3 Line drawn images
(a) Recognition level equal 130
(b) Recognition level equal 90

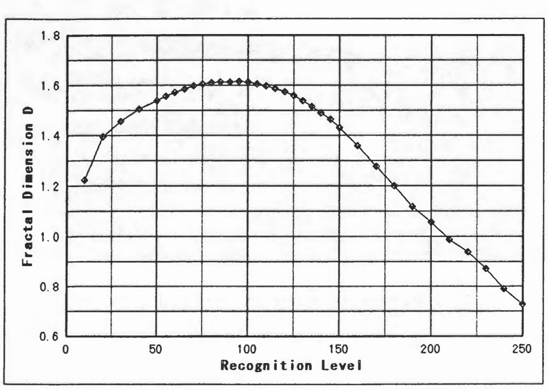


Fig. 4. Influence of recognition level to the fractal dimension

4. GOOD STANDARD VALUE OF FRACTAL DIMENSION

It is required that the line-drawn pattern must be good quality well presenting the features of the original image. As previously mentioned, the selection of the recognition level is important procedure to determine the final image quality. If recognition level is selected at low value, the dark part of the image can be well recognized. In contrast, high recognition level might flash the information away. Anyway, the recognition level must be carefully selected to give best final image quality.

In this section, we discuss about the best standard value of the fractal dimension. It is necessary to evaluate the quality of landscape by comparing to it. It may be good idea to determine by referring to commonly acceptable good scenery in classic landscape paintaings, such as of V.W. van Gogh, C. Monet or P. A. Renoir. The quality of landscapes can be qualitatively evaluated by testing whether its fractal dimension falls into the good standard range or not. Of course, inside of the good standard range means good quality and outside opposite.

4.1 Case of Monet's paintings

Monet's paintings are often foggy and then it must be more careful to select the value of the recognition level. When we use 105 to Fig.5("a Magpie" 1869), then good results are obtained, as shown in Fig.6. Some other 5 paintings were also tested.

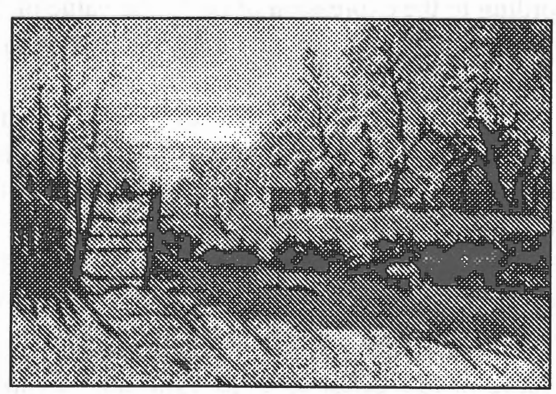


Fig.5 Sample from Monet's paintings

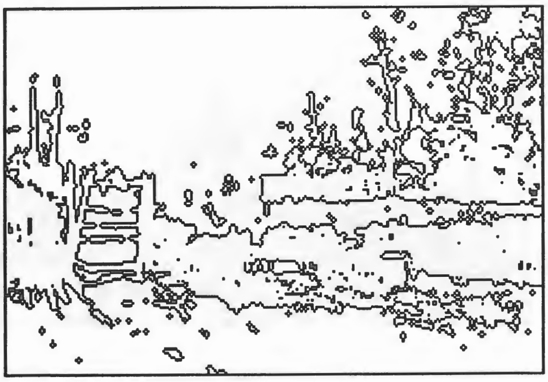


Fig. 6 Line-drawn image

4.2 Case of Renoir's paintings

Figure 7(a) (" La Seine, chateau " 1881) is an example of monochromed from Renoir's painting as original image and (b) is the converted one. In this case, the tone is quite delicate and thus we used 75 for the recognition level. His other 5 paintings were also tested.

(a)

(b)

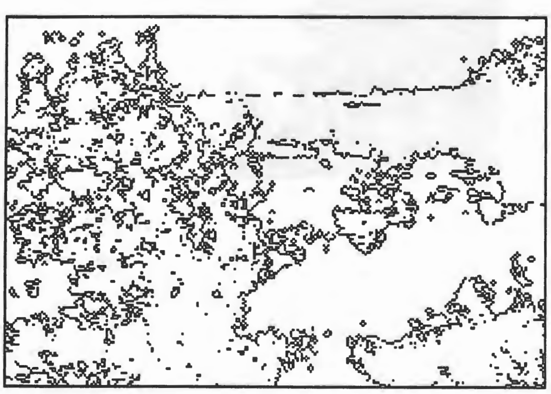


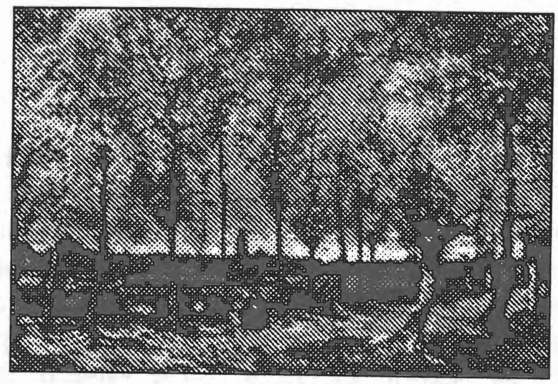
Fig.7 Sample from Renoir's paintings
(a) Monochromed image, (b) Line-drawn image

4.3 Case of Gogh's paintings

Figure 8(a) is original (monochromed) and (b) is the converted one of Gogh's painting titled "Poplar Avenue, 1885."

We obtained D =1.610 for the recognition level of 95. His other 5 paintings were also tested.

(a)



(b)

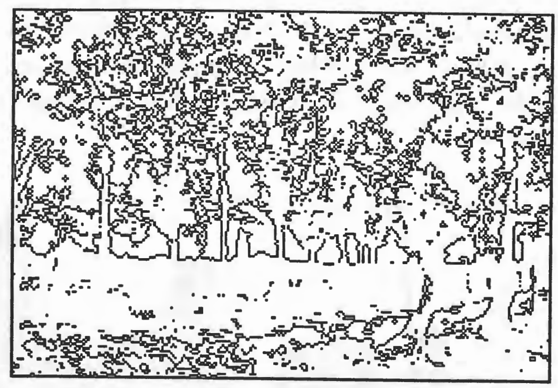


Fig. 8 Sample from Gogh's paintings
(a) Monochromed image, (b) Line-drawn image

The averaged values of the fractal dimension obtained from these three cases (15 articles of 5 each) are listed in Table 1. As described, the recognition level was selected as to obtain good quality image at each cases ignoring conversion conditions. In the table, the fractal dimension averaged for each painter is denoted by D_m and ΔD is the distribution deviations.

We see that all values of fractal dimension obtained for these good scenery are always within the range from 1.50 to 1.65. As the consequence, it may be reasonable to understand that even other landscapes reveal the fractal dimension in this range should be good. Hereafter, we use the range of the fractal dimension as the best standard for quantitative evaluation of landscape quality.

Table 1 Averaged values of the fractal dimension D_m and deviations ΔD.

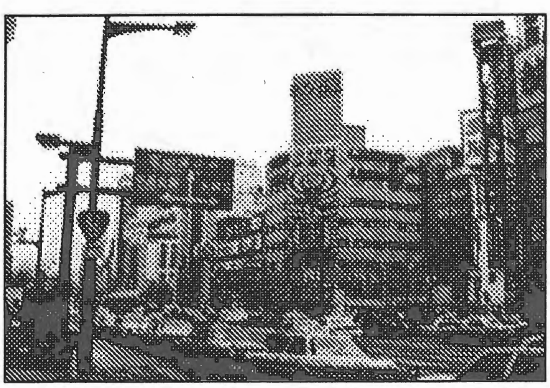
Painter	No	D_m	ΔD
Monet	P 1 ∼ P 5	1.580	- 0.11 ∼ + 0.07
Renoir	P 6 ∼ P10	1.640	- 0.07 ∼ + 0.05
Gogh	P11 ∼ P15	1.530	- 0.12 ∼ + 0.10

5. SOME TRIALS

Urban landscapes, nevertheless each buildings may be designed with considerations about good matching to surrounding conditions, often are no control, for instance, suffered by commercial advertising boards and so on. In Sapporo, its down town, called Susukino area, may be an example of it, as shown in Fig. 9. The value of fractal dimension obtained from the image was 1.700. It is obviously out of the range of good quality and it is then understood that the landscape quality is poor.

Figure10 is another example of poor landscape quality, giving D =1.380, which is also out of the range.

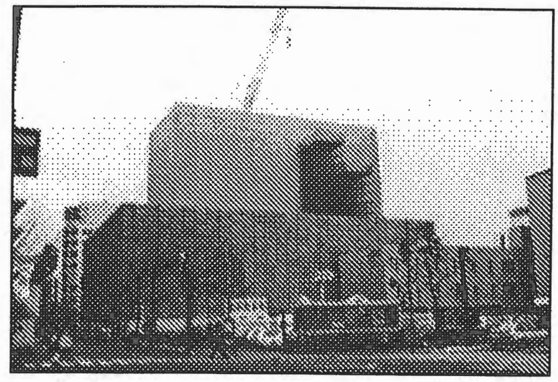
(a)



(b)

Fig.9 Landscape sample 1 for trials
(a) Original image, (b) Line-drawn image

(a)



(b)

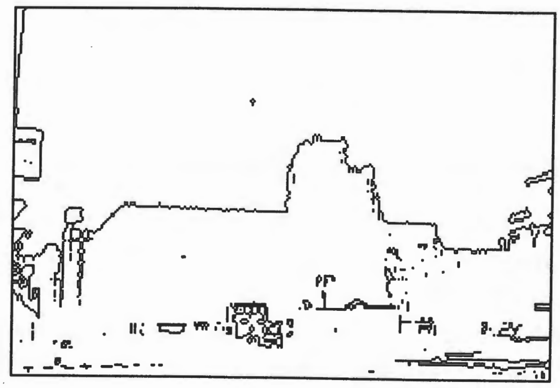


Fig.10 Landscape sample 2 for trials
(a) Original image, (b) Line-drawn image

Figure11 may be an exception, since D =1.230 for setting the recognition level at 95, although we feel good scenery of Tokyo. In this case, the knowledge about the object could make observers misjudge.

(a)

(b)

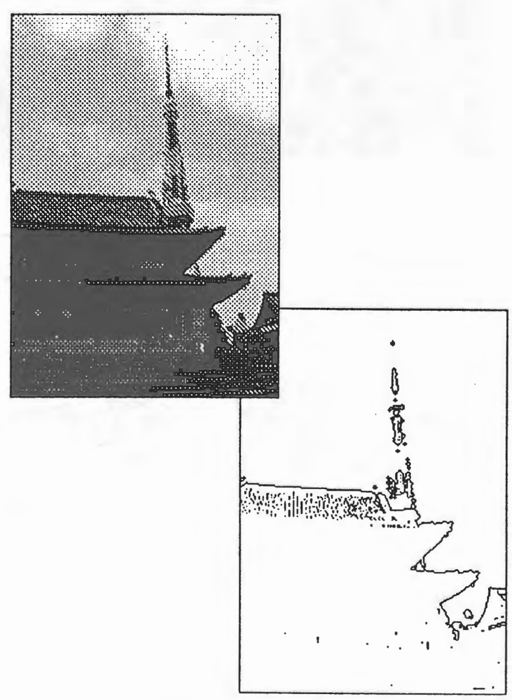


Fig.11 Landscape sample 3 for trials
(a) Original image, (b) Line-drawn image

6. CONCLUSIONS

A quantitative approach to evaluate the quality of urban landscape including light-up has been developed by using fractal theorem. In the method, fractal dimension is obtained by applying the box-counting method to landscape image under test and is judged whether the value falls into inside of the range indicating good quality or not. The value of fractal dimension for good quality have been successfully determined by referring to commonly acceptable good scenery in classic landscape paintings, such as of Gogh, Monet or Renoir and found within the range from 1.50 to 1.65. This means that the landscape giving the fractal dimension inside of the range must be good quality,while poor quality, if outside.

Some test samples of landscape photo were analyzed by using the evaluation technique. In almost all cases, the judgments well agreed to general feeling to the image except the case if observer has got too much knowledge about the objects in the scenery.

The system is still under improvement of its capability for permitting to process color images, which present us more precise information of the landscape.

Reference

[1] Benoit B. Mandelbrot: " The fractal geometry of nature " . W. H. Freeman and Company, New York. 1983