商経学叢　第59巻第2号　2012年12月
Journal of Business Studies Vol. 59,No. 2, December 2012

The Relation of the Purchase Effect by the Fractal Dimension and the SD Method of Product Packaging

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Abstract　In order to decide the packaging design as a face of goods, man's subjectivity has estimated. However, if there is a method of finding objective what draws people's eyes out of two or more designs; it is expectable to raise purchasing effect also from appearance irrespective of the contents of a product.
The writer has inquired in the past that man's eyes are guided to the high picture of a fractal dimension. This research compared the fractal dimension about the packaging design of 45 kinds of canned beer of little note. Are simultaneous, SD (Semantic Differential) Method was performed and it investigated also about the relation between a design and a fractal dimension. As a result, high purchasing effect was seen by canned beer with the design of the high fractal dimension. The report of the Internet proved the popularity and sales track record of canned beer.

Key words　fractal dimension, semantic differential, product packaging
May　15, 2010, accepted

概要　商品の顔としてのパッケージ・デザインを決めるには、人間の主観によって評価してきました。しかし、複数のデザインの中から、人の目を引き付けるものを、客観的にみつける方法があれば、製品内容にかかわらず、見栄えからも購買効果を上げることが期待できます。
筆者は、人間の目が、フラクタル次元の高い画像に誘導されるという過去研究を行ってきました。本研究は、知名度が低い 45 種類の缶ビールのパッケージ・デザインについて、フラクタル次元を比較しました。同時に SD(セマンティック・ディファレンシャル)法を行い、イメージとフラクタル次元の関係についても調べました。その結果、フラクタル次元の高いパッケージ・デザインを持った缶ビールに、高い購買効果がみられました。缶ビールの人気や、売り上げ実績については、インターネットの報告で実証しました。

I INTRODUCTION

Product packaging is an extremely important factor that affects the sales of a product. Product packaging serves several roles including protecting and wrapping the product, facilitating transport and storage, conveying product information to the consumer, giving an impression about the product, and motivating consumers to want to buy the product. Furthermore, product package design is a factor that even determines the image of the product contained in the package.

Until now, package evaluations were performed subjectively and obtaining objective evaluations based on numerical values was not possible. However, if people tend to prefer images with a high fractal dimension, then an examination of the fractal dimension of product package images could help determine how preferable a product package would be, or serve as one index for evaluating whether a product package would attract attention.

Previous research related to product packages have focused on aspects related to the buyer's motives in purchasing food or daily use items [2]. We investigated whether university students considered color, package design, product design, quality, advertising, style, brand, manufacturer, price, form, safety, and functionality in their purchase decisions, and concluded that package design was the most important factor. In addition, in research regarding the affect of visual sensory information on taste, Sakai & Morikawa (2006) showed that evaluation scores differed if the visual sensory information was changed, even when assessing the same food product[9].

Fractal dimension research related to the agreeability of human faces (Oyama-Higa, Miao, & Ito 2007) showed a tendency for photographs of smiling faces to have a higher fractal dimension than photographs of expressionless faces[7]. Furthermore, research investigating the relationship between eye movement while viewing pictures and the fractal dimension of those pictures (Nagai, Oyama-Higa, & Miao 2007) has shown that the gaze tends to be concentrated on areas of pictures with high fractal dimension[6].

In this study, we calculated the fractal dimension for canned beer packaging to

determine the relationship between the package and the buyer's impression of the product. The experiment overview and method are described in section 2. Section 3 describes the fractal dimension calculation and the relationship with the semantic differential (SD) method of evaluation. The calculation results and perspectives for the future are discussed in section 4.

Ⅱ EXPERIMENT OVERVIEW AND EXPERIMENT METHOD

The experiment was performed in a laboratory from September 25 through October 3, 2007. Eighteen subjects (11 men and 7 women) ranging in age from 19 to 26 years (mean 22 years) participated. None of the subjects had ever previously consumed the various canned beers shown in the photographs. All subjects had normal vision.

A Fractal dimension calculation and grouping

First, the photograph of each of the 45 types of canned beer was assigned a number from 1 to 45, and the fractal dimension was calculated for each photograph using the planar and cubic methods. See the Appendix for details of calculating the fractal dimension.

The photographs were ranked in descending order by fractal dimension according to the results of the planar and cubic methods. The five photographs with the lowest total based on the two methods (hereafter referred to as the high fractal group), and the five photographs having the highest total (hereafter referred to as the low fractal group) were extracted and selected for further evaluation using the SD method.

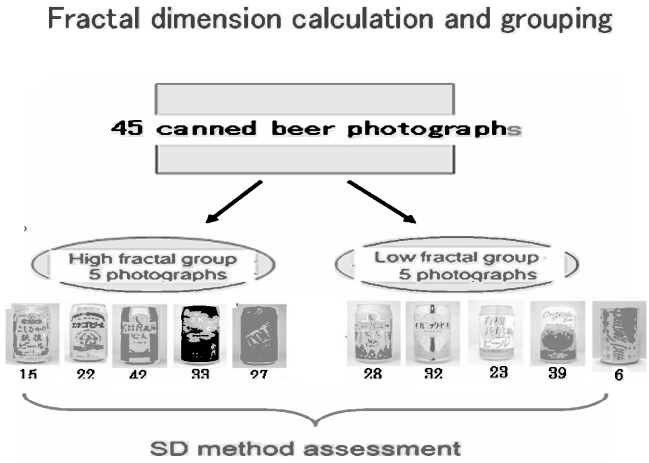

Figure. 1 Selection of targets for the SD method of assessment

B Assessment by the SD method

A chair was placed so that the eye level of a subject sitting in it would be at the same height as the center of a computer display 57 cm away. Five photographs from the high fractal group and five photographs from the low fractal group were randomly displayed, and subjects were asked to assess each photograph one at a time on the computer display (Fig. 2).

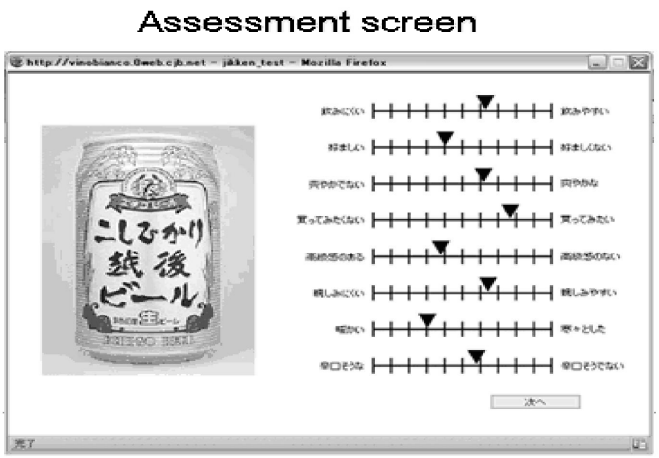

Figure. 2 Assessment screen based on the SD method

The 16 descriptive terms used in the SD method, the order of presentation, and positive or negative orientation are shown in Table 1. The order of presentation and positive or negative orientation were determined randomly.

The 16 terms were randomly selected from a list of sensitivity words created by Nagamachi, (1995) that were thought to be relevant to impressions of canned beer[2].

Table 1. Descriptive terms used in the SD method

Adjective number		Descriptive terms
1	Difficult to drink	Easy to drink
2	Preferable	Not preferable
3	Not refreshing	Refreshing
4	Would not like to buy	Would like to buy
5	Expensive-looking	Not expensive-looking
6	Not friendly	Friendly
7	Warm	Chilling
8	Seems dry	Does not seem dry
9	Seems cool and fresh	Does not seem cool and fresh
10	Not soft	Soft
11	Not fashionable	Fashionable
12	Eye-catching	Subdued
13	Not cute	Cute
14	Delicious-looking	Not delicious-looking
15	Not premium	Premium
16	Nice	Not nice

The estimation screen was 500 × 700 pixels centered in the display. A photograph of the canned beer was presented on the left half of the screen at a size of 239 × 358 pixels, and eight sliders paired with opposing adjectives were presented on the right half of the screen.

The sliders could be moved by dragging the mouse, and subjects were instructed to move the slider to the position they felt appropriate for that product. Assessment values were designed to record a maximum value of 100 and a minimum value of –100.

Ⅲ RELATIONSHIP BETWEEN THE FRACTAL DIMENSION CALCULATION AND SD METHOD ASSESSMENT VALUES

A Fractal dimension calculation

The fractal dimensions of the beer photographs in the high and low fractal groups used in the SD estimation method (Fig. 1) are shown in Table 2.

Table 2. Fractal dimension and rank of assessed canned beer photographs

Photograph No.	Planar Method	Cubic Method	Planar Method Rank	Cubic Method Rank	Rank Total
15	2.639	2.798	1	1	2
22	2.606	2.677	4	2	6
42	2.613	2.676	3	3	6
33	2.628	2.669	2	5	7
27	2.603	2.661	5	7	12
28	2.430	2.516	41	40	81
32	2.426	2.494	42	42	84
23	2.421	2.493	43	43	86
39	2.409	2.491	44	44	88
6	2.401	2.477	45	45	90

Figure. 3 High fractal group (upper row) and low fractal group (lower row) of canned beer photographs and photograph numbers

B Relationship between fractal dimension and assessment values

We divided fractal dimension into two groups (highvalue/low value) and performed Student t-test (Alpha 0.05) of 16 term of SD using all subject data. As a result, we found twelve terms that were significantly different relations. Fig. 4 shows the results.

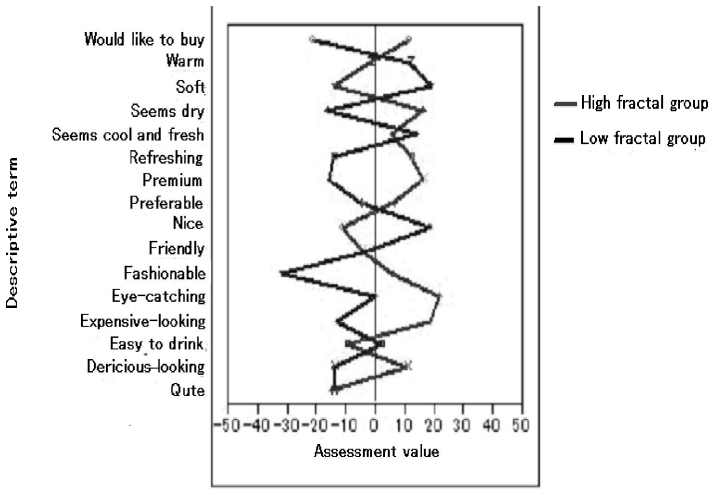

Figure. 4 Assessment values of each descriptive terms which are significantly different with high/low of the fractal dimension.

We performed partition analysis of 12 items where significant difference was seen in. Fig.5. As a result, three remarkable rules were found.

The rule of the high fractal dimension..

Rule 1. 35 cases in 90 (38.9%)

Premium >= -63 , Preferable >= 0,

Cute <16, and Delicious-looking >=5

The rule of the low fractal dimension..

Rule 2. 25 cases in 90 (27.8%)

Friendly >=41 and Delicious-looking < 5

Rule 3. 19 cases in 90 (21.1%)

Eye-catching < 49, Preferable < -16, • Friendly < 41

and Delicious-looking < 5

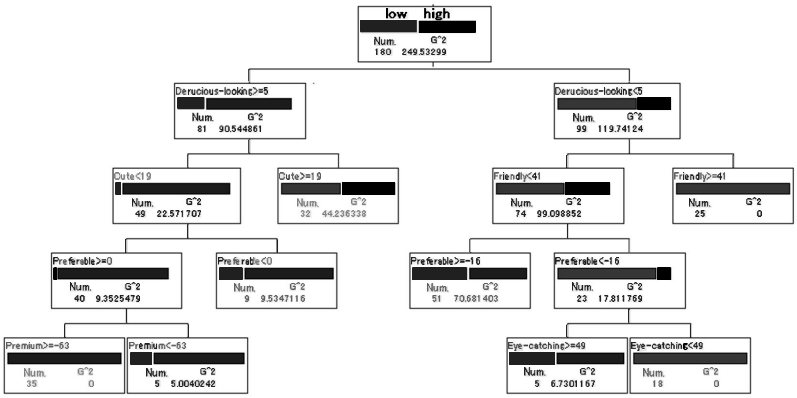

Figure. 5 Partition analysis of twelve items

The correlation coefficients between the fractal dimensions calculated by the planar method and the assessment values are shown in Table 3. Furthermore, the correlation coefficients between the fractal dimensions calculated by the cubic method and assessment values are given in Table 4.

Table 3. Correlation coefficient between the planer method fractal dimension and the assessment value of each descriptor.

No.	Descriptor	Peason's correlation coefficient	Spearman's rank correlation coefficient
1	Easy to drink	-0.309	0.188
2	Preferable	0.458	0.479
3	Refreshing	0.705	0.467
4	Would like to buy	0.815	0.782
5	Expensive-looking	0.831	0.600
6	Friendly	0.056	0.418
7	Warm	-0.253	0.067
8	Seems dry	0.672	0.285
9	Seems cool and fresh	-0.301	0.225
10	Soft	-0.065	0.273
11	Fashionable	0.754	0.782
12	Eye-catching	0.676	0.697
13	Cute	0.053	0.176
14	Delicious-looking	0.864	0.794
15	Premium	0.845	0.745
16	Nice	-0.643	-0.418

Table 4. Correlation coefficient between the cubic method fractal dimension and the assessment value of each descriptor

No.	Descriptor	Peason's correlation coefficient	Spearman's rank correlation coefficient
1	Easy to drink	−0.293	0.164
2	Preferable	0.423	0.358
3	Refreshing	0.697	0.442
4	Would like to buy	0.805	0.733
5	Expensive-looking	0.822	0.624
6	Friendly	0.059	0.394
7	Warm	−0.228	0.006
8	Seems dry	0.664	0.309
9	Seems cool and fresh	−0.350	−0.334
10	Soft	0.634	−0.248
11	Fashionable	0.728	0.758
12	Eye-catching	0.688	0.624
13	Cute	−0.069	0.079
14	Delicious-looking	0.864	0.867
15	Premium	0.835	0.697
16	Nice	−0.640	−0.394

For Pearson's correlation coefficient, when using a non-correlated test of each adjective assessment value and the 2D fractal dimension, significant correlations were found for "would like to buy" ($t = 3.98$, $df = 8$, $p < .01$), "expensive-looking" ($t = 4.23$, $df = 8$, $p < .01$), "delicious-looking" ($t = 4.85$, $df = 8$, $p < .01$), and "premium" ($t = 4.47$, $df = 8$, $p < .01$). A similar tendency was observed in the results of the 3D method.

C Discovering latent factors using the assessment value factor analysis

A factor analysis based on the principal factor method was performed to reveal latent adjective factors. Rotation was performed using the promax rotation method, and three factors were extracted.

The factor matrix for each adjective is shown in Table 5.

Table 5. Factor matrix of each descriptor

No.	Descriptor	Factor 1	Factor 2	Factor 3
1	Easy to drink	0.376	0.468	0.156
2	Preferable	0.614	−0.028	−0.016
3	Refreshing	−0.027	−0.608	−0.356
4	Would like to buy	0.823	−0.058	−0.030
5	Expensive-looking	0.612	−0.257	−0.120
6	Friendly	0.517	0.354	0.008
7	Warm	0.192	0.552	−0.179
8	Seems dry	0.097	−0.765	0.253
9	Seems cool and fresh	0.012	0.244	0.749
10	Soft	−0.073	0.776	−0.075
11	Fashionable	0.797	−0.188	0.024
12	Eye-catching	0.220	−0.128	0.028
13	Cute	0.525	0.364	−0.001
14	Delicious-looking	0.877	−0.109	0.042
15	Premium	0.686	−0.230	−0.009
16	Nice	0.133	0.815	−0.179

The first factor was set to “desire to purchase quality products” because all of the following terms were included: “would like to buy,” “delicious looking,” “expensive looking,” “cool,” and “premium.” The second factor was set to “soft feeling” because the adjectives such as “soft” and “warm” were included. The third factor was set to “light feeling” because the adjectives “refreshing” and “dry” were included.

D Relationship between fractal dimension and latent factors

The correlation coefficients between extracted factors and fractal dimension are shown in Table 6.

Table 6. Pearson’s correlation coefficient of the fractal dimension and each factor

	Planar method	Cubic method	First factor	Second factor	Third factor
Planar method	1	0.996	0.836	−0.623	−0.496
Cubic method	0.996	1	0.824	−0.612	−0.524
First factor	0.836	0.824	1	−0.535	0.630
Second factor	−0.623	−0.612	−0.535	1	−0.634
Third factor	−0.496	−0.524	0.630	−0.634	1

For Pearson's correlation coefficient, when performing a non-correlated test, a

significant correlation was found between the 2D fractal dimension and the first factor, "desire to purchase quality products" ($t = 4.31$, $df = 8$, $p < .01$). A significant correlation was also found between the 3D fractal dimension and the factor "desire to purchase quality products" ($t = 4.11$, $df = 8$, $p < .01$).

Table 6 shows a high correlation between the first factor (desire to purchase quality products) and both the 2D and 3D fractal dimensions, indicating a negative correlation between the second factor (soft feeling) and the fractal dimension.

Ⅳ EVALUATION OF THE RESULT

The canned beer used to compare labels omits the one of a famous beer company in Japan. Therefore, this investigation was done by using the local beer not notorious.

Evaluation 1:

Result of examining hot seller of beer by the Internet later. The 33rd canned beers with high fractal dimension of Fig. 1 were a local beer hot selling rankings and 1st place.

[http://www.rakuten.co.jp/yonayona/111011/718975/#tp24]

Evaluation 2

The 42nd was popular ability No.1.

[http://store.shopping.yahoo.co.jp/yohoyonayona/b7dab0e6c2.html]

Evaluation 3

Moreover, popularity was high, and the 15th and 22nd canned beers had been won the championship in the contest of the beer.

[http://www.rakuten.co.jp/yagishoten/425762/44805 4/]

Evaluation 4

The canned beer with low fractal dimension was not displayed in sales information in the Internet.

V DISCUSSION

Biological information exhibits a chaotic behavior, and until now, it has been difficult to explain human information processing using subjective methods [5],[1]. In other words, delicate human information processing, in particular, cannot be analyzed in detail by traditional linear analytical methods. By using nonlinear and complexity methods of facial fractal analysis, our findings suggest that information processing in human recognition might be explained and characterized by fractal dimensions.

We demonstrated that higher fractal dimensions of canned beer packaging led to an increased impression of high quality and a greater desire to purchase. Moreover, the analysis showed that low fractal dimensions of canned beer packages contributed to a soft feel. The analysis results indicated a tendency for the third factor, "light feel," to be perceived for low fractal dimensions.

From the calculations of fractal dimensions for canned beer package photographs and the results of the SD method, a high correlation was found based on Pearson's correlation coefficients for the descriptors "would like to buy," "delicious-looking," and "premium." Since a significant difference was detected between the high fractal group and the low fractal group for the terms "would like to buy," "delicious-looking," and "premium," canned beer photographs with high fractal dimensions should be perceived as being more desirable to buy, more delicious-looking, and of higher premium quality.

Although traditionally, resorting to subjective assessments such as the SD method used in this experiment would have been necessary to measure the good or bad aspects of product packaging, these results showed the feasibility of calculating the fractal dimension of such product packaging to obtain an objective index of such aspects.

Further research is required to gather data on a variety of product types and a broader range of ages and subjects most appropriately suited to the products being examined.

Acknowledgement

We thank Mr.Yu Toishi of the Oyama laboratory,Kwansei Gakuin University which cooperated with making of experimental data of Packaging.

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Appendix Fractal Dimension Estimations

The word fractal, introduced by Mandelbrot was used to describe the irregular structure of many natural objects and phenomena (Mandelbrot, 1977). Fractal geometry shows that nature exhibits a fundamental character generally known as self-similarity. This means, that however complex the shape and/or dynamic behavior of a system, by observing it carefully and imaginatively, one can find features in one scale which resemble those in other scales.

The fractal model of an imaged 3-D surface, including that of a digital photograph image, provides a natural description of most textured and shaded images. A defining characteristic of a fractal is that it has a fractal dimension. The fractal dimension of

an image gray-level intensity surface corresponds quite closely to our intuitive notion of roughness. To infer the fractal dimension of a 3-D surface from the image data, one method is to assume the gray level I(x) at pixel x changes according to a fractal Brownian function (Pentland, 1994). After some simplification operations, the following relationship is given for any displacement of Δx (pixel) within an image

$$E\left[\left|I(x+\Delta x)-I(x)\right|\right]\cdot\left|\Delta x\right|^{-H}=C\ , \qquad (1)$$

where E[ ] is the mean value when keeping Δx (pixel) fixed, and H and C are constants. By conducting logarithm operations on equation (1), we obtain the value of H as the slope of the regression line fit to log–log data. The fractal dimension D of the image surface is derived from

$$D = 3 - H. \qquad (2)$$

To simplify the calculation, two methods have been developed to easily and quantitatively deal with the imagery (Shimada et al., 2000). One of these methods, called the cubic method, infers the fractal dimension of the 3-D intensity surface from image data concerning covering processes at increased resolutions (2). Considering a cube, each edge of which is a pixel of size r, the number of cubes required to cover the surface of an image is N(r). Furthermore, if the relationship
exists with a constant C, then H gives an estimation of the fractal dimension of the image surface.

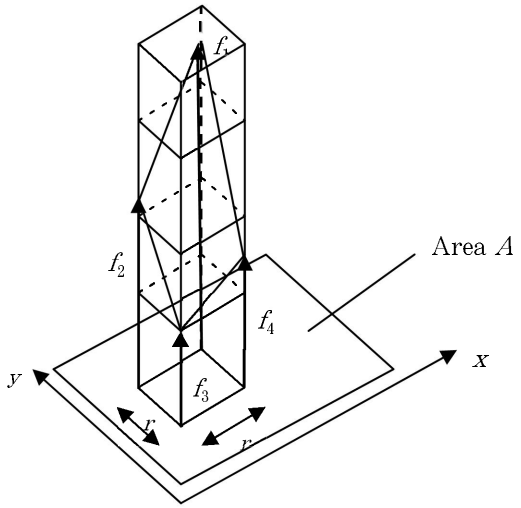
$$N(r)\cdot r^{H}=C \qquad (3)$$

Fig 5 shows an area A on which an image surface is assumed. Considering the volume unit of a cube of size $r\times r\times r$ and an area unit of $r\times r$ on A, if the surface portion above the area of $r\times r$ is completely covered by the cubes, the required number n(r) is

$$n(r) = floor\{\frac{\max(f_i) - \min(f_i)}{r}\} + 1 \quad (4)$$

In equation (4), the "floor" is the integer, and fi (I = 1, 2, 3, 4) are respective gray levels of the image intensity.

$$N(r) = < n(r) > \cdot (\text{area of } A) / r^2 \quad (5)$$



Figuew. 5 Estimation of the fractal dimension over image area A.

When the average value of n(r) over all of A is denoted as <n(r)>, the total number required to cover the image surface above A.

Finally, fractal dimension D is estimated by the regression fit to successive log–log data points of log10(r) vs. log10N(r), with increased sizes of r.

Another approach, called the area method, involves counting the number of area units covering an area, instead of the cubic units. This method calculates the fractal dimension representing the undulating complexity of the picture density by using a method to change the degree of coarse graining and a parameter-based model method:

$$H = \frac{-\log_{10}\left(\frac{E[F(at)]}{E[F(t)]}\right)}{\log_{10}\left(\frac{1}{a}\right)} \quad (6)$$

In equation (6), setting t to a fixed value and calculating the number of partitions by calculating the length unit of $E[F(a)]$ as 1/a, or calculating the number of surface partitions of the image density curved surface as the minimum area unit of $\frac{1}{a}\times\frac{1}{a}$, the above equation can be represented as $N(1/a)$. By setting $1/a = r$, equation (1) can be rewritten as

$$\log_{10} N(r) = -H \log_{10} r + \log_{10} N(1) \quad (7)$$

For images, the calculated value on the left side of equation (2) is dependent on r; thus, variability is normal. However, if the image is fractal in nature, linearity should be largely preserved.

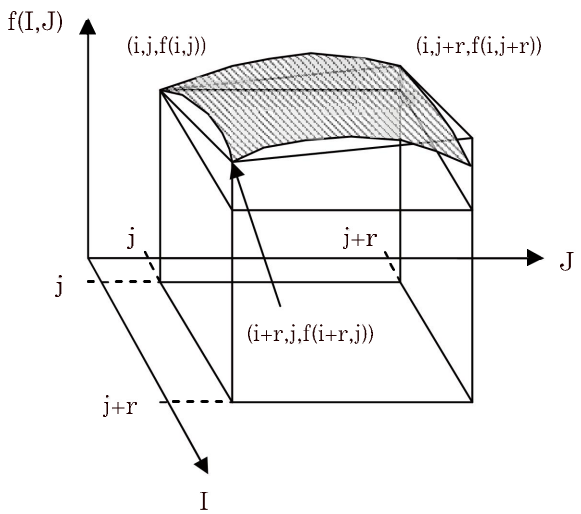


Figure. 6 Area approach to computing fractal dimensions.

In this way, fractal dimension H can be calculated by determining the slope of the regression line by the least-squares method for multiple sample values $(\log_{10} r, \log_{10} N(r))$, $(r = 1,2,\cdots)$; the obtained value can be used as an estimate for $-H$.

For two-dimensional objects such as images, setting the image density curved surface area, calculated using units with small areas such as $r \times r$, to $S(r)$, we obtain

$$S(r) = r^2 \cdot N(r) \tag{8}$$

Therefore, equation (7) can be rewritten as

$$\log_{10} S(r) = (2 - H)\log_{10} r + \log_{10} S(1) \tag{9}$$

Here, the surface area of an $r \times r$ small area density curve is a triangular area with twice the surface area shown in Figure 3 of $(i, j, f(i, j)), (i + r, j, f(i + r, j)), (i, j + r, f(i, j + r))$. By deriving the regression line slope by the least-squares method from multiple sample values of $(\log_{10} r, \log_{10} S(r))$, $(r = 1,2,\cdots)$, the estimated value $2 - H$ can be used to calculate the fractal dimension H.

This paper reforms what was published at the society report magazine of IEEE-SMC2008.