An Analytic Study of Architectural Design Style by Fractal Dimension Method

Kuo-Chung Wen, Yu-Neng Kao

***Abstract*—The design style form, is the different current thought and the local characteristic, the penetration idea but gradually develops into has the representative design form. One kind of typical style form usually is and the local humanities factor and the natural condition close correlation also must have in the creation the idea and the model characteristic. The style although displays to the form, but the style has art, the culture, the social development and so on the profound connotation, said from this in-depth meaning, the style does not equate to the form, therefore the design style embodiment is this research institute needs to go into seriously.**

***Index Terms*—architectural master, designing style, fractal dimension, architecture analysis**

I. Introduction

The style of the architecture exists in the form of the designing works, though unable to define clearly, appear in the works of different periods. What kind of pattern does its designing style have? This research hopes to analyze out the designing behavior of master's works of the architecture, and find out the possibility of the style in the form of probing into and designing further.

Theory of this research main application for fractal geometry theory. The fractal geometry theory the architectural design will analyze the fractal dimension value, again will induce respectively constructs the master its architectural design the fractal dimension, by this fractal dimension value took the design style classification the foundation, will penetrate this new style classified method, will discuss its design style classification the feasibility.

This research constructs in the history the different school of thought and the thought took the design style classification the basis, and designated design work the modern architecture master does for the research object, makes its work a specification processing, carries on the dimension computation by the fractal geometry theory, and induces the dimension value scope, establishes the dimension information bank.

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This research results includes: 1. Establishes the fractal dimension computational method, calculates the architectural design work the fractal dimension; 2. Constructs value of and the attribute information bank the construction modern architecture master work; 3. Establishes the fractal dimension relations matrix table analysis to classify of architectural design style pattern the modern construction history different master; 4. Proposed the fractal geometry theory analysis result with discusses its possible application

II. Fractal Theory

A. Fractal Geometry

Fractal geometry is the study of mathematical shapes that display a cascade of never-ending, self-similar, meandering detail as one observes them more closely. Natural shapes and rhythms, such as leaves, tree branching, mountain ridges, flood levels of a river, wave patterns, and never impulses, display this progression of self-similar form. Fractal concepts are being used in many fields from physics to musical composition. Architecture and design, concerned with the control of rhythm, can benefit from the use of this relatively new mathematical tool. The Fractal dimension provides a quantifiable measure of the mixture of order and surprise in arrhythmic composition. Fractal geometry is a rare example of a technology that can reach into the core of design composition [4, 5].

Architectural composition is concerned with the progression of interesting forms from the distant view of the façade to the intimate details. This progression is necessary to maintain interest. As one approaches and enters a building, there should always be another smaller-scale, interesting detail that expresses the overall intent of the composition. This is a fractal concept. Fractal geometry is the formal study of this progression of self-similar detail from large to small scales [5].

Broadly speaking, there are two ways that fractal concepts can be used in architecture and design. First, the fractal dimension of a design can be measured and used as a critical tool. As an example, the lack of textural progression could help explain why some modern architecture was never accepted by the general public. It is too flat. Second, fractal distributions can be used to generate complex rhythms for use in design. As an example, the fractal dimension of a mountain ridge behind an architectural project could be measured and used to guide the fractal rhythms of the project design. The project design and

the site background would then have a similar rhythmic characteristic. In both criticism and design, fractal geometry provides a quantifiable calibration tool for the mixture of order and surprise [5].

B. The Fractal Dimension

Each stage of the generation process for a fractal curve adds more length to the curve. A fractal curve generated through an infinite number of steps will have infinite length. The length of different fractal curves grows from one generation stage to the next at different rates. The rate of growth of the length of the fractal curve is the distinguishing feature of the curve. The central concept is that length and the size of the instrument used to measure it are related. The relationship turns out to be a power law [4]:

$$(y) \text{ is proportional to} (x)^{d} \quad (1)$$

This law is also important to the definition of dimension. In mathematics there are many definitions of dimension in relation to a particular problem type. To understand fractal concepts, one needs to be familiar with three of theses dimension definitions:

Self-similarity dimension (Ds)
Measured dimension (d)
Box-counting dimension (Db)

All these dimensions are directly related to Mandelbrot's fractal dimension (D). For the purposes of the design concepts presented in this book the self-similarity dimension (Ds) and the box-counting dimension (Db) are equivalent to Mandelbrot's fractal dimension (D). The measured dimension (d) is related to Mandelbrot's fractal dimension by the equation (D=1+d). The discussion of these dimensions that follows is based on the explanations found in *Chaos and Fractals [8]*.

C. Box-Counting Dimension (Db)

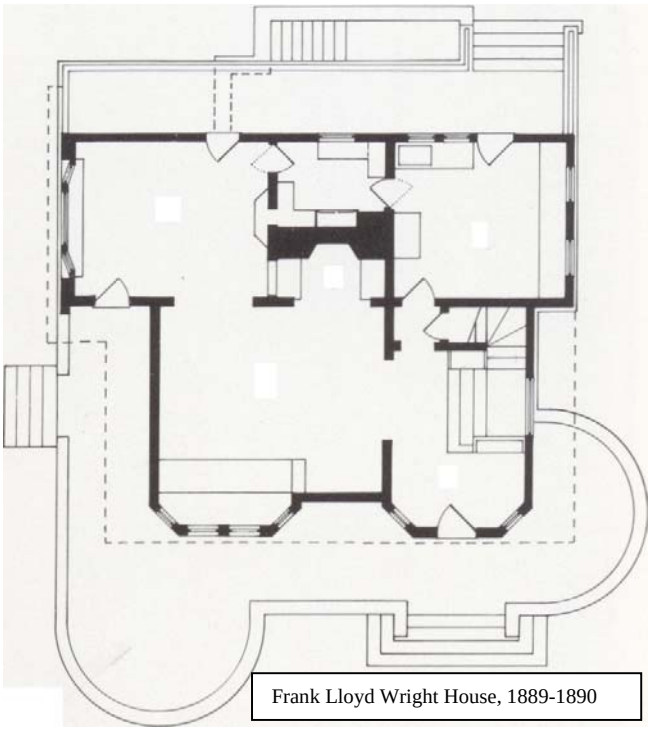
The box-counting dimension is a systematic extension of the measured and covering dimensions. It is produced in the following manner. Superimpose a grid of square boxes over the image in question. The grid size is given as (s). Count the number of boxes that count the resulting number of boxes that contain the image. This will result in a number of boxes N(s). Repeat this procedure, changing (s) to smaller and smaller grid sizes, and count the resulting number of boxes that contain the image N(s). As in the measured and covering dimensions, the next step is to plot log [N(s)] versus log (1/s) on a log-log diagram. The slope of the straight line that best represents the data is an estimate of the box-counting dimension (Db). The slope of the line (Db) is given by the following formula:

$$Db = \frac{[\log (N(_{S2})) - \log (N(_{S1}))]}{[\log (1/_{S2}) - \log (1/_{S1})]} \quad (2)$$

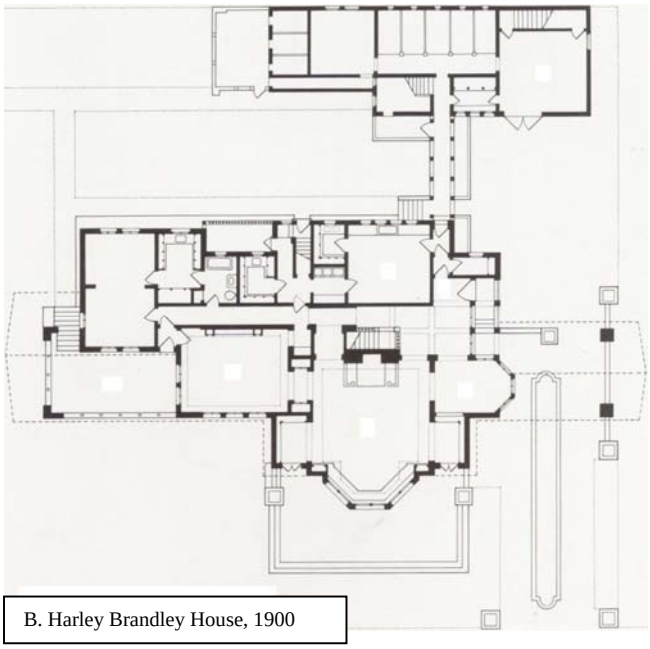
III. FRACTAL-BASED IMAGE PROCESSING

A. Images

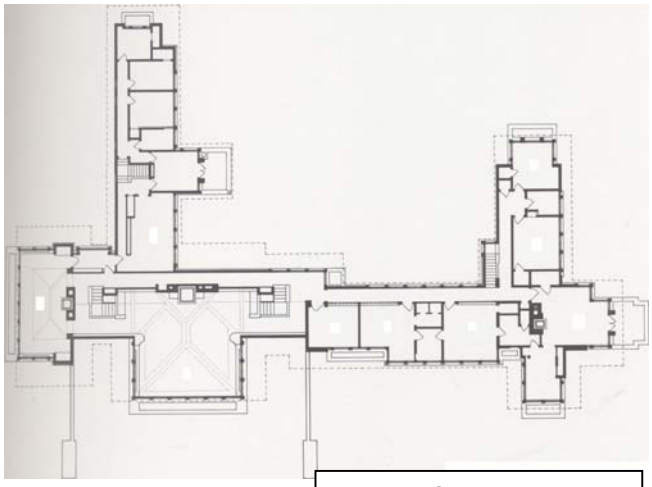
This research chooses three modern architectures master's work, and takes a housing building plane as research object. The modern architectures master [10] is Frank Lloyd Wright[1,2,3,6], Le Corbusier[11,13,14] and Mies van der Rohe[9,17,19,20,21].



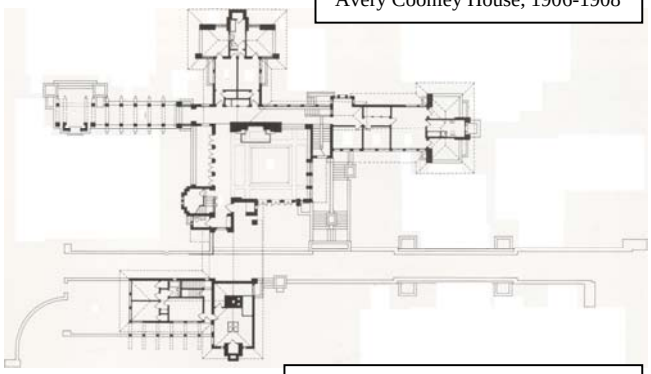
Frank Lloyd Wright House, 1889-1890



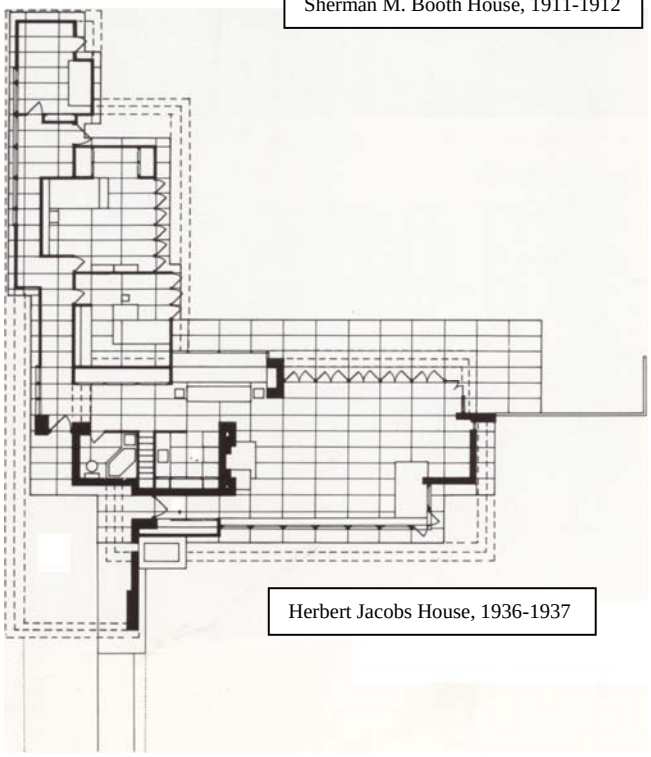
B. Harley Brandley House, 1900



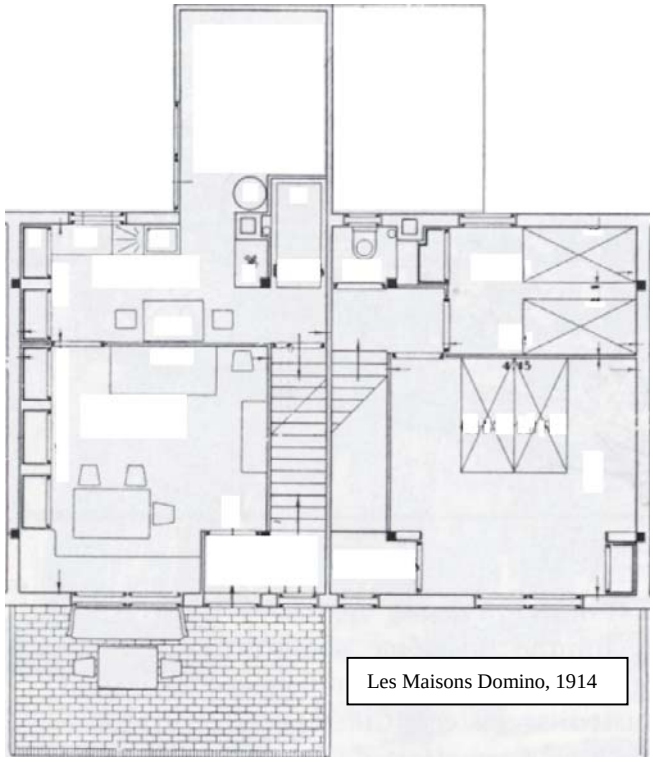
Avery Coonley House, 1906-1908



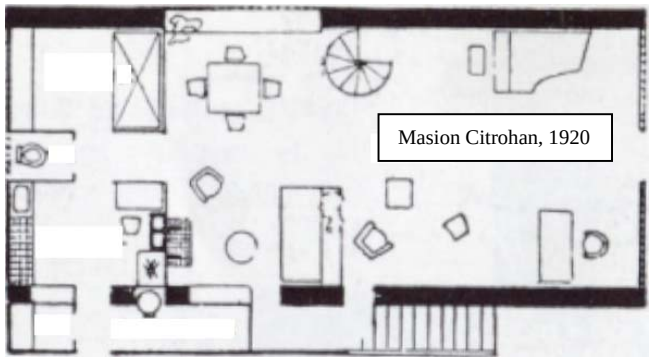
Sherman M. Booth House, 1911-1912



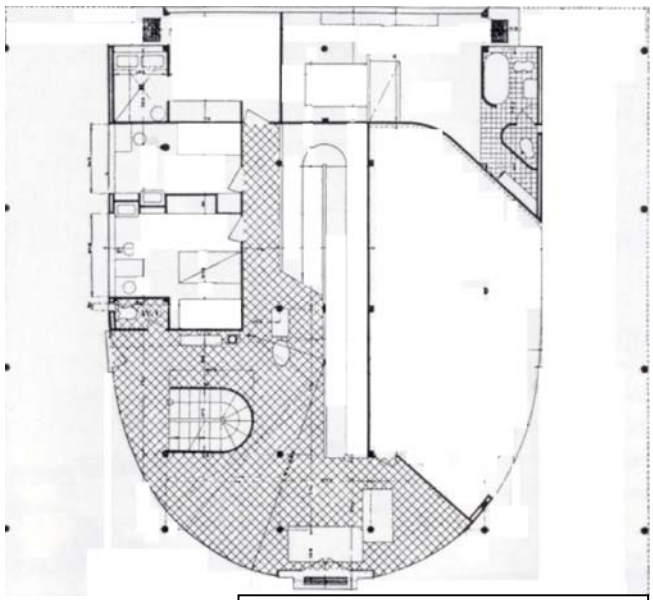
Herbert Jacobs House, 1936-1937



Les Maisons Domino, 1914

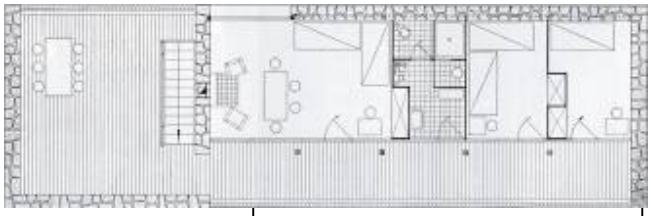


Masion Citrohan, 1920

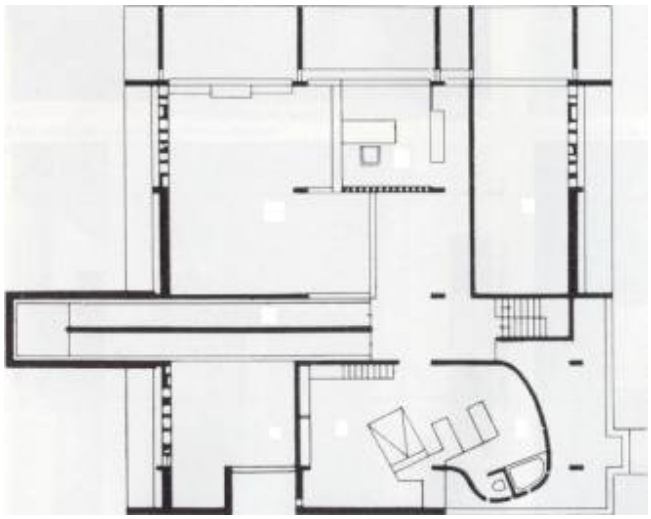


Maison Savoie a Poissy House, 1929-1931

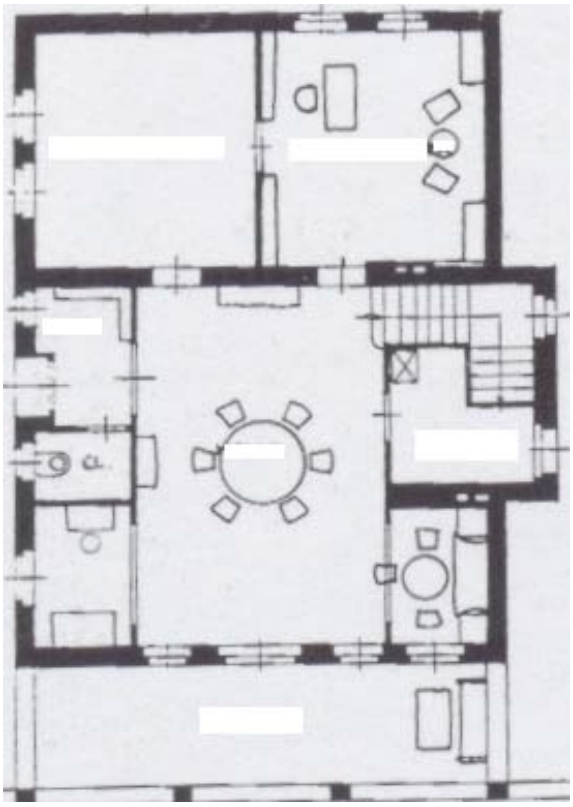
Fig. 1. housing design work images of Frank Lloyd Wright



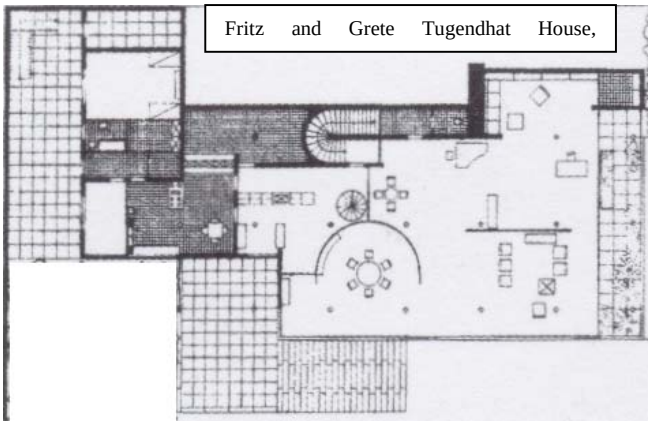
Maison aux Mathes(Ocean) House , 1935



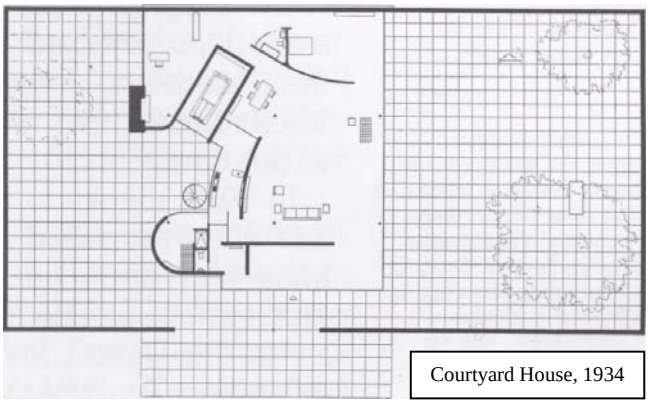
Villa Shodan a Ahmedabad House, 1956



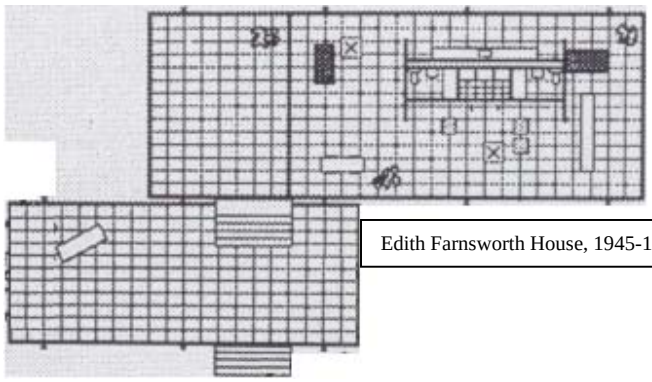
Alois Riehl House, 1907



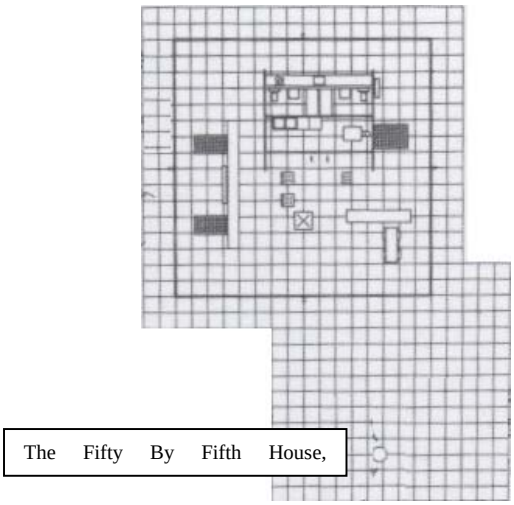
Fritz and Grete Tugendhat House,



Courtyard House, 1934



Edith Farnsworth House, 1945-1950

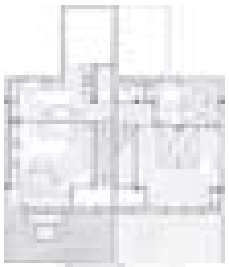
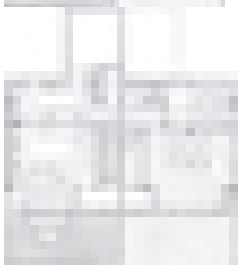


The Fifty By Fifth House,

Fig. 3. housing design work images of Mies van der Rohe

B. Using the Box-Counting Dimension

TABLE I
BOX COUNT FOR THE LES MAISONS DOMINO HOUSE PLANS

Scale	Images	Db
S1:1		
		D(s1-s2)=1.791
S2:1/2		
		D(s2-s3)=1.749
S3:1/4		
		D(s3-s4)=1.907
S4:1/8		
		D(s4-s5)=1.876
S5:1/16		
		D(s5-s6)=1.878
S6:1/32		

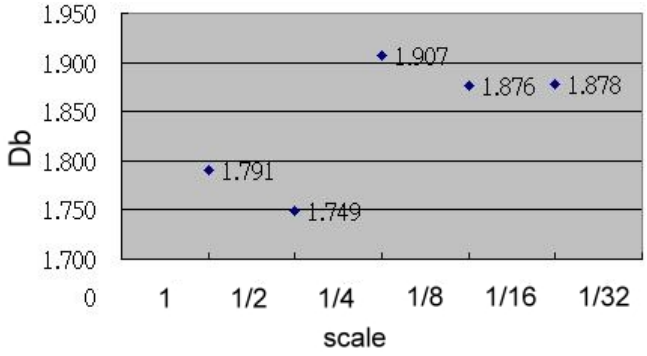


Fig. 4. fractal dimension comparison

V. RESULTS AND DISCUSSIONS

A. The Information Bank Establishes

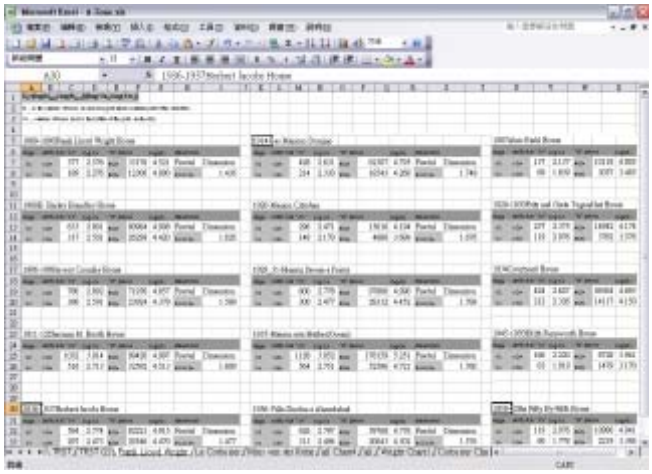


Fig. 5. fractal dimension data bank

B. Fractal Dimension of the Master's work

Frank Lloyd Wright's fractal dimension value is average. The fractal dimension value is lower in beginning and ending.

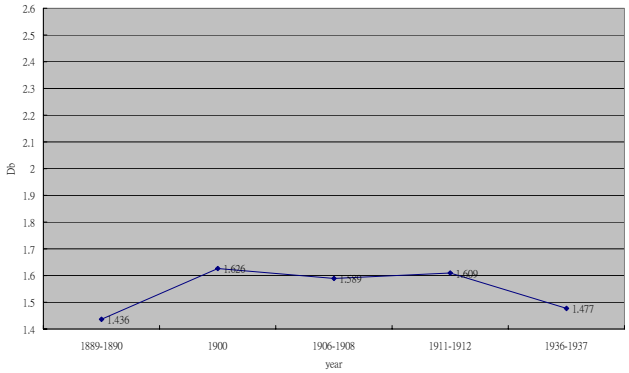


Fig. 6. the fractal dimension of Frank Lloyd Wright's work

Le Corbusier's fractal dimension value is average. The fractal dimension value is lower and lower.

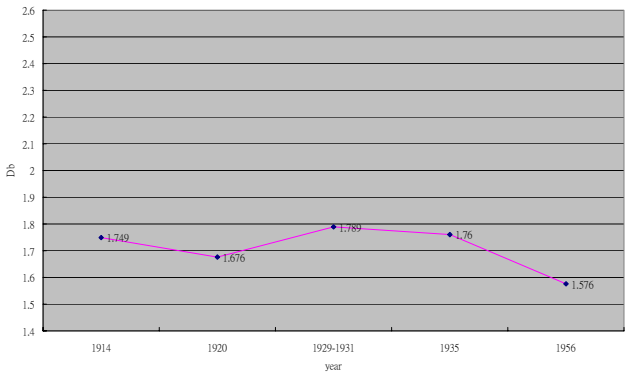


Fig. 7. the fractal dimension of Le Corbusier 's work

Mies van der Rohe's fractal dimension value is not average. The fractal dimension value is higher and higher. Then, the fractal dimension value is over 2. This doesn't conform to the fractal rule.

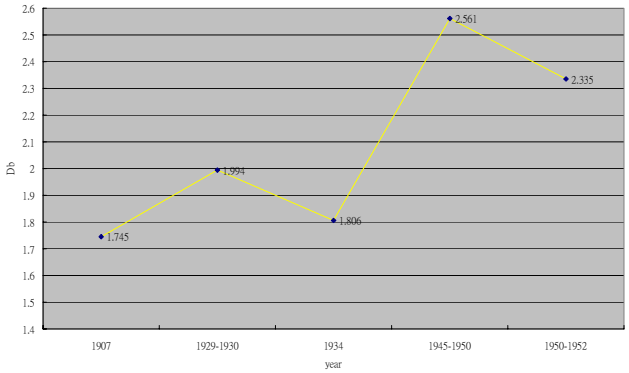


Fig. 8. the fractal dimension of Mies van der Rohe 's work

C. Comparison of the Fractal Dimension of the Master's work

Mies van der Rohe's fractal dimension value is higher. Le Corbusier's fractal dimension value is medium Frank Lloyd Wright's fractal dimension value is lower.

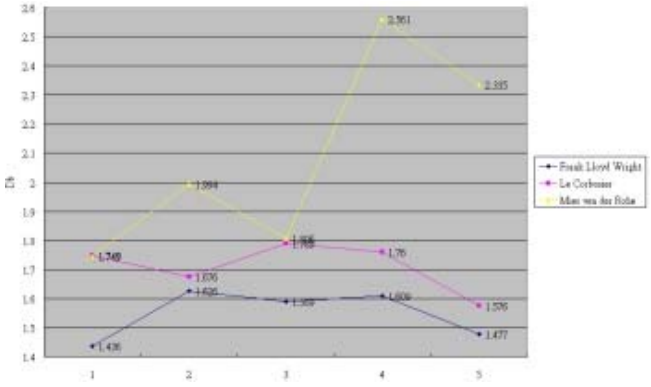


Fig. 6. comparison of the fractal dimension of the master's work

VI. Conclusion

In this paper, we have developed an approach to style classification from image and fractal. Consider what the fractal analysis of the building plan. Frank Lloyd Wright, Le Corbusier had an amazing range of design implementation. Their work conforms to the fractal rule, may use this work to take the style the classified basis.

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