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The Theory of Biomedical Knowledge Integration (Ⅶ)

── The Non-Euclid Macro-Micro Transform Law

Hanfei Bao

Lab of Informationization and Standardization of TCM
Shanghai Univ. of Traditional Chinese Medicine
Shanghai, China, bhf2002@online.sh.cn, bhflhl@yahoo.com.cn

Abstract This article continued to do the scholastic pursuits on some profound mechanisms in the life systems, which are believed to be related to the further development of Medical Informatics. It discussed at first the structural nature of things, then probed a principle which is a basis for both of the fractal theory and the wavelet analysis, being called the shape-constancy law of the basic constructors at the different scale levels. And the paper also ventured the equivalency between the shape of wave and matrix, thus presented a new concept "***shaped-number***", being expected to work in the operations of some bio-medical functions or shapes.

Keywords BioMedical Informatics, Artificial Intelligence, the Theory BioMedical Knowledge Integration, Fractal Theory, Wavelet Analysis

The Theory of BioMedical Knowledge Integration (BMKI)[1-19] focuses on the integration or networking of the various bio-medical knowledge in many different fields and is quite imaginably facing to many deep-hidden basic mechanisms or meta-mechanisms, which is believed to be related with the development of BioMerdical Informatics. Thus the systematical and radical reconsiderations of the basic principles in Bio-Medicine are absolutely required in Information Era. That might be one reason why BMKI has been involved in a series of new probes theoretically and methodologically from its first stage.

1. Structure and Medicine

The law of movement-stillness relationship of the never-stopped beating hearts hardly follows the Newtonian Mechanics $(x, y, z) = f(t)$. The concept of stillness of a heart in the sense of the Newtonian Mechanics means death in Bio-medical Mechanics. The continuously and rhythmically heating means the existence or nature of a living heart, being its normal and stable state. In another word, the never-stopped beating of a heart could be interpreted as “stillness” or “relax status” in cardio-physiology, just looking how happy or how relax an energic dog is when being set free out of the door..

Very like the shape of heart beating, many biomedical mechanisms have their own basic or intrinsic constructors or morphologic units and they are also the essences of those things. In a certain sense, these morphologic units can be regarded as the results of some kinds of inertial motions.

The traditional medicine observes and measures, in many situations, the concentrations of substances, and perhaps we can call it “numerical medicine”. But the most cases in biomedicine face to the normal, abnormal, dynamical, static or potential unit structures or constructors, including macro-, micro- and even molecular-anatomy, such as cell-, DNA-, heart-, menstrual-cycle, blood vessel tree, bronchus tree, protein-complex, protein-network, the regulation loop of the thyroid gland hormone, etc.

Obviously we have not so far the powerful tools of Informatics and Mathematics to deal with those structures. Then how we can operate on those structures or shapes? Can those structures be reduced into the particles smaller and smaller endlessly, as we do on the real number axis? Can we make “numerical medicine” being transformed into “structural medicine”?

2. The Theory of Dimensionality

(1) The dimensionality

So called dimensions in the sciences might be, in many cases, regarded as a kind of “freedom” of the factors or generalized forces. They can act in simple, multiple-and-independent (or orthogonal) and multiple-and-dependent (interrelated or combined) ways.

There are usually mutual relations between the dimensions. Some dimensions may prompt, counterwork, or restrain the other ones. For example, a crowd of literary tools on the table may be scattered about ***freely***, but when they were put into a schoolbag and the “freedom” of scattering has been stopped, because a certain dimension of the schoolbag does against the “freedom”. In fact, the restrain mechanism or blocking mechanism between the dimensions plays the important roles in the organization or self-organization of a variety of things, especially organisms, such as the mechanisms of cell membrane, the walls of blood vessels and stomach, pericardium, ……

Then what is the measurement of dimension or the dimensionality?

As we known, if a line segment has been split into two, then the number of segment equals two (1×2^1) ; if a side of a square has been split into two, then the number of square equals four (1×2^2) ; if a side of a cube has been split into two, then the number of cube equals eight (1×2^3) . Thus the measurements of dimension for line, square and cube are 1,2 3, respectively. They are so called integral dimensions.

The concept of measurement of dimension thereby is generalized by the scientists of the Fractal Theory: "If a graph is composed by a^D pieces of similar graphs which are created by reducing the original graph by 1/a times, the D is the measurement of dimension or dimensionality."[24]

That is called ***similarity dimensionality*** by the scientists in the Fractal Theory. The ***similarity dimensionality*** is defined as $D=\log b/\log a$, where a is the proportional scale for reducing and b the number of the smaller units consequently. Herewith we may see that dimensionality can be thought as movement feature of the number-change of the smaller units following the macro-to-micro ratio-change.

Additionally, dimensionality may be taken as a measurement of a dimension-composition, such as the integer dimensionality reflects the ***jointly-and-independently-composition*** of several homogeneous or equivalent dimensions or the characterization of a certain dimension-composition-style.

From above viewpoint, Euclid space and its generalizations reflect the ***jointly-and-independently- composition*** of several real number axes (the "homogeneous or equivalent dimensions"), as mentioned above.

Accordingly so called generalized n-dimensional spaces or victor spaces in many mathematics are usually not integer dimensionality in nature, even if those dimensions are independent or orthogonal (not the case mostly although) , because they are usually not homogeneous. Thus imaginably, in the most biomedical systems the dimensionalities are much far from the ideal or integral ones. If these physical parameters are non-independent, then the dimensionalities of those spaces are almost impossible to be integral ones.

If we can get a non-integral dimension rather stationary in the macro-micro course by a scale-to-count relation, then we call the dimensionality fractal.

(2) The Fractal Theory

The term "Fractal" was presented by B.B. Mandelbrot in 1975, originating from Latin word "fractus", meaning irregular status. [24]

Koch curve is often used to show the phenomenon of fractal. If the scale (eg the power of a microscope) having been magnified by 3 times, then the multiplication of the number of constructors or details is by 4, ie $3^{\log_3 4}$, thus the measurement of dimension of Koch curve is $\log_3 4$, the value is 1.2618…(see Fig. 1).

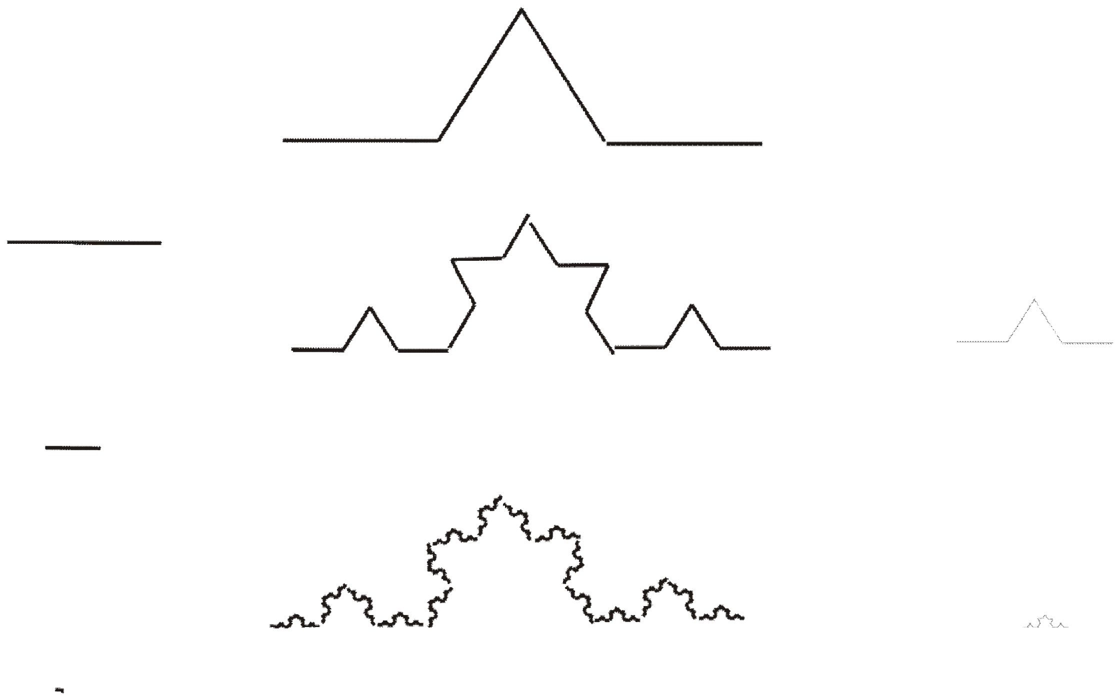

Fig. 1 Koch curve: the left showing the course of the scale movement, and the right showing the course of the number-of-constructor movement.

(3) The Characteristic Pattern and The Differentiability

The diameter of the earth or blood vessels etc have been taken as the measurement of characteristics by the fractal scientists: when the scale (a macro-micro relationship) reaching a certain level, those non-characteristic feature will lose their significance, whereas the characteristic ones remain prominent. For example, the surface of the earth is, in fact, not smooth because there are mountains, oceans, rivers, lakes, …… But if we minimize the scale to some degree, say a football, the diameter of the earth becomes the unique feature, and the surface of it becoming smooth, or so called being anywhere differentiable (never changing suddenly).

Now we turn to Koch curve and can easily see that there is no the measurement of characteristic feature. Regardless how you change the scale, it would be never smooth or being anywhere differentiable.

When we talk about the differentiability of things, in fact, we never leaves the real number axis, because in our brain or ideal logic, forever the point is splitable and forever the number movement such as 0.1, 0.01, 0.001,…… exists. But when taking Koch curve in account, we can not help changing our view completely, namely, to change our ***viewpoint*** to ***view-constructor***, and try to find another "anywhere differentiability" based on constructors rather than on point, as traditionally.

The constructor-features or fractal features exist widely, especially in a variety of life systems or organism, because where the dimensions mostly run jointly rather than independently. Besides, we may spread the meaning of macro-micro movement from spatial scale to temporal one, eg prolonging sampling interval of time, or even to population scale, such as to see the behaviors of objects of the populations 100, 1000, 10000,⋯⋯

But, of course, if we try to observe the behaviors or characters of the complexes of different size, constituted by the components of different number and different natures, that should be perhaps another story.

3. The Fractal Basis of Wavelet Analysis

(1)the principle of wavelet analysis

The essential point of Fourier Transform is considering that any shapes of signal may be decomposed into a series of sine or cosine waves. In other words, any signal is composed by or can be reduced to a series of unit functions, rather than by or to unit particles in oscillation as traditionally. But the waves such as sine and cosine are non-compact support functions, extending to infinity in both directions and being non-zero over the entire domain.[25] That means Fourier analysis, based on the global distribution of frequency of a signal, can not characterize the "local behavior" of a signal and therefore is not suitable for the non-stationary signal, where sometimes full of the local features.

The same as Fourier Transform, Wavelet Transform or analysis holds also the viewpoint that any signal might be reduced to a series of unit functions, but it distinguishes itself from Fourier Transform by being based on compact support functions or "mother" wavelet function, *viz* being non-zero in limited domain only. The "mother" wavelet functions might be changed by means of scale and translation into the "working" wavelet functions. In fact, the sine waves or cosine waves may approximatively be taken as "mother wavelets" being ready to be shifted and scaled to form the working "wavelet" [21].

(2) The concept of wavelet function[23]

Assuming $L^2(R)$ be an integrable space for the square of a dimension and we have a function $f \in L^2(R)$. The basic part or less-variable part of the function f may be similarly expressed by a scaling function $f(t)$. $f(t)$ may be regarded as a filter of f, ie the low-pass filer. As the author's understanding, one may think of it as a shaped-divider, and the original function f as a shaped-dividend, imagining there being a division operation between two wave shapes instead of two traditional numbers. Let another function or wavelet function $y(x)$ represent the filter of the detailed part or more-variable part of the function f, called high-pass filter. Thus the wavelet function $y(x)$ is a shaped-divider for the detailed part of f.

Fig 2 shows the most simple orthogonal wavelet mother function Haar wavelet mother function, presented by Haar in 1910. From Fig. 2 it is very plain to see the way how the shapes of filters are transformed into their number forms or the matrixes.

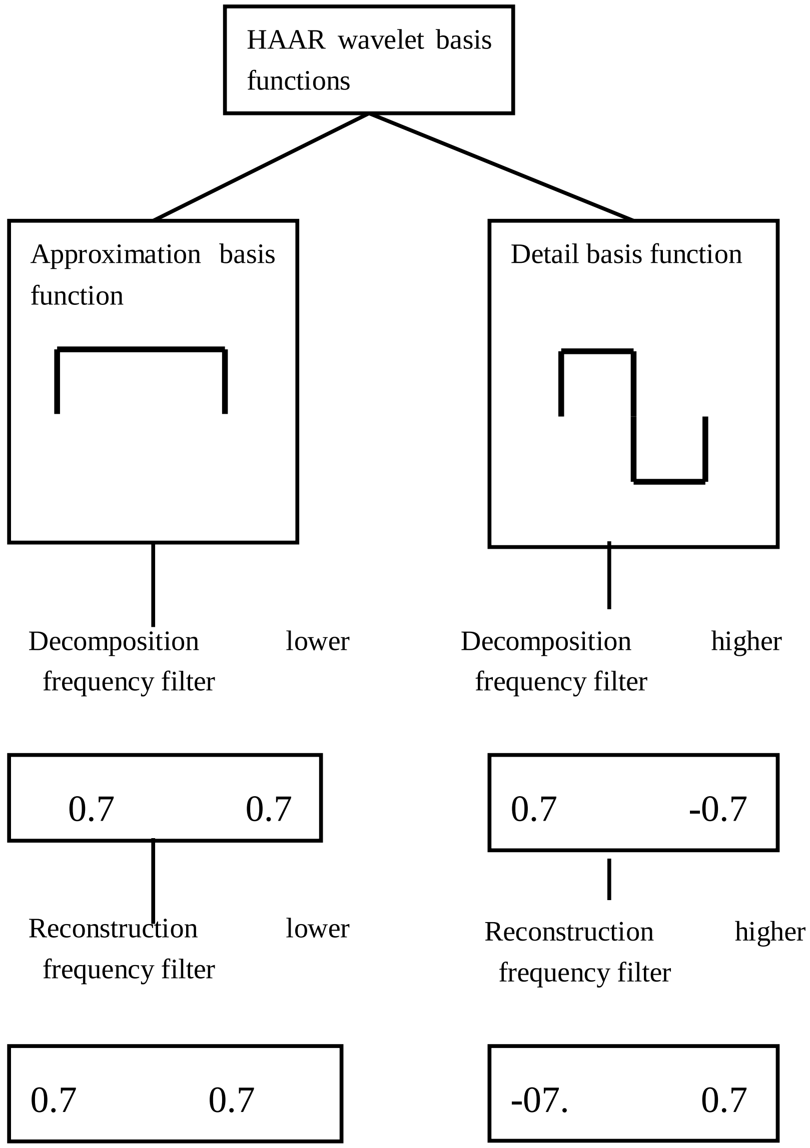

Fig.2 The wavelet filters can be transformed to the digital forms (matrices here) matching to the shape of the functions, ie approximation basis function and detail basis function.

4. The Common Basis of Fractal Theory and Wavelet Analysis

Both wavelet analysis and fractal theory reveal the same macro-micro relationship: the structure-reducibility (rather than particle-reducibility as traditional) . They share also a common principle, that is, for some objects or processes, there is the shape-unformity of their constructors at different scales. The only difference between them is that the constructors in wavelet analysis are from a set of given mother wavelets, got by "occasional or empirical" way as said, whereas those in the fractal theory, in princile at least, extracted out of the original signal at different scales. But, of course, as presented above, many fractal examples are in fact made artificially.

Fig. 3 dipicts an fictitious instance of wavelet analysis provided by Internet[22] . In the picture, one can see the uniformity of the shapes of the constructors of both the approximation function at the left and detail function at the right at different scales.

Fig 4 shows the steps of macro-micro movement of Koch curve, which is similiar to that in Fig. 3, and it can be clearly seen that the "smooth part" at the left and the "rough part" at the right of Koch curve are correspoding to the approximation function and detail function of wavelet analysis shown in Fig 3, respectively.

5. Matrix: A Throwback of Number

If in the history of the civilization of human being, the concept of number were extracted from the size, shape, etc of the various original or natural things, the matrix might be, as the author's personal view, considered as throwback of the number, ie going back and more close to the nature. Matrix is a very special calculating object, being an complex of value, site, location, relationship (self-reversal, forward-backward, whole-part, etc). It is taken in this paper as the generalized number, serving as the implementor or operator of ***structured-number*** or ***shaped-number***. It is believed by the author that matrix may act as an important role for ***structured-number*** or ***shaped-number***, as it did a great job in the history of the foundation of the Theory of Quantum Mechanics.[20]

Let't look at here the above mentioned instance of wavelet analysis presented in Internet[22], which processes and split a signal [90 70 100 70] into lower-frequency part (the essential part) and higher-frequency part (the variable part) . The processes may be described as following steps: (1) take the average of the sum of 90 and 70, remaining others unchanged; (2) take the average of the sum of 100 and 70, remaining others unchanged; (3) take the average of the difference of 90 and 70, remaining others unchanged; (4) take the average of the difference of 100 and 70, remaining others unchanged. The result is [80 85 10 15]. Then repeat the processes after the same principle and get the last result [82.5 -2.5 10 15].

The previous steps may be completed by a matrix multiplication. To more plain, the author gave the all details of the multiplication course to the visualize the matching between the "shapes" of matrix (as shown graphically) and the shapes of wavelet basis functions, ie the approximation basis function and the detail basis function.(see Fig 2)

$$[90 \quad 70 \quad 100 \quad 70]\times\begin{bmatrix} 1/2 & 0 & 1/2 & 0 \\ 1/2 & 0 & -1/2 & 0 \\ 0 & 1/2 & 0 & 1/2 \\ 0 & 1/2 & 0 & -1/2 \end{bmatrix} =$$

[90×(1/2)+70×(1/2)+100×0+70×0 90×0+70×0+100×(1/2)+70×(1/2) 90×(1/2)-70×(1/2)+100×0+70×0 90×0+70×0+100×(1/2)-70×(1/2)] =[80 85 10 15]

$$[80 \quad 85 \quad 10 \quad 15]\times\begin{bmatrix} 1/2 & 1/2 & 0 & 0 \\ 1/2 & -1/2 & 0 & 0 \\ 0 & 0 & 1 & 0 \\ 0 & 0 & 0 & 1 \end{bmatrix} =$$

= [80×(1/2)+85×(1/2)+10×0+15×0 80×(1/2)+85×(-1/2)+10×0+15×0 80×0+85×0+10×1+15×0 80×0+85×0+10×0+15×1] = [82.5 -2.5 10 15]

6. How to Get the Shaped-Number for A Signal

The Author presented here a course to get a ***shaped-number*** of a particular signal:

(1) taking a as the scale, sampling signal and getting s_1 from the original signal;

(2) $s = s + s_1$,($s = s + s_1$);

(3) choosing the detailed or variable area v_a from s_1;

(4) taking a/p as the scale, sampling signal and getting s_2 from v_a;

(5) magnifying s_2 by p and getting s_2', adding s_2' to s synchronously : $s = s + s_2'$;

(6) choosing the detailed or variable area $v_{a/p}$ from s_2;

(7) taking a/p^2 as the scale, sampling signal and getting s_3 from $v_{a/p}$;

(8) magnifying s_3 by p^2 and getting $s_3^{'}$, adding $s_3^{'}$ to s synchronously : $s = s + s_3^{'}$;

…………

(9) choosing the detailed or variable area $v_{a/p^{n-2}}$ from s_{n-1};

(10) taking a/p^{n-1} as the scale, sampling signal and getting s_n from $v_{a/p^{n-2}}$;

(11) magnifying s_n by p^{n-1} and getting $s_n^{'}$, adding $s_n^{'}$ to s synchronously : $s = s + s_n^{'}$;

(12) taking the average of s as ***shaped-number***: $N_s = s/n$, in many cases, N_s could be taken as the characteristic shape or pattern of the diseases;

(13) transform N_s into the ***shaped-number-operator***, such as the wavelet coefficient N_m, based on satisfying certain prerequisites;

(14) applying N_m to process signal for a variety of purposes.

Again take Koch curve as an example to depict whole course stated above(see Fig 5).

7. Non-Euclid Macro-Micro Transform Law in Biomedicine

About the so called Non-Euclid Macro-Micro Transform Law, the brief descriptions were given bellow:

（1）In many cases of the organisms, it might go to a nonsense for a macro-micro movement under the meaning of traditional particle, but it might make sense under the meaning of structure (see Fig. 6).

（2）Such macro-micro movements might be non-integral and fractal, very often.

（3）Non-Euclid macro-micro transform laws in organisms are determined by the mechanisms of space formations. Contrast to Euclid space and its gener alized ones, many biological spaces are made by the non-symmetrical or non-o rthogonal compositions of heterogeneous dimensions rather than by the symmetr ical or orthogonal compositions of homogeneous dimensions.

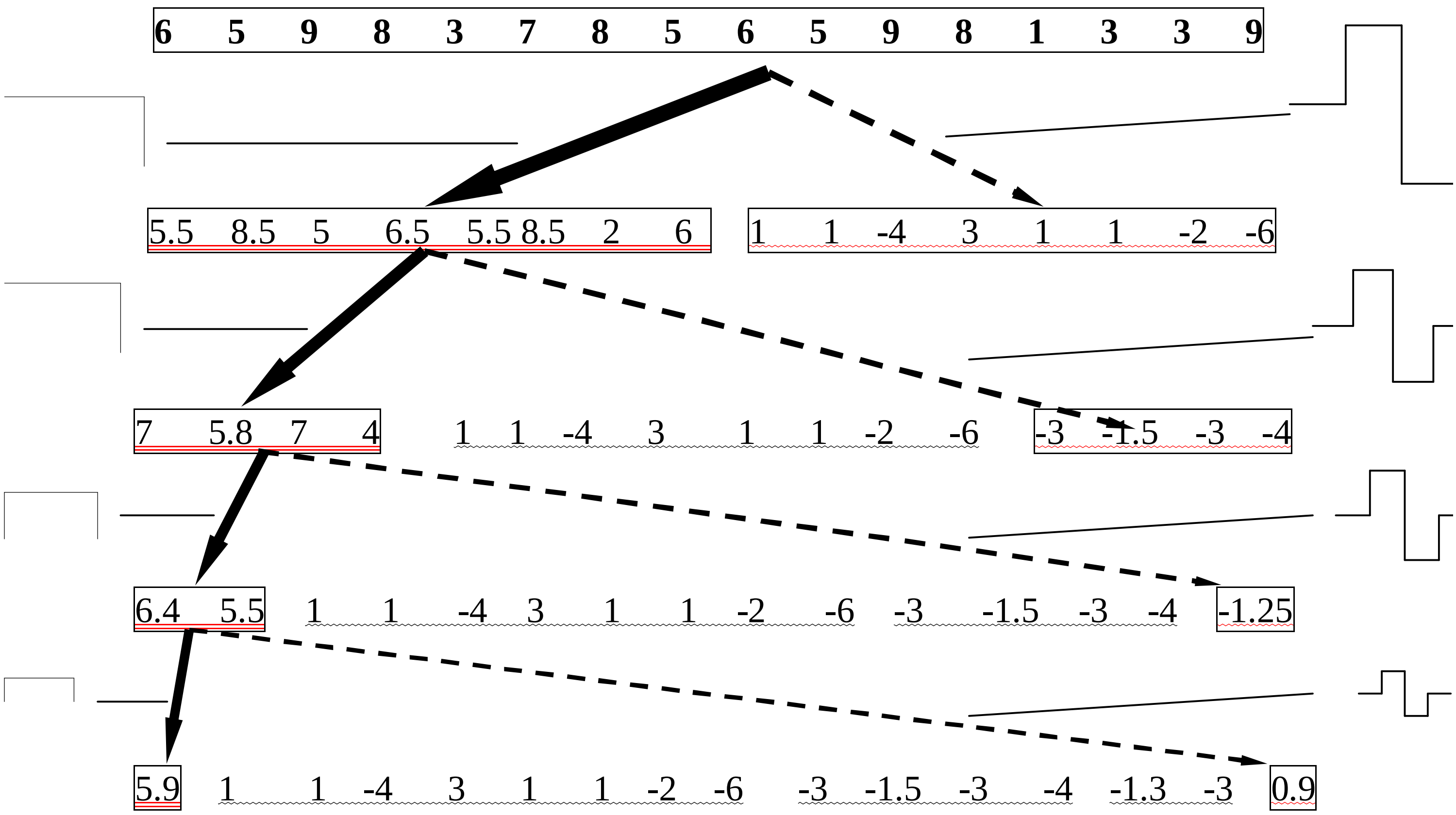

Fig. 3 the process of multi-resolution analysis of wavelet transform: the original signal at the top, the thick solid arrows for getting the "approximation" part of the signal, and the thin dotted arrows for the "detail" part. Haar "approximation" basis function at the left and Haar "detail" basis function at the right.

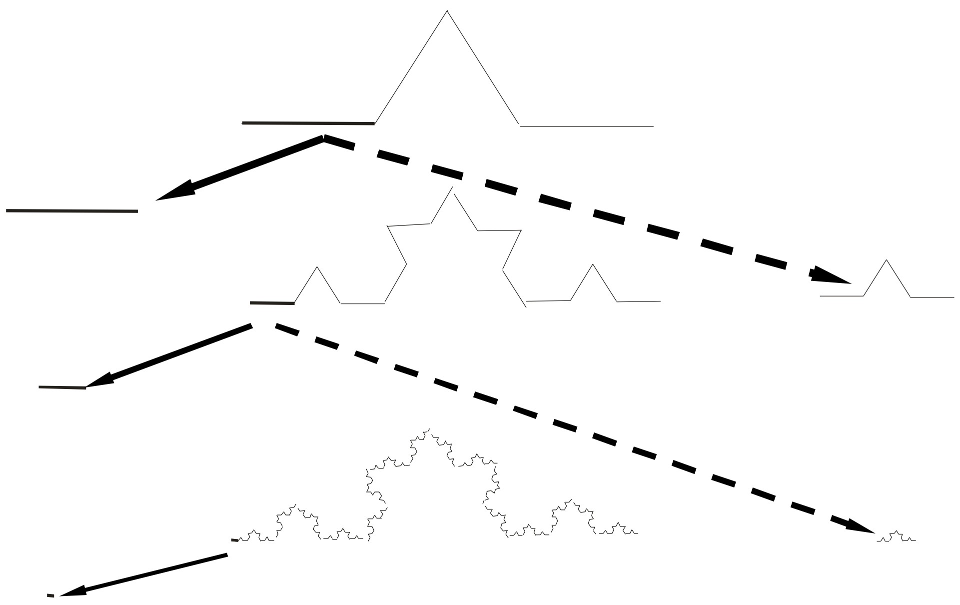

Fig 4 The scale or smooth parts at the left and the detail or rough parts at the right of Koch curve in fractal analysis, corresponding to the Haar “approximation” basis function and Haar “detail” basis function at Fig. 3.

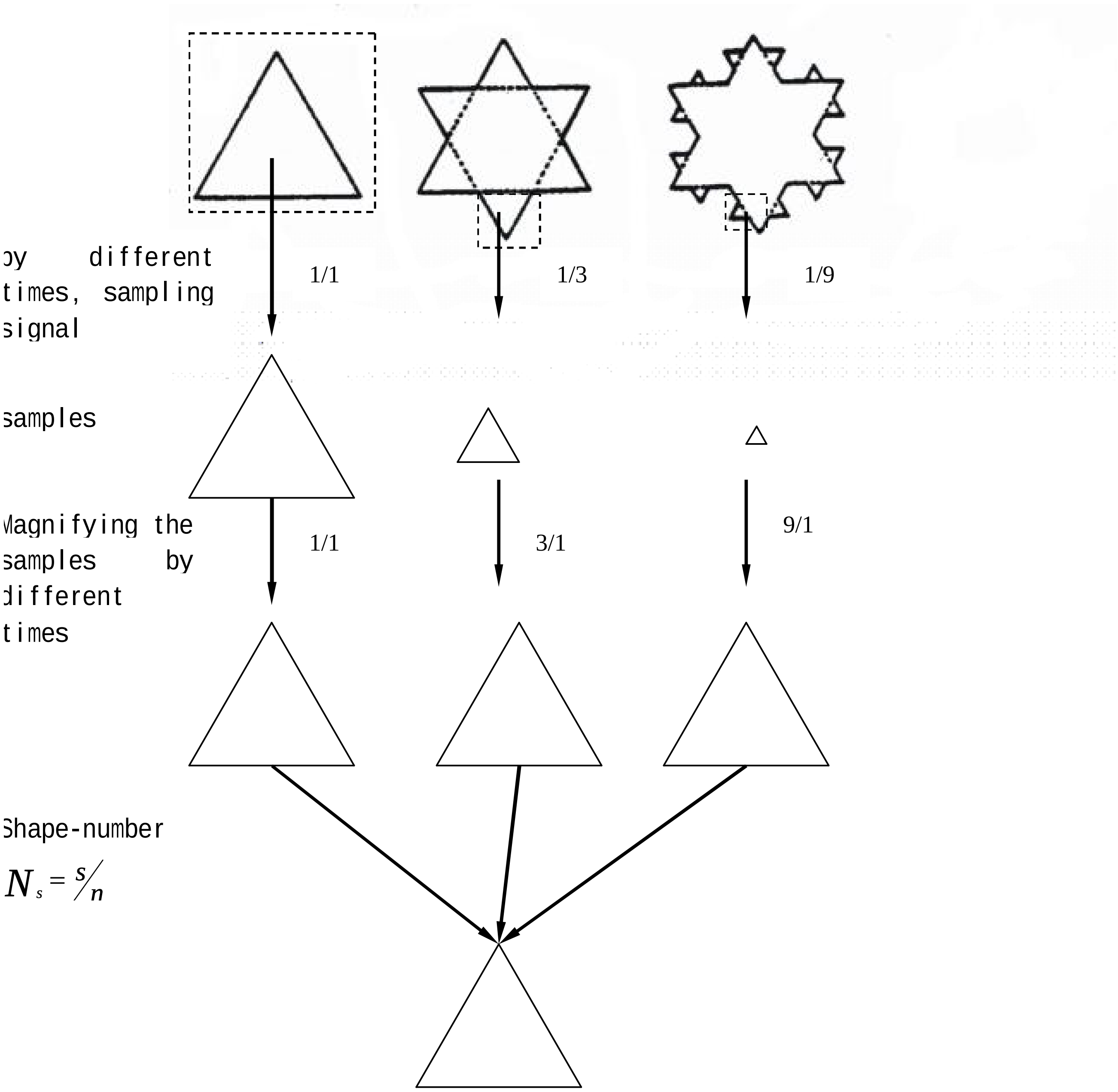

Fig 5 A diagram taking Koch curve as an example to show the processes of creating a ***shaped-number*** for a particular structure or signal: taking the samples on different scale, magnifying the samples on corresponding scale conversely, choosing the detailed area, getting the sum of the processed samples and reaching the average or the ***shaped-number*** of that structure, ie the characteristic shape of it.

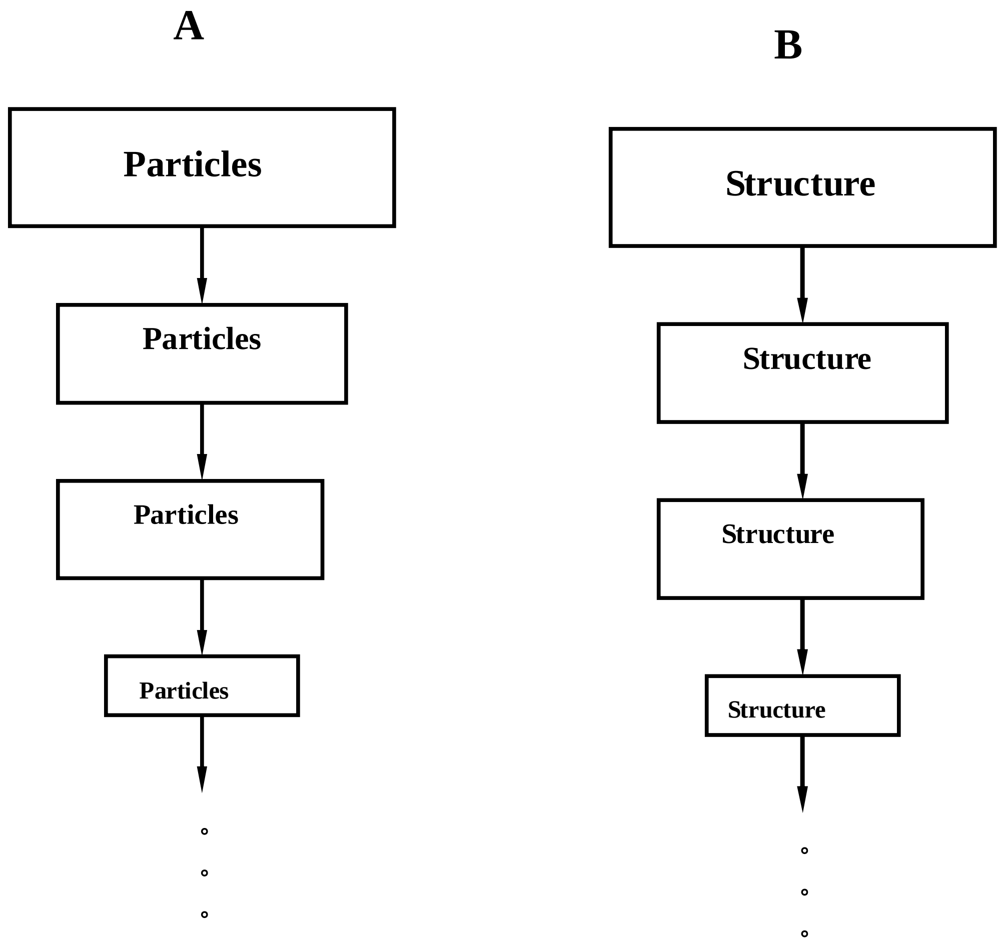

Fig 6 a diagram of Euclid Reductionism(A) and Non-Euclid Reductionism(B), the former is reduced into particles(entity, relation or event), and the latter into structures.

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