

# Exploration of fractal and chaos logics based on universal logic \*

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**Abstract:** Opinions that people think about the nature are basically changing, that is to say, turning to multimode, temporality and complexity. Fractal and chaos are sunrise sciences, which research nonlinear natural system. This paper mainly analyzes the basic characteristics of fractal phenomenon and chaos system, expatiates on the correlation of fractal, chaos and universal logic, fully discusses the necessary and probability of setting up fractal logic and chaos logic, and gives the compendium of fractal logic and the way of the implementing of chaos logic. The paper raises: a). Along with the fact that people search after the order of nature more and more thoroughly, the naissance of chaos logic and fractal logic is not only the inevitable production, but also the objective requirement for continuing to do that. b). The principles of universal logic offer the formal frame and the producing rules for establishing the architecture of a concrete logic system, and this makes it possible to set up fractal logic and chaos logic. c). Fractal and chaos logics will play an important and positive role in researching complicated system, and gradually consummate themselves in the applications.

**Key words:** universal logic; fractal logic; chaos logic; nonlinear sciences

## 1 Background

Logic is the science about forms and rules of right thought. The target of logic contains formal logic and dialectical logic, the purpose and task about right thinking, and the significance of logic for science and practice activities<sup>[1,2]</sup>. Such is that, and it is important to know the purpose of logic. It can help us to understand the question “Why do set up fractal logic and chaos logic” in the following content.

### 1.1 The characteristics of classical logics

Here the classical logics include two-valued logic, multi-valued logic and mathematical logic. In the opinion of universal logic<sup>[3]</sup>, classical logics are “rigid logics” that have the following main features:

①. The truth-value of proposition is integer

In two-valued logic, the truth-value of proposition only is one of numeral zero and numeral one, Along with the request of the development of other subjects, especially cybernetics, multi-valued logic appears. It allows that the truth-value of proposition can be one of more than two numerals. But they are still “rigid logics”, because their proposition’s values are integer.

②. Independence of the correlation of propositions

In classical logic inferential systems, there is latent hypothesis that every proposition is independent from others. Otherwise the inferential march is difficult. In other words, generally don’t consider the correlation of different propositions.

### ③. The uniqueness of the operating model of connectives

In classical logics, even in the fuzzy logic<sup>[4,5]</sup>, the operating rules of connectives are defined and cannot be changed in the process of reasoning, such as:  $\sim P = 1 - P$ ,  $P \wedge Q = \min(P, Q)$ ,  $P \vee Q = \max(P, Q)$ ,  $P \otimes Q = \min(1, 1 - P + Q)$ ,  $P \ll Q = 1 - |P - Q|$ . Document [3] has fully discussed the rationality of this operating model of fuzzy prepositional connectives. Because of the complexity of the real world, the operating rules of connectives should be defined as the formula cluster that changes continuously which is controlled by general correlation<sup>[3]</sup>.

## 1.2 Necessary of fractal and chaos logics

The volition and duty of scientists are exploring laws of nature. Physical scientists try to make clear the spin, color and taste of elementary particle. And biologists study the biologic evolvment, etc. All of them go with saying. But there are more complicated problems that puzzle people now. People are thinking why the change of weather cannot be forecast correctly<sup>[6-8]</sup>, but the “Feigenbaum constant”<sup>[9,14]</sup> doesn’t change with the difference of different systems and their running equations? People believe that these secret problems implicate some deep laws of nature. And such is chaos, which make these problems understood. In going step further research, people find that chaos systems contain order, which have the feature of fractional dimension in some degree<sup>[9]</sup>. Fractal, as another new subject, has much progress, so a main aspect of chaos is fractal, and researching fractal is an effective way for studying chaos.

Now days, fractal has definite application and development in some fields, such as: molecule science, physics, chemistry, and life sciences etc<sup>[10-13]</sup>. But, to some extent, fractal is only a kind of computational mathematics, and it is helpless for the reasoning and forecast of complicated system. At this time, the fields of chaos’s application are limited to control system. How do chaos and fractal develop fast and apply extensively in 21st century, in which the complicated sciences play a very important role? Obviously, there will be many heated spots in judging, reasoning, and controlling of every factor and every process of complicated system. This needs right and effective logical reasoning besides mathematical calculation. It undoubtedly requires the development of logic. Such is the fact, in the time of going deep into and developing the classical logics, “universal logic”, as a new subject, has been produced. It is a flexible logic system that includes uncertainties. It analyzes the scope of applications of classical logics and fuzzy logic. And lists the four factors which all kinds of logic must possess. The principles of universal logic offer the formal frame and the producing rules for establishing the architecture of a concrete logic system<sup>[3]</sup>. It is a guide to set up “fractal logic” and “chaos logic”. So the naissance of chaos logic and fractal logic is involuntary production. They will be powerful “tool logic” for people to study complicated system.

## 2 The features and relationship of chaos and fractal

### 2.1 Basic features of chaos

Chaos phenomena can be found everywhere in the matter world from macroscopic world to microcosmic fields. It subtly hangs together the presentational disorder and inherent laws. The basic features of chaos are<sup>[9]</sup>:

#### ①. Internal randomness

A system may be in chaos state is the reflection of internal randomness of nonlinear dynamics. The nonsteady property of parts of a system is just the characteristic of internal randomness, and it is sensitive to the initial value. According to this, E.N.Lorenz put forward the famous “butterfly effect”.

### ②. Fractional dimension

Chaos systems have the feature of fractional dimension. It says that the geometry form of their running tracks in the phase space can be described by fractional dimension. The tracks of movement infinitely twist, fold and distort in the phase space, and form infinite ranks structures that are self-similar. This kind of structures is the famous “strange attractor”.

### ③. Orderliness in disorder

Chaos phenomenon is an order state although it is not recurrent on all levels of all parts of the system. It has infinite self-similar structure. So long as the precision in calculation of the equipment in laboratory are enough high, we can find and show the pattern of the orderly movement of chaos system in small measure region.

## 2.2 Basic features of fractal

We already mentioned: the obvious feature of fractal is self-similar, others features include infinite complex, infinite subtle structure and so on<sup>[9,15]</sup>.

### ①. Self-similar

Many things have self-similar property in structure. For example with tree, branch is a small edition of the whole tree, while the branch of branch is smaller edition, see fig 1. Fractal is so important that it has been applied in all kinds of fields just because of its self-similar property. Many objects can be described accurately by fractal, such as plant, snowflake, scenery picture, and music work.

### ②. Infinite complex and subtle

Another important feature of fractal is that it has infinite complex and infinite subtle structure. This kind of structure can be paint by iterative functional system (IFS).

### ③. Fractional dimension

It is difficult to give the definition of fractal accurately without the conception of fractional dimension. We can describe fractal object more properly with fractional dimension than without it.



Fig 1: Fractal plant

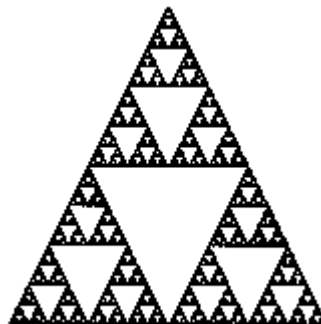


Fig 2: Sierpinski triangle

### 2.3 The relationship of chaos and fractal

It is important for us to make clear the relationship of chaos and fractal. Here are some items about this.

①. From chaos to order

We know that chaos is a kind of nonperiodic dynamical behavior; it looks disorderly and unsystematic, but contains abundant connotation, such as strange attractor, bifurcation, and windows etc. So we can say that chaos implies order, and it isn't a stochastic process that cannot be controlled. The Sierpinski triangle (see fig 2) can be drawn by some very simple rules and calculation, but it is a very wonderful pattern. We can obtain Sierpinski triangle even if using stochastic method. This characteristic is absolutely necessarily for people to study chaos. That is that disorder contains order.

②. From order to similitude

The order characteristic of nature is a reflection of dynamical behavior of system's self-organized. The order things mean laws that may be found. Here the word "order" is "generalized order", so it includes the laws of not only linear science but also nonlinear science, and the latter is more important. The result of research is that the internal order of chaos has the characteristic of fractional dimension. For example, smoke from kitchen chimneys spirals and rises. Every spiral forms a unclosed circle, and all of the circles are similar.

③. From similitude to fractal

The further study states that it is the self-similar structure that makes chaos have the fractional dimension property. So we can research chaos through fractal, and make chaos and fractal powerful tools for researching nonlinear science.

From chaos to order, from order to similitude, and from similitude to fractal, these sum up the relation between chaos and fractal. Because chaos system has the fractional dimension property, researching fractal is becoming the effective way by which for studying chaos.

## 3 Exploration of fractal logic based on universal logic

### 3.1 Introduction of universal logic principles

Because of the requirements of development of computer, information technology and artificial intelligence, universal logic<sup>[3]</sup> was born, which stress the relational flexibility of different objects (tasks, proposition, connectives). Universal logic is a common architecture of logical theory system, which is "self-contained and exoteric". It is self-contained because it puts up the common characteristics of all kinds of logics at these days, which are the four factors. More than that, it also gives a logic builder for creating concrete logic system according to the need of application. It is exoteric because it allows new logical system join into its frame, and other people can expand and perfect its architecture if necessary.

Universal logic puts forward the four essential features of all kinds of logics. They are research filed, proposition connectives, relational quantifier, set of common rules and appropriate inferential model. For a concrete logic system, it must have appropriate semantic explanation, and it can hold its own features. The one task of authors in the flowing time is trying best to set up fractal logic and chaos logic based on the principle of universal logic with its logic builder.

### 3.2 Compendium of fractal logic

#### 3.2.1 The four factors of fractal logic

##### ①. The research filed of fractal logic

The research filed of fractal logic is all things that have fractal features, which may be geometric objects that are self-similar, and statistic data that are self-similar. To some degree, setting up fractal logic is building logical inferential system based on fractal mathematics. The true-value field of proposition is a multi-dimension and super order space:

$$W = \{ \perp \} [0, R]^D \langle \alpha \rangle$$

Here,  $W$  is the space of true-value field,  $[0, R]$  is the radix space,  $R$  is a real number,  $D$  is the fractional dimension space,  $\{ \perp \}$  is the undefined space or other spaces,  $\langle \alpha \rangle$  is the accessorial characteristics of proposition or predication.

Obviously, because of the fractional dimension feature of fractal, we must be a multi-dimension space based on continuous-valued radix. And because the fractional dimension is not smaller than three in chaos system, it is necessary for us to expand the true-valued field from  $[0, R]$  to  $[0, +\infty]$ , even  $[-\infty, +\infty]$ . By the way, the negative is significative some times in fractal.

##### ②. Proposition connectives of fractal logic

About the proposition connectives of fractal logic, authors try to set about to analyze the fractal principle firstly, then study the mutual relativity of different parts of fractal object, and give the model of operation. Table1 shortly lists some proposition connectives of fractal logic. Using these proposition connectives, authors have get some significative results, which will be expatiated in another special paper.

Table1: the proposition connectives and their operation models of fractal logic

No.	Connective	Denotation	Operation model
1	Not	$\sim_k$	$N(x, k) = D(R - D^{-1}(x))$
2	And	$\wedge_h$	$A(x, y, h) = \Gamma^R [D((D^{-1}(x))^m + D^{-1}(y)^m - R)^{1/m}]$
3	Or	$\vee_h$	$O(x, y, h) = \Gamma^R [D(R - ((R - D^{-1}(x))^m + (R - D^{-1}(y))^m - R)^{1/m})]$
4	Implication	$\rightarrow_h$	$I(x, y, h) = \Gamma^R [D((R - D^{-1}(x))^m + D^{-1}(y)^m)^{1/m}]$
5	Equality	$\leftrightarrow_h$	$E(x, y, h) = \text{ite} \{ D((R +  D^{-1}(x)^m - D^{-1}(y)^m )^{1/m})   m \leq 0; D((R -  D^{-1}(x)^m - D^{-1}(y)^m )^{1/m}) \}$
6	Average	$\oplus_h$	$V(x, y, h) = D(R - (((R - D^{-1}(x))^m + (R - D^{-1}(y))^m) / 2)^{1/m})$
7	Combinatorial	$\odot_h^e$	$C^e(x, y, h) = \text{ite} \{ \Gamma^e [D((D^{-1}(x))^m + D^{-1}(y)^m - e^m)^{1/m}]   D^{-1}(x) + D^{-1}(y) < 2e; D(R - (\Gamma^{R-e} [((R - D^{-1}(x))^m + (R - D^{-1}(y))^m - (R - e)^m]^{1/m}))   D^{-1}(x) + D^{-1}(y) > 2e; \}$
8	Series	$\otimes_h$	$R(x, y, h) = D(R - (((R - D^{-1}(x))^m + (R - D^{-1}(y))^m)^{1/m}))$

Notes:

- a).  $R$  is the radix space dimension of the research field,  $D$  is the actual dimension of fractal object, function  $D(x)$  calculates the dimension of fractal object “ $x$ ”, but  $D^{-1}(x)$  constructs the fractal object with dimension “ $x$ ”, Here  $D^{-1}(x)$  and  $D(x)$  denote two reverse operating processes, but not the converse mathematical operators
- b).  $h$  denotes general correlative coefficient,  $k$  denotes general self-correlative coefficient, see Reference[3];
- c). In the operation cluster,  $m \in \mathbf{R}$ , and there is a similar relation between  $m$  and  $h$ , i.e.  $m = (3 - 4h)/(4h(1 - h))$ ;
- d). Function  $\Gamma^{\mathbf{R}}[x]$  denotes  $x$  is restricted in  $[0, R]$ , if  $x > R$  then it equals to  $R$ ; if  $x < 0$  it equals to  $0$ .
- e).  $S = \text{ite } \{\beta | \alpha, \gamma\}$  is condition expression, it means that if  $a$  is true, then  $S = \beta$ ; else  $S = \gamma$ .
- f). In formula 7,  $e$  denotes by combinatorial connective  $\odot_h^e$ ; in formula 8,  $n$  denotes the dispersion of series.

### ③. Relational quantifier of fractal logic

Nowadays universal logic supplies these quantifiers: generality quantifier, existential quantifier, assumptive quantifier, boundary quantifier, locational quantifier, and transitional quantifier. They are useful in fractal logic, and we will add other quantifiers such as progressional quantifier, similar quantifier etc.

### ④. Set of common rules and appropriate inference model

According to the proposition connectives and quantifier of fractal logic, we can construct the set of common rules and appropriate reasoning model. This has us study the classification of fractal objects, the different features of different kinds of fractal objects, the intention of fractal reasoning, and what and how fractal logic plays in the complicated system. After we know them we can set up the primary model of fractal logic. Table 1 shows some operation models of the proposition connectives when the radix space is  $[0, R]$ .

#### 3.2.2 Semantic explanation of fractal logic

Any logic that is used to reason in a concrete system has its own concrete semantic explanation for proposition, connectives, quantifiers, and set of rules<sup>[16]</sup>. When a doctor diagnoses a patient, numeral zero means no illness, and numeral one means illness. In the same way, when fractal logic is used to reason in fractal system, it is necessary for us to give the semantic explanation of true-value, connectives, quantifiers, and set of rules. For example, we can suppose that the true-value represents the fractional dimension of fractal objects, and the general relativity of proposition and connectives represents the degree of similitude of fractal objects.

#### 3.2.3 Study of application of fractal logic

Although it has not long time since fractal became a subject, it reveals self-similitude law of nature. So fractal has some applications in many fields, such as philosophy, mathematics, physics, molecular chemistry, material science, life sciences, biology, anthropology, computer science, information technology, geognosy, and artistic beauty. However, after analyzing these applications, we find that fractal seems a boundary subject, but it mainly plays a role of computational mathematics. People display the kinetic behavior of fractal things mainly by iterative function. In fact, fractal should be a boundary subject. So there is unprecedented difficulty when we want to use fractal theory for forecasting the behavior of control system after a long time, even it is very difficult to resolve some typical fractal problems. In author's opinion, it is possible to put the axe in the helve by the reasoning of fractal logic. Here are some fractal problems that may be given

satisfactory answers by fractal logic.

①.This is a typical fractal problem<sup>[10,12]</sup>, here calls it “**Fractal person question**” :

A fractal person,

walk one fractal mile,

Buy a fractal cat,

catch a fractal mouse,

The fractal pallium of the fractal person,

thinking that the fractal cat is eating the fractal mouse,

the fractal mouse is being absorbed by the fractal small intestine of the fractal cat.

**Question1:** “When one fractal minute wears away, whether the whole fractal cat will be absorbed, or how much meat of the cat will be absorbed?”

②.Authors put up the following problem, call it “**combined carpet question**” . It can show the other field of application of fractal logic.

There are two carpets named C1 and C2, and their acreages are S1 and S2. Their brocades are similar but not same. The carpets have surface roughness because the surfaces of them are not slippy. Let’s suppose that we have worked out the roughness parameters by calculating their fractional dimension, which are D1 and D2.

**Question2:** “Suppose that we break up the two carpets, and mix their brocades, then weave the mixed brocade into a new carpet named C3, and its acreage is equal to the sum of the foregoing two carpets, that is  $S_3=S_1+S_2$ . The question is that what the roughness parameters D3 of the third carpet is?”

The result of research show that it is very difficult even not possible for conventional fractal mathematics to satisfactorily answer the “fractal person question” and “combined carpet question”. It is easy to see that the first question needs more fractal reasoning and fractal forecast with fractal logic than numerical calculation. In the second question, it is necessary and important for us to establish the fractal’s combined rule. Obviously, D3 is not equal to the sum of D1 and D2 in most cases, so we should analyze the degree of comparability of C1 and C2, and the correlativity of D1 and D2. To our happiness, this is consistent with the conception of general correlation and general self-correlation. So if we set up fractal logic based on universal logic, it will play an important positive effect for revealing these kinds of puzzles.

③.Through researching general correlation of fractal objects with fractal logic, it may be possible to open out the substance of “One hair affects the whole body” in life science, find the internal drive of the process of physics, chemistry, biology, and other natural phenomena, and predict the developing direction or final result of them.

④.With the development and application of fractal logic, more than that, we can set up chaos logic based on universal logic and fractal logic. Chaos logic can be used in chaos control, weather prediction, earthquake forecast and so on.

#### 4 The implementing process of chaos logic

After knowing about the above content, we can form the “trilogy of chaos logic” , they are: universal logic→fractal

logic→chaos logic→complicated system. Fig 3 is the sketch map of the development of chaos logic.

#### 4.1 Universal logic—the foundation of fractal logic

There are two reasons for us to choose universal logic as the foundation of fractal logic. Firstly, universal logic affords the formal frame for all kinds of logics, and gives the producing rules in its logic builder, we can set up fractal logic with the logic builder of universal logic. Secondly, the general correlative coefficient and the general self-correlative coefficient<sup>[3]</sup> can be used to describe the self-similar characteristic and the fractional correlative dimension of fractal objects, which is one of main parts of fractal logic.

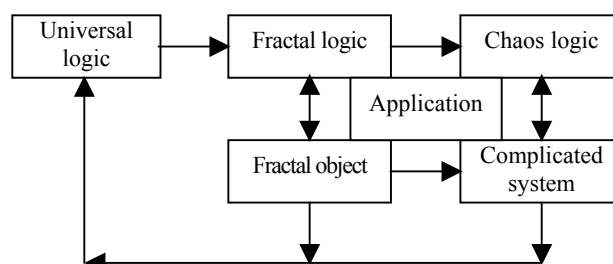


Fig 3: The sketch map of the development of chaos logic

#### 4.2 Fractal logic—the bridge to chaos logic

Seen from fig 3 that universal logic is the principles and foundation of the whole logical system, and fractal logic is the bridge to chaos logic. Because chaos system is more complicated than fractal phenomenon in indeterminate cases, it is more difficult to study chaos system and set up chaos logic directly. However, chaos system has the fractional dimension characteristic, so we can set up fractal logic firstly, and then set up chaos logic.

#### 4.3 Complicated system—the way of application and perfecting of chaos logic

From the view of epistemology, the purpose of all new subjects or sciences is only one, which is that it tries to help people understand the nature phenomena more accurately, and master the law of nature well and truly, and chaos logic is not exception here. None but the applications in different kinds of complicated systems can perfect chaos logic gradually. Especially, it can boost the development of the four factors of chaos logic. According to a concrete application, we can constitute the operating characteristic set besides the common set of rules if necessary.

## 5 Summarization and prospects

To this day, authors have already made some progress in fractal logic. We can get logical results with the emulator of fractal logic when researching some fractal things. But there are many puzzles on the way to fractal logic and chaos logic, and it is a long-term and hard task to set up and perfect fractal logic and chaos logic. This paper is only an entrance to fractal logic and chaos logic, and avoids lots of logical and mathematical formulas. Authors mainly analyze the basic characteristics of fractal theory and chaos system, expound the correlation of fractal, chaos and universal logic, and fully discuss the necessary and probability of setting up fractal logic and chaos logic. Based on the content of this paper, we can have the following summarization:



①. Along with the fact that people search after the order of nature more and more thoroughly, the naissance of chaos logic and fractal logic is not only the inevitable production, but also the objective requirement for continuing to do that.

②. The principles of universal logic offer the formal frame and the producing rules for establishing the architecture of a concrete logic system, and this makes it possible to set up fractal logic and chaos logic. This paper gives the compendium of fractal logic and the way of the development of chaos logic.

③. For researching complicated system, fractal logic and chaos logic will play an important and positive role. With the development and application of fractal logic and chaos logic, we can reveal the internal drive of more and more natural phenomena, and predict the developing direction or final result of them. At the same time, fractal logic and chaos logic will gradually consummate themselves in the applications.

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# 基于泛逻辑的分形与混沌逻辑初探

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**摘要:** 人们对自然的看法正经历着一个根本性的改变, 即转向多重性、暂时性和复杂性, 分形论与混沌学则是研究此类非线性自然系统的新兴科学。本文主要分析了分形现象与混沌系统的基本特征, 阐释了分形、混沌、泛逻辑之间的相互关系, 充分讨论了建立分形逻辑与混沌逻辑的必要性与可能性。并给出了分形逻辑的研究纲要和混沌逻辑的实现途径。文章指出: a). 随着人们对自然规律认识得越来越深入, 分形逻辑与混沌逻辑的产生是其必然产物, 也是人们进一步深入认识自然的客观需要; b). 泛逻辑学原理给出了产生具体逻辑系统的形式化框架与生成规则, 它为分形逻辑与混沌逻辑的建立提供了可能; c). 分形逻辑与混沌逻辑在复杂系统中将有重要的积极的作用, 并在其应用中逐渐自我完善。

**关键词:** 泛逻辑; 分形逻辑; 混沌逻辑; 非线性科学

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