Chaotic continuous growth model for dragons based on an ecological assessment system

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Abstract. As a magical immortal creature in the game world or internet world, the dragon has a huge volume, excellent flight capabilities, and fire-spraying skills. Exploring the growth of dragons is innovate and legendary significance to the deep exploration of the universe by mankind. The characteristics of dragon growth and its influence caused by the environment were studied, the factors causing energy change in dragons were fully analysed, several differential-equation models were established to solve the changes of energy in dragons, and the influence of their environment on dragons. By studying the question of whether three dragons can coexist, we find that the habitat and range of one of them will change due to the different relationships between the other two dragons, so we established a two-layer system to solve the reciprocal competitive relationship between two dragons and established a chaotic continuous model of three dragons. These conclusions can also be used to evaluate the use of some easily dissipated device materials, calculate the life span and optimal service life of some materials, solve problems governed by system models with interactive effects therein.

1. The first section in your paper
As a magical immortal creature in the game world or internet world, the dragon has a huge volume, excellent flight capabilities, and fire-spraying skills. Exploring the growth of dragons is of legendary significance to the deep exploration of the universe by mankind. Based on Bai’s simulation of the bovine growth curve and the estimation of genetic parameters, we first studied the problem of dragon growth: we first used the most basic factors pertaining to their own systematic analysis. Dragons can fly: the title reflects the fact that the existence of dragons meets the tenets of fundamental biology, so the density of the dragon itself must be relatively stable, and no greater than the maximum density of an object capable of flight [1].

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We then analysed the growth of the dragon’s body shape and found that as long as the density of the dragon is relatively constant, its mass will change in proportion to its volume, and in theory its volume can be infinitely enlarged [2].

Based on the above conclusions, another important factor that affects the change in mass of a dragon, that is, the energy that dragons acquire and release, can be found. For the acquisition of dragon energy, there is a positive correlation between Helong’s weight gain and length gaining, in contrast, the release of energy is negatively correlated with the increased mass of the dragon [3-4].

In this paper, the characteristics of dragon growth and its influence on the environment were studied by scientific method, the factors causing energy change in dragons were fully analysed, several differential-equation models were established to solve the changes of energy in dragons, and the influence of their environment on dragons. In task one, we established a dragon-visualisation model entailing detailed feature description, creatively revealing the life habits of all aspects of dragons, and discovered that as long as the density is constant, dragons can achieve continuous growth in an immortal state. We constructed radar graphs to represent four different types of dragons, namely attack, defensive, agile, and equilibrium-types, and obtained a comprehensive strength function for dragons. In task two, we established a continuous differential equation model for the action of dragons and their ecological environment. To study the changes of energy, a differential equation model with statistical characteristics was proposed. In task three, because the three dragons are subject to factors based on mutual checks and balances, their growth index constitutes a chaotic system. By studying the question of whether three dragons can coexist, we find that the habitat and range of one of them will change due to the different relationships between the other two dragons, so we established a two-layer system to solve the reciprocal competitive relationship between two dragons and established a chaotic continuous model of three dragons.

2. Model establishment
The Dragon has a huge volume, excellent flight ability and fire spraying skills, and exploring the growth of dragons is of great significance to the deep exploration of the universe by mankind. In this paper, the characteristics of dragon growth and its influence on the environment are studied by scientific method, the factors causing energy change in dragons are fully analyzed, several differential-equation models are established to solve the changes of energy in dragons, and the influence of ecological environment on Dragons.

First, we set a 24-hour period to match each calendar day, during which dragons will look for food to allow themselves to grow in size and gain energy, as can be seen from the Fig.1. As a result, dragons also consume energy to acquire energy. When dragons forage, they need to fly to find food (localised crawling foraging expeditions are discounted).
When dragons find their target prey, they attack, which leads to further energy consumption: dragons are deemed to mainly launch fire-based attacks on their prey, and doing so will also consume energy [5].

Dragons attack at the same time, there will be some energy loss, used to recuperate against foreign enemies and the damage caused thereby.

The loss of Trokosi energy in the waste excretion of dragons is counted in the use of the dragon’s own energy, therefore, we derive a preliminary differential equation (1) to express hypothesis of the model.

$$\frac{dW}{dt} = \alpha - \tau \beta$$  \hspace{1cm} (1)

where $\alpha$ represents the amount of energy obtained, $\beta$ represents the amount of energy consumed, and $w$ is the correlation coefficient between two energies.

The change in weight is equal to the difference between acquisition and consumption, in which the energy obtained refers to the net energy absorbed after deducting that for basic metabolism, and the energy consumed is the energy consumed when active.

3. Equations and Mathematical Expressions

3.1. Model solution and analysis of results

Based on the analysis of the acquisition and consumption of energy, we analyse the components of energy in vivo and obtain the following energy equivalent relationship:

which is the main reason for energy consumption. All energy acquired by a dragon is thus divided and can be seen Fig. 2 and Fig.3 below:

![Energy conversion diagram](image-url)

**Figure 1.** Energy conversion

**Figure 2.** Energy equivalent relationship
**Figure 3.** Distribution of energy consumption in dragons

There is a certain proportional relationship between the energy of dragons and each other, and $e_1$, $e_2$, $e_3$, and $e_4$ represent the percentage of each direction of energy. After a single energy acquisition, the change in the energy whereabouts of the dragon is shown in the Figure 4:

**Figure 4.** Dragon’s daily energy acquisition and consumption

It also shows that the energy that dragons eventually get is equal to the energy they get from eating minus that consumed while feeding.

When studying the weight over a dragon’s life, we found that it would go through three stages, namely, the long-term, a stable period, and a recession period. Dragons grow for a period of time, in the state of high-speed growth, the more energy they acquire, the faster they grow; after a long period of growth, they reach a stable period, during which the rate of growth will gradually decrease; in the final stages of a dragon’s life, it enters a period of gradual decline in bodily function, at which point its rate of growth tends to zero. Specific trends are shown in the following four images.

Through these body weight changes, we probably learned about the changing trend in a dragon’s weight, and gain a preliminary understanding of the effects of energy analysis.
3.2. *NIN model of the ecosystem*

Analysis of the problem and hypothesis of the model are established as below,

1) The only source of energy in a dragon is the food that it eats.

2) Relative to the growth time axis of the dragon, we need to consider the impact of the self-recovery of its ecosystem.

3) The ecosystem of the dragon is a circle centred on the dragon.

To study the use of the ecosystem by a dragon, we first use the idea of a differential to take the radius of the ecosystem used by the dragon at each time to make a large element, that is, Dr, and then can be seen in the and Eqs(2) and Fig.5.

\[ S_1 = 2\pi r \, dr \]  

(2)

Where, ‘\( S_1 \)’ represents the area of the new ecological environment, ‘\( 2\pi r \)’ represents the perimeter of the ecological environment, ‘\( dr \)’ represents the radius of the ecological environment.

\[ e_i = \pi r^2 C_1 + C_0 2\pi r \, dr \]  

(3)

Figure 5. Ecological environment

\[ \alpha = \frac{\pi r^2 C_1 + C_0 2\pi r \, dr}{S} \]  

(4)

Where \( C_0 \) is Initial energy concentration of the ecosystem, \( C_1 \) is Energy concentration after self-repair of ecosystem. \( S \) is Total ecosystem area, \( r \) is the ecosystem radius used by dragons.

Dragons derive energy entirely from their prey, but consume energy in predation. Based on the previous analysis of the growth of dragons, it is noted that, with the growth of a dragons, its volume and demand for food constantly increase, because the energy of a dragon is obtained from its ecosystem, therefore, the radius of the ecosystem increases.
3.3 Establishment of model

![Energy Acquisition Flow Chart]

**Figure 6.** Energy Acquisition Flow Chart

As can be seen from the Fig.6, where N represents an ecosystem that can provide energy for dragons, and I represents an ecosystem that is barely able to provide energy after being used by dragons. Because the ecological environment has a certain ability to repair itself, the energy-losing ecological environment can be restored to the ecological environment that can provide energy for dragons through self-repair. The state change of ecological environment is shown as: N \rightarrow I \rightarrow N.

After self-healing, the ecological environment that provides energy for dragons will once again be used by dragons, meaning that this part of the environment will once again become a system that cannot provide energy for dragons.

Assumptions:

1) The total area of the ecosystem is S, n(t) + i(t) = S.

2) To survive, the newly used ecosystem area of the Dragon is S_1, it is proportional to the area of the ecosystem that dragons do not use, and the coefficient of proportionality is k.

3) The energy-losing ecosystem is self-repairing at a fixed rate of h, thus again becoming an ecosystem capable of providing energy to dragons.

We identified the model:
\[ \frac{di(t)}{dt} = ki(t)s(t) - hi(t) \]

\[ i(0) = i_0 \]

Solving (5) gives:

\[ i(t) = \frac{1}{\frac{k}{nk - h} + \left( \frac{1}{i_0} - \frac{k}{nk - h} \right) e^{(b-nk)t}} \]

\[ h \neq nk \]

(6)

\[ i(t) = \frac{i_{0}}{kt + \frac{1}{i_{0}}} \]

\[ h = nk \]

(7)

Results and analysis:

\[ \lim_{t \to 0} i(t) = \frac{nk - h}{k} \]

\[ \lim_{t \to 0} i(t) = 0 \]

(8)

3.4 The BI model of energy

3.4.1 Analysis of the problem

We analysed the spray of fire as a way in which dragons consume energy. Dragons need to attack the prey they find before eating it, and they then use their own most distinctive and aggressive skill: spraying fire. We considered the following aspects: the fire intensity of the dragon, the fire radius of the dragon (attack radius when catching prey), and so on.

We analysed the combat capability of dragons and mainly studied the size of the flame energy of dragons every time they sprayed fire. Dragons may be able to spray flames to attack their prey when they are in combat, depending on the size of the flame, but due to the lack of flame energy from the dragon jet, it will in some cases cause the dragon to be unable to complete the hunt. This may result in further depletion of the dragon’s own energy or unnecessary trauma due to the failure to resolve the attack on its target as soon as possible. On the other hand, if the dragon sprays enough flame energy or wastes too much fire each time, it will greatly reduce the number of times it can spray fire. To analyse this situation, we have established the BI model and analysed the energy of the dragon jet flame.

3.4.2 Assumptions of the problem

1) The amount of fire a dragon sprays each time is relatively fixed.
2) The total energy used for Spitfire consumption in dragons is a constant \( q_1 \), and \( i(t) + b_1(t) = q_1 \).
3) The energy that dragons can use to spray fire at a time is proportional to \( b_1(t) \) and the coefficient of proportionality is \( j \) (fire intensity).
4) The energy consumed by the dragon spray of fire will not be replenished immediately, but it can eventually be replenished.
5) Dragons constantly consume energy when they spray fire, but do not cause great trauma to themselves.

Establishment of model is below as followed.

\[ \begin{align*}
\frac{di(t)}{dt} &= jb(t)i(t) \\
i(0) &= i_0
\end{align*} \]

\[ \begin{align*}
\frac{di(t)}{dt} &= j(b(t) - i(t)) \\
i(0) &= i_0
\end{align*} \]

(9)

Solving (9) gives the following result:
\[ i(t) = \frac{q}{14 \left( \frac{q}{i_0} - 1 \right)} e^{jqt} \]  

3.4.3 Results and analysis

Where \( \frac{di}{dt} \) is solved to find the maximum value at \( t_1 = \frac{\ln \left( \frac{q}{i_0} - 1 \right)}{jq} \), as shown in the figure. This can represent the peak moment of energy consumption, which in part means the dragon is at a critical moment in a battle, which is similar to the match point in a sports competition. When the fire intensity \( j \) increases, \( t_1 \) will decrease, in other words, the dragon’s battle-critical moment comes quickly, which is intuitive; however, as \( t \to \infty \), \( i(t) \to q \), which means that the dragon’s energy is completely depleted (clearly counter-intuitive). see Fig. 7 below.

**Figure 7.** Energy fluctuation diagram

From the discussion above the effect of the energy of the dragon jet flame on its own energy loss is found. In addition, each time a dragon sprays a fire, the fire radius also has a certain effect on its energy consumption.

When a dragon sprays a fire, it needs to consume more energy if it is to reach a relatively large attack radius, however, given the dragon may need to continue to spray fire and attack for a longer time, it cannot consume its own energy at will. Therefore, if the dragon consumes a certain amount of energy when spraying fire, the range of flames it sprays is inversely proportional to the flame strength.

3.4.4 The study of flight and energy

1) Analysis of the problem

Earlier, we analysed the energy consumed by a dragon in spraying fire, and obtained and solved the governing model equations. Through analysis and comparison, we find that this equation is also suitable for other ways of consuming energy. For dragon flight, we only consider short flights for the time being (regardless of the effect of the temperature band), focusing on the altitude of the flight and the speed of flight as two factors that affect energy consumption the most. High-altitude flight entails more energy consumption, the same, accelerated flight will entail further consumption of energy. Based on these two analyses, we have a model for this problem.

2) Assumptions of the problem

(1) The total energy consumed during the flight is \( P \), and the energy consumed based on flight speed and flight altitude is \( P_1 \) and \( P_2 \), respectively.

(2) The speed of dragon flight and the altitude of flight per unit time are proportional to the energy consumed by dragon flight respectively, and the coefficient of proportionality is \( k \).
(3) When dragons use more energy to increase their altitude, the energy left to provide flight speed is affected, in other words, because the total energy consumed by dragons in both areas is certain, so when one of them is large, the other quantity can only be smaller.

The hypothesis of this model is exactly the same as that of the BI model equation of the energy consumed by Oberwenron fire, so the BI model is found to be also suitable for the consumption of energy in dragons during flight (see Appendix for detailed calculations).

3) Establishment of model

The way dragons consume energy in vitro is to resist great trauma, and in this regard the energy that resists such trauma is positively correlated with flight and use of fire. The energy consumed by dragons in this area, when not considering ecological natural disasters, only that in predatory consumption, means that, the longer the predation time, the more energy consumed to withstand trauma. Based on the above analysis, we deduce a functional relationship image of the energy and time consumed by dragons against such trauma. see Fig. 8 below.

![Figure 8. Functional diagram](image)

3.5 Results and analysis

The remaining form of energy left in the body is used for its own growth, which is translated into the energy needed for its own growth to increase the size and weight of the dragon. By the energy of the Oberwenron body, we find that:

$$e_i = e_1 + e_2 + e_3 + e_4$$  \[(11)\]

We also consider that the consumption of dragon energy is divided into energy consumption in vivo and energy consumption in vitro, so the output efficiency of dragon energy consumption is $\tau = \frac{e_1 + e_2 + e_3}{e_1}$, which also represents the energy conversion efficiency of dragons.

3.6 Regional model of three dragons

3.6.1 Analysis of the problem

We established and analysed the relevant models of the growth conditions of a dragon, the demand and consumption of energy, and the relationship with their environment. Based on the images, we are able to observe the changing relationship between them, and then we discussed the areas needed for three dragons.
The three dragons in the novels are born of his mother, so it is unlikely that they will compete fiercely with each other in the novel. The three dragons cannot be exactly the same because there are differences between all the individuals, that is, there must be strong and weak points. In other words, no matter what kind of survival relationship, there must be a balance between them allowing coexistence. We therefore deduced the following diagram showing the relationship between dragons and the chaotic system that they comprise, be see the Fig.9 and Fig.10.

![Diagram of dragons and chaotic system](image)

**Figure 9.** Attractor effects on the chaotic system

![Graph showing energy competition between dragons](image)

**Figure 10.** Dragon competition for energy

\[
\frac{\partial W_1}{\partial W_1} = \alpha_1 (W_2 + \theta_1 W_3) - \beta_1 (W_2 + \varepsilon_1 W_3) \quad (12)
\]
\[
\frac{\partial W_2}{\partial W_2} = \alpha_2 (W_1 + \theta_2 W_3) - \beta_2 (W_1 + \varepsilon_2 W_3) \quad (13)
\]
\[
\frac{\partial W_3}{\partial W_3} = \alpha_3 (W_1 + \theta_3 W_2) - \beta_3 (W_1 + \varepsilon_3 W_2) \quad (14)
\]

A group of coupled equations can be formed between them to form a chaotic system.

According to the coefficients of \(\alpha\) and \(\beta\) in the formula, we can understand that when \(\alpha > \beta\), there may be a competitive relationship between the two other dragons, because the calculated value is relatively large, and the other two dragons will obtain less energy, so they can become competitive...
with this relationship. Similarly, when \( \alpha < \beta \), there is a reciprocal relationship between the other two dragons, therefore, we can establish a dual system, first for the analysis of the relationship between the two dragons, and then the two dragons formed the system to optimise the treatment, so that it reaches an equilibrium state, and the solution of the problem at this time to the new system (the system can be regarded as a one-stop view), will now form the system and the rest of the dragons will establish a new system, and study the relationship between the three dragons to cooperate to obtain a living area. The relationship flowchart appears below.

3.6.2 Establishment of the model and its results (see Fig. 11 below)

3.6.3 Competitive relationship between two dragons
Since the competitive relationship between dragons stems from their conflict of interest in energy, they are certainly fighting to increase their acquired energy, and here we have built a Guno model of a two-dragon competition.

The Guno model is a game in which all participants make simultaneous decisions and understand the benefits to all parties, which belongs to the static game model of information as a class of games. The two dragons involved in the competition need to master each other’s game information before they act. The competitive game between the two dragons can be understood as follows:

\[
\begin{align*}
I &= QR - C \quad (15)
\end{align*}
\]

Where \( I \) is the net energy acquired by dragons, \( Q \) denotes the total energy acquired by dragons, and \( R \) is the efficiency of transformation of energy by a dragon. The equation by which the two dragons harvest energy is:

\[
\begin{align*}
I_1 &= [a + b(q_1 + q_2)]q_1 - d_1q_1^2 \quad (16) \\
I_2 &= [a + b(q_1 + q_2)]q_2 - d_2q_2^2 \quad (17)
\end{align*}
\]

Solving (16) and (17) gives,

\[
\frac{\delta E_1}{\delta q_1} = a + 2bq_1 + bq_2 - 2d_1q_1 \quad (18)
\]
\begin{align*}
\frac{\partial E_2}{\partial q_2} &= a + 2bq_2 + bq_1 - 2d_1q_2 \\
N &= \frac{a(2d_1 - b)}{3b^2 - 4b(d_1 + d_2) + 4d_1d_2}
\end{align*}

So at this time the two dragons constitute the first layer of the system footprint, and can be expressed as 2N. Under full benefit sharing, we analysed the reciprocal relationship and obtained the following model:

\begin{align*}
\frac{dx_1}{dt} &= (r_1 + \frac{mx_2}{1+nx_2})x_1 - a_1x_1^2 - y_1x_1^2x_2 \\
\frac{dx_2}{dt} &= (r_2 + \frac{fx_1}{1+gx_1})x_2 - a_2x_2^2 - y_2x_2^2x_1
\end{align*} (21)

Where \(x_1\) and \(x_2\) are the energy of the ecological system within which they live; \(r_1\) and \(r_2\) are the rate of acquisition of energy of the two dragons, \(a_1\) and \(a_2\) are the the constraint coefficient of energy acquisition between dragons, \(\frac{mx_2}{1+nx_2}\) and \(\frac{fx_1}{1+gx_1}\) are saturation terms. \(y_1x_1^2x_2\) and \(y_2x_2^2x_1\) refer to the energy that the ecosystem fails to recover by itself.

The data are processed and the following relationships are obtained using MATLAB software:

When \(a_1a_2 > mf\), this model is balanced, and the maximum value for a single dragon can be obtained:

\[
M = \frac{r_1x_1 + r_2x_2 - r_1r_2}{a_1 + a_2}
\] (22)

There are four different relationships between the two organisms in the bi-level system. In the relationship, the first is the relationship between the two dragons, see Fig. 12 below:

**Figure 12. Double relationship graph**

Using the results of the above model analysis, we find data pertinent to the first system. Then we regard the first system as an individual and establish the second relationship with the other dragon. We find that this outermost relationship plays an important role in the state of the three dragons, see Tab. 1 below.

| First relationship     | Second relationship     | Results      |
|------------------------|-------------------------|--------------|
| Reciprocal relationship| Reciprocal relationship | Realisable   |
| Reciprocal relationship| Competitive relationship | Realisable   |
| Competitive relationship| Reciprocal relationship | Realisable   |
4 Conclusion

1) Taking a dragon as the basic research object, we established a model for its energy intake and energy consumption under different living conditions, and analysed the changes in energy balance of this creature in detail. This conclusion can also be used to evaluate the use of some easily dissipated device materials.

2) According to the resulting model, we continued to analyse the situation around various data and deduced optimal environmental conditions for the growth environment of the dragon. This conclusion can be used to calculate the life span and optimal service life of some materials.

3) In the survival system with multiple dragons, there are mutual influences among them, which will eventually form a chaotic system. Therefore, we established a multi-layer model, and formed a system with two dragons, and finally obtained a model system. This conclusion can be used to solve problems governed by system models with interactive effects therein.

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