




Mathematical modeling and simulation of data chaos model optimization calculation process

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Abstract The optimization calculation process of big data chaos model cannot be optimized in the global scope and has uncertain factors. A new optimization calculation method of big data chaos model is proposed in this work based on the improved genetic algorithm. The proposed work is an attempt to analyze and extract the correlation dimension, the maximum Lyapunov exponent, and the time series using mathematical modeling. It is analyzed from the observed outcomes that the original parameters are genetically operated by real number coding, and the absolute value of the error time integral performance index is regarded as the minimum objective function for parameter selection. This work introduces a square term and penalty function of the input control to find the optimal index and fitness function. The next generation population is produced until the parameters converge or meet the requirements. The method proposed in this article achieves average running time of 0.85 for correlation dimension, 0.74 for Lyapunov index and 0.76 for time series entropy,

thereby outperforming the traditional method. The simulation experiment results show that the proposed method has a high optimization ability.

Keywords Big data · Chaos model · Optimization calculation · Mathematical modeling

1 Introduction

For big data, efficient search and optimization calculation process is very important. The optimization process cannot be characterized by any mathematical conditions. Therefore, whether it is analyzed from the perspective of mathematics or calculation, the optimization calculation problem is a huge challenge (Go et al. 2019). It has the disadvantages of not being able to achieve the best in the global scope and having many uncertain factors. The proposed work presents an optimization method based on an improved genetic algorithm, which analyzes and extracts the correlation dimension, the largest Lyapunov exponent, and the time series (Song and Ma 2018; Li et al. 2020).

The mathematical modelling through computer simulation, which is performed on a computer, and intended to estimate the behavior of or the result of a real world or actual framework. Figure 1 presents the mathematical modelling process, which represents the running of a system. It can be utilized to investigate and acquire new bits of knowledge into innovation and to estimate system's performance for its complexity for logical solutions (Safaei et al. 2016).

In the examinations on nonlinear dynamical frameworks the authors sorted out that, since no logical answer for the majority of nonlinear frameworks can be acquired, the

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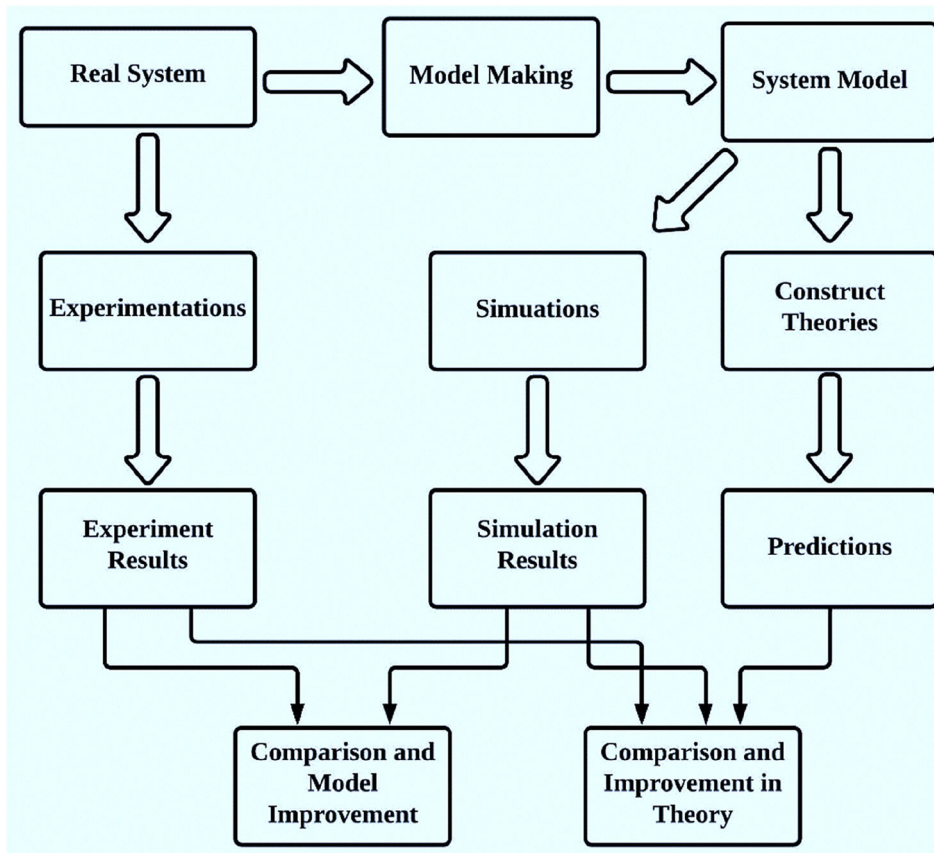


Fig. 1 Process of mathematical modelling

entire set of solutions can be researched in the supposed phase space spanned by the arrangement of variables needed for a total description of conditions of the framework (Quarteroni 2009). A couple of years after the fact, while exploring the three-body issue, it is observed that little perturbations can profoundly influence the solution (Jong 2002). To explore nonlinear dynamimcs, the authors have presented the ideas of phase portrait, segment, orbit, return map, bifurcation, fixed point, etc. A large portion of these ideas were utilized by Andronov’s school during the 20 s (Yuan et al. 2014) still the first representation in the phase space of a now called “chaotic arrangement” was because of the arrangement Edward Norton Lorenz (Ay and Arnosti 2011). The alleged Lorenz attractor accordingly represents the primary chaotic attractor ever drawn. From the Lorenz’s paper publication during mid of 70 s very few papers were published. Among the individuals who added to the development of “chaos hypothesis,” turbulence from one study can be considered (Zeigler et al. 2018), also about bifurcation (Oliva et al. 2017), the new clamorous attractors (Santos et al. 2003), 12. Xiang hypothesis for presence of chaos in guide (Xiang et al. 2010). These commitments, published before 1980, and

highlights the word “chaos” just as related procedures to research these new sorts of solutions.

The present work introduces a square term and penalty function of the input control to find the optimal index and fitness function. The selection operation completed through the fitness ratio method and the optimal retention strategy. The population processed through selection, crossover, and mutation operators. The contribution of the proposed method is a big data chaotic model optimization calculation using an improved genetic algorithm for the analysis and extraction of correlation dimension, largest Lyapunov exponent, and time series. The real number coding is implemented to perform genetic operations on the original parameters. The absolute value of the error time integral performance index is regarded as the minimum objective function for parameter selection, and the square term and penalty function of the input control are introduced in the objective function. Then the optimal index and fitness function are obtained, and the fitness ratio method and optimal retention strategy completes the selection operation. The population is processed through selection, crossover and mutation operators. The processes involve the population selection, crossover and mutation to produce

the next generation population and this process continues until the converge requirements met. This proposed chaotic model based on genetic algorithm, analyzes and extracts the correlation dimension, largest Lyapunov exponent, and the time series. The simulation experiment results show that the proposed method has a high optimization ability.

The remaining part of this manuscript is arranged as: Sect. 2 presents the recent work carried out in the field of optimization calculation. Section 3 comprises of the Lyapunov Exponent extraction followed by the optimization calculation process of big data chaos model based on improved genetic algorithm in Sect. 4. Simulation results as analyzed in Sect. 5, which is further followed by the conclusion of work in Sect. 6.

2 Literature review

In order to understand the effect of learning and cognitive procedure of distance beginners. Wen et al. designed a chaotic recognition cognitive learning framework based on chaos optimization along with analysis of big data. The model considers learners' knowledge inspiration, learning mission necessities and the rate of modification of cognitive directions, and transforms the learning procedure of reserve learning into multi-objective optimization. Experimental outcomes indicates that the model can efficiently increase the teaching superiority of distance teaching progressions in colleges and universities, and has the expansibility and compatibility (Wen et al. 2019). Chen et al. proposed a framework of arc model on the basis of experimental evaluation to measure the ability of the model to predict molten pool changes and thermodynamics involved in the welding procedure. The computational methodology adopted considered on the basis of dynamics of computational fluid approach and applied using a finite volume approach on D3 field of computation. Line electrodes along with arc plasma and work pieces are regarded as auto consistent approaches. The significant welding constraints, containing arc current, rate of wire feeding, thickness of work piece, geometry and speed of welding, kinds of metal alloy for work piece and wire, are set to modifiable constraints. By adjusting these constraints, the concert of arc welding can be projected, and various situations can be matched to enhance the performance of welding (Chen et al. 2020). He et al. proposed a new semi-implicit solution strategy for Sm-link equations to resolve nonlinear numerical equations after the discretization of mathematical models. The outcomes show that the average complete deviation among experimental information and calculated values is 8.8% and 8.2%, respectively. By analyzing the dynamic development of ventilation drying, it is establish that the drying process is carried out from both

ends of the pipe to the center. In addition, the results show that the uneven distribution of liquid retention may decrease the effectiveness of dehydrated air in the later stage of drying process. Therefore, we recommend that when the water vapor at the channel spreads the minimum set value, the drying process will be transferred to the immersion test stage. Finally, many factors affecting the drying process studied (He et al. 2020).

Yin et al. discussed the connection among revise likelihood and process efficiency. The progression purpose of process efficiency is proposed to drive the overlapping iterative procedure of multi-coupled actions. The development procedure with input data apprise is studied, and an imitation ideal is projected to acquire precise develop iteration process. It is very valuable to examine the risks in the expansion process, and has moral flexibility and adaptability. The scheming technique of procedure value of overlapping iterative procedure is specified, and the optimization ideal of invention growth process is delivered (Yin et al. 2019).

Structures, frameworks and individuals together creates a dynamic system, and like the climate, are made out of cooperating elements which are embedded into feedback hoops and are sensitive to little changes. Disposing of undesirable model may cause a magnification of mistakes in model predictions. These predictions are of no use after a specific measure of time. These frameworks are nonlinear dynamic frameworks which are delicate and unpredictable in detail because they are open either to outside influences or to their own delicate internal fluctuations. One work suggest a comprehensive quality wherein everything influences all the other things. This idea additionally underlies Gaia Theory about the development of firmly coupled frameworks. Building environmental frameworks are unpredictable unique frameworks since they include the building and its frameworks; the processes which occur in planning, designing, developing and building operating; the information and communication frameworks; and the individuals who are utilizing the building (Sharma and Kumar 2019; Sharma et al. 2019a). New models are expected to comprehend in a more profound manner how changes in these ecological, financial and social factors affect building execution and this requires an integrated approach (Li et al. 2012; Bhalaiik et al. 2020). This is relevant to the development industry which has tended to not receive the assembling mechanical designing mindset (Rafiei et al. 2013; Rathee et al. 2020). Intelligent buildings are another conspicuous model indicating a hierarchical structure of complex control systems (Jiang et al. 2012; Dhiman et al. 2021a). The original definition of intelligent structures was carried out when buildings were outfitted with IT (Pathak et al. 2018; Dhiman et al. 2021b) but has enlarged in importance during

recent years. Presently it is usually recognized that an intelligent building should have the capability to learn and change its presentation for its occupants to meet variations in the environment (Qureshi and Yusuf 2019; Poongodi et al. 2020). Intelligent structures introduce the idea of the human being as an essential piece of the system, instead of the individual outside of the framework, which can be better understood with regards to complex adaptive socio-ecological systems (Sharma et al. 2019b). A particular challenge of considering intelligent structures is to create models that join the real factors of complex hierarchical systems with myriad of intelligent segments and human natures, rather than to exclude them away (Sharma and Kumar 2017).

3 Extraction of Lyapunov exponent

The chaotic characteristic parameter of big data is the Lyapunov exponent, so the calculation of this parameter is an important step to extract the chaotic characteristic.

Lyapunov exponent can describe the chaotic intensity of big data, and it has many description forms. This paper uses the largest Lyapunov exponent, which is described as follows:

Hypothesis β_{n_1} , β_{n_2} are two points that are infinitely close in space, and the distance between them can be described as $\beta_{n_1} - \beta_{n_2} = \delta_0 < 1$ use $\delta_{\Delta n}$. Describe over a period of time Δn . After, starting at 2 points β_{n_1} , β_{n_2} . The distance between the 2 trajectories, which is $\delta_{\Delta n} = \beta_{n_1+\Delta n} - \beta_{n_2+\Delta n}$. Then the largest Lyapunov exponent can be described as:

$$\delta_{\Delta n} \approx \delta_0 e^{\lambda \Delta n}. \quad (1)$$

Assuming that λ is a positive number, the exponentials of adjacent orbits are separated, which is chaos. Because the distance between the two orbits is usually relatively close, the formula (1) is only in $\delta_{\Delta n}$. It is valid when the value is relatively small. Otherwise, the separation efficiency of adjacent tracks will be greatly reduced, and formula (1) does not hold.

4 The optimization calculation process of big data chaos model based on improved genetic algorithm

Based on the above analysis of the chaotic feature extraction results of big data, an enhanced genetic algorithm with adaptive boundary and mutation is used to optimize the chaotic model. The precise development is as follows:

4.1 Chromosome coding method

This text chooses the real number encoding form. Assuming that the parameters to be optimized are described by M , using them as components to form a row vector with M dimensions, the individual code can be obtained: $P = [p_1, p_2, \dots, p_M]$; where P represents an individual, p_i as a component randomly formed in the parameter space of the i -th parameter, M is used to describe the total amount of all parameters that need to be optimized. Each individual in this article has three components in different directions k_p , k_i , k_d , the value range is 0.001–50.

4.2 Calculate fitness function

The absolute value of the error time essential enactment index is taken as the minimum objective function of the optimization process, to obtain the dynamic process that meets the requirements. Introduce and regulate the input square term, thereby reducing the possibility of excessive control. In order to prevent overshoot, this article also introduces a penalty function. If overshoot, the overshoot is regarded as one of the optimal indicators. If $e(t) \geq 0$, the optimal indicator can be described as:

$$J = \int_0^* (w_1 |e(t)| + w_2 u^2(t) + w_4 |e(t)|) dt + w_3 t_u. \quad (2)$$

If $e(t) > 0$, the optimal index can be described as:

$$J = \int_0^* (w_1 |e(t)| + w_2 u^2(t) + w_4 |e(t)|) dt + w_3 t_u. \quad (3)$$

Among them, $e(t)$ is used to describe the system error, $u(t)$ is used to describe the data output, t_u used to describe the rise time. w_1 , w_2 , w_3 , w_4 used to describe the weight.

The fitness function can be described as:

$$f_i = 1/J + 10^{-10}. \quad (4)$$

4.3 The optimal preservation plan and the optimization of the selection operator

The probability of each individual being selected is proportional to its fitness. Use f_i describe the fitness value of an individual, the probability of the individual being selected P_s . It can be described as:

$$P_s = f_i / \sum_j f. \quad (5)$$

In order to avoid deleting individuals with high fitness values, this article stipulates that individuals with high fitness values in each generation do not need to be genetically manipulated and can directly enter the next generation, thereby improving the overall operating efficiency.

4.4 Adaptive crossover and mutation algorithm

Crossover rate p_e and mutation rate p_m perform adaptive adjustment calculations

$$\begin{aligned}
 p_e &= k_1(f_{\max} - f'_e)/(f_{\max} - f_{avg}), & f'_e &\geq f_{avg} \\
 p_m &= k_3, & f'_e &< f_{avg} \\
 p_m &= k_2(f_{\max} - f)/(f_{\max} - f_{avg}), & f &\geq f_{avg} \\
 p_m &= k_4, & f &< f_{avg}
 \end{aligned} \tag{6}$$

In summary, using the improved genetic algorithm to optimize the correlation dimension, Lyapunov exponent, and time series h, the detailed process is depicted in Fig. 2.

First obtain the basic range of all parameters to implement the encoding operation; then randomly generate n individuals to form the initial population; and then find the fitness function value f_i . Finally, the operation of the population is completed through selection, crossover, and mutation operators to form the next generation population; the second and third steps are repeated until the requirements are met or the parameters are converged (Wu et al. 2019; Rodriguez and Diaz 2018).

5 Experimental results analysis and discussion

In order to verify the effectiveness of this method, relevant experimental analysis is needed. The experiment uses Intel Core 2 Due T7600@2.33 GHz, 4 GB memory, HITACHI PATA 7200 rpm 500 GB hard disk PC, Windows7 SP1 operating system, and simulates in MATLAB 7.0 environment.

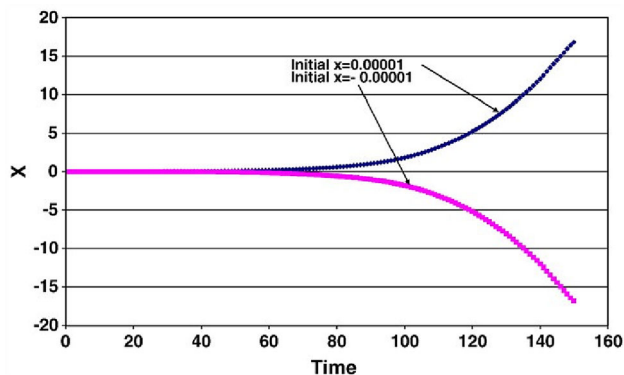


Fig. 3 Sensitivity illustration at initial conditions

Figure 3 illustrates sensitivity at initial conditions from time series. From the experimentation, it is observed that with little change in system parameters can lead to the substantial change in a system. As any point in a framework’s history can be considered as another beginning stage or starting point, the term of butterfly impact, which refers to the framework’s sensitivity to the early conditions. Bifurcations are firmly connected with attractors as they signifies to any subjective change starting with one sort of attractor to other, which presents a hop in phase space. Such unpredictable dynamics can be clarified by the panarchy structure as depicted in Fig. 3 indicating how a framework, made of numerous progressive systems and versatile subsystems, works at discrete scales, depending upon how much the adaptive pattern of each sub-framework is synchronized. It portrays the key attributes of every complex framework: change and stability. Conversely, inside the chaotic regions, more modest zones of

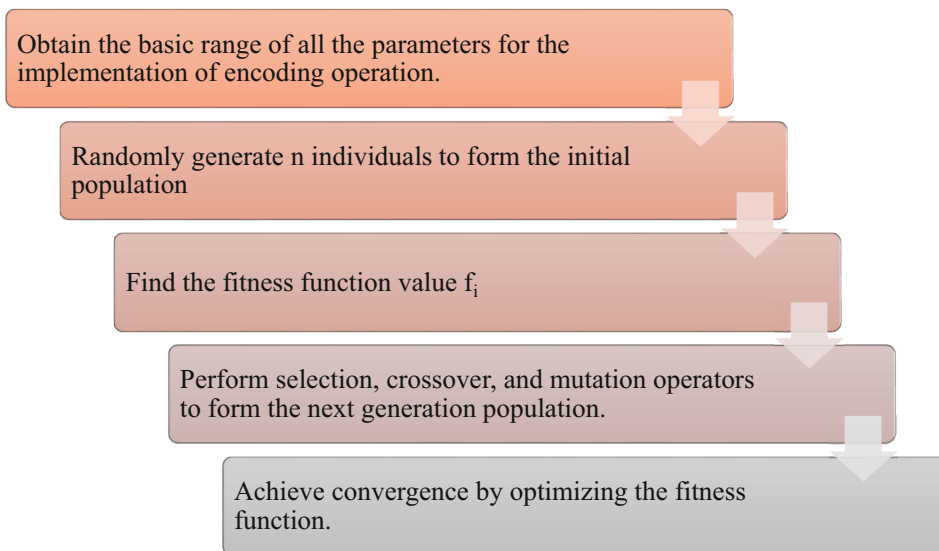


Fig. 2 Flowchart of the optimization calculation process

Table 1 Performance comparison results of method proposed in this article and traditional methods

Parameter	Method	Mean and standard deviation
Correlation dimension	Global optimal	8.21 ± 1.66
	Process of this article	8.21 ± 1.39
	Traditional technique	8.17 ± 0.15
Lyapunov index	Global optimal	230 ± 0
	Process of this article	230 ± 0
	Traditional technique	230 ± 0
Time series entropy	Global optimal	2 ± 0
	Process of this article	2 ± 0
	Traditional technique	1.99 ± 9.3

Table 2 Comparison outcomes of the operation efficiency of technique projected in this article and the traditional method

Parameter	Method	Average number of iterations	Average running time (s)
Correlation dimension	Process of this article	103	0.85
	Traditional technique	215	1.63
Lyapunov index	Process of this article	105	0.74
	Traditional technique	234	1.56
Time series entropy	Process of this article	59	0.76
	Traditional technique	138	1.59

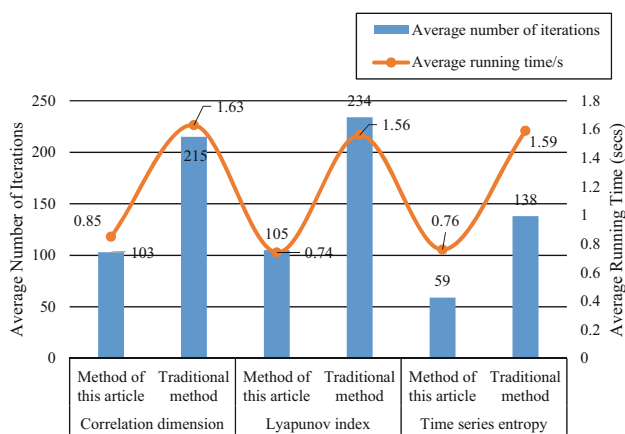


Fig. 4 Comparative analysis of different parameters of the proposed method and the traditional method

stable periodicity are detectable and these areas show up at a lot more limited size. Such redundancy of similar example at various scales is distinguished as fractal. These perceptions give a clarification with respect to why the chaotic framework is dynamic and nonlinear: it is difficult to predict the result for a given initial state. The connection between the elements, states in the framework can't be

predicted and these connections change nonlinearly and erratically over the time span (Bhalaik et al. 2020). Figure 3 presents the shows illustration of sensitivity to initial conditions from the Lorenz tumultuous time arrangement.

Table 1 describes the comparison results of the average value and standard deviation of the method in this paper and the traditional simulated fishing method.

Analysis of Table 1 displays that the process in this paper can accurately obtain the global optimal value of all chaotic parameters, and the optimization performance is particularly special stable. However, the traditional simulation fishing method can only find the optimal value of Lyapunov exponent, which leads to poor optimization performance (Hamdi and Abie 2014; Li et al. 2018).

Table 2 describes the comparison outcomes of the iteration number and running time of the technique in this paper and the traditional simulated fishing method. More elaborative comparison of these values is done in Fig. 4 for clear understanding. The mathematical modelling through computer simulation, which is performed on a computer, and intended to estimate the behavior of or the result of a real world or actual framework. The experimental analysis shows that the proposed method has a high optimization capability. The simulation experiment results show that the proposed method has high optimization ability. The

selection operation is completed through the fitness ratio method and the optimal retention strategy. The population is processed through selection, crossover, and mutation operators. This proposed chaotic model based on genetic algorithm, analyzes and extracts the correlation dimension, the largest Lyapunov exponent, and the time series.

Analysis of Fig. 4 displays that the technique in this paper can quickly converge to the global extreme every time, while the traditional simulated fishing method is both as there are precocious or local optimal situations. The running period of the technique in this paper is only about half of the traditional simulated fishing method, which verifies the efficiency of the method presented in this paper.

6 Conclusion

This paper proposes a big data chaotic model optimization calculation method based on an improved genetic algorithm, which overcomes the shortcomings that the big data chaos model optimization calculation process cannot achieve the global optimization and has uncertain factors. The selection operation is completed through the fitness ratio method and the optimal retention strategy. The population is processed through selection, crossover, and mutation operators. The square term and penalty function of the input control are introduced in the function to find the optimal index and fitness function. By implementing the improved genetic algorithm to optimize the correlation dimension, Lyapunov exponent, and time series, the system presents higher improvement. The experimental analysis displays that the method projected can quickly cover the global extreme every time, while the traditional simulated fishing method is both as there are precocious or local optimal situations. The method proposed in this article achieves average running time of 0.85 for correlation dimension, 0.74 for Lyapunov index and 0.76 for time series entropy, thereby outperforming the traditional method. Thus, the running time of the method in this paper is about half of the traditional simulated fishing method, which verifies the efficiency of the proposed method.

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Declarations

Conflict of interest The authors declare that they have no conflict of interest.

Research involving human participants and/or animals This article does not contain any studies with animals performed by any of the authors.

Informed consent Informed consent was obtained from all individual participants included in the study.

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