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Automation

Stabilization of Chaotic Time Series by Proportional Pulse in the System Variable Based on Genetic Algorithm

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Abstract: The PPSV (Proportional Pulse in the System Variable) algorithm is a convenient method for the stabilization of the chaotic time series. It does not require any previous knowledge of the system. The PPSV method also has a shortcoming, that is, the determination of λ is a procedure by trial and error, since it lacks of optimization. In order to overcome the blindness, GA (Genetic Algorithm), a search algorithm based on the mechanics of natural selection and natural genetics, is used to optimize the λ_i. The new method is named as GA-PPSV algorithm. The simulation results show that GAPPSV algorithm is very efficient because the control process is short and the steady-state error is small.

Key words: stabilization; chaotic time series; genetic algorithm

Deterministic chaos, being characteristic as chaotic systems by their strong sensitivity to small perturbations in their initial conditions, has been studied by most scientists. As a branch of these studies, control and stabilization of the chaotic systems have been widely developed in recent years. Consequently, many control methods have been proposed [1]. Among these methods, PPSV [2] is a useful one. It allows us to stabilize chaotic systems by applying Proportional Pulse to the System Variable and does not require any previous knowledge of the systems. Especially in some cases, which may be difficult to find an accessible system parameter, this method is suitable. In this method, one performs changes in the system variables in the form of instantaneous pulses spaced in time, namely, every interval P, in the form

$$x_{ki} = [1 + \lambda_i \alpha_{kip}] x_{ki} \quad (i = 1, 2, \cdots, m;\ k = 1, 2, \cdots) \qquad (1)$$

where x_{ki} represents the ith variable of the system in k instant of time (time series) and λ_i, which can be positive or negative, regulates the strength of the pulse. The value of m is the sum of all variables and α_{kip} has the form as following

$$\alpha_{kip} = \begin{cases} 1 & k=0 \pmod p \\ 0 & k\neq 0 \pmod p \end{cases} \quad (i=1,2,\cdots,m; k=1, 2, \cdots) \qquad (2)$$

As a sample, we use PPSV method to stabilize the x time series of the Lorenz system. The Lorenz model is expressed as the following form [3]

$$\begin{cases} dx/dt = -\sigma x + \sigma y \\ dy/dt = rx - y - xz \\ dz/dt = xy - bz \end{cases} \qquad (3)$$

when the values for the parameters are $\sigma = 10$, $r = 28.0$, $b = 8/3$, the model stands for a chaotic system. All the numerical work has been performed by employing a fourth-order Runge-Kutta algorithm to generate the x time series, where the initial condition is (0, 1, 0) and the step length is 0.01. We began to inject proportional pulses to x variable every step (here $p=1$) when $(x_k, y_k, z_k) = (9.448\,998, 19.309\,462, 7.774\,043)$ and the desired fixed point is 4.5. When λ_i is -0.18, the steady-state error can be limited within 0.05 and the stabilization process is 135 steps. From the sample above, we discovered that PPSV method has a shortcoming, that is, the control process is relative long. We think the main reason is that the determination of λ is a procedure by trial and error, for it lacks of optimization. Until x_{ki} is stabilized, we can not determine whether λ_i is adequate.

1 Introduction of GA

Genetic Algorithm (GA) is a search algorithm based on the mechanics of natural selection and natural genetics. It is different from the traditional optimization and search procedure in four ways [4]:

(1) GA works with a coding of the parameter set, not the parameters themselves.

(2) GA searches from a population of points, not a single point.

(3) GA uses payoff (objective function) information, not derivatives or other auxiliary knowledge.

(4) GA uses probabilistic transition rules, not deter-

ministic rules.

Genetic Algorithm (GA) often includes seven operations: coding, decoding, fitness calculation, copy, selection, crossover and mutation.

2 GAPPSV Algorithm and its Application

In order to overcome the shortcoming of PPSV, a new method named GAPPSV algorithm is proposed in this paper. In our algorithm, PPSV is still used as the stabilization method and GA is used to optimize the value of λ_i. Equation (1) is changed to the following form

$$x_{k_i}^{'} = [1 + \lambda_{ki}\alpha_{kip}]x_{k_i} \quad (4)$$

where λ_{k_i} is no longer a constant, it altered with the iterative procedure.

Now, let's use GAPPSV algorithm to stabilize the x time series of Lorenz system. The control condition is the same as the above sample. The value of λ_k ($k=1,2,\cdots$) are determined by GA, where the population size is 30, the length of binary coding is 10 bits, the range of λ_k is set to $[-1, 1]$ and the maximal iterative generation is 200. Fitness function is selected as the following form

$$\text{fitness}(x_k^{'}) = |x_{k-1} - x^*| \quad (k=1,2,\cdots) \quad (5)$$

where $x_{k-1} = f(x_k^{'})$ is the actual output of the system and x^* is the desired fixed point. The genetic algorithm is operated as following steps:

(1) Some excellent individuals (about 10% of the population size) with higher fitness take elitist model, that is to say, they go to the next generation without any operation.

(2) Most individuals (about 80% of the population size) take one-point crossover operation, where the mate pair and the cross-site are selected at random.

(3) The remainder individuals (about 10% of the population size) undergo one-point mutation operation, where mutant site is also set at random.

When GAPPSV algorithm is used to stabilize the x variable of the Lorenz model, the control result is shown in **figure 1** (x coordinate is the iterative steps and y coordinate is the iterative data of x variable).

In order to demonstrate the control result clearly, the iterative data are displayed in **table 1** (because of the space, only 12 steps are listed):

As shown in figure 1 and table 1, it needs only one step to achieve the goal. Furthermore, according to the iterative data we recorded, the steady-state error is 0.04.

In a word, the control result is satisfactory when GAPPSV algorithm is used to stabilize the chaotic time series.

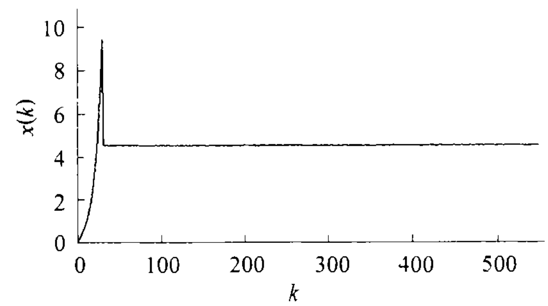

Figure 1 The control result of GAPPSV algorithm

Table 1 The iterative data about x variable of Lorenz model

No.	λ_k	x_k	y_k	z_k
1	−0.691 105	4.502 658	19.855 858	8.341 594
2	−0.364 614	4.500 762	20.370 173	8.911 648
3	−0.376 344	4.499 332	20.853 378	9.483 135
4	−0.386 119	4.503 301	21.307 346	10.056 180
5	−0.390 029	4.531 625	21.737 186	10.635 352
6	−0.409 580	4.506 402	22.133 766	11.207 660
7	−0.419 355	4.489 355	22.499 868	11.773 984
8	−0.423 265	4.498 177	22.840 872	12.339 609
9	−0.431 085	4.502 220	23.156 610	12.902 754
10	−0.438 905	4.501 310	23.447 020	13.461 599
11	−0.444 770	4.503 481	23.713 320	14.016 324
12	−0.456501	4.480 865	23.952 770	14.560 223

3 Conclusoins

(1) GAPPSV algorithm can stabilize the chaotic time series quickly.

(2) The steady-state error is very small.

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References

[1] L. Q. Chen, Y. Z. Liu: *Advances in Mechanics* (in Chinese), 28 (1998), No. 3, p. 299.

[2] M. A. Matias, J. Guemez: *Phys.Rev.Lett.*, 72 (1994), No. 10, p. 1455.

[3] C. X. Yi: *Nonlinear Science and Their Applications in Geoscience* (in Chinese), Meteorological Publishing House, Beijing, 1995, p. 211.

[4] G. L. Chen, X. F. Wang, Z. Q. Zhuang, D. S. Wang: *Genetic Algorithm and Its Application* (in Chinese). People's Posts and Telecommunication Publishing House, Beijing, 1996.