Research on Electronic Signal-Assisted Control System Based on Computer Big Data

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Abstract. Based on computer big data, this paper proposes a new scheme to realize the detection of weak electronic sinusoidal signals using the sensitivity of chaos to parameters in a specific state. This scheme can effectively detect weak sinusoidal signals deep in the background of color noise. The method of chaos detection is given, and the influence of noise on the system state is analyzed. Simulation experiments show that the chaos detection system is very sensitive to small signals, and has a strong ability to suppress any zero-mean color noise.

Keywords: Computer; Big data; Electronic signal; Sinusoidal signal; Chaotic state; System control.

1. Introduction

In recent years, with the in-depth research and wide application of chaos theory in various fields of modern science, people have begun to use chaos theory in the detection of weak signals. The theory and method of weak signal detection. Among them, the method of using chaotic oscillator to detect weak signals in various complex noise backgrounds has attracted more and more attention due to its advantages of low equipment cost and obvious physical meaning [1]. Due to the power of chaotic dynamic systems Due to the extreme sensitivity of the learning behavior to the initial parameters, chaotic oscillators can be used to detect and extract weak signals. Under the background of white noise or color noise, there are two main ways to extract weak sinusoidal signals: one is to use the signal to be measured. Weak signal detection can be performed on the change of the phase plane trajectory that makes the dynamic behavior of the system transition from a chaotic state to a large-scale periodic state. Existing studies have shown that even for sinusoidal signals with a signal-to-noise ratio as low as -111.46dB, this method still has the ability to detect weak signals. Good detection performance. The key to applying this method is to accurately discriminate the phase transition of the system, but this is not easy to grasp in practice, thus affecting the effectiveness of the method. Another method is to establish the relationship between the characteristic index of the system dynamics behavior at the critical bifurcation state and the signal parameters of the signal to be measured realizes the estimation of the signal parameters. The principle is simple [2]. The disadvantage is that the nonlinear least squares algorithm (NLLS) is used to estimate the signal parameters, which greatly increases the amount of computation, and because the nonlinear least squares algorithm does not necessarily guarantee that the estimated value reaches the global optimal solution, this method is inconvenient. Engineering implementation. If a fast and globally optimal estimation method can be found, the estimation characteristics will be greatly improved.

The chaos detection method proposed in this paper applies a periodic perturbation force to the chaotic system in a specific state, perturbs the chaotic state, and makes the system mutate from the chaotic state to the large-scale periodic state, so as to detect weak signals according to the change of the phase plane trajectory of the system [3]. The simulation results show that under the background of any zero-mean color noise, the method still has good detection performance even for sinusoidal signals with a signal-to-noise ratio as low as about 111.46dB.

2. Duffing equation of periodic frequency

The rapid change of the phase plane of the system state shows that this detection method has good real-time performance [4]. In order to detect periodic signals of other frequencies, we change the equation by an equal amount, so that it can be applied to the detection of various frequencies. Let t= $\omega\tau$, then start from the original equation and transform it into a kinetic equation on time scale τ (Figure 1 is quoted in A Hybrid Fuzzy Logic Proportional-Integral-Derivative and Conventional On-Off Controller for Morphing Wing Actuation using Shape Memory Alloy, Part 1: Morphing system mechanisms and controller architecture design). The specific process is as follows:

$$x''(\mathrm{t}) + kx'(\mathrm{t}) - \mathrm{x}^3(\mathrm{t}) + x^5(\mathrm{t}) = f\cos\omega t + input(\mathrm{a}^*\cos\omega\,\mathrm{t}) + \mathrm{zs} \tag{1}$$

Then x(t)=x ($\omega\tau$)= (τ)

$$x'(\mathrm{t}) = \frac{dx(\mathrm{t})}{dt} = \frac{1}{\omega}\frac{dx_t(\tau)}{dt} = \frac{1}{\omega}x_t(\tau) \tag{2}$$

$$x''(\mathrm{t}) = \frac{1}{\omega^2}\frac{d^2x_t(\tau)}{d\tau^2} = \frac{1}{\omega^2}x_t(\tau) \tag{3}$$

Substitute into (2) to get:

$$\frac{1}{\omega^2}x_t(\tau) + \frac{k}{\omega}x_t(\tau) - \mathrm{x}_t{}^3(\tau) + \mathrm{x}_t{}^5(\tau) = f\cos(\omega\,\mathrm{t}) + \mathrm{input}(\mathrm{a}^*\cos\omega\,\mathrm{t}) + \mathrm{zs} \tag{4}$$

Written in the equation of state form:

$$\begin{cases} x' = \omega y \\ y' = \omega(-\mathrm{ky} + \mathrm{x}^3 - \mathrm{x}^5 + \mathrm{fcos}(\omega\tau) + \mathrm{input}(\mathrm{a}^*\cos\omega\tau) + \mathrm{zs}) \end{cases} \tag{5}$$

Or written as

$$x'' = -wkx' + w^2(\mathrm{x}^3 - \mathrm{x}^5 + \mathrm{fcos(wt)} + input(\mathrm{a}^*\cos(\mathrm{wt})) + \mathrm{zs}) \tag{6}$$

When the frequencies to be measured are different, build a model:

$$\frac{1}{\omega^2}x_t(\tau) + \frac{k}{\omega}x_t(\tau) - \mathrm{x}_t{}^3(\tau) + \mathrm{x}_t{}^5(\tau) = f\cos(\omega\tau) + \mathrm{input}(\mathrm{a}^*\cos\omega\tau) + \mathrm{zs} \tag{7}$$

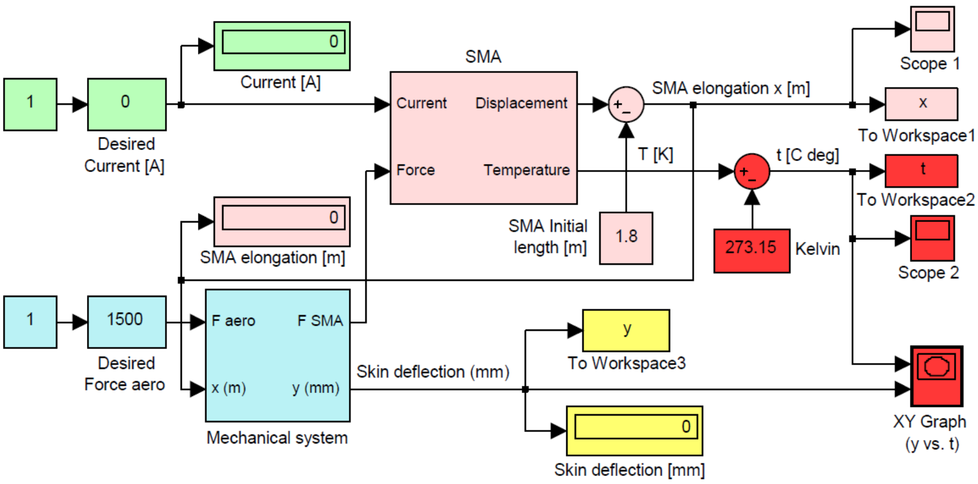

Fig. 1 Simulink simulation model

Since equation (7) is obtained by the mathematical equivalent transformation of equation (1), the state characteristics of the system will not be changed. When establishing the simulation model, the periodic signals of different frequencies can be detected only by adjusting the corresponding proportional coefficient, which makes it universal [5]. Adjust the value of W according to the different frequencies of the actual signal to be measured. In the graphical model, since gain, gain1 and gain2 are all functions of w (gain=w*w, gain1=1/w, gain2=w*k= w/2), so as long as the amplifier gain value of these modules is adjusted, periodic signals of different frequencies can be measured. Since the equation is derived from equation (1), the time scale of the observed system is different, and the state and change law of the system will not be changed, so periodic signals of different frequencies can be detected, just because x`, y` change to the previous w times, so the only difference is the speed of the system.

3. Determination of chaotic system threshold

Computing the Melnikov function is

$$M(t_0) = \int_{-\infty}^{\infty} f(q^0(t)) \wedge g(q^0(t), t + t_0) dt \tag{8}$$

From Duffing's equation

$$f(\mathrm{x}) = \begin{bmatrix} y \\ -x^3 + x^5 \end{bmatrix} \quad g(\mathrm{x}) = \begin{bmatrix} 0 \\ -ky + f\cos(\omega \mathrm{t}) \end{bmatrix} \tag{9}$$

But

$$\begin{aligned} M(\mathrm{t}_0) &= \int_{-\infty}^{\infty} \left[y(\mathrm{t})(-\mathrm{ky}(\mathrm{t}) + \mathrm{f} \bullet \cos\omega(\mathrm{t} + \mathrm{t}_0)) \right] dt \\ &= \int_{-\infty}^{\infty} -ky^2(\mathrm{t})\,\mathrm{dt} + \int_{-\infty}^{\infty} y(\mathrm{t}) \bullet \mathrm{f} \bullet \cos\omega(\mathrm{t} + \mathrm{t}_0)\,\mathrm{dt} \\ &= \int_{-\infty}^{\infty} -k \bullet \left(\pm \frac{3\sqrt{6}t}{(3t^2+4)^{3/2}} \right)^2 dt + \int_{-\infty}^{\infty} f \bullet \left(\mp \frac{3\sqrt{6}t}{\left(3t^2+4\right)^{3/2}} \right) \bullet \cos\omega\left(t + t_0\right) dt \\ &= -\frac{3\sqrt{3}\pi}{32} k \pm f \bullet \frac{12\sqrt{6}\omega\pi^2}{\left(3\pi^2 + 16\omega^2\right)^{3/2}} \bullet \sin\omega t_0 \end{aligned} \tag{10}$$

Obtained by $M(t_0) = 0$

$$\frac{3\sqrt{3}\pi}{32} k = f \bullet \frac{12\sqrt{6}\omega\pi^2}{\left(3\pi^2 + 16\omega^2\right)^{3/2}} \bullet \sin\omega t_0 \tag{11}$$

Solve for $\sin\omega t_0 = \frac{\sqrt{2}k\left(3\pi^2 + 16\omega^2\right)^{3/2}}{256\omega\pi f}$. And because of $\left|\sin\omega t_0\right| \le 1$, so $\left|\frac{\sqrt{2}k\left(3\pi^2 + 16\omega^2\right)^{3/2}}{256\omega\pi f}\right| \le 1$. Again because of $\frac{dM(\mathrm{t}_0)}{d\,\mathrm{t}_0} = f \bullet \frac{12\sqrt{6}\omega^2\pi^2}{\left(3\pi^2 + 16\omega^2\right)^{3/2}} \bullet \cos\omega t_0$. If $\frac{dM(\mathrm{t}_0)}{d\,\mathrm{t}_0} \ne 0$.

then it must be $\cos\omega t_{\ne} = 0$. So $\sin\omega t_0 \ne 1$. As long as $\left|\frac{\sqrt{2}k\left(3\pi^2 + 16\omega^2\right)^{3/2}}{256\omega\pi f}\right| < 1$, there must exist t_0 such that $M(t_0) = 0$ and $\frac{dM(t_0)}{dt_0} \ne 0$.

Therefore, according to the relevant theorem of Melnikov function: at this time, $M(t_0)$ must have t_0 independent of ε, so that $M(t_0) = 0$ and $\frac{dM(t_0)}{dt_0} \ne 0$ at the same time. Therefore, for a sufficiently small ε, in the Poincare map corresponding to Eq. (12), the stable invariant manifold and the unstable invariant manifold must intersect transversely. That is to say, the transversal homoclinic point must appear at this time, so this system may appear chaotic solution.

4. Constructing the Nanovolt Signal Generator

The measurement of nanovolt-level weak sinusoidal signals has become a frontier topic in signal processing work [6]. The key to nanovolt-level weak sinusoidal signal measurement lies in how to fully suppress the measurement noise generated by the measurement line. The CF-920 series is used as the data sampling system, and the schematic diagram of connecting it with the chaos detection system is shown in Figure 2 (the picture is quoted from Design of a Matching Network for a High-Sensitivity Broadband Magnetic Resonance Sounding Coil Sensor).

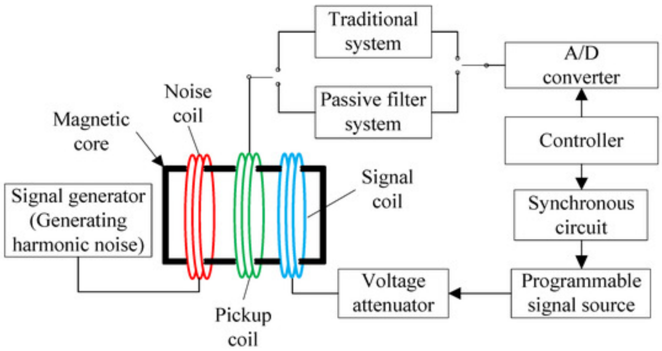

Fig. 2 Schematic of Nanovolt Signal Generator

According to the connection circuit in Figure 2, the signal generator is used to generate 100mV, 1kHz, sinusoidal signal, the normalized frequency is 0.31Hz, the sinusoidal signal is attenuated to nV by the resistor network, amplifiers I and II are pre-isolation amplifiers, using their own independent power supply power supply, and amplifiers I, II are completely independent electrically, so the noise they produce is uncorrelated with each other. After the signal is pre-amplified, the peak value is about a few millivolts, and it is polluted by noise [7]. Therefore, the signal needs to be sent to the CF-920 signal detection and analysis system for further amplification before acquisition. The CF-920 signal detection and analysis system is a dual-channel data acquisition and analysis system with excellent performance produced by Kono Instruments, Japan. The equivalent input bandwidth is 0-100kHz, with perfect performance and accurate measurement. It should be noted that after the signal is sent to the CF-920 system, two channels of correlated noise will inevitably be generated. However, since the CF-920 system adopts a dual-channel design, the correlation between the two channel noises is weak, and there are more additive noises. To be irrelevant, the processed nV sinusoidal signal is finally introduced into the chaos detection system.

5. Simulation Analysis

In order to verify the effectiveness of the proposed method, the sinusoidal signal with a signal-to-noise ratio of -20dB which fails the cross-correlation detection method is detected. In order to verify the ability of the Duffing chaotic oscillator to detect weak signals, we designed the pure noise signal and the signal mixed with the signal to be measured and the strong noise to act on the Duffing detection system respectively. input, and then detect the magnitude of the amplitude of the signal to be measured [8]. The detection capability of the system is determined by adjusting the size of the noise and the signal to be measured. We test with w=1rad/s and w=100*Pirad/s simulations, respectively, to check that the duffing oscillator chaos detection system has universal adaptability. It is assumed that the frequency of the sinusoidal signal to be detected is known, but its amplitude is unknown. In order to detect the sinusoidal signal submerged in the strong noise, under the condition of known signal frequency, the relevant parameters of the chaos detector are set as: the initial state of the system (x, y) = (0, 0), the angular frequency $\omega = 1$. Damping ratio k=0.6, sampling time h=0.01. When the signal to be checked is not added, the amplitude γc of the driving force in the critical state of the chaotic system is determined by the algorithm proposed by us. Let the initial actuating force be γ=0.98, and the iterative step size of the actuating force is $\Delta\gamma$=0.0001 (simulation experiments show that this value will not cause λ1 to oscillate around the zero value), and by calculating the amplitude of the actuating force in the critical state of the chaotic system, we get When γ=0.9838, the maximum Duffing oscillator $\lambda 1 \approx 0$ is shown in Fig.3.

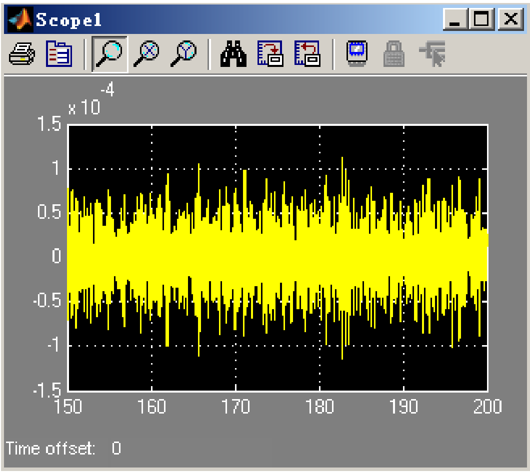

Fig. 3 The relationship between the maximum Duffing oscillator and the driving force amplitude

This value can be determined as the driving force amplitude γc in the critical state of the system. In order to verify the correctness of this amplitude, it is substituted into equation (6), and the Duffing oscillator of the system can be obtained by the QR decomposition method as shown in Fig. 4 Show.

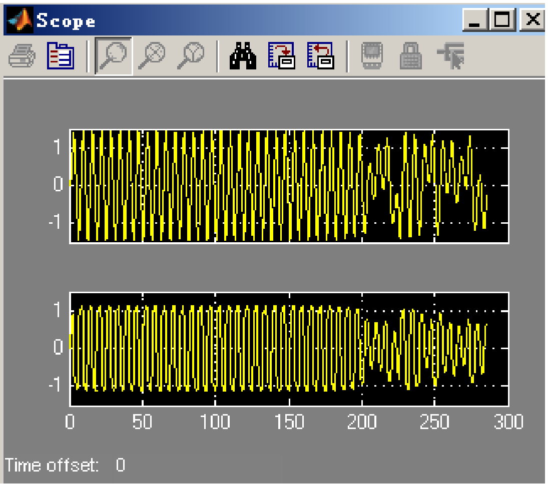

Fig. 4 Duffing oscillator in critical state of chaotic system

Observing the phase trajectory of the system at this time (see Fig 5), it also shows that the system is in a critical state, and the amplitude of the actuating force is accurate.

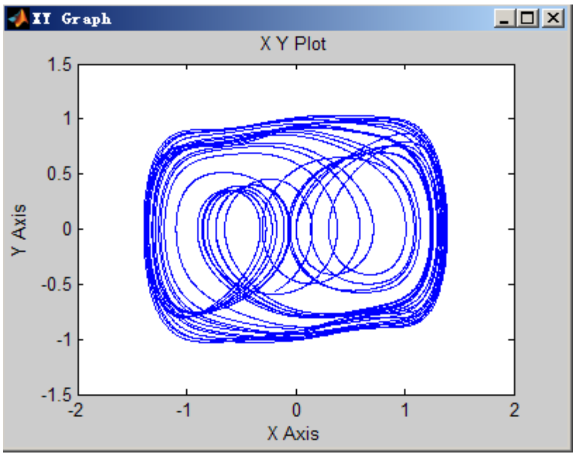

Fig. 5 Phase trajectories of a chaotic system in a critical state

From the experimental results given in Table 1, it can be seen that the weak signal detection method proposed in this paper can effectively detect sinusoidal signals of any known frequency from strong noise, and because the method combines the noise suppression and chaos of the cross-correlation method The signal extraction advantage of the detection method, and the Duffing oscillator quantization criterion is introduced, which is superior to the single chaotic method and cross-correlation method in detection accuracy.

Table 1. Comparison of detection results of three methods for sinusoidal signals

	ω/(rad·s-1)	1		10	
	SNR/dB	-1	-10	-5	-20
	Amplitude	0.01	0.05	0.2	0.8
The method of this paper	Detection value	0.0097	0.048	0.191	0.821
	error/ (%)	3	4	4.5	2.6
Chaos method	Detection value	0.0094	0.0523	0.206	0.768
	error/ (%)	6	5	4.5	4
cross-correlation method	Detection value	0.0092	-	0.218	-
	error/ (%)	8	-	9	-

6. Conclusion

In this paper, a specific chaotic detection system for detecting weak harmonic signals under the background of zero-mean color noise is proposed, and the principle and method of weak signal detection based on the phase trajectory change of chaotic system are analyzed by using the Melnikov function, and it is demonstrated that the system has the ability to detect noise. It has a wide range of adaptability. The simulation results show that the above chaos detection method is feasible.

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