



Research on Intelligent Detection Method of Weak Sensing Signal Based on Artificial Intelligence

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Abstract. In order to improve the detection and recognition ability of weak sensing signal, an intelligent detection algorithm of weak sensing signal based on artificial intelligence algorithm is proposed. The weak sensing signal model is constructed, the weak sensing signal is separated and processed adaptively, the scale and delay of the weak sensing signal are estimated adaptively, and the high resolution spectral features are extracted. The extracted spectral feature is studied adaptively and detected intelligently by artificial intelligence algorithm, and the spectral peak search of weak sensing signal is realized. The spectral feature component method is used to realize the interference suppression of weak sensing signals, thereby improving the detection of the method. The simulation results show that the algorithm has high accuracy and anti-interference ability, and improves the detection and recognition ability of weak sensing signal.

Keywords: Artificial intelligence method · Wireless sensor network · Weak sensing signal · Intelligent detection

1 Introduction

The research on weak sensing signal detection method of wireless sensor network have important application value in the field of wireless sensor network communication optimization and signal recognition. The research of related signal detection method have paid great attention to [1]. In the detection and recognition of weak sensing signal, it is necessary to detect weak sensing signal, detect and estimate the weak sensing signal emitted by wireless sensor network, and detect the weak sensing signal through weak sensing signal. Realize weak sensing signal detection and weak sensing signal recognition, improve the accuracy and automation level of weak sensing signal detection and recognition. In the traditional method, the time-frequency coupling algorithm is used for the detection of weak sensing signal, and the time-frequency feature decomposition method is used to separate the signal to improve the fault detection performance [2]. If the weak sensing signal and interference noise have strong coupling, the detection performance is not good. In reference [4], a weak sensing signal detection algorithm based on fractional Fourier time-frequency coupling is proposed to solve the optimal solution of phase fuzzy number search for signal

characteristics of wireless sensor networks, and the phase compensation results of weak sensing signal parameters are obtained [3]. The ability of fault detection is improved, but the anti-interference ability of this method is not good and the computational complexity is high. In order to solve the above problems, an intelligent detection algorithm of weak sensing signal based on artificial intelligence algorithm is proposed in this paper. The weak sensing signal model is constructed, the spectrum decomposition of the multi-carrier weak sensing signal is carried out, the weak sensing signal is separated and processed adaptively, and the parameters such as the scale and delay of the weak sensing signal are estimated adaptively. According to the spectrum offset characteristics of weak sensing signal, high resolution spectral feature extraction is carried out, and artificial intelligence algorithm is used for adaptive learning and intelligent detection of weak sensing signal, and the intelligent detection of weak sensing signal is realized. Finally, the simulation results show the superior performance of this method in improving the fault detection ability of wireless sensor networks.

2 Analysis of Weak Sensing Signal Model and Characteristic Parameters

2.1 Preliminary Knowledge of Model Construction of Weak Sensing Signal

Before studying the phase characteristics of weak sensing signal, it is necessary to construct the signal model of weak sensing signal and construct the model of signal output source. Pattern recognition of weak sensing signal is carried out, combined with sensing information processing method, the feature sampling of weak sensing signal is carried out, and the following three characteristics of weak sensing signal are given [4].

(1) Length of weak sensing signal

Because the length of the weak sensing signal interferes with the amplitude of the signal, the length of the signal can effectively feedback the fault category by taking the length of the signal as the characteristic quantity. Firstly, the length fl , between the optimal sampling points of the weak sensing signal n_b is obtained. Then with the parameter estimation results of fl , the weak sensing signal length l is obtained as:

$$fl = x(\max z_{x n_b}) - x(\min z_{x n_b}) \tag{1}$$

$$l = a \cdot fl + b \tag{2}$$

Where, a, b represent the characteristic decomposition coefficient, for the given broadband high resolution weak sensing signal $x(n)$ and scale d , $\bar{E}(n_i, d)$ F is used to represent the energy of the weak sensing signal, the maximum energy of the weak sensing signal is expressed by $\max\{E(n_i, d)\}$, and λ is used as the correlation coefficient. Used to describe the signal to improve the resolution and sensitivity of weak sensing signal [5].

(2) Amplitude is the effective characteristic quantity of weak sensing signal, which represents the maximum wave peak and wave valley difference of weak sensing signal:

$$z_{\max} = \max_{y=n_1}^{n_2} \left\{ \max_{x=m_1}^{m_2} \{z_{xy}\} - \min_{x=m_1}^{m_2} \{z_{xy}\} \right\} \quad (3)$$

The depth of weak sensing signal directly affects the amplitude of the signal, which is the characteristic of depth, and is related to the length and width of weak sensing signal [6].

(3) Energy distribution characteristics of weak sensing signals:

$$E = \sum_{x=n_1}^{n_2} \sum_{y=m_1}^{m_2} z_{xy}^2 \quad (4)$$

After analyzing the three main feature quantities of weak sensing signal, the correlation relationship of each feature quantity of weak sensing signal is analyzed and compared [7]. Combined with association rule mining and spectrum feature extraction method, the aggregation degree of weak sensing signal in each feature quantity is obtained [8]. According to the estimation results of signal characteristic quantity E , the 3D size of weak sensing signal is comprehensively reflected, and the fault detection of wireless sensor network is realized by combining artificial intelligence algorithm method.

2.2 Analysis of Characteristic Parameters of Weak Sensing Signal

Let the broadband high resolution weak sensing signal be a set of stationary random signals, which is represented by the power spectrum characteristic decomposition of the signal by $x(t)$, the joint parameter estimation of time and frequency of $x(t)$, and the acquisition of discrete signal $x(n)$. The short time Fourier transform is used to windowed the signal, and the output window function is $h(t)$. The spectrum width of the weak sensing signal is $T = (2d + 1)T_s$, $F_s = 1/T_s$. Artificial intelligence algorithm is used to decompose the spectrum of weak sensing signal:

$$X_p(u) = F^p x(t) = F^\alpha [x(t)] = \int_{-\infty}^{+\infty} K_p(t, u) x(t) dt \quad (5)$$

Combined with the high-order statistic analysis method, the high-order cumulant special decomposition of $X_p(u)$ can be expressed as follows:

$$X_p(u) = \begin{cases} \sqrt{\frac{1-j \cot \alpha}{2\pi}} e^{j\frac{\alpha^2}{2} \cot \alpha} \int_{-\infty}^{+\infty} x(t) e^{j\frac{\alpha^2}{2} \cot \alpha - j u \csc \alpha} dt & \alpha \neq n\pi \\ x(u), \alpha = 2n\pi \\ x(-u), \alpha = (2n \pm 1)\pi \end{cases} \quad (6)$$

Adaptive blind separation is performed for weak sensing signal, and parameters such as scale and delay of weak sensing signal are estimated by adaptive estimation of parameters of weak sensing signal:

$$X_1(k) = FFT[x_1(k), x_1(k+1), \dots, x_1(k+N-1)]^T \quad (7)$$

The wavelet detector is used to combine the time domain characteristic quantity and the frequency domain feature quantity of the signal to estimate the joint parameters [9]. The estimation model of the characteristic parameters of the weak sensing signal is obtained as shown in Fig. 1.

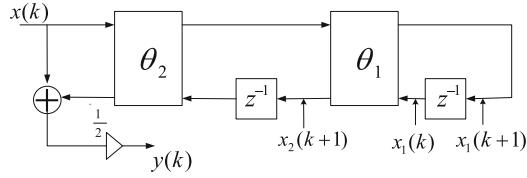


Fig. 1. Estimation model of characteristic parameters of weak sensing signal

3 Optimization of Intelligent Detection Algorithm for Weak Sensing Signal

On the basis of constructing the weak sensing signal model, the spectrum decomposition of the multi-carrier weak sensing signal is carried out, and the weak sensing signal is separated adaptively and blindly [10]. The order of the spectrum decomposition of the weak sensing signal is order 2. The parameters $a_1(t)$ and $a_2(t)$ of the time-frequency joint of the weak sensing signal are determined by the following formula:

$$\begin{cases} a_1(t) = -2m(t) \cos(\theta(t)) \\ a_2(t) = m^2(t) \end{cases} \quad (8)$$

According to the spectrum offset characteristics of the weak sensing signal, the high resolution spectral feature extraction is carried out [11], and the sampling signal of the m element of the signal acquisition array is obtained as follows:

$$s_m(t) = \cos\{2\pi f_0[t + \tau_m(\theta)]\} \quad (9)$$

The left beam output of weak sensing signal windowing using narrow time domain window is expressed as follows:

$$l(t) = \left(\sum_{m=1}^M u_m \right) \cos(2\pi f_0 t) - \left(\sum_{m=1}^M v_m \right) \sin(2\pi f_0 t) \quad (10)$$

Where, the high resolution spectral feature extraction of weak sensing signal is as follows:

$$u_m = \cos[2\pi f_0 \tau_m(\theta)]; v_m = \sin[2\pi f_0 \tau_m(\theta)] \quad (11)$$

For weak sensing signals, artificial intelligence algorithm is used for adaptive learning and intelligent detection of the extracted spectral features [12]. The modulation pulse parameters of the two array outputs are obtained as follows:

$$l(t) = A_l \cos(2\pi f_0 t + \alpha_l) \quad (12)$$

According to the characteristic aggregation point of weak sensing signal, the time frequency localization of weak sensing signal is carried out, and the output sample of window function is recorded as follows:

$$x_k = \sum_{n=0}^{N/2-1} 2(a_n \cos \frac{2\pi kn}{N} - b_n \sin \frac{2\pi kn}{N}) \quad k = 0, 1, \dots, N-1 \quad (13)$$

Where, a_n represents the variable scale offset, from which the spectral peak of the weak sensing signal is obtained as follows:

$$f_{Env}(s) = \begin{cases} \sqrt{\frac{2}{\pi}} e^{-s^2/2}, & s \geq 0 \\ 0, & s < 0 \end{cases} \quad (14)$$

$$f_{power}(p) = \begin{cases} \frac{1}{\sqrt{2\pi}} p^{-1/2} e^{-p/2}, & p \geq 0 \\ 0, & p < 0 \end{cases} \quad (15)$$

Artificial intelligence algorithm is used, the minimum convergence error iteration of spectral peak search for weak sensing signal is expressed as follows:

$$\begin{aligned} e(n) &= d(n) - \hat{\mathbf{w}}^H(n) \cdot \mathbf{x}(n) \\ \hat{\mathbf{w}}(n+1) &= \hat{\mathbf{w}}(n) + \mu \cdot \mathbf{x}(n) \cdot e(n) \end{aligned} \quad (16)$$

Combined with beamforming method to suppress sidelobe interference, if $x = 0$, the gain vector is updated:

$$\begin{aligned} \boldsymbol{\mu}(n) &= \mathbf{x}^T(n) \mathbf{P}(n-1) \mathbf{x}(n) \\ \mathbf{k}(n) &= \frac{\mathbf{P}(n-1) \mathbf{x}(n)}{\lambda + \boldsymbol{\mu}(n)} \end{aligned} \quad (17)$$

According to the results of artificial intelligence algorithm, the output signal model of weak sensing signal intelligent detection is obtained [13–15]. The structure model of weak sensing signal intelligent detector is shown in Fig. 2.

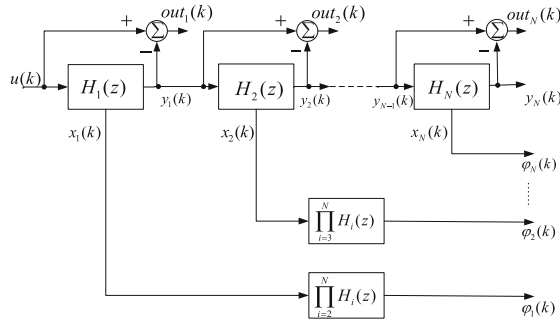


Fig. 2. Structure model of intelligent detector for weak sensing signal

4 Simulation Experiment and Result Analysis

In order to test the performance of this method in the intelligent detection of weak sensing signal, the simulation experiment is carried out. The experiment is based on Matlab 7 simulation tool. The maximum frequency of signal acquisition is 5 Hz, and the sampling sample length of weak sensing signal is 1024, the sample test set is 1000, the training set is 200, and the iterative step number of artificial intelligence algorithm is 2400. According to the above simulation parameters, the time domain waveform of weak sensing signal $x(t)$ is given as shown in Fig. 3.

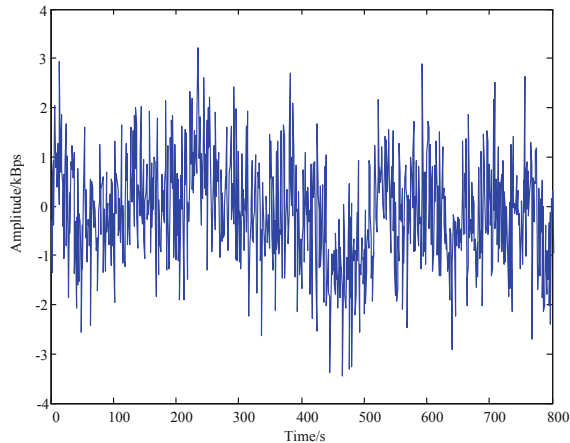


Fig. 3. Time domain waveform of weak sensing signal

High resolution spectral feature extraction and intelligent detection of the original weak sensing signal are carried out, and the results of feature extraction are shown in Fig. 4.

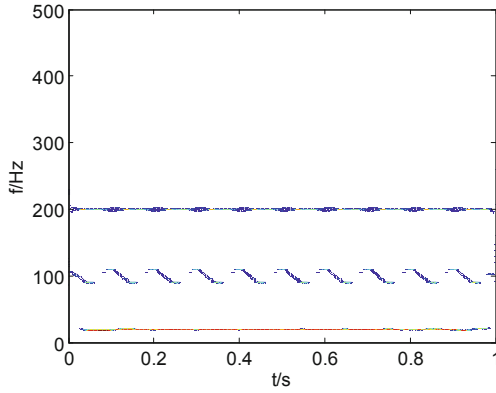


Fig. 4. Results of high resolution spectral feature extraction of weak sensing signals

Analysis of Fig. 4 shows that the proposed method can detect the sensing signals of different intensities and is free from external interference. The analysis Fig. 4 shows that the method in this paper has good resolution ability and improves the detection performance, and tests the accuracy of weak sensing signal detection by different methods. The comparison results are shown in Fig. 5, the detection performance of this method is high and the anti-interference is good.

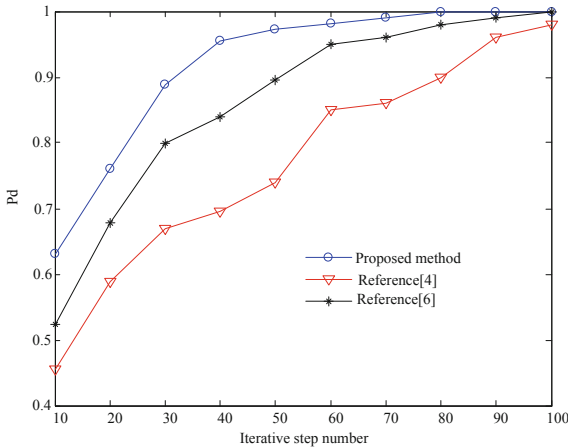


Fig. 5. Comparison of detection performance

The test performance is tested and the comparison results are shown in Table 1. The analysis shows that the accurate probability of weak sensing signal detection by this method is higher.

Table 1. Comparison of accurate probabilities of detection.

SNR/dB	This paper method	Reference [4]	Reference [5]
-10	0.923	0.893	0.901
-5	0.989	0.923	0.923
0	1	0.943	0.936
5	1	0.956	0.945
10	1	0.9780	0.956

5 Conclusions

In this paper, the detection method of weak sensing signal is studied, and the weak sensing signal emitted by wireless sensor network is detected and estimated, so as to realize the detection and recognition of weak sensing signal. An intelligent detection algorithm for weak sensing signals based on artificial intelligence algorithm is proposed. The weak sensing signal model is constructed, the spectrum decomposition of the multi-carrier weak sensing signal is carried out, the weak sensing signal is separated and processed adaptively, and the parameters such as the scale and delay of the weak sensing signal are estimated adaptively. According to the spectrum offset characteristic of weak sensing signal, the high resolution spectral feature is extracted, and the extracted spectral feature is studied and detected intelligently by artificial intelligence algorithm, and the spectral peak search of weak sensing signal is realized. Combined with beamforming method, sidelobe interference suppression is realized and detection performance is improved. It is found that the proposed method has high accuracy and good anti-interference ability in weak sensing signal detection, and effectively improves the signal detection ability.

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