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Zero offset temperature compensation based on MEMS gyroscope

Xiaoguang Zhang, Pengchuan Kang and Yu Liu

School College of Opto-electronic Engineering, Chongqing University of Post and Telecommunications, Chongqing 400065, China

Abstract

MEMS gyroscope zero offset is one of the main error sources of inertial navigation system, and the change of ambient temperature has an important effect on MEMS gyroscope zero offset. Aiming at the above situation, a zero-offset temperature compensation method based on wavelet threshold denoising and RBF neural network is proposed. The temperature-related MEMS gyro output data were collected by the designed experimental scheme, and the zero-offset temperature compensation was carried out by different temperature compensation methods. The experimental results show that compared with the original output, polynomial fitting and RBF neural network, the zero-bias temperature compensation method based on denoising RBF neural network has higher accuracy and better adaptability, which effectively improves the output accuracy of MEMS gyroscope, and then improves the accuracy of inertial navigation system.system.

Keywords

MEMS; Wavelet transform; Neural network; Temperature compensation.

1. Introduction

All Inertial navigation system based on MEMS inertial devices is widely used in aviation, aerospace, land and other navigation fields due to its advantages of strong autonomy, low cost, small size, low power consumption and anti-interference. However, its disadvantages are that navigation errors accumulate over time and it cannot carry out autonomous navigation for a long time. However, its disadvantages are that navigation errors accumulate over time and it cannot carry out autonomous navigation for a long time.

The zero offset of MEMS inertial components is one of the main error sources. At the same time, the change of ambient temperature greatly affects the zero bias of MEMS inertial devices, which further reduces the performance of inertial navigation system. The zero bias of MEMS gyroscope is nonlinear with temperature, and there is a large random noise in the gyroscope output. Conventional polynomial fitting compensation or piecewise interpolation compensation can not accurately characterize the change of zero deviation with temperature. The temperature compensation based on fuzzy logic is too complicated, and is based on the problem of grey theory mode existing in error error multiplicity, and the relationship between temperature and temperature variation and zero offset of MEMS gyro is not taken into full consideration by the two methods, so the practicability of the two methods needs to be further verified. The zero offset temperature compensation method based on wavelet threshold denoising and RBF neural network was used to realize the zero offset temperature compensation of MEMS gyroscope and improve the output precision of MEMS gyroscope[1].

2. Relevant theoretical analysis

The zero-offset temperature compensation method based on wavelet threshold denoising and RBF neural network is used to process the MEMS gyro output data. The theories involved are mainly wavelet threshold denoising and RBF neural network.

2.1. Wavelet threshold denoising

The output of MEMS gyro has a lot of noise, so it is necessary to choose a suitable filter algorithm to denoise it. Wavelet threshold denoising can well explain the nonstationarity of MEMS gyro signal and the correlation of the obtained signal. The denoising process of MEMS gyro signal consists of three steps:Wavelet decomposition of MEMS gyro signal.After decomposition, the threshold value of the high frequency coefficient is quantized.Wavelet reconstruction.In this paper, Daubechies wavelet is selected as the wavelet function of wavelet decomposition, and the semi-soft threshold function with both hard and soft threshold advantages is used as the threshold function.After determining the wavelet function and threshold, the MEMS gyro signal can be de-noised by wavelet threshold.

2.2. RBF neural network

In order to realize MEMS gyroscope zero-offset temperature compensation after MEMS gyroscope threshold de-noising, the relationship between temperature correlation and MEMS gyroscope zero-offset output should be established accurately. In this paper, a self-learning, self-organizing and self-adaptive RBF neural network is selected to establish the relationship between temperature correlation and zero bias output of MEMS gyroscope Thus the zero offset temperature compensation of MEMS gyro is completed[2].

RBF neural network is a forward network with single hidden layer. The first layer is the input layer, which is composed of signal source nodes. The second layer is the hidden layer, and the number of nodes is determined according to needs. Gaussian function is selected as the neuron kernel function of the hidden layer to carry out spatial transformation of input information. Layer 3 Is the output layer, and its function is linear function. The output information of implicit layer is linearly weighted and then output, which is the output result of neural network[3].

3. The experimental scheme

Place the MEMS inertial navigation system in the high and low temperature test box.The specific experimental scheme is as follows The target temperature -25℃and slope 1℃/min were set to realize the cooling process. When the temperature of the incubator reached the set temperature, the temperature was kept for 1h. The temperature value was set at 50℃ and the slant rate at 1℃/ min, and the heating experiment was carried out to collect and save the MEMS-IMU data. After the temperature box was set at 50℃, the temperature should be kept for 1h. The temperature value was set at -25℃ and the slope was set at 1℃/ min, and the cooling experiment was conducted to collect and save the MEMS-IMU data. After the set temperature of the incubator reached -25℃, the temperature was kept for 1h. Finally, the temperature rose to the room temperature, temperature after a period of power. The above experiment was repeated for 3 times[4].

The MEMS gyro and temperature data obtained by the temperature chamber under high and low temperature experiment are used to train the RBF neural network[5]. In order to compare the characteristics of MEMS gyro RBF neural network before and after wavelet threshold denoising, the MEMS gyro output before and after denoising was studied by network learning respectively, and then the error accuracy of the two gyroscopes in the set period was compared. The input of RBF neural network is selected as temperature T, temperature gradient T '= dT/dT and temperature gradient change rate dT'/dT, and the corresponding network output is MEMS gyroscope output. With the increase of random error of MEMS gyro, the training time of the neural network will be longer, the error will increase correspondingly, and the accuracy of the neural network will decrease accordingly. Therefore, before training MEMS gyro, it is very useful to use wavelet threshold denoising to reduce the output noise[6]. Taking Z gyro heating as an example, the training error of RBF neural network is shown as follows[7].

Multi-term fitting, RBF neural network and denoising RBF neural network should be used to distinguish the zero-skewness temperature output and movement of Z-toro. Then the identified parameters are used to compensate the zero bias of Z gyro. The output of the compensation results obtained by the three methods is shown in Figure 4, and the mean and standard deviation of the error after compensation are shown in Table 1.Under the same precision requirement, the wavelet threshold denoising can not only save the training time, but also reduce the number of neurons, so as to simplify the complexity of neural network, so as to reduce the requirement of real-time processing on system hardware.

Table 1 Mean error and standard deviation

Type	The mean(°/s)	The standard deviation(°/s)
The original data	0.280	0.062
Polynomial fitting	0.002	0.031
Denoising RBF	0.00043	0.008

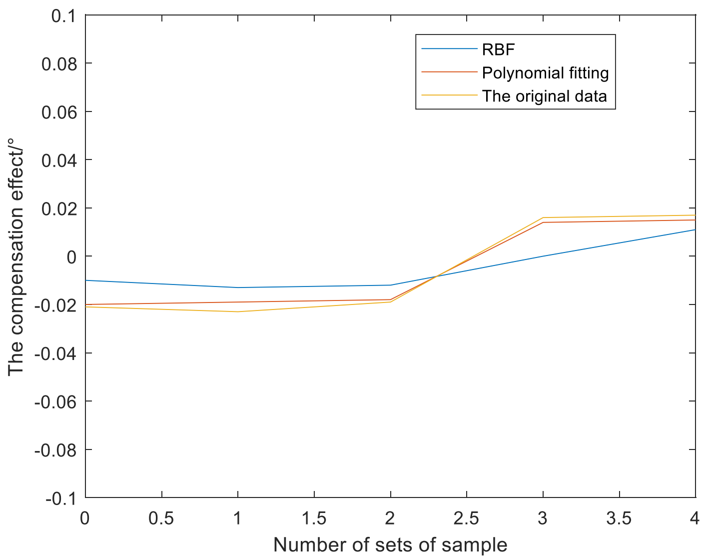

Figure 1:Comparison of compensation before and after the three methods

In the heating experiment, compared with the multinomial fitting method, RBF neural network is used to zero MEMS toroidal Partial temperature compensation can make the average error of the compensated method only 29.5% of the multi-term fitting method. At the same time, if MEMS gyro carries out wavelet threshold denoising before RBF neural network identification, the noise of data can be effectively reduced, the accuracy of model can be improved, and the mean value of zero bias error can be further reduced by 27.1% compared with the mean value obtained by RBF neural network. When the temperature drops, the mean value of RBF neural network is larger than that of polynomial fitting method. The mean value of the denoising RBF

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neural network is only 9.3% of the polynomial fitting method. It can be seen that the compensation of denoising RBF neural network is superior to polynomial fitting method and RBF neural network in both heating and cooling.The final compensation result of the three ways is as follows.

4. Summary

Aiming at the zero offset of MEMS gyroscope in MEMS inertial navigation system (MEMS) changing with temperature, the zero offset temperature compensation of MEMS gyroscope based on wavelet threshold denoising and RBF neural network was completed on the basis of theory and experiment. The compensation results show that the proposed compensation method is superior to other compensation methods in both temperature rise and temperature drop, which improves the output precision of MEMS gyroscope and improves the navigation performance of MEMS inertial navigation system. Moreover, the proposed compensation method has stronger adaptability and has certain practical engineering application value.

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