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RESEARCH ON AEROCRAFT ATTITUDE TESTING TECHNOLOGY BASED ON THE BP ANN

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ABSTRACT

For measure parameters of aerocraft attitude, this paper puts forward the BP ANN model based on the information integration theory, the problem of lower angular speed accuracy and bigger navigation error are solved. Through researching the aerocraft attitude affection based on the output of the gyro/geomagnetic sensor, the network model are set up. The gyro/terrestrial magnetic sensor output signal is used as input, and real-time three axis angular speed as output. After trained for the test samples, we got the higher precision of angular speed first, then calculated attitude angle applied the approximation formula method, reduced systematic errors. After lots of experiments on the no magnetic turntable, the result shows that the method has the characteristics of fast convergence and better angular speed accuracy.

Keywords: *Neural Network, Gyroscope, Terrestrial Magnetism*

1. INTRODUCTION

In order to attack the enemy target more precise and efficient, a higher demand has been put forward to the guidance of modern weapons parts. One of the premises of guidance is real time measurement of flight body posture and motion trajectory in the process of flight body flying to the target. Therefore, the study of flight parameter real-time measuring algorithm will be the key point of guidance. The combination based on geomagnetism and gyroscope is to use the characteristics of magnetometer, such as wide measuring range, high stability, no drift, anti-jamming, small volume, low cost, and characteristics of gyroscope for example high reliability, dynamic range wide, impact resistant vibration, small volume, light weight, low cost, short drift, both of their features make up the low cost of the geomagnetic/gyro strap down attitude test system.

In the previous research of the flight body attitude testing technology, the limitations such as algorithm complexity, installation error and accumulation error lead to the precision limitation of angular velocity calculation. This paper established the neural network model between the gyro/geomagnetic output information and flight body angular velocity on a new type of small size, high spin flight body sports posture, and got a more precise angular velocity, improved the precision of strap down inertial navigation system. The BP model of neural network is high nonlinear, more close to the flight body actual movement state[1].

Section 2 presents the model of BP neural network, includes the structure of BP neural network and network design. In section 3, we propose the model and simulation analysis. Section 5 gives a conclusion to the whole paper.

2. THE MODEL OF BP NEURAL NETWORK

Neural network is a black box modeling tools, it can learn and store a lot of input-output model mapping relationship, decide the modeling of the system through the math skills, without previously describe the mathematical equations of mapping relation. Compared with other methods, it has the characters such as strong adaptation and learning ability etc, and it is a real multiple input-output system. In the practical application of artificial neural network, 80% to 90% of the artificial neural network model utilizes the BP network or its change form, the BP network model is a relatively perfect model in theory, it embodies the essence parts of the artificial neural network. Its learning

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rule use the steepest descent method, through the back propagation to constantly adjust the network weights and threshold, to make the error sum of squares minimum.

2.1 The Structure of BP Neural Network

Back-Propagation Network (BP Network for short) is a multilayer Network to make W-H learning rule generalization, and train the weight of the differentiable nonlinear functions. Structure including input layer, hidden layer, output layer (as shown in Figure 1), has the advantage such as reliable basis, rigorous process and high accuracy, good in use, etc.

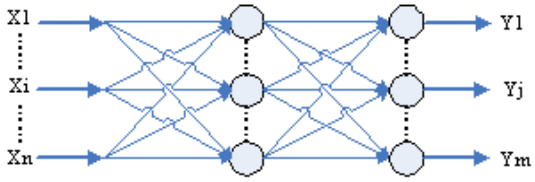

Figure 1: Structure of BP Neural Network

BP algorithm has two parts: positive transmission of the information and back propagation of the error. While in positive spreading, propagation direction is input layer→ hidden layer→output layer, the state of each layer neurons can influence of the next layer only. If the output layer cannot get the expected output, then it turns to the back propagation process of the error signal. Through the two processes alternating, in weight vector space it executes the error function gradient descent strategy, then dynamically iterative search a group of weight vectors, and make the network error function minimum, then the process of information extraction and memory complete.

BP network has a layer or multi- hidden-layer. The main difference with other model is showed in the activation function. BP network of activation function can be differential everywhere, therefore it cannot use the threshold function {0, 1} of two value type or symbol function {-1, 1}, the S type the logarithm or tangent of activation function and linear function [2]-[5] are often used in BP network.

2.2 Network Design

In geomagnetic/gyro strap down inertial navigation scheme, to access the information of flight body attitude, adopt the BP network to model design, according the nonlinear of real-time dynamic testing and geomagnetic/gyro output information. In the BP network design, generally speaking the number of layer of network, the number of neurons and activation function of each layers, initial value and so on should be considered.

First make sure layer of network selected. To analyze the relationship between the output information of test device and angular velocity information required, the situation should take to be considered that increasing network layer can make the network complicated and prolong the training time of network weights, so three layers BP neural network of geomagnetic/gyro output information and angular velocity information must be built. To take the output proportion of the geomagnetic/gyro as the input layer neurons of the network, and the three axis of angular speed acquired as output neurons, and to determine the hidden neurons need the experience and times experiment. Through training and contrast in a number of different hidden unit , it can make the learning time and error precision to achieve the best condition.

Because the S type function has feature of nonlinear amplification coefficient, it can turn the input signal from the minus infinity to the positive infinite into -1 to 1, so the S type activated function can do well to address and gain on the relationship of nonlinear input/output. Because of the strap down inertial navigation system is nonlinear, the initial value has great relationship with the result that if study can reach the local minimum or not and whether can converge. Generally speaking it is hope to get each neuron output values are close to zero after initial weighting, so it can ensure that each neuron weights can adjust in the place of the biggest change of their S type activation function, so, generally get the initial weights as random number between the (1, 1). Likewise the input data also need normalize, to make those larger inputs still fall in bigger gradient place of transfer function. Taking trainlm as Network training function, learning algorithm of this function is Levenberg-Marquardt algorithm [6]-[8], and the benefit is convergence fast speed and the training error of network much smaller.

3. ESTABLISHMENT OF THE MODEL AND SIMULATION ANALYSIS

Taking the geomagnetic/gyro output of the flight body under the different regular patterns as the training samples, as far as possible to contain the samples have comprehensive information, and strong follow representative, strong balance as well, so as to make the good foundation for the accuracy of the prediction.

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Now assume that flight body have different characteristics of motion, its attitude angle equation is: yaw Angle $\alpha = (i\pi/180)\sin(j\pi t/10)$, pitch angle $\beta = (m\pi/180)\sin(n\pi t/20)$, roll angle $\gamma = k\pi t$, of which i, j, m, n = 5, 10,……,60, k = 30, 31,…… ,40.

According to the installation position and sensitive direction of matrix of gyroscope-magnetic sensors in the ideal condition, the sensor output specific force equation can be got:

$$fi = fi(HX, HY, HZ, \gamma)$$

Among them HX、HY and HZ respectively represent the weight at the geographic coordinate system in three axis for geomagnetic vector H, γ for gyro provide turn attitude angle.

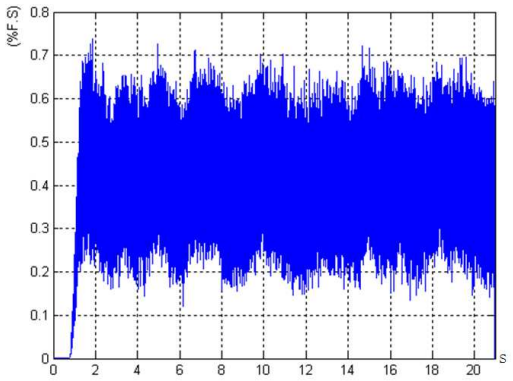
The angular velocity of three axis can be got from the transition matrix of elasticity coordinate to the inertia coordinate system:

$$\begin{bmatrix} \omega_x \\ \omega_y \\ \omega_z \end{bmatrix} = \begin{bmatrix} \cos\beta\cos\gamma & \sin\gamma & 0 \\ \cos\beta\sin\gamma & \cos\gamma & 0 \\ \sin\beta & 0 & 1 \end{bmatrix} \begin{bmatrix} \dot{\alpha} \\ \dot{\beta} \\ \dot{\gamma} \end{bmatrix}$$

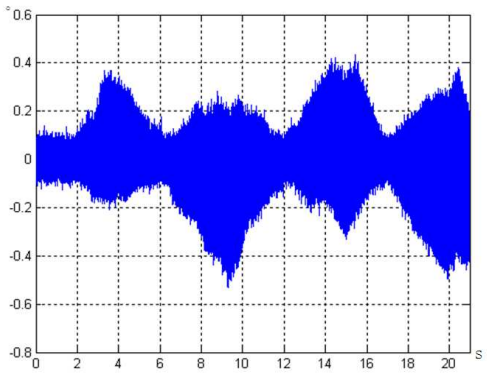
Among them: $\omega_x, \omega_y, \omega_z$ respectively represent the angular velocity in the x, y, z axis of weight; Getting 8 group of flight body from the provisions characteristics of motion range above, to determine the output of the geomagnetic/gyro f1, f2, f3 and f4 as four input of layer neurons, from the theoretical calculation the three axis angular velocity value $\omega_x, \omega_y, \omega_z$ can be got as three output of neurons layer. Because the input signal is simulated waveform, the input layer can be seen as four unit input, then input data is seen as sampling time series. To establish a network model step which the length is 0.001 s, sampling points 20000.

After getting the input and output variables and normalize, to process the data in [0, 1]. Taking the output matrix of geomagnetic/gyro sensor in different characteristics of motion as Input data, theoretical matrix of three axis angular speed under corresponding different characteristics of motion as the target samples. TO use the S type tangent function: tansig as The interlayer transfer function of network, the S type logarithmic Function: logsig the output layer of the transfer function, trainlm as training function. Through the network training of different hidden layer neurons, the best hidden layer neurons number can be obtained , 50. After training, the network error can meet requirements.

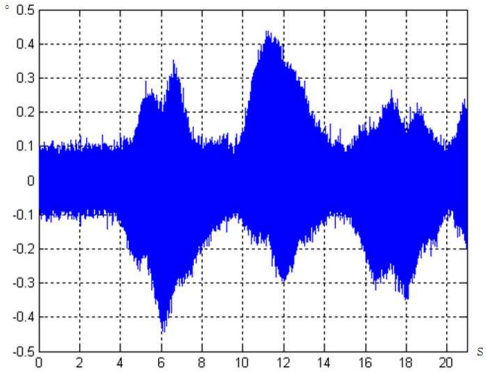
After the network training completes , to the team of network input, to take the motion data not in training set as a test sample, then to validate whether the trained network has the good generalization ability, that is whether the input not be trained can reasonably be responded. The three axis of angular velocity error curve have been gotten show in the (a), (b), and (c) in Figure 2. Compared with the traditional test methods, it is known that the error range has greatly reduced.



(a) Pitch Angle of Error Curve



(b) Roll Angle of Error Curve



(c) Yaw Angle of Error Curve

Figure 2: Each Attitude Parameter of Error Curve

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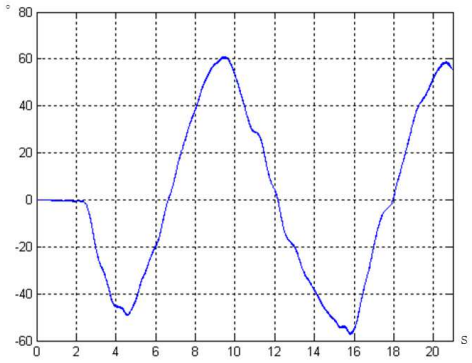
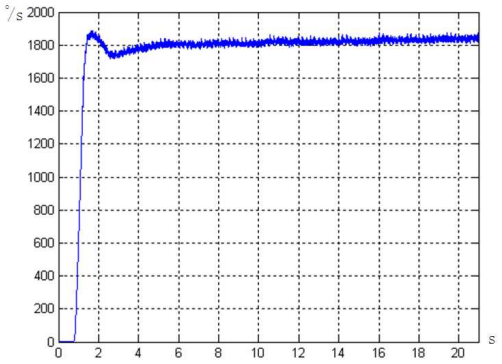
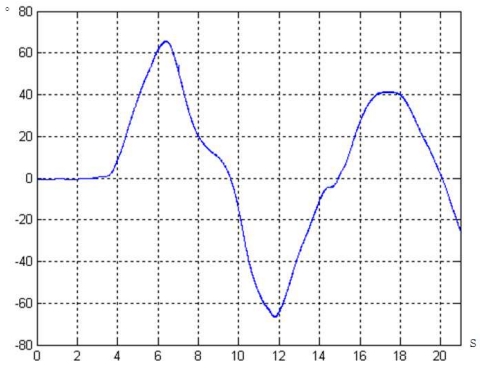
Each attitude parameters measurement results are shown in Figure 3. Compare with the real output results in non-magnetic turntable， this method has high accuracy.



(a) Pitch Angle



(b) Roll Angle



(c) Yaw Angle

Figure 3: Each Attitude Parameter of Curve

4. CONCLUSION

In geomagnetic/gyro strap down inertial navigation system, the previous solution of angular velocity is got from the accelerometer output by formula directly, and then obtains the flight body stance. This article can calculate angular velocity accurately by accelerometer through the establishment of BP neural network between output information of geomagnetic gyro and flight body movement angular velocity, and then get Angle by using formula approximation method, compared with the theoretical value, it is confirmed that the feasibility and accuracy of angular velocity of flight body in BP neural network model established. In addition, when adding network training samples, and make sure the selected sample information can represent the flight body sports posture as possible, increasing network generalization ability, such the measurement accuracy will be further improved. But the increasing of the number of training samples will be consumed with great memory and prolong the network training time, so the sample of network training should as far as possible have representative and rationality.

REFRENCES:

[1] ZHAO Yu-Xin, LIU Wei, and GAO Wei, “Application of BP neural network to alignment of SINS”, *Journal of Harbin Engineering University*, Vol.24, May 2003, pp. 513-517.

[2] SU Yu-Tao, WANG Hui-Nan, and REN Hai-Lin, “Application of compensatory neural networks in INS parameter estimation”, *Journal of Chinese Inertial Technology*, Vol.12, January 2004, pp. 15-18.

[3] Shu T Lai, “Attitude Determination of a spinning and Tumbling Rocket Using Data Form Two Orthogonal Magnetometers”, *AFGL-TR-91-0108, AD A102908.*

[4] Blackwell William J, “A neural network technique for atmospheric compensation and temperature/emissivity separation using LWIR/MWIR hyperspectral data”, *Algorithms and Technologies for Multispectral*, Vol.14, May 2004, pp. 604-615.

[5] CUI Min, MA Tei-Hua, and ZHANG Meng, “Research on Calibration And Error Compensation for Gfsins”, *Journal of Electronic Measurement And Instrument*, Vol.9, September 2009, pp. 23-26.

[6] ZHANG Hui, CAO Yong-Hong, MA Tei-Hua, and FAN Jin-Biao, “Research on Optimization Algorithm of Gfsins Compensating Fixed Errors”, *Journal of Projectiles Rockets Missiles and Guidance*, Vol.2, February 2009, pp. 13-17.

[7] BAO Ya-Qi, CHEN Guo-Guang, WU Kun, and WANG Xiao-Rong, “Research on Attitude Determination Using

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ISSN: 1992-8645 www.jatit.org E-ISSN: 1817-3195

Magnetometers and MEMS Inertial Sensors", *Acta Armamentarii*, Vol.10, October 2008, pp. 1227-1231.

[8] XUE Liang, LI Tian-Zhi, LI Xiao-Ying, and CHANG Hong-Long, "Study of Micro Attitude Determination System Based on MEMS Sensors", *Chinese Journal of Sensors and Actuators*, Vol.3, March 2008, pp. 457-460.

[9] MA Bao-Guo, and ZHOU Shi-Qin, "Research of Inertial EFPI Fiber-optic Gyro", *Aerodynamic Missile Journal*, Vol.1, No.1, January 1999, pp. 39-41.