Design of Aircraft Antiskid Braking System Based on BP Neural Network and Genetic Algorithm[1]

Yuanjin Zhang[a], Huawei Wu [*b], Zhigang Tan [c]

Hubei University of Arts and Science, Xiangyang, China

[a]394296412@qq.com, [b]9438043@qq.com, [c]309651212@qq.com

Keywords: Aircraft anti-skid brake; BP neural network; Genetic algorithm; Slip ratio

Abstract. In the research of aircraft anti-skid braking system, this paper proposes a control algorithm based on GA – BP. Aiming at the nonlinearity, time variation and uncertainty of aircraft anti-skid braking system, this paper takes the relative slip ratio as the objective function. Under the condition of the consistent parameter, this paper takes the Matlab as the simulation platform. On this basis, system modeling, simulating and performance analyzing are done. The simulation results show that this method is superior to the conventional BP neural network. It provides a good theoretical basis for the optimization design of aircraft braking system.

Introduction

With the rapid development of the aviation industry, the safety and reliability of the aircraft during the flight are more and more concerned by people. aircraft landing is a non-linear, time-varying process， efficient aircraft braking system[2] not only can protect people's safety, but also can be stable in a short time to brake.

BP neural network [1] has a strong ability to deal with nonlinear problems, and the aircraft braking system is a nonlinear system. But BP neural network has a significant disadvantage. BP neural network is easy to fall into the minimum in the process of operation. Genetic algorithm is an innovative evolutionary algorithm. Darwin's theory of evolution suggests that the biological nature of the natural world through selection and inheritance to produce the most adapted to the survival of the offspring, the genetic algorithm is used to imitate the theory to find the best answer in the field of control.

The modeling of aircraft anti-skid braking system

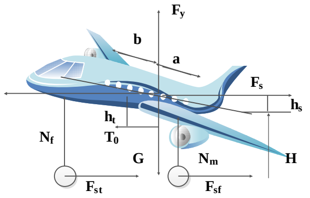
The plane is regarded as the ideal center of mass system; without considering the crosswind and runway asymmetry, The motion of the machine is simplified as the direction of motion and the motion of the vertical direction; Assuming that the braking performance of all the brake wheels are in accordance with the same, and the left and right sides of the motion state of the machine is the same, control box synchronization control.

[*] Corresponding author: Huawei WU (9438043@qq.com)

This paper is sponsored by science and technology research project of Education Department of Hubei Province Q20142604

Dynamics modeling of aircraft braking system

When the aircraft landing, the relationship between the sliding acceleration and ground force is shown in figure 1:



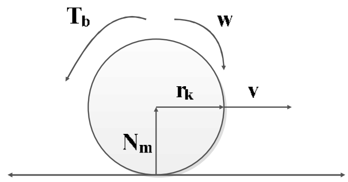


Fig. 1 Dynamics model of aircraft landing Fig. 2 Wheel dynamics model of aircraft landing

From the above diagram, we can get the following equation:

$$T_0 - F_x - F_{xf} - F_{xt} - F_S = MX''$$

$$G - N_m - N_f - F_y = MY''$$ （1）

（2）

$$N_m * a\cos\theta + F_s(h_s + h_t) - N_f * b\cos\theta - T_0 h_s - (F_{sf} + F_{st})H = I\theta$$

（3）

Among them, h_s is the parachute to the center of gravity of the distance, T_0 is the aircraft landing when the rest of the reasoning, F_s is parachute tension, F_x is the aircraft flight resistance, F_{xt} is the aircraft main wheel of the binding force, F_{xf} is the aircraft wheel binding force, G is gravity aircraft, F_y is the aircraft lift, θ is aircraft elevation, N_m is runway on the main gear strut force, H is the center of gravity of the aircraft height from the ground, b is the distance from the front wheel center to center of gravity, h_t is the distance from the engine thrust to the center of gravity, a is the mainly wheel center to center distance, N_f is the runway, the wheel support.

Machine wheel dynamics modeling of aircraft braking system

The force diagram of the tire and runway is shown in figure 2:

According to the tire and track of the subject to be able to list the equation:

$$J\omega = T_f - T_b$$ （4）

$$T_f - F_{xm} * r_k = u_m * N_m * r_k$$ （5）

Among, T_b is aircraft landing torque, N_m is vertical load of tire, r_k is the radius of the aircraft tire, F_{xm} is the friction between tire and runway, J is aircraft tire rotation inertia; ω is aircraft tire angular velocity, u_m is the coefficient of friction between tire and track.

The design of controller

In this paper, the design of the BP neural network controller (slip ratio of the best classifier) schematic diagram of the structure as shown in figure 3:

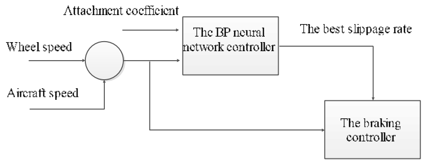


Fig. 3 Structure of BP neural network

Among them, the genetic algorithm and BP neural network are combined in the BP neural network controller. BP neural network algorithm is easy to fall into the weight of the minimum, which leads to the failure of training, affecting the training rate. After introducing the genetic algorithm, we can find the weight of the global optimization, avoid unnecessary mistakes in the training process, and improve the training speed and accuracy. BP neural network controller of the three training programs include: machine wheel speed, sliding speed and the combination coefficient, to calculate the optimal slip ratio. According to a domestic aircraft to get three parameters, and then used in the Matlab simulation.

The design of BP neural network

Under normal circumstances, the selection of hidden layers is a complicated problem, increasing the number of hidden layers in the accuracy of the same time; it will increase the time of network training, so as to make the network more complex. In this paper, the selection of hidden layers is a double layer. According to the expert experience, the choice of the number of hidden layer nodes is 10. Therefore, the structure of BP neural network designed in this paper is 2-10-10-1.

Genetic algorithm design and flow chart

In this paper, genetic algorithm is introduced in the BP neural network controller, and the disadvantages of the simple BP neural network are optimized. Detailed genetic algorithm optimization design mainly includes the following aspects of the content:

The basic control parameters of genetic algorithm

The initial population number: 50; the initial crossover probability: 0.95; the initial probability of mutation: 0.05; the structure of the neural network: 2-10-10-1.

The choice of coding mode

Here, we transform these parameters into chromosomes with an independent structure. BP neural network weights are real numbers, so the optimization of the genetic algorithm in this paper we choose the floating point based coding.

Design of genetic operation

Select operation

The fitness value of each chromosome is served by a good number of categories. The individual copy probability of serial number k is:

$$P = [min + (max - min) * (pop - k) / (pop - 1)] / pop \tag{6}$$

Where pop is the number of population,max∈（1.5,2），max+min=2，k=1,2,…,pop.

Crossover operation

Uniform crossover operation is the crossover operation mode:

$$a' = \alpha * a + (1 - \beta) * b \tag{7}$$

$$b' = (1 - \alpha) * a + \beta * b \tag{8}$$

By adjusting the R control, to change the scope of changes in the crossover operation .Alpha, beta is a uniform distribution of random numbers on the interval.

Mutation operation

$$v'_k = v_k + k (b_k - b_k) r \tag{9}$$

$$v'_k = v_k + k (v_k - a_k) r \tag{10}$$

In this paper, we use the variation operation, Parent individual s=（$v_1,v_2,\dots,v_n$），The component of variation is v_k.Sub individuals produced by non-uniform variation z=（$v_1,v_2,\dots,v_k, \dots v_n$）, The variation of the area is $[a_k,b_k]$, Two directions of variation are 0 and 1. k∈（0,1）

Selection of objective function

This article measures the standard is the error function.

$J = F(E) = E_{max} - E$ (11)

Among them, Emax is the maximum value of the error function.

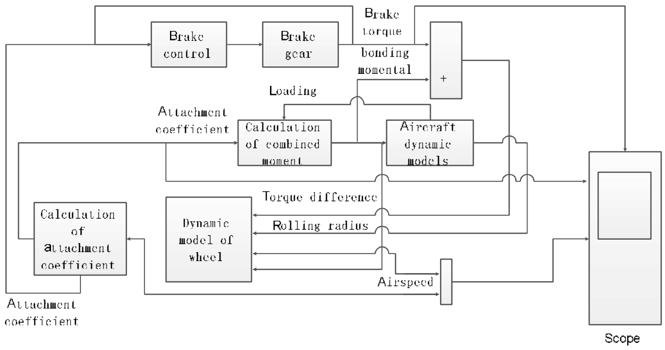


Figure 4 Aircraft landing modeling and simulation

Simulation of system

In this paper, genetic optimization algorithm BP neural network algorithm and simple BP neural network algorithm are compared. Two different kinds of data are obtained through simulation experiment, then carries on the comparative analysis. The example of the simulation of the model is domestic aircraft [6] [7]. The simulation diagram of the system is shown in figure 4.

The simulation results of aircraft speed are shown in Figure 5, the simulation results of slip ratio are shown in Figure 6, the simulation results of the braking distance are shown in Figure 7.

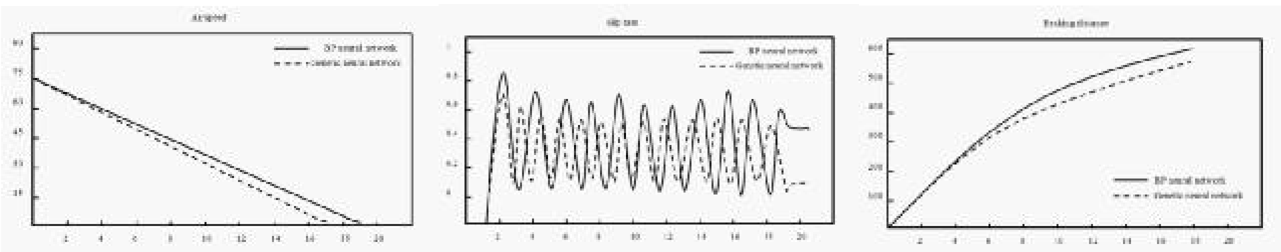


Figure 5, 6, 7 Simulation results of aircraft speed/ slip ratio/ braking distance

Conclusions

Compared with BP neural network, the control law based on genetic algorithm to optimize neural network is designed in this paper has the shorter braking time, smaller running distance and higher utilization rate of ground adhesion coefficient. It is proved that the design of the control law is robust.From the simulation results, the use of the method of braking, improve the performance of the aircraft brake; basically meet the expected control objectives.

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