Control Method of 4WS Based on Neural Network

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***Abstract*—This paper introduces an active 4WS control method based on neural network. The method takes nonlinear dynamic characteristic of vehicle and tire into account. And discerns them by neural network method according to those actual survey data come from real vehicle. It shows that it has a good control property and can improve the safety and handling stability of vehicle effectively.**

Keywords- neural network; 4WS; control method

I. INTRODUCTION

Four-wheel steering refer to that the rear wheel similar to the front wheel as the rear wheel also has steering function. When the driver manipulate the steering wheel, they are able to rotate around the four wheels, at the same time they can control the direction of four wheels, no matter the same direction or contrary [1]. 4WS system not only enhance the stability of steering at high speeds, which is convenient for car to mobile from one lane to another lane, but also improve the conveniency of steering at low speeds, reducing the turning radius when a U-turn and improving the flexibility when in parking spot [2].

At present, all driving conditions in 4WS control system, such as weight, friction coefficient and tire characteristics, are set in advance, and regardless of the actual driving conditions and how changes in the movement of vehicles, the driving conditions are regarded as unchanged. This article describes 4WS control methods based on artificial neural network, taking the dynamic nature of the vehicle and tire friction nonlinearity into account. Using the data measured from vehicle, we can identify the nonlinear dynamic characteristics of vehicle and tire, which base on neural network method [3]-[5].

II. THE ACTIVE CONTROL METHOD OF ELECTRONICALLY CONTROLLED FOUR-WHEEL STEERING SYSTEM

A. Vehicle Dynamics Model Identification

When the lateral acceleration is small, the movement of vehicles, two-wheelers in the linear model can be described as follows:

$$\frac{d\beta}{dt}=\frac{2(k_f+k_\gamma)}{mv}\beta-(\frac{2(l_f k_f-l_\gamma k_\gamma)}{mv^2}+1)\gamma+\frac{2k_f}{mv}\delta_f+\frac{2k_\gamma}{mv}\delta_\gamma \qquad (1)$$

$$\frac{d\gamma}{dt}=\frac{2(l_f k_f-l_\gamma k_\gamma)}{I}\beta-(\frac{2(l_f^2 k_f-l_\gamma^2 k_\gamma)}{vI})\gamma+\frac{2l_f k_f}{I}\delta_f+\frac{2l_\gamma k_\gamma}{I}\delta_\gamma \qquad (2)$$

Where: m: body mass;
I: Moment of inertia;
β: Side slip angle at the center of mass;
γ: Yaw rate;
δ_f δ_γ: Front and rear steering angle;
l_f l_γ: Centroid away from the front, the distance between the rear axle;
k_f k_γ: Front and rear cornering stiffness;
v: Speed.

Together constitute the neural network with the hybrid modeling system, equation (1) and (2) should become the following discrete form:

$$\beta(n+1)=a_{11}\beta(n)+a_{12}\gamma(n)+b_{11}\delta_f(n)+b_{12}\delta_\gamma(n) \qquad (3)$$

$$\gamma(n+1)=a_{21}\beta(n)+a_{22}\gamma(n)+b_{21}\delta_f(n)+b_{22}\delta_\gamma(n) \qquad (4)$$

Figure 1 shows the nonlinear dynamic model of the vehicle linear model and neural network hybrid recognition system. The basic idea of the design is that the linear model of the two-wheelers in the upper part of Figure 1 is only suitable for relatively small lateral acceleration and the neural network in the lower part of the Figure 1 is designed for compensation the error caused by the linear model of two-wheelers when the lateral acceleration is large. This is why the neural network add lateral acceleration into input factors. The hybrid recognition system actual output is designed by sum of the upper and lower part of the model's output. This reflects the neural network compensate for the two linear model in case of lateral acceleration. Conversely, the existence of two analytical model can greatly reduce the neural network learning tasks, thus shorten the learning time. Upper and lower part of the Figure act as the complement of each other and avoid weaknesses together to complete the vehicle nonlinear dynamic modeling tasks.

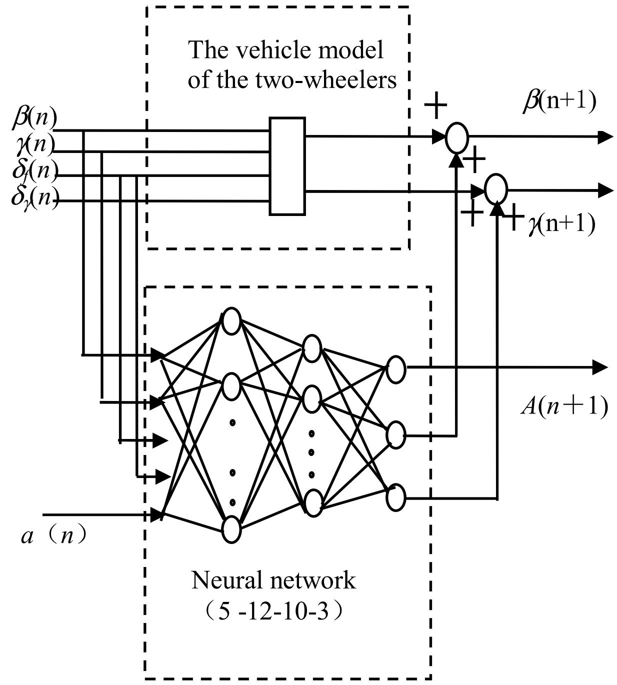

Figure 1. Neural network hybrid recognition system

The hybrid system five input parameters: the side slip angle β(n), yaw rate γ(n),front and rear wheel steering angleδf(n), δγ(n), and lateral acceleration a(n). The output parameter is β(n+1), γ(n+1) and a(n+1).

BP network layer neurons: 5-12-10-3. Transfer functions of the two hidden layers are the bipolar Sigmoid function; output layer is linear function.

The amplitude of the training timeδf(t)is 3.4 degrees and 5.5 degrees step function and sine function (frequency was 1.0Hz and 1.5Hz), δγ(t)is a random waveform, training speed is 80km / h, the ground friction coefficient 0.7, 3500 training samples is obtained in the condition which sampling period is 0.04s within the 140s.

B. Hybrid Control System

Control tasks in this program is to take the initiative to adjust the rear wheel steering angle δγ to ensure that slip angle β is zero Figure 2 shows the hybrid controller schematic.

The linear control equation expressed by linear model of two-wheelers in equation (3) and (4) can be derived as follows:

$$\delta_\gamma = -\frac{k_f}{k_\gamma}\delta_f + \frac{2(l_f k_f - l_\gamma k_\gamma) + mv^2}{2k_\gamma v}\gamma \quad (5)$$

In figure 2, the neural network act as the complement of the linear control due to the control error caused by the linear control not considering lateral acceleration. This why we add side acceleration a(n) into output factors in neural network.

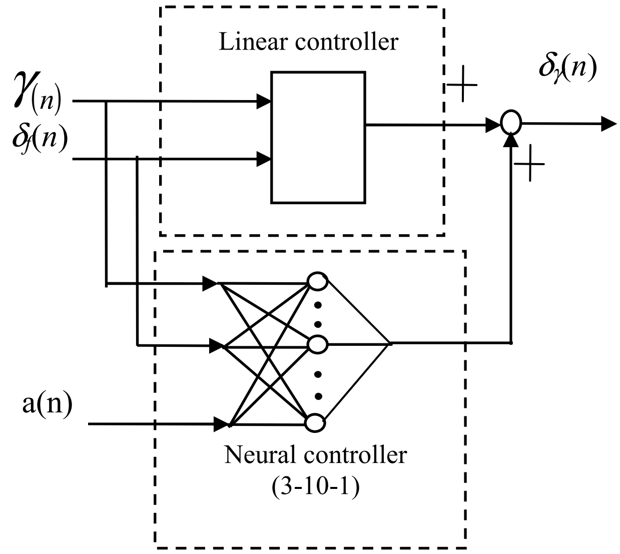

Figure 2. Hybrid controller schematic

Network structure: 3-10-l. Hidden layer with bipolar Sigmoid function.

The output of hybrid Controller is rear-wheel steering angle δγ.

To minimum, Nagai propose discriminant function.

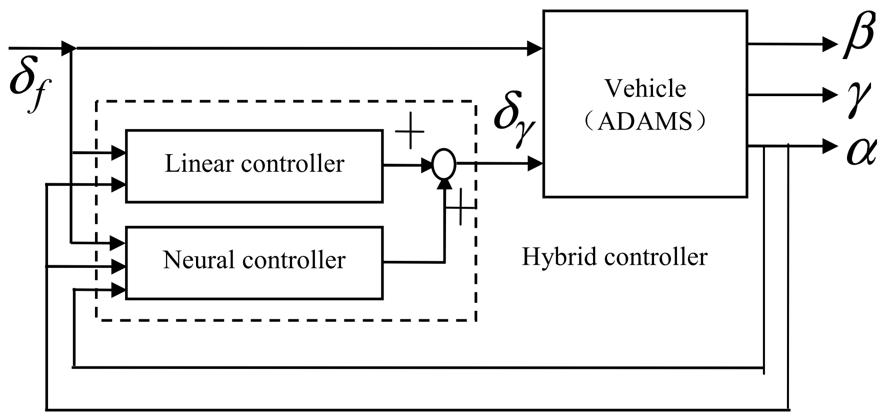

Figure 3. The 4WS control system of hybrid controller

The discriminant (6) not only require β should approximate zero, but also hope δγ as small as possible. ρ1 and ρ2 is weight coefficient. Weights value in Neural controller is modified based on reduction of the discriminant function J.

$$J = \frac{1}{2}\sum_{n=1}^{N}[\rho_1 \beta^2(n) + \rho_2 \delta_\gamma^2(n)] \qquad (6)$$

Figure 3 is the 4WS control system block diagram with hybrid controller.

The vehicle system in Figure 3 is imitated through multi-body dynamic analysis software ADAMS. Input a and γ is obtained from software ADAMS. System input is front wheel steering angle δf given by the driver.

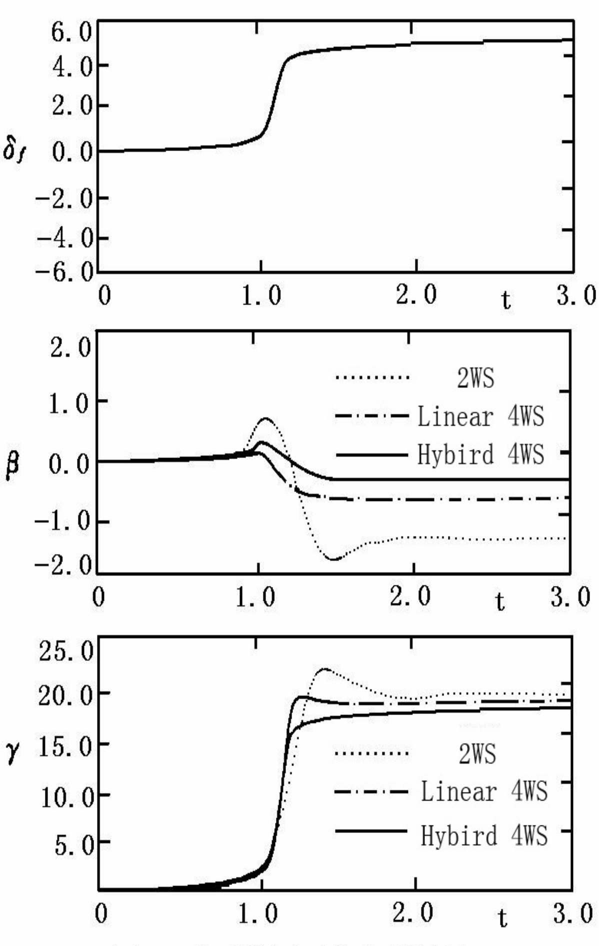

Figure 4. Controllable effect of step function

III. COMPUTER SIMULATION

In case that speed v = 80km / h, the ground friction coefficient is 0.7, we use computer to simulate. In terms of input signal δf step function and sine function, we all have received satisfactory effect. Figure 4 shows that two curves of angle β and γ in condition of linear control and hybrid control when δf change from 0° to 4.8° in 0.2s.

No matters in hybrid modeling or hybrid controller, neural networks are parallel work with linear models or linear controller. This structure of the neural network reduce the number of neurons, thereby speeding up the learning process; while in terms of the linear part, the neural network nonlinear played a role in compensation. This is the unique feature of this program.

IV. CONCLUSION

This paper introduce a four-wheel steering control method based on neural network, then designing the nonlinear dynamic characteristics of the vehicle linear model and neural network hybrid recognition system ,and using the data measured from the vehicles to identify nonlinear dynamic characteristics of the vehicles and tires. Finally, the control system of the computer simulate the computer and the results show that the method has good control feature, and is able to improve the car's active safety and steering stability.

REFERENCES

[1] WANG Zhixin. The Study of Four-wheel Steering System Based on Improving the Vehicle's Handing Stability[J]. Journal of Liaoning Provincial College of Communications, 2011, 13(1):42-45

[2] TIAN Chengwei, ZONG Changfu, HE Lei. Control Strategy of 4W Steer-by-wire System [J]. Journal of Jilin University (Engineering and Technology Edition, 2010,40（5）:1176-1182

[3] Fausett L. Fundamental of Neural Networks[M]. Prentice Hall, 1994

[4] Cai Xuan, You Linru, Zhuang Guiyu. Control Method of PMSM Based on Fuzzy-Neural Network[J]. Mechanical & Electrical Engineering Technology, 2009(5):31-33.

[5] ZHANG Caizhen.A Study of the Control Theory of Fuzzy Neural Network[J]. Journal of Lanzhou Railway University (Natural Sciences), 2000, 19(6):26-29