Design of NARX Model for Dry Friction System of the Three-piece Bogie

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Abstract. The discontinuous and non-smooth natures of the dry friction system make it difficult to obtain a universal and accurate friction model for different friction phenomena. To reveal the characteristics of the suspension system of a three-piece bogie with dry friction, nonlinear autoregressive with exogenous input (NARX) is studied. Particle swarm optimization (PSO) algorithm is applied to the datasets for the numbers of input delays and the hidden layer neurons adjustments while the mean squared error (MSE) is set as the objective function. An experimental model of the bogie with dry friction structure is designed, and the experimental results are compared with the predicted results of the PSO-NARX model. Results show that the model can predict the dynamic behavior of the system accurately. It is very necessary to add the exogenous input value of the present moment in the NARX model, which will help improve the accuracy of the network.

Introduction

Dry friction occurs in all actual mechanical systems, in which surfaces are in contact with each other and can slide freely between each other. The characteristic of the dry friction plays a significant role in the dynamic system of freight wagons across the world for its low manufacturing cost and low maintenance cost. The study of friction dynamics has very important theoretical and practical significance. Several models of friction dynamics have been proposed. These include the Coulomb friction law, the LuGre model, the Leuven model, the Maxwell-slip model, and so on. But it is difficult to obtain a universal, accurate, and concise friction force model for different friction phenomena. Previous research has proven that the NARX method is a feasible way to establish the dynamic model of a system. the modelling of dry friction was described by using a NARX type shunting neural network model [1]. However, the basis for the selection of NARX model parameters is not stated, and it is impossible to determine the parameters with a unified standard. Swarm intelligence has been proved as a technique that can solve Non-deterministic Polynomial-time computational problems. The purpose of this paper is to study the parameter setting method of the NARX model base on the PSO method for railway freight car bogies with dry friction model.

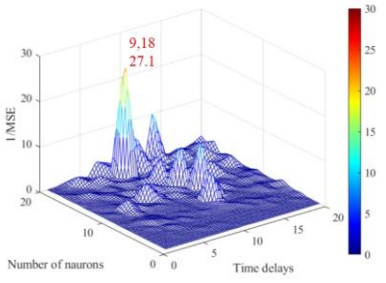

Figure 1: The 1/MSE values

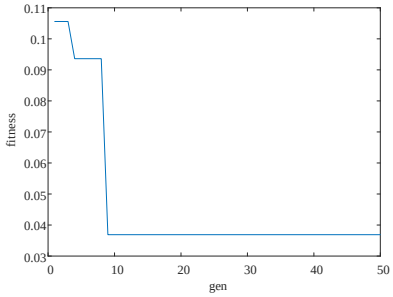

Figure 2: Convergence Curve

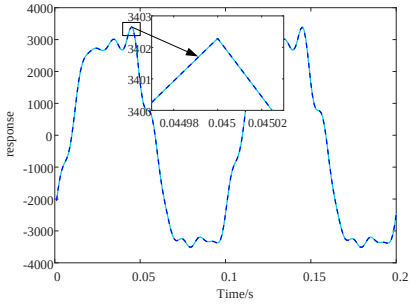

Figure 3: Results Comparison

Results and discussion

This paper aims to propose a new element type for the establishment of the bogie suspension models with dry friction system based on nonlinear autoregressive with exogenous input (NARX). The number of time delays and the number of neurons in NARX cannot be calculated using a fixed expression, but the PSO optimization method can be used to obtain more accurate recognition accuracy. An experimental model for bogie dry friction is designed, and the displacement, velocity, acceleration, and load obtained from the test are used as the input and output data of the NARX system. The results show that the PSO-based NARX network can well establish the dynamic model of the dry friction system, and the error MSE reaches 0.037. The present value of the output y(t) is defined in terms of its pas values y(t-1), … , y(t-q) and the past values of the input x(t-1), … , x(t-q). The prediction accuracy is improved when the present value x(t) is added to the input data, and the error MSE is reduced from 0.043 to 0.037. The prediction results of experimental data with different characteristics prove that the PSO-NARX neural network has good generalization performance for dry friction dynamic systems. the PSO-NARX model can predict the dynamic behavior of the system accurately. This paper provides a new element type for the establishment of suspension models in dynamic analysis, and it can be used to further improve the accuracy and calculation efficiency of simulation analysis.

References

[1] Wong C X, Worden K. (2007) Generalised NARX Shunting Neural Network Modelling of Friction. J. Mechanical Systems & Signal Processing 21(1):553-572.