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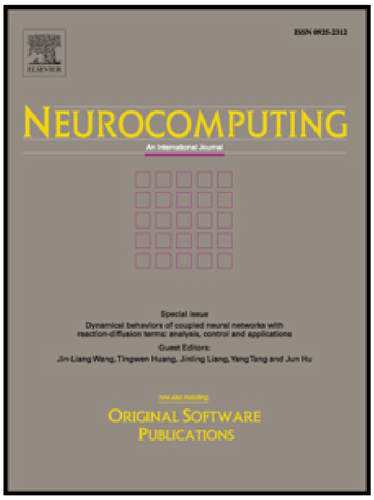

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Nonlinear Identification of One–Stage Spur Gearbox Based on Pseudo–Linear Neural Network

Junguo Wang [a*], Jie Zhang [a], Yongji Wang [b], Xiuyang Fang [a], Yongxiang Zhao [a]

[a] School of Mechanical Engineering, Southwest Jiaotong University , Chengdu , Sichuan, P.R. China
[b] School of Automation, Huazhong University of Science and Technology, Wuhan, Hubei, P.R. China

Abstract: This paper aims to study the new methodology of nonlinear system identification problem of one–stage spur gearbox. Consider the influence of the complicated factors, the model of a one–stage spur gearbox obviously possesses the nonlinear dynamic characteristics. To identify the nonlinear system, a pseudo–linear neural network (PNN) based on the idea of gained–scheduling techniques and extended linearization model is presented. The PNN consists of multilayer architectures, in which the first hidden layers and output layers are the same as those used in a multilayer perceptron (MLP). The second hidden layers are composed of neurons with multiplication function, whose outputs are the products of the inputs. In order to improve the identification effectiveness, an extended Kalman filter (EKF) algorithm is employed to train the weights of the PNN, and model verification of a class of nonlinear system is fulfilled via computer simulation. The PNN identification approach of a one–stage spur gearbox in no–load and load condition are based on the experimental data, which are subdivided into a training set and a testing set. The training set is used for identification the PNN model of displacement and acceleration, while the testing set is applied to examine the classification accuracy of the proposed PNN model. To compare the identification precision, the diagonal recurrent neural network (DRNN) and MLP based on EKF methods are applied to model the same gearbox respectively. The final results of identification and comparison of the one–stage spur gearbox demonstrate that the proposed PNN paradigm has the applicability and good performance.

Keywords: Artificial neural networks (ANNs); Extended Kalman filter (EKF); Data acquisition; System identification.

1. Introduction

As a very important device in almost all machinery, gearbox is applied to transmit or arrange power as per the process need. For the purpose of simulation and vibration–based condition monitoring of a geared system, it is crucial to monitoring the gear condition based on solid knowledge about the meshing mechanism or fault mechanism [1]. Considering the internal and external excitations such as backlash, static transmission error, time-varying meshing stiffness and harmonic torque of asynchronous motor, the model of one–stage spur gearbox obviously exhibits the nonlinear dynamic characteristics [2]. In general, this class of non–linear model can be obtained by various methods, and vibration response can also be modelled theoretically or measured experimentally. Gearbox modelling is considered as a fundamental problem which is still the object of much ongoing research. As a result, a great deal of research has been conducted to study different dynamic models of gear systems [3-4]. Different mathematical gearbox models were examined in [4], and gear modelling with coupling vibration was also adopted in [5] for simulating the system dynamic behaviour.

Among the different methods for system identification, ANNs have become the outstanding method exploiting nonlinear pattern recognition properties and offering advantages for automatic detection, whereas they do not require an in depth knowledge of the system behaviour [6-7]. So far, the most widely used neural network for system identification is multilayer perceptron (MLP), usually interconnected in a feed–forward way, and back–propagation (BP) method is commonly used as a part of algorithms that optimize the performance of the MLP. But the feedforward network is a static mapping and without the aid of tapped delays it does not represent a dynamic system mapping. Meanwhile, BP algorithm with a gradient method has a tendency to get stuck in the local minima and becomes unable to find the global minimum [8]. On the other hand, lots of efforts have been focused on the design of network architectures of fast learning adjustable weight matrices, and learning algorithms [9-12]. In the neural network based system identification and design, the problem is how to find a neural network with suitable type and architecture, on which the controller design and system analysis can be easily carried out.

There exist many nonlinear approaches enabling to deal with nonlinear plants identification. For instance, the gained scheduling technique is an effective method [13], in which the system model can be linearized around the equilibrium points, the controller will be expressed as a parameter model of the system. The key question of gain scheduling is to determine the auxiliary variables to be used as scheduling variables. Moreover, it is difficult to give general rules for this method. In 1993, Matsuo and Hasegawa [14] proposed the pseudo-linear system as a special system of affine dynamical system which realizes any input/output map with causality. Applying the ease of linear system analysis, Banks and Mhana [15] leads to introduce pseudo–linear form representation of nonlinear systems, which is also known as extended linearization [16]. The pseudo–linear identification method (PLID) is considered as an explicitly linear approach to the joint state and parameter estimation