Multidimensional nonlinearity Time Series Forecasting Based on Multi-reservoir Echo State Network

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Abstract. Echo State Network(ESN) has a simple structure and can achieve excellent forecasting effect. In this paper, we will delve into the nonlinear prediction ability of echo state network, analyze the structure and principle of it, then propose a new multi-reservoir echo state network prediction model based on the output mode. Finally, the model is tested with different dimensions by Mackey-Glass and Lorenz chaotic systems. After verification, it is found that the proposed multi-reservoir echo state network can accurately predict longer.

Introduction

ESN has feedback connections between neurons and has rich dynamic properties, so it can store partial information and has the property of instant memory. It consists of three parts: input, hidden layer and output, and the most important and only trainable part of ESN is the output weight[2]. Among it, randomly and sparsely connected neurons make up the hidden layer of the ESN[1]. Thus, the input is represented by a high-dimensional, non-linear representation. The ESN improves the inherent shortcomings of the recurrent neural network, and has wide application in time series prediction, pattern recognition, image processing, signal processing and so on.

In recent years, ESN has been applied to various fields, among which series prediction is more widely used. Zhou et al. proposed an adaptive flow prediction method reservoir based on ESN[4]. Sun et al. used the ESN model to predict stock price[5]. Hu et al. proposed a modified optimization model of bagged ESN based on differential evolution algorithm to estimate energy consumption[6].

From above descriptions, it can be seen that the echo state network is used in sequence prediction in various fields. But researchers mostly focus on optimizing the single-layer echo state network, and use different optimization algorithms to achieve better prediction results. Generally speaking, the larger the number of nodes in the neural network, the more complex the system can be expressed. However, If the number of neurons in the only reservoir is increased, the network will be over-fitted. Therefore we found adding multiple reservoirs to the echo state network can increase network complexity while preventing overfitting. Inspired by this, we propose a Multi-reservoir echo state network(MESN) based on the fully connected output mode. Subsequently, the model is used to nonlinearity predict chaotic systems of different dimensions, through simulation and comparative experiments, to explore more significance of MESN.

Results and discusion

In this article, we constructed a new multi-reservoir echo state network to forecast multidimensional nonlinear time series. Besides, in order to avoid the disappearance of input, we add input to each reservoir by merging matrices. Then we use the complicated one-dimensional MackeyGlass_t17 and three-dimensional Lorenz chaotic system to conduct experiments respectively. The comprehensive results show that increasing the reservoir can increase the prediction effect to a certain extent, but it is not infinite.

Besides, no matter how much the number of layers and the reservoir are increased, the network runs very fast. Therefore, the ESN with multiple reservoir still has great advantages in structure and time. In addition to nonlinear time series prediction, ESN is also used in artificial intelligence, brain like computing and so on, it needs more and further research.

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