

# A literature review on the application of neural networks in the time series prediction

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**Abstract.** With the coming of the big data era, the demand for analysis and processing of mass data has become bigger and bigger. Prediction by using mass data has become an indispensable part of people's daily lives and work, among which time series prediction has received widespread attention and been widely researched. Based on neural networks and recent years' research on time series prediction, this article discusses the improvement and application of neural networks in time series prediction, including BP Neural Network, Long Short-term Memory Network (LSTM) and Neural Networks based on cluster analysis. By analyzing the purposes and consequences of these improved methods, this article clarifies the necessity and superiority of the (improved) neural networks in time series prediction. For example, through research and discussion, it finds that using improved neural networks for prediction can not only dramatically increase the accuracy of prediction, but also improve the anti-interference ability of the model. In other circumstances, improved neural networks can also use various methods to make the data match the model better in specific problems and so on. In the end, this article discusses the current problems and difficulties in neural networks in time series prediction, clarifying the problems that prediction needs a high match between model and data, the demand for the choice of model is high and so on. Then it makes prospects for future research, expecting the appearance of more models and improved methods.

**Keywords:** Neural Networks, time series prediction, BP Neural Network, LSTM, cluster analysis.

## 1. Introduction

With the development of technology and the proposal of the concept of informatization, nowadays people's demand to mine information and find relevance from mass data to make a series of analyses and decisions are becoming bigger and bigger. At the same time, making predictions by observing the connection between data has caught more attention. From weather prediction, yield prediction to object lifespan prediction, data prediction has been seeded in every aspect of people's daily lives, among which time series prediction is a special and highly concerned one.

While analyzing data, deep neural networks are often a reliable method. And the research for deep neural networks and time series prediction is always developing, which has great application in various aspects like facial recognition, image recognition, stock price forecasting, and meteorological data forecasting. At the same time, targeted at time series, a neural network has a good prediction effect under many practical circumstances. With the increasing demand for prediction, this article will

introduce neural networks and time series prediction at first, and then research three kinds of neural networks that predict time series together with the ways that they are improved (BP Neural Network, LSTM and Neural Networks based on cluster analysis). By reading documents in recent years and making summaries, this article is expected to understand the application situations of different kinds of neural networks, specific improved methods and the purpose of improvement, in order to clarify the limitations and drawbacks of the application of neural networks in time series prediction and propose suggestions and expectations for possible problems.

## **2. Basic concepts introduction**

### *2.1. Neural networks*

People have never stopped exploring the human brain. Inside these explorations, applying the neuron which receives and conveys information in human brains in machines, to make machines deal with information as intellectually as human brains is always a heated topic focused on by countless researchers.

In 1943, the MP model was proposed by MCCULLOCH, WS and PITTS, W [1]. This model definitely played a significant role in the whole neural network research. After this, the unsupervised Hebb rule and the supervised Delta rule were all proposed, adding energy to the neural network research. However, these were all single-layer neural networks. At that time, their impacts and influences were not good enough, and the situations they could apply to were limited as well. Under the circumstance that multi-layered neural networks were not confirmed to be feasible, the research on neural networks was at a standstill. Although the increase in layers could provide the network with more flexibility, the training algorithm for parameters was a big bottleneck, which restricted the development of multi-layered neural networks [2]. Until 1986, a Back Propagation (BP) neural network was proposed [3]. Neural networks started developing rapidly and made breakthroughs constantly. Then, the emergence of deep learning tackled the problems of overfitting and the slow fitting speed of shallow neural networks. And it could mine and classify data containing many parameters that were difficult to deal with before more accurately and performed much better than traditional models under unsupervised circumstances. Since then, many deep learning models with more network layers have been proposed and applied, making great contributions to many aspects of research like word processing, image processing and risk prediction and so on.

### *2.2. Time series prediction*

In data prediction, a great deal of data has a connection with time, such as stock price data, meteorological data and other time series data. As for time series data, a time series is a set of sequential data. It's always the consequence of the observation of a potential process within an equal time interval, according to a given sampling rate [4]. Just due to the high correlation between time series data and time, the time series prediction is carried out depending on time. Simply speaking, it uses previous time's data to predict next time's data, meaning it makes analysis and predictions for data in the time dimension.

Traditional time series prediction methods mainly combine time series parameter models (MA, AR and ARMA). By considering practical situations based on the predictive object and data situation, together with their own understanding and cognition of different time series parameter models, researchers decide which parameter model they choose according to the prediction data set. But traditional time series prediction is very dependent on the choice of model, since whether the choice is correct or not can dramatically determine the accuracy of the prediction result [5]. The choice of an incorrect model will influence the model solution and prediction effect. Then, time series methods (support vector machines etc.) based on machine learning appeared. Although they achieved good achievements and could deal with nonlinear problems and make effective predictions to some extent, they didn't work well on long-term predictions and could hardly suit large scale datasets [6]. With the emergence and development of multi-layered neural networks, time series prediction using deep

learning can deal with these problems better with the help of multi-layered neural networks. Time series prediction has shown better applicability and accuracy.

### 3. Current models

Nowadays, with the coming of the big data era, the demand for research in mass data is becoming bigger and bigger. Since many simple and traditional models cannot solve problems effectively, the time series prediction model based on deep learning is more significant. With its development, time series prediction with deep learning has shown its universality and accuracy in many aspects like stock price forecasting, risk pre-warning prediction, lifespan prediction and so on. There are many scholars improving and combining deep learning models. This article introduces several common time series prediction models using neural networks and their improvement and application to them.

#### 3.1. BP Neural Network and improved BP Neural Network

Due to its typical structure (including input layer, hidden layer, output layer) and its back propagation characteristics, a BP Neural Network can be a kind of neural network that has a certain fault tolerance rate and can increase accuracy by reducing error in continuous training. It can also be used to deal with nonlinear data prediction problems.

When making predictions, a reasonable improved BP Neural Network combined with specific circumstances can reduce prediction error and mine information better. At the same time, there are plenty of ways to improve BP Neural Networks as well. For example, when predicting stock prices, because of the large amount of data, Xi Liu [7] combines BP Neural Network with Principal Component Analysis and Mind Evolutionary Computation considering specific situations. This can not only achieve the aim of dimension reduction, but also optimize the initial weight and threshold of a neural network. At last, the correct rate of directional prediction of this model reaches 84.62%, which increases the accuracy of stock price forecasting dramatically. As for the research on air quality forecasting, He Su [8] builds BP Neural Network based on PCA-LM arithmetic and an improved BP Neural Network based on LM arithmetic, which both perform better than the common BP Neural Network, since the former model has a fast speed and a strong anti-jamming ability and the latter model has a better prediction accuracy, which further verifies the possibility.

Except for principal component analysis, there are many other ways to improve the BP Neural Network, such as combining LASSO with the BP Neural Network to select multiple data features [9]. When predicting wind power data, using wavelet can decompose data on different scales and then using BP Neural Network to make predictions respectively [10], which gives a better prediction result.

#### 3.2. Long Short-term Memory Network

Of course, apart from BP Neural Network, Recurrent Neural Network (RNN) and Long Short-term Memory Network (LSTM) based on RNN can also predict time series data effectively, among which the LSTM model has a wider application. Compared to the RNN model which has the problems of gradient disappearance and gradient explosion, LSTM can solve the problem of time series prediction based on long-term data better.

Because of its good memory ability over a long period of time and the mass data it uses, LSTM is widely applied to mass data. Jiazeng Wang [11] uses MDF technology when predicting stock prices, and reconstructs the stock factor vector of daily frequency data for prediction. He builds the ELSTM-BL model and the ELSTM-ALPHA model for combinatorial problems. At the same time, because of the characteristic that parameters can be set, scholars have also made great progress in LSTM based on different situations and requirements in recent years. In order to increase the feasibility and accuracy of the model, Gang Song [12] and other scholars combine particle swarm optimizer (PSO) and LSTM, making the model network structure closely match the stock price data.

Because of its complexity and hard calculations, LSTM can also be combined with a Gated Current Neural Network to reduce the complexity of the prediction model structure. For example, when predicting the remaining life of bearings, Bofeng Mao [13] combines LSTM with GRU and Attention

Mechanism. By using gated recurrent units, the overall structure of multiple Long-short-term Memory Networks is simplified, which at the same time guarantees the good memory ability of LSTM. Then the use of attention mechanism quantifies the different impacts of different data by function and gains the corresponding contribution degree to increase the accuracy of the whole prediction.

Of course, there are many improvements in the selection of data inputs in LSTM as well. Jixiang Lu [14] and other scholars combine Convolutional Neural Network (CNN) and LSTM model. By extracting eigenvectors through CNN, they construct eigenvectors with time series methods and input them into LSTM, dramatically increasing the prediction accuracy. Xianglong Luo [15] and other scholars make correlation screening using the KNN algorithm and set different thresholds to select relevant inspection stations to gain data and reduce error.

### 3.3. Cluster analysis

Cluster analysis is one of the most significant research contents in many research directions like data mining, pattern recognition and so on, which plays an essential role in the recognition of the internal structure of data [16]. In recent years, apart from improved BP Neural Network and LSTM, cluster analysis has shown good ability in data mining as well.

For example, when Xiaoli Sun [17] and other scholars predict the station passenger flow, they use time series cluster analysis to classify and then predict based on the time characteristics of passenger flow, which shows a good superiority. When Tian Dong [18] predicts power load, he builds prediction model based on cluster analysis and LSTM. By using the excellent analysis ability of cluster analysis, he uses imbalanced data cluster analysis algorithms to classify patterns of data and build prediction models for each pattern respectively to better adapt to the cyclical characteristics of load sequence in order to gain a prediction model with better accuracy. When Xingjie Liu [19] and other scholars make predictions, in order to avoid information redundancy and loss without increasing the burden on neural networks, they build an improved neural network wind speed prediction model based on fuzzy rough sets and cluster analysis, reducing factors and optimizing model input. By using improved cluster analysis based on weighted Euclidean distance, they build each cluster prediction model, achieving the goal of effectively increasing prediction accuracy with fewer models.

## 4. Conclusion

This article focuses on all kinds of applications of neural networks in time series prediction. With the introduction of neural networks and time series prediction, this article succinctly shows us the development process of neural networks and time series prediction and defines the superiority and necessity of using deep learning methods to predict time series by analyzing the advantages and disadvantages of development in each stage.

Targeted at the development of the mass data era and many scholars' research contents, this article mainly introduces three kinds of neural networks and improved neural networks predicting time series—BP Neural Network, LSTM and neural networks based on cluster analysis, and makes analysis and elaboration according to different improvement methods. From the research results, it can be seen that when using neural networks to predict time series, reasonable data processing is often required, like screening data, reconstructing data and so on, to make different kinds of data match the corresponding model better and increase accuracy. At the same time, considering the complexity and calculation speed of the whole neural model.

Time series prediction based on neural networks has high accuracy and can adapt to different circumstances and data through different improvement methods, together with the combination of other models. Meanwhile, it can be seen that although neural networks are rapidly developing and there are already many excellent models, there is still a high demand for model selection when making predictions, which means the need to match the data with the model as much as possible. This also leads to an increase in the difficulty of model improvement, as well as a high level of accuracy.

Therefore, it is expected that more new neural network models will be proposed and applied in time series prediction circumstances through improvement and combination.

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