# Chapter IX
# A Novel Recurrent Polynomial Neural Network for Financial Time Series Prediction

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## ABSTRACT

*The research described in this chapter is concerned with the development of a novel artificial higher-order neural networks architecture called the recurrent Pi-sigma neural network. The proposed artificial neural network combines the advantages of both higher-order architectures in terms of the multi-linear interactions between inputs, as well as the temporal dynamics of recurrent neural networks, and produces highly accurate one-step ahead predictions of the foreign currency exchange rates, as compared to other feedforward and recurrent structures.*

## INTRODUCTION

This research is concerned with the development of a novel artificial neural networks (ANNs) architecture, which takes advantage of higher-order correlations between the samples of a time series as well as encapsulating the temporal dynamics of the underlying mathematical model of the underlying time series.

Time series prediction involves the determination of an appropriate model, which can encapsulate the dynamics of the system, described by the sample data. Previous work has demonstrated the potential of neural networks in predicting the behaviour of complex, non-linear systems. Various ANNs were applied in the prediction of time series signals with varying degrees of success, the most popular being multi-layered perceptrons (MLPs) (Fadlalla & Lin, 2001; Bodyanskiy & Popov, 2006; Chen & Leung, 2005; ). In this work, we turn our attention to artificial higher-order neural networks (HONNs).

Artificial higher-order or polynomial neural networks formulate weighted sums of products or functions of the input variables, which are then processed by the subsequent layers of the network (Fulcher & Brown, 1994; Ghosh & Shin 1992). In essence, they expand the representational space of the neural network with non-linear terms that can facilitate the process of mapping from the input to the output space.

This remaining of this chapter is organised as follows. In Section 2, we provide a brief introduction to the problem of time series prediction, describing the fundamental issues which govern the analysis of time series systems. In Section 3, we introduce the various ANNs, which will be used in our work, describing the concepts of their architectures, learning rules and issues related to their performance. Section 4 is concerned with the evaluation criteria for the performance of the artificial neural networks architectures in the problem of one-step ahead prediction of the foreign exchange rates. Section 5 presents the simulation results of the proposed neural network, i.e., recurrent Pi-sigma network, and provides a performance comparison with relevant feedforward and recurrent ANN architectures. Section 6 is concerned about the identification of the NARMAX model using the proposed recurrent Pi-Sigma neural network. Sections 7 and 8 give the conclusion of the research and provide recommendations for further development of the work, respectively.

## TIME SERIES ANALYSIS

A time series is a set of observations $x_t$, each one being recorded at a specific time t (Anderson, 1976). A discrete time series is one where the set of times at which observations are made is a discrete set. Continuous time series are obtained by recording observations continuously over some time interval.

Analysing time series data leads to the decomposition of time series into components (Box & Jenkins, 1976). Each component is defined to be a major factor or force that can affect any time series. Three major components in time series may be identified. *Trend* refers to the long-term tendency of a time series to rise or fall. *Seasonality* refers to the periodic behaviour of a time series within a specified period or time. The fluctuation in a time series after the trend and seasonal components have been removed is termed as the *irregular* component.

If a time series can be exactly predicted from past knowledge, it is termed as *deterministic*. Otherwise, it is termed as *statistical*, where past knowledge can only indicate the probabilistic structure of future behaviour. A statistical series can be considered as a single realisation of some stochastic process. A stochastic process is a family of random variables defined on a probability space. A realisation of a stochastic process is a sample path of this process.

The prediction of time series signals is based on their past values. Therefore, it is necessary to obtain a data record. When obtaining a data record, the objective is to have data that are maximally informative and an adequate number of records for prediction purposes. Hence, future values of a time series x(t) can be predicted as a function of past values (Brockwell & Davis, 1991):

$$x(t+\tau) = f(x(t-1), x(t-2), ..., x(t-\varphi)) \tag{1}$$

where τ refers to the number of prediction steps ahead, and φ is the number of past observations taken into consideration (also known as the order of the predictor).

In the above formulation, the problem of time series prediction becomes one of system identification (Harvey, 1981; Ljung, 1999). The unknown system to be identified is the function f(·), with inputs the past values of the time series. When observing a system, there is a need for a concept

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