A heuristic method for forecasting chaotic time series based on economic variables

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***Abstract*— Time series is one of the most attractive and mysterious mathematical subjects. Weather temperature, rainfall, water flow volume of a river and other similar cases in meteorology are known and predictable time series; amount of load peak, electricity price and other similar cases in electrical engineering are considerable time series. Time series forecasting is highly taken into account in economy. Stocks price in stock exchange market, currency equivalent rate in such market as Forex, world price of petroleum, sugar, gas, gold and other key stuffs are best known time series. The discovery of chaos in economics time such as stock exchange is highly regarded by scholars of economics. In recent years, chaos has proven in many economic time series such as stock changes. Also, it has been proven that discovery of chaos will help to forecast time series by intelligent algorithms better than before. In this paper, by propose a new heuristic method inspired from chaotic characteristic of economic time series, forecasts this time series by means of artificial neural networks. In proposed method, output of chaotic function is used to help time series prediction well.**

Keywords-component; Time series, Chaos theory, Artificial neural networks, Heuristic methods, Stock and currency value forecasting.

I. INTRODUCTION

Data which are obtained from observing an event during a period of time are very useful and of great importance. Weekly amount of interest, stocks price in stock market, monthly price indices, annual sale amount and etc are observed in economy. In meteorology, we observe the maximum and the minimum daily temperature degree, annual rainfall and drought indices and wind speeds in different hours. In biological sciences, electrical activity of heart is observed in millisecond durations. In all of these instances, we deal with time series data. A time series is an order of numbers (usually real-number values) which has been recorded time intervals such as annual, monthly, weekly, daily duration or even as much small as millisecond. In following, we see some samples of time series.

In Figure 1, look at daily stocks price of IBM Company and amount of transactions in the first month of 2001. Although, January is a 31-day month, here, shows values corresponding to 21 days of it and the other days are of no value because of holidays. In table 1, Taiwan Stock Exchange Capitalization Weighted Stock Index (TAIEX), which is one of the most important time series, is represented for 40 consecutive days [1].

Time series S is represented as an ordered sequence: S=($x_1, x_2, \ldots, x_n$) where is the observed value at time . Since these time intervals are often equal to each other, representing them is neglected and only observed values are shown as a sequence of numbers.

Several studies relating to ANN and statistical models have been conducted in the literature. Traditional forecasting methods are limited in their effectiveness as they make assumptions about the distribution of the underlying data, and often fail to recognize the interrelatedness of variables [6]. Both linear and nonlinear models were used to predict stock returns [7] who emphasize the Nonlinear Model proving to be more effective. Such studies prove that the nonlinear model presents more consistent results for stock exchange market. For this reason, ANN applications have been widely used in a variety of areas in financial markets [8], [9]. Reference [9] confirmed that ANN was used for the solution of numerous financial problems. References [10], [11], [12] emphasized that ANN could be used in the prediction of financial markets, in particular, the prediction of stock market indexes which are considered to be a barometer of the markets in many countries. Empirical evidence suggests that although these models appear to be capable of explaining the movements of major exchange rates in the long run and in economies experiencing hyperinflation, their performance is poor when it comes to the short run and out-of-sample forecasting [13]. Conventional time series models forecasting on global approximation models, employing techniques such as linear and non-linear regression, polynomial fitting and artificial neural networks. Such models are better suited to problems with stationary dynamics [14]. In [15] and [16] the application of unsupervised clusters for the segmentation of the input space, and feed forward neural networks (FNNs) acting as local predictors for each identified cluster, was proposed. Neural network researchers and developers using

the generalized method for determining the minimum necessary training set size will be able to implement neural networks with the highest forecasting performance at the least cost [17].

This paper is organized as follows: Section II presents the chaos theory. Section III describes the artificial neural networks. Section IV explains the proposed heuristic algorithm and advantages. In Section V, we describe the experiments and demonstrate the results, showing the improvements of the proposed method. In Section VI some discussion and concluding remarks are presented.

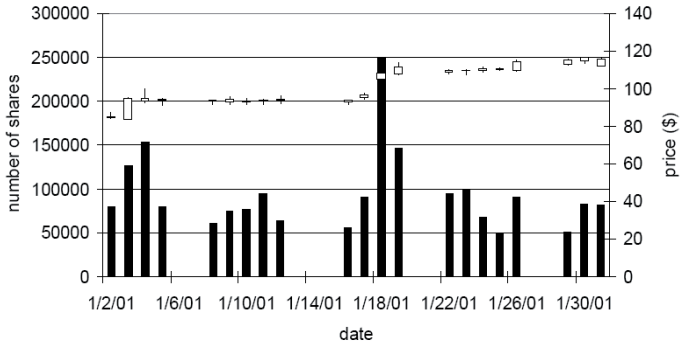


Figure 1. Daily stocks price of IBM Company and amount of transactions

Table 1. Taiwan stock exchange index dataset (TAIEX)

Date	Actual index (Close Value)	Date	Actual index (Close Value)
1998/08/03	7599.04	1998/08/31	6550.11
1998/08/04	7593.14	1998/09/01	6335.09
1998/08/05	7499.73	1998/09/02	6471.68
1998/08/06	7471.74	1998/09/03	6251.38
1998/08/07	7530.02	1998/09/04	6463.15
1998/08/10	7372.12	1998/09/07	6800.73
1998/08/11	7383.98	1998/09/08	6942.26
1998/08/12	7351.51	1998/09/09	6894.57
1998/08/13	7362.55	1998/09/10	6803.83
1998/08/14	7348.04	1998/09/11	6841.83
1998/08/17	7273.85	1998/09/14	6860.17
1998/08/18	7181.59	1998/09/15	6857.96
1998/08/19	7293.4	1998/09/16	6972.54
1998/08/20	7270.84	1998/09/17	7000.52
1998/08/21	7213.37	1998/09/18	6961.76
1998/08/24	6957.75	1998/09/21	7029.4
1998/08/25	6908.33	1998/09/22	7033.99
1998/08/26	6814.33	1998/09/23	6962.17
1998/08/27	6813.3	1998/09/24	6979.95
1998/08/28	6723.77	1998/09/25	6979.89

II. CHAOS THEORY

Traditional view to economical phenomena, in which it attempted to make a linear model of data with stochastic process strategy, believed that the observed perturbations and disorders of them were because of various stochastic inputs and external shocks. In studying chaos, the reason of data oscillations like oil price data is internal mechanism of its generator system and because of out-generating and stochastic shocks has not been led to such seemingly disorderly behaviors [5].

In economy cycle, two reasons could be considered for justifying oscillations. According to neoclassic idea, the main factor of creating oscillations is out-generating forces, whereas the second view, which is in accordance with Keynsian theories, considers the internal interactions of economy as the oscillations cause such that increasing activity in one part of economy may cause more increment of activities in other parts and vice versa. In the first view, with respect to unpredictable and stochastic nature of shocks there is no place for financial policies and indeed, imposing these policies may also make absence of economic stabilization more serious. But in the second view, according to determined process of creating series and consequently, their predictability, economic stabilizing policies are able to be executed. Fans of second view use perturbation as a witness to their claim and justify economic stabilizing policies as a main factor of creating commercial periods with respect to nonlinear and determined chaotic processes in economic series; like that for explaining commercial periods in case of existence of chaotic process in large economic variables, there would be no need to out-generating shocks assumption. Therefore, in a chaotic system, seemingly stochastic oscillations have been resulted from internal mechanism of nonlinear data generating system and have no relation with external momentums occurrence. Hence, it would be possible to consider irregular changes of some economic variables trend such as gross domestic product and/or large changes in stocks market like changes in October, 1987, as the result of their chaotic structure [16].

III. CHAOTIC MODELS

The most common and the simplest chaotic system so-called logistic mapping is defined as:

$$X_{n+1} = rX_n(1 - X_n) \quad (1)$$

Where, r is logistic coefficient. In above equation, r causes butterfly effect. To understand this better, in Figure2, one dimensional logistic map of X_n changes is shown with assumptions r=3.95 and X_0= 0.2 where X_0 denoting start point. As it is obvious from figure, X_n changes seem completely stochastic and no certain pattern could be

considered for it. But when variables relation is considered in consecutive iterations in a 2-dimensional map, data changes trend would have a certain pattern (Figure 3).

Studying chaotic time series and discovering a hidden chaos signal inside an economic time series is taken into account as an important goal. Importance of this subject leads us to find a chaotic signal and forecast a time series by means of combining this chaos signal with that time series. Author's studies show great ability of neural networks in very accurately forecasting of classic series like output time series of logistic function. In other words, a neural network can forecast output of such chaos function as logistic well. Based on it, authors have concluded that to utilize the chaos logistic function output for better prediction.

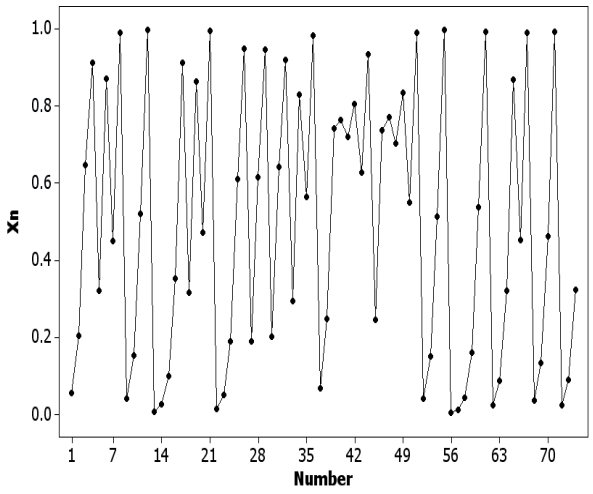


Figure 2. 1D logistic map

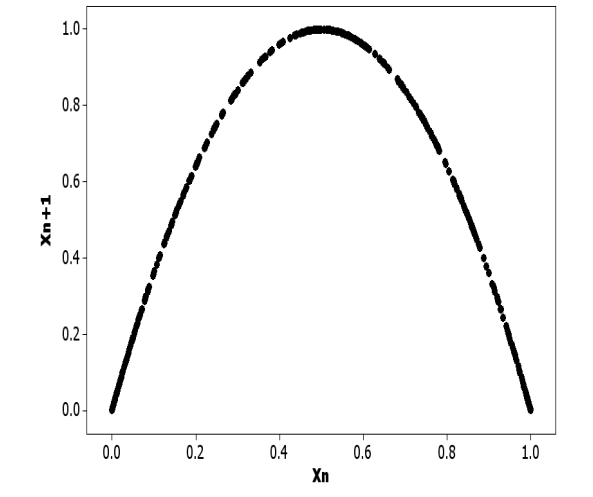


Figure 3. 2D logistic map

IV. ARTIFICIAL NEURAL NETWORKS

Neural networks have been known for more than 50 years. Neural networks pattern is human brain. They are used for learning widely. One of the biggest problems of neural networks is weakness in interpreting of their results. In fact, results of network are not easy. Many researchers have likened neural networks to a black box [10].

Neural networks model is one of the most applicable modeling methods for complex and large problems consisting of hundreds variables. Neural networks can be used for classifying problems (where the output is a class) or regression problems like estimation (where output is a numeral value) [6].

Each neural network consists of a single input layer which each node of this layer is equivalent to one of prediction variables. Every input node connects to all hidden layer nodes. Available nodes in hidden layer can be connected to the nodes of another hidden layer or output layer. Weights of edges, that are those connecting lines of different layers nodes to each other, are unknown parameters which are determined by training method and training data given to the system.

The number of nodes and hidden layers and way of connecting nodes to each other (topology) determine the neural network. User or software that designs a neural network has to define number of nodes, hidden layers, activity function and limitations related to weights of edges.

In Figure 4, a multi-layer Perceptron network is shown, which is the most proper artificial neural network for forecasting time series. In order to train weights in this neural network, back-propagation error rule is used.

Artificial neural network with classic training is the simplest method for forecasting time series [1]. Multi-layer neural network is an appropriate network for predicting and categorizing data. To train this neural network which works forward, back-propagation error rule is considered as a classic training method that is of high rate and accuracy [9].

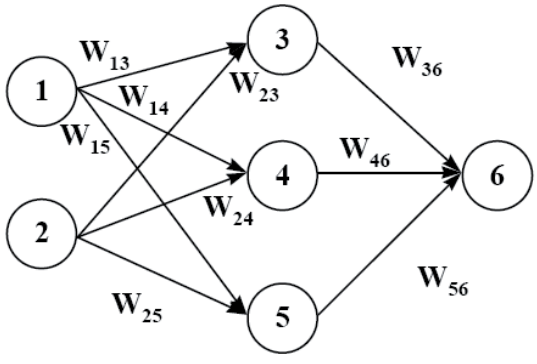


Figure 4. Multi Layer Perceptron neural network and Weights of edges

V. PROPOSED HEURISTIC ALGORITHM

In previous algorithms that forecasted time series by means of neural network, only time series itself was used; in the way that the neural network received certain number of consecutive numbers of time series as input and this series was trained. For instance, the stocks prices of first, second and third days of stocks time series are considered as the first input pattern of network and the price of forth day is considered as output. Stocks prices of second, third and forth days of stocks time series are considered as the second input pattern and objective output is the fifth day price. Thereafter, neural network gets consecutive input patterns as the price of days n, n+1 and n+2 and objective output is considered as the price of day n+3 to learn the time series succession [18]. In this method, in many chaotic time series, network training error wouldn't decrease and network wouldn't learn time series succession and would have incorrect prediction for many input points. Figure 5 presents traditional method of time series prediction by neural networks.

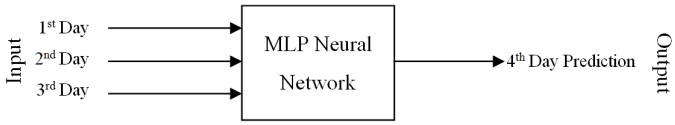


Figure 5. Neural Network structure in past paper

Time series prediction by intelligent algorithms unlike prediction by mathematical-statistical methods requires specialized knowledge about type of time series and quantitative-qualitative information. The more precise knowledge about time series being predicted, the more aware prediction we would have. This inside knowledge of time series would lead us to aware and heuristic algorithms in artificial intelligence.

In this paper, according to many-year studies of authors about the nature of chaotic time series in different scientific areas and mostly in economics, a heuristic and innovative method was proposed which is only interpretable with understanding the hidden properties of time series. This method is applicable on many time series inspired from economic variables like stocks price. In this method, beside the main time series that has chaotic oscillations, a standard chaotic series (here, logistic function output) that is proposed by an expert person is given as an independent input to forth node of neural network input. Neural network learns objective time series order by means of an auxiliary time series with itself which is added to neural network input. Figure 6 shows the proposed heuristic method by authors.

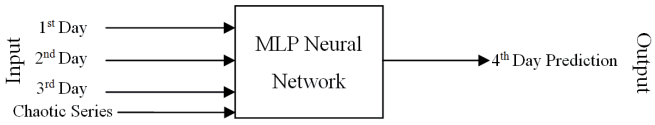


Figure 6. Neural Network structure in proposed method

VI. EXPERIMENTAL RESULTS

This section discusses about comparison between prediction by previous methods and the proposed methods on two known time series. In Figures 7 and 8 forecasted time series by classic method and the proposed method beside an actual time series is shown. As it observes, graph of predicted times series by the proposed algorithm is much more compatible with graph of actual time series. This compatibility shows more precise prediction of time series. In table 2, classic method error and the proposed method error were compared with respect to mean square error. It observes that the proposed method error for two valid time series of Taiwan stocks and currency price is much less than classic method. For Iran Khodro stocks time series, the proposed method error is almost the same as the classic method. The reason of high accuracy of predicting the two first time series is the high degree of chaos in them to the third one.

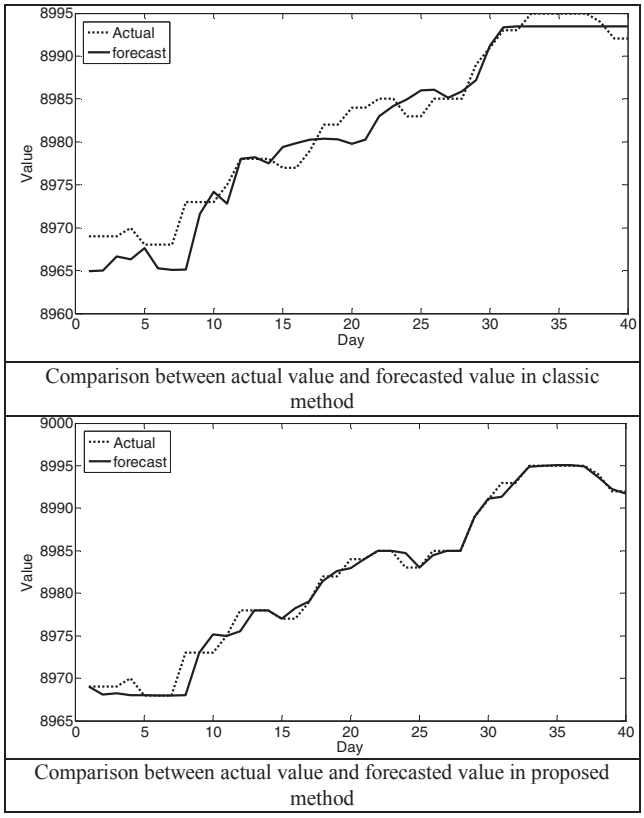
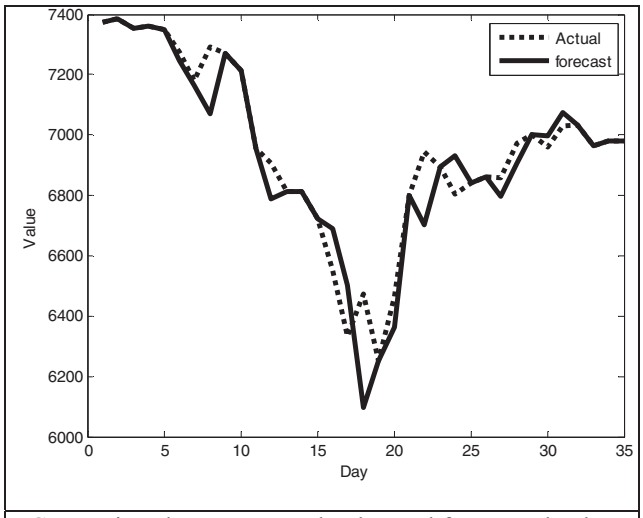
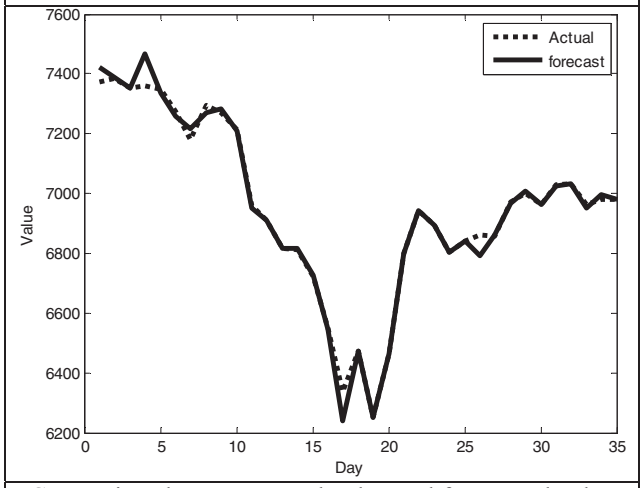


Figure 7. Dollar price forecast by classic method and the proposed method



Comparison between actual value and forecasted value in classic method



Comparison between actual value and forecasted value in proposed method

Figure 8. TAIEX time series forecast by classic method and the proposed method

Table 2. A comparison of MSE for different methods

Dataset	Error (MSE)	
	Classic method	Proposed method
Dollar price	368	327
TAIEX	1363	870
Iran khodro stock price	687	693

VII. CONCLUSION

In this paper, a new heuristic method is proposed based on the understanding and experience of authors of hidden patterns existing in time series of economic variables. In this algorithm, for better forecasting of an economic variable time series, an auxiliary chaotic series was used as the separate input of neural network. Experimental results showed much less error of the proposed algorithm. To continue this research, authors look proposing an optimal auxiliary series for improving predictions. A proper option as the auxiliary series is the output of a special chaos function.

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