

# Improvement in Forecasting Accuracy Using the Hybrid Model of ARFIMA and Feed Forward Neural Network

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**Abstract** In recent years, autoregressive fractionally integrated moving average (ARFIMA) models have been used for forecasting of long memory time series in the literature. Major limitation of ARFIMA models is the pre-assumed linear form of the model. Since many time series in real-world have non-linear structure, ARFIMA models are not always satisfactory. Both theoretical and empirical findings in literature show that combining linear and non-linear models such as ARIMA and artificial neural networks (ANN) can be an effective and efficient way to improve forecasts. However, to model long memory time series, any hybrid approach has not been proposed in the literature. In this study, a new hybrid approach combining ARFIMA and feedforward neural networks (FNN) is proposed to analyze long memory time series. The proposed hybrid method is applied to tourism data of Turkey whose structure shows dominantly the characteristic of long term. Then, this hybrid method is compared with other methods and it is found that the proposed hybrid approach has the best forecasting accuracy.

**Keywords** Feed forward neural networks, ARFIMA, Hybrid approach, Long memory

## 1. Introduction

A popular class of models for time series with long memory behaviour is the ARFIMA  $(p, d, q)$  model ([27]). This kind of models extended classical ARIMA  $(p, d, q)$  models by assuming the differencing parameter  $d$  as a real value. It is well known that ARFIMA models are linear time series model. Since some long memory time series have both linear and non-linear structures, ARFIMA models can be inadequate for this type of series. Therefore, these time series are modeled by a hybrid of linear and non-linear models, and by this way forecast accuracy is improved.

ANN have been widely used to model time series in various fields of applications[4] and used as a good alternative method for both linear and non-linear time series forecasting. Since ANN can model both non-linear and linear structures of time series, it is obvious that it can give good results in forecasting. As[37] mentioned, one of the most popular neural net paradigms is the feed forward neural network that is used in our study.

[40]review the literature for forecasting time series by ANN.

Both theoretical and empirical findings in literature show that combining different methods can be an effective and efficient way to improve forecasts. Therefore, hybrid of

ARIMA and ANN methods has been used for modelling both linear and non-linear patterns equally well.[30] proposed hybrid ARIMA and support vector machines model.[38] combined seasonal time series ARIMA model and FNN.[41] introduced a hybrid of ARIMA and FNN models.

Forecasting tourism data is an important task since it is employed for future planning. In the literature, there have been many studies using time series analysis in tourism data.[10],[39],[23-25], and[22] presented survey studies. Recently,[35] have summarized the studies on this topic in the last decade such as[18, 19, 5, 6, 17, 29] and[31]. Empirical results in all of these papers show that artificial neural networks can produce better results than those generated by conventional time series methods. However, ARFIMA models, which are also applied in our study while modelling the tourism data, have been found very successful for the analysis of tourism data in[7].

In this paper, to model long memory time series which have both linear and non-linear structures, a new hybrid method is proposed by modifying[41] hybrid method. This paper aims to obtain better forecasting accuracy by modelling both linear and non-linear patterns of long memory time series. Therefore, if more accurate forecasts are obtained, better plans for activities of tourism will be made. The some hybrid methods have been proposed in[15], [16],[20],[28],[32],[33] and[41] studies. Although there have been some methods combine ARIMA and ANN models, the combination of ARFIMA and ANN models haven't proposed in the literature. The proposed method is the first study about combining of ARFIMA and feed forward neural network.

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The proposed method is applied to the tourism data of Turkey. This monthly data concerns the number of tourists coming to Turkey between the periods 1995:1-2005:12.

The rest of the paper is organized as follows. In Sections 2 and 3, ARFIMA models and elements of FNN are presented, respectively. In Section 4, the proposed hybrid approach is introduced. In Section 5, the proposed method is applied to the tourism data of Turkey and compared with ARIMA, ARFIMA and FNN models. In the last section, the efficiency of the proposed method is discussed.

## 2. ARFIMA Models

ARFIMA models are used to model long range dependent time series. ARFIMA models were introduced by [11]. ARFIMA  $(p, d, q)$  model can be given by

$$\varphi(B)(1-B)^d X_t = \theta(B)e_t, \quad -1/2 < d < 1/2$$

where  $B$  is the back-shift operator such that  $BX_t = X_{t-1}$  and  $e_t$  is a white noise process with  $E(e_t) = 0$  and variance  $\sigma_e^2$ . The polynomials  $\varphi(B) = (1 - \phi_1 B - \dots - \phi_p B^p)$  and  $\theta(B) = (1 - \theta_1 B - \dots - \theta_q B^q)$  have orders  $p$  and  $q$  respectively with all their roots outside the unit circle. [3] extended the estimation of ARFIMA models for any  $d > -1/2$  by considering the following variation of the ARFIMA model:

$$\varphi(B)(1-B)^\delta (1-B)^m X_t = \theta(B)e_t, \quad -1/2 < \delta < 1/2 \quad (1)$$

The integer  $m$  is the number of times that  $X_t$  must be differenced to achieve stationary, and thus differencing parameter is given by  $d = \delta + m$ . General properties of ARFIMA models were given by Hosking [13, 14] and [2]. Studies about the parameter estimation of ARFIMA models still continue. Many maximum likelihood (ML) methods for ARFIMA are proposed in literature such as approximate ML methods (AML) by [12, 14, 21] and [2]; exact ML method (EML) by [36]; conditional sum of square (CSS) method by [8]. Note that CSS method is as efficient as EML method and it is identical with AML method by [2] that is based on infinity autoregressive presentation.

## 3. Elements of FNN

Elements of the ANN are network architecture, learning algorithm and activation function. Determining these elements that affect the forecasting performance of FNN should be considered carefully.

One critical decision is to determine the appropriate architecture, that is, the number of layers, number of nodes in each layers and the number of arcs which interconnect with the nodes [42]. FNN has been used by many studies in forecasting. However, determining of the architecture is a basic problem. Since, in the literature, there is no general rule for determining the best architecture, many architectures can be considered as the correct architecture. Fig. 1 depicts the broad FNN architecture that has single hidden layer and single output.

Learning of FNN for a specific task is equivalent to find-

ing the values all of the weights such that the desired output is generated to the corresponding input. Various training algorithms have been used for the determination of the optimal weights values. The most popularly used training method is the back propagation algorithm ([34]). In the back propagation algorithm, learning of the ANN consists of adjusting all weights such as the error measure between the desired output and actual output ([9]).

Another element of FNN is the activation function. It determines the relationship between inputs and outputs of a network. In general, the activation function introduces a degree of the non-linearity that is valuable most of the FNN applications. The well known activation functions are logistic, hyperbolic tangent, sine (or cosine) and the linear functions. Among them, logistic transfer function is the most popular one ([40]).

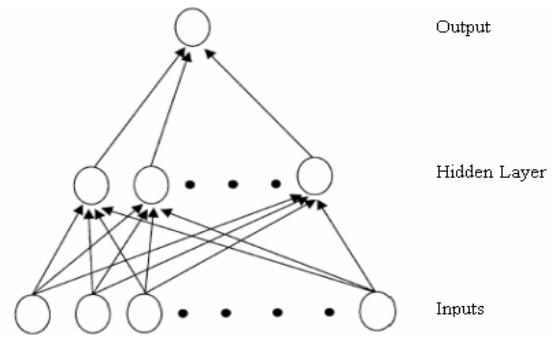


Figure 1. A broad FNN architecture

## 4. The Proposed Hybrid ARFIMA and FNN Approach

ARFIMA processes have been used to model long memory time series. However, it is clearly that using ARFIMA processes for modelling non-linear problems is not adequate because ARFIMA model is based on a linear structure. Applications of hybrid methods in the literature show that combining different methods can be an effective and efficient way to improve forecasts. Since it is difficult to completely know the characteristics of data in a real problem, hybrid methodology which has both linear and non-linear modelling capabilities can be a good approach for practical purposes. Therefore, to model time series having both linear and non-linear structures, hybrid approaches are proposed. To model long memory time series, any hybrid approach has not been proposed in the literature. In this paper, by modifying Zhang's [41] hybrid approach, a new hybrid approach is proposed to solve this problem. The proposed hybrid ARFIMA and FNN approach is given as follows:

It is assumed that a time series can be considered composing of two components, which are a linear autocorrelation structure part and a non-linear part respectively. The model is as follows:

$$y_t = L_t + N_t \quad (2)$$

where  $y_t$  denotes original time series,  $L_t$  denotes the linear component and  $N_t$  denotes the non-linear component.

Linear component is estimated by ARFIMA model and residuals obtained from the ARFIMA model.

$$e_t = y_t - \hat{L}_t \quad (3)$$

are estimated by FNN of [35]. Here  $\hat{L}_t$  is the forecasting value for the period  $t$  of the time series  $y_t$  by ARFIMA. Residuals are vital in examining the linearity assumption of the model. Autocorrelation coefficients are used to decide whether the residuals have linear relation or not. On the other hand, non-linear relation cannot be determined since the autocorrelation coefficient can be only employed for linear relation. Thus, the residuals might denote non-linear relation even though the autocorrelation coefficients for the residuals are approximately about zero. Therefore, the residuals obtained from the time series model generated by ARFIMA are analyzed by using FNN. With  $n$  input nodes, the FNN model for the residuals can be written as

$$e_t = f(e_{t-1}, e_{t-2}, \dots, e_{t-n}) + \varepsilon_t \quad (4)$$

where  $f$  is a non-linear function determined by the FNN and  $\varepsilon_t$  is the random error. The estimation of  $e_t$  by (4) will yield the forecasting of non-linear component of time series,  $N_t$ . By this way, forecasting values of the time series are obtained as follows:

$$\hat{y}_t = \hat{L}_t + \hat{N}_t \quad (5)$$

Consequently, our proposed method in this study consists of two phases. In the first phase, the time series is analysed by using ARFIMA models. In the next phase, the residuals obtained in the previous phase are examined by FNN and then forecast values obtained from these two models separately are summed. Besides, in this study, two different hybrid models are employed since two different FNN models are used in the second phase. One FNN model includes logistic activation function in all layers of the network. Second one includes logistic activation function in the hidden layer and linear activation function in the output layer.

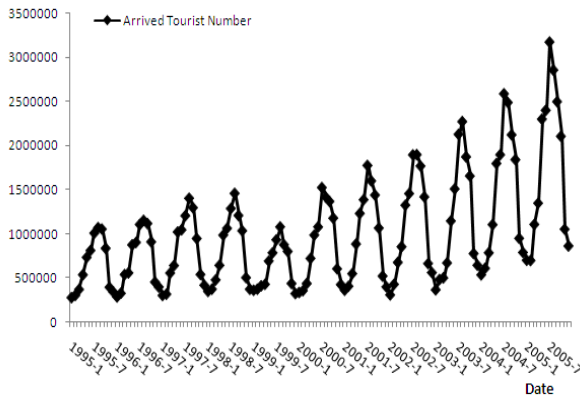


Figure 2. The tourism data of Turkey

## 5. Empirical Results

The proposed hybrid method is applied to the tourism data of Turkey which is plotted in Fig. 2. This monthly data concerns the number of tourists coming to Turkey between

the periods 1995:1-2005:12. For comparison, the data is also modeled by ARIMA, ARFIMA, and FNN. The last 24 observations of the data are used for comparing the methods by obtaining the values of root mean square error (RMSE), mean absolute percentage error (MAPE), median absolute percentage error (MdAPE) and the rest of the observations are used for the parameter estimation of the models.

Firstly, the tourism data of Turkey is analysed by ARFIMA models. Tourism series has seasonality. Therefore, the stationary series  $y_t$  can be given by

$$y_t = (1 - B^{12})x_t \quad (6)$$

where  $B$  is backshift operator and  $x_t$  represents the tourism series. In this empirical study, we will try to estimate the series,  $y_t$ . We see that transformed  $y_t$  series has a long memory structure after the transformations of  $x_t$  by (6) using R/S test by [26]. Therefore we use ARFIMA models to estimate  $y_t$  series. The most appropriate model is determined as ARFIMA (1,  $d$ , 3) by Bayesian information criterion [1] in S-Plus package program and this model is given as follows:

$$(1 - 0.6694B)(1 - B)^{0.8472} y_t = (1 + 1.1118B - 0.211B^2 - 0.3094B^3) e_t$$

where  $e_t$  is found as a white noise series using Box-Pierce Test. RMSE value of forecasts obtained by using ARFIMA (1,  $d$ , 3) model for last 24 data points is given in Table 1.

Secondly, the tourism time series is directly analysed by two different FNN models. When the best architecture design was determining, trial and error method was used. Although some systematically approaches to determine architecture design exist in the literature, they are not preferred generally since they do not guarantee the best architecture. Thus, in the literature, the most preferred and used method to determine ANN structures in time series forecasting studies is trial and error method. And this method is performed relevant to considered data. ANN is also a method based on the data examined.

Therefore, trial and error method is used in our study. The first used FNN model, which includes logistic activation function in the hidden layer and linear activation function in the output layer, is called FNN1. The other one, which includes logistic activation function in all layers, is called FNN2. For each FNN model, 144 architectures are examined by varying the number of neurons in the hidden layer and in the input layer 1 to 12. By these trials, the best architecture, which has the lowest RMSE value for the test set, is determined. For FNN1 model, the best architecture was found as FNN1(11-2-1), which includes 11 neurons in the input layer and 2 neurons in the hidden layer. FNN1(11-2-1) forecasts and the original tourism series of Turkey for 2004 and 2005 are shown in Table 1. In addition to this, calculated RMSE, MAPE, and MdAPE values for FNN1(11-2-1) are presented in Table 2.

Similarly, the best architecture for FNN2 was found as FNN2(9-2-1). The forecast values for 2004 and 2005 are presented in the Table 1 and calculated RMSE, MAPE, and MdAPE values for FNN2(9-2-1) are given in the Table 3. Neural networks tool box of Matlab 7.0 version is used in the

analysis.

Finally, the tourism data is examined by employing the proposed hybrid approach presented in Section 4. In the first phase of the proposed method, the tourism data is analysed by ARFIMA model. As mentioned, ARFIMA (1,  $d$ , 3) is determined as the most proper model. In the second phase, the residuals obtained in the first phase are analysed by using FNN1 and FNN2 models, separately. For each model, 144 architectures are examined by varying the number of neurons in the hidden layer and in the input layer 1 to 12. For FNN1 and FNN2 models, FNN1(9-1-1) and FNN2(1-1-1) are determined as the best architectures, respectively. Then, the predicted values obtained by ARFIMA (1,  $d$ , 3) and FNN1(9-1-1) are summed. These results belong to the first hybrid method that is called Hybrid1. Similarly, the predicted values obtained by ARFIMA (1,  $d$ , 3) and FNN2(1-1-1) are summed and the results of Hybrid2 are obtained. For

2004 and 2005, the forecast values obtained from the hybrid methods are presented in the Table 1. The values of RMSE, MAPE, and MdAPE for these two hybrid methods are given in Table 2. It is clearly seen from the results that when the FNN2 model is used in the hybrid model, better results are obtained. Therefore, we prefer to employ FNN2 model in the proposed hybrid method. From Fig. 3, we can observe the forecast values of all models.

In Table 3, the values of RMSE, MAPE, and MdAPE for all methods are given for comparison. It is observed from this table that the proposed hybrid method gives the best results in terms of all used forecasting criteria since this method has the smallest values for all used criteria. Another important result is the two FNN models give the worst forecasts. Although FNN have proved success in forecasting time series, we see that the FNN models are ineffective for the data long memory structured.

**Table 1.** The forecast values all models for 2004 and 2005 years

Years	Months	Arrived Tourist	FNN1	FNN2	ARFIMA	Hybrid1	Hybrid2
2004	1	533694	344768,9	376335,6	416133,9	419944,8	386530,6
2004	2	607854	341352,6	332571,4	641719,3	646715,6	612116
2004	3	784107	678142,5	751137,1	649299,4	653110,2	619696
2004	4	1104270	845048	912568,1	936036,5	944716,4	1021014
2004	5	1799130	1711521	1734246	1793856	1822219	1764252
2004	6	1898435	1978509	2170997	2286676	2290487	2257073
2004	7	2591140	2282384	2501986	2664369	2668180	2634766
2004	8	2492794	2310259	2295122	2648661	2652472	2619058
2004	9	2125025	2171820	2210089	2114695	2118506	2085092
2004	10	1842277	1864182	1761691	1886205	1890016	1856602
2004	11	948815	765851,6	749584,7	883477,4	887288,3	853874,1
2004	12	789367	574577,7	714452,7	774765,1	778587,5	745161,8
2005	1	700469	339856,1	504233,4	660239,5	664050,5	745216,9
2005	2	696639	461956,7	596319,9	777671,9	781484	862649,3
2005	3	1107348	955891,1	1004237	924881,4	928692,3	1008969
2005	4	1348264	1226735	1324642	1439153	1471983	1409606
2005	5	2302959	1979914	2103214	2299779	2303590	2270179
2005	6	2402912	2300745	2734980	2343557	2347368	2313981
2005	7	3178676	2382115	2791199	3242057	3245874	3212453
2005	8	2860973	2425905	2761472	3069867	3073678	3040263
2005	9	2502010	2254302	2413297	2466237	2470048	2551156
2005	10	2108136	2067655	2074658	2143569	2147381	2113966
2005	11	1052561	945803,6	890123,6	1105490	1109301	1075887
2005	12	861851	750568,8	911640,4	889786,3	893597,2	974763,7

**Table 2.** RMSE, MAPE, and MdAPE values of the hybrid methods

Years	Criteria	Hybrid1	Hybrid2
2004	RMSE	144037	134191
	MAPE	0.0032	0.002
	MdAPE	0.0691	0.053
2005	RMSE	98057	91749
	MAPE	0.0016	0.0013
	MdAPE	0.0444	0.0412

**Table 3.** RMSE, MAPE, and MdAPE values of all methods

Years	Criteria	FNN1	FNN2	ARFIMA	Proposed Method
2004	RMSE	184877	164046	143868	134191
	MAPE	0.0052	0.0024	0.0031	0.0020
	MdAPE	0.1271	0.0871	0.0591	0.0533
2005	RMSE	322515	184351	94447	91749
	MAPE	0.0126	0.0031	0.0014	0.0013
	MdAPE	0.1329	0.0899	0.0414	0.0412

## 6. Conclusions

Long memory time series have been analysed by using ARFIMA models which are based on linear structure. ARFIMA models are not always adequate for long memory time series that have both linear and non-linear structures. Therefore, the hybrid method which combines linear and non-linear models can be an effective way to improve forecasting performance. Motivated by this idea, in this paper, a hybrid model of ARFIMA and FNN is proposed to increase forecasting accuracy. Applying the proposed hybrid method to the tourism data of Turkey, we see that the proposed method is more successful than the other methods in terms of obtaining better forecasts. All computational processes related to neural networks are done with Matlab 7.0 software. As a result, the best forecasts are obtained by using the proposed hybrid ARFIMA and FNN2 (1-1-1) model. It is also seen that using only FNN models are ineffective for this long memory structured time series. This is also an important result for the ANN studies in the future. In further studies, we hope to improve the forecasting accuracy by changing the type of ANN in hybrid models presented here.

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