Forecasting of Foreign Currency Exchange Rate Using Neural Network

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Abstract-Foreign exchange market is the largest and the most important one in the world. Foreign exchange transaction is the simultaneous selling of one currency and buying of another currency. It is essential for currency trading in the international market. In this paper, we have investigated Artificial Neural Networks based prediction modelling of foreign exchange rates using five different training algorithms. The model was trained using historical data to predict four foreign currency exchange rates against Indian Rupee. The forecasting performance of the proposed system is evaluated by using statistical metric and compared. From the results, it is confirmed that the new approach provided an improve technique to forecast foreign exchange rate. It is also an effective tool and significantly close prediction can be made using simple structure. Among the five models, Levenberg-Marquardt based model outperforms than other models and attains comparable results. It also demonstrates the power of the proposed approach and produces more accurate prediction. In conclusion, the proposed scheme can improve the forecasting performance significantly when measured on three commonly used metrics.

Keywords: Artificial Neural Network, Back Propagation Algorithm, Forecasting, Foreign exchange rate and Training Function.

I. INTRODUCTION

Foreign Currency Exchange (FOREX) is involved with the exchange rates of foreign currencies compared to one another. These rates provide valuable data needed for currency trading in the international monetary markets. FOREX rates are influence by a variety of factors including political and economic events, and even the psychological state of individual traders and investors. These factors are highly connected and interact with one another in a highly complex manner. Those interactions are very dynamic, erratic and unstable. This complexity makes predicting FOREX rates difficult [1]. Trading at the right time with the relatively correct approach can bring large profit, but a trade based on incorrect movement can risk big losses. Using suitable analytical tool and best methods can reduce the effect of mistakes and also can increase profitability.

Artificial Neural Network (ANN) is a powerful programming method generated with an inspiration of the learning attribute of human brain. It consists of neurons which have information uploading, learning and recalling features like human brain cell [3]. These features enable them to assess undesigned instructions and generate the solution for them. Therefore, this method is considered as an effective and powerful approach for problem solving and analysis in several areas.

ANN plays a vital role in foreign exchange rate prediction process. It is a nonparametric, nonlinear and data driven modelling approach. It also has flexible nonlinear function mapping capability, which can approximate any continuous measurable function with desired accuracy.ANN presents a number of advantages over conventional methods of analysis [4]. ANNs are universal and highly supple approximations first used in the fields of engineering and cognitive science. In recent years, ANNs have been increasingly popular in finance for tasks such as pattern recognition, classification, optimization, robotic control and time series estimation operations.

In this paper, we apply ANN for predicting foreign exchange rates of Indian Rupee (INR) against four other currencies such as Pound Sterling (PS), United States Dollar (USD), EURO and Japanese Yen (JYEN) using their historical data. Five different ANNs based models using existing learning algorithms were considered. A total of 820 historical exchange rates data for each of four currency rates, were collected and used as an inputs to build the prediction model in our study and then additional 205 exchange rates data were used to evaluate the model. The prediction results of all these models were compared based on statistics metric. From the results, it is observed that the Levenberg-Marquardt (LM) based model show competitive results and forecast more accurately than other models.

The rest of the paper is organized as follows: Section 2 will discuss the related works. A detailed description of the proposed method for forecasting foreign exchange rate is given in section 3.Performance of the system has been discussed in section 4 and conclusion is presented in last section.

II. LITERATURE REVIEW

In past two decades, a number of studies have been conducted for forecasting exchange rates using neural networks. Here, a brief review is given in the following:

Adewole adetunji et.al.[1] present a neural network system for foreign exchange rate prediction. The authors observe the performance of the proposed method for USA dollar, European Currency (EURO), Great Britain Pound (GB) and Japanese Currency (Yen) against Nigerian Money (Naira). Athanasios Sfetsos et al. [2] have introduced a system to compare four methods including random walk , linear regression, auto regression integrated moving average and artificial neural network in forecasting exchange rate between US dollar and GB pound.Carney et al. [3] have suggested that neural network models are better than the conventional model methods in predicting foreign exchange rates on Deutsche marks, British pounds, Swedish krona and U.S. dollars. The authors employed two methods single-step predictions and multi-step predictions. They discovered multi-step models had more accurate predictions than the single-step models. Diebold et al. [4] have investigated ten weekly spot rates and did not find any significant difference in both in-sample fit and out-of-sample forecasting across these exchange rate series. Hann et al .[5] have presented a new approach to compare neural network models with linear monetary model in forecasting exchange rate between U.S. dollar and Deutsch mark. Jingtao Yao et al. [6] have developed a system using neural network for prediction. Time series data and simple technical indicators, such as moving average, are fed to the neural networks to catch the movement in currency exchange rates between American dollars and five other major currencies. The authors indicate that without using extensive market data, useful predictions can be made and a paper profit can be achieved for out-of-sample data with a simple technical indicator. Joarder Kamruzzaman et al. [7] have investigated artificial neural networks based prediction modeling of foreign currency rates using three learning algorithms, namely, Standard Back propagation (SBP), Scaled Conjugate Gradient (SCG) and Back propagation with Bayesian Regularization (BPR).The authors have shown that SCG based model outperforms other models when measured on two commonly used metrics and attains comparable results with BPR based model on other three metrics. Kuan et al. [8] have developed a new technique for predicting foreign exchange rate. The authors also examined the performance of feed-forward neural and recurrent neural. Lavanya et al. [9] have discussed various back propagation algorithm to predict foreign exchange rate between Australia dollar and Chinese yen. The authors said that LM based algorithm can predict accurately than other algorithms. It also has smallest mean square error. Prem chand kumar et al. [10] presents two neural network models for cash forecasting for a bank. One is daily model and other is weekly model. They have shown that the proposed system performs better than other forecasting systems. It can be scaled for all branches of a bank in an area by including historical data from these branches. Refenes [11] have discussed a constructive learning algorithm to forecast the exchange rate between U.S. dollar and the Deutsche mark. Rudra P pradhan et al. [12] employs artificial neural network to forecast foreign exchange rate for US dollar, Pound, Euro and Japanese Yen against Indian rupee. They used two types of data for forecasting, daily and monthly. The superiority of the proposed model shown that the information that is hidden in exchange rate could be better extracted using ANN. Verkooijen et al. [13] have proposed a method to forecasts monthly exchange rate between U.S. dollar and Deutsche mark using neural networks. He finds that the neural network performance is very similar to the linear structural models in out-of-sample forecasting. Vincenzo Pacelli et al. [14] have introduced neural network based model to forecast exchange rate between euro and us dollar up to three days ahead of last data available. By the analysis of the data it is possible than the artificial neural network model developed can largely predict the trend of three days of exchange rate. White [15] suggested that the relationship between conventional statistical and neural networks approaches for time series forecasting are complementary.

III. NEURAL NETWORK FORECASTING MODEL

ANN can approximate a continuous measurable function arbitrarily to any desired accuracy. A suitable network structure is to be determined so that any continuous function can be approximated well. A very simple network may not approximate the function well and complex network may over fit the data [5], [6], [7]. The most commonly used neural network is multilayer feed forward network. A multilayer network has more layers between an input and output units. Typically, there is a layer of weights between adjoining levels of units. A three layer network is illustrated in Fig.1.

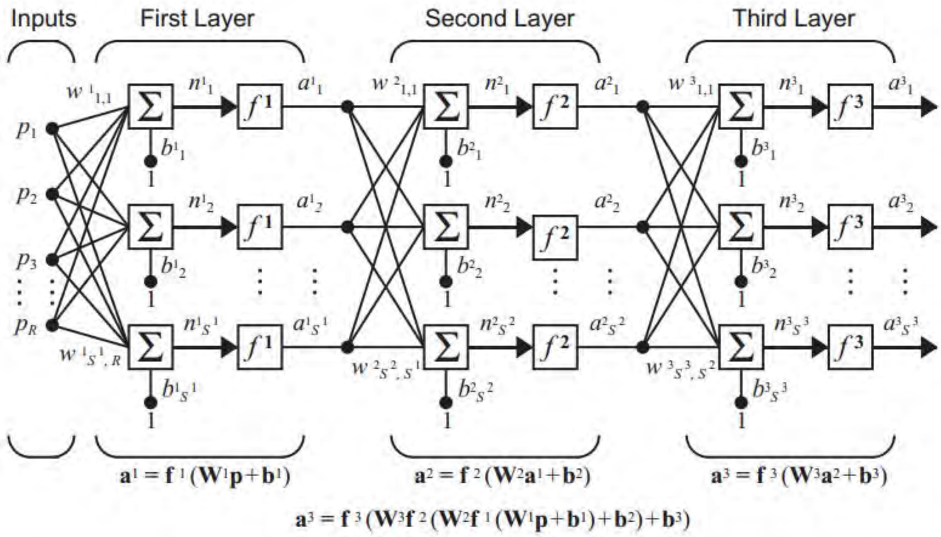


Fig.1.Multilayer network

Multilayer network can solve more complicated problem than single layer, but training of them is more difficult. A training algorithm is used to attain a set of weights that minimizes the error produced by the network. There are many different algorithms available. No study has been reported to systematically determine the generalization performance of each algorithm.

Data normalization is the process to keep the data within a certain range, 0 to 1 or -1 to 1.Generally, normalization is needed in order to remove unwanted data. In this work, we normalize the data to the value between 0 to 1.The data normalization has been done using the following equation:

$$Y_{i,out} = \frac{Xi - X\min}{X\max - X\min}(hi - li) \tag{1}$$

Where,

$Y_{i,out}$-Normalized value of the input or output

Xi-Original input.

Xmin-minimum value of original input

Xmax-maximum value of original input

hi-Upper bound of the normalizing interval(in our case 1)

li-lower bound of the normalizing interval(in our case 0)

After normalization process, the input data set is divided into training set, which consists of 70-80% of whole data and the testing set consists of the rest of the observations. Sigmoid transfer function is used in all hidden layers. It is a nonlinear function and thus captures the nonlinearity in data. Linear transfer function is used in the output layer, which is a standard choice in neural network and also used to prevent the loss of generality.

A. *BPNN Algorithm*

The Back Propagation Neural Network (BPNN) algorithm is a popular technique sufficient to accomplish many learning problems. BPNN algorithm consists of two processes which are fed forward and back propagation. In feed forward step, the data which the network receive from outside are conveyed from input layer at output layer, and in back propagation step the error term of the network is transferred from output layer to the first layer. This algorithm is based on delta learning rule in which the weight adjustment is done through Mean Square Error (MSE) of the response to the sample input [9], [10]. The set of these sample patterns are repeatedly presented to the network until the error value is minimized. The back propagation algorithm has emerged as one of the widely used learning procedures for multilayer networks as shown below:

The training algorithm used in the back propagation network is as follows:

1. Initially set the weights to small random values.
2. While stopping condition is false, do step 3 to step 10.
3. For each training pair do step 4 to step 9.

4. Each input unit receives the input signal x_i and broadcasts it to all nodes in the hidden layer.

5. For each hidden node (h_j , j=1…p) in the hidden layer calculate the sum of its weighted input values

$$h_{inj} = b_{hj} + \sum_{i=1}^{n} x_i w_{ij} \tag{2}$$

$$h_j = f(h_{inj}) \tag{3}$$

Where,

b_{hj}-is a bias on hidden unit j.

x_i- represents input vector.

W_{ij} –denotes the weight connection between input layer to hidden layer and

f-represents the activation function

6. For each output node (y_k,k=1…m) in the output layer sums its weighted input values

$$y_{ink} = b_{oj} + \sum_{j=1}^{p} h_j v_{jk} \tag{4}$$

$$y_k = f(y_{ink}) \tag{5}$$

here,

b_{oj}-bias on output unit k,

v_{jk}- represents the weight which connect node j in the hidden layer to node k in output layer.

7.Compute δ_k for each output neuron, ($y_{k,k=1\ldots m}$)

$$\delta_k = (t_k - y_k) f(y_{ink}) \tag{6}$$

Where,

t- target vector and

δ_k-error at output unit k.

8. After receiving delta values from the above layer each hidden unit (h_j,j=1…p) calculates the sum of its delta input

$$\delta_{inj} = \sum_{k=1}^{m} \delta_j v_{jk} \tag{7}$$

$$\delta_j = \delta_{inj} f(h_{inj}) \tag{8}$$

Where,δ_j-the error at hidden unit j.

9. Then update the values of its bias and weights at each output unit (y_k , k=1...m) .Weight correction as follows:

$$w_{ij}(new) = w_{ij}(old) + \Delta w_{ij} \tag{9}$$

$$\Delta v_{jk} = \alpha \delta Z_k \tag{10}$$

α-denotes the learning rate and formula for updating of bias is given by,

$$\Delta b_{hk} = \alpha \delta_k \tag{11}$$

$$v_{jk}(new) = v_{jk}(old) + \Delta v_{jk} \tag{12}$$

and

$$b_{hk}(new) = b_{hk}(old) + \Delta b_{hk} \tag{13}$$

Then update the values of its bias and weights at each hidden unit (hj , j =1...p)). Formula for weight correction is given by,

$$\Delta w_{ij} = \alpha \delta_j x_i \tag{14}$$

Formula for bias correction term is given by,

$$\Delta b_{hj} = \alpha \delta_j \quad (15)$$

Therefore,

$$w_{ij}(new) = w_{ij}(old) + \Delta w_{ij} \quad (16)$$

and

$$b_{hj}(new) = b_{hj}(old) + \Delta b_{jk} \quad (17)$$

10. Then test the stopping condition. The stopping condition may be minimization of the errors, number of epochs etc.

IV. EXPERIMENTAL RESULTS AND DISCUSSION

In this section, we describe the foreign exchange rate data collection and simulation results.

A. Data Details

The data used in this study is the foreign exchange rate of four different currencies against Indian Rupee made available for Reserve Bank of India. We considered exchange rate of PS, USD, EURO and JYEN.A total of 1205 days data were considered of first 80% data was used in training and the remaining 20% for evaluating the model. The plots of exchange rates for four currencies are shown in Fig.2.

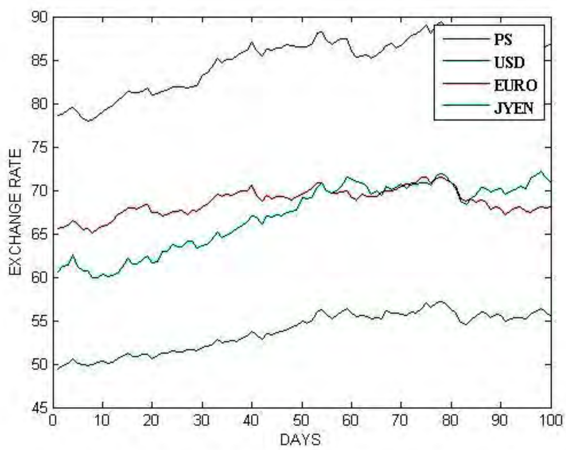


Fig.2. Historical exchange rates for PS, USD, EURO and JYEN against INR

B. Simulation Results

Foreign currency exchange rate data is a simple function approximation problem. A 1-4-1 layer network, with tansig transfer function in the hidden layer and linear transfer function in the output layer, is used to approximate the trend of the exchange rate.

The designed neural network model was trained with three inputs, four hidden layers and one output unit to predict the exchange rate. The final weight set of weights to which a network settles down depends on many factors such as number of hidden layers, initial weights chosen and learning parameters used during training. For each algorithm, the paper trains the network with different learning parameters and initial weights. The number of hidden nodes varied from 5-25 and the training was terminated iteration 500.The network that yielded the best result out of many trails in each algorithm is presented for analysis.

The paper compares four neural network training performances by using the INR against PS, USD, and EURO and JYEN exchange rate. Five different training algorithms are used in the network to see the general performance of each algorithm in the different problems

The below table lists the algorithms that are tested and the acronyms we use to identify them.

GD: traingd- Batch gradient descent

GDM: traingdm- Batch gradient descent with momentum

GDA: traingda-Variable Learning Rate Back-propagation

RP: trainrp –Resilient Back propagation

LM: trainlm- Levenberg-Marquardt

TABLE 1
MSE for Each Algorithm in the Different Epoch for Indian Rupee against PS

Algorithm	**50/500**	**100/500**	**150/500**	**200/500**	**250/500**	**300/500**	**350/500**	**400/500**	**450/500**	**500/500**
GD	0.0508	0.0382	0.0321	0.0282	0.0255	0.0234	0.0217	0.0204	0.0193	0.0184
GDM	0.0662	0.0504	0.0428	0.0345	0.0275	0.0228	0.0197	0.0175	0.0158	0.0145
GDA	0.0211	0.0116	0.0096	0.0088	0.0083	0.0092	0.0077	0.0073	0.0085	0.0068
RP	0.0044	0.0029	0.0024	0.0021	0.0019	0.0017	0.0016	0.0014	0.0013	0.0012
LM	**0.00011**	**0.00051**	**0.000037**	**0.000022**	**0.000016**	**0.000014**	**0.000014**	**0.000013**	**0.000012**	**0.000011**

TABLE II
MSE for Each Algorithm in the Different Epoch for Indian Rupee against USD

Algorithm	**50/500**	**100/500**	**150/500**	**200/500**	**250/500**	**300/500**	**350/500**	**400/500**	**450/500**	**500/500**
GD	0.0423	0.0306	0.0255	0.0225	0.0203	0.0187	0.0175	0.0164	0.0155	0.0148
GDM	0.0574	0.0315	0.0243	0.0205	0.0182	0.0167	0.0157	0.015	0.0144	0.0139
GDA	0.0233	0.0187	0.0146	0.0123	0.0111	0.0097	0.0084	0.0078	0.0074	0.0072
RP	0.0011	0.0007	0.0005	0.0004	0.0004	0.0003	0.0003	0.0003	0.0003	0.0003
LM	**0.000188**	**0.000045**	**0.000030**	**0.000024**	**0.000021**	**0.000016**	**0.000009**	**0.000007**	**0.000006**	**0.000005**

TABLE III
MSE for Each Algorithm in the Different Epoch for Indian Rupee against EURO

Algorithm	**50/500**	**100/500**	**150/500**	**200/500**	**250/500**	**300/500**	**350/500**	**400/500**	**450/500**	**500/500**
GD	0.0531	0.044	0.0394	0.0362	0.0335	0.0312	0.0292	0.0274	0.0257	0.024
GDM	0.0516	0.0371	0.0335	0.0314	0.0298	0.0284	0.0272	0.0259	0.0248	0.0236
GDA	0.0305	0.0204	0.0167	0.0138	0.0119	0.0109	0.0104	0.0095	0.009	0.0088
RP	0.0041	0.0027	0.0022	0.0019	0.0017	0.0014	0.0013	0.0012	0.0011	0.0011
LM	**0.000202**	**0.000066**	**0.000045**	**0.000033**	**0.000028**	**0.000018**	**0.000014**	**0.000012**	**0.000011**	**0.000010**

TABLE IV
MSE for Each Algorithm in the Different Epoch or Indian Rupee against JYEN

Algorithm	**50/500**	**100/500**	**150/500**	**200/500**	**250/500**	**300/500**	**350/500**	**400/500**	**450/500**	**500/500**
GD	0.0245	0.0173	0.0145	0.0129	0.0119	0.0111	0.0105	0.01	0.0096	0.0093
GDM	0.0487	0.0204	0.0144	0.0119	0.0106	0.0098	0.0092	0.0087	0.0084	0.0081
GDA	0.0126	0.0093	0.0083	0.0072	0.0067	0.0058	0.0054	0.0049	0.0045	0.0043
RP	0.0018	0.0011	0.0008	0.0007	0.0006	0.0005	0.0005	0.0005	0.0005	0.0005
LM	**0.000024**	**0.000008**	**0.000005**	**0.000003**	**0.000003**	**0.000002**	**0.000002**	**0.000002**	**0.000002**	**0.000002**

The model has been designed and tested using MATLAB 7.10 for forecasting foreign exchange rates. The training results of the all proposed models are listed in Table I to Table IV. Table shows the MSE for each algorithm in different epochs of Indian Rupee against PS, USD, EURO and JYEN exchange rate data training process. In the algorithm data in the first line 50/500, the first number 50 represents the iterations and the second number 500 is the maximum number of iterations. From the tables can be inferred the relationship among algorithms. For accurate prediction, the model should have minimum value of MSE. From all the tables, it is observed that GD, GDM and GDA algorithms are very slow. RP and LM algorithms consistently perform better than other models for all currencies. But, LM based model converges quickly and also have smaller MSE for all currencies.

The further illustration of the proposed scheme performance are shown in Fig. 3,Fig. 4,Fig.5 and Fig.6.It is a plot of time required for the network to converge versus the MSE convergence goal. From the below figures, It is observed that as the error is reduced, the improvement provided by the Levenberg-Marquardt algorithm based model becomes more pronounced.

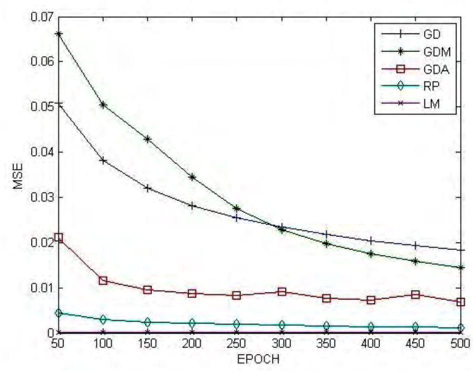


Fig.3.Performance comparison for PS/INR

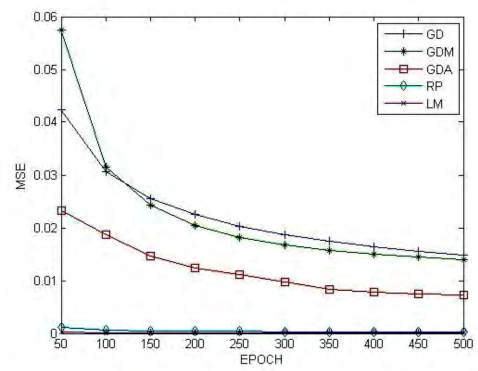


Fig.4.Performance comparison for USD/INR

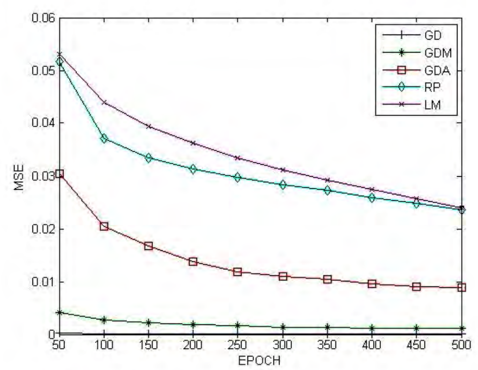


Fig.5.Performance comparison for EURO/INR

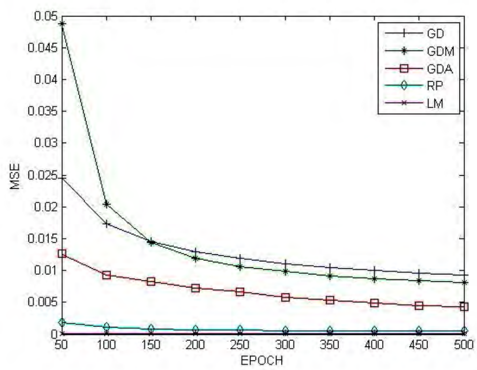
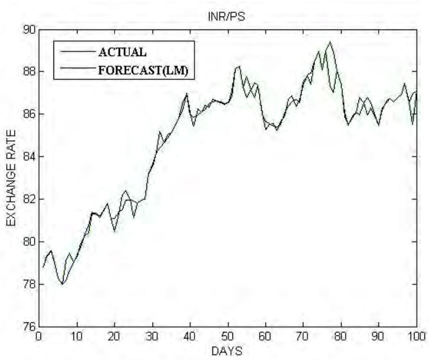


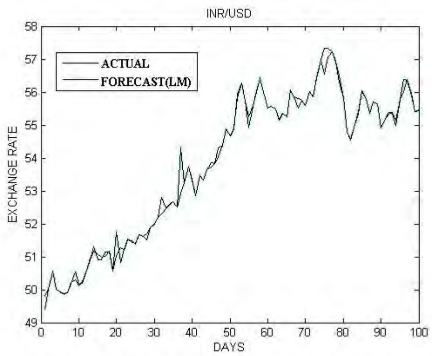
Fig.6.Performance comparison for JYEN/INR

The above figures show a plot of MSE versus epochs for INR against PS, USD, EURO and JYEN. From the above tables and plots, it is observed that in LM algorithm, the error decreases more rapidly than in other algorithms. It converges quickly from the beginning of the training. LM algorithm is best suited to deal with function approximation problem where the network has up to several weights and the approximation accurate. The results also demonstrate that LM algorithm provides best performance with faster convergence and has a smallest MSE than other four algorithms.

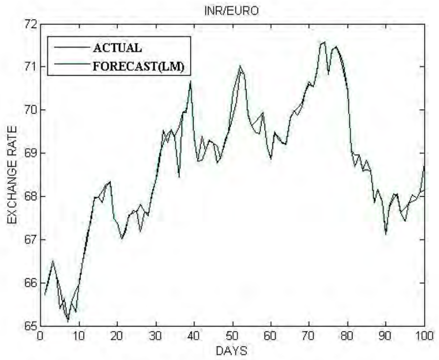
The diagrams showing the output forecast by neural network model and actual time series over 100 days for four currencies are shown in Fig. 7.(a)~(d).



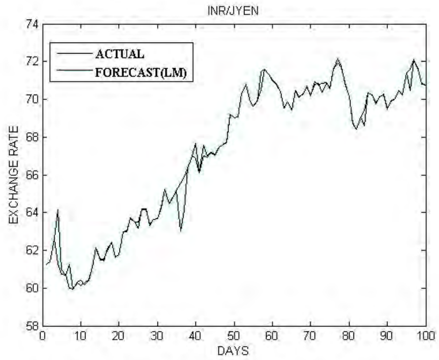
(a)PS/INR



(b) USD/INR



(c) EURO/ INR



(d)JYEN/ INR

Fig.7. Forecasting of different currencies by LM based neural network model over 100 days

C. Performance Metrics

The forecasting performance of the proposed technique is evaluated widely used three statistical metrics, namely, Root Mean Square Error (RMSE), Mean Absolute Error (MAE) and Mean Absolute Percentage Error (MAPE).The simulation results of these measures are illustrated in Table V.

1. RMSE: it returns root mean squared errors between actual and predicted values and can be written as

$$RMSE = \sqrt{\frac{1}{N}\sum_{k=1}^{N}\left(\left|A_k - P_k\right|\right)^2} \tag{18}$$

2. MAE: it gives the average absolute error between actual and predicted values,

$$MAE = \frac{1}{N}\sum_{k=1}^{N}\left|A_k - P_k\right| \tag{19}$$

3. MAPE: mean absolute percentage error between actual and predicted values is calculated as

$$MAPE = \frac{1}{N}\sum_{k=1}^{N}\left|\frac{A_k - P_k}{A_k}\right| X100 \tag{20}$$

Where A_k is the actual value, P_k is the predicted value and N is the number of data.

TABLEV
Measurement of Prediction Performance

Currency	Algorithm	RMSE	MAE	MAPE
PS	GD	0.1382	0.1109	3.451
	GDA	0.0843	0.0647	2.024
	GDM	0.1208	0.0923	3.012
	RP	0.0374	0.0274	0.845
	LM	0.0361	0.0109	0.337
USD	GD	0.12	0.0956	3.597
	GDA	0.0843	0.0665	2.492
	GDM	0.1171	0.0917	3.476
	RP	0.02	0.0141	0.527
	LM	0.0332	0.0087	0.326
EURO	GD	0.1575	0.125	3.247
	GDA	0.0843	0.0763	1.971
	GDM	0.1559	0.1235	3.218
	RP	0.0346	0.0256	0.661
	LM	0.0480	0.013	0.339
JYEN	GD	0.0985	0.0768	3.246
	GDA	0.0843	0.0537	3.709
	GDM	0.0906	0.0716	3.968
	RP	0.0224	0.0175	1.226
	LM	0.03	0.0085	0.570

Table V shows the results of input sample of 1205 observations. A MAPE below 5% is the measure of a highly accurate prediction. From the table 5, it is observed that LM algorithm always performs better than other algorithms in terms of performance metrics for all currency exchange rates. For example, in case of forecasting JYEN rate, MSE, MAE and MAPE achieved by LM algorithm 0.03, 0.0085 and 0.570 respectively. Smaller values of these three metrics indicate higher accuracy in forecasting. This means that LM algorithm is capable of predicting exchange rate more closely than other models.

V.CONCLUSION AND FUTURE WORK

This paper has presented and compared five neural network models to perform foreign currency exchange using historical data. As a result of comparison of these methods; it has been observed a remarkable difference between the performances of them. On this accomplishment, a well designed network structure acts as great role. We finally conclude that LM based model achieves closer prediction for all currencies than other models and 1-4-1 as the network structure has found to be the best performance for FOREX rate data. From the results, it is found that BPNN can be used to correctly predict FOREX rate, thereby decreasing the risk of making unfair decisions. The BPNN was chosen for this application because it is capable of solving wide variety of problems and it commonly used in forecasting. We would like to expand our work is to explore more properties of Matlab neural network software, testing more parameters to increase the accuracy of the prediction, decrease the time consumed in the process and reduce memory usage.

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