FOREX rate prediction using ANN and ANFIS

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Nathan D'Lima
M.E. Student
Computer Department,
St. Francis Institute of Technology
Mumbai, India.
nathan.dlima@gmail.com

Shamsuddin S. Khan
Assistant Professor
Computer Department,
St. Francis Institute of Technology
Mumbai, India.
shams21980@gmail.com

***Abstract*— Currency exchange is the trading of one currency against another. FOREX rates are influenced by many correlated economic, political and psychological factors and hence predicting it is an uphill task. Some methods to predict the FOREX rate include statistical analysis, time series analysis, fuzzy systems, neural networks, and hybrid systems. These methods suffer from the problem of accurately predicting the exchange. A Artificial Neural Network (ANN) and a hybrid Neuro-Fuzzy system (ANFIS) are proposed to predict the future rate of the FOREX market. The MLP is used to predict the rise or fall in the exchange rate while the ANFIS model is used to predict the exchange rate for the next day. For the experiment, USDINR exchange rate from the forex market is used. Mean Square Error (MSE) and Mean Absolute Error (MAE) are used as performance indicators. The ANN achieved an MSE of 0.033 and MAE of 0.0002 during training while the ANFIS model achieved an MSE of 0.024 and a MAE of 6.7x10-8. The ANN achieved an MSE of 0.003 and MAE of 0.00082 while the ANFIS model achieved an MSE of 0.02 and a MAE of 0.00792 during the testing phase.**

Keywords*— *FOREX; ANN; ANFIS; Forecasting; Neuro Fuzzy; Hybid System

I. INTRODUCTION

Foreign Exchange or Foreign Currency Exchange is commonly known as FOREX or FX. The foreign exchange market is a common place where currencies are traded. The FOREX market is used to determine the relative price between a particular currency pair. The exchange market is a decentralized marketplace, i.e. there is no centralized place where transactions are made. Currencies are traded in several market places all around the world. It is the largest financial market in the world which trades over $4.9 billion daily [1]. Foreign currency exchange works similar to the stock market. The relative price of a currency pair is dependent on the demand and supply of those currencies in the market. Unlike the stock market the FOREX market is always online. One can trade any currency with any other at any time of the day. The most widely traded currency pairs are called majors (EUR/USD, USD/JPY, GBP/USD and USD/CHF) and commodity pairs (AUD/USD, USD/CAD, NZD/USD) due to the large volume of trading [2].

Banks, investment managers, hedge funds, corporations and individual investors are the traders in the FOREX market [3]. Private and Central Banks are the largest currency traders in the market. Banks help clients in forex transactions. Central banks are responsible for the forex prices and help stabilize a nation's economy. Investment managers and hedge funds use large accounts to trade in different currencies. Import and export operations are usually done by corporations which trade currencies to pay for services and goods. Individual investors form the smallest part of the traders in the forex market and usually trade currencies for profit.

The FX market affected by a variety of factors which include inflation, rate of interest, capital account balance, role of speculators, cost of manufacture, debt, gross domestic product, political and economic stability, employment, macroeconomic and geopolitical events [15]. The market is a very unpredictable entity. An increase in supply or a decrease in demand for a currency can cause the value of that currency to fall and vice versa. It is rare for two currency pairs to have the same relative value for a long period.

II. LITERATURE REVIEW

Kodogiannis and Lolis in [6] use 4 existing methods and propose a new defuzzification method for a hybrid system to predict the foreign exchange rates. The methods used were Multi-Layer Perceptron (MLP), Radial Basis Function (RBF), Autoregressive Recurrent Neural Network (ARNN) and Modified Elman network. They proposed the Bisector of Area (BOA) defuzzification technique for Adaptive Fuzzy Logic System (AFLS). MLP uses standard Back Propagation (BP) algorithm. RBF uses an Orthogonal Least Squares method for learning. ARNN uses a generalized BP algorithm for training the model. AFLS model was trained by an error back propagation algorithm. Data from end of 1997 to end of March 2000 of the currency pair USD/GBP was used. The hybrid AFLS model performed better than other model in terms of Percentage Relative Error, Root Mean Squared Error (RMSE) and Standard Error Deviation.

A combination of Soft and Hard Computing techniques are used in [7]. The soft computing methods used are a Neural Network trained by sealed conjugate gradient algorithm and a Neuro Fuzzy system implementing Takagi-Sugeno Fuzzy Inference System. Hard computing techniques used are Multi Adaptive Regression Splines (MARS), Classification and Regression Trees (CART), and a hybrid CART-MARS technique. Exchange rates of Australian Dollar with US Dollar, Singapore Dollar, New Zealand Dollar, Japanese Yen and United Kingdom Pounds were considered. Data from January 1981 to April 2001 was used, 70% of which is used training and the rest in testing and validation. The RMSE values of the test revealed that the hybrid methods (Neuro-Fuzzy and CART-MARS) performed better than other techniques.

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In [8] Alizadeh, Rada, Balagh and Esfahani used a neuro-fuzzy approach to forecast exchange rates for US Dollar against Japanese Yen (USD/JPY). 28 fundamental and technical candidate inputs are given as input to the model. Data samples from January 2001 to August 2008 are taken from Reuters 3000 Xtra Hosted Terminal Platform. 60% of the data is used for training while the rest is used for testing the model. The neuro-fuzzy method used was Adaptive Neuro-Fuzzy Inference System (ANFIS). A Sugeno-Yasukawa model, Feedforward Multi-layer Neural Network and Multiple Regression was also used to forecast the exchange rate. The RMSE and mean error of the prediction (BIAS) for the ANFIS model are better than other approaches.

Pacelli, Bevilacqua, and Azzollini use an Optimal Topology Design Multi-Layer Perceptron Neural (MLP) through a Multi-Objective Genetic Algorithm to predict the exchange rates for Euro-US Dollar in [9]. Data was collected from January 1999 to December 31, 2009. The proposed model can predict the trend to 3 days. Coefficient of determination (R2), Mean Absolute Error (MAE), Mean Square Error (MSE), Mean Square Percentage Error (MSEP), Root Mean Square Error (RMSE), and Root Mean Square Percentage Error (RMSEP) are used as statistical indicators.

Kordos and Cwiok use a MLP neural network to determine the optimal buy and sell time for a stock in [10]. The inputs consist of past stock prices and technical indicators like Simple Moving Average, Rate of Change, Relative Strength Index, Commodity Channel Index, Stochastic Oscillator, Average True Range, and hummer and shooting star candle formations. Price change for the past 3 days relative to the current price was given while a 6, 9, 14 and 21 day period of the technical indicators were used. Experiments were performed on stocks of Amazon, Apple, Microsoft and Yahoo. The data between January 1995 and December end 2004 was used in training and data between January 2005 and January 2008 was used for testing.

In [11] Gharleghi and Nor use a hybrid system application for forecasting the exchange of Malaysian Ringgit against US Dollar. They compared Random Walk, Neural Network and Neuro-Fuzzy Inference Systems for the data between January 1998 and September 2010. The model predicts 3, 6, and 12 steps ahead. Root Mean Square Error (RMSE), Mean Absolute Error (MAE), Mean Absolute Percentage Error (MAPE) and Variance Proportion (VP) are used as performance measures. The Neural Network and Neuro-Fuzzy models outperformed the Random Walk model.

An Ensemble Neural Network and Ensemble Kernel based Partial Least Squares (K-PLS) method are used to predict the US Dollar per Indian Rupee (USD/INR) and Euro (USD/EUR), and Australian Dollar per Euro (AUD/EUR) in [12]. For the study, exchange rates between January 2010 and December 14, 2011 are used for USD/INR while data between January 2010 and December 22, 2011 are used for USD/EUR and EUR/AUD. Mean Absolute Error (MAE), Root Mean Square Error (RMSE) and q2 and Q2 errors are used as performance metrics. USD/INR was found to be more predictable than USD/EUR. AUD/EUR is predictable in one day ahead mode but not over a long term.

Kia, Fathian, and Gholamian use a Multi-Layer Perceptron (MLP) and Radial Basis Funciton (RBF) to improve the exchange rate forecast using Auto-Regressive Integrated Moving Average (ARIMA) in [13]. The hybrid ARIMA+MLP+RBF model uses ARIMA to predict the exchange rate. The error of the ARIMA model is given to the MLP and the combined error of ARIMA and MLP is given to RBF to further reduce the error. Dataset from 1st April 2001 to 31st July 2010 is used. RMSE and Directional Success (Dstat) are used as performance measures. The hybrid model works better than the three individual methods.

In [14] Fallahzadeh and Montazeri propose a hybrid neuro-fuzzy system based on interval type-2 fuzzy c-means clustering, MLP neural network and interval type-2 fuzzy model. A combination of back-resilient and back-propagation is used to speed up learning. Exchange rates for Euro (EUR) and Swiss Franc (CHF) against US Dollar are used from January 2005 to October 2012. Closing Price and Stochastic Oscillators (%K and %D) are used as inputs. The proposed model is also compared with its fuzzy c-means based type-1 equivalent and a FLANN based neuro-fuzzy system. The proposed system can handle fluctuations accurately.

Chandar, Sumathi, and Sivanandam use a Neural Network with 3 learning algorithms in [16] to forecast the exchange rates between Indian Rupee (INR) and Pound Sterling (GBP), US Dollar (USD), Euro (EUR) and Japanese Yen (JPY). Learning algorithms used are Batch Gradient Descent (GD), Batch Gradient Descent with Adaptive Learning (GDA) and Resilient Back Propagation (RP). Data for five years from January 2008 to December 2012 was collected from Reserve Bank of India. Root Mean Square Error (RMSE), Mean Absolute Error (MAE) and Mean Absolute Percentage Error (MAPE) are used as performance measures. The RP algorithm predicts the exchange rates more accurately than the other methods.

In [17] Beneki and Yahmohammadi use 3 algorithms to predict the exchange rates between US Dollar (USD) and United Kingdom (GBP), European Union (EUR) and China (CNY). Neural Networks (NN), Vector Singular Spectrum Analysis (VSSA), and Recurrent Singular Spectrum Analysis (RSSA) are compared on the basis of Root Mean Square Error (RMSE) and Direction of Change (DC). VSSA and RSSA outperform NN for highly unpredictable Chinese currency while there is not much difference for GBP and EUR.

III. PROPOSED SYSTEM

The proposed model is a combination of an Artificial Neural Network (ANN) and a hybrid Adaptive Neuro-Fuzzy Inference System (ANFIS). The ANN is used to predict the trend of the exchange rate. It gives the trend, whether it will rise or fall, of the exchange rate as output. The ANFIS model is used to predict the next day price of the exchange rate.

3.1. Artificial Neural Network (ANN)

The Artificial Neural Network models the input data to predict the trend of the FOREX market. It has a 4-5-1 design

as shown in Fig. 1. The model takes 4 input variables and provides the trend as output. It has one hidden layer that has 5 neurons. The number of neurons in the hidden layer was decided based on the results of experiments conducted. All hidden layer and output layer neurons use a sigmoid activation function [20]. The ANN model uses a standard Error Back Propagation Training Algorithm [20] which implements the delta learning rule [18].

The inputs given to the model are the previous day Closing Price (CP), and three technical indicators – Simple Moving Average (SMA), Exponential Moving Average (EMA) and Rate of change (ROC). All the technical indicators have a period of 14 days. The technical indicators are explained in detail in [5].

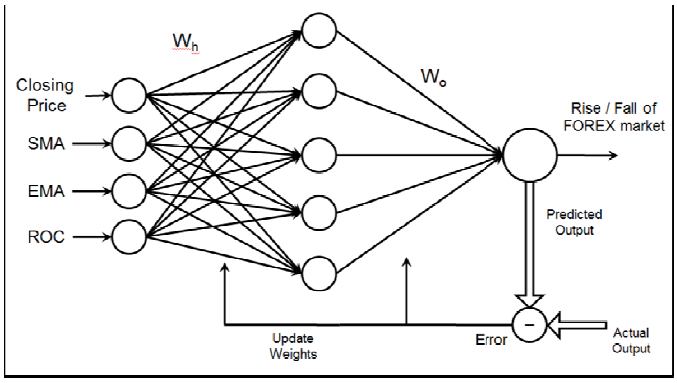

Fig. 1. Artificial Neural Network Architecture

Moving Averages are used to determine the trend or direction of the market. They are based on past data and are usually a step behind. Despite the lag, they help filter out noise from a given graph. SMA and EMA are the most popular moving averages [5]. Simple Moving Average (SMA) is the average of the closing prices for a particular period as shown in in (1). The Exponential Moving Average (EMA), defined in (2), is a more recent average of the closing prices.

$$SMA\ (t) = \frac{1}{n}\sum_{i=0}^{t} CP_i \qquad (1)$$

$$EMA(t) = \frac{2}{n+1} CP_t + (1 - \frac{2}{n+1}).SMA(t) \qquad (2)$$

The SMA moves slower as compared to EMA. A change in direction of the price caused EMA to change direction quicker than SMA. A crossover between the moving averages signifies a change in the trend. If the EMA crosses the SMA from below, it signifies a rise in price whereas if the EMA crosses the SMA from above, it signifies a fall in price.

Rate of Change (ROC) is a momentum oscillator that measures percent change in the price between periods. It is done by comparing the current closing price with the closing price n periods prior as defined in (3). The plot of ROC fluctuates above and below the zero line. The ROC gives a signal before the actual change in the direction of a price occurs [10]. So long as the ROC remains positive the price increases and decreases when ROC becomes negative.

$$ROC = \frac{Today's\ Close - Close\ N\ days\ ago}{Close\ N\ days\ ago}.100 \qquad (3)$$

Experiments were conducted to find the suitable number of hidden neurons that give the least error. Table 1 shows the results of the experiments. The minimum value of MSE for each set of hidden neurons is taken and a comparison of these values shows that 5 hidden neurons give the least MSE with a learning constant of 0.1 and a momentum value of 0.25 as shown in Table 1.

TABLE I. ERROR GENERATED BY NUMBER OF HIDDEN NEURONS.

Learning rate	Momentum	No of hidden neurons	Avg MSE
0.15	0.1	4	0.030060
0.1	0.25	5	0.029779
0.1	0.25	6	0.031510
0.1	0.15	7	0.032367
0.1	0.1	8	0.033397
0.1	0.2	9	0.033285
0.15	0.25	10	0.034705

3.2. Adaptive Neuro Fuzzy Inference System (ANFIS)

Adaptive Neuro Fuzzy Inference System or ANFIS is a hybrid neuro-fuzzy technique that is used to predict the next day value of the exchange rate. The ANFIS model has 2 inputs – Closing Price and SMA, with 5 input membership functions for each input. The number of membership functions for each input was decided based on the results of experiments conducted as shown in Table 2. The basic structure is described in more detail in [18] and [19]. The output of this model provides the predicted exchange price of the currency pair.

Fig. 2 shows the structure of the ANFIS model. The model uses a first order Sugeno FIS and a grid clustering technique to generate 25 rules based on the inputs and the input membership functions. The output of each rule is a linear combination of input variables plus a constant term, and the final output is the weighted average of each rule's output.

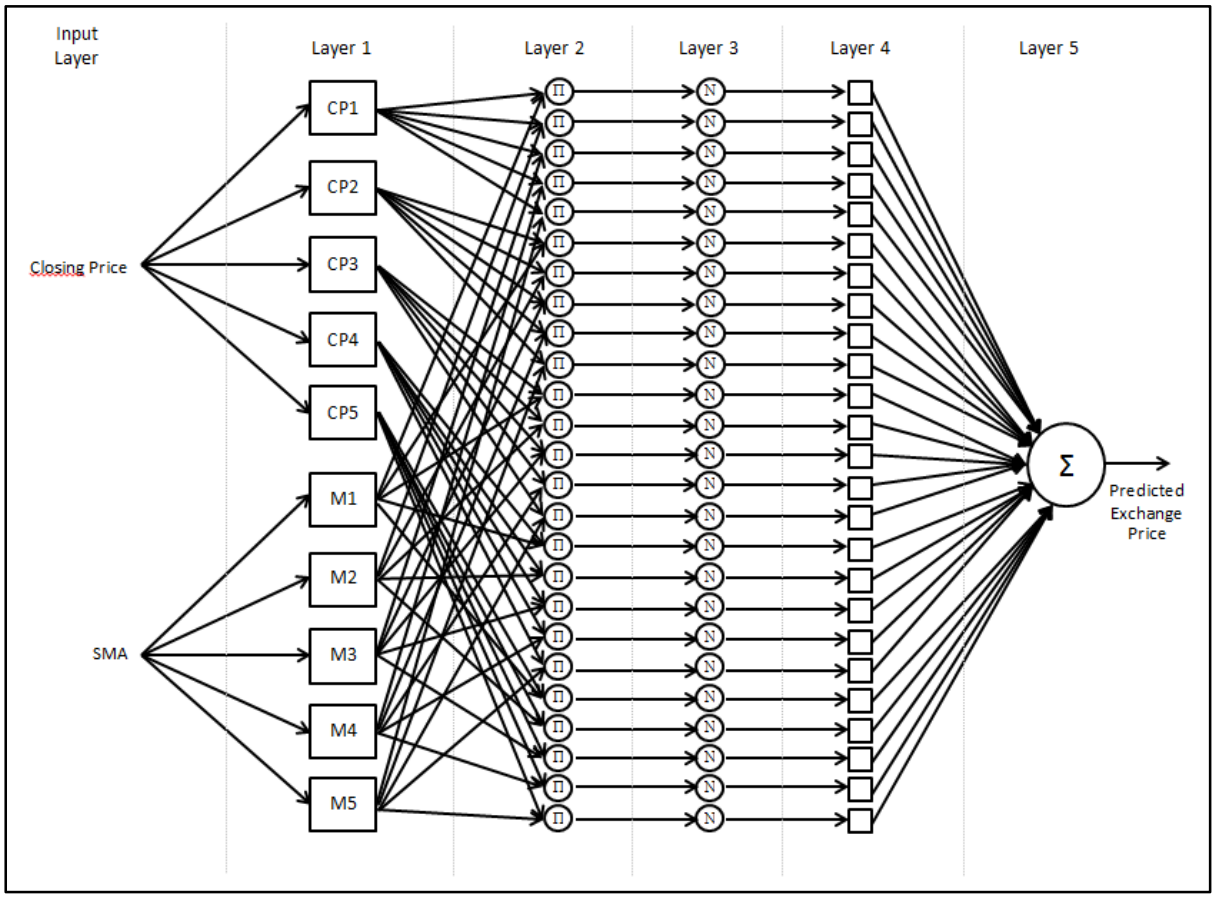

Fig. 2. ANFIS Architecture

TABLE II. ERROR GENERATED BY NUMBER OF MEMBERSHIP FUNCTIONS PER INPUT VARIABLE.

No of MF	Training			Testing		
	Time	MSE	MAE	Time	MSE	MAE
2	19.544	0.0255	$2.77x10^{-09}$	0.052	0.0254	$6.94x10^{-03}$
3	48.508	0.0249	$8.90x10^{-09}$	0.043	0.0242	$6.80x10^{-03}$
4	106.512	0.0248	$3.23x10^{-08}$	0.045	0.0245	$6.96x10_{-03}$
5	230.834	0.0241	$4.52x10^{-08}$	0.055	0.0247	$6.27x10^{-03}$
6	432.546	0.0240	$8.23x10^{-08}$	0.063	0.0327	$8.92x10^{-03}$
7	1436.395	0.0235	$9.04x10^{-08}$	0.063	0.0307	$8.37x10^{-03}$
8	1982.937	0.0233	$1.66x10^{-07}$	0.069	0.0307	$8.85x10^{-03}$

IV. EXPERIMENTAL RESULT

The proposed hybrid system is used to predict the trend and next day's value of the exchange rate between US Dollar and Indian Rupee (USD/INR). The experiment was conducted on a desktop computer running a Windows 7 Home Basic Operating System with 2 GB RAM and a 500 GB hard disk. The models were programmed in MATLAB 2013a.

A. Data

The data for the exchange rate between USD/INR is taken from [4]. Daily exchange rates from 1st November 1993 to 31st May 2015 are used. There are a total of 7882 records of which 75% is used in training and the rest is used for testing the models. The data set is stored as a separate comma separated values (csv) file. The data is pre-processed to convert the slash notation (dd/mm/yyyy) to a comma notation (dd,mm,yyyy) for easier computation.

B. Performance metrics

The evaluation of the performance of the proposed system is done using two metrics, namely, Mean Square Error (MSE) and Mean Absolute Error (MAE). MSE is the mean of the squared errors of the prediction model. The error is the difference between the predicted value and the actual value. MAE is the average of the absolute error between the predicted value and the actual value.

$$MSE = \frac{1}{n}\sum_{i=1}^{n}(predicted\,value_i - actual\,value_i)^2 \quad (4)$$

$$(n = no\,of\,records)$$

$$MAE = \frac{1}{n}\sum_{i=1}^{n} | predictedvalue_i - actualvalue_i | \quad (5)$$
$$(n = no\,of\ records)$$

Table 3 shows the results of the models in training and testing. The MSE and MAE values for the trend prediction using ANN are very small indicating a good and accurate prediction. Lower values of the performance metrics indicate a high accuracy in the forecasting of the exchange rate. The performance of ANFIS shows that the model can predict 1 day look ahead exchange rate with high accuracy. As compared to other methods discussed, the proposed system has lower MSE and MAE values.

TABLE III. PERFORMANCE MEASURE OF PREDICTION OF TREND AND EXCHANGE RATE.

Method	Training		Testing	
	MSE	***MAE***	***MSE***	***MAE***
Artificial Neural Network	0.033	7.36×10^{-5}	0.003	0.25
ANFIS	0.024	5.49×10^{-9}	0.023	8.68×10^{-8}

V. CONCLUSION

A hybrid model consisting of an Artificial Neural Network and an Adaptive Neuro-Fuzzy Inference System is introduced. The proposed system predicts the trend of the forex market and the exchange rate for the next day for the USD/INR currency pair. This market has a slight noisy nature, but experiments show that the proposed system can predict the trend as well as the exchange rate with high accuracy. The combination of the two models (ANN + ANFIS) makes a robust predicting method. The model can be further developed to combine the output of the ANN with the input for ANFIS and make a more robust model for a more accurate prediction model.

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