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Research Article

Foreign Exchange Rate Prediction using Hybrid of ANFIS and Wavelet with Feature Extraction and Feature Selection

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Abstract

Foreign exchange rate prediction is required for making strategy of foreign trading and other financial purposes. The ability to accurately predict the future behavior of time series data is very crucial using statistical methods; instead, hybrid techniques may perform better than individual. This paper focuses on hybrid approach of three different techniques: wavelet for removing noise and non-linearity from chaotic time series data, feature extraction for extracting new features and feature selection for selecting best features. Adaptive Neuro-Fuzzy Inference System (ANFIS) is applied for prediction of linear Foreign Exchange (FX) data. The empirical result shows that hybrid approach with optimized extracted features: SMA (Simple Moving Average), WMA (Weighted Moving Average) and VAR(Variance) provides the best predictive result with Mean Absolute Percentage Error (MAPE)=1.246, Mean Absolute Error (MAE)= 0.011 and Root Mean Square Error (RMSE)= 0.013.

Keywords: ANFIS (Adaptive Neuro-Fuzzy Inference System), Wavelet, Feature selection, Feature extraction.

Introduction

Prediction is a process of analyzing the future values that are based on study of historical data to construct a predictive model. It is very difficult to construct a good model when the data is non-linear and chaotic in nature (Kazem, Sharifi, Hussain, Saberi, & Hussain, 2013). Predictive model based on conventional or statistical techniques are not completely suited for non-linear data(Jang, 1993) like Foreign Exchange (FX) data because of its uncertain and fluctuating behavior. To overcome this limitation, advanced non-linear methods like machine learning techniques have been frequently applied by many researchers from last few decades.

In this proposed research work hybridization of wavelet, feature extraction, feature selection and Adaptive Neuro-Fuzzy Inference System (ANFIS) is used to construct a predictive model for next week FX rate prediction. Wavelet is used to remove non-linear nature and noise from existing data without losing its originality in terms of information. It decomposes the data and extracts the de-noised information by removing unwanted signals from data. Feature extraction has been used to extract new features from existing features. In this proposed work features are extracted using some parameters suggested by authors(Barak, Heidary, & Tichý, 2015; Hota, Shrivas, & Hota, 2018). Five new features: Simple Moving Average (SMA), Exponential Moving Average (EMA), Weighted Moving Average (WMA), Variance (VAR) and Standard Deviation (Std_Dev) are extracted based on our previous work (Handa, Hota, & Tandan, 2015). This knowledge and behavior of the system is use to train the model and predict outcome based on appropriate choice of fuzzy membership functions. Experimental data used to develop predictive model is partitioned into training and testing data sets using dynamic partitioning method k-fold. MATLAB code have written to train the model and measured with Mean Absolute Percentage Error (MAPE), Mean Absolute Error (MAE) and Root Mean Square Error (RMSE).

The rest part of this paper is organized as follows :Section 2 gives a brief overview of the literature; section 3 describes architecture of proposed work; section 4 explores dataset and methodology and section 5 elaborates experimental result, finally section 6 concludes the findings of the research work.

Literature Review

In this research work many interesting research papers are reviewed based on FX rate prediction using different intelligent techniques. The review of literature also represents the hybrid approach by combining multiple suitable approaches for prediction. Author (Gherman, Terebes, & Borda, 2012) has analyzed the time series data using wavelet transform and GJR-GARCH model which is enhancement of GARCH model to improve

prediction. Author (Ustazhanov, 2014) studied about wavelet analysis using MATLAB- Simulink wavelet tool in order to reduce unwanted noise signal from digital signals. Author (Sifuzzaman, Islam, & Ali, 2009) has discussed about the applications of wavelet represents the comparison between fourier transform and wavelet transform and show the reliability and accuracy of wavelet transform.

Many feature selection techniques have been also applied to get best features among the existing features, author (Su & Cheng, 2016) have studied a forecasting model which is integration of non-linear feature selection methods and ANFIS and results show that the proposed model effectively improve accuracy of forecasting. A new feature selection technique is proposed by author (Hota et al., 2018) called RRFST which reduces the features from original feature space by selecting feature randomly and remove it if accuracy is increased or unchanged, otherwise feature is being replaced to its original feature space, this proposed technique produces remarkable performance in terms of accuracy. Other authors (Kozlowski, 2005; Pradnya P & Ruikar, 2013; Tan, 2009) have also suggested to construct forecasting models.

ANFIS is widely used as predictive model either individual or in combination with other techniques due to its capability to tune its fuzzy membership function for producing better predictive results. A hybrid ANFIS models are suggested by many authors(Kazem et al., 2013; Su & Cheng, 2016) integrated with many intelligent techniques like SVR, feature selections and many more. Authors (Barak et al., 2015) have presented wrapper ANFIS-ICA algorithm and results having superiority in time decreasing as well as increasing prediction accuracy as compared to wrapper Genetic algorithm (GA).

A hybrid ANFIS model with Empirical Mode Decomposition (EMD) is suggested by author (Wei, 2016) for stock time series forecasting. Author sought out some research related problems like AI is difficult to understand, stock investors are not aware about variables used, short-term decisions based on recent price fluctuations but most time series models use only the last period of stock price. To overcome these drawbacks, this study proposes a hybrid forecasting model using linear model and Moving Average Technical Index (MATI). The proposed model is compared with Chen's model, Yu's Model. AR, ANFIS and SVR model to compare the performance of models. Authors [21] have developed a model with ANN techniques like MLP and RBFNN for FX rate prediction. The performance of model is evaluated using MAPE and MAE. It shows that MLA outperform than RBFNN in FX rate prediction. The outcome shows that input parameters with close are given better result than input parameters without close. In most of the research papers it was not analyzed that the feature subset which will predict FX more precisely as only feature of FX data (Next week FX rate) is not sufficient to produce better predictive result.

Architecture of Proposed Work

Process flow of proposed predictive model using hybrid of wavelet, feature extraction, feature selection and ANFIS is shown in Figure 1. The original FX data are normalized using simple normalization technique in range between 0 to 1, this normalized FX data are used to extract features with the help of mathematical formulae suggested by the authors. In addition to this, wavelet de-noising is applied as preprocessing of INR/USD data set and retrieved 5 new features i.e SMA, EMA, WMA, VAR and Std_Dev including original feature space (Next week FX rate).

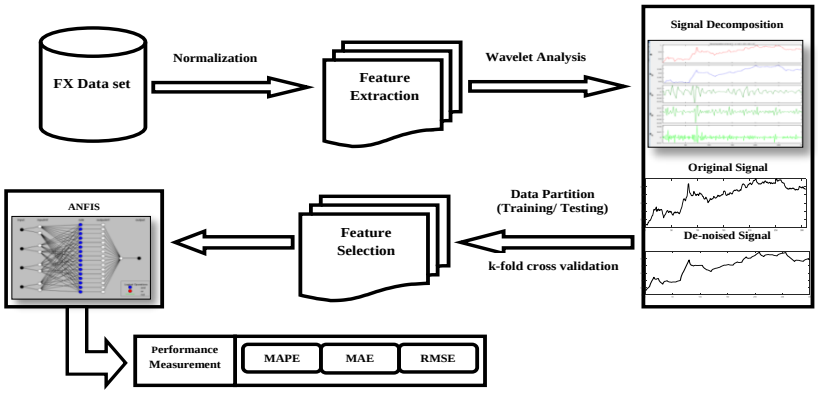


Fig. 1. Process flow diagram of proposed work.

To select the best feature among these 6 features, Remove-Replace Feature Selection Technique (RRFST) suggested by (Hota et al., 2018) is applied using 10-fold cross validation and given to ANFIS [14] for one week ahead prediction of FX rate data. Predictive model is finally validated with MAPE, MAE and RMSE.

Methodology

DATASET

We have used 5 years INR/USD FX weekly data as experimental data collected from www.fx.sauder.ubc.ca. The period of collected data set is from January-2012 to December-2017 with total 300 observations. The data is normalized using min-max boundaries and fit the data in pre-defined boundaries [0 1] by dividing each sample value with the largest value among the total observations of each attribute. The detail of data is presented in Table 1.

Table 1.Summary of dataset.

Particular	**Detail**
Index Data	FX Data: INR/USD weekly data.
Period	01-January-2012 to 31-December-2017 (5 years)
Total # of Observations	300
Downloaded From	**www.fx.sauder.ubc.ca**
Data Partition	10-Fold cross validation (Training/ Testing)

Feature Extraction

Feature extraction is process of generating new features from existing features. The predictive model may perform better in case of extracted features rather than existing features. The current study focuses on identifying new feature subset with the help of feature extraction and feature selection and to develop a hybrid predictive model with least number of features. In this research work five new features are extracted suggested by many researchers (Handa et al., 2015) these features are: Simple Moving average (SMA), Weighted Moving Average (WMA), Exponential Moving Average(EMA), Variance and Standard deviation. SMA is calculated using equation 1.

$$\text{SMA}=\frac{\sum_{i=0}^{n} x_i}{n} \quad (1)$$

wherex_i = value of *i* position, n= total number of observations.

EMA is calculated by using equation 2 and 3.

$$multiplier=\frac{2}{(N+1)} \quad (2)$$

$$EMA_t=(x_t - EMA_{t-1}) * multiplier + EMA_{t-1} \quad (3)$$

where EMA_{t-1} is EMA value at *(t-1)* time interval. x_t is value at time *t.*

WMA, Variance and Standard Deviation are calculated using equation 4, 5 and 6 respectively.

$$WMA_t = \frac{\sum_{i=n}^{1} x_i*(i-1)}{\sum_{i=n}^{1} \frac{(n*(n+1)}{2}} \quad (4)$$

where x_i = value of *i* position, *n*= total number of observations.

$$var=\frac{\sum((x_i-\bar{x}))^2}{(n-1)} \quad (5)$$

$$\text{Standard Deviation}=\sqrt{\frac{1}{n-1}\sum_{i=1}^{n}((x_i - \bar{x})^2)} \quad (6)$$

where $\bar{x}$ = mean value, n= total number of observations.

Wavelet

Wavelets are mathematical functions that solve certain mathematical problems [8] and requirements that are used to represent data or functions. It is not a new idea but become popular from few decades in economical and financial dataset for scientific applications (Masset, 2008) like signal processing, pattern recognition and image processing, which does not suffer from the limitations of fourier analysis and filtering methods. In this study wavelet is used for signal de-noising using function 'daubechies2 (db2)' at level 3. It decomposes the signal at different scale (MathWorks, 2017) and analyze signal according to scale as shown in figure 2.

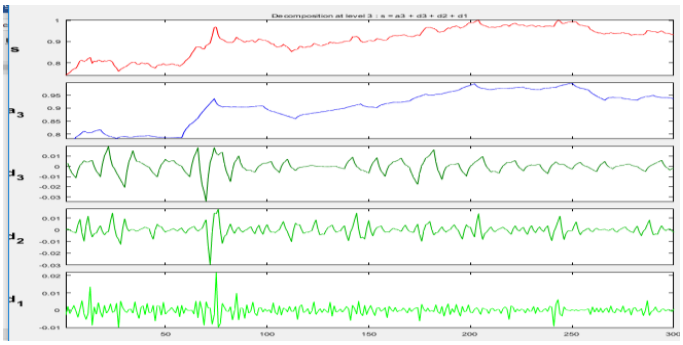
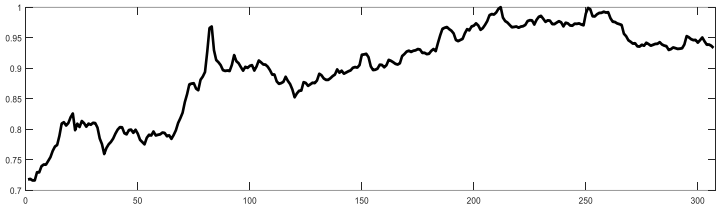
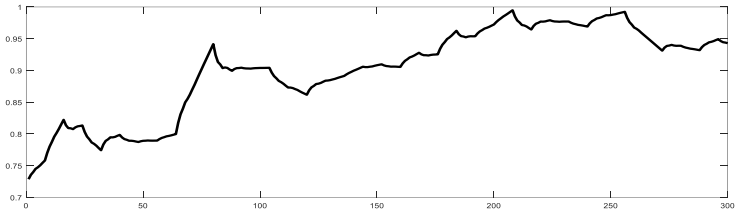


Fig. 2. Signal decomposition using wavelet.

This tool removes white noise from signal at time of decomposition at each level [9]. This de-noised signal is then fed to the model as input signals and the result comes from this model is compared with original signal without wavelet de-noising. Figure 3 (a) and (b) represents the difference between original and de-noised signal respectively.



(a)



(b)

Fig. 3.(a) Original INR/USD FX signal (b) INR/USD FX signal after de-noising using wavelet.

Feature Selection

Feature selection in unsupervised scenario is very crucial as one has to select most relevant features among number of features when no class labels are available (Xie, Ren, Zhang, & Tang, 2018). In this proposed work we have used the Remove and Replace Feature selection technique (RRFST) proposed by (Hota et al., 2018). This FST reduces the features from FX data set based on simple remove and replace policy .The main motive of RRFST is to reduce the feature space as much as possible with the activity of remove and replace, in this algorithm a feature is randomly selected from the original feature space and if accuracy is being increased or unchanged then

feature is removed from feature space otherwise feature is replaced to its original feature space. This process will continue until we get the best result with reduced feature subset.

Adaptive Neuro-Fuzzy Inference System (ANFIS)

Conventional mathematical functions or rules are not enough to solve uncertainty of datasets. There are no standard methods for transforming the human knowledge into rule base of fuzzy inference system. To alleviate this problem and minimizing the error and maximizing the performance of model, some effective methods are constructed fortuning membership functions (MF's). Integration of fuzzy system and neural network called Adaptive Neuro-Fuzzy Inference System (ANFIS) is introduces by (Jang, 1993). Architecture of ANFIS is used for non-linear functions and identifies the non-linear components to predict the time series data with its fluctuating behavior. It is a network called adaptive system that consist of nodes and directional links and there is no weight are associated with it, system's input output determined by the parameters that can be modified based on nodes which are connected to network (Jang & Sun, 1995). It is a multilayer feed forward network in which nodes are connected to each other through a link and particular membership function is performed to input signals by each node to generate a single node output (Walia, Singh, & Sharma, 2015) as shown in figure 4.

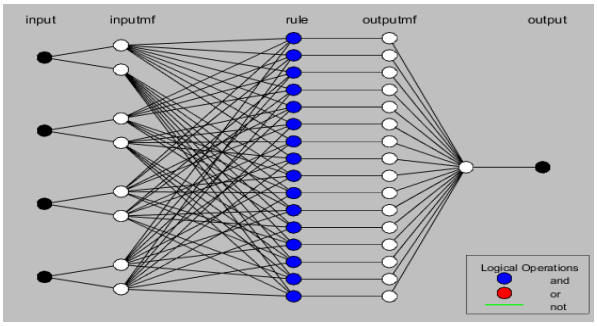


Fig. 4. Structure of ANFIS

Most important thing while designing an ANFIS model is the number of membership functions, training epochs and fuzzy rules, during tuning of these parameters, sometimes the system become over fitted the data or sometimes it is not able to fit the data; so, it is very crucial part to adjust these parameters. A hybrid algorithm which is integration of the Gradient descent method and lest square methods with a mean square error method is used for adjusting these parameters. A hybrid learning algorithm has been used by adaptive system to identify parameters of fuzzy inference system which is integration of Gradient descent method and lest square methods for training FIS membership function parameters to emulate a given training data set (Rezaei, Hosseini, & Mazinani, 2014).

The fuzzy logic takes into account the vagueness and uncertainty of the system that is being modeled while the neural network gives it a sense of adaptability. ANFIS networks have been successfully applied to classification tasks, rule-based process control, pattern recognition and similar problems. Here a fuzzy inference system comprises of the fuzzy model (sugeno) (takagi) proposed by Takagi, Sugeno and Kang to formalize a systematic approach to generate fuzzy rules from an input output data set. The architecture of ANFIS is shown in figure 5 where four input features i.e. SMA, WMA, Var and Std_Dev are used and given to the ANFIS model where 'gbellmf' is used as membership function of ANFIS and generate next week FX as one output from the ANFIS model.

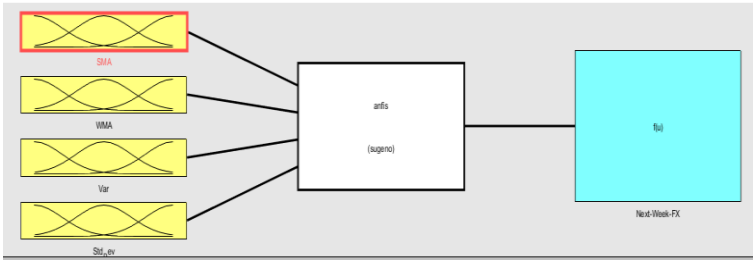


Fig 5. Architecture of ANFIS

ANFIS is a hybrid learning procedure, it uses fuzzy if-then rule with appropriate membership function. A membership function (MF) is a curve that defines how each point in the input space is mapped to a membership

value (or degree of membership) between 0 and 1. In this study generalized bell membership function named 'gbellmf' is used, with three parameters as shown in figure 6 and equation 7.

$$bell(x;a,b,c) = \frac{1}{1+\left|\frac{x-c}{a}\right|^{2b}} \quad (7)$$

Where parameter b is usually positive, if b is negative then shape of MF become upside-down bell.

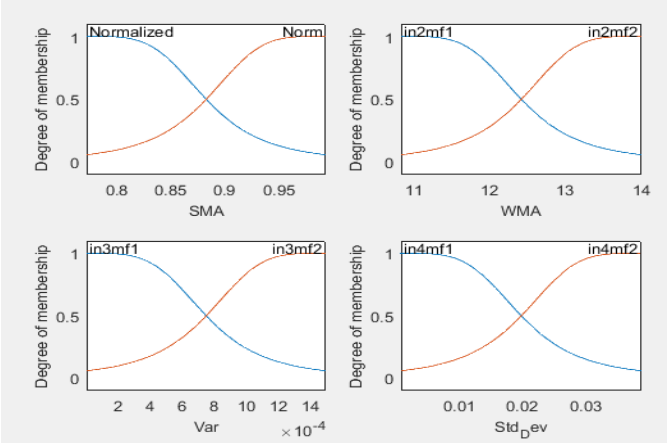


Fig. 6.Generalized bell membership function (gbellmf) used in ANFIS in INR/USD data of indices SMA, WMA. Var and std_Dev.

Result and Discussion

The hybrid approach of feature extraction, wavelet, feature selection and ANFIS using five years historical weekly data of FX collected from **www.fx.sauder.ubc.ca** is carried out in this experiment. Downloaded data set is normalized using normalization formula to range the value in between [0 1] .Five different features are extracted based on original feature space as explained in section 4.2. Another pre-processing technique called wavelet is then applied to remove noise [10] from fluctuated FX rate data as explained in section 4.3. After de-noising of data a new feature selection technique called RRFST proposed by (Hota et al., 2018) is used.

The experimental result shown in table 2 clearly reflects that FX data with only feature (Next week FX rate) does not guarantee the performance of model, instead other extracted features may play important role in the prediction process. After preprocessing of the data ANFIS model is producing consistent result with least MAPE=1.246, MAE= 0.011 and RMSE= 0.013 without original feature. This approach confirms that feature extraction is some time necessary to develop good prediction model.

Table 2. Comparative MAPE, MAE and RMSE for INR/USD exchange rates using RRFST and ANFIS for 1-week-ahead prediction.

FeatureSpace	Removed Feature	Replaced Feature	MAPE	MAE	RMSE
Next_Week_FX, SMA, EMA, WMA, VAR, Std_Dev	---	---	1.569	0.014	0.017
Next_Week_FX, SMA, EMA, WMA, VAR	Std_Dev	---	3.674	0.032	0.045
SMA,EMA,WMA,VAR, Std_Dev	Next_Week_FX	Std_Dev	1.389	0.012	0.015
SMA,WMA,VAR, Std_Dev	EMA	---	1.277	0.011	0.014
SMA,WMA,VAR,	**Std_Dev**	**---**	**1.246**	**0.011**	**0.013**
SMA,VAR,	WMA	---	1.942	0.017	0.026
SMA,WMA,VAR	---	WMA	---	---	---

Conclusion

FX prediction may not produce good result with only one feature; this is the reason why authors are looking for feature extraction. Feature extraction is the process of generating new features from existing features which produces good predictive results. This paper explores data preprocessing with normalization, data smoothing through wavelet, feature extraction and feature selection before developing ANFIS model. In this research work SMA, WMA and VAR are selected as best feature sub set to develop a model with accurate predictive result with MAPE= 1.246, MAE = 0.011 and RMSE= 0.013 with ANFIS.

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