Conclusion and Future Work

5.1 Summary and Conclusions

This thesis took up financial time series forecasting as one of the core tasks of data mining. Forecasting financial time series data are not an easy proposition as they are found to be non-linear, volatile and fluctuating. In this thesis, three important financial time series data and from different fields such as, stock market indices, currency exchange rate and electricity prices have been studied using machine intelligence and evolutionary computing techniques. However, to arrive at an appropriate method or model of forecasting for a particular financial time series, a vast body of related literature has been reviewed as well as a comparative analysis has been made with other models applied by researchers. As a result of this process, three innovative models for the above said three financial time series have been developed. Briefly, they are as below:-

5.1.1 Stock Market Indices

To forecast stock market indices, a hybrid Functional Link and Interval Type-2 Fuzzy Neural System (FLIT2FNS) has been used where the antecedent part of each fuzzy rule is an Interval Type-2 fuzzy set and the fuzzy rules are of the Takagi – Sugano Kang (TSK) type and the consequent part comprises a Functional Link Artificial Neural Network (FLANN). Two other approaches namely the integrated FLANN and Type-1FLS, and Local Linear Wavelet Neural Network (LLWNN) have also been considered to find out which suits better. The disadvantages of LLWNN and, FLANN and Type-1FLS vis-à-vis EFLIT2FNS model have been discussed in
chapter 2. Secondly, two optimization technique, Backpropagation and Particle Swarm Optimization (PSO) learning algorithms have been chosen to optimize parameters of all the approaches and have also been compared. Since BP converges locally and is likely to be trapped in local solution that may or may not be the global solution, PSO has been preferred to. The average MAPE obtained from FLIT2FNS-PSO model is 0.32% for one day ahead prediction for all three datasets (S&P 500, BSE, DJIA); whereas, it is 1.1% and 1.4% for FLANN and Type-1FLS-PSO and LLWNN-PSO models, respectively.

5.1.2 Currency Exchange Rate

A hybrid Evolutionary Functional Link and Interval Type-2 Fuzzy Neural System (EFLIT2FNS) has been taken to predict the currency exchange rate data of five different currencies (Japanese Yen, Chinese Yuan, Indian Rupee, South Korean Won and Switzerland Franc vs. US Dollar) for six different time horizons starting from one day to one year. The parameters of both the antecedent and consequent part of the fuzzy rules are optimized by the gradient descent algorithm. Further, to overcome the limitations of the above said algorithm, two evolutionary algorithms i.e., Genetic Algorithm (GA) and Differential Evolution (DE) are used to optimize all the parameters used in the models. The average MAPE obtained from FLIT2FNS-DE model for all the datasets for one day to 12 months ahead prediction varies from 0.5% to 1.2%.

Though IT2FLS model is applied in other fields (process control, engineering design, financial trading, credit evaluation, medical diagnosis and cognitive simulation), its application to forecasting financial time series (i.e. stock market
indices and currency exchange rate) is not reported in the related literature. Besides this, appropriate learning algorithm has also been used to enhance the performance of the model.

The \textit{tanh} function used in FLIT2FNS is a unique contribution of the thesis as it provides the required nonlinearity in the output. Further, in terms of real number it provides a range from -1 to +1. It is used extensively in system identification and as an activation function in MLP networks.

### 5.1.3 Electricity Prices

The forecasting of electricity prices understood to be most chaotic financial time series is at a nascent stage. Though DFWNN model has been applied for system identification and control, it is unique of this thesis is that it has been applied to forecasting electricity prices. To forecast electricity price of California and Spain energy market for one to twenty four hour in advance, a dynamic filter weight adaline using a sliding mode weight adaptation technique has been applied. The filter weights for this neuron constitute of first order dynamic filters with adjustable parameters. Sliding mode invariance conditions determine a least square characterization of the adaptive weights average dynamics whose stability features may be studied using standard time varying linear system results. A comparative study with a local linear wavelet neural network model has also been made. This demonstrated that the DFWNN outperformed LLWNN. To enhance the performance of DFWNN it has further been integrated with Differential Evolution algorithm. In case of California electricity prices, the average MMAPE for DFWNN is 5%, but when it is integrated with DE, it is 2.3%. Similarly, for Spain (WMAPE) it is 8.6% and 3.4%.
The three models developed in this thesis to predict financial time series can prove useful in real-life application, at least, when the time horizon is the shortest.

### 5.2 Future Work

Depending on the research work conducted and presented in this thesis, the roadmap for the future work can be in the following line:-

- The experiment results obtained from each of the models used for three financial time series data show that prediction accuracy is better when the time horizon is shorter. Other machine intelligence tools like SVM, Rough set and stochastic learning algorithms such as Ant Colony Algorithm, Artificial Immune System, Bacteria Foraging can be explored for better prediction accuracy in case of longer time horizon.

- A combination of statistical model, ARIMA, ARCH, GARCH and neural network will be studied in future research project for mining financial time series databases. The statistical methods help in dealing with voluminous datasets and neural network handle the non-linearity.

- Volatility movements and stock trend forecasting can be a new research area by using new variants of evolutionary computing technique with new neural network architecture. This will be useful for stock trading and portfolio management where investors could sale or buy stocks.

- Electricity market and currency exchange rate market should be studied in a detailed manner taking into account various risk management concepts.
LIST OF PAPERS PUBLISHED

List of papers published in International Journal


List of papers published in National Journal


List of papers published in IEEE Conference

1. S. Chakravarty, R. Bisoi, “Particle Swarm Optimization Based Local Linear Wavelet Neural Network for Forecasting Electricity Prices”, ICEAS, IEEE, 2011.


List of papers published in International Conference


**List of papers published in National Conference**


