**DS-670 Assignment 3: Expected Contribution and State of the Art Mohamed Mohamar**

My idea is to use linear regression and neural network time series analysis to build a model to predict and forecast stock market volatility. The model will be built from the work I did last semester with Professor Robert Finn in the predictive analytics and expert design course, using R packages “LM” and “NEURALNET”. Here is how Professor Finn expressed the idea: “In project 1 you wrote R code to generate time series for the 20 betas derived from your linear regression of log-returns on your 20 chosen factors over the first three quarters of the dates for which we have data. You then used these time series to forecast the 20 betas for the first date not included in the model which gave you an expected return for each stock in your model over the next time period. This expected return was then employed to rank your stocks and split them into 5 groups with group 1 having the highest expected return and group 5 the lowest expected returns. The average actual returns for each group was then calculated for the first date not included in the model. You then continued this process on a rolling basis for the rest of the dates for which we have data. In project 2 you performed the same task as in Project 1 using a neural network instead of a linear model. The following are plausible extensions of your project from DS-640, all of which should be included in your Capstone.

1. Use time series analysis to predict neural network weights as in the case of a linear model.

2. Incorporate factors other than fundamental factors into the model. These should include technical indicators, macro-economic factors, and differenced or first and second derivative information.

3. An increase of the frequency of the model from quarterly to daily.

4. Streamline the R code employed in the DS-640 projects, i.e. recode the project in R so that your code is modular and compact as possible.

5. Perform a detailed analysis for the whole market as well as at least three economic sectors.

This analysis should address not only the factors driving performance of the model but also the investibility of your model. This entails simulation of a portfolio controlling for risk and liquidity of the assets traded.”

My goal is ultimately to build a high performant stock market analysis compact model that can be used as an investment tool.

Due to the fact that the application of Neural Networks to stock markets is relatively new, we don’t have a lot of literature available on this particular subject. The availability of the R package NEURALNET has made research possible about how to predict and forecast stock market volatility using Neural Networks. With this project, I am hoping to contribute to the research in this field. Nonetheless, following is some of the recent state of the art research done about this exciting and challenging field of data science. Note that I am only able to get 8 research papers that relate, directly or indirectly, to the application of Neural Networks for predicting and forecasting stock market volatility.

1. **An adaptive local linear optimized radial basis functional neural network model for financial time series prediction**

Errors generated at the prediction point are important factors for risk estimation in financial time series analysis. Optimization has recently contributed a lot to the improvement of forecasting and prediction models. In this paper, A. Part, S. Das, S. N. Misha, and M. R. Senapati apply a “local linear radial basis functional neural network (LLRBFNN) model” to classify Yahoo Inc. financial data. According to the authors, “The LLRBFNN model is learned by using the hybrid technique of backpropagation and recursive least square algorithm.” It “uses a local linear model in between the hidden layer and the output layer in contrast to the weights connected from hidden layer to output layer in typical neural network models.”  The authors show that “the obtained prediction result is compared with multilayer perceptron and radial basis functional neural network with the parameters being trained by gradient descent learning method. The proposed technique provides a lower mean squared error and thus can be considered as superior to other models. The technique is also tested on linear data, i.e., diabetic data, to confirm the validity of the result obtained from the experiment.” *Patra, A., Das, S., Mishra, S.N. et al. Neural Comput & Applic (2017) 28: 101. doi:10.1007/s00521-015-2039-0*

Compared to the model that I am aiming to build, the LLRBFNN model has a more broad application because its technique can be used on other types of data such as diabetic data. However, I expected my model to be more precise and accurate in terms of prediction and forecasting stock market. That is because of the flexibility of the R packages LM and NEURALNET that I am using and the adaptive nature of the NEURALNET package. The authors only used Yahoo Inc. data while I am using multiple financial indicators and applied to at least three different financials sectors.

1. **Forecasting stock market indices using hybrid network**

“In this paper, a hybrid network consisting of a trigonometric Functional Link Artificial Neural Network (FLANN) and Fuzzy Logic System named as Functional Link Neural Fuzzy (FLNF) Model is used to predict the stock market indices. The proposed model uses a functional link neural network to the consequent part of the fuzzy rules. The consequent part of FLNF model is a non-linear combination of input variables. Two stock market indices (data sets) i.e., Bombay Stock Exchange and Standard's and Poor's (S&P500) are collected for experimentation. Samples for 4000 trading days from 1st March 1993 to 23rd July 2009 are collected from the former and 3228 trading days from 1st March 1993 to 09th June 2006 for the later. This model is used to forecast stock market indices one day, one week and one month in advance. A comparative analysis between the proposed hybrid model and that of FLANN has also been given. The MAPE and RMSE are used to find out the performance of both the models and it shows the superiority of the hybrid model.” *Prachitara Satapathy, Snehamoy Dhar, "A hybrid functional link extreme learning machine for Maximum Power Point Tracking of partially shaded Photovoltaic array", Power Communication and Information Technology Conference (PCITC) 2015 IEEE, pp. 409-416, 2015.*

This model is a hybrid of neural network and fuzzy logic. The authors are using this model “to predict the stock market indices” They use two market indices data sets in their experimentation: the Bombay Stock Exchange and the S&P500. Compared to my expected model this model has a lesser scope because, in my model, I am using multiple indicators of the stock market data and I will apply to at least three different financial sectors.

1. **Stock Market Prediction by Non-Linear Combination based on Support Vector Machine Regression Model**

“Stock market predictions comprise challenging applications of modern time series forecasting and are essential to the success of many businesses and financial institutions. In this paper, stock market forecasting is based on Support Vector Machine (SVM) regression. Firstly, using different linear regression model to extract linear characteristics of stock market system. Secondly, using different Neural Network algorithms to extract nonlinear characteristics of stock market system. Finally, the SVM regression is used for the nonlinear combination forecasting model of different stock exchange prices. Empirical results obtained reveal that the prediction by using the nonlinear combination model is generally better than those obtained using other models presented in this study in terms of the same evaluation measurements. Those results show that that the proposed nonlinear modeling technique is a very promising approach to financial time series forecasting.” *K. Ashwin Kumar, T. Niranjan Babu, Nitish Vaishy, K. Lavanya. International Journal of Advanced Research in Computer Science, Vol. 7, No 7 (2016)*

This model has similarities with the one that I am building, in the sense that both models are using Linear Regression and Neural Network algorithms.

1. **Times Series Forecasting using Chebyshev Functions based Locally Recurrent neuro-Fuzzy Information System**

“The model proposed in this paper, is a hybridization of fuzzy neural network (FNN) and a functional link neural system for time series data prediction. The TSK-type feedforward fuzzy neural network does not take the full advantage of the use of the fuzzy rule base in accurate input-output mapping and hence a hybrid model is developed using the Chebyshev polynomial functions to construct the consequent part of the fuzzy rules. The model to be known as locally recurrent neuro fuzzy information system (LRNFIS) is used to provide an expanded nonlinear transformation to the input space thereby increasing its dimension which will be adequate to capture the nonlinearities and chaotic variations in the time series. The locally recurrent nodes will provide feedback connections between outputs and inputs allowing signal flow in both forward and backward directions, giving the network a dynamic memory useful to mimic dynamic systems. For training the proposed LRNFIS, an improved firefly-harmony search (IFFHS) learning algorithm is used to estimate the parameters of the consequent part and feedback loop parameters. Three real world time series databases like the electricity price of PJM electricity market, the widely studied currency exchange rates between US Dollar (USD) and other four currencies i.e. Australian Dollar (AUD), Swiss Franc (CHF), Mexican Peso (MXN), Brazilian Real (BRL), along with S&P 500 and Nikkei 225 stock market data are used for performance validation of the newly proposed LRNFIS*.” A.K. Parida, R. Bisoi, P.K. Dash, S. Mishra. International Journal of Computational Intelligence Systems, Vol. 10 (2017) 375–393*

The model proposed in this paper relies on the fuzzy neural network (FNN) while mine relies on the feed-forward neural network, also known as the multilayer perceptron.

1. **Multi-step ahead electricity price forecasting using a hybrid model based on two-layer decomposition technique and BP neural network optimized by firefly algorithm**

“In the deregulated competitive electricity market, the price which reflects the relationship between electricity supply and demand is one of the most important elements, making it crucial for all market participants to precisely forecast the electricity price. However, electricity price series usually has complex features such as non-linearity, non-stationarity and volatility, which makes the price forecasting turn out to be very difficult. In order to improve the accuracy of electricity price forecasting, this paper first proposes a two-layer decomposition technique and then develops a hybrid model based on fast ensemble empirical mode decomposition (FEEMD), variational mode decomposition (VMD) and back propagation (BP) neural network optimized by firefly algorithm (FA). The proposed model is unique in the sense that VMD is specifically applied to further decompose the high frequency intrinsic mode functions (IMFs) generated by FEEMD into a number of modes in order to improve the forecast accuracy. To validate the effectiveness and accuracy of the proposed model, three electricity price series respectively collected from the real-world electricity markets of Australia and France are adopted to conduct the empirical study. The results indicate that the proposed model outperforms the other considered models over horizons of one-step, two-step, four-step and six-step ahead forecasting, which shows that the proposed model has superior performances for both one-step and multi-step ahead forecasting of electricity price.” *Deyun Wanga, Hongyuan Luoa, Olivier Grunderc, Yanbing Lina, Haixiang Guoa. Applied Energy Volume 190, 15 March 2017, Pages 390–407*

The results of the work of the authors in the paper are similar to what I aim to get from my model. The only thing that remains to be discovered is how accurate my model will be compared to theirs.

1. **A novel macroeconomic forecasting model based on revised multimedia assisted BP neural network model and ant Colony algorithm**

“In this paper, we propose a novel macroeconomic forecasting model based on the revised multimedia assisted BP neural network model and the ant colony algorithm. Macroeconomic forecasting foundation forecasts the object past and present operating law, therefore, when the operational predict that must describe the analysis and this rule. Because the limitation and forecast technique of choice fault forecast technique can create the uncertainty of the forecasting result, our model mainly focus on the following two aspects. (1) Uncertainty in forecasting method selection errors is even more evident. The probability that the wrong prediction method brings the correct prediction result is very small. (2) Limitations of the forecasting methods. Any kind of forecasting method has its applicable conditions and the environment, it is not omnipotent, nor is it immutable, therefore, more of the state-of-the-art techniques should be researched to enhance the traditional approaches. We use the ant colony algorithm to modify the BP model to make it fit for holding the character that forecasting that a point refers to forecasting a definite value, this value and actual value completely same possibility is very low, this explained that a point forecast successful probability is very low, therefore uses the forecasting result judgement forecast method the fit and unfit quality to be not very comprehensive. Forecast that a sector refers to the future reality leaving in the prediction interval, or prediction interval including the future realistic value which will hold special meaning. The experiment on the stock, gold, exchange and inflation indicate that the proposed model can predict the price well with the satisfactory result.” *Kuang, Y., Singh, R., Singh, S. et al. Multimedia Tools and Application (2017). doi:10.1007/s11042-016-4319-9*

This paper’s authors used the same Neural Network that I am using to build my model. However, because algorithms are built very differently and designed to solve a specific, I do not think it is not a good idea to use one algorithm to modify another one. Which is what the authors of this paper are doing. That might lead to some unattended consequences.

1. **Does Artificial Neural Network Forecast Better For Excessively Volatile Currency Pairs.**

“This study predicts the exchange rates for three currency pairs (USD-INR, GBP-INR, and EUR-INR). We have used multi-layer perceptron (MLP) neural network architecture based on feed-forward with back-propagation learning method.  The sample of the study covers daily data for the period from January 2009 to January 2016. The findings of the study confirm that the neural network predicts better for more volatile currency pairs (GBP-INR and EUR-INR) as compared to a less volatile currency pair (USD-INR). The study further observes that the optimal forecast horizon for the neural network model should be equal to the optimal lag length used in the construction of the model. This study aims to contribute in the area of foreign exchange forecasting. Exchange rate plays a crucial role in the macro-economy of a country. Hence, prediction of currency exchange rate becomes imperative for various stakeholders such as government, the central bank, and investors to maximize the returns and minimize the risk in their decision-making.” *Sarveshwar Kumar Inani, Manas Tripathi, Saurabh Kumar. The Journal of Prediction Markets, Vol.10, No 2 (2016)*

My model uses exactly the same algorithm of the Neural Network. The authors are applying it to better predict currency exchange rate volatility, while I am using it to predict and forecast stock market volatility.

1. **Single-hidden layer neural networks for forecasting intermittent demand**

“Managing intermittent demand is a vital task in several industrial contexts, and good forecasting ability is a fundamental prerequisite for an efficient inventory control system in stochastic environments. In recent years, research has been conducted on single-hidden layer feedforward neural networks, with promising results. In particular, back-propagation has been adopted as a gradient descent-based algorithm for training networks. However, when managing a large number of items, it is not feasible to optimize networks at item level, due to the effort required for tuning the parameters during the training stage. A simpler and faster learning algorithm, called the extreme learning machine, has been therefore proposed in the literature to address this issue, but it has never been tried for forecasting intermittent demand. On the one hand, an extensive comparison of single-hidden layer networks trained by back-propagation is required to improve our understanding of them as predictors of intermittent demand. On the other hand, it is also worth testing extreme learning machines in this context, because of their lower computational complexity and good generalization ability. In this paper, neural networks trained by back-propagation and extreme learning machines are compared with benchmark neural networks, as well as standard forecasting methods for intermittent demand on real-time series, by combining different input patterns and architectures. A statistical analysis is then conducted to validate the best performance through different aggregation levels. Finally, some insights for practitioners are presented to improve the potential of neural networks for implementation in real environments.” *F. Lollia, R. Gamberinia, A. Regattierib, E. Balugania, T. Gatosb, S. Guccib. International Journal of Production Economics. Volume 183, Part A, January 2017, Pages 116–128*

The model proposed by the authors of this paper is using a single hidden layer neural network, which I think is very simplistic in terms of prediction and forecasting. Compare to my model, I think my model would perform better because I am using a multiple hidden layers in my application of the neural network.