



## Prediction of Stock Closing Price by Hybrid Deep Neural Network

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### ABSTRACT

*Stock price prediction is a highly uncertain and money making approach. There a lot of methods and tools used for this purpose. In this research paper, we present a hybrid deep neural network for prediction of stock prices. This model will predict the day closing price of any stock on the basis of certain parameters. This hybrid model will be the integration of fuzzy inference system with the deep neural network. Fuzzy inference system has the capability to handle the uncertain information but it has the limitation that it cannot learn from the example sets. Deep neural network with more than one hidden layer has the capability to learn from the experience but it cannot handle the uncertain information. If these two models are integrated together then the resulting model can learn from the examples and can handle the uncertain information. In this paper will make some predictions through this model and it will be tested on multiple stocks.*

**Keywords:** Stock prediction, deep neural network, fuzzy inference system

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### INTRODUCTION

There has been a long research in the field of stock market prediction [1]. The stock market is considered to be very dynamic and complex in nature [2]. An accurate prediction of future prices may lead to higher yield of profit to investors through stock investments. As per the prediction, the investor shall be able to pick the stocks which may give a higher return. Almost every investor today wants to analyse the stock which he or she wishes to pick for investment. There a many investments based companies which invest money of their clients in stock. These companies also follow many analytics techniques [3].

The early prediction methods in this domain used to take high effort from the analysts and their result were hard to match with the fluctuating prices of stocks [4]. Most of them were based on conventional statistical techniques. This was the era when machine learning was not a trend. But the time has changed and many analytics works are done on the basis of machine learning techniques [5]. Various machine learning tools have been used by the researchers to predict the prices of stocks [1]. Various models of the artificial neural network have been used in stock price prediction with their own strength and limitation [6]. After the improvement and advancement in the field of predictive analytics, now deep learning techniques are in trend. They are more capable and have better performance than conventional machine learning techniques [7]. Popular deep learning techniques like variants of deep neural networks have been used in stock market prediction and their result has been much better than the conventional machine learning or statistical techniques [8].

In this research paper, we have developed a new model of the deep neural network. This model is a hybrid model in which a deep neural network has been integrated with fuzzy inference system. The resultant model may be termed as Hybrid Deep Neural Network (HDNN). In this HDNN model both the deep neural network and fuzzy inference system have their own capability and due to these special features we have used this model in our work. In our earlier review paper, we have presented an overview of this model [9]. There are possibilities that some uncertainties may remain present in the data available for predictive analytics. We need to make predictions on the basis of this data based on machine learning algorithms. But the neural network model cannot handle the uncertainties present in the data. To handle these uncertainties, fuzzy inference system may be applied. If both models are combined together, this new model will have the capability to make predictions by learning from the data with handling the uncertain information.

In our work, we have taken the two years' historical prices of 7 companies. On the basis of certain parameters that affect the price of any stock, we have predicted the day closing price of every stock. A HDNN will be used which is

the integration of deep neural network with fuzzy inference system. The data will be normalized and applied to HDDN for training and testing. Once the model is stable, we will make a prediction for any stock. This model will be tested on all the 7 stocks.

Our paper is organized as follows. In the next section we will discuss our proposed model that how this model is developed and how will it work. After that in the next section, we will discuss the dataset to be used by our model. After the dataset, we will show the survey of experiments in which we will discuss the performance and result of the model. Finally, we discuss the conclusion of our research and its future aspects.

### HYBRID DEEP NEURAL NETWORK

In this research, we have developed a hybrid model of neural network. This model is the integration of fuzzy inference system with a deep neural network. This model is based on a fuzzy neural network with multiple hidden layers. A fuzzy neural network is a learning model which applies the parameters of fuzzy systems by exploiting the techniques from neural networks [10]. The deep neural network with n number of hidden layers is used in our model and the value of n can be fixed at the time of training. More hidden layers in the network will give the better accuracy in the result but the increase in the number of hidden layers results in an increase the complexity of the system and hence degrades the performance of training. So deciding the number of hidden layers is also the part of the training process. This HDNN model is presented in figure1.

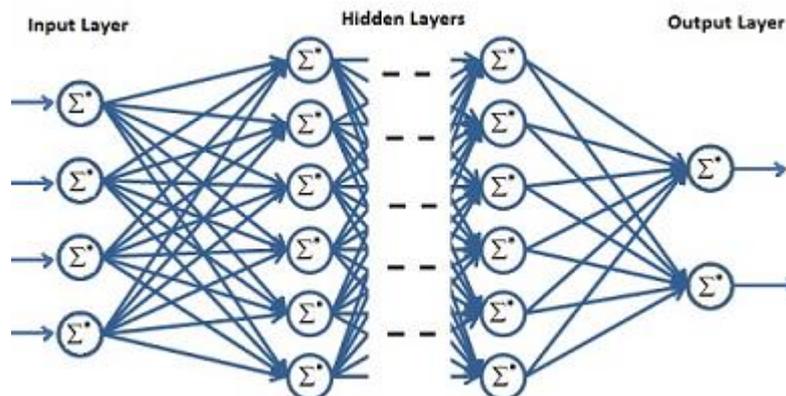


Fig. 1 Hybrid Deep Neural Network (HDDN)

At each node of the network, we have used Mamdani Fuzzy Inference System (FIS). This FIS will map the input to its corresponding output. First, the fuzzy rules  $\Sigma^*$  will be determined for this process which can be followed as:

$$\text{Fuzzy Rule } \Sigma^* = \text{If } x \text{ is } G \text{ and } y \text{ is } H \text{ Then } y = p.a + q.b + r$$

where  $x$  and  $y$  are inputs and  $G$  and  $H$  are membership functions and  $p$ ,  $q$  and  $r$  are the linear parameters in Then-part. In this rule,  $+$  and  $*$  are not the arithmetic addition and multiplication operations but these are the fuzzy OR and fuzzy AND respectively. These can be defined as follows:

$$\text{Fuzzy OR: } \mu_{A \cup B} = T_{\text{sum}}(\mu_A(x), \mu_B(x)) \tag{1}$$

and 
$$\text{Fuzzy AND } \mu_{A \cap B} = T_{\text{prod}}(\mu_A(x), \mu_B(x)) \tag{2}$$

In both the equations above, we have used T-norms. To find the fuzzy OR, product T-norm is used and to find the fuzzy AND, sum T-norm is used.

In the process of fuzzification, with the Gaussian membership function, we have converted all the input values into corresponding fuzzy values. The Gaussian membership function used in fuzzification is given in equation 3.

$$\mu_{A_i}(x) = \exp \left[ -\left( \frac{x - b_i}{2a_i} \right)^2 \right] \tag{3}$$

where  $\mu_{A_i}$  is the degree of membership function for fuzzy set  $A_i$  and  $a$  and  $b$  are the parameters of membership function that can change the shape of the membership function. Once the input values are converted into fuzzy values, these fuzzified inputs will be combined according to the fuzzy rule to establish a rule strength. The consequence of this rule will then be found by combining the rule strength and the output membership function. These consequences are then combined to get an output distribution and this output distribution is finally defuzzified. This defuzzification of output distribution will be done by the Mean of Maximum (MoMax) method which is given in [4]:

$$z = \sum_{j=1}^l z_j T_j \tag{4}$$

where  $z$  is the mean of maximum,  $z_j$  is the point at which the membership function is maximum and  $l$  is the number of times the output distribution reaches the maximum level. After this defuzzification process, the output in crisp form is received at the output layer.

### ALGORITHM

The algorithm of HDNN is given as:

1. For fuzzification, use Gaussian function  $\mu$  to convert crisp input values into corresponding fuzzy values.
2. Determine fuzzy rule  $\Sigma^*$  according to the input values. Use T-norms for fuzzy operations fuzzy OR and fuzzy AND.
3. Initialize the fuzzy parameters  $p$ ,  $q$  and  $r$ .
4. Repeat steps 5 to 11 until training conditions met.
5. Update the fuzzy parameters  $p$ ,  $q$  and  $r$ .
6. Update the number of hidden layers and number of nodes at each layer.
7. Combine fuzzy inputs according to  $\Sigma^*$  to establish rule strength.
8. Find the consequence of the rule by combining  $\Sigma^*$  with  $\mu$ .
9. Obtain the output distribution by combining the consequences.
10. Obtain the crisp output  $z$  by MoMax method.
11. Match the obtained output with target output
12. Exit.

#### Algorithm: Hybrid Deep Neural Network (HDNN)

The steps used in the above algorithm are used in our HDNN model for the prediction of stock closing prices. In the above algorithm, we have proposed to take a random number of hidden layers and a random number of nodes at each layer. This number can be adjusted at the time of training according to the accuracy of the model and training performance. There is no any predefined method to find the number of hidden layers and number of nodes at each layer. So it is decided while training by adjusting the numbers at each epoch of training. The fuzzy parameters discussed in the algorithm can be initialized by random values and these can also be adjusted at the time of training.

### DATA SET

In our research, we have applied our model in stock price prediction. We have predicted the day closing price of a stock on the basis of some input parameters. The price of every stock is affected by many parameters. We have included these important parameters as input for the model and on the basis of these input parameters we have predicted the day closing prices. In table -1 given below, we have represented the parameters.

There are a lot of factors which affects the stock market and the price of each individual stock. Total 10 factors we have taken as an input parameter in our dataset which is the most important factors. Indian stock market is dependent on factors including domestic and global factors. Global factors like Dollar price, crude oil price, performance of US stock market and the opening of Japanese stock market leaves a great impression on the Indian stock market. We have used a parameter named SENT\_SCR which is the market sentiment is given in the range of 0 to 5. A lower score will be given when the market is in bearish form and a higher score will be given when the market is in bullish form. 52 week's highest and lowest prices of a stock are also taken as input parameters because it also has an importance while investing or selling a stock by the investors. When a stock reaches its 52 weeks highest, there are chances that profit booking may start in the stock. If news about the stock, I good and it is moving around it 52 weeks lowest then many investors prefer this type of stock for investment.

We have taken 4 years, January 2014 to December 2017, historical prices of 7 stocks- Infosys, SBI, ONGC, Tata Motors, Reliance Industries, Adani Enterprise, and Future Retail. While selecting these stocks, we have taken care to choose a dominating stock from each major sector of the stock market. Apart from the historical prices of these 7 stocks, we have also collected the historical prices of the same duration for all the remaining input parameters. Firstly, these parameters are arranged in the data frame for each individual stock for pre-processing. We have applied our HDNN model for day closing price prediction of each individual stock. 70% of the data is used for training purpose and 30% of the data is used for testing purpose. On the successful prediction for one stock, the model will be applied to remaining 6 stocks one by one for predicting their day closing prices. Finally, we will present a consolidated performance and result in an analysis of prediction by the model.

Table -1 Description of Parameters

S. No		Parameter Name	Parameter Description
1	Input	SENSEX	BSE Sensex Index value
2		NIFTY 50	NSE Nifty 50 Index Value
3		ST_52_High	Stock's 52 weeks highest price
4		ST_52_Low	Stock's 52 weeks lowest price
5		PREV_CLOSE	Previous day closing price of the stock
6		DOLLAR	Current Dollar to INR rate
7		CRUDE	Current crude oil price
8		HANG_SENG	Hang Seng Index
9		DAX	Dow Jones Index
10		SENT_SCR	Market sentiment score
11	Output	DAY_CLOSE	Day closing price of the stock

EXPERIMENT AND SURVEY OF RESULT

We have fixed our HDNN model as a 10-12\*3-1 network. There are 10 nodes at input layer because there are 10 input parameters. There are 3 hidden layers with 12 nodes at each layer. To predict the output, 1 node is taken at the output layer. First, we have applied our model to predict the day closing price of Infosys. It has given 97.2% accuracy in the prediction. Later we have applied our model on remaining 6 stocks for prediction of their day closing prices. The following parameters have been used to measure the training performance of the model;

(a). Mean Squared Error (MSE): The MSE measures the quality of a predictor. If Y is a vector of n predictions, and X is the vector of observed values of the variable being predicted, then the MSE can be calculated as:

$$MSE = \frac{1}{n} \sum_{i=1}^n (X_i - Y_i)^2 \tag{5}$$

(b). Root Mean Square Error (RMSE): The RMSE is used as a measure of differences between values predicted by a predictor and actual values. It is the square root of MSE. It can be calculated as:

$$RMSE = \sqrt{\frac{\sum_{i=1}^n (X_i - Y_i)^2}{n}} \tag{6}$$

where Y is a vector of n predictions, and X is the vector of observed values of the variable being predicted.

(c). Mean Absolute Error (MAE): The MAE is the measure of differences between two continuous variables. It can be calculated as:

$$MAE = \frac{\sum_{i=1}^n |Y_i - X_i|}{n} \tag{7}$$

where Y is a vector of n predictions, and X is the vector of observed values of the variable being predicted. In table 2 given below, we have represented the training performance of HDNN on all the 7 stocks.

The performance by HDNN in prediction on test sample is given in figures [2-8].

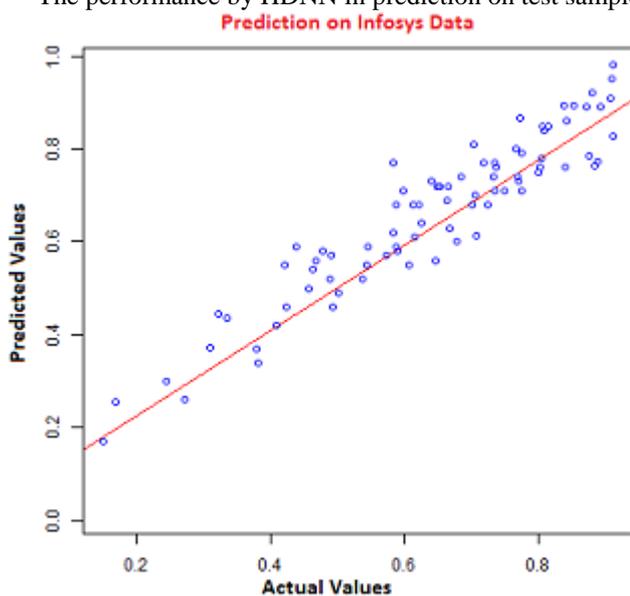


Fig. 2 HDNN Prediction on Infosys

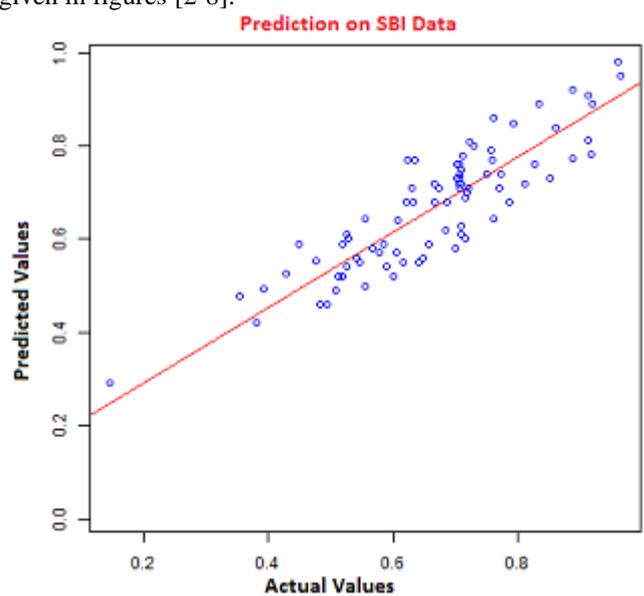


Fig. 3 HDNN Prediction on SBI

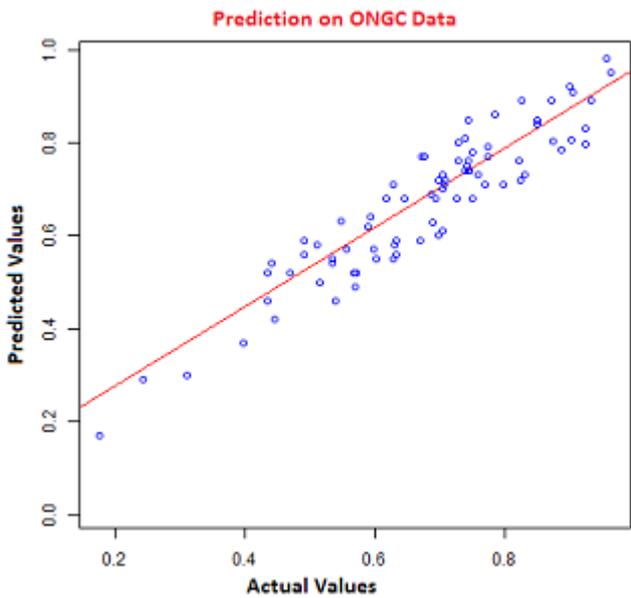


Fig. 4 HDNN Prediction on ONGC  
Prediction on Reliance Data

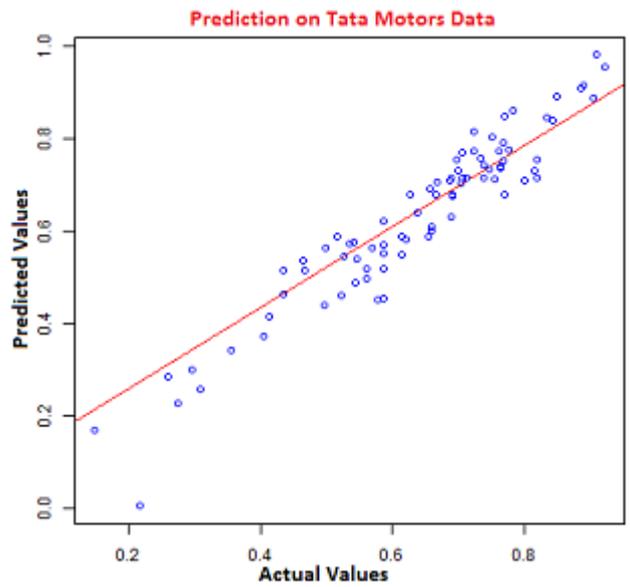


Fig. 5 HDNN Prediction on Tata Motors  
Prediction on Adani Ent. Data

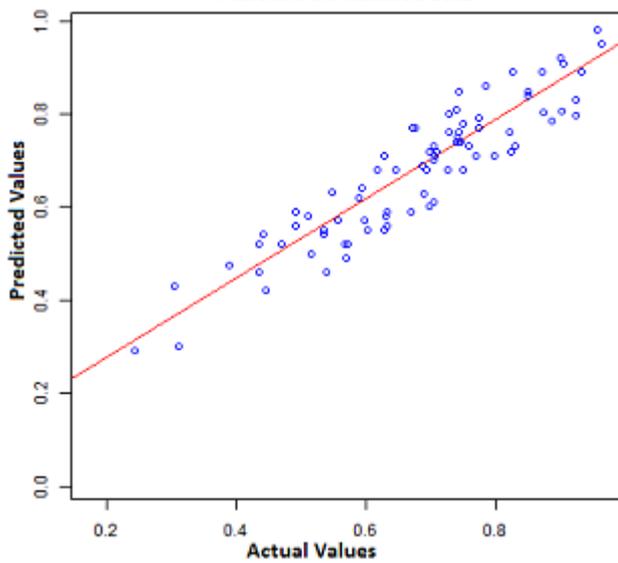


Fig. 6 HDNN Prediction on Reliance Industries

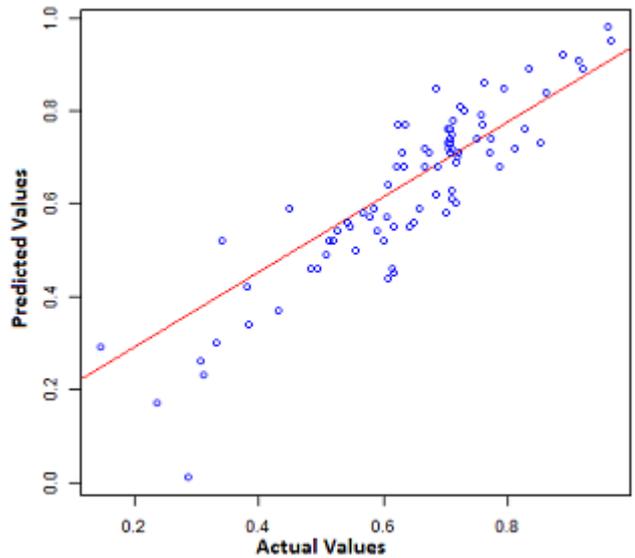


Fig. 7 HDNN Prediction on Adani Enterprises

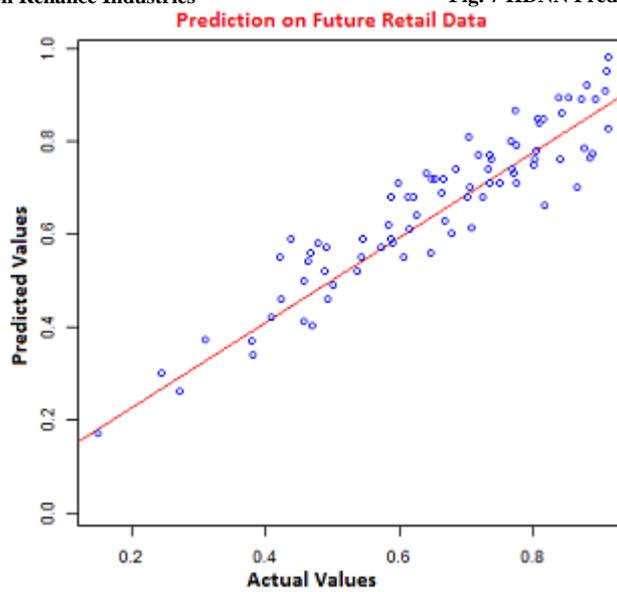


Fig. 8 HDNN Prediction on Future Retail

Table -2 Training Performance

	Infosys	SBI	ONGC	Tata Motors	Reliance Ind	Adani Ent	Future Retail
MSE	0.0048	0.0038	0.0041	0.005	0.004	0.0055	0.0044
RMSE	0.06	0.085	0.074	0.065	0.054	0.049	0.072
MAE	0.058	0.043	0.078	0.095	0.1	0.08	0.074

Table -3 Accuracy in Prediction

	Run 1	Run 2	Run 3	Run 4	Run 5	Average Accu-
	Correct (%)					
Infosys	96.90	97.10	97.50	97.80	96.80	97.22
SBI	98.20	97.90	98.50	98.00	97.90	98.10
ONGC	98.50	97.90	98.00	98.10	97.60	98.02
Tata Motors	97.50	96.80	97.90	97.20	96.85	97.25
Reliance Ind	97.40	98.60	98.10	97.85	98.10	98.01
Adani Ent.	98.20	98.40	97.95	97.55	98.80	98.18
Future Retail	95.30	96.10	95.90	97.00	96.95	96.25

It can be seen from figures [2-8] that HDNN model has given a very good result of prediction on all the 7 stocks. The above figures are the plots of predicted values and its corresponding actual values. Now in table 3, we have represented the accuracy of prediction by HDNN model for all the 7 stocks in 5 runs.

It can also be seen in the table -3 that HDNN has given a very good accuracy in predicting day closing prices of stocks. Its average accuracy is always around 97% or above. For Future Retail, it has given 96.25% average accuracy but it is also a very good result.

### CONCLUSION

In our research, we have developed a hybrid deep learning model which is the integration of deep neural network with fuzzy inference system. We applied the concept of fuzzy logic and deep learning in this model. This model was applied to predict the day closing price of a stock. We applied this model on 7 stocks and it has given an outstanding result. Its average accuracy in predicting the day closing price of a stock is around 97.5 %. Now there is a very open scope for this model. This model was applied on stock market prediction in our research. But there are a lot of work today where predictive analytics is required for predicting future values. There are many financial organizations which use this concept for financial investments. Every prediction in the organization or company is based on certain input values. So this model will be very much useful for these organizations which are related to predictive analytics. Not only the organizations who do financial investments, but the organizations which want to predict the sale value of its products based on certain factors can also use this model. Additionally, there also an open opportunity to add additional features to this model to improve its performance and accuracy. So it can be said that there is a very wide opportunity and open scope for this model.

### REFERENCES

- [1] Eunsuk Chong, Chulwoo Han, Frank C Park, Deep Learning Networks for Stock Market Analysis and Prediction, *Expert System with Applications*, **2017**, 83, 187-205.
- [2] Ritika Singh and Shashi Srivastava, Stock Prediction using Deep Learning, *Multimedia Tools and Application*, **2016**, 76 (18), 18569-18584.
- [3] J Han and N Kamber, *Data Mining Concepts and Techniques*, San Francisco, Morgan Kaufmann Publishers, **2001**.
- [4] E Schoneburg, Stock Price Prediction using Neural Networks: A Project Report, *Neurocomputing*, **1990**, 2, 17-27.
- [5] *Machine Learning: What it is and why it matters*, www.sas.com, Retrieved 12-02-2018.
- [6] X Zhong and D Enke, Forecasting Daily Stock Market Return using Dimensionality Reduction, *Expert System with Applications*, **2017**, 67, 126-139.
- [7] Vaibhav Kumar and ML Garg, Deep Learning in Predictive Analytics: A Survey, *IEEE International Conference on Emerging Trends in Computing and Communication Technologies*, Dehradun, India, **2017**.
- [8] MR Vargas, SLP Beatriz and Alexandre G Evsukoff, Deep Learning for Stock market prediction, *IEEE International Conference on Computational Intelligence and Virtual Environments for Measurement Systems and Applications*, Annecy, France, **2017**.
- [9] Vaibhav Kumar and ML Garg, A Hybrid Deep Learning Model for Predictive Analytics, *International Journal of Research in Advent Technology*, **2018**, 6, 27-31.
- [10] A Abraham, Adaptation of Fuzzy Inference System Using Neural Learning, *Fuzzy System Engineering: Theory and Practice*, Nadia Nedjah et al. (Eds.), Studies in Fuzziness and Soft Computing, Springer Verlag Germany, ISBN 3-540-25322-X, **2005**, Chapter 3, 53-83.