International Journal of Research in Advent Technology, Vol.6, No.1, January 2018
E-ISSN: 2321-9637
Available online at www.ijrat.org

A Hybrid Deep Learning Model for Predictive Analytics

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Abstract: - This research paper proposes to develop a hybrid deep learning model which will be an integration of deep neural network and fuzzy logic. There are so many benefits of deep leaning model over other learning models. But they have limitation that they cannot handle uncertain data. Fuzzy logic systems have the capability to handle uncertain data but they cannot learn from examples. If these both models are integrated together, they can produce a best result in predictive analytics. In this paper we will analyze this proposed model.

Index Terms: - Deep leaning, predictive analytics, deep neural network, fuzzy systems.

1. INTRODUCTION

Predictive analytics is a term which describes a variety of statistical and analytics techniques. It analyzes current and historical facts to make predictions about future [1]. It develops models that can predict future events and behaviors. Most predictive models generate a score- higher score indicates a higher likelihood of the behavior given or event occurring. Machine learning, a branch of Artificial Intelligence, includes a number of advanced statistical methods for regression and classification which can further be used in predictive analytics. Neural Networks have been used very popularly for forecasting, predicting and other predictive analytics [2]. The deep neural network, a variant of multilayer perceptron, has also been used very significantly be many researchers in predictive analytics [3]. It has a wide application in pattern recognition and other machine learning practical. This research paper proposes to develop a hybrid deep neural network for predictive analytics. This hybrid model will be an integration of deep neural network and fuzzy systems. This model may be applied initially in stock market prediction for prediction of future price of a stock and later it can be applied in other problem domains.

2. LITERATURE REVIEW

Predictive analytics is an area of data mining that deals with extracting information from data and using it to predict trends and behavior patterns [4]. The core of predictive analytics relies on capturing relationships between explanatory variables and the predicted variables from past occurrences, and exploiting them to predict the unknown outcome. It is important to note, however, that the accuracy and usability of results will depend greatly on the level of data analysis and the quality of assumptions. Predictive analytics is often defined as predicting at a more detailed level of granularity, i.e., generating predictive scores (probabilities) for each individual organizational element. It has various applications- Analytical customer relationship management (CRM), clinical decision support systems, customer retention, marketing, fraud detection, project risk management etc [5].

Deep learning is a branch of machine learning based on a set of algorithms that attempt to model high-level abstractions in data by using a deep graph with multiple processing layers, composed of multiple linear and non-linear transformations [6]. Research in this area attempts to make better representations and create models to learn these representations from large-scale unlabeled data. Some of the representations are inspired by advances in neuroscience and are loosely based on interpretation of information processing and communication patterns in a nervous system, such as neural coding which attempts to define a relationship between various stimuli and associated neuronal responses in the brain [7]. Various deep learning architectures such as deep neural networks, convolutional deep neural networks, deep belief networks and recurrent neural networks have been applied to fields like computer vision, automatic speech recognition, natural language processing, audio recognition and bioinformatics where they have been shown to produce state-of-the-art results on various tasks. Deep learning algorithms are based on distributed representations. The underlying assumption behind distributed representations is that observed data are generated by the interactions of factors organized in layers. Deep learning adds the

assumption that these layers of factors correspond to levels of abstraction or composition. Varying numbers of layers and layer sizes can be used to provide different amounts of abstraction [8].

Convolutional Neural Networks (CNN) are biologically-inspired variants of MLPs. From Hubel and Wiesel's early work on the cat's visual cortex, we know the visual cortex contains a complex arrangement of cells. These cells are sensitive to small sub-regions of the visual field, called a *receptive field*. The sub-regions are tiled to cover the entire visual field. These cells act as local filters over the input space and are well-suited to exploit the strong spatially local correlation [3].

A deep neural network (DNN) is a variety of artificial neural network which has more than one hidden layers [9]. DNNs have special feature that they can model the complex relationships which are non-linear. DNNs generally have the feedforward architecture. Some recurrent architecture have also been used by researchers in language modeling [10]. Convolutional neural networks have been used as deep neural networks very popularly in the area of image processing [11].

Along with the capabilities, neural networks have certain limitations. However these models are capable of learning complex nonlinear relationships, but they can model lower level of human reasoning [12]. Fuzzy logic is a powerful tool which can model the thinking perception of human to a certain accuracy [13]. Theory of fuzzy system has been applied as a mathematical approach and it has been proven the inaccuracy in the human thinking process. After adapting the intelligent approaches, the fuzzy inference system has given many accurate models in reasoning as well as in prediction [14]. The integration of fuzzy inference system with neural network results in a hybrid model, popularly known as Neuro-Fuzzy systems [15]. The fuzzy part incorporates the human reasoning process and the neural network part simulates the human brain learning process through examples. When combined this model gains the capability to adopt the human learning handling with uncertainties in the examples.

Stock market prediction has a very long research record in financial economics [16], [17], [18], [19]. It is the act of predicting future price of a stock traded on an exchange. When predicted correctly, it may result in a very high profit to the investors. There are various economics and statistical methods used by the analysts in the past to predict the price of stocks on the basis of market movements [20]. There are various research have been done with artificial neural networks for accurately prediction of stock prices. With the capability of extracting features from a large data set without relying on prior knowledge, deep neural networks have also been used in this work and given highly accurate results [21].

Although many researchers have developed techniques for predictive analytics, but developing such a system which can predict more accurately than other existing techniques is still a competition. Various machine learning as well as deep learning concepts are used in data analytics for better predictive analytics.

Deep neural networks are very successful models and are being popularly applied in the domain of machine learning. They have given better result in predictive analytics, however they have limitation in adapting the human reasoning process as they work at the low level of human thinking. They have another limitation of handling with the uncertainties present in the data which is used in learning. Fuzzy inference system can model the reasoning process but it has limitation that it cannot learn from the data and hence cannot predict a future value.

3. HYBRID DEEP NEURAL NETWORK MODEL

Predictive analytics is a highly demanding field in the area of business intelligence. Many machine learning methods have been developed and are being used in business intelligence to earn higher profit in the market. They produce result that are the base of growth of any organization. In highly competitive ecosystem, best result will have better chances of survival. There are many methods being used in the field but development of such a method which can give best result among all will always be in demand.

In the area of predictive analytics, where prediction is based on past data, a machine learning model will always produce a best result. In the domains like stock market prediction, price of a stock can be predicted on the basis of its past performance including some outside factors which affect the price of a stock. The continuous research in this field has given a more accurate prediction than the previous models. Accuracy in prediction is directly proportional to the profit earned in stock trading. There are many uncertainties present in the available data used for fitting of the model. If these uncertainties are fixed by fuzzy reasoning methods, the deep neural network model will produce more accurate results and similarly more accurate prediction will be done by this hybrid model.

In this research work we propose to develop a hybrid deep neural network model for predictive analytics. This approach is expected to produce better results in its performance as compared to other existing techniques.

The main steps to develop the proposed model will include the following:-
(i). Collection of stock market data which include historical prices of at least 30 stocks and historical values of some important factors that affect the stock market.
(ii). Development of a hybrid deep neural network model for predictive analytics.
(iii). Model will be trained on 70 percent example sets and will be tested on rest 30 percent example sets.
(iv).Comparing the performance of the proposed technique with other existing techniques.

4. RESEARCH METHODOLOGY

The methodology which shall be used for conducting the proposed research shall include the following major steps:-

(i). Deep Neural Network for Prediction:-
A deep neural network (DNN) is a variety of artificial neural network which has more than one hidden layers. DNNs have special feature that they can model the complex relationships which are non-linear. DNNs generally have the feedforward architecture. Some recurrent architecture have also been used by researchers in language modeling. Convolutional neural networks have been used as deep neural networks very popularly in the area of image processing. A typical architecture of deep neural network is represented in figure 1 given below.

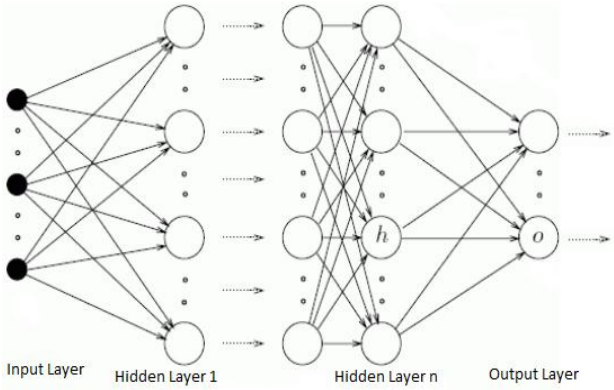

Fig. 1. Deep Neural Network

All the processing DNNs are very much similar to the feed forward model of artificial neural networks. Backpropagation learning can be performed to find the matching between produced outputs and desired output. The change in weight in this process can be obtained as:

$$w_{ij}(t+1) = w_{ij}(t) + \eta\frac{\partial C}{\partial w_{ij}} + \xi(t)$$

where η is the learning rate , C is the cost function and ξ is the stochastic term and w_{ij} is the weight associated with the interconnection between i^{th} node of one layer and j^{th} node of next layer.

(ii). Fuzzy Inference System

Fuzzy inference system is the fundamental part of fuzzy reasoning. It has decision making as its primary work. It uses IF-THEN rules for differencing. It takes crisp set as input and produces the crisp set as the output. Two processes work in intermediate- fuzzyfication and defuzzyfication. In fuzzyfication process, crisp quantities are converted into fuzzy quantities and in defuzzyfication process, fuzzy quantities are converted into crisp quantities. There is a rule base in this system which consists of the IF-THEN rules. A membership function is used to convert crisp values into fuzzy values and vice-versa. Its block diagram can be represented as below figure.

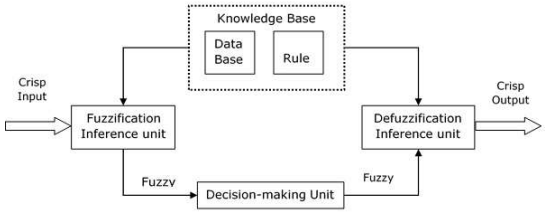

Fig.2. Fuzzy Inference System

(iii). Hybrid Deep Neural Network

A hybrid deep neural is the integration of fuzzy inference system with deep neural network. The crisp output produced by fuzzy inference system will be used by deep neural network between input layer and first hidden layer. The operation to combine output value of neuron and weight value will be based on fuzzy IF-THEN rules.

(iv). Prediction of Stock Prices

Historical value 30 stocks will be collected for training the neural network. Apart from the past value of stock, there are several important factors like

crude oil price, gold price etc. also affect the price of a stock. So historical values of these factors will also be collected. These all attributes will be taken as input values and closing price of a stock will be taken as output value. Our system will be trained and then tested on this input output pattern. Once fitted the system will be able to predict the future of any stock

(v) Performance Evaluation
The following indices may be used for performance evaluation of the proposed model and comparison with other existing models:-

(a). Normalized Mean Squared Error (NMSE)
The NMSE (Normalised Mean Square Error) is an estimator of the overall deviations between predicted and measured values. It is defined as:

$$NMSE = \frac{1}{N}\sum \frac{(P_i - M_i)^2}{\bar{P}\bar{M}}$$

$$\bar{P} = \frac{1}{N}\sum_i P_i$$

$$\bar{M} = \frac{1}{N}\sum_i M_i$$

(b). Root Mean Squared Error (RMSE)

RMSE is the square root of MSE, defined as follows:

$$RMSErrors = \sqrt{\frac{\sum_{i=1}^{n}(\hat{y}_i - y_i)^2}{n}}$$

(c). Mean Absolute Error (MAE)
MAE is defined as follows: $\mathbf{MAE} = \frac{1}{n}\sum_{i=1}^{n} |\boldsymbol{x}_i - \boldsymbol{x}|$

5. CONCLUSION

An efficient method for predictive analytics is proposed to be developed which will give better result than other existing models and will be useful in predicting the behavior of a dependent variable. The application of this model is not limited to the stock price prediction but there are many possible applications of this model. It may open scope of application in other domains of data science. This model can be used in the growth of an organization by predictive analysis of customers. The use of predictive analysis is set to grow as businesses acknowledge the organizational benefits that data driven tools bring. Businesses must overcome a number of challenges if they are to fully realize the potential of predictive analytics in the future. As such, rather than relying on complex systems which requires extensive and specialist knowledge, businesses need tools which are intuitive and accessible for employees across an organization. For optimal use of predictive analytics, the majority (70%) believe that the business as a whole should be driving it. Organizations will only be truly successful in their endeavor to extract future forecasts from historical data once their users have the power to turn data into insight.

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