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PREDICTING STOCK MARKET INDICES USING NEURAL NETWORKS

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ABSTRACT

Investing in stock markets is a decisive role for every investor. Speculation in the market makes an investor distressed about his investment. Hence predicting the exact stock market price at high accuracy helps investors to invest wisely to yield more returns. Most of the literature has been carried in predicting the stock market prices using various Logistic regression, ARIMA and machine learning techniques. This paper aims at predicting the stock indices of developed markets and emerging markets using deep learning neural network techniques i.e., Artificial Neural Networks (ANN) and Recurrent Neural Network (RNN). The data consists of daily prices open, close, high, and low, volume of NIFTY 50, S&P 500, New York Stock Index, Korean Stock Index and Dow Jones Index Jan 2014 to July 2019. The open price of the index is fed as input to the models. This study predicts the next day index and gives a comparative analysis between the two models based on the accuracy of prediction. Based on the performance of the models, the best model would be suggested to the investors for the investors.

Key words: Stock Index, Deep Learning, Artificial Neural Networks, Recurrent Neural Networks.

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1. INTRODUCTION

Financial System plays an important role in the economy. Financial Systems help the countries to get financially stable by coping with investments. Investments or raising capital for the financial requirements enhances foreign investment and trade financing. Based on the process of raising of capital every financial system has come out with different kinds of instruments to raise the capital. Some of the financial institutions that emerged taking investment as prime function include central banks, inter-governmental organizations and

multilateral treaties. Now there are different financial instruments evolved to raise the capital or funds for the organisation.

Some of the popular global stock index include

- FTSE All World Index
- S & P Global 100 Index
- S & P Global 1200 Index
- Dow Jones Global Titans 50
- Russell Global Index

Stock market prediction had been a topic of great interest for the researchers and investors. Predicting the stock market indices was of great help to the investors to decide upon their investment plan.

The growth of the stock market is enormous in last decade. Emerging markets like India, China, South Africa have attracted more investors as the returns are high when compared with the developed markets like America, Australia etc.,. Hence this paper focuses on both emerging market indices and developed market indices for the prediction.

This research paper focuses on predicting the stock market indices using deep neural networks of Artificial Neural Network (ANN) and Recurrent Neural Network (RNN) based on the accuracy of prediction. The present study evaluates the performance of the two models separately and gives a comparison between Artificial Neural Networks (ANN) and Recurrent Neural Network (RNN).

The paper is organised in to different sections: Section 2 gives the insights of previous literature done in prediction using machine learning and deep learning technique, Section 3 deals with data extraction and the methodology Section 4 presents the analysis and the results Section 5 provides conclusion and summary.

2. REVIEW OF LITERATURE

Qiu Mingyue [2014] in his research stated that Artificial Neural Network is an essential tool to predict the Tokyo Stock Index Nikkei using Back propagation and suggested that the two drawbacks of ANN are the convergence and inability to local minima hence he applied Genetic Algorithm and Simulated annealing to improve the accuracy of ANN model. In order to evaluate the performance of the model Mean Squared Error is used.

Andres Arevalo, Jaime Nano [2018] in his research states that the accuracy of the prediction ranges from 62% to 72% for the next predicted one minute average price by using the techniques of Artificial Neural Networks and the Empirical Mode Decomposition.

Gilberto Batres-Estrada [2014] in his thesis used Deep Belief Network (DBN) with three hidden layers and the logistic regression network to predict S&P 500 stock market prediction. The results obtained were compared and is proven that deep learning networks are better compared to the other stable models.

Gabriele D Acunto [2016] in his dissertation conducted research to forecast the financial time series by using Deep learning techniques of Multiple Layer Perceptron, Convolution Neural Network and Recurrent Neural Network. All these models are compared based on the performance of the prediction of the model. The research proved that the Recurrent Neural Network with LSTM has the high accuracy of 96.2% at 5 epochs only as compared to the convolution neural network.

Alexiei Dingli and Karl Sant Fournier [2017] in their research used Convolution Neural Network to predict next month stock price. The model has shown 65% Accuracy with 2

hidden layers taking closing stock price as the input and the next week price direction at 60% accuracy.

Alexiei Dingli and Karl Sant Fournier [2017] research paper used Machine learning techniques of ARIMA have achieved Root Mean Square Error (RMSE) of 0.0117 for next day stock price prediction using regression classification and 0.0613 RMSE for next day difference in price using regression technique.

Ariel Navon, Yosi Keller [2017] in his research paper derived a deep learning scheme to predict the trends of NASDAQ stocks and implemented Stochastic Gradient Descent along with Convolution Neural Network with ReLu activation function. They have also used Sharpe ratio which is proven to be statistical measure to estimate the significance of forecasting.

Bjoern Krollner, Bruce Vanstone, Gavin Finnie, [2010] states that Artificial Neural Network (ANN) is a dominant algorithm identifying the trade-off between risk return of the investors.

Manna Majumder, MD Anwar Hussain, [2008] predicted S&P CNX Nifty 50 index reported the accuracy in predicting the next day stock price using Artificial Neural Network is found to be 89.65% where the average accuracy is found to be 69.72% over 4 periods of time.

Lufuno Ronald Marwala [2010] in his dissertation used three artificial intelligence techniques namely neural network, support vector machines and neuro-fuzzy systems are implemented to forecast the stock market index. The techniques are compared with benchmarked techniques of Auto Regressive Moving Average (ARMA) and Random Walk Model (RW). The study revealed that the three artificial intelligence techniques outperformed the base models of forecasting. Support Vector Machine model was outperformed as compared to other two with respect to the accuracy of MSE and RMSE are taken into consideration.

Mingyue Qiu , Yu Song [2016] has focused on the prediction of stock market index for next day. In order to predict the next day stock index a deep learning model of Artificial Neural Network is used and predicted with the accuracy. In order to optimize the model Genetic Algorithms (GA) are used and the performance of the prediction is compared with the previous results.

Martin Victor Sewell [2017] has used the Hidden Markov Models which is trained on foreign exchange data and derived fisher kernel to support Vector Machines (SVM). The model has failed to predict and hence the descriptive perspective risk metric should be superior to any existing methods to evaluate the performance.

Qiyuan Gao, [2016] states the application of Recurrent Neural Network with Long Short Term Memory (LSTM) with 600 neurons and then starts decreasing. The accuracy of the six stocks with the optimized RNN gives the accuracy of 59.50% on BLK stock, 49.75% on Google Stock, 58.25% on QCOM stock, 55.50% on XOM, 54.50% on IBM Stock, 51.50% on JPM Stock in predicting the next day stock price.

Talal Alotaibi, Amril Nazir, Roobaea Alroobaea, Moteb Alotibi, Fasal Alsubeai, Abdullah Alghamdi, Thamer Alsulimani, in their research paper states that Artificial Neural Network (ANN) is the efficient tool in prediction of stock markets and applied ANN on Saudi Arabian Stock Exchange (TADAWUL) and Oil historical prices with back ward propagation. In his research paper he suggested that Median Price and Close price are the best inputs in Neural Network. Trainbr which is Bayesian regularization function was giving high accuracy.

3. RESEARCH METHODOLOGY

3.1. Source of Data

The data used for predicting the stock market indices is auto regressive data collected form secondary source of stock market indices. Overall five stock indices are considered for prediction. The five stock indices include NIFTY 50, S&P 500, Dow Jones, NewYork Index and KOSPI which is from both developing and developed markets.

The time period selected for the study is between Jan 2014 to Oct 2019. The dataset consists of High, Low, Open and Closing prices of daily stock index. The daily closing price of the stock index is considered as the input variable to predict one day stock index by using Deep learning neural networks i.e., Artificial Neural Network (ANN) and Recurrent Neural Network (RNN).

3.2. Limitations of the Study

- The macro economic factors that affect the market indices are not taken into consideration.
- The study is restricted only in predicting the next day stock index considering the closing price of before days index.

3.3. Deep Learning Algorithms

3.3.1. Neural Network

Neural Networks have emerged from the biological working of human brain. Human brain is composed of millions of neurons that are connected to each other. Each neuron has the capacity to store the information that is fed as an input.

Neural Networks also works on the same principle of human brain. In neural networks every neuron is a processor that performs a weighted average of multiple input signals. Depending on the number of inputs, hidden layers will be applied by giving certain weights and then an output signal will be generated by providing some activation functions.

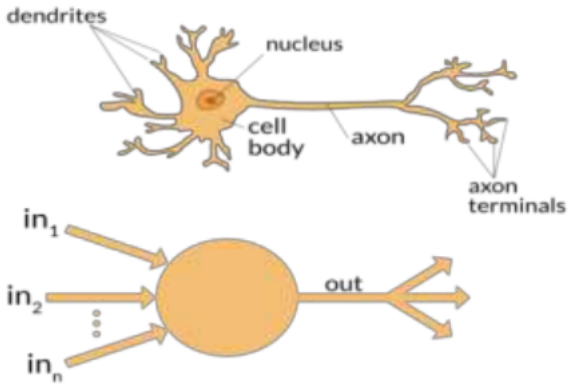

Figure 1 Source from analytics Vidhya

3.3.2. Artificial Neural Network

ANN works with Feed-forward Neural Networks which will be having multiple neurons which are connected to each other. ANN has 3 layers :

- Input Layer
- Hidden Layer
- Output Layer

Input Layer : Input Layer is the layer where you feed in the input data or the historical data.

Hidden Layer : Hidden Layer consists of number neurons that has to be fed for a model. There can be finite number of neurons defined in each layer. There can also be multiple hidden layers. But there is no principle that the number of neurons in each hidden layer should be the same. All neurons in a hidden layer are connected to all the neurons in the next layers.

There are several combinations of connections between the input layer and the hidden layer. However the basic working is that the state of neurons in the first layer will be probabilistically determined by the state of neurons in the following layer, depending on the sign and strength of connection.

If connections are weak then connection neurons in the next layer may have equal or almost equal probability of any state.

If connections are strong then the sign of the weight of connected neurons will be similar or opposite with next layer.

But basically ANNs are trained with back propagation algorithm. Back propagation algorithm works on basic differential calculus and chain rule of differentiation. The algorithm takes cost function, activation function, weight and inputs into consideration.

Output Nodes: After processing the input variables at input nodes and hidden nodes with the requisite weights the outputs are executed based on the number of inputs.

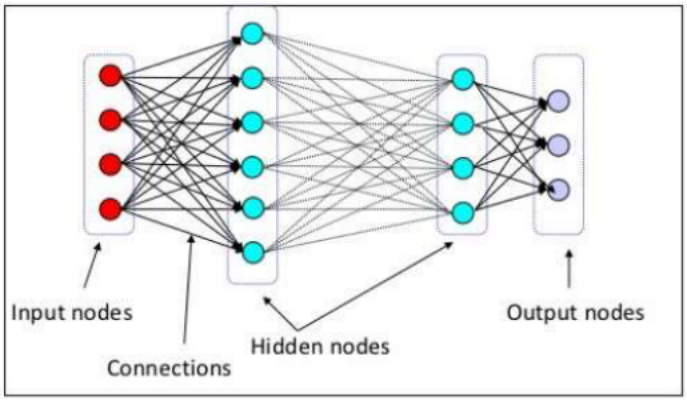

Figure 2 Dnuggets; Deep learning key terms

3.3.3. Activation Functions

Activation functions are the functions used to activate a neuron in neural network. These activation functions verify whether the information received by the neuron is relevant or to be ignored. Activation function transforms the input signal and the output received is fed as input signal in the next layer of neurons.

Actually there are many types of activation function used in neural networks. The basic activation function is $\propto (x) = \sum wixi$ which is weighted average.

Y = Activation (∑ (Weight * Input) + bias)

The most common activity functions used are:

Identity function

f(a) = a

This function lets the activation value go through

Threshold activity function

$$f(a) = \begin{cases} 1, if a \leq 0 \\ 0, if a \geq 0 \end{cases}$$

This function activates the neuron of the activation is above a certain value

Sigmoid function

$f(a) = \frac{1}{1+e^{-a}}$

This function is used when output is bounded between 0 & 1 and it is interpreted as the probability of neuron to activate. It is commonly called logistic function

Hyperbolic Tangent

$f(a) = \frac{e^{a} - e^{-a}}{e^{a} + e^{-a}} = \frac{1 - e^{-2a}}{1 + e^{-2a}}$

Bipolar Sigmoid

$f(a) = \frac{1}{1 + e^{-a}} - 1 = \frac{1 - e^{-a}}{1 + e^{-a}}$, when the output range is (-1,1)

3.3.4. ReLu / Rectified Linear Unit

$f(a) = \begin{cases} a, if a \geq 0 \\ 0, if a > 0 \end{cases}$, This function is a mix of identity and threshold function and it is called as 'Rectifier'

However ANNs have several limitations, because of difficulty in setting the weights and biases that enable ANN correctly approximate the target data as the process is really an optimization. ANNs may also get over trained and leads for over-fitting of the model i.e. it memorizes the data and fails to give generalized the data. The other reason for over-fitting is due to the fact that Neural Networks (NN) has a very large number of parameters, when the number of parameters is large over fitting is more likely.

3.3.5. Recurrent Neural Networks

Recurrent Neural Network deals with time series data by defining the recurrence relation over the sequence.

$S_t = f(S_{t-1}, X_t)$

Where S_t = State at step 't'

S_{t-1} = State at previous step.

X_t = Current step.

In RNN each state depends on all previous computations. RNNs have memory over time because the states 'S' contains the information of the previous steps. RNNs have the capacity to remember information arbitrarily for long period of time, but practically they are limited to look back only a few steps.

RNNs can take different combinations like one-to-one, one-to-many, many-to-one, many-to-many. The basic working of RNN has only two parameters an input weight 'U' and recurrence weight 'W'. Let 'Y' be the last state then the recurrence relation is defined by this network as

$S_t = S_{t-1} \times W + X_t \times U$

RNN estimates the same weight matrix to compute all the state updates. But RNNs has the difficulty of vanishing gradient and exploding gradient problem. When training RNN the gradient values jump out of the parameter values which leads to exploding gradients. On the other, long term components go to zero exponential, this is vanishing gradients.

The exploding and vanishing gradient is expressed as:

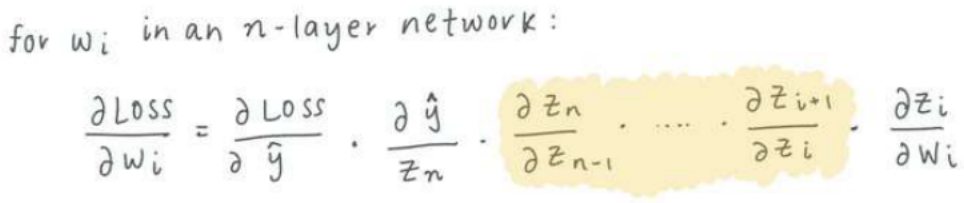

Figure 3 Source: The Vanishing Gradient Problem by harinisuresh

If |w| > 1 the gradient grows exponentially.

If |w|<1 the gradient shrinks exponentially.

This is known as Vanishing gradient. RNN works with Long Short Term Memory (LSTM) which can handle long term dependencies due to memory cell. LSTM consists of three gates.

- An Input gate
- A forgot gate
- An Output gate

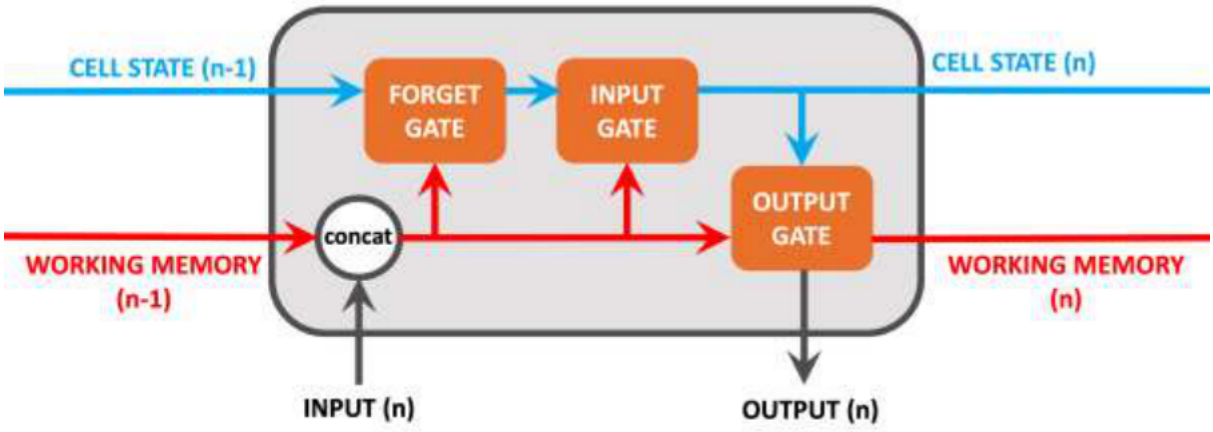

Figure 4 Source: bouvet-deler explaining-recurrent-neural-networks

Long Short Term Memory (LSTM) takes the cell state at time to predict the value. Usually the cell state can be altered by specific gates. LSTM gates use Logistic Sigmoid Function if the output is 0 and 1 and element wise multiplication which reduces the values while running through the gates.

Forget Gate: It takes the previous value of the output and the current input, squashes with logistic function or the element wise multiplication with the cell and leaves an output with the all relevant information through which it erases the irrelevant information.

Input Gate: This takes decides what new information is to be added. The input is taken from the previous output and the current input and transforms into a tan h function.

Output Gate: It is the gate that exhibits the exact output after transforming the cell memory with specific blocks of information.

Analytical Framework

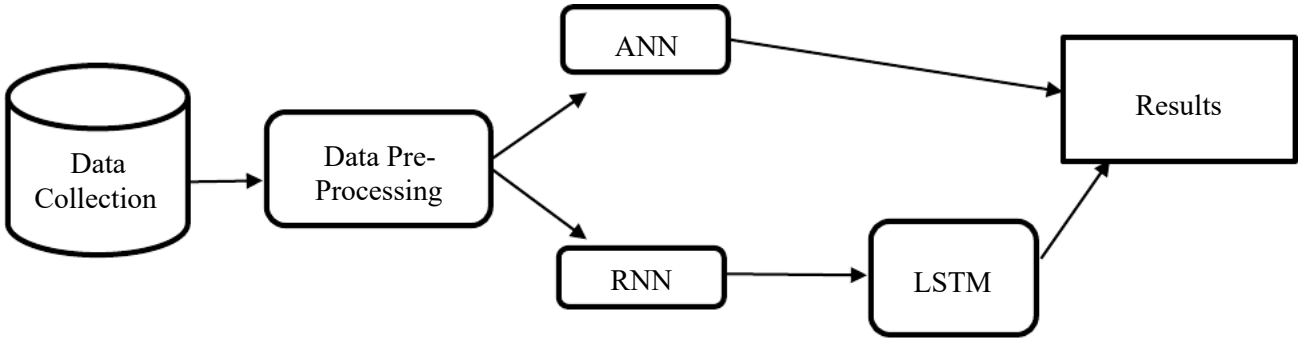

Figure 5 Analytical Framework

4. RESULTS AND CONCLUSION

Table 1 shows performance metrics related to Artificial Neural Network having 2 dense units with 100 epochs for the selected five stock indices. The table contains the loss function which determines the accuracy of prediction. It also exhibits the hyper tuning parameters for evaluating the model performance by considering accuracy, precision, recall and F Score.

Table 1 Showing the Performance metrics of Artificial Neural Network (ANN)

Name of the stock index	MSE	Accuracy	Precision	Recall	F Score
S & P 500	0.2130	0.8560	0.8600	0.8531	0.8567
Dow Jones	0.2020	0.8480	0.8520	0.8452	0.8486
KOSPI	0.1985	0.8500	0.8554	0.8452	0.8503
NewYork Stock Index	0.2113	0.8502	0.8612	0.8370	0.8490
NIFTY 50	0.2074	0.8520	0.8612	0.8412	0.8514

It is observed from the above table that the accuracy of prediction for all the selected five stocks is around 85% but the error is more which states that the difference between actual and the prediction is more. Precision and Recall states that out of 1349 observations 84% of the observations out of the selected stocks are been predicted accurately. Since F Score is approximately nearer to 1 that is around 0.85 it is best in prediction.

Table 2 shows performance metrics related to Recurrent Neural Network having 2 dense units with 100 epochs for the selected five stock indices with Long Short Term Memory (LSTM) layers. The table contains the loss function which determines the accuracy of prediction. It also exhibits the hyper tuning parameters for evaluating the model performance by considering accuracy, precision, recall and F Score.

Table 2 Showing the Performance metrics of Recurrent Neural Network (RNN)

Name of the stock index	MSE	Accuracy	Precision	Recall	F Score
S & P 500	0.0011	0.844	0.8425	0.8492	0.8450
Dow Jones	0.0010	0.848	0.8520	0.8452	0.8486
KOSPI	0.0016	0.854	0.8509	0.8611	0.8560
NewYork Stock Index	0.0015	0.846	0.8486	08452	0.8469
NIFTY 50	0.0015	0.854	0.8565	0.8531	0.8548

It is observed from the above table that the Recurrent Neural Network (RNN) has high accuracy of prediction with respected to selected five stocks that is around 84% along with the less error rate when compared with Artificial Neural Network (ANN) which states that the difference between actual and the prediction is more. Precision and Recall states that out of 1349 observations 85% of the observations out of the selected stocks are been predicted accurately. Since F Score is approximately nearer to 1 that is around 0.85 it is best in prediction.

5. CONCLUSION

Based on the above results it is clear that Recurrent Neural Network model predicts with high accuracy when compared with Artificial Neural Network. This is because as Recurrent Neural Network takes the time sequence and the adopts Long Short Term memory to store the recent input values. Recurrent Neural Network has the high learning rate with less loss function value. Whereas the RNN is accurate only in predicting the values for very short period as the period of forecasting increase the accuracy may comedown.

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