Q-Learning based Stock Market Prediction for Indian Stock market

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Abstract— *Stock market prediction is a complex activity. Especially with globalization, an event in one part of world, affect the stock price in a stock exchange located far off. Previous statistical methods relying only on past behavior of stock prices are not sufficient to predict stock market in good accuracy. This necessitates better methods. In this aspect, stock market prediction activity must be viewed as continuous and dynamic and the algorithm to predict must be learning based. In this paper, we propose a Q-Learning based algorithm for prediction of stock market and the multi parameters are used for guiding the learning. The proposed solution was implemented for Indian stock market for stocks in different business area to prove its effectiveness.*

I. INTRODUCTION

Stock market is place where companies listed stocks can be traded. Every day the price of stocks changes due to market factors and company's performance. Most of time , more than companies performance, the economic factors influence the people sentiment in deciding the demand and supply and the stock market price is affected due to it. With increased globalization, the external factors affecting stock prices are not limited to countries in which stock market is present, but the influence is global. Stock market investors are interested in tools which can predict the stock market prices well in advance so that they can devise their trading decisions to achieve maximum profit. In past, there were many solutions attempted to model the stock market based on company's performance alone, past behavior of stocks etc. With recent emergence of social networking many solution to predict stock market based on public sentiments expressed by tweets, Facebook posts. Many such attempts try to model stock market and fall short in accuracy. The reason being stock market investment is quite complex behavior which evades rationalism. In this kind of volatile market, more accurate tools to predict stock market is of great importance.

Indian stock market is the oldest in Asia. Most of the trading in the Indian stock market takes place on its two stock exchanges: the Bombay Stock Exchange (BSE) and the National Stock Exchange (NSE). The BSE has been in existence since 1875. The NSE, on the other hand, was founded in 1992 and started trading in 1994. However, both exchanges follow the same trading mechanism, trading hours, settlement process, etc. At the last count, the BSE had about 4,700 listed firms, whereas the rival NSE had about 1,200. Out of all the listed firms on the BSE, only about 500 firms constitute more than 90% of its market capitalization; the rest of the crowd consists of highly illiquid shares.

Indian securities exchange is the most established in Asia. The two major stock exchanges of the country are: the Bombay Stock Exchange (BSE) and the National Stock Exchange (NSE). The BSE was established in 1875. The NSE was established in 1992. The trading mechanisms, and settlement process are controlled by SEBI for both NSE and BSE. NSE has 1200 listed stocks and BSE has 4700 listed stocks.

With rapid economic progress after 1996, Indian stock market is most profitable in world with profitability more than 200% and it has attracted many domestic and international investors. This is reflected in the average turnover per day crossing 12,000 crores in BSE and NSE. In this scenario, stock market prediction system for Indian stock market is of prime importance.

One of the prime area of machine learning based on behavioral psychology is reinforcement learning which deals with how software can take action in a context based on the cumulative reward to increase the opinion. It is self adaptive system which fine tunes itself based on reward or punishment. In this work, we apply reinforcement learning method for stock market prediction. And most of stock market prediction is based on single factor like previous day prices, reference to other indexes like commodity, dollar etc. Since many factors affect stock market in some amount, we treat it as a multi input and apply a multi model reinforcement learning to predict the stock market.

II. RELATED WORK

In [1] authors addressed the aspect of predicting price movement of stocks and Index in Indian stock market. The authors have compared various prediction models such as "Support Vector Machine" (SVM), "Artificial Neural Network" (ANN), "Naïve Bayes" and "Random forest" by choosing two of these approaches as input to prediction models. This approach uses 10 technical parameters based on previous price of stock and the commodity channel index. The problem with this approach is it consider only historical trend and reject current market cue. So the accuracy is not good.

In [2] authors proposed a trading signal platform based on "Extreme Learning Machine" (ELM) to predict stock price using two concurrent data sources. Historical market prices and features selected from financial news articles are used to train ELM for stock price prediction. The architecture of their solution is below

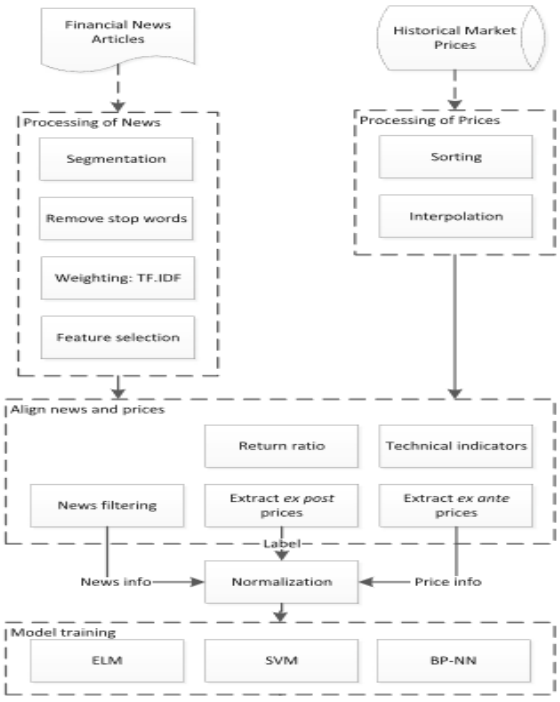


Figure 1: Architecture of "Extreme Learning Machine"

In [3], authors have proposed a prediction model which uses "Discrete Wavelet Transform" (DWT) to parse the stock time series data and obtain approximation and coefficients.

These approximation and coefficients are used as input to the back propagation Neural Networks to predict the future price of the stock.

Approximation coefficients can depict the grainy structure of data and the coefficients obtained can identify ruptures, discontinuities and distinctiveness in the provided data set to identify the long term trends.

In [4] authors have used a method of statistical attributes reduction technique called as "Factor Analysis" (FA), to choose the inputs from the raw data.

They have proposed a prediction model based on A "Feedback Functional Link ANN" (FFLANN) with "Recursive Least Square" (RLS) training. The authors have used following ten technical indicators for forecasting.

Name of the technical indicator	Formula	Explanation
Simple moving average (SMA)	$\frac{1}{N}\sum_{i=1}^{N} x_i$, N = no. of days, x_i = today's price	It is the simple average of the values by taking a window of the specified period.
Exponential moving average (EMA)	$(P \times A) + (Previous\ EMA \times (1 - A))$ $A = 2/(N + 1)$ P-current price, A-smoothing factor, N-time period	An average of the values in the specified period but it gives more weightage to recent values and thus it is more close to the actual values. EMA10, EMA20 and EMA30 are used in the simulation.
Accumulation/distribution oscillator (ADO)	$\frac{(CP-LP)-(HP-CP)}{(HP-LP)\times(Period's\ volume)}$ CP-closing price, HP-highest price, LP-lowest price	It measures money flow in the security. It attempts to measure the ratio of buying to selling by comparing price movements of a period to the volume of that period. The ADO also has been calculated for each day/pattern in the experiment
Stochastic oscillator (STOC)	$\%K = \frac{(Today's\ close - Lowest\ low\ in\ K\ Period)}{(Highest\ high\ in\ K\ period - Lowest\ low\ in\ K\ period)} \times 100$ $\%D = SMA$ of $\%K$ for the period	It is a momentum indicator that shows the location of the current close relative to the high/low range over a set of number of periods. Closing levels which are consistently near the top of the range indicates accumulation (buying pressure) and those near the bottom of the range indicate distribution (selling pressure). Two oscillator indices %K and %D are used.
Relative strength index (RSI)	$RSI = 100 - \frac{100}{1+\left(\frac{U}{D}\right)}$, U = total gain/n, D = total loss/n, n = no. of RSI period	It calculates the internal strength of the security. In the present case the periods have been taken as 9 days (RSI9) and 14 days (RSI14).
Price rate of change (PROC)	$\frac{(Today's\ close - close\ X\ period\ ago)}{(close\ X\ period\ ago)} \times 100$	The PROC indicator displaysthe difference between the current price and closing price x-time periods ago. Through experimental results it has been found that value of x taken as 12 and 27 are considered best for technical analysis.
Closing price acceleration (CPACC)	$\frac{(close\ price - close\ price\ N\ period\ ago)}{(close\ price\ N\ period\ ago)} \times 100$	It is the acceleration of the closingprices in the given period.
High price acceleration (HPACC)	$\frac{(high\ price - high\ price\ N\ period\ ago)}{(high\ price\ N\ period\ ago)} \times 100$	It is the acceleration of the highprices in the given period.

In [5] authors proposed a hybrid prediction model by combining a)"Interval Type2 Fuzzy Logic System" (IT2FLS), b)"Computationally Efficient Functional Link Artificial Neural Network"(CEFLANN) c)"Exponential Generalized Autoregressive Conditional Heteroskedasticity (EGARCH) to obtain accurate prediction of the prices from the data under practical variance of time.

The integrated model upgrades the capacity of EGARCH show through a joint estimation of the vital highlights of EGARCH such as leverage effect caused due to the variation in secondary membership functions IT2FLS and CEFLANN.

The secondary membership functions having higher and lower limits of provide the predication window to handle complex variations in volatility compared to IT1FLS. The performance of the hybrid prediction model was compared with Gaussian with fixed mean and uncertain variance functions also with Gaussian with uncertain mean and fixed variance functions.

The model was also been compared with different fuzzy time series models and GARCH models by adopting four performance metrics: "Rel MAE, RMSFE, MAFE and MSFE". The authors also have used a Differential Harmony Search (DHS) algorithm to optimize the attributes of fuzzy time series models. The results of the proposed model shows a significant improvements in predicting volatility of the market while compared to other models.

In [6] authors have proposed a forecasting model adopting multi objective optimization called “Multi Objective Particle Swarm Optimization”(MOPSO) which forecasts the market by optimizing four performance parameters using genetic algorithms to train the adaptive model.

In [7] author adopts deep learning to predict market variations based on occurrence of events. The events are gather from various sources and populated in dense vectors and the model is trained using a Neural Tensor Network. A “Deep Convolutional Neural Network” is adapted to construct the prediction model that can forecast the effect of event on the stock prices in both short-term and long-term.

In [8] authors have proposed "Cuckoo Search"(CS) prediction model. The model is based on the "Swarm Intelligence Improvement method” which can easily tune the SVM parameters. The framework uses previous data of High, Low, Open, Close and Volume also uses various price indicators and predicts the next day’s closing price of the stock.

In [9], authors have adopted a blended predictive model that uses set of base classifiers that works on same input data set and learns. The Meta classifier learns from base classifiers results and provide much accurate prediction of risk and return.

III. OVERVIEW

Our solution for stock market prediction is a continuous learning system based on Reinforcement learning. The system learns the best prediction strategy at each stage based on multiple parameters of stock index history, local trend in market and global market trend.

IV. PROPOSED SOLUTION

The proposed solution consists of Q-Learning based reinforcement learning at its core. The states are the basics of the Q-Learning system and at each state, multiple actions can be taken, the reward or punishment score is given based on the result accuracy. At each state for each actions the score is aggregated and the action with highest aggregated score is executed to predict at that state and based on the accuracy the score is again updated. By this way the knowledge for best decision to be taken at each state is built in form of scores for the actions.
The system for Q-Learning stock prediction accepts three sequences of input for any stock

Input = < H, LM, GM>

H - H is the History of stock prices on daily basis over a period of time T. (T is minimum 1 month and the accuracy of system increases with increase in T value)

LM – LM is the sequence of rows in form of (Li,Si) where Li is the local stock market index like BSE or NSE and Si is the stock market value for that stock on that day.

GM – GM is the sequence of rows in from of (Gi,Si) where Gi is the global index (like petrol price or gold price) and the Si is the stock market value for that stock on that day.

The LM data is split into N equal intervals and for each interval the variance is measured and based on the variance threshold value the state is decided as L,M,H

States of LM	Variance Percentage Threshold
L	0-5%

M	5-10%
H	>10%

The GM data is split into N equal intervals and for each interval the variance is measured and based on the variance threshold value the state is decided as L, M, H.

States of GM	Variance Percentage Threshold
L	0-5%
M	5-10%
H	>10%

Combing all combination of LM and GM nine states are created.

States	Description
LL	Local =L , Global=L
LM	Local =L , Global=M
LH	Local =L , Global=H
ML	Local =M , Global=L
MM	Local =M , Global=L
MH	Local =M , Global=L
HL	Local =H , Global=L
HM	Local =H , Global=L
HH	Local =H , Global=L

At each state, three actions are designed.
Action Set= {FC, SC, TC}

FC is the ARIMA classifier which is trained of that values in N interval and used to predict the stock price based on history of stock price alone

SC is the Linear Classifier which calculates the stock price based on the correlation value between the stock price and the local market index. Based on least square fitting it learns the linear association.

TC is the Linear Classifier which calculates the stock price based on the correlation value between the stock price and the global market index. Based on the least square fitting it learns the linear association.

Over the T values, in N intervals for each state the N interval values belong the stock price is predicted using all three classifier in the action set and the score is calculated for each action based on the accuracy of the predicted price as follows

Condition	Score
Actual Price > Predicted Price	100- (Actual Price-Predicted Price)/ Predicted Price
Actual Price==Predicted Price	100
Actual Price < Predicted Price	-100

The score is aggregated for each action in each state. The state representation is shown below

States	Action - Score
LL	FC - 0 SC - 0 TC - 0
LM	FC - 0 SC - 0 TC - 0
LH	FC - 0 SC - 0 TC - 0
ML	FC - 0 SC - 0 TC - 0
MM	FC - 0 SC - 0 TC - 0
MH	FC – 0 SC - 0 TC – 0
HL	FC – 0 SC - 0 TC – 0
HM	FC – 0 SC - 0 TC – 0
HH	FC – 0 SC - 0 TC – 0

The score for each state is updated in aggregated manner using Moving Average Model

Score = Current Score *alpha + (1-alpha)*Score

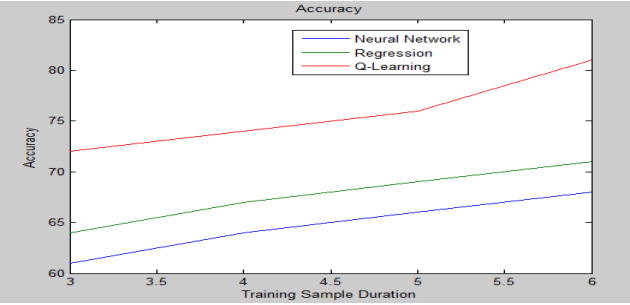
The states are trained and once the state model is ready it can be used for forecasting stock price.

At any point of time, when stock price has to predicted, the previous T/N values are taken and state of stock market is decided based on the variance of T/N local and global market value data, the state will be one of the 9 states and the action with highest score is taken in that state and based on the accuracy the score for the action is again updated.

V. PERFORMANCE ANALYSIS

To evaluate the performance of system we have considered 5 stocks in Indian stock market. For local trend we have taken BSE score and for global trend we have considered gold price. The accuracy of the system is measured for next 3 days.

For training the dataset is considered for 3 months to 6 months interval and the accuracy is plotted below



The next day forecast variance for stocks in 5 different industry is considered – Software, Manufacturing, Health care , Automobile and Small scale and the variance is stock price for next day is measured and compared with neural network and regression. The result is below

Industry	Neural Network	Regression	Q-Learning
Software	15	14	3
Manufacturing	10	11	2
Health care	14	13	2
Automobile	9	8	1
Small Scale	20	19	7

VI. CONCLUSION AND ENHANCEMENTS

We have detailed our proposed solution for stock market based on Q-Learning Reinforcement learning. We measured the accuracy of system and compared with Neural Network and regression based forecasting. From the results we proved that the accuracy of the proposed system is higher than other methods. Currently we have explored three actions, in future we plan to use multiple actions and also combination of actions to be taken at state.

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