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Original Research

Presenting an Explanatory Model of Stock Price Using Deep Learning Algorithm

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ABSTRACT

This study aimed to present an explanatory model of stock price using deep learning algorithm for companies listed in the Tehran Stock Exchange. In this study, a deep learning network was used to predict stock prices. The study was applied-developmental research in terms of purpose. To test the research questions, accounting data were prepared from 2011 to 2020 and input variables were calculated based on it for the model. The method of systematic elimination sampling has been used in this study. The results indicated that the precisions of prediction has a high precisions in the deep learning model. The proposed algorithm was reviewed according to its prediction accuracy and modeling cost. According to the data volume, it was found that the prediction accuracy in the deep learning model has a relative superiority and the diagram of performance characteristic and AUC criteria also showed this superiority in detection power.

1 Introduction

Achieving the economic growth and creating the investment motivation is accelerated in a country when it has active and reliable capital markets. The existence of active capital markets always encourages many investors and leads capital and financial resources to productive sectors [14]. Prediction in capital markets has always encountered challenges, doubts and errors, and the used methods have weaknesses that restrict their application. The stock price prediction has always considered as a challenging topic for researchers [32]. This market's high rates of return and uncertainty has caused the investors to use a variety of methods to facilitate the decision-making process [33]. The stock price information is one of the most important information in the capital market for investors, which is fundamentally nonlinear, non-parametric and chaotic dynamics [25]. This indicates that investors should use time series that are non-stationary and have a chaotic structure [17]. Therefore, stock price prediction is not only very challenging but also very popular with investors today [17]. Stock price and its related information are the criterion which is important to shareholders and capital market actors are attempting to scientifically be

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able to predict stocks in the future. By presenting new models of stock price prediction can help investors. The closer these predictions are to reality, the more correct the decisions that are made based on such predictions [10]. With increasing scientific progress, computer learning has precious and infinite energy, order, and capability of data processing compared to traditional investment [24].There are numerous models for computer learning methods that deep learning algorithm is among the most important and well-known models in this field. This study aimed to present an explanatory model of stock price using two methods of deep learning algorithm, and ultimately it reviewed the predictability of the model's prediction and suggested the appropriate model.

2 Theoretical Foundations and Research Background

The information of companies' risk and stock returns has a particular importance for investors and shareholders. Stock price changes over different time intervals and cash flows of companies, such as dividends, play a very important role in determining the risk and stock return [1]. It is necessary to reviewed the existing pricing models permanently and introduce more appropriate models to make the right decisions for investment and allocate the capital resources optimally. The results of previous studies represent that in the Tehran Stock Exchange, cash profit items as well as cash flows are more accepted as a criterion for buying and selling stocks than other accounting information [6]. A company's risk and stock price changes are a function of transferring information from inside to outside. By analyzing the studied companies' cost stickness, it is argued that operational risk is also an important factor that influences the stock prices crash risk [12]. There are many evidences representing the complexity of time series, such as stock market prices, and their random nature; this causes they be unpredictable by changes. Whereas, it is possible that these time series are a certain dynamic nonlinear process, or that is chaotic, and as a result can be predictable [5]. Although, in existing theories, the mass behavior of stock price is mainly defined based on a kind of imitation and behavior repetition, but it is difficult to provide a mathematical model to identify this phenomenon. Iran's capital market is facing the phenomenon of closing the symbol and this can influence the stock prices [7]. According to that the problem of stock price prediction is a matter of learning and optimization [10], this issue has been in the center of attention in recent years, and much has been said in the societies related to artificial intelligence and machine learning. Deep learning refers to a subset of learning algorithms and machine learning-based methods that attempts to discover complex patterns in data and model high-level abstractions. This property of deep learning has brought significant successes for this type of methods in the area of machine learning; so that they perform better than humans in some areas, such as identifying objects. Some deep learning techniques focus on analyzing and predicting the time series, which help us predict by discovering unknown patterns from the data. According to the nonlinear and chaotic system of the stock market, the traditional analysis does not have enough precisions [8]. So, what is investigated in this study is to present an explanatory model of stock price using deep learning algorithm and comparing it with neural network. In this way, the researcher considers the modeling of deep learning algorithm in order to predict stock prices and provides an optimal model for predicting stock prices in the long-term with the least error.

2.1 Experimental Background

Zhang, G.P [30] express that the precision of the combined model of autoregressive stacked moving aver model is accumulated and the neural network was better than the combination of each model alone. The results of Chan, M.C. [16] represented that the neural network can satisfactorily predict better time series and weight selection method led to lower computational costs. Kim, K. J., Han, I [21] express that genetic algorithm and neural network can be used to reduce the future complexity of the price time

series. Lendasse et al. [31] predict the index using the neural network. The results of their research represented that the use of neural networks works better than linear methods. Lahmiri S. [22] believed that most neural network inputs used to predict the exchange rate were single-variable, whereas neural network inputs used to predict the market price index and economic growth were multivariate in most cases. In terms of performance, there is a combined comparison between the neural network and other models. The reasons may be data differences, prediction levels and type of neural network model.

Das S. P. & Padhy [18] suggest that artificial neural networks have excellent learning capability, but they often are incompatibility and unpredictability for performance of data with disruption. Results of Sang et al. [28] represent that the genetic algorithm is considered as a promising method for immediate selection of artificial neural network. Pang et al. [26] suggest the use of monitored neural networks as learning technology in order to design a prediction for financial time series. Mahmud et al. [23] propose a fault detection model, a generalized intelligence and deep regression neural network, which is a supervised deep learning model, has a low precision and speed. The results of analysis and simulation by Cha et al. [15] indicate that this algorithm can achieve an average detection accuracy of 93.4% or higher for continuous wave signals of FM (frequency modulation), Frank, Costas, and phase shift keying/frequency shift keying. Sato M. et al. [27] express that deep learning networks are very useful compared to traditional manual methods to extract secret characteristics. Ubbens J. et al. [29] suggest the use of deep learning theory for studying the characteristics of active response of candidate and transforming the problem of extracting the response of property learning and categorization which is the use of words vectors to represent the problem properties.

The results of Kiani Mavi et al. [9] on the prediction of the company's stock price represent that the prediction by the standard back propagation (SBP) algorithm with momentum is better than the standard BP. Mehrara et al. [11] express that stock price prediction is useful using data mining techniques, including neural network and decision trees and logical regression. The results of Momeni and Mohammadi [12] indicate that a company's stock price crash risk is a function of transfering its information from inside to outside. By analyzing the studied companies' cost stickness, it is argued that operational risk is also an important factor that influences the stock prices crash risk. The probability of crash risk is reduced for companies with cost stickiness. Arab Salehi and Kamali Dehkordi [6] point out that it is necessary to reviewed the existing pricing models permanently and introduce more appropriate models to make the right decisions for investment and allocate the capital resources optimally. The results of their studies represent that in the Tehran Stock Exchange, cash profit items as well as cash flows are more accepted as a criterion for buying and selling stocks than other accounting information. The results of Khosravi Nejad and Shabani Sadr Pisheh [2] represent that there is no a significant difference between linear and nonlinear models in predicting the stock price index.

3 Based on Previous Researches at Home and Abroad, the Following Hypotheses Were Tested in This Study

The most important questions of the study are:

- ✓ Question 1: Is the deep learning algorithm model a suitable model for stock price prediction?
- ✓ Question 2: What are the most important variables of stock price prediction based on the learning algorithm model?

4 Methodology

This study was an applied research and was descriptive in terms of data collection method; and the scale of data measurement was relative. The population was consisted of all companies listed in the Tehran Stock Exchange from 2011 to 2020; their characteristics were as follows:

1) They followed the fiscal year ending March.
2) They were not a financial and credit institution.
3) Their stock market information was available.
4) They had not changed their fiscal year during the research period.

So, all companies listed in the stock exchange were used which were qualified between 2011 to 2020. The required information for this study and financial information of companies has been collected in the sections related to the literature from library resources and from the stock exchange and the Rahavard Novin software, respectively.

4.1 Research Model

The research conceptual model is as follows:

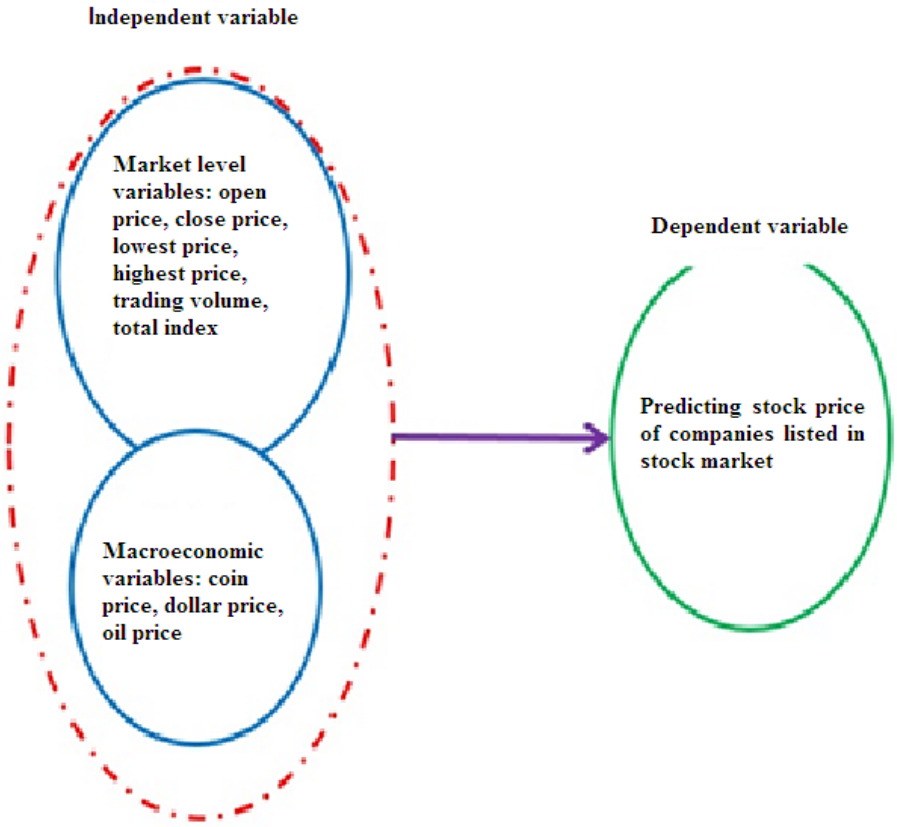

Fig.1: The Research Conceptual Model
Source: Taken from of the researcher findings from the literature of the research subject

5 Introducing the Model Variables

5.1 Dependent Variables

The stock price is the dependent variable used in this study which has been extracted from the information available on the site of Tehran Stock Exchange for sample companies.

5.2 Independent Variables

The independent variables used in this study are divided into two groups of market surface variables and macro variables as follows:

Independent variables at the market level are: open price, close price, lowest price, highest price, trading volume, total stock market index. The information related to these variables has been extracted from the existing information on the website of Tehran Stock Exchange for sample companies.

The macro-independent variables are: coin price, dollar price, oil price. Information related to these indicators has been extracted from the website of the Central Bank of the Islamic Republic of Iran.

Table 1: Explaining the Independent and Dependent Variables Used in the Study

Details	Category	Symbols	Variable name
A price which is traded per share at the start time of trading	Intra-company	Open	Open price
The lowest price which is traded on a daily time interval per share.	Intra-company	Low	Lowest price
The highest price which is traded on a daily time interval per share.	Intra-company	High	Highest price
The last price which is traded on a daily time interval per share.	Intra-company	Close	Close price
The trading volume per each trading day	Intra-company	Volume	Trading volume
Daily stock price index	Macroeconomics	TEP IX	Total stock market index
Daily coin price	Macroeconomics	Coin	Coin price
Daily U.S dollar price	Macroeconomics	Dollar	Dollar price
Daily price of Brent oil	Macroeconomics	Oil	Oil price

In this study, we use the logarithmic return method to preprocessing the properties.
(Relation (1))

$$X_i = \text{difference}\,(\log(X_i)),\ (i = 1, \text{number of characteristics}) \tag{1}$$

First, we calculate the logarithm of the values of each property and then calculate the return values ($x_{i+1} - x_i$) per each property. Now, we consider creating the target variable.

$$\text{i.}\quad d = \text{Close}_{i+1} - \text{Close}_i\ ,\ (i = 1, \text{number of observation})$$
$$\text{ii.}\quad \text{if } d > 0 \text{ then } y = 1 \text{ else } y = -1 \tag{2}$$

First, we calculate the difference between the values of two consecutive returns per property, and then there is upward trend of stocks if the result of this difference is positive, and if it is negative, it represents the down trend. We encode the uptrend with 1 and the down trend with -1.

6 Method of Testing Research Questions

Considering that the findings of most of these studies suggest the superiority of artificial intelligence methods over statistical linear models. So, due to the weaknesses of linear methods and the advantages of nonlinear methods in prediction, for example, more adaptability with real world problems, better prediction performance and no dependence on specific assumptions, the current study presents a model for stock price prediction using two models of deep learning algorithm and neural network:

In general, machine learning is divided into predictive (supervised learning) and descriptive (unsupervised learning) categories:
Supervised learning is to find an appropriate pattern for predicting the target variable based on a set of predictive variables or (characteristic or property). The target variable and the predictor variables or properties are usually showed by 'y' as the output and 'x', respectively; and the following model is used.

$$D = \{(X_i . y_i)\}_{i=1}^{N} \quad (3)$$

But unsupervised learning is to find a suitable model to better describe the relations between the data; in the unsupervised learning, the training data set lacks target variable and we only deal with a set of inputs.

$$D = \{(X_i)\}_{i=1}^{N} \quad (4)$$

In this study, due to the existence of a target and supervisor variable, which is the price variable of companies listed in the Tehran Stock Exchange, we find that it is necessary to use the supervised learning approach, and on the other hand the problem is defined in regression form due to the small or continuous scale of the target variable and ultimately the predictions from two powerful algorithms of machine learning (support vector regression) are compared using two criteria of accuracy and sensitivity and the final model is presented as the best prediction model.

7 Research Findings

The time interval used in this study was the years between" 2011 to 2020". Therefore, the studied data in this study was related to the years 2011 to 2020. The statistical sample was consisted of 653 companies in different industries during the study time interval. The collected data was related to 10 years and the variables were calculated and considered on a daily basis.

Table 2: The Statistical Results of Describing the Dependent and Independent Variables

Variables	Average	Median	Standard deviation	Minimum	Maximum	Range
Open	5341.13986	1574	13656.2189	15	749260	749245
High	5457.98172	1605	13951.2216	15	749260	749245
Low	5191.26794	1540	13208.7795	14	690000	689986
Close	5323.36732	1572	13583.5419	14	749260	749246
Volume	5272162.75	570273.5	38073633.8	1	6104750214	6104750213
TEPIX	174881.953	79393.8	293230.306	11178.5	2065114.3	2053935.8
Coin	22801754	12032000	20943474.5	2480000	113490000	111010000
Dollar	64682.3188	37380	50516.3024	9910	229410	219500
Oil	69.5594857	63.69	24.8802179	9.12	128.14	119.02

Source: Researcher findings

According to the average values of the variables and their standard deviation, it is found that there is a high range of oscillation and dispersion around the average in the 10-year period of data. Also, if we pay attention to the minimum, maximum and change range of these variables, we can justify this high value of standard deviation.

The importance of normality of data distribution is because of this that the normality of dependent variable distribution is usually one of the basic assumptions in statistical inferences such as linear regression model; while this problem is solved in the machine learning approach and the inference basically does not matter. Therefore, if the dependent or target variable does not observe the normal distribution, there is no interruption in the work and this is an advantage.

7.1 Testing the Research Questions

7.1.1 Testing the Research Questions Using Deep Learning Model

In order to examine the results of data analysis using the deep learning model, first the data set was divided into two groups: training and test. In such a way that 80% of the data was considered for training and 20% for test. Accordingly, the number of 340305 data from 648 companies were allocated to the training set and the number of 85775 data were allocated to the test set. Also, the data belonging to five companies were evaluated separately using created models.

Table 3: The Results of Prediction Accuracy of Deep Learning Model

Model description	Precision	Sensitivity	Specificity	FPR (1- Specificity)
Deep learning	73%	69%	76%	24%

Considering Table 3, we found that the deep learning model has an accuracy of 73% with a sensitivity of 69% that the obtained coefficients have the necessary adequacy to predict stock prices. Consequently, it can be acknowledged that the deep learning model has the necessary adequacy to predict stock prices.

Table 4: Confusion Matrix of Deep Learning Model

Details	**negative**	**positive**	**Description**
Total positive (-1)	9140	33087	**TRUE**
Total negative (1)	29740	14592	**FALSE**

According to Table 3, we find that the deep learning model can make true prediction with accuracy of 73 percent. Also, we can use the concepts of Sensitivity (true positive rate) and Specificity (true negative rate), if we want to examine the test results separately based on the levels of the objective function (binary). Based on Table 4, true positive rate and true negative rate are 69% and 76%, respectively, in the deep learning model. That is, the model was able to correctly recognize 69% of the down trend and 76% of the uptrend. Therefore, it can be concluded that deep learning model can be a suitable approach to predict the daily price trend of companies listed in stock market using macro and intra-company variables. The results confirm the results of Sato et al. [27] on the suitability of deep learning models for predicting stock price; So, the answer to this question can be a positive answer that whether the deep learning algorithm model is a suitable model for stock price prediction?

Another evaluable result is Receiver Operating Characteristics (ROC) curve, which is created by drawing the true positive rate ratio in terms of false positive rate. A Figure 2 is continues according to the variability of its values threshold.

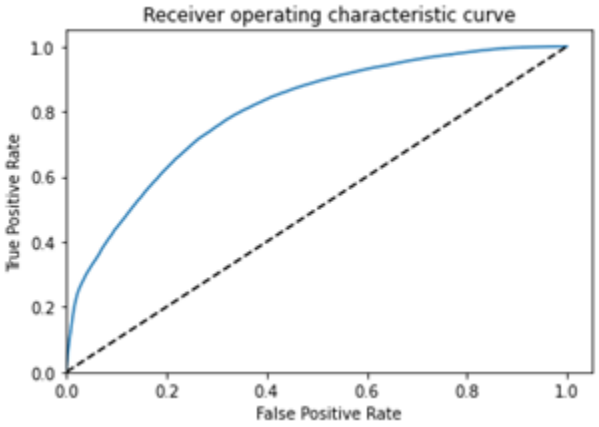

Fig. 2: Characteristic Curve of the Performance of Deep Learning Model

Another criterion is the AUC or the level below the Receiver Operating Characteristics (ROC) curve, indicating the detection power or correctness of a test results. The correctness of the test results depends on how well the test method is able to show the difference between the true positive (TP) and true negative (TF) results correctly. If this number is close to 1, it means that the true positive rate is high and the test method has a good detection power or correctness. According to the given details, the AUC value is equal to 80% per the test of the deep learning model, which the test has an excellent detection power based on the general rules by Hosmer. While this criterion is 77% for the neural network model, which the test has a good detection power based on the general rules by Hosmer.

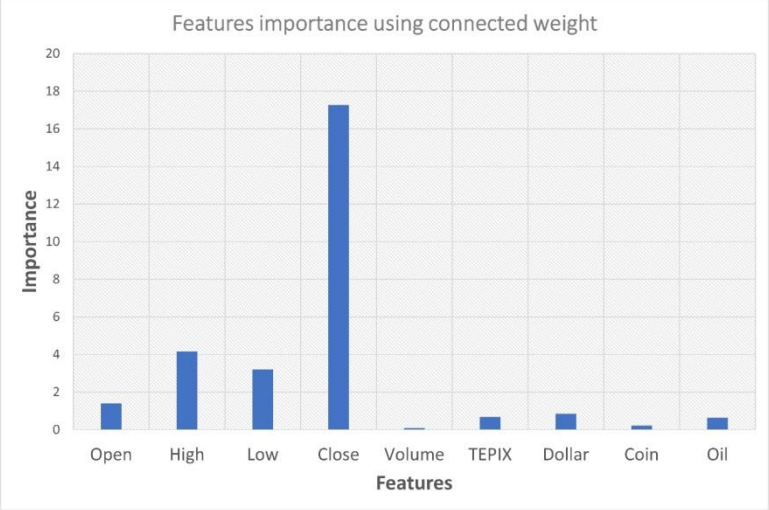

Fig. 3: The Importance of Properties in Predicting the Target Variable in the Deep Learning Model

According to Figure 3, which illustrates the importance of input variables in predicting the daily stock price trend of the studied companies, we find the Close variable, which is the symbol the close price of daily trading and an intra-company variable, has the most effect on the target variable, i.e. the daily price trend as well as in the deep learning model. Then, the High variable is in lower priority, which is the symbol of the highest price of daily trading. Among the macroeconomic variables, the dollar price in free market and the total stock market index with Dollar and TEPIX symbols, respectively, are more

important than other macroeconomic indexes in the daily price trend; therefore, we can refer to variables such as the close price of daily trading, the highest price of daily trading, the dollar price in free market, and the total stock market index in answer to this question: "What are the most important variables in stock price prediction based on the learning algorithm model?"

8 Conclusion and Discussion

In this study, the researcher used the model of deep learning to solve the problem of classifying the prediction of the daily stock price trend. The machine learning algorithm should be selected based on the type of classification problem as well as data volume and computational power and other related cases. Thus, the proposed algorithm was reviewed according to its prediction accuracy and modeling cost. According to the data volume, it was found that the prediction accuracy in the deep learning model has a relative superiority and the diagram of performance characteristic and AUC criteria also showed this superiority in detection power. But it is possible to consider the algorithm's performance from another aspect, and it is the speed of convergence to model, which clearly refers to the time factor. In the modeling process, we observed that the deep learning model converges to 75% in the prediction accuracy under the same conditions for running the algorithm. By performed review, it was found that the convergence time of the deep learning model to 70% prediction accuracy is approximately 0.4 times. On the other hand, the simple neural network model should spend about 3 times in order to converge to the prediction accuracy at the level of the deep learning model. This study's results confirm the results of the research by Mehrara et al. [11], Chan [16], Lendasse et al. [31], Das and Padhy [18] and Sato et al. [27] on the satisfactorily predict of time series by deep learning model. Based on this study's results, it is suggested to use a deep learning model to predict stock price.

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