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A method based on wavelet denoising and DTW algorithm for stock price pattern recognition in Tehran stock exchange

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ABSTRACT

The primary reason most people invest in stocks is the potential return compared to alternatives such as bank certificates of deposit, gold, and Treasury bonds. This requires accurate information about the stock market, price changes and predicting future trends. The main purpose of this study is to present a method based on wavelet denoising and dynamic time warping to identify the stock price pattern in the Tehran Stock Exchange. Instead of focusing and summarizing different and numerous methods to predict stock prices, this research concentrates on neural networks and wavelet denoising, and dynamic time warping to identify the stock price patterns. This methodology has been approved by researchers as a new effective technique. In this regard, first, using the wavelet denoising preprocessing step, noise is removed from the stock price time series, and then the extracted data was used as input to the dynamic time warping prediction model. MATLAB software version 9.11 was used to analyze the research data. The statistical population of the present study includes 3 shares among the shares of steel industry companies of Tehran Stock Exchange. The research was conducted in the period 2016 to 2020. The results show that the predictions obtained from the dynamic time warping method equipped with the wavelet denoising preprocessing step in comparison with the predictions obtained from the dynamic time warping method without the wavelet denoising preprocessing step in the sample, have been associated with much less accuracy and error.

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1- INTRODUCTION

Achieving economic growth and development in the country requires continuous monitoring and control of financial markets. In economic literature, financial markets as the flow of financial resources from non-productive sectors to productive play a vital role in economic growth, job creation, investment, stabilization of monetary and financial variables and overall improvement of society's welfare(Jafari Samimi & Baloonejad, 2013). Facilitating economic activities at the world level greatly increases the importance of these markets (Zolfaghari, 2018).

The financial system of each country is responsible for transferring savings and allocating them as investment resources. The role of the financial subsystem is to transfer funds from units with surplus to those with a lack of funds (Mohammadi, Mosleh Shirazi, Abbasi, & Akhlaghpour, 2019). In a general classification, financial markets are divided into two categories: money and capital markets. The stock exchange is an organized and formal capital market in which buying and selling of shares or government bonds or bonds related to reputable private institutions is done under certain rules and regulations (Feghehmajidi. Ali & Shahidi.Fariba, 2018). The capital market by providing features such as low transaction costs, appropriate dissemination of market information and clarification in this area, attracting harmful liquidity in other parallel markets, assigning returns to investors in appropriate risk, increasing liquidity and facilitating securities exchanges (Osoolian & Koushki, 2020). The stock exchange is the most important pillar in attracting and properly organizing financial resources in the country. In most countries the stock exchange has two important functions. As a ready market for securities, it ensures their liquidity and thus encourages people to channel savings into corporate investment.

For this reason, it is of particular importance to create conditions where investors would have a wide range of investment products to choose from (Sadeghi & Beheshti Tabar, 2019). Every conscious decision depends on a forecast of its consequences. In a general definition, forecasting means the possible estimation of future events based on present and past information (Khaidem, Saha, & Dey, 2016).

Forecasting changes in company stock prices is one of the most important measures in financial markets. Researchers consider it a big challenge to predict how the stock market will move. This has attracted the attention of researchers and policymakers in the last two decades. They use these forecasts in evaluating and pricing assets, optimal allocation of financial resources, and evaluation of risk management performance. The dynamic nature of stock markets means the price of traded shares can change quickly(Hoseeini Ebrahimabad, Jahangiri, Ghaemi Asl, & Heydari, 2020). The purpose of forecasting in the stock market is to determine the direction of the future movement of stocks. The more correct this prediction is, the more profit investors will get. Considering the significant amount of investment in the stock market, the lack of knowledge and sufficient details can lead to significant losses.

Since stock market data **is** generated periodically, it is considered time-series data. For stock prices, time series forecasting is common to track the price movement of the security over time (Bao, 2008).

The purpose of this research is to compare different stock price forecasting methods and determine the most effective ones. For a long time, in scientific and professional circles, the use of non-classical methods to identify the model and predict the behavior of complex systems has become common and usual.

In many complex and non-linear systems, whose modeling, prediction, and control through classical and analytical methods seem very difficult and sometimes even impossible, the use of non-classical methods with features such as intelligence will be desirable (Asgari

Oskoei, 2002; Shojaei & Heidarzadeh Hanzaei, 2021; TEHRANI, MOHAMMADI, & MOHAMADALIZADEH, 2011).

The research and studies carried out so far in the field of stock price modeling and forecasting have mostly been based on the proof of this hypothesis that the changes in stock prices and returns in the Tehran Stock Exchange, despite being very similar to random behavior, it was not accidental, but rather chaotic (Raoofi & Mohammadi, 2018). Therefore, short- and medium-term modeling and forecasting can be performed using complex and powerful models such as neural networks, fuzzy networks, etc. (Khaloozade. H & Khaki Sedigh, 2005). In contrast to the other current survey studies that concentrate on summarizing many methods used for forecasting the stock market, this research concentrates on neural networks and wavelet denoising, and dynamic time warping to identify the stock price patterns.

1-1- *Research Hypothesis*

In order to achieve the goals of the research, two hypotheses have been proposed and tested:

1) The method based on wavelet denoising, and dynamic time warping is able to estimate the stock price and provide an effective model to identify the price trends of the companies accepted in the Tehran Stock Exchange.

2) Applying wavelet denoising pre-processing step removes noise from time series signals and has a direct relationship with increasing accuracy and reducing error in price prediction by dynamic time warping method and recognition of stock price pattern.

2- METHODOLOGY

The required data has been collected from the website of the Tehran Stock Exchange Organization. Excel software was used to categorize the research data and MATLAB version 9.11 software was used to analyze the research data. Basic metal such as steel and copper in Iran constitute the most important part of the country's non-oil exports. This industry in Tehran Stock Exchange also has the highest correlation with the stock index. About 15% of the total value of the Tehran Stock Exchange is owned by the Basic Metals Group, and the Isfahan Mobarake Steel, Khuzestan Steel, and Khorasan Steel companies have the largest share of the total capital market value, respectively, compared to other Metals Group companies. As a result, among other industries active in the Tehran Stock Exchange, the basic metals industry and among the shares of companies active in the metals industry, the aforementioned 3 shares were selected as the statistical population of the research. The required data, 1300 data for each company, were collected during a four-year period. Also, the K-fold method has been used to divide the stock transactions of each company into training and test sections.

2-1- *Wavelet Transform*

The wavelet transform decomposes the signal into a weighted linear combination of a set of parent wavelet functions and mother wavelet functions. So that the mother and father wavelet functions (scale functions) are orthogonal functions that divide the function space into a series of orthogonal low and high-frequency spaces(Leal, Costa, & Campos, 2019). Therefore, after applying the wavelet transformation to the signal, we are faced with four coefficients, two of which are known as approximate coefficients and the other two are partial coefficients. Approximate coefficients contain low-frequency information, which are the same coefficients resulting from the functions of the parent wavelet, and partial coefficients contain high-frequency information, which are the same coefficients resulting from the transformation of the mother wavelet.

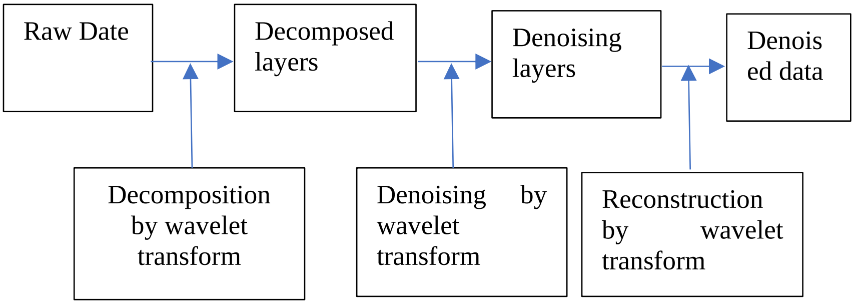

Figure 1. Denoising by wavelet transform
Source: Result Research

Wavelet transform can be considered as a piece-by-piece decomposition of information in a time series. In this process, the primary information is first decomposed into layers by wavelet transformation, which is called function decomposition (Paliwal, Choudhur, & Govandhan, 2014). Each part of the decomposed signal can be considered as a wavelet coefficient and a scaling coefficient. In wavelet analysis, data is divided into two groups with high and low frequencies. By applying the father wavelet on the original data, low-frequency data is obtained, which determines the main characteristics of that data. By applying the mother wavelet to the original series, high-frequency data is obtained, which is called noise. In fact, the main purpose of wavelet decomposition is to separate the main features of the series from the noise (Cottis, Homborg, & Mol, 2016). After removing the noise from the time series, the denoised layers are reconstructed using wavelet transform and the denoised data is extracted the denoised data is extracted (RAEI, MOHAMMADI, & FENDERESKI, 2015).

In this research, the discrete Mallet wavelet and Butterworth[1] transform are used to extract the average phase and amplitude with application in removing noise from time series signals of stock trading. For two-dimensional signals, the function f(x,y), the decomposition formula is:

1 butterworth

(1) $$C_{n,m}^{j} = \frac{1}{2}\sum_{k,j\in Z} \overline{h}_{k-2,n}\, \overline{h}_{j-2,m} C_{k,j}^{j-1}$$

(2) $$d_{n,m}^{j1} = \frac{1}{2}\sum_{k,j\in Z} \overline{h}_{k-2,n}\, \overline{g}_{j-2,m} C_{k,j}^{j-1}$$

(3) $$d_{n,m}^{j2} = \frac{1}{2}\sum_{k,j\in Z} \overline{g}_{k-2,n}\, \overline{h}_{j-2,m} C_{k,j}^{j-1}$$

(4) $$d_{n,m}^{j3} = \frac{1}{2}\sum_{k,j\in Z} \overline{g}_{k-2,n}\, \overline{g}_{j-2,m} C_{k,j}^{j-1}$$

Where $C_{n,m}^{j-1}$ represents the approximate information in the signal with the scale of 2^{j-1} and $C_{n,m}^{j}$represents the approximate information in the signal with the scale of 2^{j} (LL), and $C_{n,m}^{j}$ represents the approximation of the horizontal direction and the partial vertical component of the signal dimension (LH). $d_{n,m}^{j2}$ represents the horizontal part of the signal with dimension 2^{j} and the approximate part in the vertical direction (HL part). $d_{n,m}^{j3}$ represents the diagonal part of the partial component in the signal dimension (HH part). The signal reconstruction formula will be as follows:

(5) $$C_{n,m}^{j-1} = \frac{1}{2}\sum_{k,j\in Z} C_{k,j}^{j} h_{n-2k}\, h_{m-2k} + d_{k,j}^{j1} h_{n-2k} g_{m-2k} + d_{k,j}^{j2} g_{n-2k} h_{m-2k} + d_{k,j}^{j3} g_{n-2k} g_{m-2k}$$

Where h and g represent the coefficients of the low-pass and mid-pass filters, respectively (Mallat, 2009).

2-2- *Dynamic time warping*

In time series, dynamic time warping is an algorithm for measuring the similarity between two time sequences that may differ in speed or time(Han et al., 2020) . For example, DTW can find the similarity between two walking patterns even if their walking speed or acceleration is not the same in time intervals (Kim et al., 2018). In fact, DTW can analyze any data that can be obtained as a sequence of information (Izakian, Pedrycz, & Jamal, 2015). In general, DTW is a method that finds the most optimal matching between two time sequences with certain constraints (Myers, Rabiner, & Rosenberg, 1980). The dynamic time warping approach calculates the best mapping between two time series according to the dynamic changes of time (Jiang et al., 2020).

To better understand how this method works, consider two time series in the form $A = \{a_1, a_2, a_3, \dots, a_i, \dots, a_n\}$ and $\{b_1, b_2, b_3, \dots, b_j, \dots, b_m\}$. At first, we form the matrix dist(m,n) in such a way that each element of dist(i,j) represents the square of the Euclidean distance between two points ai and bj in two time series which is obtained from the following relationship:

(6) $$\text{Dist}(i, j) = (a_i - b_j)^2$$

$P = \{p_1, p_2, p_3, \dots, p_k, \dots, p_K\}$ shows the matching path between two time series A and B, where K represents the length of the path and applies to the inequality Max(n,m) < K < n+m+1. Also, the kth element represents the relationship between two corresponding points in the two time series under investigation. This matching path is limited to the following conditions:

1) Boundary condition: The starting point of the path corresponds to the first point of the two time series and the end point of the path corresponds to the end point of the two time series and these points correspond to the beginning and end points of the dist(m,n) matrix. In other words, it can be said that $p_1 = [1,1]$ و $p_k = [m, n]$.

2) Continuity condition: The matching path between two time series is continuous and without jumps. Therefore, the specified points in this path are adjacent and in the dist(m,n) matrix, they move only along the diagonal, horizontal and vertical lines without jump. Considering $p_k = [i_k, j_k]$ and و$p_{k-1} = [i_{k-1}, j_{k-1}]$ the following two inequalities will be established.

$$i_k - i_{k-1} \leq 1 \quad (7)$$

$$j_k - j_{k-1} \leq 1 \quad (8)$$

3) Uniformity condition: The matching path of two time series in each step is progressive in at least one of the time series and fixed or progressive in the other and cannot go back. Considering $p_k = [i_k, j_k]$ and $p_{k-1} = [i_{k-1}, j_{k-1}]$ this condition will be established if the following two inequalities are established:

$$i_k \geq i_{k-1} \quad (9)$$

$$j_k \geq j_{k-1} \quad (10)$$

4) Warping window width: In finding the best route, it should be noted that the optimal route is one whose deviation from the diameter of the matrix is not large. To achieve this condition, a number like k is determined as the width of the warping window, and the following inequality holds for all points of the route:

$$|i_k - j_k| \leq k \quad (11)$$

In Figure 2, there are different matching paths for two time series with different lengths of 6 and 8. According to the matrices in Figure 1, the boundary condition is not established in the matching path specified in matrix A. In the path specified in matrix b, the continuity condition is not met. The selected matching path in matrix C does not satisfy the condition of uniformity, and also in matrix D, the swing window condition is not met, and finally, in matrix C, we have an optimal matching path that has all the necessary conditions.

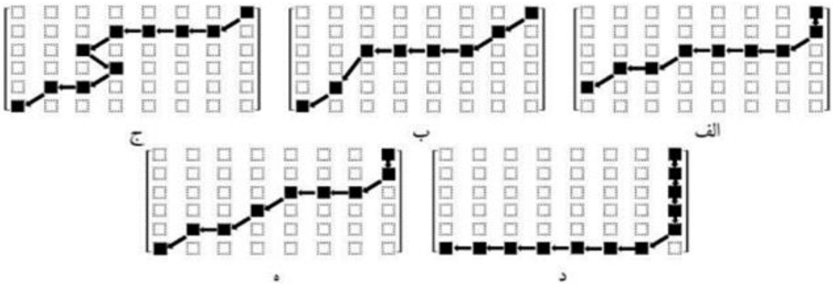

Figure 2. Different matching paths for two financial time series of lengths 6 and 8
Source: Result Resaerch

The optimal matching path is the shortest possible path, as a result of this path, taking into account the mentioned conditions, by minimizing the cumulative distance calculated using the following matrix:

(12) $$DIST_{DTW} = [min\{\sum dist(i_k, j_k)\}]^{\frac{1}{2}}$$

To find the minimum value of this function and as a result to achieve the optimal matching path by using the cumulative distance definition and using the $DIST_{m,n}$ matrix, the $D_{m,n}$ matrix must be formed in such a way that its dimensions are obtained from the following recursive relation:

(13) $$d(i,j) = dist(i,j) + min\{d(i,j-1), d(i-1,j), d(i-1,j-1)\}$$

After completing the above-mentioned matrix, the optimal path will be recursively obtained from the element d(m,n) to d(0,0) with the minimum distance criterion in each path and considering the mentioned conditions. Then according to the path obtained, in the matrix $D_{m,n}$and its corresponding rows in the matrix $DIST_{m,n}$, the elements of the matching path P are obtained (Sadeghi & Beheshti Tabar, 2019).

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2-3- *Research variables*

1) Opening Price: The first traded price in the current day
2) the highest price: the highest trading price of the share in the current day
3) Lowest price: the lowest price of the share transaction in the current day
4) Closing price: the last trading price of the share in the current day
5) Closing price: the weighted average of all the prices that each share was traded in the current day.

3- FINDINGS

3-1- *Data analysis and findings*

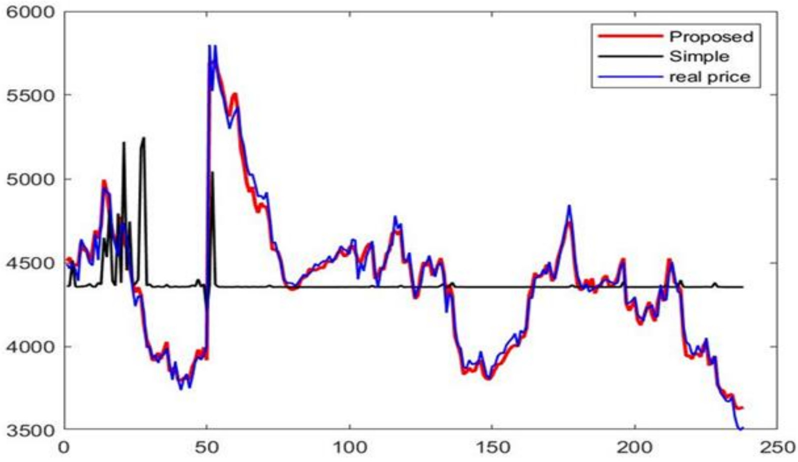


Figure 3. Forecast chart of Mobarake steel price trend in Isfahan in the proposed method and the compared method
Source: Result Resaerch

Figure 3 shows the forecast trend of Isfahan Mobarakeh Steel Company stock price, that the proposed method (red line) is exactly on the actual price chart (blue line). This shows the high accuracy of the proposed research method (dynamic time warping equipped with wavelet denoising step). However, the prediction of the price trend according to the compared method (black line), the dynamic time convolution method without wavelet denoising step, has low power and the predicted trend is not in accordance with the actual price trend.

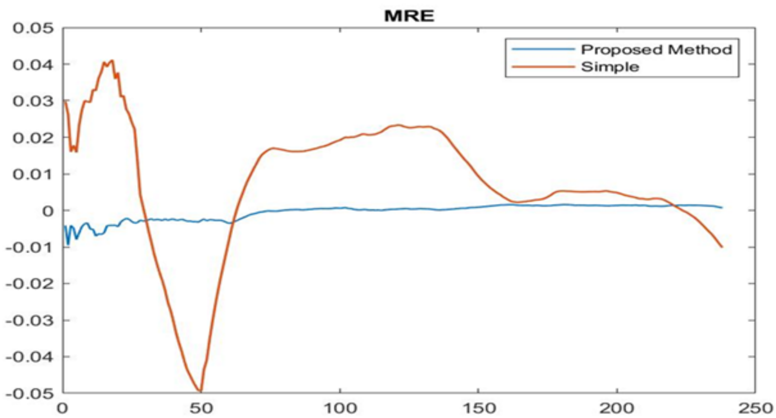
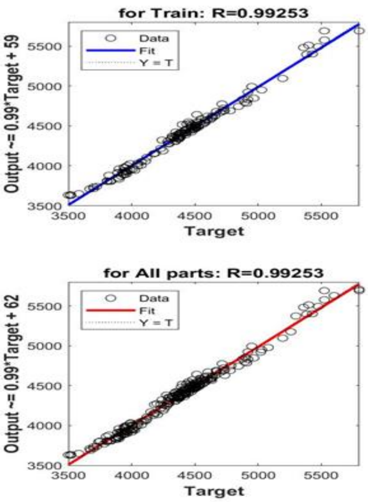


Figure 4. The average relative error of forecasting Mobarake steel in Isfahan in the proposed method and the compared method
Source: Result Resaerch

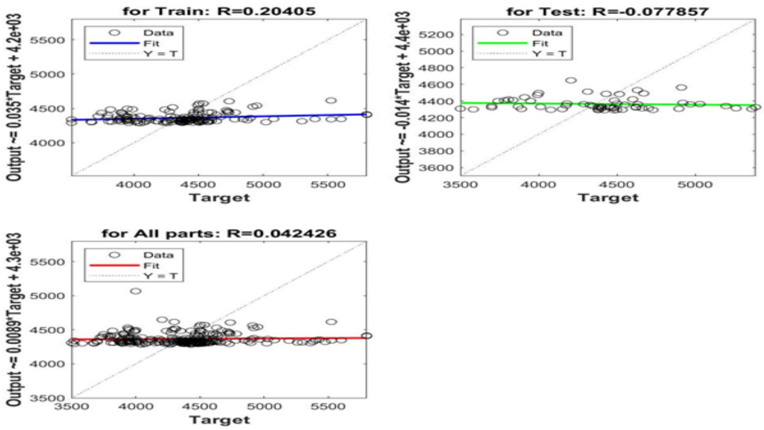
Figure 4 shows the average relative error of forecasting the share price of Isfahan Mobarakeh Steel Company, which according to the proposed method (blue line), was almost equal to zero during the entire test period and was associated with very little fluctuation around the zero axis, but in the compared method (orange line), the average amount of relative error is very high and in the range of -0.05 to 0.04, it has faced severe fluctuations.



Part A.

Figure 5. Regression analysis of Isfahan Mobarake steel stock price trend in the proposed method

Source: Result Resaerch



Part B.

Source: Result Resaerch

Figure 5 shows the results of the regression analysis of the prediction of the stock price trend of Isfahan Mobarakeh Steel Company, which according to the proposed method (Figure A) in the training section, test and both sections indicates 99% accuracy, but according to the compared method (Figure b) indicates 20% accuracy in the training section, 7% accuracy in the test section and 4% accuracy in both sections. Therefore, this analysis shows that it is possible to trust the results of stock price predictions in the coming years through the proposed method in this research.

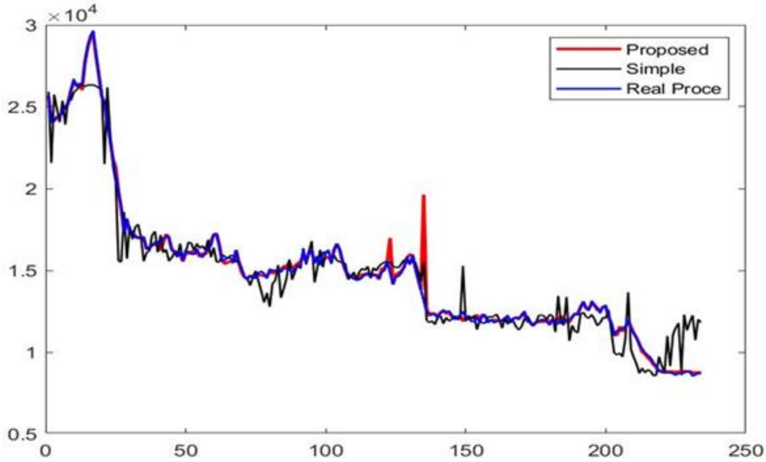


Figure 6. Forecast chart of Khorasan steel company's stock price trend in the proposed method and the compared method
Source: Result Resaerch

Figure 6 shows the prediction of the stock price trend of Khorasan Steel Company that the price prediction trend in the proposed method (red line) is completely consistent with the actual price trend (blue line) and the price prediction trend in the compared method (black line) is also very close to the real price trend.

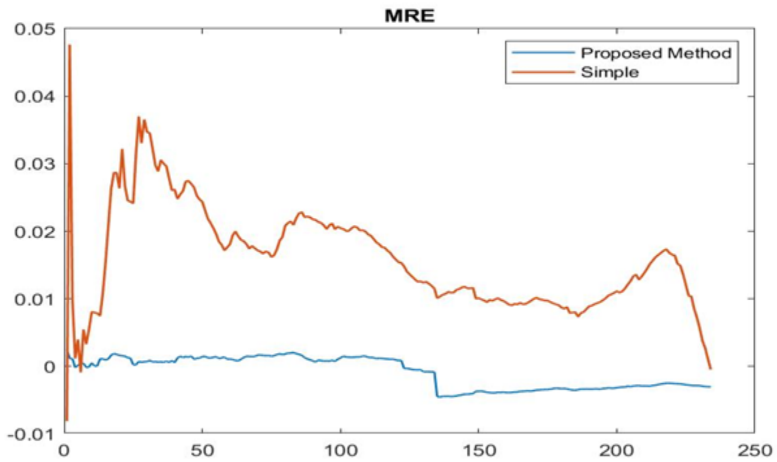
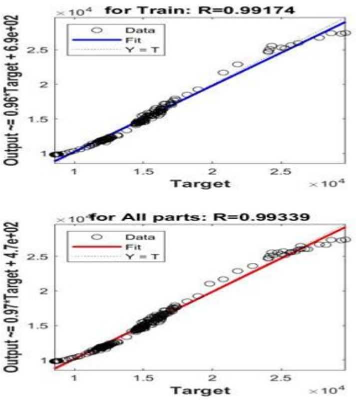


Figure 7. The average relative error of prediction of Khorasan Steel Company in the proposed method and the compared method
Source: Result Resaerch

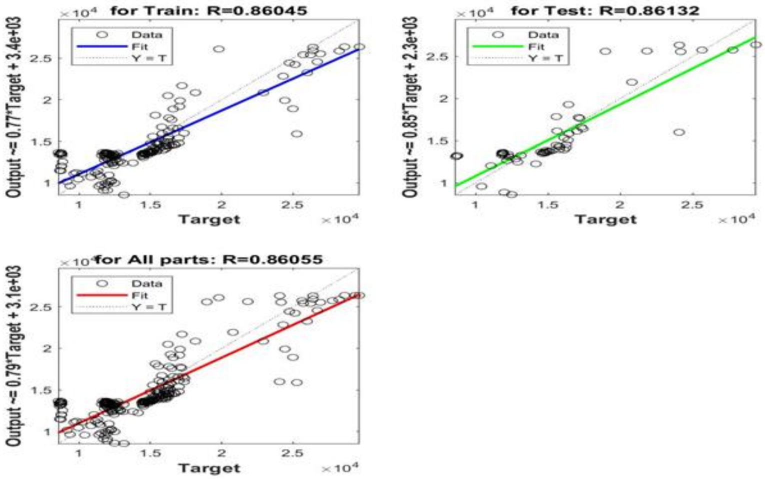
Figure 7 of the average relative error of Khorasan steel company's prediction for the proposed method (blue line) and the comparison case (orange line) shows that the proposed research method has faced a very small fluctuation in the range between -0.01 and 0. So that in the beginning to the middle of the investigated range, the error rate was close to zero and after that the error tended to be -0.01, but in the compared method, the fluctuations are still very high and vary in the range of -0.01 to 0.05.



Part A.

Figure 8. Regression analysis of stock price trend of Khorasan steel company in the proposed method

Source: Result Resaerch



Part B.

Source: Result Resaerch

Figure 8 the regression analysis of the stock price forecast of Khorasan Steel Company according to the proposed method (Figure A) in the training section, test and both sections, shows 99% accuracy. Therefore, this analysis shows that it is possible to trust the results of stock price predictions in the coming years through the proposed method in this research. The regression of predicting the stock price trend of Khorasan steel company according to the compared method, which is shown in part b, indicates an accuracy of about 86% for the educational, test and both parts of the stock transactions.

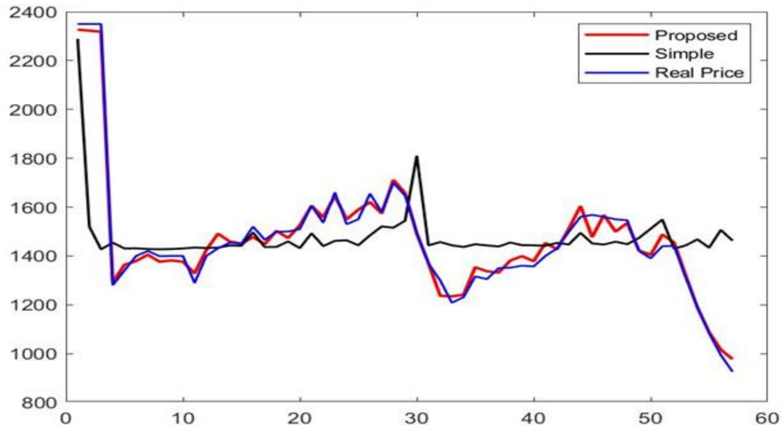


Figure 9. Chart of forecasting process of stock price of Khuzestan Steel Company in the proposed method and compared method
Source: Result Resaerch

Figure 9 shows the stock price trend of Khuzestan Steel Company that the price trend according to the proposed method (red line) is very close to the actual stock price trend (blue line), but according to the compared method (black line), it is with the actual price trend It does not correspond much, which reveals the low accuracy of the prediction with the mentioned method.

The compared method shows a trend with very low and almost constant price fluctuations in the entire range of the test in 2018, with the exception of high fluctuations in the beginning and middle of 2018, which is not consistent with reality.

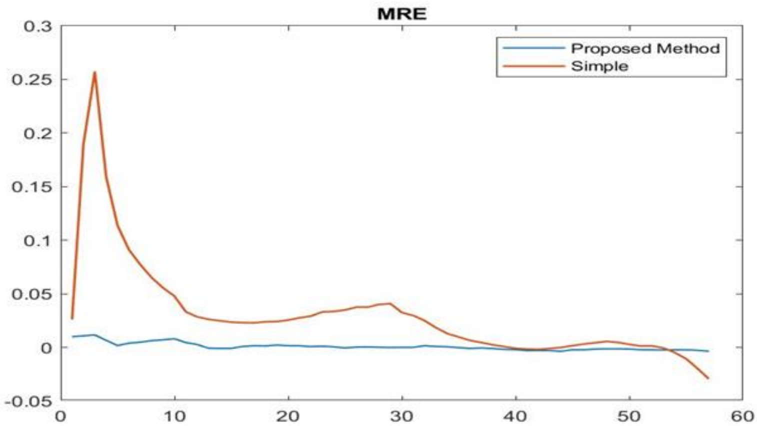
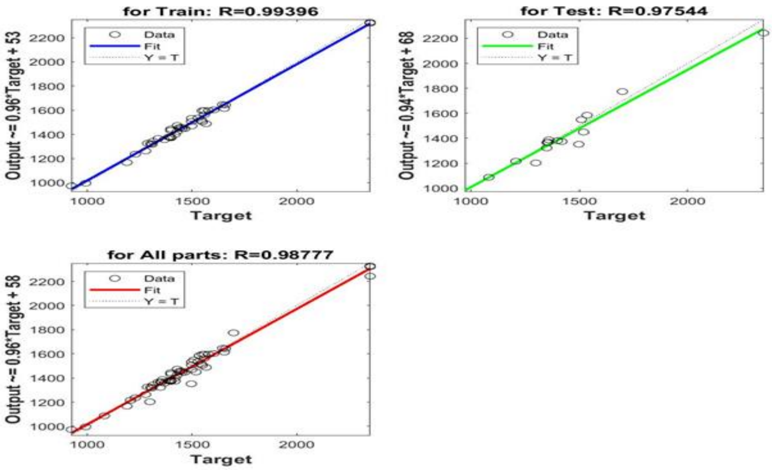


Figure 10. The average relative error of stock price prediction of Khuzestan Steel Company, the proposed method and the compared method
Source: Result Resaerch

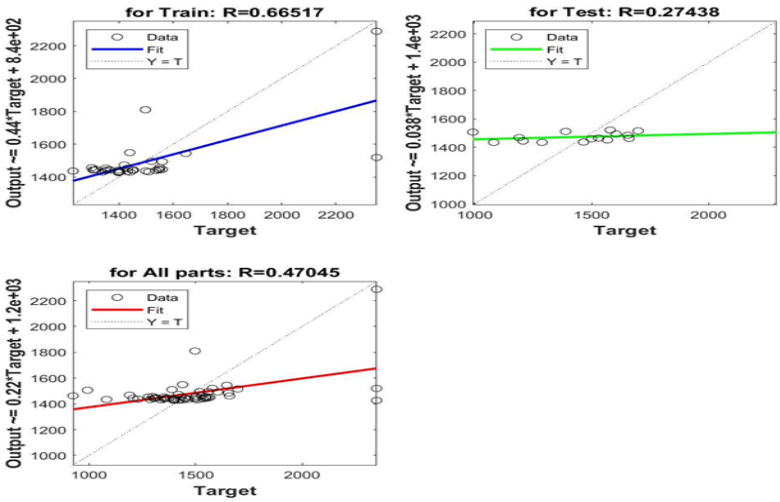
Figure 10 indicates the average relative error of forecast of Khuzestan Steel Company according to the proposed method (blue line) and the comparison case (orange line). The figure indicates that the proposed research method has still lead a very low error and the error has fluctuated in the range of 0 to 0.01 and until the end of the test range, it has faced an error of almost 0 in price prediction. But in the compared method, the fluctuation of the error is variable in the range of -0.03 to 0.26, so that in the beginning of 2018, the prediction error of the price trend is very high compared to the middle to the end of 2018.



part A.

Figure 11. Regression analysis of Khuzestan steel stock price trends in the proposed method

Source: Result Resaerch



Part B.

Source: Result Resaerch

Figure 11 shows the results of the regression obtained from the trend of stock price forecasting in Khuzestan Steel according to the proposed method (Part A) and the compared method (Part B). The regression analysis of the forecasting of the Khuzestan Steel Company's stock price trend in the proposed method shows an accuracy of 99% for the stock transactions of the educational sector and 97% for the stock transactions of the test sector and 98% for the stock transactions of both sectors. Therefore, this analysis shows that it is possible to trust the results of stock price predictions in the coming years through the proposed method in this research.

Part B shows the regression analysis of the Khuzestan steel price trend prediction in the compared method, which indicates 66% accuracy for the educational sector stock transactions, 27% accuracy for the test sector stock transactions, and 47% accuracy for the stock transactions at the both parts.

4- CONCLUSION

Global changes in financial markets and dynamic business uncertainties have become a driving force for accurate prediction of price trends in financial markets. Forecasting stock prices in the stock exchange allows investors to make timely and informed decisions about buying or selling stocks, thus reducing the financial losses of investors.

Therefore, in this research, due to the problems in predicting stock prices using the simple dynamic time convolution method (without wavelet denoising), the wavelet denoising approach was used as a pre-processing step. In contrast to the other current survey studies that concentrate on summarizing many methods used for forecasting the stock market, this research concentrates on neural networks and wavelet denoising, and dynamic time warping to identify the stock price patterns. There are many smart techniques, each of which has advantages and disadvantages, one of the new smart methods that has better results than some other methods is the dynamic time warping (DTW).

The proposed framework started with the pre-processing step of wave denoising in order to reduce the examples of useless transactions and remove noise from the trading signals of the shares of the three companies Mobarake Isfahan Steel, Khorasan Steel and Khuzestan Steel.

Then, the prediction of trading signals was modeled with dynamic time warping problem. At the end, the results obtained from the dynamic time warping method with the preprocessing step of wavelet denoising and the results obtained from the simple dynamic time warping method without wavelet denoising were compared.

The statistical population of the present study includes three shares among the shares of companies operating in the Tehran Stock Exchange (Mobarakeh Steel of Isfahan, Khuzestan Steel, Khorasan Steel). The reason for this choice is that about 15% of the total value of the Tehran Stock Exchange is owned by the basic metals group. These three companies have the largest share of the total value of the capital market, respectively, compared to other companies of Metals Group. As a result, among other industries active in the Tehran Stock Exchange, the basic metals industry and among the shares of companies active in the metals industry, the aforementioned 3 shares were selected as the statistical population of the research.

In this study, a method based on wavelet transform and dynamic time twist (DTW) were used to identify the stock price pattern in the Tehran Stock Exchange. In other words, first the wavelet transform method is used to smooth the main stock price chart; then, using the DTW algorithm to find the diagram with the shortest distance from the target diagram under the roller window method, the identification and analysis of the target diagram can be accomplished.

The results indicate that: the forecasting chart of the stock price trend of Mobarakeh Steel Company of Isfahan in the proposed method was very consistent with the real price chart, which shows the high accuracy of the proposed research method, but the forecasting of the price trend for the compared method is the time twist method. Dynamics without wavelet defrosting step have low power and the predicted trend does not correspond to the real price trend. In general, the results of the findings indicate the high accuracy and reliability of the stock price prediction of the studied steel companies.

The average relative error rate of prediction of stock price of Mobarakeh Steel Company of Isfahan for the proposed method was almost zero during the whole test period and was accompanied by very little fluctuation around axis 0, but in the comparative method, the average relative error rate was very high. And has been associated with severe fluctuations in the range of -0.05 to 0.04. Also, the results of regression analysis predict the stock price trend of Mobarakeh Steel Company of Isfahan for the proposed method in the training section, test and both sections show 99% accuracy, and for the comparative method, indicate 20% accuracy in the training section. Accuracy is 7% in the test section and accuracy is 4% in both sections.

The study of Khorasan steel for the proposed method and the method compared also shows the high accuracy of the proposed method. The forecast chart of the stock price trend of Khorasan Steel Company for the proposed method was in accordance with the real price trend and in the comparative method, the price chart is very close to the real price trend. The average relative error of forecasting the stock price of Khorasan Steel Company for the proposed method, has faced very little fluctuations and has been fluctuating in the range of -0.01 to 0, but according to the method compared, the fluctuations are very high and in the range of 0.01 - varies up to 0.05. Also, the results of regression analysis predict the stock price trend of Khorasan Steel Company based on the proposed method in the training, test and both sections, showing 99% accuracy, but based on the method compared, the accuracy is approximately 86% .

The stock price forecast chart of Khuzestan Steel Company for the proposed method is very close to the real stock price trend, but for the method compared, it does not correspond to the real price trend, which reveals the low accuracy of the forecast with this method. This indicates that in the study of Khuzestan steel, we are faced with high accuracy of prediction for the proposed method. The average relative error of forecasting the stock price of Khuzestan Steel Company for the proposed method was almost zero and fluctuated between 0 and 0.01 in the whole period, but in the comparative method, the error varies in the range of -0.03 to 0.026. The results of regression analysis predict the stock price trend of Khuzestan Steel Company for the proposed method in the training section shows 99% accuracy, in the test section 97% accuracy and in both sections, 98% accuracy, but in the comparative method, it shows 66% accuracy in the training section, 27% accuracy in the test section and 47% accuracy for transactions in both sections.

Changing the statistical population and using data from other groups (such as automobile industry) and using similar methods used in this article may be proposed as a proposal. It is also suggested to use other artificial intelligence methods such as neural networks in pattern recognition and stock price prediction in Tehran Stock Exchange.

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