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Modeling and prediction of Bitcoin prices based on blockchain information

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Abstract

Bitcoin has recently attracted considerable attention in the fields of economics, cryptography, and computer science due to its inherent nature of combining encryption technology, monetary units and blockchain. This paper reveals the effect of neural networks (NNs) by analyzing the time series of the Bitcoin process. We also select the most relevant features from Blockchain information that is deeply involved in Bitcoin's supply and demand and use them to train models to improve the predictive performance of the latest Bitcoin pricing process. In this paper, the purpose of Bitcoin price prediction is to use the combined method of signal decomposition into intrinsic components (EMD) and support vector regression (SVR) algorithms. The proposed method uses the intrinsic component decomposition method as a denoising step in the training data. We conduct an empirical study that compares the proposed method with other linear and non-linear benchmark models on modeling and predicting the Bitcoin process. Our empirical studies show that NN performs well in predicting Bitcoin price time series and explaining the high volatility of the recent Bitcoin price also the Mean Square Error (MSE) of the proposed method is calculated and compared with previous works.

Keywords: Blockchain, Bitcoin Prices, Financial market prediction, Machine learning
2020 MSC: 91G15, 91G45

1 Introduction

Bitcoin is a decentralized, anonymous, exclusive ownership, and in nation-free currency [19]. Fry and Cheah [7] found that in view of the innovative characteristics of decentralization and traceability of bitcoin, bitcoin has attracted extensive attention from the media and investors. After the rise and fall of cryptocurrency prices in recent years, bitcoin is increasingly seen as an investment asset. Investors see bitcoin as a speculative investment, similar to the Internet stocks of the last century [12]. Bitcoin as a cryptocurrency, itself appears for a short time compared with the sovereign currency [2]. Unlike the sovereign currency, bitcoin is a decentralized digital currency without any government credit support, so the price of bitcoin is highly volatile. It produces much more volatility than sovereign currencies. Its

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price rose from zero value when it was established in 2009, to about $13 per bitcoin in January 2013, and then soared to about $20000 per bitcoin in December 2017. Since bitcoin started trading, its highly unstable nature has been plaguing investors, and it may be a bubble, threatening the stability of the financial system. Therefore, it is necessary to make a good prediction of the price of the special currency. The possibility of predicting the price trend of bitcoin is a practical problem. It not only affects a country's economic policy at the macro level but also strongly affects investors decision to buy and sell investment instruments at the micro-level.

Matkovskyy and Jalan [5] found that the accurate prediction of bitcoin price can not only provide decision support for investors but also provide reference for the government to formulate regulatory policies. Equally noteworthy are the factors that influence bitcoin prices. In addition to the internal factors such as block size, hash rate, mining difficulty, trading volume, and market value of bitcoin, this study thinks that the factors should be more comprehensive: firstly, this study thinks that the Google and Baidu search index is an important factor affecting bitcoin because it is an important indicator to measure investors' attention and media hype and reflects the sentiment of the highly speculative cryptocurrency market [23]. Secondly, this study argues that the irrational factors such as major events and investor sentiment caused by economic policies will also affect the price of bitcoin [13]. Papadopoulos [8] shows that there is good interaction between bitcoin price and gold price. Dyhrberg [6] proved the similarity among bitcoin, gold, and the US dollar through the GARCH model. Therefore, this study takes the gold price and the dollar index as the influencing factors of bitcoin price. By selecting the above external factors, the problem of simplifying bitcoin price prediction is avoided.

2 Bitcoin and Blockchain

2.1 Economics of Bitcoin

Satoshi Nakamoto is the creator of Bitcoin [19]. This name was used for the first time in 2008 and it is still unclear if this is a real name or nickname. In 2008, he published an article about cryptography on a mailing list of the website "www.metzdowd.com". The article introduced a kind of digital currency that later became Bitcoin. In early 2009, he released Bitcoin's source code, along with binary code compiled on "www.sourceforge.net". In June 2009, Nakamoto launched the peer to peer Bitcoin network [13] that allows individual members of the network to track all transactions, and started to mine Bitcoin. During the early days of crypto mining, there were few miners in the network. Therefore, the mining difficulty was low [8]. These few miners were able to extract huge amounts of Bitcoin. Franco's [8] study used a Bitcoin data analysis and discovered that Nakamoto extracted nearly 1,000,000 Bitcoins. Interestingly, none of these Bitcoins had ever been spent, but the reason behind it is unknown. However, it is obvious that as soon as these Bitcoins are spent by Nakamoto, his identity will be known, as blockchain transactions are trackable by everyone in the network and the transfer of these Bitcoins to a person can be tracked in the real world [8]. Nakamoto deliberately created a decentralized network and stated that after the bitter experiences of the nineties and more than a decade of public trust in third parties and their systems, many people use a decentralized network [19].

The creator of Bitcoin believes that within the next 10 years, digital currency will replace conventional currencies. Bitcoin is a digital currency that uses protocols and cryptographic algorithms to determine the security of transactions and to create new ones [6]. Bitcoin is the first transfer and transaction system that uses nodes and that does not use third party processing and confirmation of transactions. Bitcoin allows direct transactions between individuals, which is the main feature that distinguishes it from traditional currencies. The fact that Bitcoin does not need third-party agencies is one of the reasons for its popularity. This unique characteristic means that the entire system is decentralized [3]. The network assumes that most nodes—which are, in fact, individuals—are honest and intercepts all transactions. The Bitcoin system does not have a mediating entity and no third party for managing transactions; therefore, several existing nodes process each transaction. These nodes are responsible for registering each transaction in a public ledger called a blockchain. The nodes that process transactions are called "miners" and the process "mining".

As compensation for the registration of each transaction in the blockchain, a reward is given to the miner. Miners perform the calculation needed to record the data and a completed and verified process chooses a miner as the winner to update the blockchain. Each participant has a revised version of the audit, and therefore, the entire system is decentralized [18]. Recently, Shi [22] proposed a new proof-of-work mechanism that improves decentralization and reduces the risk of attacks by 51% without increasing the risk of Sybil attacks (a cyber-security attack wherein a reputation system is subverted by forging identities). Renato and Dos [6] examined the system type of Bitcoin and concluded that the Bitcoin network is not a complex system with only algorithmic complexity, and that it will probably not enter a chaotic phase. The advantages of using a blockchain network are: transparency of information, no need for third parties, the possibility of international payments, anonymity of users, irreversible payments, no transaction tax, low transaction costs, and a low risk of theft. Bitcoin is traded in more than 40 exchanges around the world, and currently has a market worth of US$ 16 billion. As Bitcoin is used by ordinary people and because of its lack of relevance to other assets, Bitcoin has become an attractive option for investors. Therefore, the ability to predict prices would be a great help for investors.

Considering the importance of the topic, many researchers have recently studied Bitcoin price prediction. Almeida et al. [1] reviewed an artificial neural network (ANN) model to predict the Bitcoin price using the last day price and turnover volumes. The main problem with their method is the requirement of a large amount data for the prediction. McNally's [17] research concerns predicting Bitcoin prices using machine learning. This was achieved by using several RNN, ARIMA, and LSTM patterns. The error percentages of the RNN, ARIMA, and LSTM models were 5.45%, 53.47%, and 6.87% respectively [11, 17]. Greaves and Au [10] investigated the characteristics of the blockchain network based on Bitcoin's future price using an ANN. The results showed that the average accuracy is approximately 55%. Shah and Zhang [21] used the nonparametric classification technique developed by Chen et al. [4] to predict price trends, claiming that a successful Bitcoin strategy would be based on Bayesian regression if its accuracy is 89%. Madan et al. [14] used Bitcoin blockchain network properties to predict Bitcoin prices. Using SVM algorithms, binomial logistic regression classifiers, and random forests, they predicted the Bitcoin price with an accuracy of 55%. Georgoula et al. [9] investigated the determinants of the Bitcoin rate along with an emotional analysis using SVM. The result showed that the amount of Wikipedia hits and hash rates in the network had a positive relationship with the Bitcoin price.

In another study, Matta et al. [15] aimed to predict Bitcoin trading volumes. They examined whether the general feeling that aggregates in a set of Twitter posts could be used to predict changes in the Bitcoin market. The results showed that there was a significant association between Bitcoin's upcoming price and the volume of tweets during a day. Similarly, the volume of Google searches for the term "bitcoin" affects the Bitcoin price [16]. In the proposed method, the goal is to predict the price of Bitcoin using the combined method of signal decomposition into intrinsic components (EMD) and support vector regression (SVR) algorithms. The proposed method uses the intrinsic component decomposition method as a denoising step in the training data.

2.2 Blockchain

Decentralization is the value pursued by all cryptocurrencies as opposed to general fiat currencies being valued by central banks. Decentralization can be specified by the following goals:

(i) Who will maintain and manage the transaction ledger?

(ii) Who will have the right to validate transactions?

(iii) Who will create new Bitcoins?

The blockchain is the only available technology that can simultaneously achieve these three goals. Generation of blocks in the Blockchain, which is directly involved in the creation and trading of Bitcoins, directly influence the supply and demand of Bitcoins. Combination of Blockchain technologies and the Bitcoin market is a real-world example of a combination of high-level cryptography and market economies. We then describe in detail how the Blockchain can achieve the abovementioned goals in Bitcoin environment [20]. A participant in a Bitcoin network acts as a part of a network system by providing hardware resources of their own computer, which is called a "distributed system". All issuance and transaction of money are conducted through P2P networks. All trading history is recorded in the Blockchain and shared by the network, and all past transaction history is verified by all network participants. The unit called "block", which includes recent transactions and a hash value from the previous "block", creates irreversible data by a hash function, and is pointed out from the next block. It takes more than a certain amount of time to generate the block to make impossible to forge all or part of the Blockchain. This algorithm is called proof of work (PoW), and the difficulty is automatically set to ensure that the problem can be solved within approximately 10 minutes.

PoW also provides incentives to motivate participants to maintain the value of Bitcoin by paying Bitcoin for the participant who created the block. PoW agreement algorithm comes with several inherent risks. First, the validity of the block can be intervened when the majority of total participants is occupied by a group with a specific purpose called 51% problem. Second, when the Blockchain is forked, a considerable amount of time is consumed to form the agreed Blockchain until the longest chain is selected after generation of several blocks. This condition causes a transaction delay because the transaction cannot be completed during that time. Lastly, there may be the capacity limit of the Blockchain or the performance limit of each node. Safety of the current Blockchain can be monitored by observing measurable variables in the Blockchain from https://blockchain.info/. Considering that supply and demand of Bitcoin are affected directly or indirectly by measurable variables involved in the formation of a Blockchain, the current study evaluates several variables related to Blockchain formation as features of the Bitcoin pricing process.

3 Proposed method

The proposed method is to predict the price of Bitcoin in dollars. The proposed Bitcoin price prediction method is based on machine learning. The details of the proposed method are shown in Figure 1.

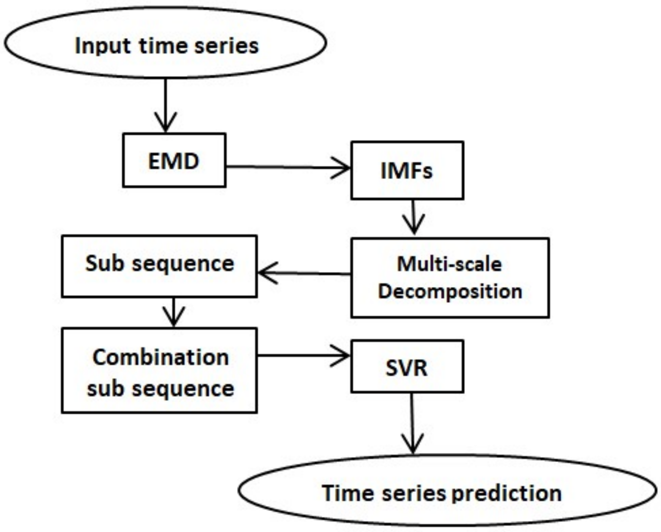

Figure 1: Details of the proposed method.

As shown in Figure 1, the Bitcoin price time series is first decomposed into intrinsic mode functions by the algorithm of signal decomposition into intrinsic component and its residual which contains noise is discarded. In the next step, the inherent components of the signals are converted into subsequences by a multi-scale decomposition method, and the load is predicted by these subsequences with the support vector regression algorithm.

3.1 Data set

The independent variable for this study is the closing price of Bitcoin in USD, taken from the Coindesk Bitcoin Price Index. This price index takes averages into account rather than focusing on a specific exchange. In the case of signals, it is possible to benefit from focusing on one exchange. But the average price is more suitable for this research; Because some exchanges have a separate price drop due to internal problems like Bitfinex which was recently hacked. As a result, there is less noise in the average data set. The closing price of more than one three-class dummy variable is selected, indicating whether the price has increased, the price has decreased, or the price has remained the same.

Using a regression model, rather than a classification model, offers the potential to compare one model to another by capturing the root mean square error (RMSE) of the models. Classifications are made based on the prediction of the regression model, for example: price increase, price decrease or staying the same. Dependent variables are taken from the CoinDesk website, Blockchain info and from the feature engineering process. In addition to the closing price, the opening price, daily high and daily low are also included. The Bitcoin data set used ranges from August 6, 2016 to August 2, 2020. Previous data up to August 2016 has been removed; because it is no longer an accurate representation of the network. In addition to the Open, High, Low and Close data from CoinDesk, the difficulty level and hash rate are taken from the blockchain. Also, the data were averaged and the mean was 0 and the standard deviation was 1.

3.2 Feature extraction

Feature extraction is the art of extracting useful dimensions from data so that machine learning models can make predictions more easily. This can be considered one of the most important parts of the data mining process in order to achieve good results in forecasting tasks. In this article, two simple moving average techniques and signal decomposition into empirical components and their combined technique are used to extract features from time series.

3.2.1 Simple moving average

Simple moving average is an example of a suitable technical indicator that records the average price during the previous days and is one of the time series analysis techniques. Time series analysis is a method of processing time series data to find statistics or important structural features of these data. A simple moving average shows the trend of a stock by calculating the average price of the stock over a certain period of time. The prices used are the final prices of the day. This method removes the noise and thus smooths the movement of the process.

$$SMA_n = \sum_{i=n-T}^{n-1} \frac{x_i}{T} \tag{3.1}$$

In Eq. 3.1, SMA_n is the simple moving average for the n-th day, x_i is the closing price on the i-th day, and T is the duration required in the simple moving average, which is typically 5, 10, 20, 50, 100, and 200 days long.

3.2.2 Signal decomposition into intrinsic components

Component decomposition into intrinsic signals is an efficient and non-linear and non-stationary time-frequency analytical method introduced by Huang et al. This method is based on the simple assumption that each signal consists of different subsets. Non-linear and non-stationary time series can be divided into a group of average and pseudo-periodic signals, where each component is called an intrinsic mode component. The steps of the signal decomposition algorithm into intrinsic components are:

The first step: determining the local maximum and minimum points of the input signal;

The second step: creating the upper envelope by fitting the cubic curve on the local maximum points and creating the lower envelope by fitting the cubic curve on the local minimum points;

The third step: averaging the upper and lower envelopes;

The fourth step: Subtracting the upper and lower envelopes from the input signal given in Eq. 3.2.

$$h_k(t) = x(t) - m_k(t) \tag{3.2}$$

The fifth step: the stopping condition was related to the IMF. This condition is given in Eq. 3.3.

$$D_k(t) = \frac{\sum_{t=0}^{T} |h_t^{k-1}(t) - h_t^k(t)|^2}{\sum_{t=0}^{T} |h_t^{k-1}(t)|^2} \tag{3.3}$$

Sixth step: If there is no fifth step, we place the signal from step four instead of the original signal and continue the process from the first step.

Seventh step: If the step condition is met, the process is finished and $c_1 = h_1^k$ is considered as the first component of the intrinsic mode, which is actually the high frequency component of the $x(t)$ signal.

Eighth step: The remainder is defined as $r_1 = x(t) - c_1^k$ and if it fulfills the condition of being an intrinsic mode component, it is considered an intrinsic mode component, otherwise, if condition A (the number of maxima and minima is equal to or more than the number of zeros) is true, it is assumed as the initial signal and steps one to four are repeated until the next intrinsic mode component is obtained, and if it does not have this condition, it is considered as the remainder r. The remainder can be defined by Eq. 3.4.

$$r_i = x(t) - c_i^k \tag{3.4}$$

Therefore, in fact, the main signal is the sum of the intrinsic mode component plus the remainder, which is obtained by Eq. 3.5.

$$x(t) = \sum_{i=1}^{n} h_i(t) + r(t) \tag{3.5}$$

In Eq. 3.5, $x(t)$ is the original data value. Each of h_i^k shows the i-th value of the intrinsic mode component and $r(t)$shows the remaining component, and n is the number of intrinsic mode components.

3.3 Support Vector Regression

The purpose of the support vector regression based on the regression model adapted from the classification and regression works is a kind of supervised learning system that is used both for grouping and for estimating the fitting function of the data in regression problems, so that the least error occurs in the data grouping or the fitting function. This method is based on the theory of statistical learning, which uses the principle of structural error minimization and leads to a general optimal solution [2, 15] 15]. Eq. 3.6 is used to implement data support vector regression.

$$SVR = \{x_i.t_i\} \quad \forall x_i \in R^m, \quad t_i \in R \tag{3.6}$$

where x_i are inputs that can have m dimensions and t_i is the target. From Eq. 3.7, we can define SVR according to regression.

$$t_i \approx y_i = W^T x_i + b \quad \forall i = 1, 2, \cdots, N. \tag{3.7}$$

The penalty function is defined by Eq. 3.8.

$$L_\epsilon(t_i, y_i) = \begin{cases} 0 & |t_i - y_i| \le \epsilon, \\ R^+ & \text{other} \end{cases} \tag{3.8}$$

where L_ϵ is the penalty function and so that the desired output should be defined between the positive and negative range of ϵ according to Eq. 3.9.

$$\aleph_i = |t_i - y_i| - \epsilon \tag{3.9}$$

In Eq. 3.9, y_i the desired output of the network should be $\aleph_i$ the error resulting from the target and the output is less than ϵ. Finally, the fine is calculated according to Eq. 3.10.

$$L_\epsilon(t_i, y_i) = \begin{cases} 0 & |t_i - y_i| \le \epsilon, \\ |t_i - y_i| - \epsilon & \text{other} \end{cases} \tag{3.10}$$

For all data, Eq. 3.10 should be minimized, for which operational risk is defined by Eq. 3.11.

$$R_{emp} = \frac{1}{N} \sum_{i=1}^{N} L_\epsilon(t_i, y_i) \tag{3.11}$$

Therefore, in general, the goal will be obtained from Eq. 3.12.

$$\begin{aligned} \min \quad & \frac{1}{2} W^T W + C \sum_{i=1}^{N} (\aleph_i^+ + \aleph_i^-) \\ \text{s.t.} \quad & -t_i + y_i + \epsilon + \aleph_i^+ \ge 0 \quad \forall i \\ & t_i - y_i + \epsilon + \aleph_i^+ \ge 0 \quad \forall i \\ & \aleph_i^+ \ge 0 \quad \forall i \\ & \aleph_i^- \ge 0 \quad \forall i \end{aligned} \tag{3.12}$$

In the above Equation, the value of C is a fixed number. Now if we consider its double form for the above Equations, for $-t_i + y_i + \epsilon + \aleph_i^+ \ge 0$ the coefficient a_i^+, for $\aleph_i^+ \ge 0$ the coefficient $a\mu_i^+$ and for $\aleph_i^- \ge 0$ coefficient μ_i^- is placed.

Now, the objective function will be the sum of Eq. 3.12 with its related constraints, and after that the derivation operation will be biased with respect to the weight, finally, for the dual objective function, it will be obtained by Eqs. 3.13, and 3.14.

$$\min \quad \frac{1}{2} \sum_i \sum_j (a_i^+ - a_i^-)(a_j^+ - a_j^-) x_i^T x_i - \sum_i (a_i^+ - a_i^-) t_i + \sum_i (a_i^+ - a_i^-) \epsilon \tag{3.13}$$

$$s.t. \quad \sum_i (a_i^+ - a_i^-) = 0, \quad 0 \leq a_i^+ \leq C, \quad 0 \leq a_i^- \leq C \tag{3.14}$$

4 Evaluation Results by Simulation

In this research, we are faced with the problem of regression and classification. Regression and classification criteria are different from each other. The regression problem is done by using the mean square error (MSE) with its square, and the way of calculating these criteria is shown in Eqs. 4.1, and 4.2. The mean square error measures the deviation of the prediction from the actual data.

$$MSE = \frac{1}{n}\sum_{i=1}^{n}(P_i - A_i)^2 \tag{4.1}$$

$$RMSE = \sqrt{\frac{1}{n}\sum_{i=1}^{n}(P_i - A_i)^2} \tag{4.2}$$

In Eqs. 4.1, and 4.2, A_i is the actual value, P_i is the predicted value and n is the number of samples. The criteria used for classification are three criteria: sensitivity, detection and accuracy. When the data can be divided into positive and negative groups, the accuracy of the results of a test that divides the information into these two categories can be measured and described using sensitivity and specificity indices. Sensitivity (True Positive Rate) means the proportion of positive cases that the test correctly marks as positive. Detection (True Negative Rate) means the proportion of negative cases that the test correctly marks as negative. In mathematical terms, the sensitivity is the result of dividing the true positives by the sum of the true positives and false negatives. In the same way, the diagnosis is the result of dividing the true negatives by the sum of the true negatives and false positives. The rate of sensitivity, detection and accuracy is obtained using the Eqs. 4.3, 4.4, and 4.5.

$$Sensitivity = \frac{TP}{TP + FN} \tag{4.3}$$

$$Specificity = \frac{TN}{TN + FP} \tag{4.4}$$

$$Accuracy = \frac{TP + TN}{TP + TN + FP + FN} \tag{4.5}$$

4.1 Noise elimination

EMD-based oscillation algorithms remove noise by using one of the IMF components; But there is no consensus on the use of IMF to exploit anomalies. Also, considering that the number of IMFs varies depending on the signal, it is not practical to use a single IMF component for displacement. Usually the average IMF of a data set is routinely used. Empirical mode analysis is an efficient and non-linear and non-constant frequency-time data analysis method. Non-linear and non-stationary time series can be divided into a group of average and quasi-periodic signals, where each component is called IMF and is calculated by Eq. 4.6.

$$x(t) = \sum_{i=1}^{n} h_i(t) + r(t) \tag{4.6}$$

The way to extract IMF components is the following algorithm:

1. In the first step, the minimum $x_l(n)$ and the local maximum $x_u(n)$ are extracted from the original signal $x(t)$.
2. In the next step, local minimum and maximum are interpolated and upper and lower functions are made. ($x_l(t)$ and $x_u(t)$).
3. In the third step, the average of these two functions calculated in step 2 is obtained.
4. The average difference is calculated from the original signal.

5. The remaining values are also calculated.

To train the proposed SVR models, we first divide the dataset into two parts, training and testing. Then we used EMD to extract the features which also performs noise removal as a training data set.

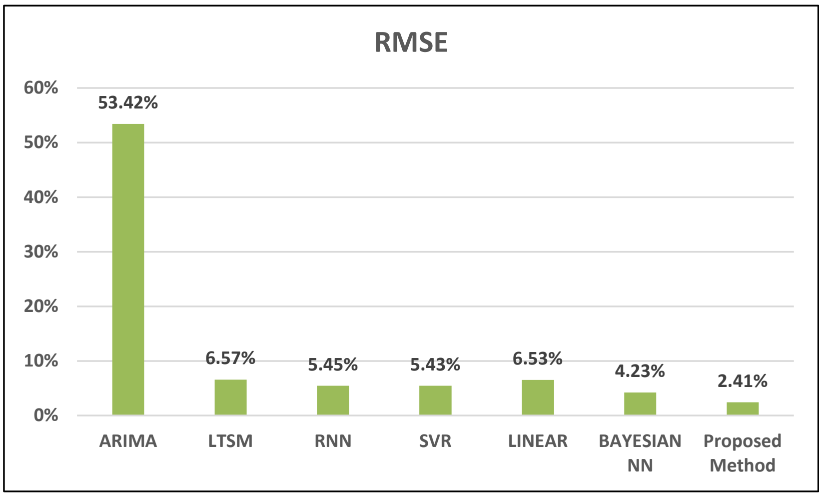

Figure 2: RMSE comparison of the proposed method with previous methods.

The prediction results of the proposed method are based on the combination of support vector regression and signal decomposition into intrinsic components on 260 time series samples. After calculation and prediction, the amount of $RMSE$ and DA was obtained, the results of which are shown in Figures 2 to 5.

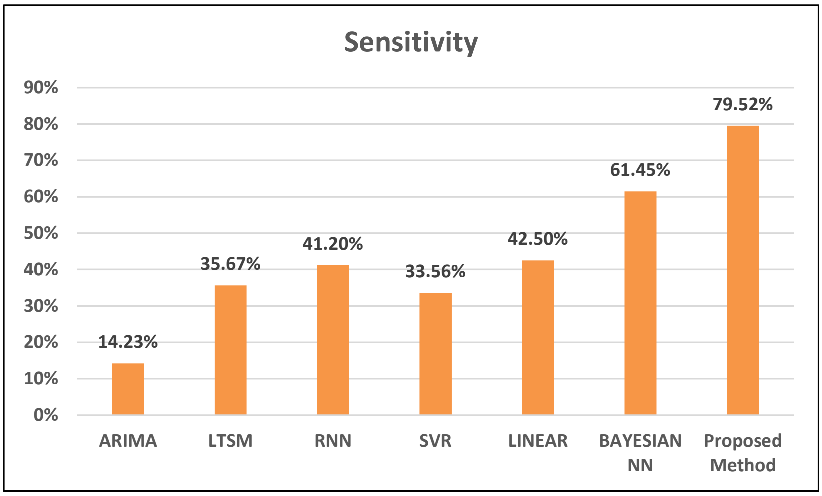

Figure 3: Comparison of the Sensitivity of the proposed method criterion with previous methods.

As shown in figures 2 to 5, the comparison of $RMSE$, Sensitivity, Specificity and Accuracy criteria has been done. As shown in Figure 1, the $RMSE$ of the proposed method is equal to 2.41, which is lower than the previous methods. The reason for this is the use of the EMD method to decompose the signal into its intrinsic components. Due to the fact that the signal noise is eliminated in this method, the efficiency is increased and the mean square error is reduced.

5 Conclusion

Bitcoin is a successful encryption project and has been widely explored in the fields of economics and computers. In this article, we analyze the bitcoin price series using regression using signal decomposition technique into intrinsic components. Investigating nonlinear relationships between input functions based on network analysis can explain the analysis of the bitcoin price series. Bitcoin diversity should be modeled and more appropriate. This goal can be by

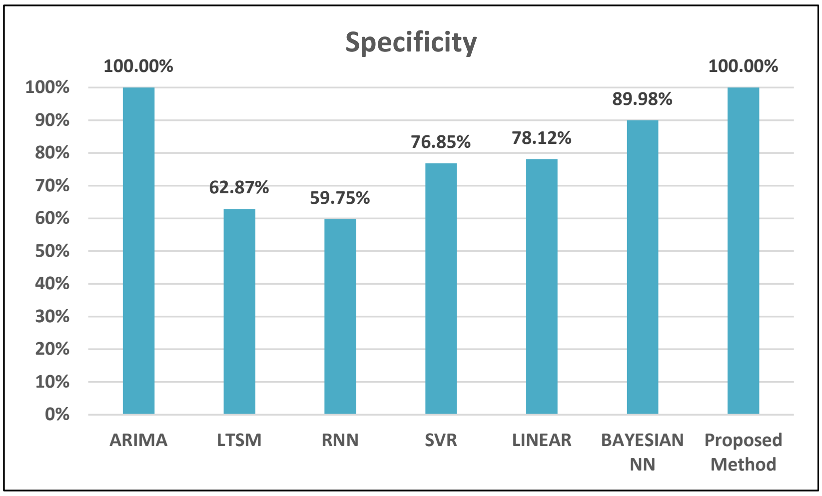

Figure 4: Comparison of the Specificity of the proposed method criterion with previous methods.

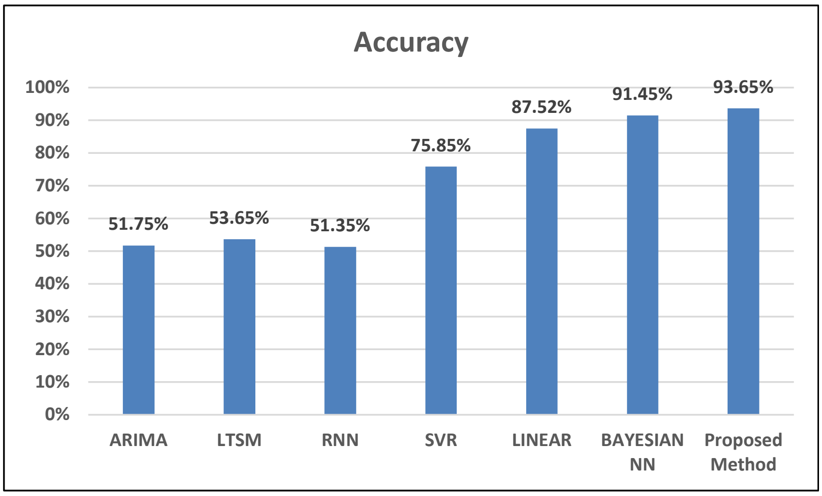

Figure 5: Comparison of the Accuracy of the proposed method criterion with previous methods.

adopting other machine learning methods or considering new input capabilities related to bitcoin variability. The decomposition of the component into the inherent signals is an analytical and efficient non-linear and non-constant method of time data frequency. This method is based on the assumption that each signal consists of different subsets. Non-linear and unnecessary time series can be divided into a group of average and quasi-periodic average signals, where each of the inherent fashion components are called. This article uses support vector regression as well as signal decomposition into intrinsic components to predict bitcoin price.

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