Analysis of LSTM and Derivative Models for Bitcoin Prediction Research

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Abstract. Bitcoin, the first cryptocurrency, has attracted much attention in the digital currency market, and its price volatility is affected by a variety of factors, posing a challenge to investors. For the sake of analytical feasibility, many studies have adopted simplified modeling assumptions. This may overlook certain key nonlinear features of the market, such as the complexity of investor behavior and the volatility of market sentiment. This study explores the application of Long Short-Term Memory (LSTM) networks and their derivative models in predicting Bitcoin prices. Recognizing the complex nature of Bitcoin's market dynamics, the research delves into the effectiveness of LSTM in capturing the nonlinear patterns of cryptocurrency prices. Furthermore, it extends the analysis to derivative models like MSM-LSTM and Empirical Mode Decomposition (EMD) LSTM, evaluating their ability to enhance prediction accuracy by addressing the limitations of the standard LSTM. This study provides an in-depth analysis of the effectiveness of LSTM and its derived models in the practical application of Bitcoin price prediction, with a special focus on their ability to capture non-linear patterns in the market. In Bitcoin price prediction, LSTM models have limitations but also great potential in capturing nonlinear patterns in the market. Extended models based on their own can perform well in Bitcoin price prediction. This study contributes to the field by suggesting strategies to improve the accuracy of the model and by providing ideas for developing trading strategies based on the results of the analysis.

Keywords: Bitcoin Prediction, LSTM, Deep Learning, Derivative Models, Time Series Analysis.

1. Introduction

Since its inception in 2009, Bitcoin, the first cryptocurrency, has transformed the digital currency landscape with its volatility and decentralization. Influenced by factors like market sentiment and regulations, Bitcoin's price dynamics offer unique challenges and opportunities.

Machine learning, especially Long Short-Term Memory Networks (LSTMs), plays an important role in improving financial market prediction [1]. This study focuses on the use of LSTM and its derivative models (e.g., Multi-Scale Memory-Enhanced (MSM) LSTM and Empirical Mode Decomposition (EMD) LSTM) for Bitcoin price prediction and explores their effectiveness in capturing nonlinear patterns in cryptocurrency prices. By analyzing these models to improve on the limitations of the standard LSTM, this study provides strategies to improve the accuracy of the models and provides ideas for developing trading strategies based on the results of the analysis.

Although there have been studies focusing on the impact of supply and demand, economic factors, and other factors on the price of Bitcoin, the dynamics and interactions of these factors still need to be explored in depth.

This study focuses on LSTM and its derivatives, like MSM-LSTM and EMD-LSTM, for predicting Bitcoin prices. We aim to analyze how these models address the non-linear nature of cryptocurrency prices and improve prediction accuracy.

The research contributes to financial technology by analyzing advanced models for cryptocurrency market predictions and bridging the gap between theoretical models and practical trading strategies. This study provides insights for investors and analysts in understanding and navigating Bitcoin's volatile market.

2. Case Description

2.1. Factors Influencing the Price of Bitcoin

Since its launch in 2009, Bitcoin has become the most prominent cryptocurrency, characterized by significant price volatility. This volatility stems from several key factors. Firstly, market supply and demand play a pivotal role. That is, when all else remains constant, its price rises as the quantity of money demanded in the market increases, and falls as the quantity of money supplied increases [2]. Unlike traditional currencies, Bitcoin's supply is capped at 21 million coins, which inherently limits supply and can lead to price surges when demand spikes [3]. Total current circulation is 19.58M (investing.com accessed on Dec 24th, 2023). Additionally, investor sentiment significantly impacts Bitcoin's value. In the current Bitcoin market, most of the trading is still done by short-term traders as well as some speculators, and this segment of the population is highly susceptible to mood swings due to social media discussions, which can have an impact on the price of Bitcoin. What's more, although short-horizon investment in Bitcoin can help investors hedge global equity market uncertainty, bitcoin itself is still affected by the global economic climate. The effects of all of the above factors are reflected in the price fluctuations of Bitcoin and show certain patterns in long-term observations. This can therefore be predicted by several machine learning and deep learning models.

2.2. Advantages and Disadvantages of LSTM

Time-series data, a frequent structure in many financial, medical, and industrial applications, is especially well-suited for handling Long Short-Term Memory (LSTM) networks, a particular sort of Recurrent Neural Network (RNN) [4]. LSTMs are designed to remember information over long periods, making them ideal for time-series data where understanding past context is crucial. At the same time, financial markets, including cryptocurrencies like Bitcoin, often exhibit non-linear and complex patterns. LSTMs can model these relationships effectively. This makes LSTMs more robust and accurate for financial forecasting compared to linear models. In scenarios like Bitcoin price prediction, where the data is often volatile and contains hidden patterns, LSTM's structure is well-equipped to uncover and leverage these patterns [5]. This leads to higher prediction accuracy, making LSTMs a popular choice in financial time-series forecasting. These features collectively contribute to their widespread use and effectiveness in tasks like predicting Bitcoin prices.

3. Analysis of the Problems

3.1. Some Limitations and Shortcomings of Using LSTM Models

Although LSTMs are a popular choice in financial time-series forecasting, they also have some disadvantages due to their limitations.

The performance of LSTM models is highly sensitive to the choice of hyperparameters, which requires extensive experimentation to optimize. The caliber of the input data affects LSTMs. Predictions can be misled by noisy or inaccurate data, and data on the Bitcoin market can be especially unpredictable and noisy. Thus using LSTM models for prediction places a higher demand on the quality of the dataset used. While LSTMs can capture patterns in price data, they may not effectively account for external factors affecting the market, such as regulatory changes or significant global economic events, unless these factors are explicitly included in the model. LSTMs can still overfit the data, especially when dealing with the highly volatile and somewhat unpredictable nature of Bitcoin prices. These factors must be carefully considered when employing LSTMs in financial forecasting models. Therefore, we can adopt some derivative models based on LSTM to improve its limitations and shortcomings, so that it can obtain higher prediction accuracy and smaller prediction error.

3.2. Some Derived Models of LSTM

To compensate for the shortcomings of the LSTM model itself, many derivative models based on it have been produced, which improve the prediction accuracy from different aspects.

3.2.1. MSM-LSTM

When it comes to predicting and quantifying uncertainty in turbulent systems with high intrinsic attractor dimensionality, the MSM is a potent data-driven technique. The attractor's global statistical information is designed to be captured by design, and it has very minimal computational complexity as compared to LSTM or GPR [6]. This hybrid model combines LSTM's ability for short-term prediction with MSM's strength in ensuring long-term stability. Specifically, MSM is employed to model regions of the attractor not well-represented in the training data, ensuring predictions remain close to the attractor and converge to the statistical invariant measure in the long term. The integration of MSM with LSTM addresses LSTM's limitation in long-term predictions, especially in chaotic systems where prediction errors can accumulate over time. It capitalizes on LSTM's accurate short-term forecasting capabilities while using MSM to maintain stability in predictions over extended periods.

3.2.2. EMD-LSTM

This model combines EMD and LSTM for improved financial time series forecasting. EMD-LSTM combines the sequence prediction power of LSTM with EMD's capacity to break down financial time series into intrinsic mode functions (IMFs) of various time scales [7]. EMD-LSTM decomposes the time series into IMFs, enabling the model to handle various frequency components separately. This is particularly beneficial for complex financial data like stock prices or cryptocurrencies. By analyzing each decomposed component individually, EMD-LSTM can offer more accurate and robust predictions, especially for non-linear and non-stationary time series [8]. EMD helps in isolating noise and trend components from the raw data, which can then be more effectively processed by the LSTM model. This hybrid approach signifies an advanced step in financial time series forecasting, leveraging the strengths of both EMD in signal processing and LSTM in sequence prediction [9].

4. Suggestions

Bitcoin is chosen as the object of study because, as the world's earliest and currently most mainstream cryptocurrency, Bitcoin has received widespread attention in the fields of economics, cryptography, and quantitative investment. It has huge commercial value in itself. The fluctuation of Bitcoin market price is related to the future profit and loss of investors. Analyzing Bitcoin price fluctuations and making predictions can help traders make the right trading strategy.

To enhance LSTM and its derivative models for tasks like Bitcoin price prediction, a multifaceted approach is recommended [10]. Optimizing hyperparameters, such as the learning rate and the configuration of hidden layers, is critical. This can be achieved through techniques like grid search or Bayesian optimization. In terms of data preprocessing, normalization, or standardization of input data, alongside strategic feature engineering, is essential. Implementing advanced regularization methods, like dropout, can mitigate the risk of overfitting [11].

Additionally, by including attention mechanisms in LSTM, the model's capacity to concentrate on crucial segments of the input sequence can be greatly enhanced [12]. Ensemble methods, combining predictions from various LSTM configurations, can also enhance accuracy and robustness. Exploring advanced LSTM architectures, including Bidirectional LSTM or hybrid models with CNNs, can offer more comprehensive data analysis. Finally, customizing loss functions to align with specific financial prediction objectives ensures the model's relevance to the task.

5. Conclusion

This study highlights the complexity of the Bitcoin market by exploring the prediction of its price. This paper explores the research of deep learning prediction models for stock prediction, especially Long Short-Term Memory Networks (LSTM) and their derived models. Bitcoin's price volatility is influenced by multiple factors, so researchers need more optimized models that can capture nonlinear patterns. Although the application of LSTM models in financial time series forecasting suffers from some limitations, this study proposes a series of improvement strategies. These strategies include optimizing hyperparameters, data preprocessing, and introducing attention mechanisms to improve model performance. Meanwhile, derived models such as MSM-LSTM and EMD-LSTM are introduced, which play an active role in improving the limitations of LSTM models. These models provide more accurate and robust predictions for the processing of nonlinear and unsteady time series data. Overall, the Bitcoin price prediction field is increasingly relying on deep learning techniques, with LSTMS and their derived models showing great potential when dealing with the market dynamics of cryptocurrencies.

The future of Bitcoin price forecasting appears to be increasingly reliant on advanced machine-learning techniques. LSTM and its derivatives show promise in handling the cryptocurrency's volatility and complex market dynamics. Future developments may include incorporating more diverse data sources, improving algorithms to better capture market sentiment and regulatory changes, and integrating real-time global economic indicators. The accuracy of these models is likely to improve, making them invaluable tools for investors and analysts in navigating the unpredictable cryptocurrency market.

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