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Geometric Brownian Motion and Its Application in the Forecasting of Bharat Heavy Electricals Limited Trends

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Abstract

This study evaluates the effectiveness of Geometric Brownian Motion (GBM) in predicting the stock market behavior of Bharat Heavy Electricals Limited (BHEL), specifically focusing on forecasting the open and close stock prices over a forthcoming ten-day period. Using historical share price data from July 14, 2023 to March 31, 2024, the GBM model is applied to predict stock price movements from April 1, 2024, to April 15, 2024. The results demonstrated high accuracy in the model's predictions, with discrepancies between forecasted and actual values generally narrow, highlighting specific instances of notable precision. Despite its effectiveness, the study identified limitations in predicting higher stock price values, suggesting a need for further model optimization to enhance accuracy at these data points. The findings emphasize the utility of advanced statistical models like GBM (Geometric Brownian Motion) in financial forecasting, aiding traders and investors in making informed decisions, with recommendations for future refinements to increase the model's applicability and precision across different market conditions.

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1. Introduction

The stock market provides a platform for buying and selling equity shares, where investors seek long-term growth and traders aim for short-term gains. Stock exchanges like BSE and NSE in India facilitate these trades through brokers offering online services. Key terms include "bull market" for rising prices and "bear market" for declines. Investors focus on profitable companies, as returns depend on careful selection and timing.

This study analyses stock market complexities, emphasizing structure, trading mechanisms, and strategies. It evaluates company performance, uses predictive models to forecast trends, examines derivatives, and employs tools like Geometric Brownian Motion to enhance decision-making and optimize profits.

2. Literature Review

The Markov chain model has been extensively utilized by scholars to analyse and forecast share price behaviour in the stock market due to its Markov properties, or short-term memory. Introduced by Russian mathematician Andrei Andreevic Markov (1856–1922), the Markov chain has long been applied in stock market analysis and prediction. Over the past decade, many studies have employed the Markov chain model to simulate stock market behaviour.

For instance, Aparna and Sarat (2015) evaluated the fluctuation of State Bank of India's (SBI) share price. Raheem and Ezepue (2016) measured and forecasted daily variations in share prices and return of the first-generation bank (NSM) on the Nigerian stock market using a different methodology. Bhusal (2017) analysed and forecasted the Nepal Stock Exchange Index (NEPSE) with the Markov chain model. Aparna and Kakaty (2017) predicted future potato prices using market data from June 4, 2014, to April 21, 2017, to forecast prices for the next fifteen days.

In the Indian stock market context, Padi et al. (2022) employed the Markov chain model for analysing and predicting stock market trends. They conducted an exploratory data analysis using real-

time data on daily closing prices of Nifty banks from the NSE. Their results indicated a high probability that Nifty Bank's closing price would rise if the bank was in a rising state. Singh et al. (2017) assessed a Markov chain model for forecasting Nifty 50's opening share price changes.

Dmouj (2006) described geometric Brownian motion, explaining it as a random walk and providing an analytical resolution based on this model. Omar and Jaffar (2014) also used the geometric Brownian motion model to predict closing stock prices for small businesses listed on the Malaysian stock exchange. Their study showed the model's accuracy in predicting short-term stock prices, specifically for a two-week period.

3. Data Set and Methodology

3.1 Data Set

Bharat Heavy Electricals Limited (BHEL), a leading Indian engineering and manufacturing PSU founded in 1964, plays a vital role in India's power sector by producing equipment for power generation like boilers, generators, and turbines. The Indian government's significant stake in BHEL underscores its strategic importance to the economy, particularly in infrastructure and energy.

Data collection for this analysis spans from July 14, 2023, to March 31, 2024—a period marked by notable events like the Chandrayaan-3 mission, highlighting BHEL's collaboration with ISRO and its impact on India's industrial and space technology advancements. Financial data from platforms like Yahoo Finance provides essential metrics, including daily closing prices and market capitalization, which are invaluable for financial research on BHEL.

3.2. Method and Design of Study

A stochastic process is a random process, that is, a change in the state of some system over time whose course depends on chance and for which the probability of a particular course is defined. It is basically a family of random variables, defined on a given probability space, indexed by the time variable t, where t varies over an index set T according to Thygesen (2023).

A variable is said to follow a stochastic process when its value changes in an unexpected way over time. A stochastic or random process is a family or collection of random variables that are indexed by a mathematical set so that each random variable in the process has a unique relationship with an element in the set. The values of each random variable in the family come from a set of numbers called the state space; this set is also called the index set or time set. It is this set that is utilized to represent the random variables. Stochastic processes are classified using the dependency relationships of the random variables, the state space, and the time parameter, together with the specification of the joint distribution function. The Markov chain is one specific type of random process among them. The Markov chain was initially introduced by Russian mathematician Andrei Andreevich Markov (1856–1922). The Markov chain is a distinct type of stochastic process in which the future value of the variable can only be inferred from its present value, not from its past data.

3.2.1 Brownian Motion

Brownian motion, also known as a Wiener process, is a mathematical model used to describe the random movement of particles suspended in a fluid. This phenomenon was first observed by botanist Robert Brown in 1827, who noticed that pollen grains in water moved in an erratic and unpredictable manner. The mathematical formulation of Brownian motion was later developed by Albert Einstein in 1905 and independently by Marian Smoluchowski, providing a theoretical foundation for understanding molecular motion by Einstein (1905)

Mathematically, Brownian motion is defined as a continuous-time stochastic process that satisfies the following properties defined by Karatzas and Shreve (1991)

1. $B(0) = 0$
2. The increments $B(t)-B(s)$ for $0 < s < t$ are normally distributed with mean 0 and variance $t-s$
3. The increments are independent.
4. $B(t)$ has continuous paths with probability 1.

Brownian motion is fundamental in various fields such as physics, finance, and mathematics. In physics, it describes the random movement of particles in a fluid. In finance, it is used to model stock prices and other financial instruments by Uhlebeck and Ornstein (1930)

3.2.1.1 Geometric Brownian Motion

An effective mathematical technique for forecasting asset values over time is the Geometric Brownian Motion approach. For BHEL, which has volatility, the Open and Close prices will be predicted using Geometric Brownian Motion in this study.

The financial market is a complicated system with many interrelated, nonlinear elements influencing it. Thus, it is crucial to know when and how to make judgments while trading this market (Naranjo et al., 2018). Derivative trading products are now attracting a lot of interest from traders and investors. This document is a financial contract that attempts to carry out a purchase or sale of commodities or assets between two or more parties (Gunarsa, 2019).

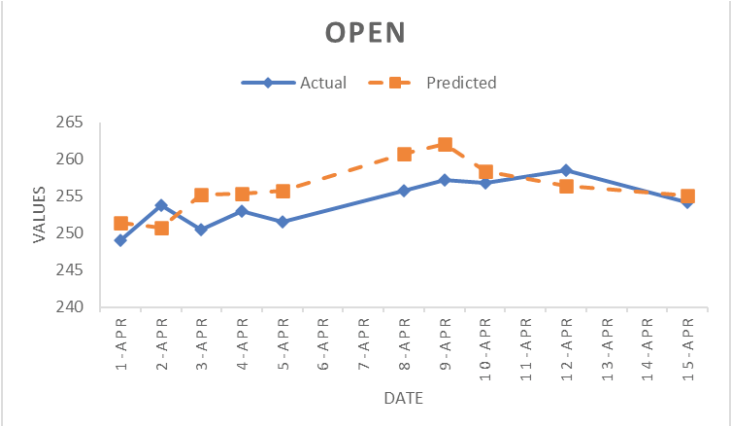
4. Results

The stock price of BHEL was gathered between July 14, 2023, and March 31, 2024. Geometric Brownian Motion is used to forecast the price for the next 10 days based on the past data of the stock price between these dates. The period of the 10 anticipated days is between April 1, 2024 – April 15, 2024.

4.1 Opening Stock Price

The opening stock price is the initial price at which a stock begins trading when the market opens for the day. Influenced by factors such as after-hours trading, news, and economic indicators, it reflects investor sentiment at the start of the trading session (Madura, 2020).

Figure1: Comparison of Actual and Predicted values of Opening Stock Price

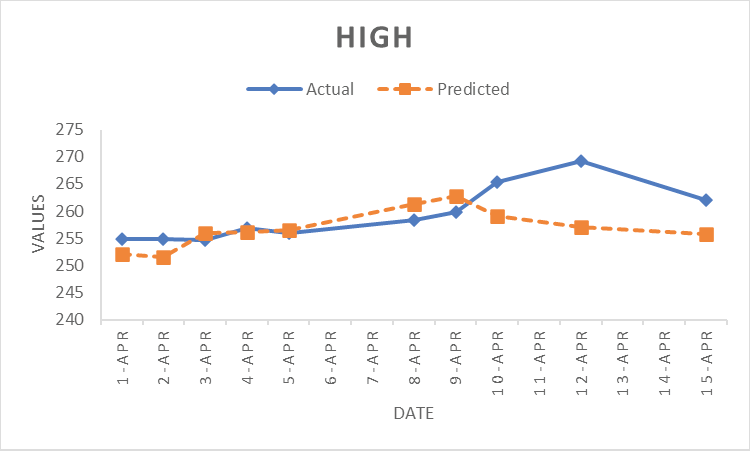


The forecasts closely align with actual stock prices on most days, underscoring their accuracy. Notably, predictions for April 10 and April 15 are especially precise, nearly mirroring the actual values. The typical deviation between forecasted and actual prices ranges between -3.5 and +3.5, demonstrating both accuracy and consistency. This level of precision suggests the robustness of the forecasting method, providing a strong foundation for informed decision-making with only minor adjustments needed for enhancement.

6.2 Highest Stock Price

The highest stock price is the maximum value a stock reaches during a specific trading period. This peak reflects heightened investor enthusiasm and favorable market conditions, often influenced by positive news or strong economic indicators. It represents the highest level of market confidence and demand for the stock during that time (Madura, 2020).

Figure 2: Comparison of Actual and Predicted values of Highest Stock Price pf the day

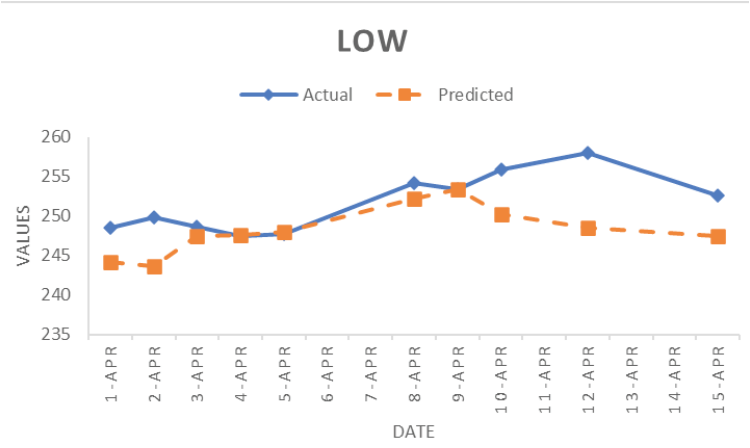


The forecasts in this dataset exhibit a strong level of accuracy, with many predicted values closely matching actual numbers. For instance, on days when the actual values were 256.9 and 255.9, the predicted values were 256.08 and 256.45, respectively. Discrepancies generally range from around -1.8 to +3.08, reflecting the model's accuracy. This consistent alignment between forecasts and actual figures highlights the model's ability to closely track real-world outcomes, underscoring its effectiveness as a forecasting tool.

6.3 Lowest Stock Price

The lowest stock price is the minimum value a stock hits within the same timeframe. This low indicates periods of market pessimism or adverse news, where investor sentiment is notably weak. It highlights the lowest level of demand and confidence in the stock during that time (Madura, 2020).

Figure 3: Comparison of Actual and Predicted values of Lowest Stock Price of the day

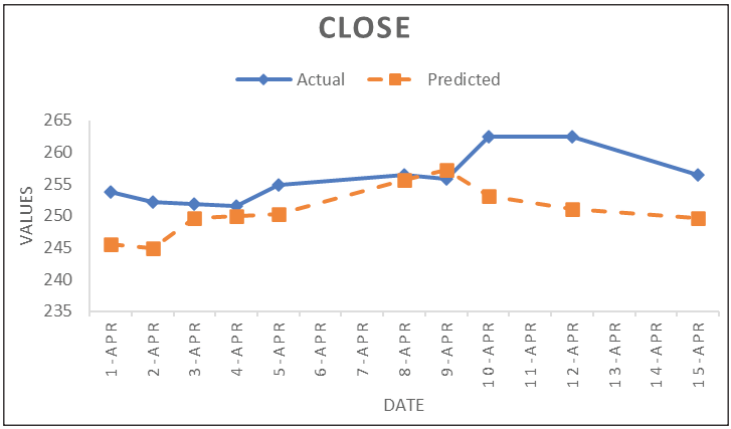


The forecasts demonstrate reliable predictive accuracy, often aligning closely with actual values. Notably, on days with actual values of 247.45 and 247.75, the predicted values of 247.67 and 247.99 showcase exceptional accuracy. Variations between projected and actual values remain tightly constrained, though larger discrepancies—up to 5 units—occur on days with higher actual values, such as 255.95 and 258. Despite these larger gaps, the forecasting method consistently tracks actual data well, affirming its robustness as a predictive tool.

4.2 Closing Stock Price

The closing stock price is the final price at which a stock trades during a regular trading session. It serves as a benchmark for performance and is influenced by the day's trading activity, economic news, and investor sentiment (Madura, 2020).

Figure 2: Comparison of Actual and Predicted values of Closing Stock Price



The BHEL stock price forecasts show a commendable degree of accuracy, with projections closely matching actual values on several days. For instance, on days with actual prices of 256.45 and 255.75, the forecasts were 255.73 and 257.21, respectively, demonstrating the model's effectiveness in these cases. However, some notable discrepancies emerge at higher actual values, such as 262.5, where predicted values were lower (e.g., 253.18 and 251.11). This trend suggests that, while the model performs well within a certain range, adjustments may be needed to improve accuracy at higher data points.

5. Conclusion

The stock market, a critical component of the global economy, facilitates buying and selling of equity shares through brokers, with investors targeting long-term growth and traders focusing on short-term gains. In India, major exchanges like the BSE and NSE handle most trading activities. Understanding market dynamics, such as bull and bear trends, is essential for informed decision-making.

Profit maximization, strongly influenced by a company's performance, relies on strategic timing and selection of high-earning companies. Statistical models like Geometric Brownian Motion (GBM) are valuable in forecasting stock prices and trends,

offering insights for strategic trading. This study used GBM to forecast stock prices from July 14, 2023, to March 31, 2024, with results showing high accuracy, particularly for opening, high, and low prices within a range of -3.5 to +3.5 units. Although the model showed limitations at higher price points, refinement could enhance its accuracy, making it a robust tool for financial forecasting.

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A vibrant market is at its best when it works for everyone: https://www.finra.org (Available online, Dated: 14/04/2024)

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