MATH 4581 Final Project
Professor John Lindhe
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PROPOSAL:

STOCKSIM:
MONTE CARLO
STOCK FORECASTING MODEL

Utilize the Brownian and Geometric Brownian Motion concepts to perform Monte Carlo simulations to predict future stock price movements.

PROJECT OVERVIEW

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Project Introduction

This project aims to utilize the concepts of Brownian and Geometric Brownian Motion, as discussed in our course, to execute Monte Carlo simulations with Python. This involves predicting 1,000 future stock price movements using historical stock data sourced from the **'yfinance'** library. Additionally, we can model these future prices under various market scenarios by computing key statistical measures such as the daily and annualized returns (μ) and the volatility (σ) from this historical data. This simulation applies to any stock listed on the exchange, providing a broad utility.

This simulation's culmination is applying a 95% confidence interval incorporating potential future stock prices within a statistically derived range. This tool is precious for investors globally, as it allows them to speculate more accurately on future prices and hedge against the inherent risks of market investment, thereby making informed financial decisions based on sophisticated risk management and predictive analytics techniques.

Questions Asked

1) What is the probability that the stock price will be above a certain level at the end of a specified time period?
2) What is the annualized volatility (σ) of the stock?
3) What is the annualized average return (μ) of the stock?
4) What is the probability the stock will be above X-Price after 1 Year?
5) What is the 95% Confidence Interval for the price of the stock after 1 Year?

Data Used

Yahoo Finance Historical Data Library - 'yfinance'

The Yahoo Finance Historical Data Library is an aggregate dataset with historical closing prices, trading prices, and other financial data for equities listed on various exchanges.

Mathematical Concepts

1) **Daily Returns** - $R(t) = \frac{P(t) - P(t-1)}{P(t-1)}$

Where $R(t)$ represents the return on day 't', and $P(t)$ & $P(t-1)$ are the adjusted closing prices of the chosen stock on day 't' and 't-1', respectively.

2) **Annualized Average Return** (μ) = $\overline{R}$ x 252

Where $\overline{R}$ is the average daily returns & 252 is the typical number of trading days in a given year.

3) **Daily Standard Deviation of Returns** (σ) = $\sqrt{\frac{1}{n-1}\sum_{i=1}^{n}(ri - \overline{r})^{2}}$

Where ri is the return on day i, $\overline{R}$ is the average daily returns, and N is the total # of returns.

4) **Annualized Volatility** (σ) = σ $\cdot \sqrt{252}$

Where the annualized volatility is the standard deviation of returns scaled to an annual measure.

5) **Stock Price Forecasting (Geometric Brownian Motion)** =

$$S(t-1) \cdot e^{(\mu - \frac{1}{2}\sigma^{2}) \cdot St + \sigma \cdot \sqrt{St} \cdot Z}$$

Where St is the stock price at time 't', μ is the annualized mean return, σ is the annualized volatility, St is the time increment (1/252), and Z is a random draw from the standard normal distribution.

6) **Probability of Stock Price Being Above a Specific Level**

$$P\ (X \geq St) = \frac{\#\ of\ Times\ St \geq X}{\#\ of\ Simulations}$$

Where St is the stock price at the end of time period 'T', and X is the specified price level (X-Level).

7) **95% Confidence Interval for Stock Price** =

$CI_{2.5}$ = 2.5th Percentile of St & $CI_{97.5}$ = 97.5th Percentile of St

This calculates the 2.5th and 97.5th percentiles to determine the 95% confidence interval.

Implementation

This project utilizes Python to implement an in-depth financial modeling tool that simulates future stock prices using historical financial data from Yahoo Finance. It uses the **'yfinance'** library to obtain historical price data for the given stock ticker the user enters. After fetching the data, the program calculates daily returns and other statistical measures using the above formulas, such as annualized returns and annualized volatility. The primary function in the code utilizes a Monte Carlo Simulation based on Geometric Brownian Motion (GBM), a standard model used for financial time-series analysis that incorporates drift & randomness to forecast future stock price movements.

Furthermore, the user inputs a specific price level (X-Level) of interest, and the program calculates the probability that the stock price will exceed this level at the end of the given year. On top of that, the program computes the 95% confidence interval for the final stock price based on the 1000 simulations. In the end, the results are displayed graphically using **'matplotlib'**, which shows multiple simulation paths and critical statistics like the target price level & confidence intervals. This project is practical as it uses historical data for risk assessment and investment decision-making, essential for portfolio managers or professional investors managing billions of dollars.

Results

Example 1 - Starbucks

```
Enter the stock ticker: SBUX
Enter the price level you're interested in (X-Level): 95
Today's Stock Price (S0): $87.61
Estimated annualized average return (mu): 19.45%
Estimated annualized volatility (sigma): 26.50%
Probability that the stock price will be above 95.0 at the end of 1 year: 63.70%
95% confidence interval for the stock price at the end of 1 year: $65.17 to $173.27
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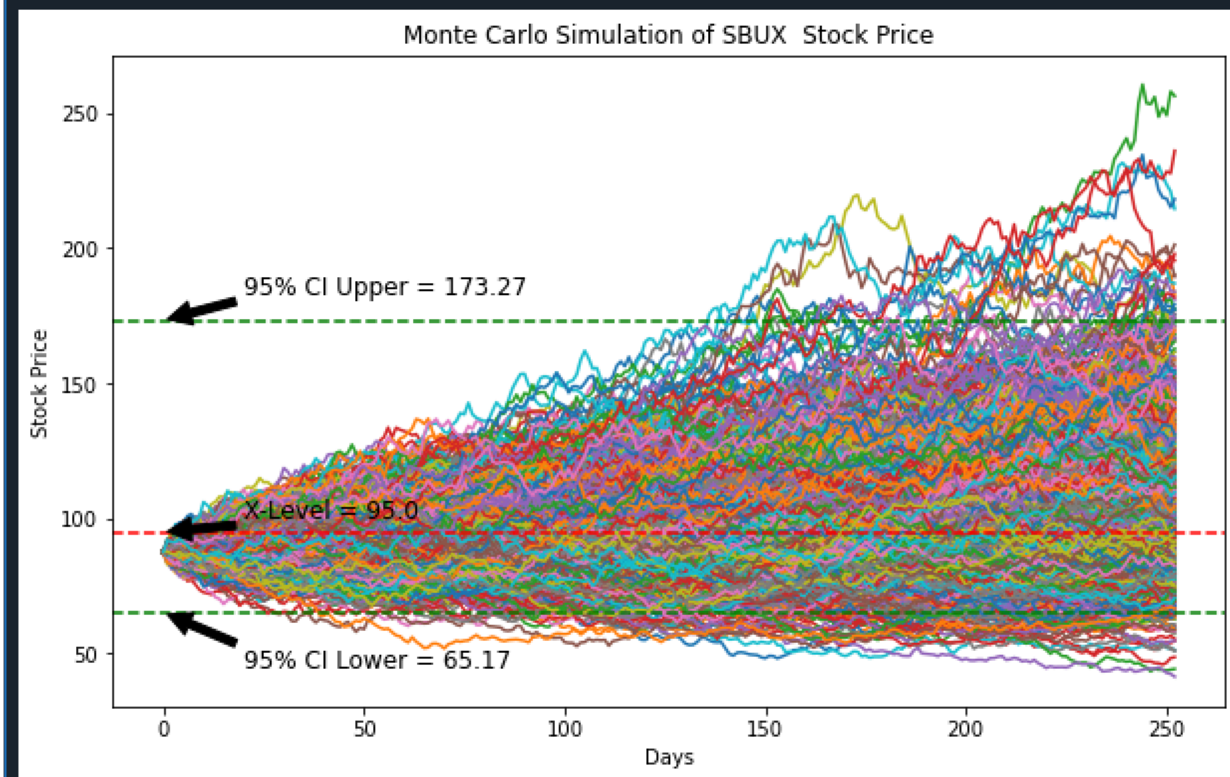

For Starbucks Corporation (SBUX) stock using the model predicts a 63.7% chance that the stock price will surpass $95 within a year, which aligns with analyst price targets on Wall Street, starting at today's closing price of $87.61, with an estimated annual growth rate of 19.45% and volatility of 26.50%. Utilizing the 95% confidence interval for the future stock price ranges broadly from $65.17 to $173.27, indicating uncertainty yet optimism in the stock price performance.

Example 2 - Microsoft

```
Enter the stock ticker: MSFT
Enter the price level you're interested in (X-Level): 473.60
Today's Stock Price (S0): $399.12
Estimated annualized average return (mu): 23.20%
Estimated annualized volatility (sigma): 25.80%
Probability that the stock price will be above 473.6 at the end of 1 year: 55.50%
95% confidence interval for the stock price at the end of 1 year: $298.08 to $802.30
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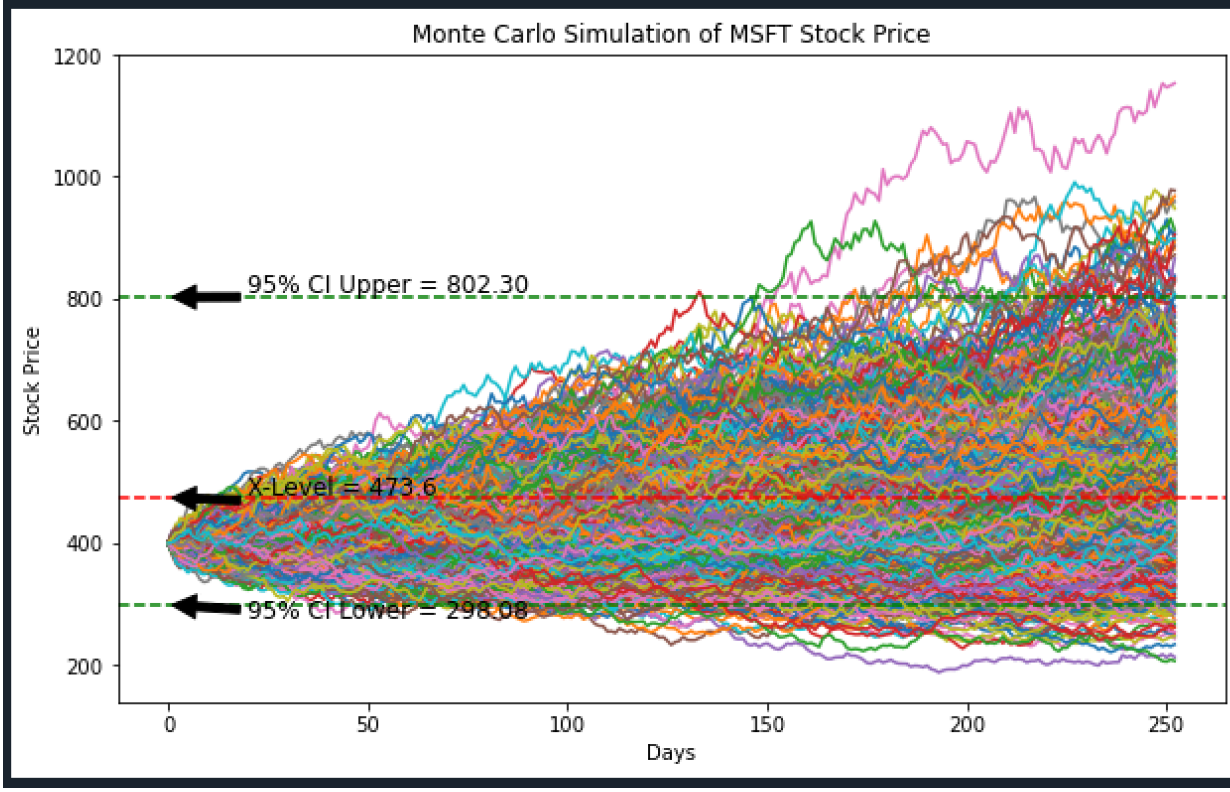

For Microsoft Corporation (MSFT), the model estimates a 55.5% probability the stock price will exceed the given target level (X-Level) of $473.60 within one year from today's stock price of $399.12, with an anticipated annual return of 23.20% and volatility of 25.8%. The 95% confidence interval for the stock's price after one year is anticipated to be between $298.08 and $802.30, showing immense volatility given the historical past of technology stocks in the market.

Implications

Although the model provides extreme value to investors and uses historical prices to simulate a range of possible future stock prices for any equity on the exchange, it comes with its limitations. For example, the model offers a data-backed approach for anticipating future price action; the projections are inherently limited by the assumption that past performance indicates future results. Since its inception, this concept has dictated the stock market, proving that every investor needs to be smart enough to outperform the market with some kind of arbitrage or regression model that accounts for random events such as recessions or market turmoil.

Additionally, investors who plan to implement this strategy should integrate it while using other strategies, such as technical or fundamental analysis, which give a baseline approach to the price of any equity in the market. Lastly, cross-referencing the model with option prices on the CBOE Exchange can show if the model does an accurate job of predicting the given price level (X-Level), as the underlying options will match the price discrepancy.

Real-World Use & Potential Model Improvements

Monte Carlo Simulations are critical in many areas within the financial sector; they provide versatility for many areas, such as portfolio management, derivative pricing, risk assessment, retirement planning, and capital budgeting. The model's ability to simulate a range of possible outcomes based on previous data, such as volatility and returns, helps institutional investors anticipate and prepare for future market scenarios. For example, in portfolio management, they can help devise optimal asset allocations that align risk and reward for the Capital Asset Pricing Model or CAPM.

Although the simulation does an excellent job at predicting future outcomes, more factors could be implemented to optimize the model's accuracy and align more with market sensitivities. Integrating macroeconomic data could provide broader context simulations, aligning closer with real-world dynamics. Additionally, adding a risk-free rate (US 10-Year Treasury Yield) can uncover hidden patterns in the data and, in turn, enhance the model's accuracy. Lastly, backtesting the model with previous deviations in stock prices can find factors that also affect equity prices, such as commodity prices, market outlook, and management decisions.