# Integrating LSTM networks and Geometric Brownian Motion for Stock Trend Prediction and Risk Management

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## Introduction

Problems
1. Unpredictable stock trends
2. Ineffective risk management
3. Impulsive trading behaviors

Solution
1. LSTM model – Predicts stock price trends to guide decisions
2. Geometric Brownian Motion simulation – Models risk through potential price fluctuations
3. Systematic trading – Uses LSTM predictions for consistent profits and reduced impulsive decisions.

## Background

Long Short-Term Memory Network (LSTM) - a type of recurrent neural network (RNN) designed to retain long-term dependencies and patterns using gating mechanisms.

Geometric Brownian Motion (GBM) – a stochastic process that is used to model stock price movements based on randomness.

This project uses NVIDIA (NVDA) stock as the case study.

## Hypothesis

If the LSTM model is integrated with Geometric Brownian Motion, it will result in better stock returns compared to passive investment strategies. Additionally, it will provide accurate stock price ranges, which can serve as a valuable tool for informed risk assessment in investment decisions.

## Research Question

Can an LSTM model combined with Geometric Brownian Motion (GBM) accurately predict the next trading day's stock price and range while achieving consistent returns that outperform passive investment strategies?

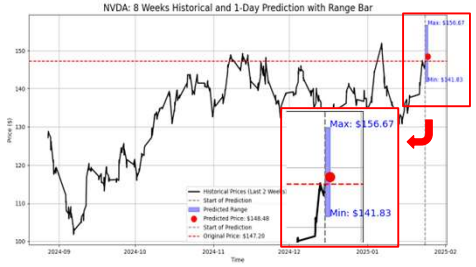
## Procedure

1. LSTM Building

< Real Vs Predicted Price >


- Train the LSTM model using 2 years of historical stock data for feature extraction and trend analysis in Python
- Optimize hyperparameters (number of layers, units, batch size, learning rate, etc.)
- Evaluate and minimize prediction error through iterative validation techniques
- Output: Predicted stock price for the next trading day

2. GBM Building




- Simplify the GBM stochastic differential equation
- Implement the GBM model in Python and input 2 years of historical stock data
- Calculate the average change and volatility of stock prices using historical data for GBM inputs.
- Integrate LSTM's predicted stock price as initial condition for GBM
- Run 10000 Monte Carlo simulations
- Output: Predicted price range for the next trading day

3. Back Testing
- Model predicts the stock price trend and the potential price range for the past 2 month
- Compare the predictions with the real-world data to determine accuracy

Asset simulation (6 month)
Simulation of investing $100 solely based on LSTM predictions.
If prediction indicates price increase, multiply the asset by the actual daily percentage change
If prediction indicates price decrease, keep the asset unchanged (no trade)

## Results

1. LSTM accuracy : 69%
2. GBM range accuracy : 94%
Even when LSTM's prediction was wrong 31% of the time, the real stock price of the next trading day was included in the GBM simulated range, ensuring a safe and informed trade.

< LSTM Result>

| Date | Real Price | Predicted Price | OK/NG |
|---|---|---|---|
| 2024-12-03 | UP | UP | OK |
| 2024-12-04 | UP | UP | OK |
| 2024-12-05 | DOWN | DOWN | OK |
| 2024-12-06 | DOWN | DOWN | OK |
| 2024-12-09 | DOWN | DOWN | OK |
| 2024-12-10 | DOWN | DOWN | OK |
| 2024-12-11 | UP | DOWN | NG |
| 2024-12-12 | DOWN | UP | NG |
| 2024-12-13 | DOWN | DOWN | OK |
| 2024-12-16 | DOWN | DOWN | OK |
| 2024-12-17 | DOWN | DOWN | OK |
| 2024-12-18 | DOWN | DOWN | OK |
| 2024-12-19 | UP | DOWN | NG |
| 2024-12-20 | UP | UP | OK |
| 2024-12-23 | UP | UP | OK |
| 2024-12-24 | UP | UP | OK |
| 2024-12-26 | DOWN | UP | NG |
| 2024-12-27 | DOWN | DOWN | OK |
| 2024-12-30 | UP | DOWN | NG |
| 2024-12-31 | DOWN | UP | NG |
| 2025-01-02 | UP | DOWN | NG |
| 2025-01-03 | UP | UP | OK |
| 2025-01-06 | UP | UP | OK |
| 2025-01-07 | DOWN | UP | NG |
| 2025-01-08 | DOWN | DOWN | OK |
| 2025-01-10 | DOWN | DOWN | OK |
| 2025-01-13 | DOWN | DOWN | OK |
| 2025-01-14 | DOWN | DOWN | OK |
| 2025-01-15 | UP | DOWN | NG |
| 2025-01-16 | DOWN | UP | NG |
| 2025-01-17 | UP | DOWN | NG |
| 2025-01-21 | UP | UP | OK |
| 2025-01-22 | UP | UP | OK |
| 2025-01-23 | UP | UP | OK |
| 2025-01-24 | DOWN | DOWN | OK |
| 2025-01-27 | DOWN | DOWN | OK |

< GBM Result >

| Date | Real Price | Maximum | Minimum | Gap | OK/NG |
|---|---|---|---|---|---|
| 2024-12-03 | 140.25 | 145.1 | 133.0 | 12.14 | OK |
| 2024-12-04 | 145.14 | 146.4 | 134.4 | 12.00 | OK |
| 2024-12-05 | 146.01 | 151.9 | 139.3 | 12.59 | OK |
| 2024-12-06 | 142.4 | 152.2 | 139.3 | 12.85 | OK |
| 2024-12-09 | 138.8 | 147.8 | 135.1 | 12.69 | OK |
| 2024-12-10 | 135 | 145.0 | 132.7 | 12.31 | OK |
| 2024-12-11 | 139.27 | 141.2 | 128.4 | 12.86 | OK |
| 2024-12-12 | 137.31 | 147.0 | 133.8 | 13.22 | OK |
| 2024-12-13 | 134.22 | 142.8 | 131.5 | 11.33 | OK |
| 2024-12-16 | 131.99 | 139.6 | 128.3 | 11.35 | OK |
| 2024-12-17 | 130.35 | 137.4 | 126.2 | 11.24 | OK |
| 2024-12-18 | 128.71 | 135.2 | 124.8 | 10.32 | OK |
| 2024-12-19 | 130.67 | 136.3 | 123.8 | 12.45 | OK |
| 2024-12-20 | 134.96 | 136.9 | 125.2 | 11.68 | OK |
| 2024-12-23 | 139.65 | 140.8 | 128.8 | 12.02 | OK |
| 2024-12-24 | 140.76 | 145.6 | 133.9 | 11.75 | OK |
| 2024-12-26 | 139.89 | 146.9 | 134.9 | 12.05 | OK |
| 2024-12-27 | 137.14 | 146.5 | 133.6 | 12.91 | OK |
| 2024-12-30 | 137.41 | 142.8 | 131.8 | 11.06 | OK |
| 2024-12-31 | 134.29 | 144.4 | 132.6 | 11.75 | OK |
| 2025-01-02 | 136.28 | 139.9 | 129.0 | 10.92 | OK |
| 2025-01-03 | 144.59 | 145.2 | 132.8 | 12.42 | OK |
| 2025-01-06 | 149.51 | 152.5 | 138.8 | 13.68 | OK |
| 2025-01-07 | 140.12 | 156.5 | 142.9 | 13.61 | NG |
| 2025-01-08 | 140.06 | 147.2 | 134.8 | 12.34 | OK |
| 2025-01-10 | 136.86 | 146.5 | 134.1 | 12.40 | OK |
| 2025-01-13 | 133.24 | 141.6 | 129.7 | 11.91 | OK |
| 2025-01-14 | 131.85 | 139.3 | 126.3 | 12.92 | OK |
| 2025-01-15 | 136.2 | 136.8 | 126.3 | 10.50 | OK |
| 2025-01-16 | 130.56 | 142.7 | 130.5 | 12.23 | OK |
| 2025-01-17 | 137.73 | 139.3 | 128.5 | 10.83 | OK |
| 2025-01-21 | 140.83 | 143.8 | 132.5 | 11.35 | OK |
| 2025-01-22 | 147.04 | 147.6 | 135.8 | 11.87 | OK |
| 2025-01-23 | 147.2 | 154.4 | 141.4 | 12.95 | OK |
| 2025-01-24 | 142.6 | 153.6 | 141.3 | 12.33 | OK |
| 2025-01-27 | 128.0 | 148.8 | 136.0 | 12.77 | NG |

3. Result of 6-month asset simulation (NVDA)
- 32% ↑ ($100 → $132)
(※ Real stock price change: $109 →$123, 13%↑)


## Limitations

- Inability to predict sudden market shocks
- Stock data availability issues
- Computational time requirement

## Conclusion

This project aimed to determine whether an LSTM-GBM hybrid model could predict stock prices and ranges while achieving better returns compared to passive strategies.

The model achieved a 31% return during a 6-month simulation, outperforming NVIDIA's 13% passive return. Additionally, LSTM and GBM achieved 69% and 94% accuracy, with GBM providing reliable risk assessments.
These results highlight the feasibility of combining deep learning and stochastic modeling for stock trading and risk management.

## Future research

- Apply the model to broader range of stocks
- Extend the methodology to other fields such as biology (e.g., disease modeling) and physics (e.g., particle simulations)
- Incorporate additional technical indicators in attempt to enhance prediction accuracy
- Include more comprehensive risk metrics in visualizations for better decision-making

## Main References

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