REPORT

Transformer-Based Model for Trading Recommendations

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INTRODUCTION

This project utilizes Python and TensorFlow to delve into high-frequency trading data, focusing on the dynamics of bid-ask spreads and technical indicators like Moving Averages, RSI, and MACD. The objective is to leverage a Transformer model, optimized for complex temporal data, to generate actionable trading insights.

This project delves into high-frequency trading data, primarily focusing on the dynamics of bid-ask spreads, and the implementation of several technical indicators such as Moving Averages, RSI (Relative Strength Index), MACD (Moving Average Convergence Divergence), and Stochastic Oscillators. Our goal is to analyze the behavior of financial markets through these indicators and develop predictive models using advanced deep learning techniques to understand their implications on trading strategies.

Dataset & Transformation

The dataset comprises detailed records of trading activities, including bid and ask prices and trading volumes, enriched with derived financial metrics and technical indicators.
Key Features in the Data:

- bid_px_00 and ask_px_00: Normalized bid and ask prices.

- price: Adjusted close price used for further analysis.

- Close, High, Low, and Open: Prices derived from the bid and ask data.

- Technical Indicators: Moving averages (SMA and EMA), RSI, and MACD were computed to capture market trends and momentum.

    o Moving Averages (SMA and EMA): Used to smooth out price data and identify underlying trends.
    o RSI (Relative Strength Index): Measures the velocity and magnitude of directional price movements.
    o MACD (Moving Average Convergence Divergence): Tracks the relationship between two moving averages of prices.

- Volatility and Spread: Calculated rolling standard deviation of prices to assess market volatility and bid-ask spreads to gauge market liquidity.

    o Rolling Standard Deviation: Indicates market volatility.

    o Bid-Ask Spread: Measures market liquidity.

Target Variable Computation
The target variable is derived to predict future market movements, crucial for generating actionable trade recommendations:

- **Future Price Calculation**: The future price (future_price) is computed as the price shifted seven time steps ahead (data['price'].shift(-7)). This setup aims to predict the price movement seven steps into the future relative to the current step.

- **Trade Signal Definition**: A trade signal is defined based on a specified threshold of price change (0.001%). If the future price is higher than the current price plus the threshold, the signal is 'Buy'; if it's lower than the current price minus the threshold, it's 'Sell'; otherwise, it's 'Hold'. This binary classification helps simplify the decision-making process for trading.

- **Significance**: This method of target variable computation is vital as it directly ties the model's output to actionable trading decisions. It simplifies the complex problem of predicting exact future prices into a more manageable classification problem, where the model needs to predict the direction of the price movement relative to a certain threshold. This approach is particularly useful in high-frequency trading, where quick, actionable decisions are crucial.

Time-based Data Splitting

For model validation and testing, we implemented time-based splitting to respect the chronological order of the data, which is critical in time series analysis to avoid lookahead bias. The dataset was divided as follows:

- **Training set:** 70% of the data, used to train the model.

- **Validation set:** 20% of the data, used to tune the hyperparameters and prevent overfitting.

- **Test set:** 10% of the data, used to evaluate the model's performance on new, unseen data.

Data Visualization

I utilized bar plots to display distributions of various attributes like 'side', 'size', and 'flags'. Key transformations included:

- **Distribution Plots**: Showed the frequency and variation in key metrics like trading volume and price movements.

- **Time Series Plots**: Illustrated trends and cyclicality in prices and indicators like RSI and MACD.

- **Correlation Heatmaps**: Assessed relationships between different features to identify multicollinearity and inform feature selection.

Price and Moving Averages
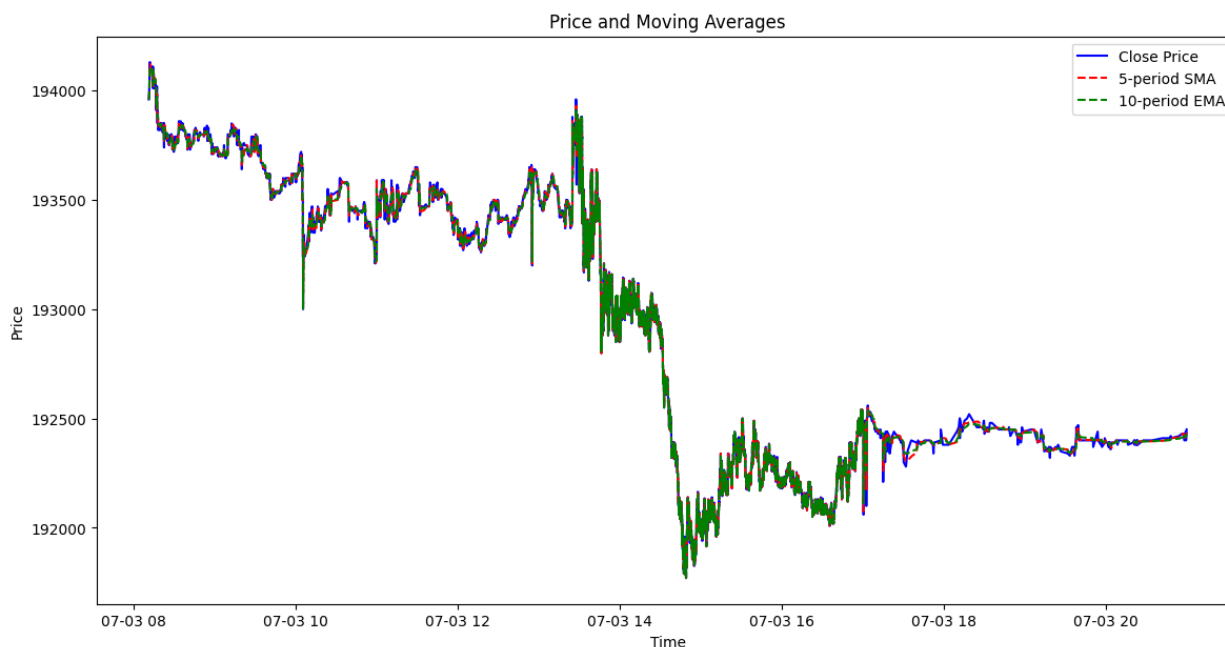
- Close Price (Blue Line): This line represents the closing prices of the asset over a specified time period. The trend is predominantly downward in the latter half of the timeframe, indicating a bearish market during that period.

- 5-period SMA (Red Dashed Line): The SMA smooths out price data by averaging the price over 5 periods. It is closer to the actual price line (blue), suggesting it reacts fairly quickly to price changes. This makes it useful for identifying short-term trends but can be more prone to noise and sudden market movements.

- 10-period EMA (Green Dashed Line): The EMA gives more weight to recent prices, which tends to make it react faster than the SMA to price changes. The 10-period EMA is smoother than the 5-period SMA and lags slightly less than the SMA in terms of capturing the price trend, which is beneficial in identifying the direction of the trend while filtering out some noise.

Volatility Analysis: The sharp drops and recoveries in price, particularly noticeable between '07-03 14' and '07-03 18', suggest high volatility. Trading strategies during such periods should be cautious, utilizing more reactive technical indicators to capture rapid changes.

Trend Analysis: The moving averages, especially the EMA, can be used to identify potential entry and exit points. For instance, when the price crosses above these averages, it might indicate a potential buying opportunity, and vice versa.
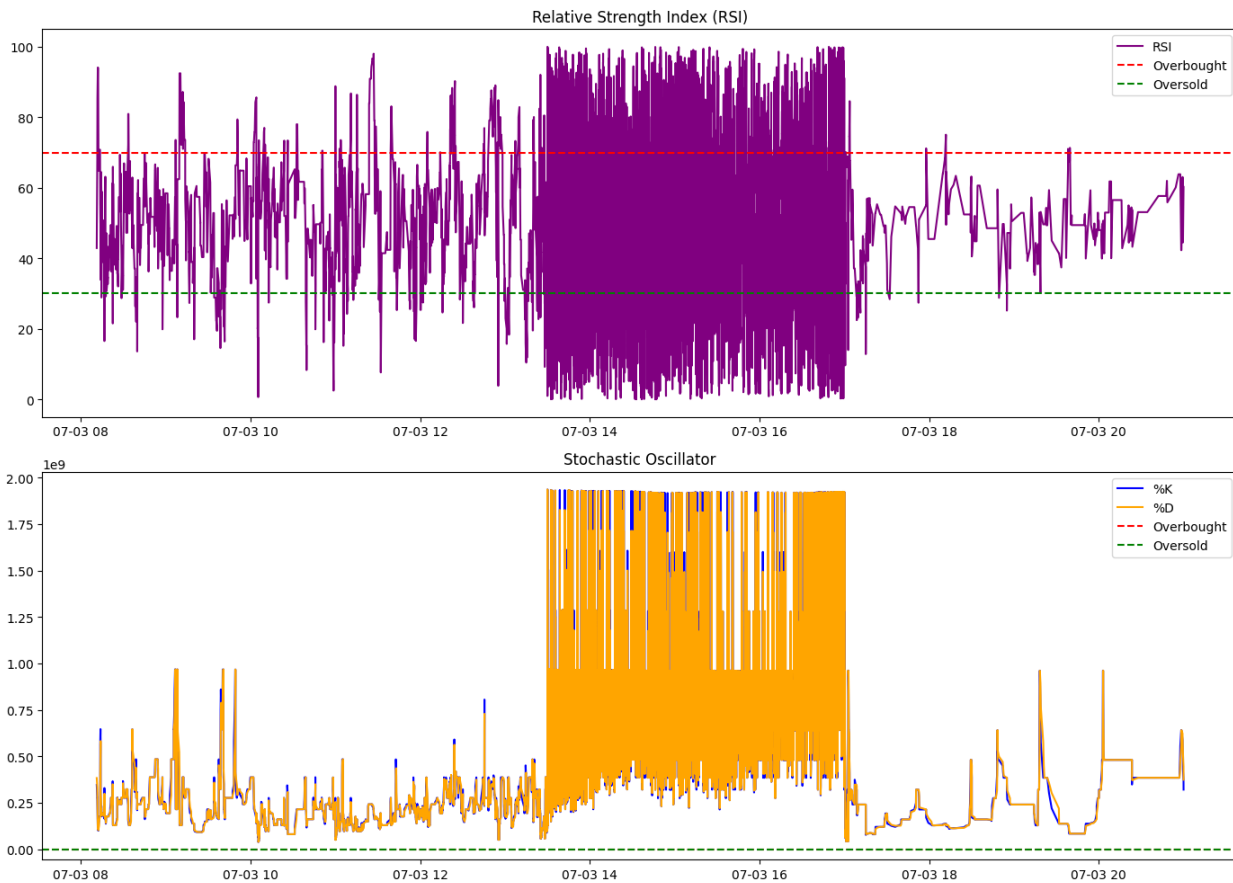
Relative Strength Index (RSI)

- **Overbought Indicator (>70)**: Potential sell signals when RSI crosses above 70.

- **Oversold Indicator (<30)**: Potential buy signals when RSI dips below 30.

Stochastic Oscillator

- **%K and %D Lines**: Watch for crossovers; %K above %D suggests bullish signals, especially below 20 (oversold).

- **Overbought (>80) and Oversold (<20)**: Suggest potential price reversals; over 80 indicates overbought, under 20 indicates oversold.

Combined Insights for Trading Strategy

- **Momentum Trading**: Use both indicators together to confirm buy/sell signals; e.g., buy when RSI > 30 and %K crosses above %D from below 20.

- **Complementary Analysis**: Always confirm these indicators with additional analysis tools like trend lines or volume data for more reliable signals.
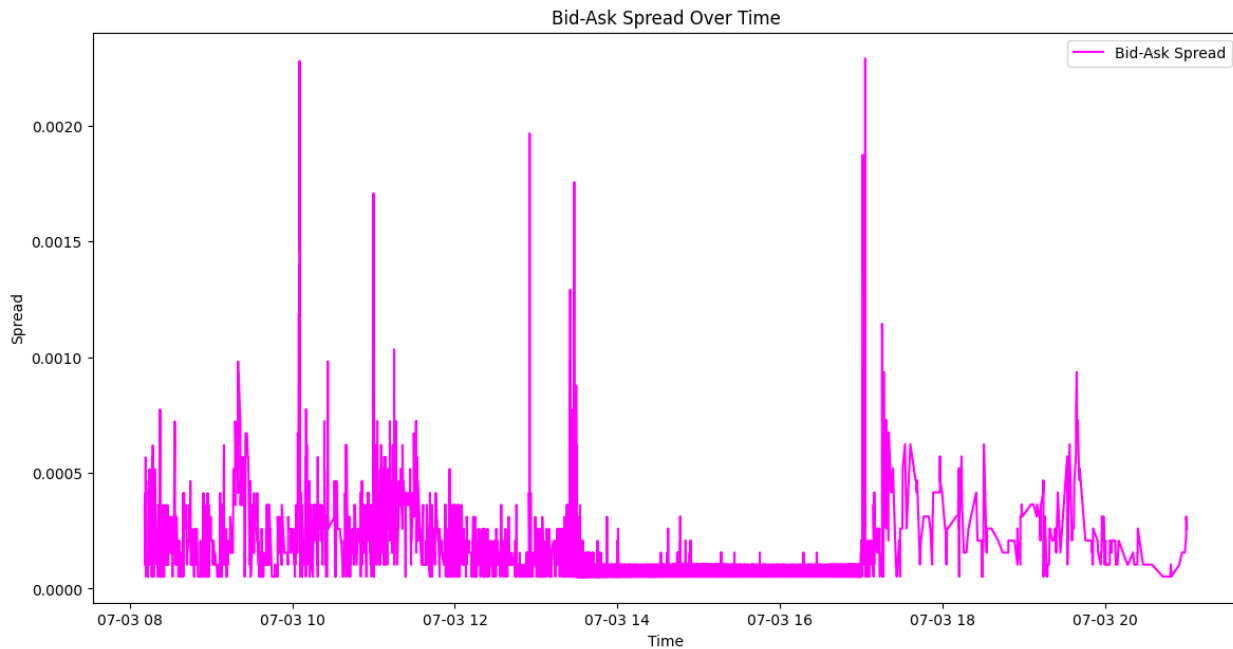
Graph Insights

- **Significant Spikes**: Indicates moments of low liquidity or high market uncertainty.

- **Stable Conditions**: Generally lower spread levels suggest good liquidity.

- **End Variability**: Increase in spread at the end points to changing market conditions.

Trading Implications

- **Increased Costs**: Higher spreads mean more expensive trades.

- **Timing Trades**: Optimal to trade during periods of narrow spread to reduce costs.

- **Liquidity Concerns**: Spikes may deter large volume trades due to potential price impacts.
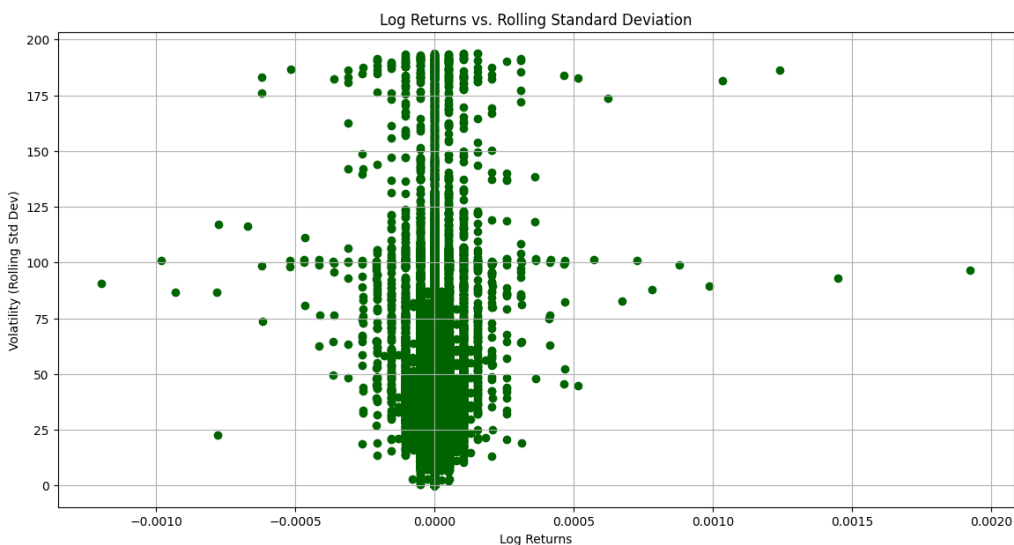

Key Observations

- **Distribution of Points**: The bulk of data points is clustered around zero log returns, with the volatility ranging broadly from low to high.

- **Volatility Trends**: Higher volatility levels are more spread out across the range of returns, but especially concentrated around lower log returns.

- **Outliers**: Few points with high log returns exhibit relatively lower volatility, which is atypical and warrants further investigation.

Insights

- **Risk Analysis**: Most of the trading or investment days experience near-zero returns with variable volatility, suggesting diverse market conditions.

- **Low Return High Volatility**: The clustering of high volatility around low returns might indicate risky market conditions, where prices fluctuate widely but don't necessarily yield high returns.

- **Stability in Extreme Returns**: Lower volatility at high return levels could suggest that big positive returns happen during more stable market conditions.

Correlation Matrix Heatmap (Excluding Last Column)
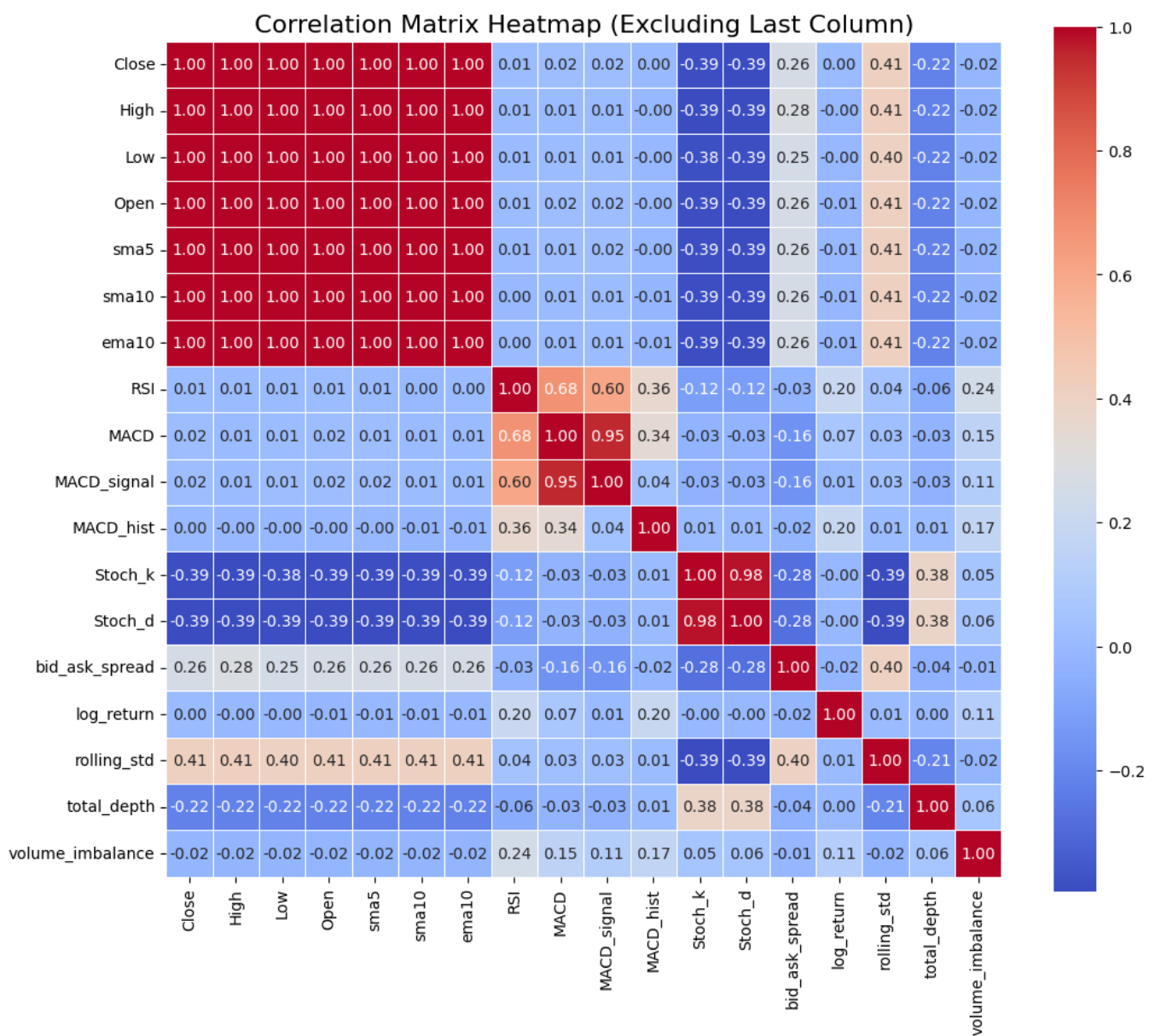
- **High Correlation**: 'Close', 'High', 'Low', 'Open', and moving averages like 'sma5', 'sma10', and 'ema10' show high correlation, supporting the use of 'Close' only to minimize redundancy.

- **Using 'Close'**: Focuses on the most significant daily price metric, reducing overfitting.

- **Stoch_k Utility**: Highly responsive, useful in high-frequency trading for capturing immediate price movements.

- **MACD Effectiveness**: Both 'MACD' and 'MACD_signal' are effective in trend analysis.

- **Redundancy of Stoch_d**: Dropping 'Stoch_d' reduces redundancy as it's highly correlated with 'Stoch_k'.

- **Unique Metrics**: 'log_return' and 'rolling_std' offer unique insights into price movements and volatility, low correlation with other variables.

Recommendations:

- Prioritize 'Close', 'Stoch_k', and MACD indicators.

- Remove 'Stoch_d' to streamline the model.

Trade Recommendations Based on Model Performance

LSTM Model
Strengths: The LSTM model's ability to capture long-term dependencies makes it particularly useful for identifying and acting on long-term trends and cyclical patterns in the market.
- **Recommendation**: Use the LSTM model to generate signals for trades that benefit from historical momentum and trends. For example, in markets where certain trends repeat over weeks or months, the LSTM can identify these patterns, suggesting when to enter or exit trades based on historical price movements.

GRU Model
Strengths: GRU's efficiency makes it well-suited for real-time trading where quick decisions are critical, and it still retains a good capability to learn from the data's temporal features.
- **Recommendation**: Implement the GRU model for intraday trading strategies where speed is crucial. It can quickly adapt to new data and make timely predictions, enabling traders to capitalize on short-term price fluctuations. This model can be particularly effective in environments with high volatility, providing faster responses to sudden market movements.

Transformer Model
Strengths: The superior performance of the Transformer, due to its attention mechanism, allows it to excel in environments where relationships and patterns across various time steps need to be understood comprehensively.
- **Recommendation**: Use the Transformer model for complex trading strategies that involve multiple assets or require integration of various market indicators. Its ability to handle large sets of data from different sources simultaneously makes it ideal for portfolio optimization and risk management strategies. This model can be used to identify correlation patterns between assets and predict how changes in one market could influence others.

Fine-Tuning Process
Fine-tuning involved adjusting several hyperparameters and architecture configurations to optimize each model's performance. The process included:
- Hyperparameter Optimization: Adjusted the model's learning rate, batch size, and the number of layers to find the optimal configuration for best performance.

- Regularization Techniques: Implemented dropout techniques to prevent overfitting, ensuring the model remains robust across various market conditions.

- Early Stopping and Learning Rate Scheduling: Utilized early stopping to halt training when validation performance degrades, alongside dynamic learning rate adjustments to optimize training phases.

Importance of Accuracy and Precision in Trading Models

Accuracy measures the overall correctness of a model across all trading signals—sell, hold, and buy. High accuracy indicates that the model reliably identifies correct actions across these categories, making it trustworthy for general trading decisions.
Precision assesses how many of the predicted actions for each category were correct. In trading:
- **Precision for Sell**: Ensures that when a sell signal is given, it is accurate, minimizing premature or unnecessary sales.

- **Precision for Hold**: Indicates reliability in maintaining positions during uncertain times, avoiding costly turnovers.

- **Precision for Buy**: Validates the correctness of buy signals, helping traders capitalize on real opportunities without missing out due to false alerts.

Model	Train		Validation		Test	
	Accuracy	Precision	Accuracy	Precision	Accuracy	Precision
LSTM	0.4794	0.6042	0.4565	0.5359	0.4838	0.5854
GRU	0.4801	0.6069	0.4549	0.5400	0.4897	0.5850
Transformer	0.4689	0.6276	0.4593	0.5288	0.4663	0.5934

In high-frequency trading, where decisions are made quickly and the cost of errors can be high, both accuracy and precision are crucial. Accuracy ensures the model's overall reliability, while precision boosts confidence in specific trading signals, thereby optimizing the execution of trading strategies and enhancing profitability.
Based on the Transformer model's performance:

- **Buy Signals**: Recommended when the model shows high precision, indicating strong upward momentum.

- **Sell Signals**: Generated during potential downtrends, where model precision aligns with significant price decreases.

- **Hold Signals**: Advised in less volatile conditions where the model indicates neither strong buying nor selling pressures.

Trade Recommendations Based on Model Performance and Data Insights

LSTM (Long Short-Term Memory)
- **Use Case**: Best suited for strategies that require an understanding of long-term trends and cyclical patterns.

- **Recommendation**: Employ LSTM for predicting seasonal or cyclical trends in markets where historical patterns provide a reliable basis for future performance. Ideal for commodities or stocks with clear historical cyclicity.

GRU (Gated Recurrent Unit)
- **Use Case**: Excellent for real-time trading scenarios where decisions must be swift and based on short-term price movements.

- **Recommendation**: Utilize GRU for day trading and high-frequency strategies in volatile markets where speed and responsiveness are critical. This model can quickly adapt to new market information, making it suitable for forex or intraday stock trading.

Transformer
- **Use Case**: Highly effective for analyzing complex relationships involving multiple variables and interdependencies.

- **Recommendation**: Leverage the Transformer model for multi-asset strategies or arbitrage opportunities where understanding the relationships between different instruments is crucial. It can also be used for algorithmic trading that incorporates a range of economic indicators and market data.

Recommendations from Data Analysis

The data analysis revealed several key insights that can inform trading strategies:

1. **Volatility Analysis**: High precision in models during periods of high volatility suggests these models can be trusted to make accurate predictions when the market is unstable. Traders can leverage this insight by increasing trade volume or adjusting risk parameters based on model signals during these periods.

2. **Technical Indicator Efficacy**: The effectiveness of specific indicators like RSI and MACD in predicting market movements suggests strategies that combine these indicators with predictive models might enhance trading performance. For instance, setting trading thresholds based on RSI levels that align with predictive signals from models like Transformers can refine entry and exit points.

3. **Correlation Patterns**: Insights from correlation heatmaps can help in identifying which markets or assets are influenced by similar factors. Traders can use this information to hedge their positions or to construct diversified portfolios that minimize risk.