002 - INTRODUCTION TO TRADING

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ITESO

Table of Contents

1. Introduction

This project focuses on the development of a systematic trading strategy based on technical analysis indicators. The objective is to design, implement, and evaluate a quantitative trading system capable of generating consistent risk-adjusted returns in the cryptocurrency market. As the project was conducted individually, the dataset used corresponds to the "Hourly BTCUSDT", which contains approximately one year of hourly price data for the BTC/USDT trading pair.

The strategy combines three technical indicators to generate long and short trading signals, applying a 2 out of 3 confirmation rule to increase reliability and reduce false positives. It aims to optimize and maximize the Calmar Ratio, seeking an appropriate balance between profitability and risk by accounting for both returns and drawdowns.

A realistic Backtesting environment was implemented, considering transaction costs of 0.125%, no leverage, and dynamic position management for both long and short trades. To ensure robustness and avoid overfitting, a walk-forward analysis was performed, dividing the dataset into training, validation, and testing periods. The optimization of hyperparameters — such as stop loss, take profit, and indicator periods — was conducted using Optuna for Bayesian optimization.

Finally, the report provides a comprehensive explanation of the strategy's design, implementation, and performance evaluation, emphasizing robustness, risk management, and statistical validity. Performance is analyzed through standard financial metrics including Sharpe Ratio, Sortino Ratio, Calmar Ratio, Maximum Drawdown, and Win Rate, complemented by portfolio value evolution charts and detailed return tables.

2. Detailed description of the strategy and rationale

The trading strategy implemented in this project is a systematic approach based on technical analysis indicators, designed to generate consistent risk-adjusted returns in the BTC/USDT market. The goal of the strategy is to include a filter mechanism to determine when to enter or exit the market in response to price changes, based on the behavior and direction of the asset, whether it exhibits positive or negative trends.

Additionally, the strategy is designed to operate in a long/short manner, allowing it to generate signals for both buying and selling positions depending on the conditions of the indicators. This approach enables the strategy to take advantage of upward and downward market movements, capturing trends in either direction to maximize potential returns.

2.1 - RSI (Relative Strength Index)

The RSI (Relative Strength Index) is a technical indicator that measures the strength of price trends of an asset over a specific period. This indicator was chosen because it helps identify overbought and oversold levels, with values ranging from 0 to 100.

If the RSI is above 70, it means the assets are overbought, which indicates that its price could start to go down. On the other hand, if the RSI is below 30, it means the assets are oversold, suggesting that its price could start to go up.

In our strategy, RSI is used to generate entry and exit signals, helping to reduce false signals while confirming the trend the asset is following. This indicator is expected to work well together with the other two indicators, providing an extra layer of confirmation and improving the reliability of the trading signals.

2.2 - Momentum (Rate of Change)

The Momentum is a technical indicator that measures the speed of price trends of an asset over a specific period (like the RSI). This indicator was chosen because it shows whether the trend is accelerating or slowing down.

If the Momentum is positive, it means that the price is rising, indicating a bullish trend. On the other hand, if the Momentum is negative, it means that the price is falling, indicating a bearish trend.

In our strategy, Momentum is used to confirm the trend direction before opening any position. For example, if the RSI indicates that the asset is oversold, Momentum is checked to ensure it is positive to validate the signal.

2.3 – Volatility (Bollinger Bands Width)

Volatility is a technical indicator that measures the degree of price variation of an asset over a specific period. This indicator was chosen because it shows how stable or unstable the market is at a given time.

When volatility is high, it means the price is changing rapidly, indicating a more unpredictable market. When volatility is low, the price moves more slowly and steadily, indicating a more stable market.

In our strategy, volatility is used to filter trading signals. For example, even if Momentum and RSI suggest trade, high volatility could indicate a higher risk of false signals, so the strategy may delay entering a position until market conditions are more favorable.

2.4 - Signal Generation

For signal generation, the strategy relies on the combined use of three technical indicators. Based on these, a “2 out of 3 confirmation rules” is applied, meaning that at least two of the indicators must show a buy condition for a long entry, or a sell condition for a short entry.

A buy signal is triggered when at least two indicators show bullish conditions, while a sell signal is triggered when at least two indicators show bearish conditions.

In the Backtesting implementation, once a valid signal is detected, the system automatically executes trades according to the available capital and predefined parameters.

Each position size is dynamically adjusted based on the current level of market volatility depends on if volatility is high, the position size is reduced to limit risk exposure; if volatility is moderate, exposure can be slightly increased to take advantage of favorable market conditions.

Additionally, stop-loss and take-profit levels are defined within the backtest, both based on volatility, with the objective of protecting capital and securing profits when the price moves in favor of the position.

Backtesting system only opens a trade when at least two of the three indicators (RSI, Momentum, and Volatility) confirm the signal. This multi-confirmation rule reduces false entries and ensures that trades are executed only under conditions with a higher probability of success. The strategy is structured as a long/short system, allowing it to take advantage of both bullish and bearish market trends.

2.5 - Position Management

For this strategy, the initial capital was set at $1,000,000, with a transaction fee of 0.125% applied to each trade.

When managing open positions, several dynamic variables are considered, including the number of shares (n_shares), entry price, exit price, stop-loss (sl), and take-profit (tp) and profit. These parameters are treated as floating values, allowing them to adapt continuously to market conditions and the portfolio's current exposure.

The Backtesting framework automatically updates the position size based on both available capital and market volatility. When volatility rises, the system reduces the number of shares to limit exposure and protect capital. Conversely, in more stable market conditions, position size can be slightly increased to capture greater profit opportunities.

In addition, a volatility-based stop-loss and take-profit mechanism was implemented to safeguard the portfolio and secure gains when the price moves favorably. This dynamic risk management helps maintain consistent returns while controlling downside risk.

Transaction costs play a significant role in the overall performance of the strategy. A commission of 0.125% per trade was applied to every buy and sell operation, which directly reduces the returns. This cost becomes more noticeable during periods of high trading frequency, as frequent entries and exits accumulate higher expenses.

To mitigate this impact, that's why we used the rule (2 out of 3 indicators), which helps reduce unnecessary trades and avoid overtrading. By ensuring that trades are only executed under strong signal agreement, the strategy maintains efficiency and minimizes the negative effect of transaction costs on overall profitability.

2.6 – Rationale

For this strategy, the main objective was to achieve the best possible performance while minimizing capital risk in each position. The approach is relatively conservative, focusing on steady returns rather than excessive exposure. However, during periods of increased volatility, the strategy has the potential to capture significant profits while keeping losses controlled.

To ensure reliable evaluation, the dataset was divided into training, testing, and validation periods (60%, 20%, 20%). This chronological split allows the strategy to be optimized on historical data and later evaluated on unseen periods, helping to reduce overfitting and confirm its robustness under different market conditions.

Risk management in this strategy is based on drawdown control, volatility filters, and confirmation rules. Volatility acts as a dynamic risk filter—when market volatility increases, the position size is reduced and trades become more selective. Additionally, the strategy applies a two-out-of-three confirmation rule (RSI, Momentum, and Volatility), which helps prevent false signals and reduces exposure to unstable market environments.

Drawdowns are further minimized through the use of stop-loss levels and adaptive position sizing, ensuring consistent capital protection during unfavorable trends.

3. Data Analysis and preprocessing

The dataset used consists of one year of hourly price data for the BTC/USDT pair. Initially, the CSV file was loaded, and missing values were removed to ensure data cleanliness and reliability. Subsequently, the records were chronologically ordered to preserve the integrity of the time series, which is essential for the correct implementation of Backtesting and a realistic evaluation of trading signals.

Next, the dataset was chronologically split into three segments: training (60%), testing (20%), and validation (20%). This division allows the strategy to be optimized on historical data, evaluated on subsequent periods, and validated on unseen data, reducing the risk of overfitting and ensuring that performance metrics reflect realistic out-of-sample behavior.

During the preprocessing phase, the technical indicators RSI, Momentum, and Volatility were calculated. Each of these indicators generates buy and sell signals, which are then combined using the “2 out of 3” confirmation rule to identify trading opportunities with higher reliability. Additionally, volatility is used as a dynamic risk filter, adjusting position sizes according to market conditions.

This preprocessing workflow ensures that the strategy operates on clean and properly structured data, incorporating all necessary calculations for signal generation, risk management, and realistic simulation through Backtesting.

4. Methodology and Implementation

This strategy is based on the combination of the three technical indicators mentioned earlier (RSI, Volatility, and Momentum). Its objective is to identify market entry and exit points based on overbought, oversold, and price strength signals, using indicator confirmation to reduce false signals and increase the reliability of trades.

For the calculation of these indicators:

The RSI detects overbought and oversold conditions. The hyperparameters optimized through the hyperparameter function are ***(rsi_window)***, ***(rsi_lower),*** and *(**rsi_upper***), allowing the indicator's sensitivity to be adjusted according to market behavior.

Momentum measures the speed of price changes, indicating whether the trend is accelerating or slowing down. The hyperparameters *(**momentum_window**)* and ***(momentum_threshold)*** allow adjusting their sensitivity and defining the levels at which buy or sell signals are generated.

Volatility is calculated using the Bollinger Bands width, serving as a risk filter that dynamically adjusts position size. The hyperparameters ***(volatility_window)*** and *(**volatility_quantile)*** acts as a dynamic risk filter, preventing trades when market volatility is too high. It allows increased exposure only when volatility is below the defined historical threshold.

Signal generation is based on the "2 out of 3" confirmation rule, which requires at least two of the three indicators to align in the same direction to open a long or short position. This helps filter false signals and ensures that trades are executed only in scenarios with a high probability of success.

This strategy supports both long and short positions without leverage. A transaction fee ***(COM)*** of 0.125% is applied to each operation, slightly reducing the available capital for every buy or sell.

The position size ***(n_shares)*** is dynamically adjusted based on available capital and prevailing market conditions, ensuring appropriate exposure for each trade.

When no confirmed signals are detected by at least two of the three indicators, the system maintains the previous position if one is already open or remains in cash if there are no active trades. This approach helps to avoid entering trade under uncertain conditions, reducing the risk of false signals and protecting capital until a clear buy or sell signal is generated.

The objective of this strategy is to optimize the strategy to maximize **the Calmar Ratio**, which evaluates the returns of a strategy in relation to its worst cumulative loss. The Calmar Ratio measures risk-adjusted performance by dividing the annualized return by the maximum drawdown.

In the code, the framework allows optimization based on the selected performance metric: **Calmar, Sharpe,** or **Sortino Ratio**.

- The **Sharpe Ratio** measures return adjusted by total risk (volatility).
- The **Sortino Ratio** focuses on downside risk, measuring returns adjusted only for negative deviations.
- The **Calmar Ratio**, as mentioned, emphasizes the balance between returns and the largest drawdown, making it particularly suitable for risk-aware strategies in volatile markets like BTC/USDT.

Backtesting allows evaluating how the strategy would have performed over historical periods, considering the available capital, params, dynamic position size, stop-loss **(sl)**, take-profit **(tp)** levels, and transaction **(COM)** fees (0.125%). This ensures that the parameter optimization is based on realistic results and that the strategy can be validated on unseen data sets to reduce overfitting.

This flexibility allows the Backtesting and optimization process to target different risk-return objectives depending on the investor's preference.

Finally, a walk-forward analysis was applied. The strategy is trained using 60% of the dataset, tested on the next 20%, and validated on the remaining 20%, which consists of unseen data following the testing period. This approach ensures that the strategy is evaluated in future, out-of-sample periods, allowing for a realistic assessment of performance, confirming robustness, and reducing the risk of overfitting.

5. Results and performance analysis

5.1 - Evaluation Metrics

Sortino Ratio

It measures how much return is obtained for each unit of downside volatility. A Sortino Ratio greater than 2 is generally considered favorable, as it indicates that the strategy generates strong returns relative to downside risk.

$$Sortino\ Ratio\ = \frac{(R_p - R_f)}{\sigma_d}$$

Where R_p represents the average returns of the portfolio, R_f is the risk-free rate, which in this case is assumed to be zero due to its absence, and σ_d is the standard deviation of the negative returns only, not the total volatility.

Sharpe Ratio

It measures how much return is obtained for each unit of total volatility. A Sharpe Ratio greater than 1 is generally considered acceptable, indicating strong returns relative to total volatility.

$$Sharpe\ Ratio\ = \frac{(R_p - R_f)}{\sigma_p}$$

Where R_p represents the average returns of the portfolio, R_f is the risk-free rate, which in this case is assumed to be zero due to its absence, and σ_p is the standard deviation of the portfolio.

Maximum Drawdown

It represents the maximum potential loss that could have occurred during the evaluation period. A lower Maximum Drawdown is generally preferred, as it indicates reduced exposure to significant losses during the evaluation period.

$$Max\ Drawdown = \frac{\mathrm{P_{max}} - \mathrm{P}_t}{P_{max}}$$

Where P_{max} denotes the historical peak value of the portfolio up to time t, and P_t denotes the portfolio value at time t.

Calmar Ratio

It reflects the relationship between profitability and maximum risk, measuring how much return is obtained for each unit of maximum drawdown. A higher Calmar Ratio is generally considered favorable, as it indicates stronger returns relative to the maximum drawdown experienced.

$$Calmar\ Ratio = \frac{R_A}{Max\ Drawdown}$$

Where R_A denotes the annual average return of the portfolio, and $Max\ Drawdown$ represents the maximum observed decline from a peak to a trough in portfolio value.

Win Rate

It indicates how often the strategy achieves profitable outcomes. A higher Win Rate is generally preferred, as it reflects a greater proportion of successful trades relative to the total number of executed trades.

$$Win\ Rate\ = \frac{Number\ of\ winning\ trades}{Total\ Number\ of\ trades}$$

Where $Number\ of\ winning\ trades$ denotes the total number of profitable trades, and $Total\ Number\ of\ trades$ represents the overall number of executed trades.

5.2 - Hyperparameter Tuning with Optuna

To optimize the trading strategy, Optuna was used to perform ***50 trials***, with the objective of maximizing the Calmar Ratio, which balances profitability against maximum drawdown.

The following hyperparameters were selected for tuning:

Hyperparam	Range			Description
rsi_window	11	-	25	Lookback period for RSI calculation.
rsi_lower	25	-	35	Threshold for overbought condition (sell signal).
rsi_upper	70	-	80	Threshold for oversold condition (buy signal).
momentum_window	10	-	22	Lookback period for momentum calculation.
momentum_threshold	0.02	-	0.1	Level at which buy/sell signals are triggered.
volatility_window	25	-	35	Lookback period for calculating volatility.
volatility_quantile	0.6	-	0.7	Level used as a filter to limit trades during high-volatility conditions.
stop_loss	0.02	-	0.03	Fraction of position price, protecting capital during unfavorable moves.
take_profit	0.05	-	0.1	Fraction of position price, securing gains when price moves favorably.
capital_pct_exp	0.05	-	0.2	Percentage of total capital to allocate per position, dynamically adjusted according to market volatility and exposure.

By adjusting these parameters, the optimization process enables the strategy to dynamically respond to changes in trend strength, market volatility, and price reversals.

This improves the precision of entry and exit signals while maintaining strict control over capital exposure.

The final configuration is designed to deliver strong risk-adjusted returns, demonstrating stability across different market conditions and reducing the likelihood of overfitting to specific historical data.

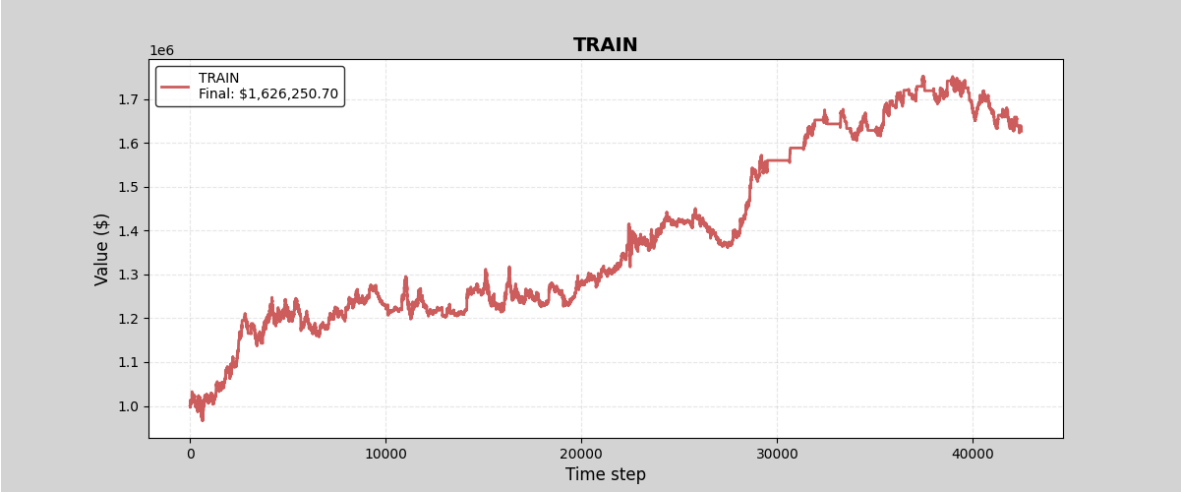
5.3 - Best Optuna Hyperparams

Hyperparam	Value
rsi_window	21
rsi_lower	32
rsi_upper	74
momentum_window	14
momentum_threshold	0.0567
volatility_window	25
volatility_quantile	0.6708
stop_loss	0.0286
take_profit	0.0915
capital_pct_exp	0.1842

Within the hyperparameter ranges explored by Optuna over 50 trials, these values produced the best results, balancing profitability and risk. They define the sensitivity of the RSI and Momentum indicators, the market volatility filter, position sizing, and risk management (stop-loss and take-profit levels), aiming to achieve consistent, risk-adjusted returns.

6 – Performance metrics graphs & tables

TRAIN (0.60)

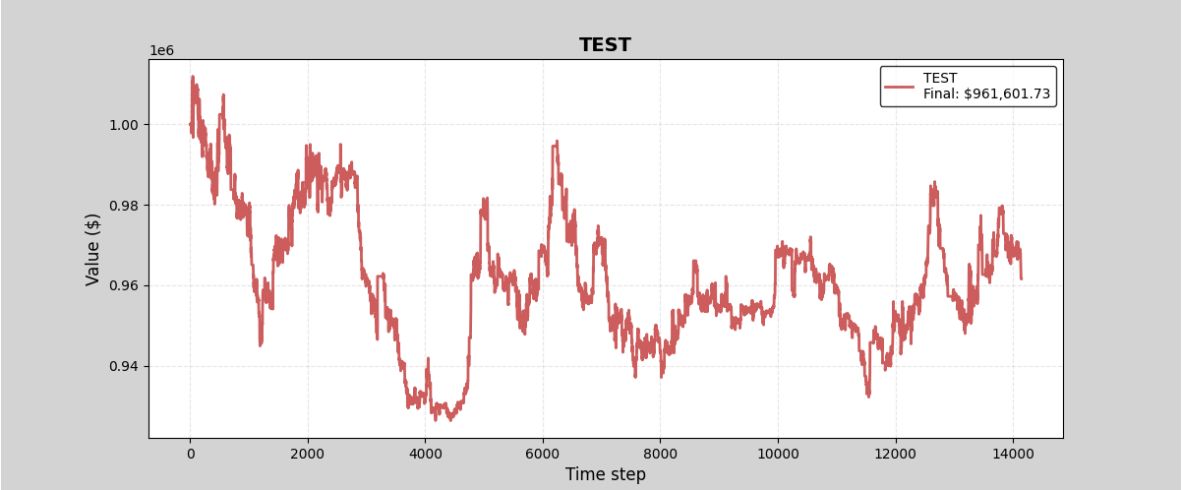


TRADING PERFORMANCE TRAIN

Metric	Value
Calmar	1.4147
Sharpe	1.002
Sortino	1.5189
Max Drawdown	7.49%
Win Rate	4.67%
Total Return	35%
Profit	$ 626,556.41
Final Capital	$ 1,626,250.70

The results obtained on the training set are promising. A Calmar Ratio close to 1.5 indicates a strong relationship between profitability and maximum risk. Although the Sharpe Ratio (1.002) is not outstanding, it shows consistency in returns adjusted for total volatility. The Sortino Ratio (1.5189) stands out even more, reflecting better management of downside risk. Additionally, the low Maximum Drawdown value suggests that the strategy avoids significant losses during any period. The only negative aspect is the Win Rate, which is below 5%, indicating few winning trades; however, the profits from those trades are considerably high, contributing to an overall return of approximately 35%.

TEST (0.20)

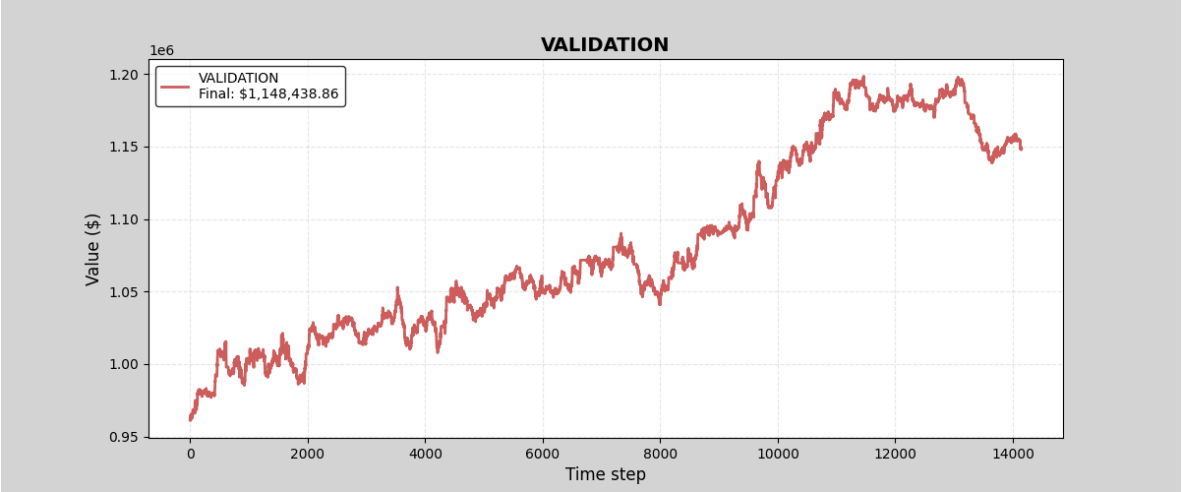


TRADING PERFORMANCE TEST

Metric	Value
Calmar	-0.2546
Sharpe	-0.2921
Sortino	-0.4496
Max Drawdown	8.46%
Win Rate	24.36%
Total Return	-3.84%
Profit	-$ 38,398.27
Final Capital	$ 961,601.73

The test results appear to be weak, showing a significant drop compared to the training performance. Despite this, the strategy did not suffer major losses, and there is potential for better returns in the upcoming validation phase. The test period ended with a total loss of 3.84%, a Calmar Ratio of -0.2546, and a Sharpe Ratio of -0.2921, indicating poor risk-adjusted performance. The Sortino Ratio of -0.4496 reflects weak downside risk management. However, the Maximum Drawdown was limited to 8.46%, and the Win Rate improved to 24.36%, suggesting that while few trades were profitable, they were not severely damaging. The final capital stood at $961,601.73, with a total loss of $38,398.27.

VALIDATION (0.20)

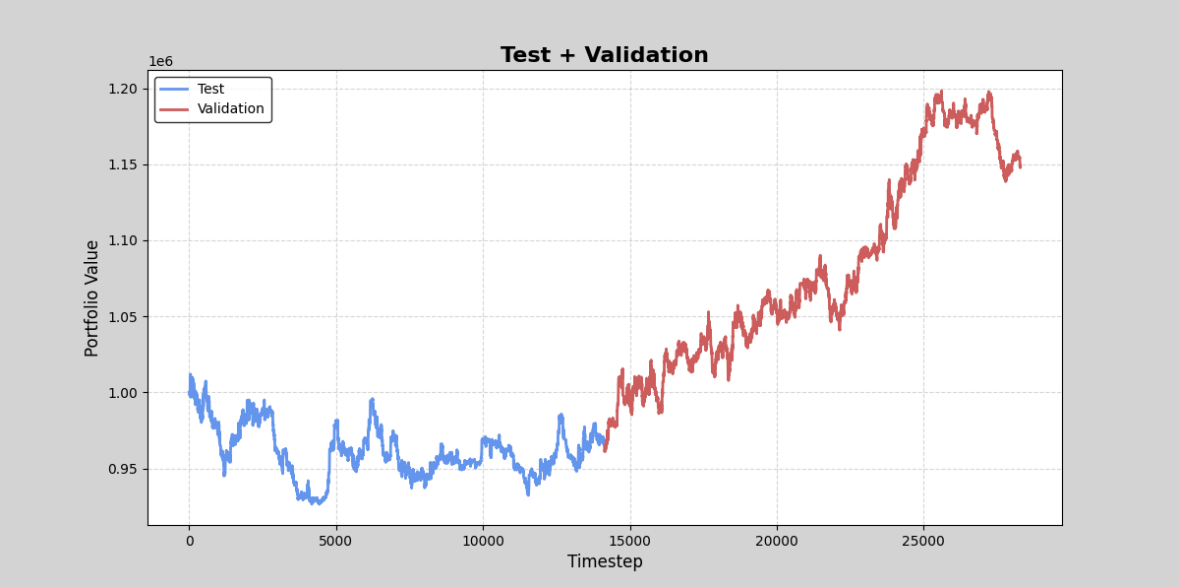


TRADING PERFORMANCE VALIDATION

Metric	Value
Calmar	2.2599
Sharpe	1.5148
Sortino	2.4857
Max Drawdown	22
Win Rate	4.99%
Total Return	19.46%
Profit	$ 187,110.04
Final Capital	$ 1,148,438.86

The validation results were significantly better than those from the test set. The Calmar Ratio of 2.2599 indicates a high risk-return efficiency, with strong returns and a very low maximum loss. The Sharpe Ratio (1.5148) confirms that the risk-adjusted returns are acceptable, while the Sortino Ratio (2.4857) is notably higher than the Sharpe, suggesting that the strategy delivers consistent returns relative to downside risk. Although the Win Rate was only 4.99%, the profitable trade generated a total return of 19.46%, resulting in a profit of $187,110.04 and a final capital of $1,148,438.86. These results show that the strategy can capture profitable opportunities while maintaining effective risk control, even with a low frequency of winning trades.

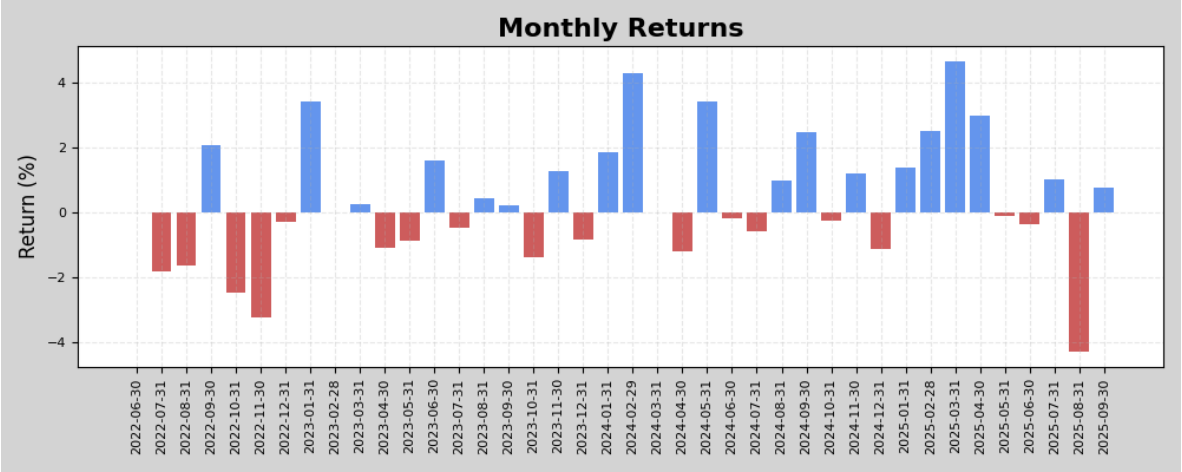
TEST + VALIDATION



This graph reinforces previous conclusions. While the strategy posted a modest loss during the initial test phase, its performance improved significantly in the validation period, which coincided with a moderately bullish market. The portfolio peaked at approximately $1.20 million before stabilizing around $1.148 million. These results highlight the strategy's potential for profitability and its effective risk management. Overall, the validation phase confirms the strategy's robustness and adaptability under favorable market conditions.

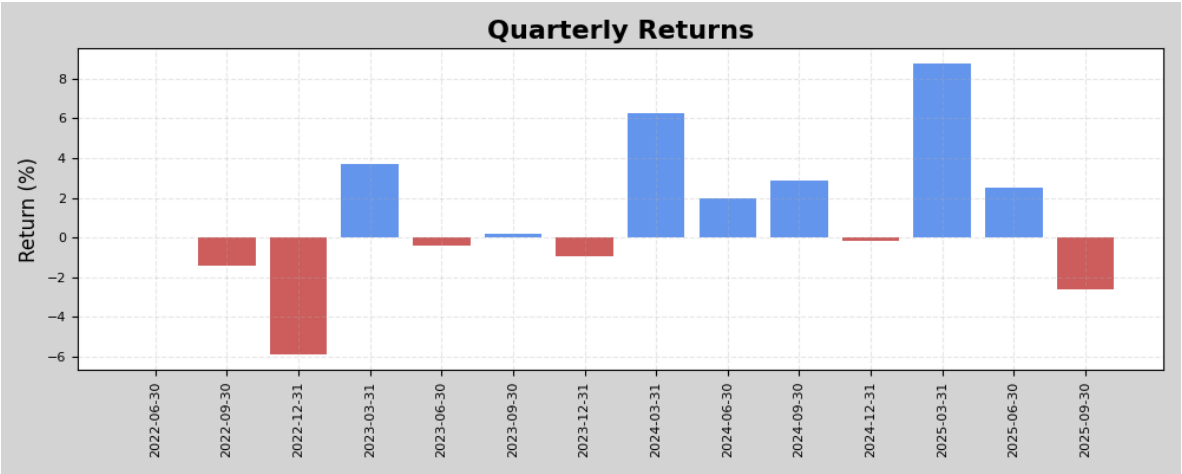
TABLES

Monthly Returns



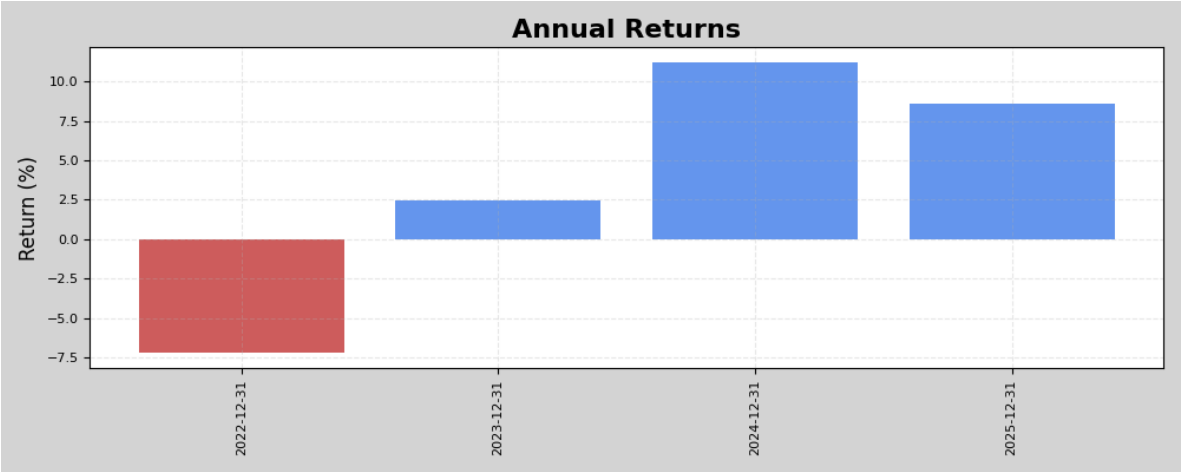
The monthly return chart confirms the strategy's favorable performance, with more months showing positive returns than negative ones. Moreover, the gains generally outweighed the losses, indicating effective trend capture and loss limitation. The consistency of profitable months highlights the strategy's robustness and potential for stable growth. Overall, the monthly return distribution supports the strategy's ability to deliver sustainable returns while managing downside risk.

Quarterly Returns



The strategy shows high variability in quarterly performance, with some periods of losses (Q4 2022 & Q3 2025) and others with strong gains (Q1 2024 & Q1 2025). Despite occasional negative quarters, the positive returns are generally stronger, indicating an overall favorable trend and progressive improvement in annual performance.

Annual Returns



The strategy shows a clear progressive improvement in annual performance, moving from losses in the first year to sustained gains in the following years. This suggests an effective adaptation of the system to market conditions and a successful optimization of its parameters over time.

Risk analysis and limitations

The strategy incorporates multiple layers of risk management, including volatility-based filters, dynamic position sizing, and a “2 out of 3” indicator confirmation rule (RSI, Momentum, Volatility). These mechanisms help reduce exposure during unstable market conditions and minimize drawdowns. Transaction costs (0.125% per trade) account for, which can impact profitability, especially during periods of high trading frequency. The use of stop-loss and take-profit levels based on volatility further enhances capital protection and profit realization.

Despite these safeguards, the strategy is not immune to limitations. Performance during the test phase revealed sensitivity to certain market conditions, with lower returns and higher drawdowns. Additionally, the low win rate suggests that while profitable trades are impactful, they occur infrequently, which may affect consistency. The strategy's effectiveness is also contingent on the accuracy of technical indicators and the stability of market behavior, which can be unpredictable.

Conclusion

Overall, the proposed strategy has demonstrated strong potential to generate consistent, risk-adjusted returns in the cryptocurrency market, specifically in the BTC/USDT pair. While the results were generally positive, there remains considerable room for improvement to achieve more consistent performance. Alternative indicators or combinations might have produced better signals; however, based on the presented approach, the strategy achieved a solid balance between profitability and capital protection.

The strategy is built upon the integration of three technical indicators—RSI, Momentum, and Volatility—using a "2 out of 3" confirmation rule, which effectively reduced false signals and enhanced trade reliability. Hyperparameter optimization through Optuna enabled fine-tuning of indicator sensitivity and key risk management levels, such as stop-loss and take-profit, contributing to greater result stability.

Monthly and quarterly performance analyses revealed a positive trend, with gains generally outweighing losses and showing progressive improvement in annual returns. The validation phase was particularly noteworthy, demonstrating sustained portfolio growth and confirming the strategy's ability to adapt to favorable market conditions.

Despite certain limitations, such as a moderate win rate and sensitivity to volatile environments, the implemented risk control mechanisms proved effective. This

reinforces confidence in the strategy as a viable tool for generating risk-adjusted returns.

In summary, the developed strategy offers a robust and adaptable framework capable of navigating diverse market scenarios. With further refinement, it holds strong potential to become a reliable solution for quantitative investing in volatile markets like cryptocurrencies.

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