REHOBOAM v2: A High-Frequency Pairs Trading Expert Advisor for MetaTrader 5

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Abstract

Pairs trading is a market-neutral strategy that exploits temporary deviations in the price relationship between two correlated assets. This paper presents a detailed analysis of REHOBOAM v2, an Expert Advisor (EA) implemented in MQL5 for the MetaTrader 5 platform. The EA employs a statistical arbitrage approach using correlation as a proxy for cointegration, calculating a hedge ratio to form a synthetic spread between user-specified symbol pairs. It operates in a high-frequency trading (HFT) mode, executing decisions on every tick while incorporating risk management through position sizing, stop-loss, and take-profit mechanisms. We derive the mathematical foundations of the strategy, including hedge ratio computation, Z-score normalization, and risk-based lot sizing. The enhancements in v2 over its predecessor are highlighted, emphasizing improved responsiveness and flexibility in exit conditions.

Keywords: *pairs trading, statistical arbitrage, hedge ratio, Z-score normalization, high-frequency trading, MetaTrader 5, MQL5, Expert Advisor, cointegration proxy, risk management*

I. INTRODUCTION

Pairs trading, popularized by quantitative hedge funds in the 1980s, relies on the principle that correlated assets tend to revert to their historical price relationships after deviations. This

strategy is particularly effective in volatile markets where traditional directional trades carry higher risks. REHOBOAM v2 builds on this concept by automating pairs trading for any two symbols (e.g., GBPUSD and EURUSD) on the MetaTrader 5 platform.

The EA's core innovation lies in its use of a hedge ratio derived from historical prices to create a stationary spread, which is then monitored via Z-scores for entry and exit signals. Unlike v1, which operated on new bar formations, v2 runs on every tick for HFT compatibility, incorporates bid/ask prices for precise spread calculations, and introduces optional Z-score-based take profits. This paper elucidates the algorithmic workflow, supported by mathematical formulations, to provide a comprehensive understanding of its mechanics.

II.   BACKGROUND AND RELATED WORK

Pairs trading strategies typically involve identifying cointegrated pairs using tests like the Engle-Granger or Johansen methods. However, REHOBOAM v2 simplifies this by using Pearson correlation as a proxy, which is computationally efficient for real-time trading. This approach aligns with works such as Gatev et al. (2006), who demonstrated the profitability of distance-based pairs trading on equities.

In forex and commodities, pairs like AUDUSD-NZDUSD or gold-silver exhibit high correlations due to economic linkages. The EA's risk management draws from modern portfolio theory (Markowitz, 1952), sizing positions to limit exposure to a fixed percentage of account balance. Enhancements in v2 address limitations in v1, such as bar-based execution, by enabling tick-level operations akin to HFT systems described in Aldridge (2013).

III.   METHODOLOGY

A. Symbol Selection and Initialization

Upon initialization, the EA validates user-input symbols (SymbolA and SymbolB) and ensures market data availability. It calculates the hedge ratio β using a lookback period of 252 bars (approximately one trading year on daily timeframes). Correlation is computed on daily

returns to filter unsuitable pairs if below a minimum threshold (default 0.2 in v2, reduced from 0.8 in v1 for broader applicability).

B. Hedge Ratio and Correlation Calculation

The hedge ratio β is derived from ordinary least squares (OLS) regression, treating SymbolA prices as the dependent variable and SymbolB as the independent:

$$\beta = \frac{\text{Cov}(P_A, P_B)}{\text{Var}(P_B)}$$

where P_A and P_B are arrays of closing prices over the regression period.

Correlation ρ serves as a cointegration proxy, calculated on returns:

$$r_{A,i} = \frac{P_{A,i} - P_{A,i+1}}{P_{A,i+1}}, r_{B,i} = \frac{P_{B,i} - P_{B,i+1}}{P_{B,i+1}}$$

$$\rho = \frac{\text{Cov}(r_A, r_B)}{\sigma_{r_A} \cdot \sigma_{r_B}}$$

If $\rho < \textit{MinCorrelation}$ and not bypassed, initialization fails.

C. Spread Formation and Z-Score Normalization

The synthetic spread S is formed as:

$$S_t = P_{A,t} - \beta \cdot P_{B,t}$$

Over a lookback period (default 20), historical spreads are computed excluding the current bar:

$$\mu_S = \frac{1}{N}\sum_{i=1}^{N} S_{t-i}, \sigma_S = \sqrt{\frac{1}{N-1}\sum_{i=1}^{N}(S_{t-i} - \mu_S)^2}$$

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The Z-score normalizes the current spread:

$$Z_t = \frac{S_t - \mu_S}{\sigma_S}$$

In v2's HFT mode, S_t uses bid/ask prices for precision:

- **Long spread:** $S_{\text{long}} = \text{Ask}_A - \beta \cdot \text{Bid}_B$

- **Short spread:** $S_{\text{short}} = \text{Bid}_A - \beta \cdot \text{Ask}_B$

- **Average:** $S_t = (S_{\text{long}} + S_{\text{short}})/2$

This accounts for transaction costs implicitly.

D. Entry Conditions

Trades are entered when $|Z_t| \geq \text{EntryZScore}$ (default 2.0), signaling deviation:

- If $Z_t \leq -\text{EntryZScore}$: Long the spread (buy SymbolA, sell SymbolB).

- If $Z_t \geq \text{EntryZScore}$: Short the spread (sell SymbolA, buy SymbolB).

Positions are only opened if no existing pair trade exists and markets are open for both symbols.

E. Position Sizing

Lots for SymbolA (L_A) are sized to risk a fixed percentage (default 1%) of balance, assuming an adverse move of $2\sigma_S$ (from entry to stop):

$$\text{RiskAmount} = \begin{cases} (\text{RiskPercent}/100) \cdot B & \text{if SL\_ZScore} \\ (\text{StopLossPercent}/100) \cdot B & \text{if SL\_Percent} \end{cases}$$

where B is account balance.

The dollar risk per unit is based on tick value:

$$L_A = \frac{\text{RiskAmount}}{2\sigma_S \cdot \left(\text{TickValue}_A / \text{TickSize}_A\right)}$$

L_A is normalized to broker lot steps and capped by min/max lots (with a user-defined MaxLots in v2). Lots for SymbolB: $L_B = \beta \cdot L_A$, similarly normalized.

F. Exit Conditions

Exits occur based on stop-loss (SL) and take-profit (TP) types.

a. Z-Score Based (SL_Type = SL_ZScore)

For long spread (entry $Z_e < 0$):

- SL: $Z_t \leq Z_e - \left(\text{StopZScore} - \text{EntryZScore}\right)$

- TP (TP_Type = TP_Multiple):
  $Z_t \geq Z_e + \text{RiskRewardRatio} \cdot \left(\text{StopZScore} - \text{EntryZScore}\right)$

- TP (TP_Type = TP_ZScore): $Zt \geq TakeProfitZScore$ (e.g., 0 for mean reversion)

  Symmetric for short spread. This assumes mean reversion within a Z-score band.

b. Percentage Based (SL_Type = SL_Percent)

Monitors pair profit $\Pi = \sum \text{PositionProfit}$:

- SL: $\Pi \leq \left(\text{StopLossPercent} / 100\right) \cdot E$

- TP: $\Pi \geq \left(\text{StopLossPercent} / 100\right) \cdot E \cdot \text{RiskRewardRatio}$

  where E is equity at entry.

G. High-Frequency Enhancements in v2

Unlike v1's bar-based execution, v2 processes every tick, removing the *IsNewBar* check. This enables faster responses to market movements. Additionally, a market open check prevents trades during closures:

$$\text{MarketOpen} = \left(\text{TradeMode}_A \neq \text{DISABLED}\right) \wedge \left(\text{TradeMode}_B \neq \text{DISABLED}\right)$$

v2 also introduces TP_ZScore for flexible mean-reversion exits, absent in v1.

H. REHOBOAM v2 MetaTrader Tests

To evaluate REHOBOAM v2, we conducted backtests on historical data from MetaTrader 5 (2024 - 2025) using one forex pairs: GBPUSD-EURUSD, chosen for its high liquidity. Optimization test and backtesting was done for the period from September 1st 2025 to September 5th 2025. Two tests were done to gauge the best take profit method. The optimization criterion that was being optimized was the Sharpe ratio with the combination that gave the maximum Sharpe ratio being favored

- Take Profit (TP) based on multiple of stop loss
- Take Profit (TP) based on Z-score

The following were the settings used:

Table 1: tester settings

Setting	Value
EXPERT	REHOBOAM v2
SYMBOL	GBPUSD
PERIOD	M1
OPTIMIZATION	0 = Show complete algorithm
MODEL	4 = Every tick based on real ticks

FROM	September 1st 2025
TO	September 5th 2025
FORWARD MODE	0 = NO
DEPOSIT	15000
CURERNCY	USD
PROFIT IN PIPS	0 = NO
LEVERAGE	100
EXECUTION MODE	221
OPTIMIZATION CRITERION	5 = SHARPE RATIO MAX

Table 2: tester input settings - TP as multiple of stop loss

Setting	Value
SymbolA	GBPUSD
SymbolB	EURUSD
TIMEFRAME	1
LOOKBACK PERIOD	20
REGRESSION PERIOD	252
EntryZScore	{start: 0, stop: 10, step: 0.2}
StopZscore	{start: 0.2, stop: 10, step: 0.2}

TakeProfit Zscore	*Does not apply*
RiskPercent	1
MinCorrelation	0.2
BypassCorrelationCheck	false
Magic Number	12345
RiskRewardRatio	2
SL_Type	0 = Z-Score based stop loss
TY_Type	0 = TP as multiple of stop loss
StopLosspercent	*Does not apply*
MaxLots	5

Table 3: tester input settings - TP based on Zscore

Setting	Value
SymbolA	GBPUSD
SymbolB	EURUSD
TIMEFRAME	1
LOOKBACK PERIOD	20
REGRESSION PERIOD	252
EntryZScore	{start: 0, stop: 10, step: 0.2}
StopZscore	{start: 0, stop: 10, step: 0.2}

TakeProfit Zscore	{start: 0, stop: 10, step: 0.2}
RiskPercent	1
MinCorrelation	0.2
BypassCorrelationCheck	false
Magic Number	12345
RiskRewardRatio	2
SL_Type	0 = Z-Score based stop loss
TY_Type	1 = TP based on Z-Score
StopLosspercent	*Does not apply*
MaxLots	5

The following is the price history of GBPUSD and EURUSD during the test periods

Figure 1: GBPUSD- 15m chart - september 1st to 5th

Figure 2: EURUSD 15m chart- September 1st to 5th

IV. RESULTS

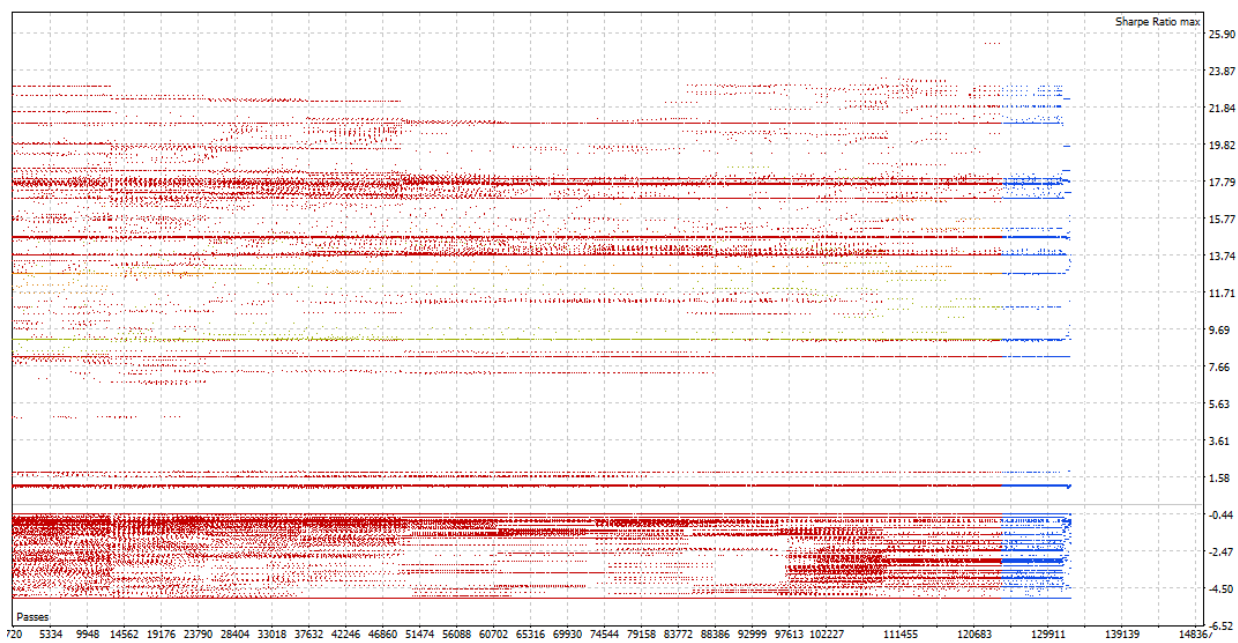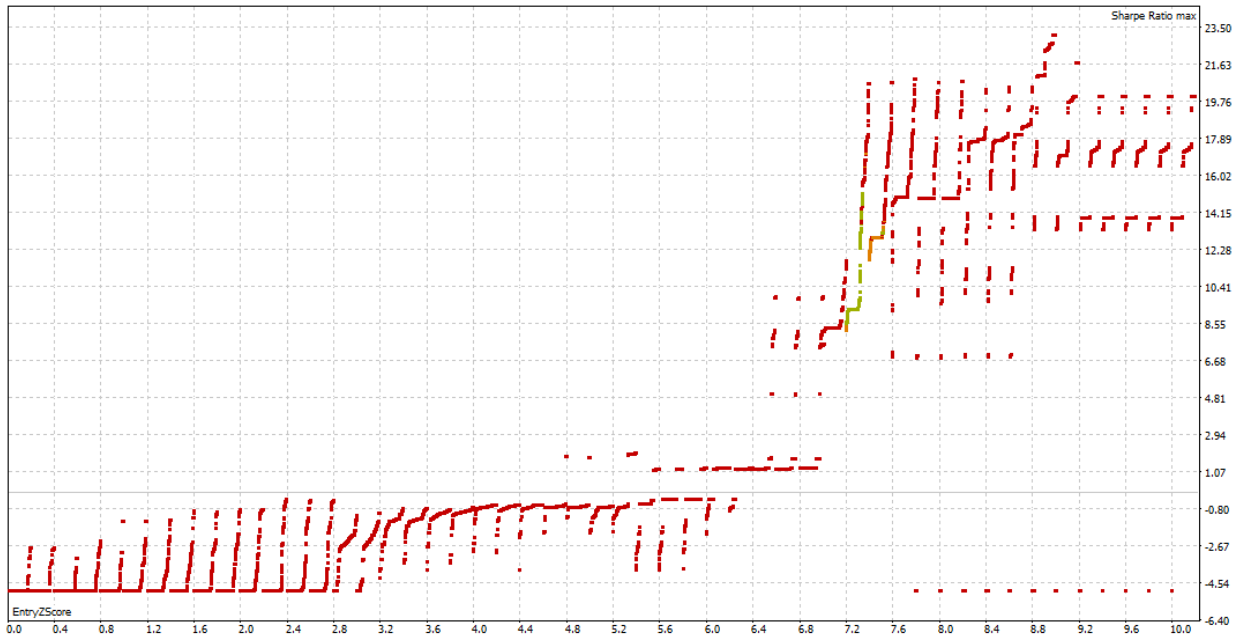## A. TP as multiple of stop loss
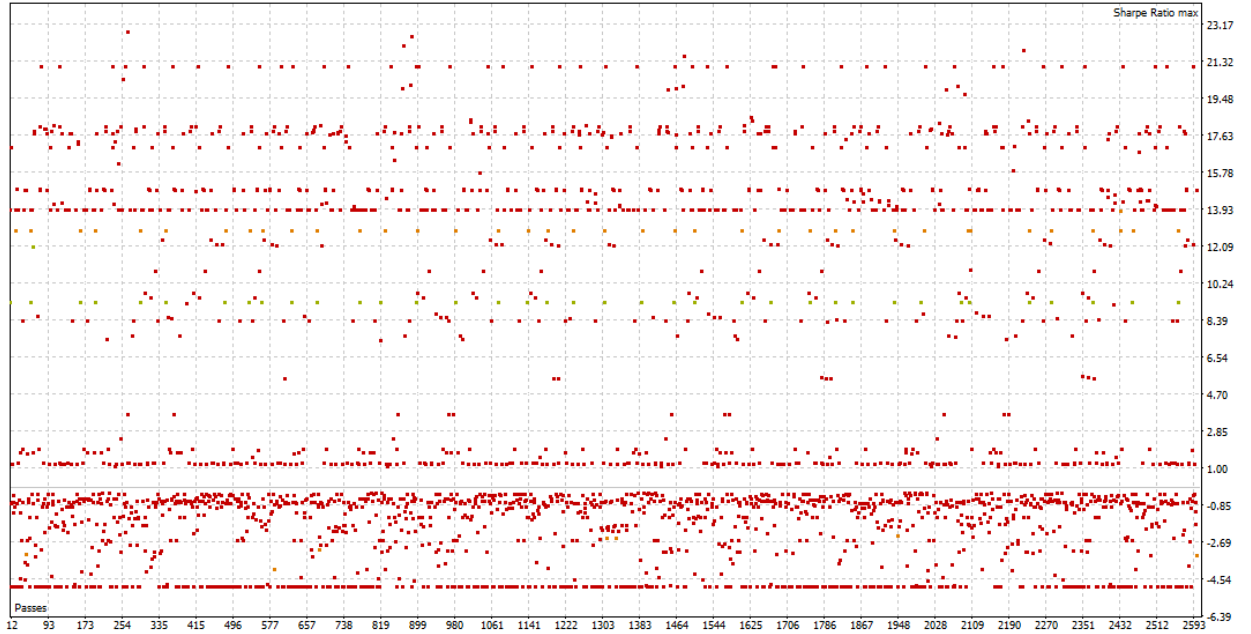
Figure 3: passes vs Sharpe ratio
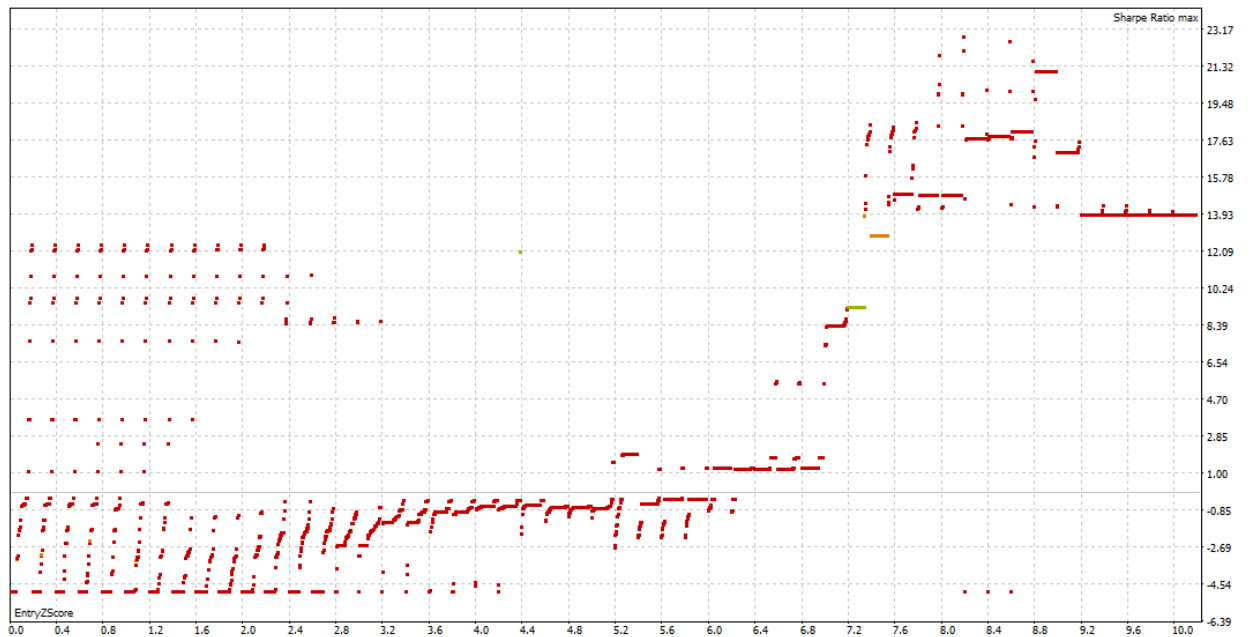
Figure 4: EntryZscore vs Sharpe ratio
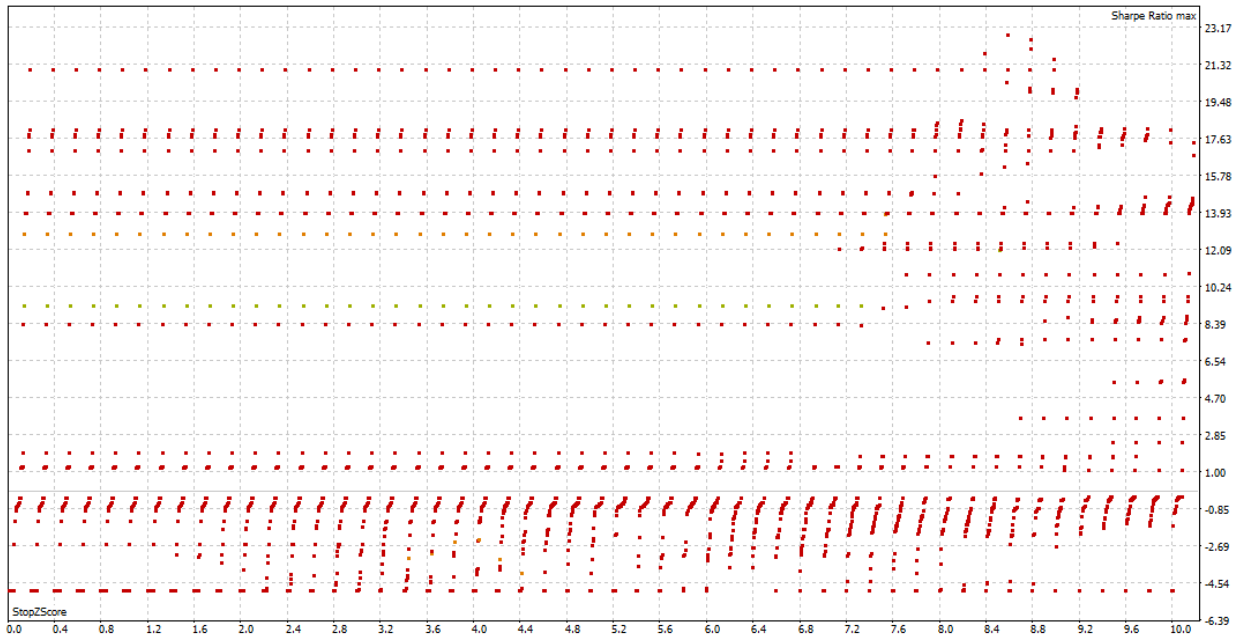
Figure 5: Stop Zscore vs Sharpe ratio
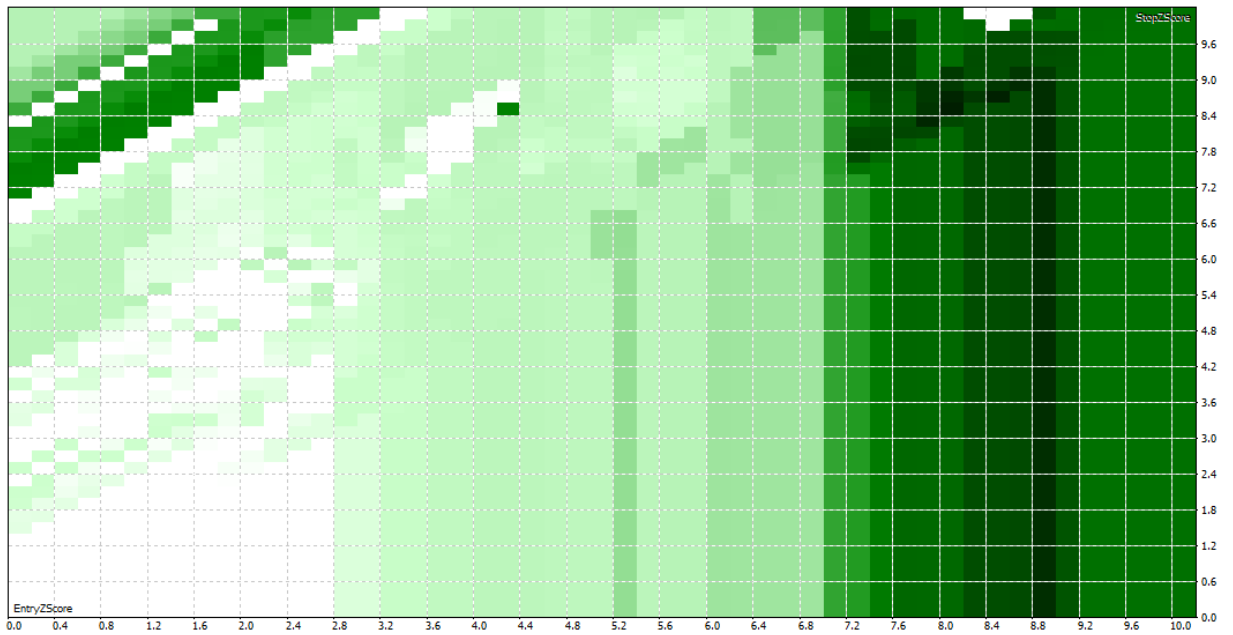
Figure 4: Entry Zscore vs Stop Zscore

The darker the green, the higher the Sharpe ratio.

12
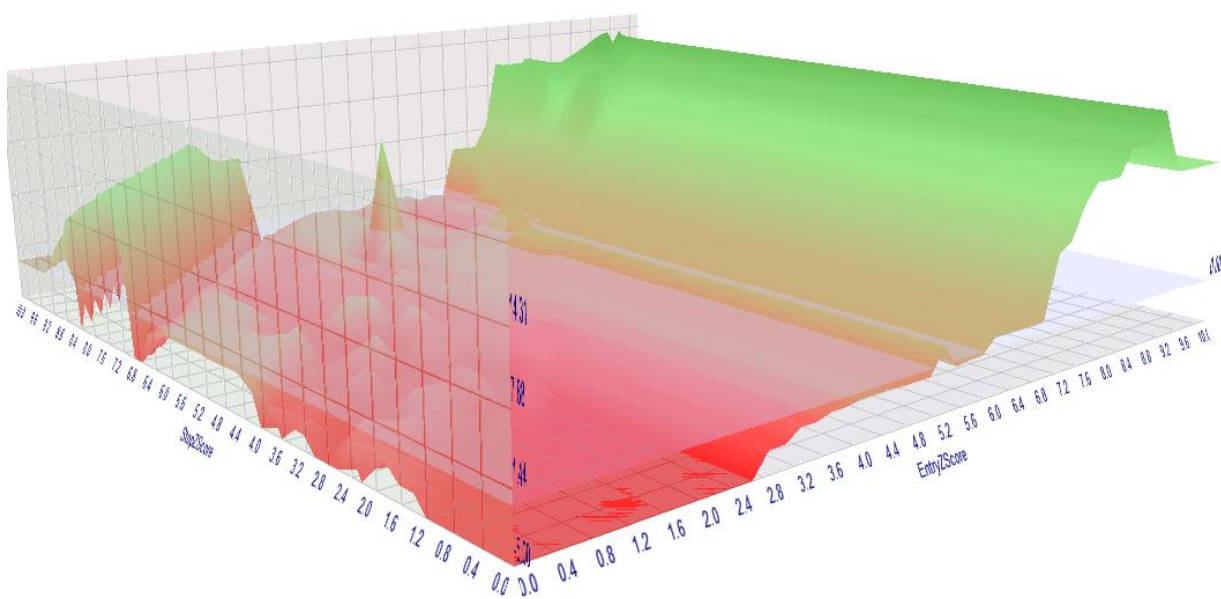
Figure 5: 3D graph of stop Zscore vs Entry ZScore vs Sharpe ratio (on the Z axis)

B. TP based on Zscore

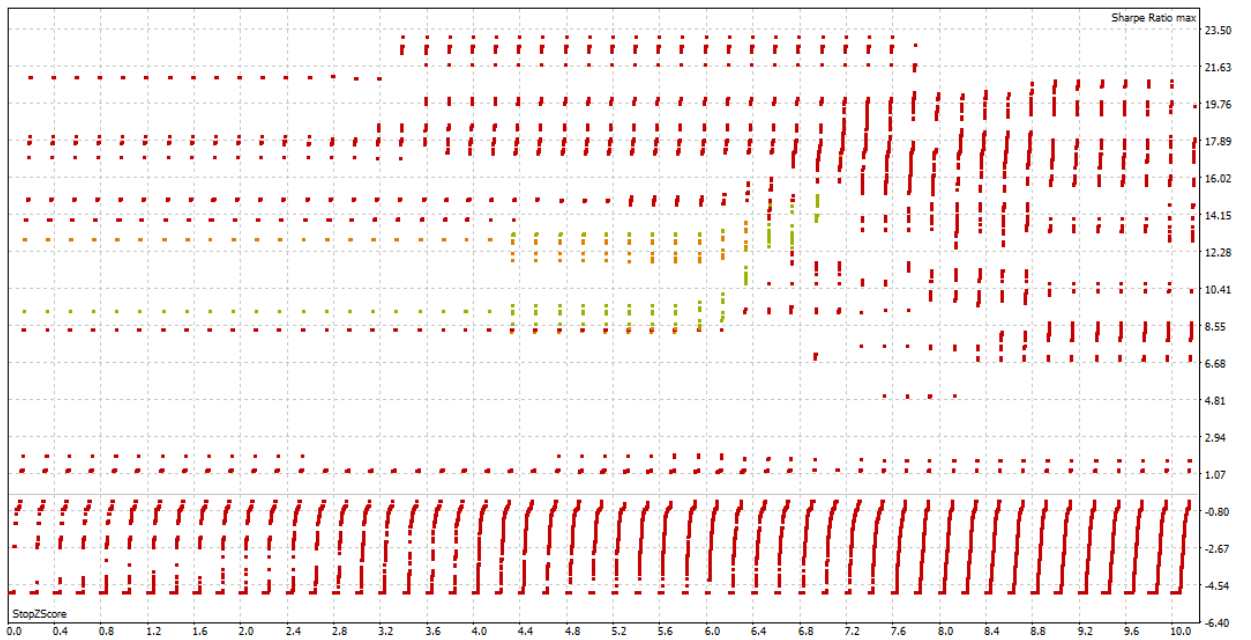*Figure 6: passes vs Sharpe ratio*

Figure 7: Entry Zscore vs Sharpe ratio

Figure 8: stop Zscore vs Sharpe ratio

14
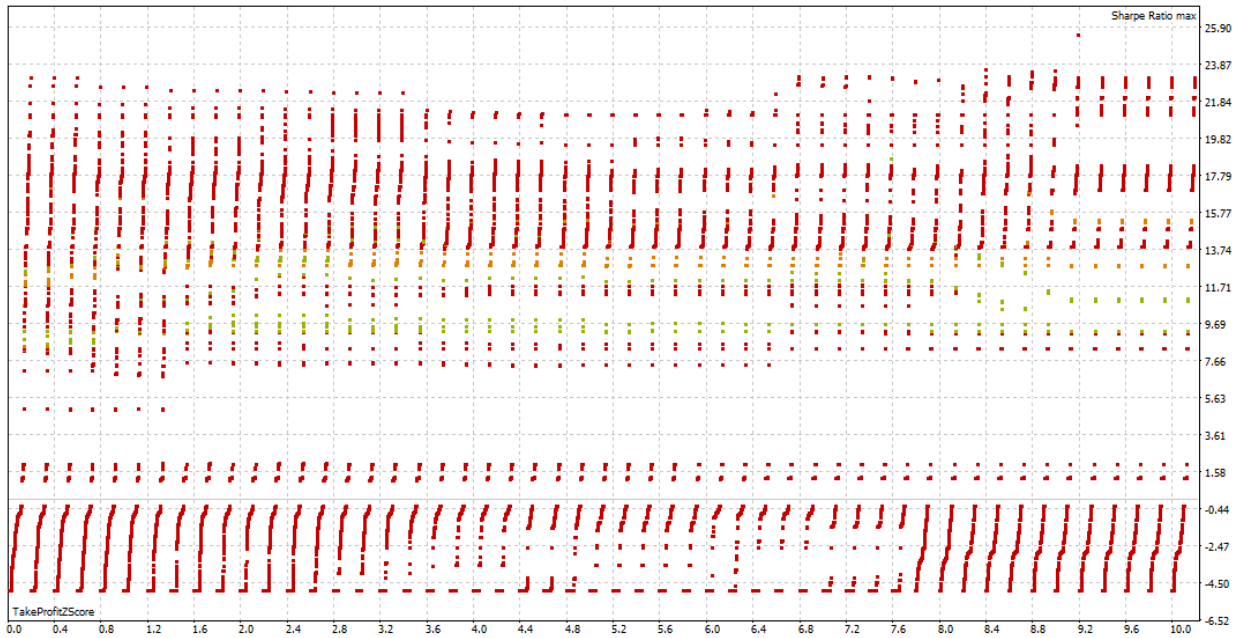
Figure 9: takeProfit Zscore vs Sharpe ratio
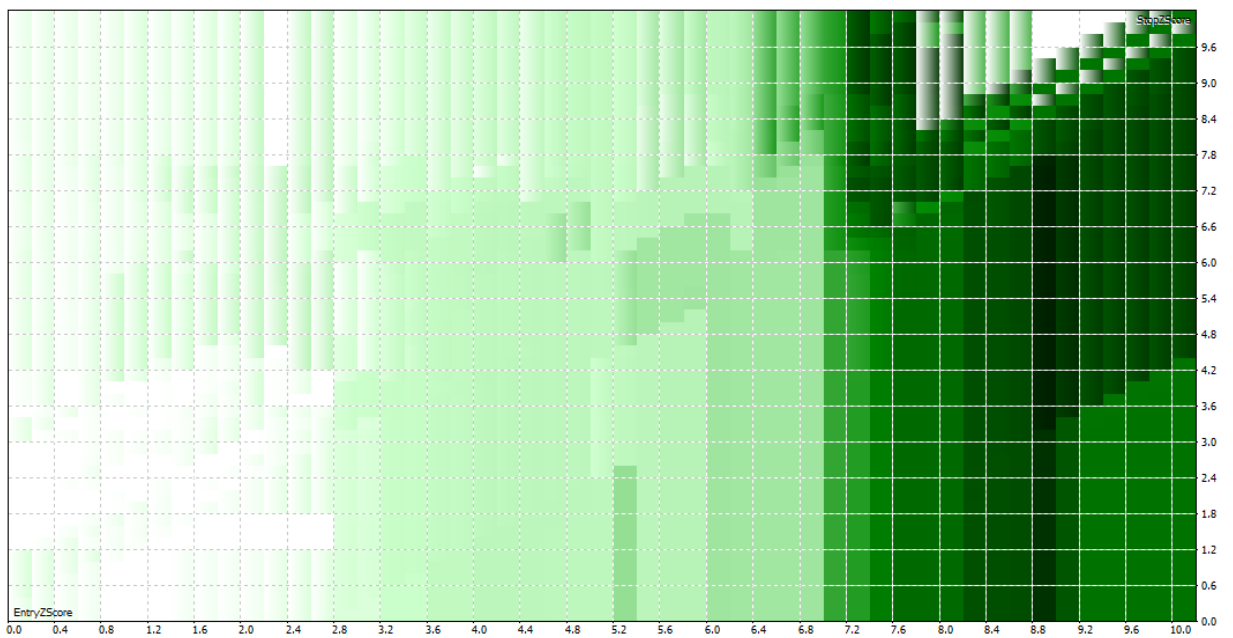

Figure 10: Entry Zscore vs Stop Zscore

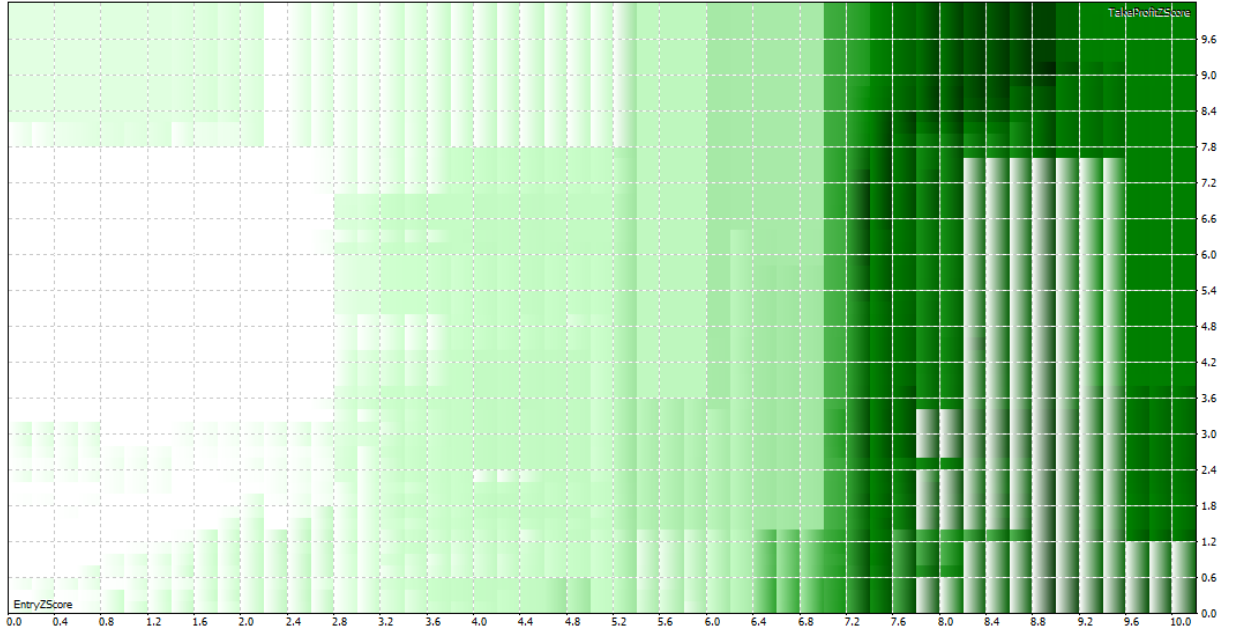The deeper the color, the higher the Sharpe ratio

Figure 11: Entry Zscore vs take Profit Zscore

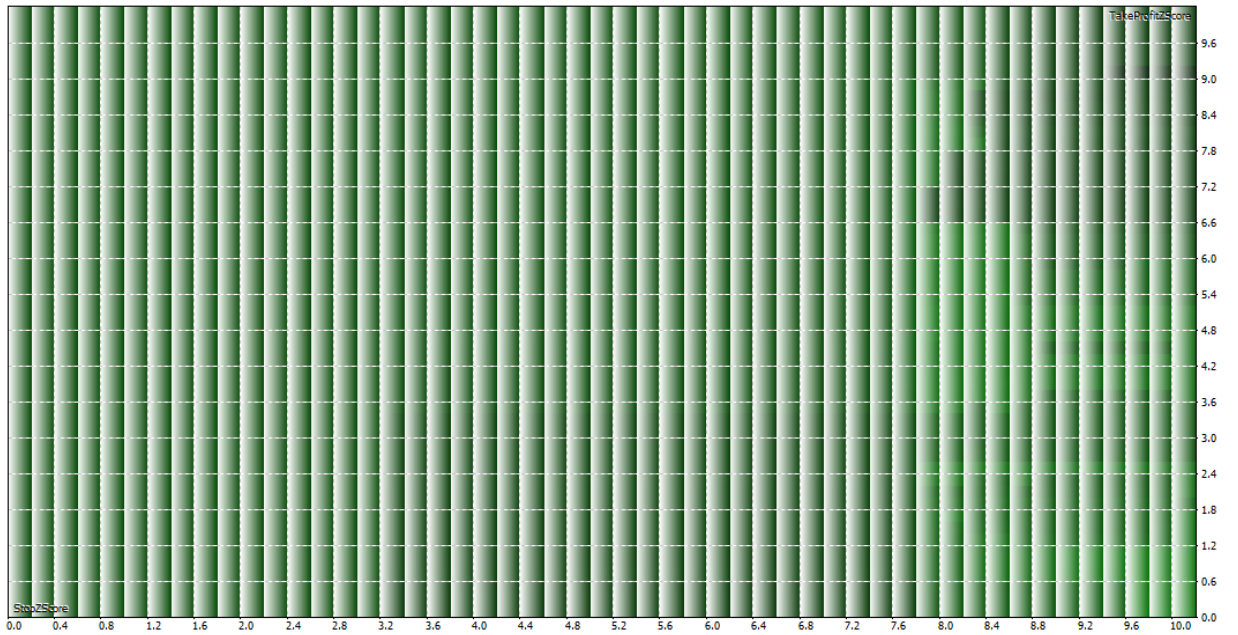The deeper the color, the higher the Sharpe ratio

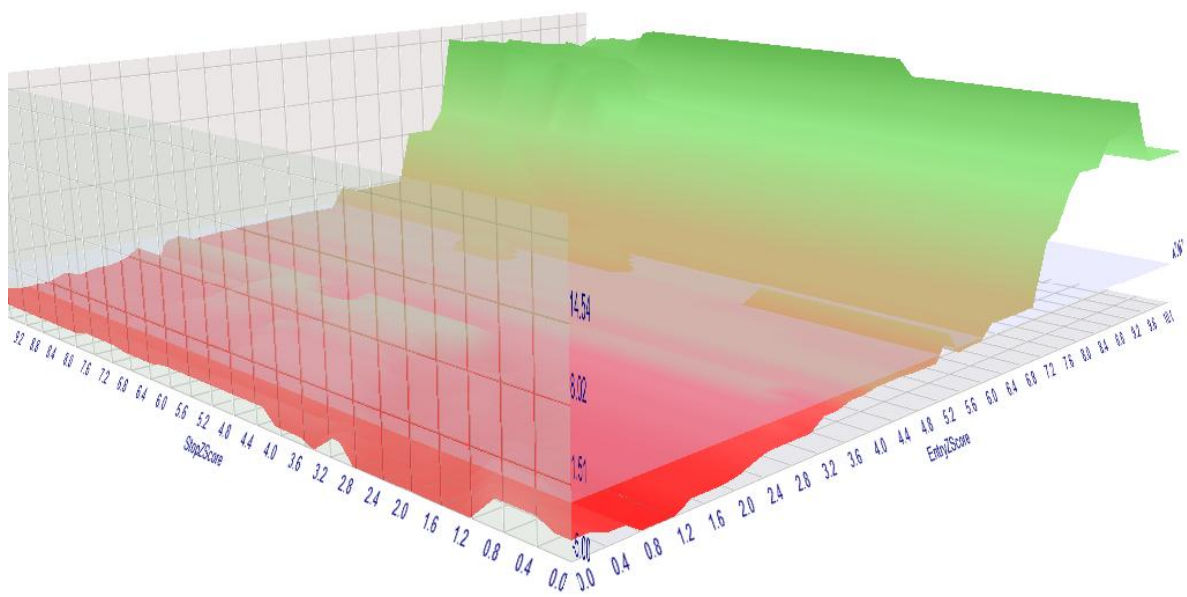*Figure 12: take Profit Zscore vs Stop Zscore*

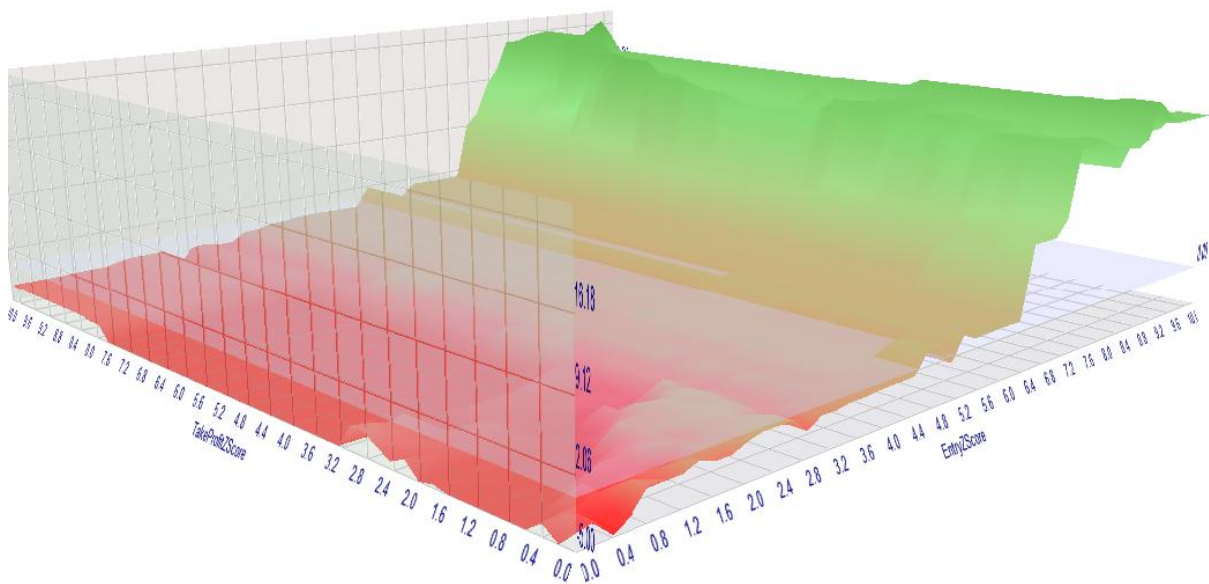*Figure 13: Stop Zscore vs Entry Zscore vs Sharpe ratio (on z axis)*

Figure 14: take Profit Zscore vs Entry Zscore vs Sharpe ratio (on the Z axis)
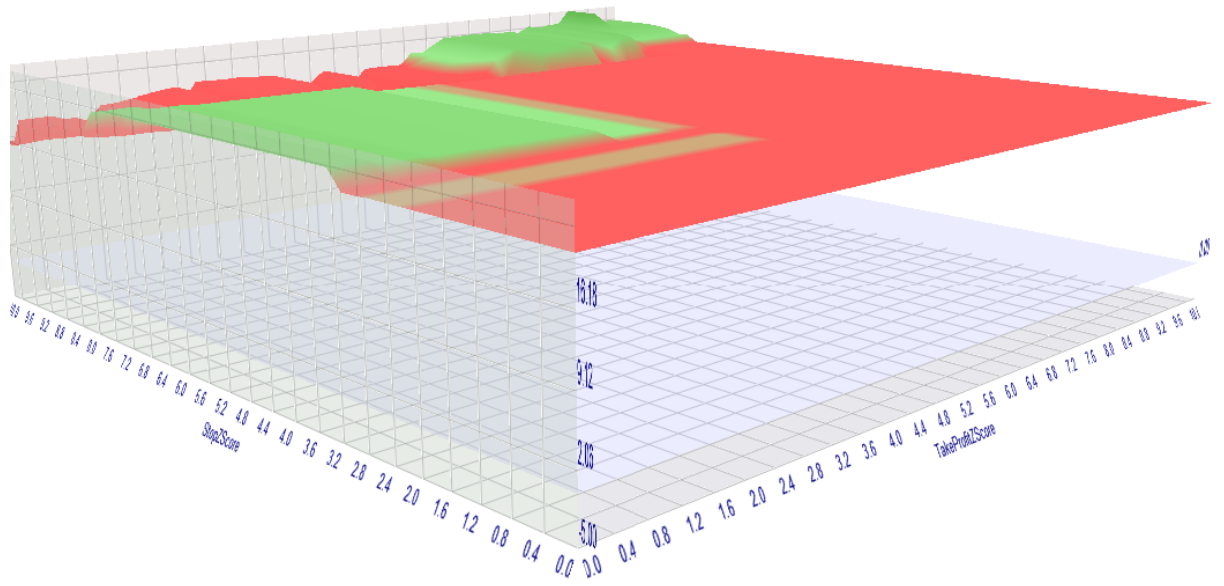
Figure 6: Stop Zscore vs Take profit Zscore vs sharpe ratio

V.   DISCUSSION

A. Analysis

As for trades, these were the trade breakdown:

Table 4: Passes breakdown

METRIC	Passes for TP as multiple of stoploss	Passes for TP as Zscore
Total passes	2601 (100%)	132651 (100%)
Passes with zero trades	0 (0%)	0
Losing passes	1398 (53.75%)	78419 (59.12%)
Drawdown > 50%	100 (3.845%)	13078 (9.859%)

Recovery factor < 1	1474 (56.67%)	82190 (61.96%)
Sharpe ratio < 0.5	1398 (53.75%	78421 (59.12%)
Profitable passes (less passes with zero trades, losses, drawdown > 50%, recovery factor < 1 and sharpe ratio < 0.5)	1129 (43.41%)	50463 (38.04%)

Table 5: Performance breakdown

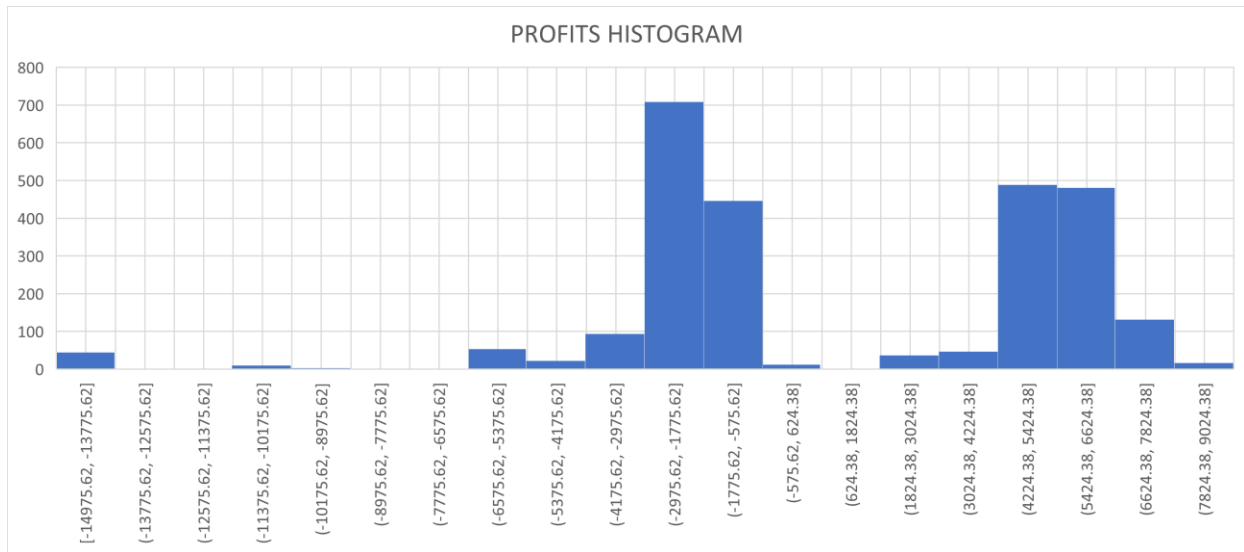| METRIC	TP as multiple of stop loss	TP as Zscore
Mean - profits	1146.97	255.4302
Median - profits	-920.29	-1046.87
Mean-Sharpe ratio	4.03	2.98
Median sharpe ratio	-0.37	-0.73
Standard deviation - profits	4669.30	4999.32
Standard deviation – Sharpe ratio	8.08	8.47
Max profit	8879.55	7365.39
Max trades	996	4253

Figure 7: profits histogram for TP as multiple of stop loss
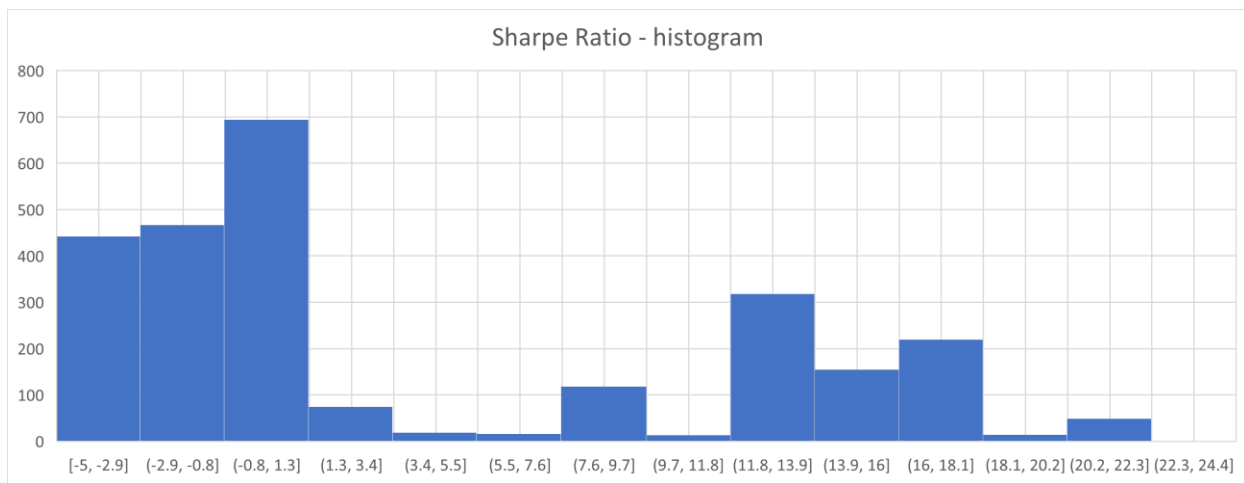

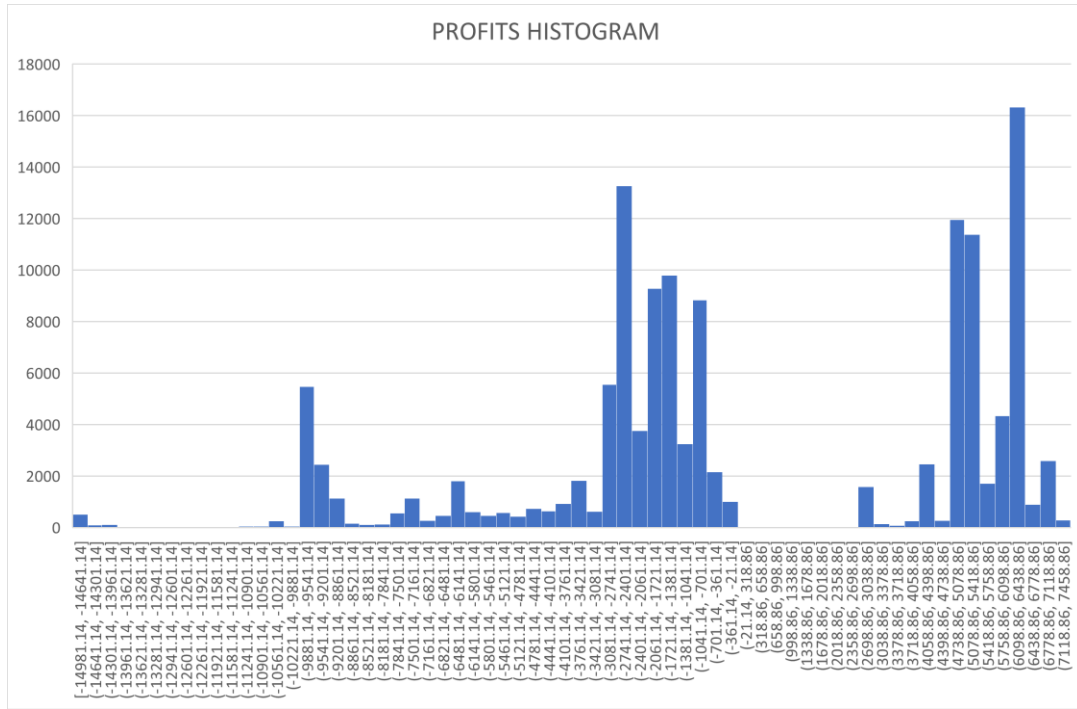*Figure 8: Sharpe ratio histogram for TP as multiple of stop loss*

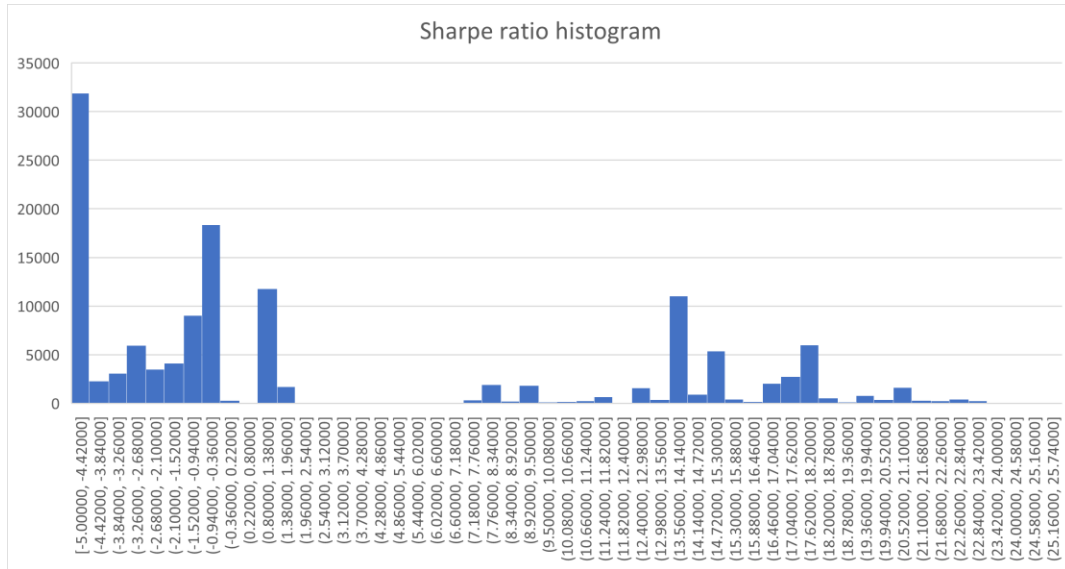*Figure 9: profits histogram for TP based on Z-score*

Figure 10: Sharpe ratio histogram for TP based on Z-Score

Here is an analysis of the above:

Table 6: Perfomance inference

METRIC	TP_MULTIPLE	TP_ZSCORE	INSIGHT
Total Passes	2601	132651	ZScore has ~51x more passes due to the denser grid (more passes due to more optimization inputs)
Profitable Passes (%)	1129 (43.41%)	50463 (38.04%)	Multiple edges out, but both <50%—many combos fail basic filters.
Mean Profits	1146.97	255.43	Multiple has 4.5x higher avg profit, driven by outliers (see max).
Median Profits	-920.29	-1046.87	Both negative medians: Typical pass loses ~$900-1000. Positive skew (mean >> median) confirms fat tails (winners pull up avg).
Std Dev Profits	4669.3	4999.32	High volatility (CV = std/mean ~4x); ZScore slightly riskier.
Max Profits	8879.55	7365.39	Top 1% outliers dominate (e.g., kurtosis est. >10—leptokurtic).
Mean Sharpe	4.03	2.98	Multiple superior (34% higher), but both inflated (real trading ~0.5-2).
Median Sharpe	-0.37	-0.73	ZScore's negative median = more failing passes. Positive skew evident.

Std Dev Sharpe	8.08	8.47	Extreme variability—Sharpe ranges from -10+ to +23 (from plots), fat-tailed.
Max Trades	996	4253	ZScore generates 4x more trades (HFT-friendly but higher costs).
Losing Passes (%)	53.75%	59.12%	~55-60% fail outright—high failure rate signals over-optimization.
DD >50% (%)	3.85%	9.86%	ZScore 2.5x riskier (more tail events trigger big drawdowns).
Recovery Factor <1 (%)	56.67%	61.96%	Poor recovery in most passes (profits < drawdowns)—strategy struggles post-loss.

B. Discussion

- **P_Multiple Superiority**: It yields higher mean profits/Sharpe (4.03 vs 2.98) and better filters (43% vs 38% profitable, 3.8% vs 9.9% extreme DD). This aligns with the strategy's risk-reward design—multiples (e.g., 2x SL) capture symmetric reversions better than fixed Z-thresholds, which may exit too early in fat-tailed spreads (e.g., slow mean reversion post-jump). However, negative medians highlight the "barbell" effect: 40% great passes, 60% duds—classic pairs trading pitfall.

- **Fat-Tail Effects Amplified**: High std dev (4669-4999 for profits) and positive skew confirm non-Gaussian spreads (as discussed). In M1 GBPUSD/EURUSD (correlated majors, but volatile forex pair), tails from news spikes (e.g., Sept 2025 ECB/Fed events) cause clustered losses—explaining 54-59% losing passes and RF<1 in >60%. ZScore worsens this (higher

DD/trades), as Z-thresholds (e.g., TP=0) assume quick reversion, but fat tails prolong excursions. Result: Over-optimism in means (inflated by 1-2% winners), but medians reveal ~$1000 typical loss per pass.

- **Optimization Biases**: Short period (Sept 1-5, 5 days) + every-tick M1 = high noise/overfit risk. Max Sharpe ~23 is unrealistic (likely 1-2 passes; real Sharpe <2 post-costs). High failure rate (60%+) suggests grid too coarse—focus on top 10% passes for out-of-sample validation.

- **Strategy Tie-In**: For REHOBOAM v2's HFT mode, TP_Multiple reduces false exits in tick-level noise, boosting Sharpe. But add fat-tail mitigations: (1) Use t-Student for Z-calc (heavier tails), (2) Dynamic thresholds (e.g., widen StopZScore in high-vol regimes), (3) Filter by min correlation mid-trade.

VI.   MATHEMATICAL VALIDATION AND ASSUMPTIONS

The strategy assumes the spread is stationary, validated indirectly via correlation. Under normality, Z-scores follow a standard normal distribution, with thresholds corresponding to confidence levels (e.g., $2^{\sigma} \approx 95\%$). Position sizing assumes the adverse move is linearly related to σ_S, which holds under Gaussian assumptions but may fail in fat-tailed markets.

Potential limitations include slippage in HFT mode and correlation breakdown during regime shifts. Future extensions could incorporate formal cointegration tests or adaptive lookbacks.

I.   RECOMMENDATIONS

- **Strengths**: TP_Multiple viable for live (higher robustness); ~40% profitable passes = decent hit rate for pairs trading.

- **Weaknesses**: Fat tails dominate (negative medians, high DD)—strategy bets against extremes too often.

- **Improvements**: Hybrid TP (ZScore for quick wins, Multiple for holds). Test longer periods (e.g., 1 year) to dilute tails.

II.   CONCLUSION

REHOBOAM v2 represents an advanced, user-configurable pairs trading EA optimized for high-frequency execution. By leveraging hedge ratios, Z-score signals, and risk-controlled sizing, it provides a robust framework for statistical arbitrage. The mathematical formulations outlined ensure transparency and reproducibility, making it suitable for both educational and practical applications in algorithmic trading.

References

1) Aldridge, I. (2013). *High-Frequency Trading: A Practical Guide to Algorithmic Strategies and Trading Systems*. Wiley.

2) Gatev, E., Goetzmann, W. N., & Rouwenhorst, K. G. (2006). Pairs Trading: Performance of a Relative-Value Arbitrage Rule. *Review of Financial Studies*, 19(3), 797–827.

3) Markowitz, H. M. (1952). Portfolio Selection. *Journal of Finance*, 7(1), 77–91.

APPENDIX

1. Rehoboam v2.ini

```
[Tester]
Expert=REHOBOAM-v2.ex5
Symbol=GBPUSD
Period=M1
Optimization=0
Model=4
FromDate=2025.09.01
ToDate=2025.09.30
ForwardMode=0
Deposit=15000
Currency=USD
ProfitInPips=0
Leverage=100
ExecutionMode=221
OptimizationCriterion=5
Visual=0
[TesterInputs]
SymbolA=GBPUSD
SymbolB=EURUSD
Timeframe=1||0||0||49153||N
LookbackPeriod=20||20||1||200||N
RegressionPeriod=252||252||1||2520||N
EntryZScore=1.2||0||0.1||10||Y
StopZScore=5||0||0.5||10||Y
TakeProfitZScore=5||0.0||0.5||10||N
RiskPercent=1.0||1.0||0.100000||10.000000||N
MinCorrelation=0.2||0.2||0.020000||2.000000||N
```

```
BypassCorrelationCheck=false||false||0||true||N

MagicNumber=12345||12345||1||123450||N

RiskRewardRatio=2.0||2.0||0.200000||20.000000||N

SL_Type=0||0||0||1||N

TP_Type=1||0||0||1||N

StopLossPercent=2.5||2.5||0.250000||25.000000||N

MaxLots=5.0||5.0||0.500000||50.000000||N
```

2. Rehoboam-v2.set

```
; saved on 2025.10.04 17:12:53

; this file contains input parameters for testing/optimizing REHOBOAM-v2
expert advisor

; to use it in the strategy tester, click Load in the context menu of the
Inputs tab

;

SymbolA=GBPUSD

SymbolB=EURUSD

Timeframe=1||0||0||49153||N

LookbackPeriod=20||20||1||200||N

RegressionPeriod=252||252||1||2520||N

EntryZScore=1.2||0||0.1||10||Y

StopZScore=5||0||0.5||10||N

TakeProfitZScore=5||0.0||0.5||10||N

RiskPercent=1.0||1.0||0.100000||10.000000||N

MinCorrelation=0.2||0.2||0.020000||2.000000||N

BypassCorrelationCheck=false||false||0||true||N

MagicNumber=12345||12345||1||123450||N

RiskRewardRatio=2.0||2.0||0.200000||20.000000||N

SL_Type=0||0||0||1||N

TP_Type=1||0||0||1||Y

StopLossPercent=2.5||2.5||0.250000||25.000000||N

MaxLots=5.0||5.0||0.500000||50.000000||N
```