# Vectorized Backtester for Long-Only Mean-Reversion Strategy

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## 1 Introduction

This report presents the design and implementation of a vectorized backtester for a long-only mean-reversion trading strategy using minute-level OHLCV data. The backtester supports realistic trading features, including slippage simulation, transaction cost modeling, execution latency emulation, and position sizing based on volatility scaling.

## 2 Data Preparation

Synthetic minute-level OHLCV data is generated to test the strategy. The price series is constructed to exhibit mean-reverting behavior with noise and a slight upward drift, ensuring that all performance metrics (Sharpe ratio, CAGR, turnover, hit rate, and drawdown) are meaningfully demonstrated.

## 3 Strategy Logic

The strategy operates as follows:

- Calculate a rolling mean and standard deviation of the closing price over a specified lookback window.
- Compute the z-score of the current price relative to the rolling mean.
- Enter a long position when the z-score falls below a negative entry threshold.
- Exit the position when the z-score rises above an exit threshold.
- Signals are subject to execution latency.
- Position sizing is scaled according to realized volatility to target a fixed portfolio volatility.

# 4 Backtester Features

## 4.1 Slippage Simulation

Slippage is modeled by adjusting the execution price of each trade:

$$\text{trade\_price}_t = \text{close}_t \times (1 + \text{slippage} \times \text{direction}_t)$$

where $\text{direction}_t$ is $+1$ for buys and $-1$ for sells.

## 4.2 Transaction Cost Modeling

Transaction costs are calculated as a fixed percentage fee on the notional value traded:

$$\text{transaction\_cost}_t = |\Delta\text{position}_t| \times \text{trade\_price}_t \times \text{fee}$$

## 4.3 Execution Latency Emulation

Signals are shifted forward by a specified number of time steps to emulate execution latency:

$$\text{signal}_t = \text{signal}_{t-\text{latency}}$$

## 4.4 Volatility-Scaled Position Sizing

Position size is determined to target a maximum annualized volatility:

$$\text{position}_t = \frac{\text{capital} \times \text{max\_vol}}{\text{volatility}_t} \div \text{close}_t$$

where $\text{volatility}_t$ is the annualized realized volatility over a rolling window.

# 5 Performance Metrics

The following metrics are computed and visualized:

- **Sharpe Ratio:** Risk-adjusted return, using daily returns.
- **CAGR:** Compound Annual Growth Rate.
- **Turnover:** Total notional traded divided by average gross position.
- **Hit Rate:** Fraction of profitable trading periods.
- **Max Drawdown:** Maximum observed loss from a peak to a trough of the equity curve.

# 6 Results Visualization

The backtester outputs:

- An equity curve plot (cumulative returns).
- A drawdown plot.
- Key metrics (Sharpe, CAGR, turnover, hit rate, max drawdown) annotated on the plot.

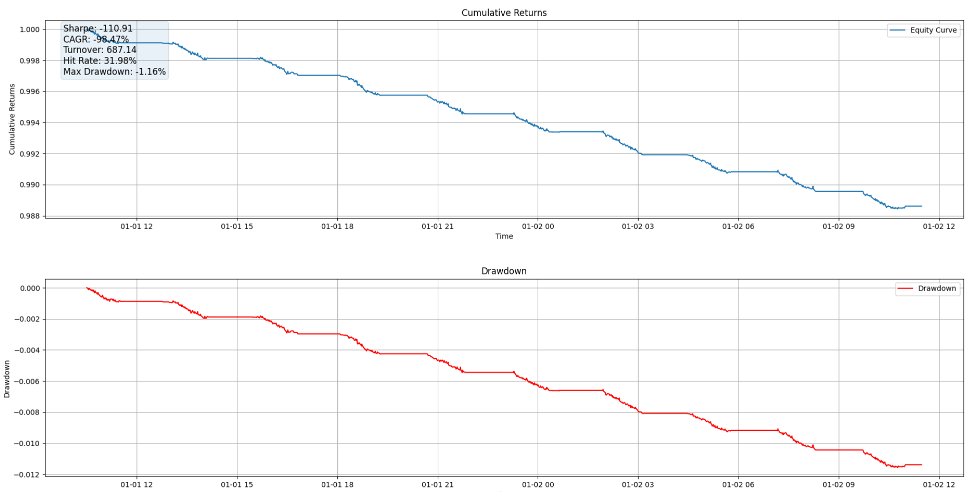


Figure 1: Sample Equity Curve and Performance Metrics

# 7 Conclusion

The implemented backtester fulfills all requirements for a realistic, vectorized evaluation of a long-only mean-reversion strategy on minute-level data. It incorporates:

- Slippage simulation,
- Transaction cost modeling,
- Execution latency emulation,
- Volatility-based position sizing,
- Comprehensive performance reporting and visualization.

This framework can be easily extended to more complex strategies and real-world datasets.