I think the take home exercise is good learning for me. So above and over the “right” strategies, I wanted to try a superset of all strategies and want to understand what makes a strategy work and what doesn’t make it work that well.

So, step 1, I made a list of all the strategies I am going to try. Here is an exhaustive list :

I am trading on a day-by-day basis using **only daily closing data** and want to implement strategies over a **200-day trading period**

1. Moving Average-Based Strategies

- ☑ **Simple Moving Average (SMA) Crossover**:
  - ☑ Calculate short-term (e.g., 10-day) and long-term (e.g., 50-day) moving averages.
  - ☑ **Signal**: Go **long** when the short-term SMA crosses above the long-term SMA (golden cross) and **short** when it crosses below (death cross).
  - ☑ **Why it works**: Captures momentum and trend reversals.
- ☑ **Exponential Moving Average (EMA)**:
  - ☑ Similar to SMA but reacts more quickly to price changes.
  - ☑ Use EMA-based crossovers or compare the closing price to the EMA for signals.
  - ☑ **Signal**: Go **long** if the closing price is above the EMA and **short** if it's below.

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2. Momentum-Based Strategies

- ☑ **Relative Strength Index (RSI)**:
  - ☑ Calculate RSI (e.g., 14-day) to determine overbought (RSI > 70) or oversold (RSI < 30) conditions.
  - ☑ **Signal**: Go **long** when RSI < 30 and **short** when RSI > 70.
  - ☑ **Optional**: Use divergence between RSI and price for reversal signals.
- ☑ **Rate of Change (ROC)**:
  - ☑ Measures the percentage change in closing price over a period (e.g., 10 days).
  - ☑ **Signal**: Go **long** when ROC > 0 and **short** when ROC < 0.
  - ☑ **Why it works**: Captures momentum shifts and continuation trends.

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3. Mean Reversion Strategies

- ☑ **Bollinger Bands**:
  - ☑ Calculate a 20-day SMA and bands 2 standard deviations above and below it.
  - ☑ **Signal**: Go **long** when the price touches the lower band (oversold) and **short** when it touches the upper band (overbought).

- ☑ **Z-Score of Price**:
  - ☑ Compute the z-score of the price based on a rolling mean and standard deviation (e.g., 20 days).
  - ☑ **Signal**: Go **long** if the z-score is below -2 and **short** if above +2 (extreme deviations from the mean).
- ☑ **Mean Reversion with RSI**:
  - ☑ Combine RSI and mean reversion to confirm signals:
    - ☑ **Buy** oversold stocks near their mean or lower Bollinger band with RSI < 30.
    - ☑ **Sell** overbought stocks near their upper band with RSI > 70.

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4. Breakout Strategies

- **Donchian Channels**:
  - Use the highest high and lowest low over the last **n** days (e.g., 20).
  - **Signal**: Go **long** when the price breaks above the upper channel and **short** when it breaks below the lower channel.
- **Support and Resistance Levels**:
  - Identify levels where the price has consistently reversed in the past.
  - **Signal**: Go **long** if the price breaks above resistance or bounces off support; **short** if it breaks below support or reverses from resistance.

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5. Statistical and Quantitative Strategies

- **Pairs Trading**:
  - Pair stocks with high correlation or cointegration and trade the spread between them.
  - **Signal**: Go **long** on the underperforming stock and **short** on the outperforming stock when their spread deviates significantly from the mean.
- **Mean-Variance Optimization**:
  - Construct a daily portfolio using past 200-day returns and volatilities to maximize Sharpe Ratio.
  - **Signal**: Allocate weights dynamically based on calculated portfolio metrics.
- **Volatility Breakout**:
  - Measure daily price range (High-Low or ATR).
  - **Signal**: Go **long** if today's close is above yesterday's range and **short** if it's below.

Apart from the above 5, I am really inclined towards mixing some of them and seeing what works and what doesn't, but way before that, I want to test them all. Once that is done, I will implement the following :

6. Hybrid Strategies

Combine multiple strategies for more robust signals:

- Example: **Momentum + Mean Reversion**:
    - Identify overbought/oversold stocks using RSI or Bollinger Bands and confirm with momentum (e.g., ROC or EMA crossover).
    - Go **long** on oversold stocks with strong momentum and **short** on overbought stocks with weak momentum.

Okay, now let us first start with SMA

- ☐ **Simple Moving Average (SMA) Crossover**:
  - ☐ Calculate short-term (e.g., 10-day) and long-term (e.g., 50-day) moving averages.
  - ☐ **Signal**: Go **long** when the short-term SMA crosses above the long-term SMA (golden cross) and **short** when it crosses below (death cross).

From the implementation shared with me by Robert (ever so thankful for it), I was able to get a good grasp over how to write the code and the basic trading environment setup for the same. The repository uses the data for the past 5 years for the top 20 stocks by market cap, and to start off, I will use the same across all strategies.

For SMA, the following results were available in the example code :

Backtest Results using shortWindow = 10 and longWindow = 50

Initial Capital: $1000000.000000

Final Capital: $2109216.951159

Linear Regression coefficients: 0.000662, 0.025080

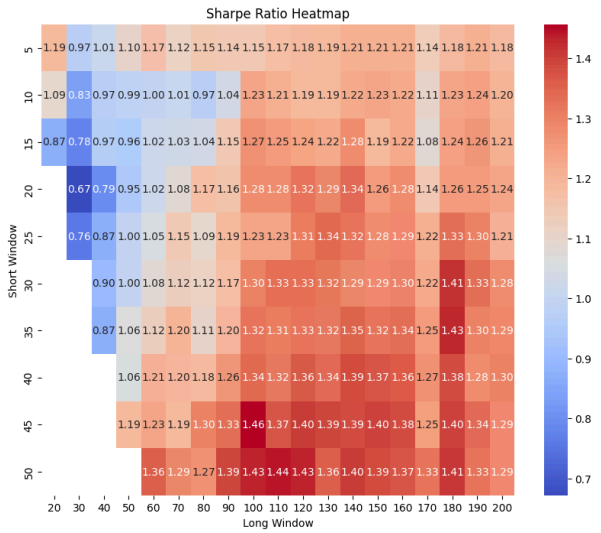
Accuracy of trading signal: 0.535805

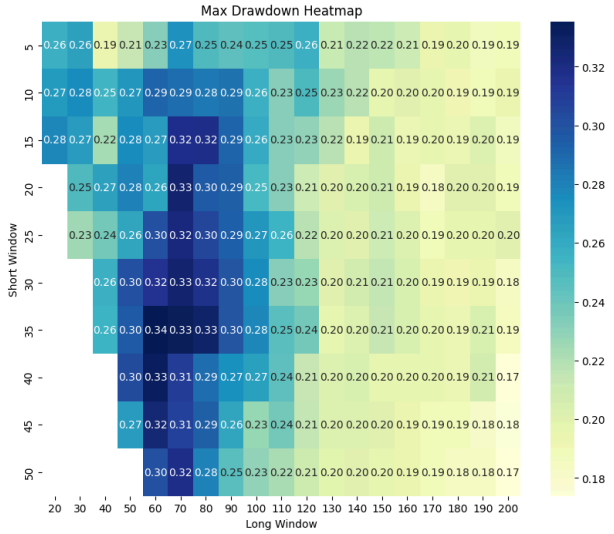
Maximum Drawdown : 0.270659

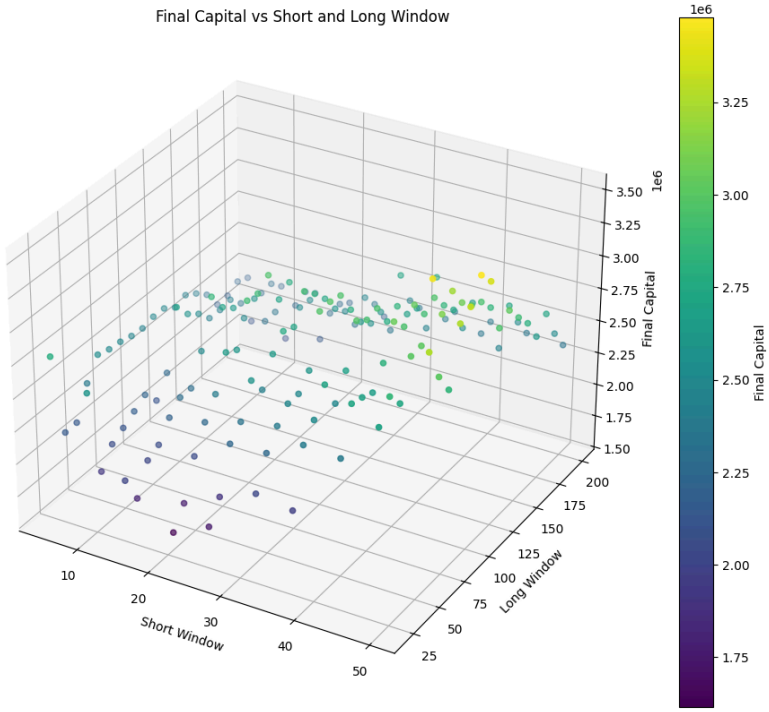
Annualized Sharpe Ratio: 0.987214

What I wanted to try next is understand what type of shortWindow and longWindow value yields the best results. For this, I tried to vary both of them for different combinations and plotted the performance metrics to pick out the best :

Here are the results :


Sharpe Ratio Heatmap
Short Window
Long Window


Max Drawdown Heatmap
Short Window
Long Window


Final Capital vs Short and Long Window
Short Window
Long Window
Final Capital
1e6

INTERPRETATION

Sharpe Ratio Heatmap:

- **Red areas (higher Sharpe Ratio):** These regions represent better risk-adjusted returns. Specifically:
    - The combinations of **long windows around 100-150** and **short windows around 45-50** yield the highest Sharpe ratios (e.g., 1.44, 1.43).
    - These combinations indicate that a longer-term perspective combined with a relatively long short-term moving average captures favorable trends effectively.
- **Blue areas (lower Sharpe Ratio):** Represent poorer risk-adjusted returns, such as when:
    - The short windows are too small (e.g., 5-15), leading to frequent noisy trades.
    - Long windows are excessively high (e.g., >180), making the strategy too slow to react to price changes.

Max Drawdown Heatmap:

- **Darker blue areas (higher drawdown):**
    - These occur in regions with **short windows >35** and **long windows between 80-130**.
    - High drawdowns suggest the strategy is exposed to significant declines during unfavorable conditions, possibly due to delayed reactions or poorly timed entries/exits. This compromises our liquidity.
- **Lighter areas (lower drawdown):**
    - Seen in regions with **short windows 10-30** and **long windows >160**.
    - Lower drawdowns indicate the strategy avoids excessive loss but might sacrifice potential returns.

Combined Interpretation:

1. **Optimal Trade-off:**
    - High Sharpe Ratio regions (e.g., short window 45, long window 100-150) correspond to areas with **moderate drawdowns (e.g., 0.3)**. This trade-off makes them attractive for balancing returns and risk.
2. **Avoid Extreme Drawdowns:**
    - Areas with very high drawdowns (>0.32) should be avoided despite potentially high returns, as the risk may outweigh the benefits.
3. **Shorter windows require tuning:** Strategies with short windows (<15) tend to have low Sharpe Ratios and exhibit higher drawdowns due to overtrading.

- Focus on combinations where:
    - **Sharpe Ratio** is highest (around 1.4).
    - **Max Drawdown** remains manageable (≤0.3).
    - For example, combinations like **short window = 45, long window = 120** seem ideal.

Now, on to the next one, EMA :

This was again in the same file Robert shared, hence, analysis proceeded with ease. The sample windows yielded the following result :

Backtest Results using shortWindow = 10 and longWindow = 50

Initial Capital: $1000000.000000

Final Capital: $7096976.914974

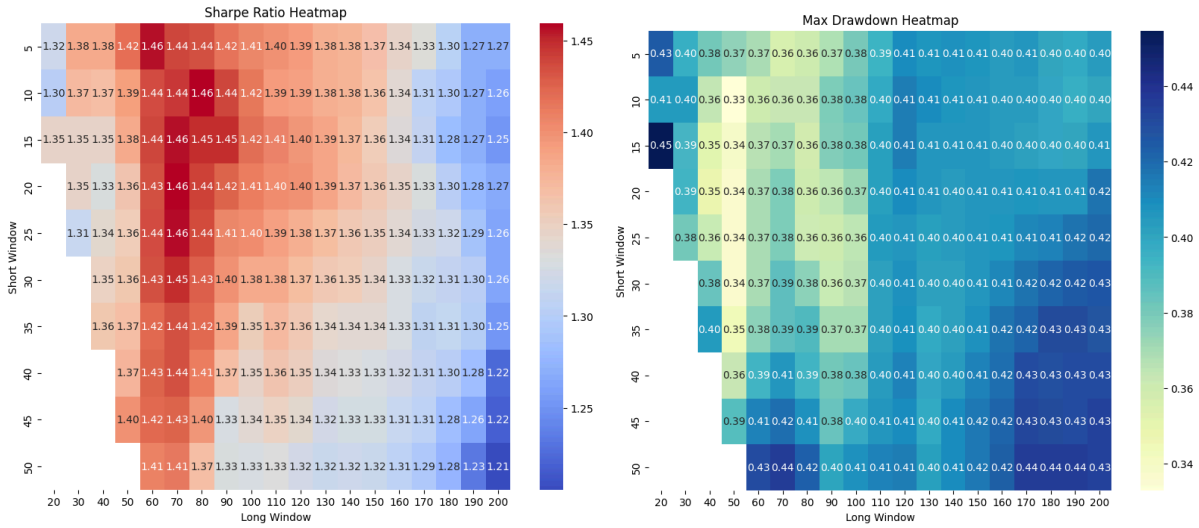
Linear Regression coefficients: 0.001859, 0.020925

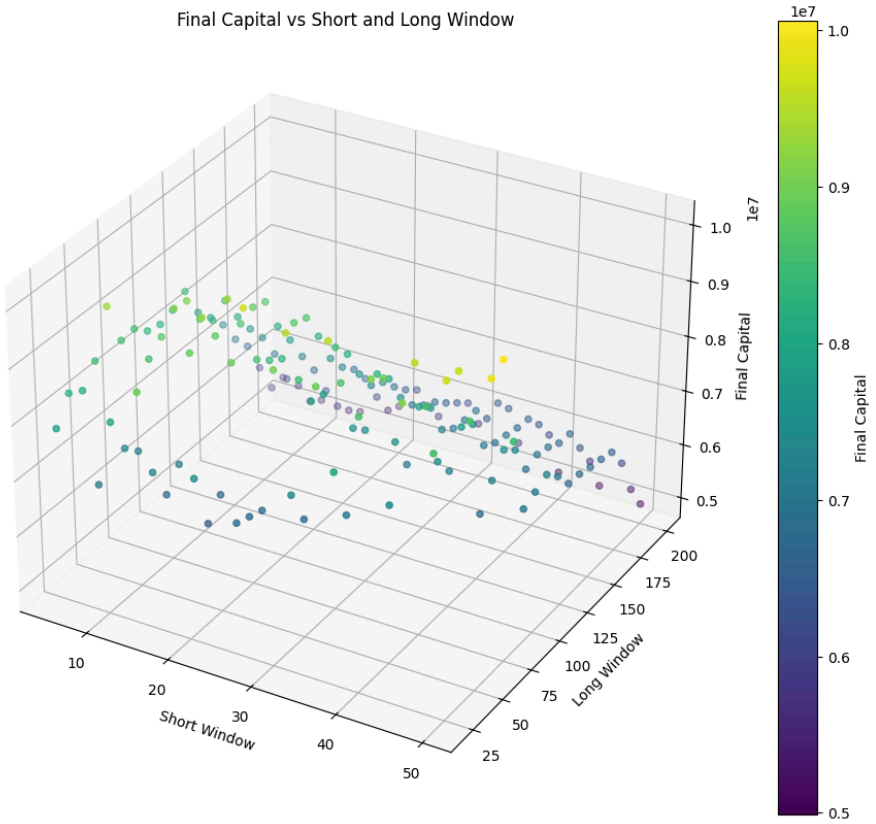
Accuracy of trading signal: 0.549284

Maximum Drawdown : 0.332940

Annualized Sharpe Ratio: 1.391464

This outperforms SMA. I would like to think that the optimal windows for this should also be similar to the SMA. The following graphs were obtained :





INTERPRETATION

1. Sharpe Ratio Heatmap

- **Red Areas (High Sharpe Ratio)**:
  - The Sharpe Ratio is highest for **short windows around 10-25** and **long windows around 60-80**. This indicates that these parameter combinations yield better risk-adjusted returns.
  - A Sharpe Ratio of 1.45 in this context suggests strong performance relative to risk.
- **Blue Areas (Low Sharpe Ratio)**:
  - Combinations where the **long window is much larger** or the **short window is near the maximum** have lower Sharpe Ratios. This could mean the strategy reacts too slowly to price changes or becomes overfit.
- **Key Insight**:
  - Short windows of **10-25** and long windows of **60-80** appear to balance quick reactions with long-term trend-following effectively.

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2. Max Drawdown Heatmap

- **Light Yellow Areas (Low Drawdown)**:
    - Low drawdowns (around **0.34-0.36**) occur with short windows of **10-20** and long windows of **50-100**.
    - These areas indicate lower peak-to-trough losses, making these parameter combinations safer.
- **Dark Blue Areas (High Drawdown)**:
    - High drawdowns (around **0.42-0.45**) occur when the **short window is small (e.g., 5)**, or when long windows exceed **120**. These setups may overreact to short-term noise or fail to adapt quickly to market changes.
- **Key Insight**:
    - Avoid combinations where the drawdown exceeds **0.4**, as they indicate significant losses during unfavorable market conditions.

Combined Analysis

- **Optimal Trade-Off**:
    - The best combination appears to be a **short window of 10-25** and a **long window of 60-100**:
        - High Sharpe Ratio (~1.45).
        - Moderate Max Drawdown (~0.36-0.38).
        - This combination provides a balance between return and risk.
- **Avoid Extremes**:
    - Very small short windows (5) or very large long windows (>150) lead to suboptimal results due to either overtrading or underreacting to market conditions.

Few observations : The EMA Calculations took way longer than SMA because of it’s recursive nature and state preservation.

Rest of the strategies are documented in the python notebook which I can explain during our live interaction.

What I have not been able to do yet :

- Combined strategy based upon stock signals (poorly executed in the hybrid.csv)
- Fundamental stock signals (deliberately chose to do technical)