

STAT 4830

Slides Draft 4 (Week 10)

Portfolio Refinement Through Iterative Sequential Modeling (PRISM)

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Our Problem

Goal:

Optimize a daily portfolio of assets to achieve high risk-adjusted returns while respecting certain constraints on . . .

leverage, drawdown, and volatility.

Specifically, our project focuses on maximizing a combination of financial risk metrics and ratios while limiting maximum drawdown over a given historical period.

Why This Matters

- Traditional mean-variance optimization oversimplifies risk by only using variance.
- Real-world portfolios must manage multiple risk dimensions (drawdown, volatility) and practical constraints (leverage, short selling) at the same time.
- Variability in the real-world and extreme events (like COVID) don't follow a nice and familiar distribution, so due to their unpredictability, traditional trading strategies have different tolerance levels to these unexpected events.
- By addressing these complexities, we aim to create a more realistic and robust decision-making strategy for creating a dynamic portfolio.

Success Metric

What the fitness score consist of...

- Sortino Ratio:

$$\frac{\mathbb{E}[R_P - R_f]}{\sigma_d}$$

- R_P = Return of our portfolio
- R_f = Risk-free rate
- σ_d = Standard deviation of negative returns (i.e., downside deviation for returns below a minimum acceptable return).

- Risk Metric - Controlling maximum drawdown, where

$$MDD(P) = \frac{90\text{-day min. portfolio value}}{90\text{-day max. portfolio value}} - 1$$

- Portfolio Constraints - we ask the model to minimize transaction costs, minimize the change in our stock positions between days, and try to maintain stable returns over time

Technical Approach

Mathematical Formulation:

Let $\mathbf{w} = (w_i)$ denote the vector of weights for asset i in the portfolio. We define the portfolio return as

$$R_P = \sum_i w_i \cdot R_i$$

Our model's goal is to maximize our defined “fitness score” by learning our weights in vector \mathbf{w} . Given this goal, our objective function is

$$\begin{aligned} \max_{\mathbf{w}} \quad & \alpha_1 \cdot \frac{\mathbb{E}[R_P - R_f]}{\sigma_d} + \alpha_2 \cdot (MDD(P)) - \alpha_3 \sum_i |w_i - w_i^{\text{prev}}| \\ & - \alpha_4 \sum_i |w_i| \end{aligned}$$

Objective Function

$$\max_{\mathbf{w}} \quad \alpha_1 \cdot \frac{\mathbb{E}[R_P - R_f]}{\sigma_d} + \alpha_2 \cdot (MDD(P)) - \alpha_3 \sum_i |w_i - w_i^{\text{prev}}| \\ - \alpha_4 \sum_i |w_i|$$

Definitions:

- R_f is the risk-free rate s.t. $\frac{\mathbb{E}[R_P - R_f]}{\sigma_d}$ is the Sortino ratio.
- α_1 scales the impact of the Sortino ratio.
- α_2 scales the impact of the drawdown term.
- α_3 is the transaction cost penalty, which penalizes large changes in portfolio weights between periods.
- α_4 is the sparsity factor, which encourages a more concentrated portfolio through L_1 regularization.
- w_i^{prev} denotes the weight of asset i in the previous period.

Note: Originally used σ_p , the portfolio's standard deviation, because we were using the Sharpe Ratio

Problem Formulation

Training & Inferencing

- We take a universe of equities, get data on them between 2022 and current day, and train an online gradient descent model
- We take 2022-2024 to be “training” (i.e. we allow it adjust odds and do not evaluate over this period)
- We compute portfolio returns, volatility, and drawdown within the OGD, taking a step for every market day

Validation

- We also calculate cumulative portfolio returns for each equity over the time period of 2024-present day
- We compare to our most effective models (found using several different hyperparameter tests)

Implementation

- Hyperparameters: We experimented with random values and chose the set that resulted in the best model specifications.
- Updated Test: We increased universe of stocks to 109 different tickers.
- We also want to penalize entropy (i.e. encourage sparsity).
- Included L_1 regularizer to enforce sparsity

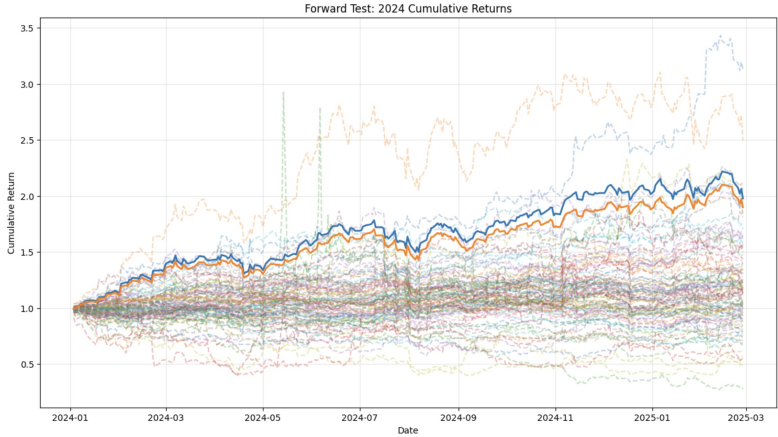


Figure 1: Intermediate Results - 2024 Cumulative Returns

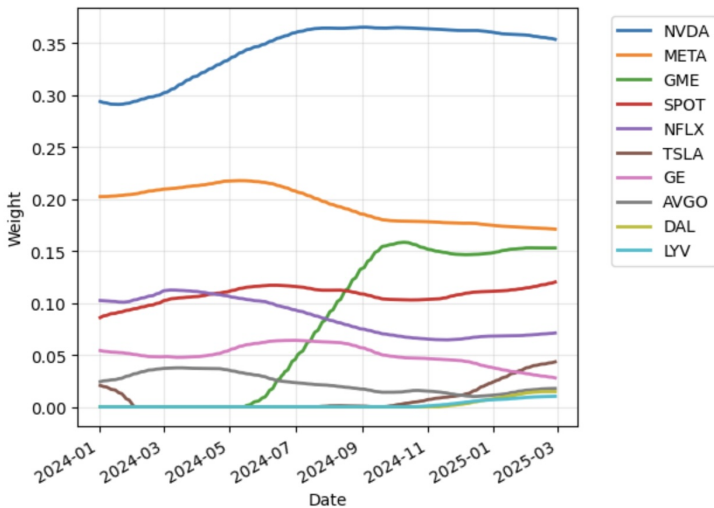


Figure 2: Intermediate Results - Cumulative Returns of our algorithm.

Next Steps

1. **Expand Data Universe**

- In addition to our current 109 stocks; add in crypto and ETFs to expand our exposure to different asset classes.

2. **Additional Risk Measures**

- Perform a literature review to find additional risk measures to incorporate into our model.
 - **Progress so far:** We have collected a corpus of 173 articles by applying three queries to EconLit, Web of Science, and Scopus.

3. **Validation**

- Acquire a longer historical window and consider testing our model against time periods that experienced sudden market shocks due to extreme events.
- Test our model with real-time data implementation.

4. **Refine Constraints**

- Enforce a leverage limit of 1.5 and allow short selling up to 30% of the portfolio.