NSGA-II is used in optimizing investment portfolios

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Content

Research Background and Objectives

- Background:
  - Maximize investment returns, minimize risk.
- Challenges:
  - Non-convex problems require effective algorithms.
  - Multi-objective optimization requires consideration of multiple portfolio goals.
- Objectives:
  - Combine machine learning with nulti-objective genetic algorithm.
  - Use surrogate models to accelerate convergence and improve result quality.
  - Compare optimization results of different NSGA-II models with the traditional Markowitz model

Definition of Terms

- Markowitz Efficient Portfolio
  - Asset allocation that maximizes return for a given level of risk, or minimizes risk for a given level of return.
- Expected Return
  - The average future return of an asset calculated based on past performance or market forecasts.

$$E[R] = \sum_{i=1}^{n} wi\, E[Ri]$$

- Risk
  - The uncertainty or variability of asset returns.
- Covariance Matrix
  - A data structure used to measure the correlation between asset returns.
  - Cov(Ri,Rj) represents the covariance between asset i and asset j.

Definition of Terms

- Portfolio Volatility

$$\sigma p = \sqrt{\sum_{i=1}^{N} wi^2 \sigma i^2 + 2 \sum_{i \neq j} wiwj\mathrm{Cov}(Ri, Rj)}$$

- Sharpe Ratio
  - Measures the ratio of portfolio return to risk.

$$S = \frac{E[Rp] - Rf}{\sigma p}$$

- Efficient Frontier
  - A curve composed of optimal portfolios
  - The maximum return for a given level of risk, or the minimum risk for a given level of return.

Core technologies and methods

- Algorithms:
  - Use selection, crossover, and mutation operations from natural evolution to perform multi-objective optimization.
  - NSGA-II: A classic multi-objective optimization algorithm based on non-dominated sorting, capable of effectively handling multiple conflicting objectives.
- Non-genetic Algorithms:
  - Efficient Frontier (Markowitz): Primarily for single-objective optimization, based on mean-variance theory, using mathematical programming to find the optimal solution.

Core technologies and methods

- Heuristic Algorithms:
  - Surrogate Models: Used during the optimization process, such as Gaussian Process Regression, to reduce the number of expensive objective function evaluations, thereby accelerating the optimization process.

Research Method

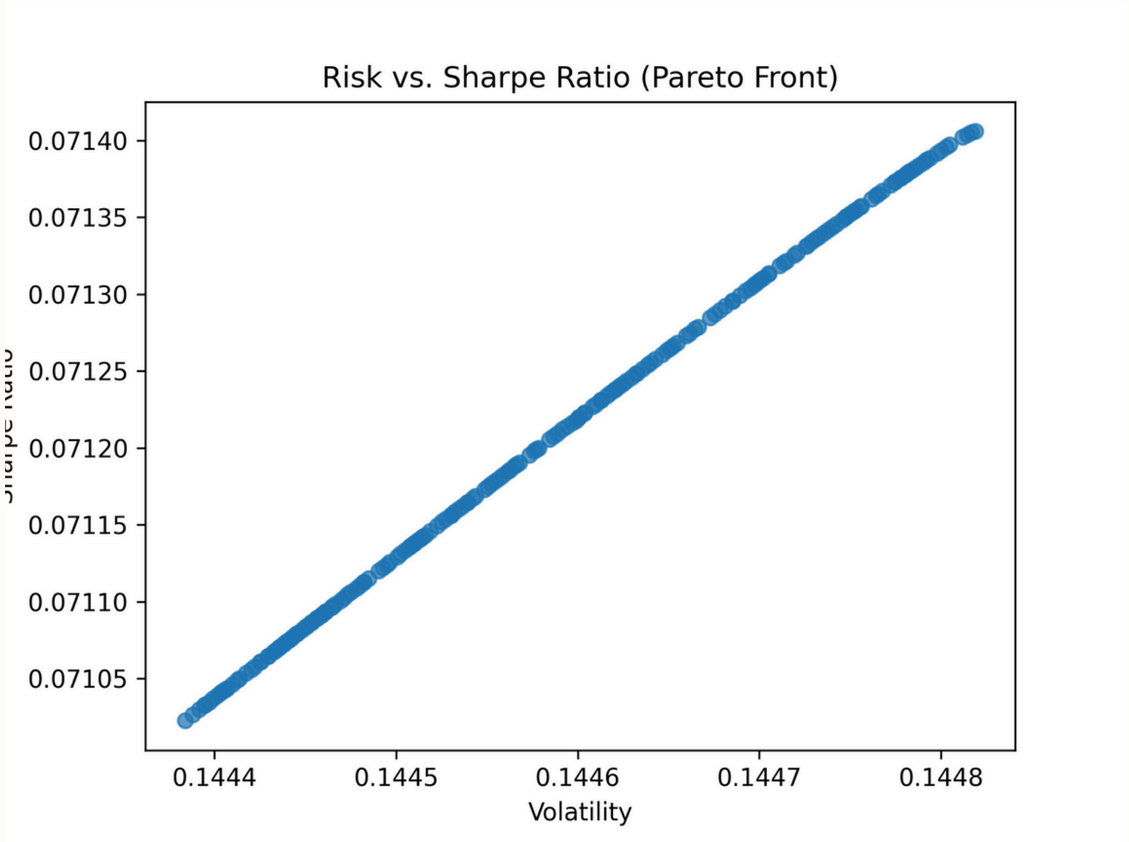
- Data Processing and Prediction:
  - Stock Data: Select daily data for AAPL, MSFT, GOOGL, AMZN, TSLA from the period 2013-01-01 to 2024-01-01.
  - Data Splitting: Split the data into 70% for optimizing the model and 30% for subsequent back-testing.
  - Calculate Expected Returns and Covariance Matrix of Assets: To prepare for portfolio optimization.

Research Method

- Genetic Algorithm Execution:
  - Randomly initialize the population, use fitness values to select the best individuals, and perform crossover and mutation.
  - Run the algorithm for 100 generations, calculating hypervolume indicators and run time for each algorithm.
- Surrogate Model Assistance:
  - Embed a surrogate model in the algorithm, adjusting its parameters to improve algorithm efficiency.
- Back-Testing:
  - Use the generated portfolio weights to simulate back-testing and compare the results with traditional optimization methods.

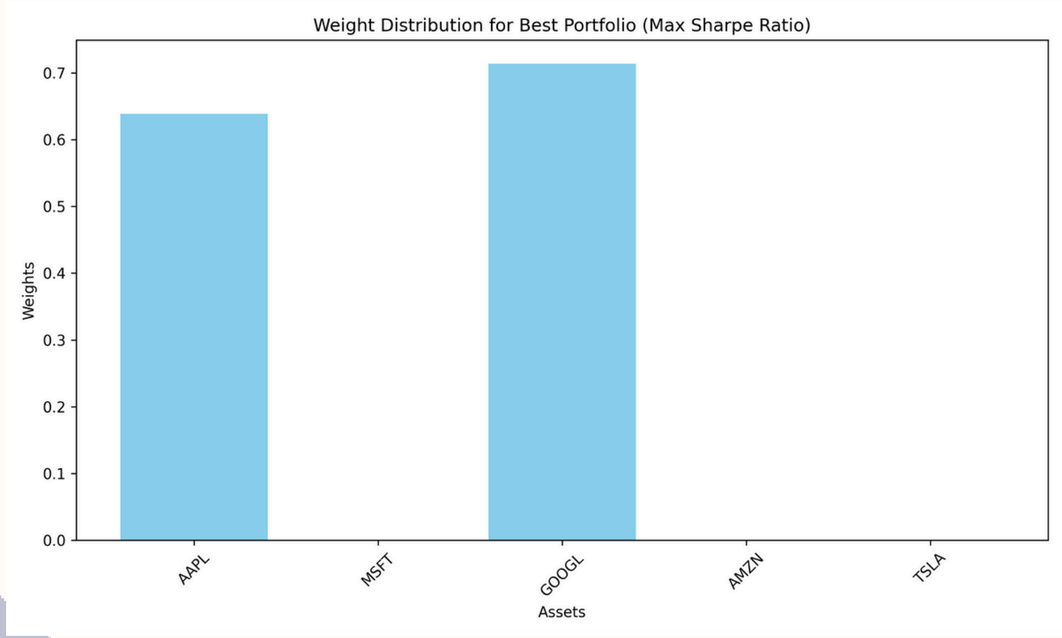
Experimental Results

- Efficient Frontier:
  - The chart shows how to choose the optimal portfolio that provides the best return at different levels of risk.
  - The solutions on the Pareto frontier reflect the best trade-off between risk and return, and the portfolio with the highest Sharpe Ratio is often the ideal choice for investors.

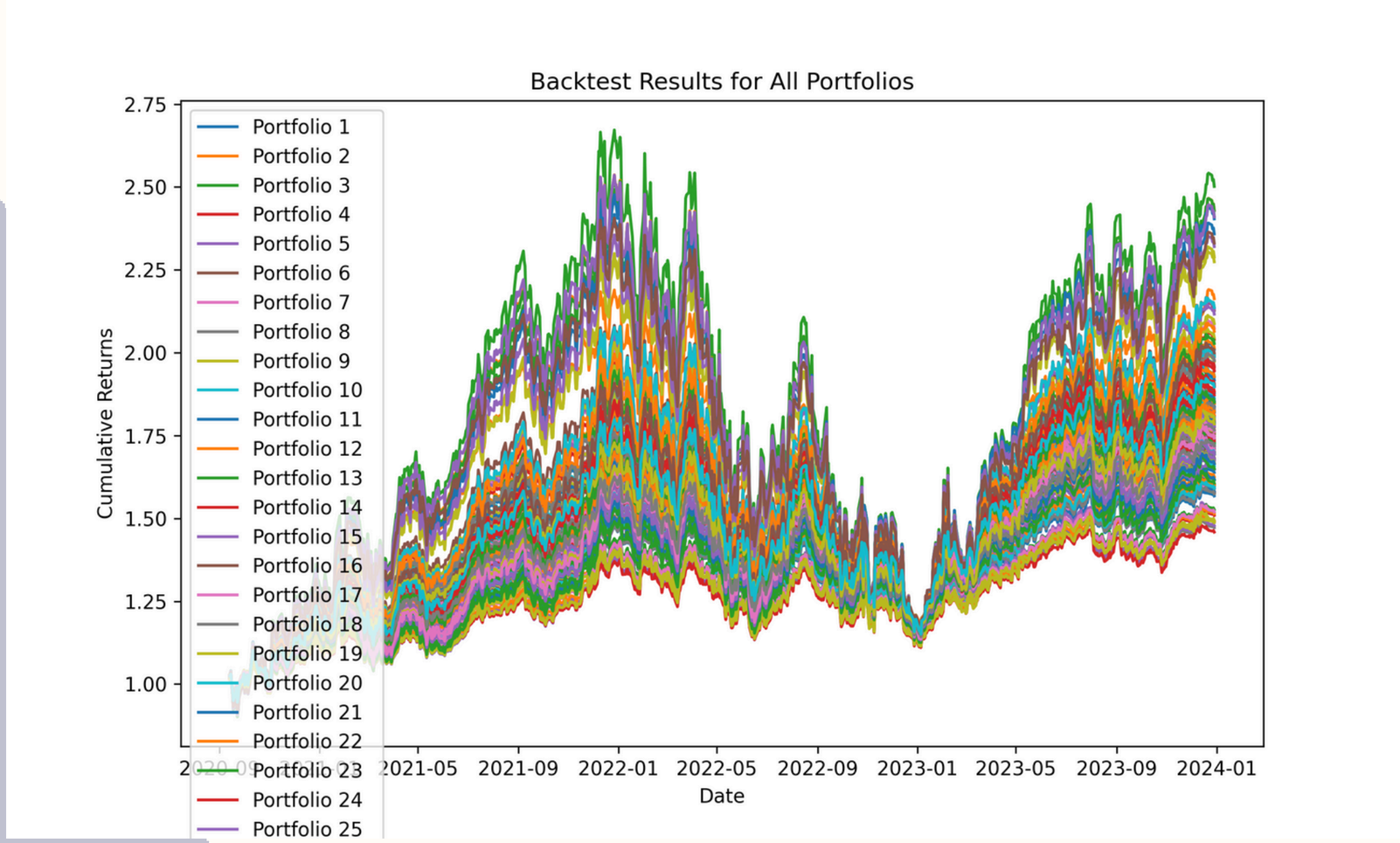


Experimental Results

- Results Using NSGA-II:
  - Multiple Optimal Solutions: NSGA-II provides multiple sets of Pareto optimal solutions, each achieving a balance between risk and return.
  - Maximizing Sharpe Ratio: For risk-neutral or risk-averse investors, choosing the portfolio with the highest Sharpe Ratio on the Pareto frontier offers the best risk-adjusted return.

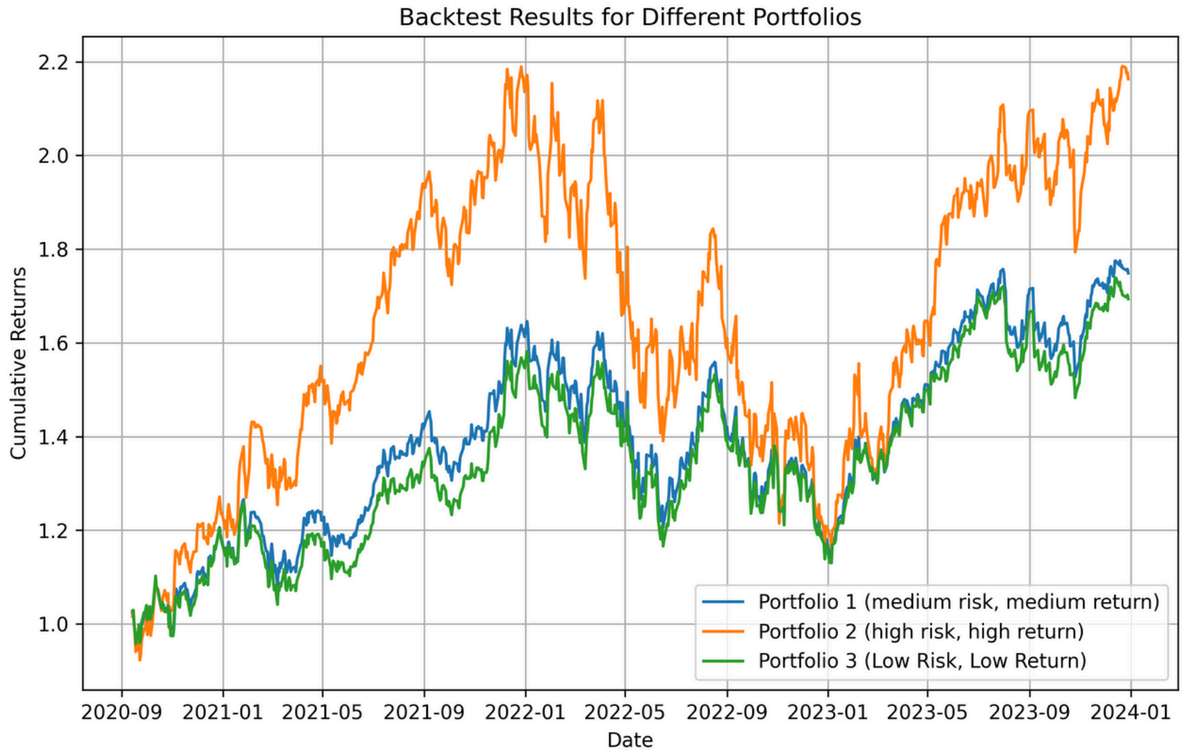


Back-Test All Portfolios Optimized by NSGA-II

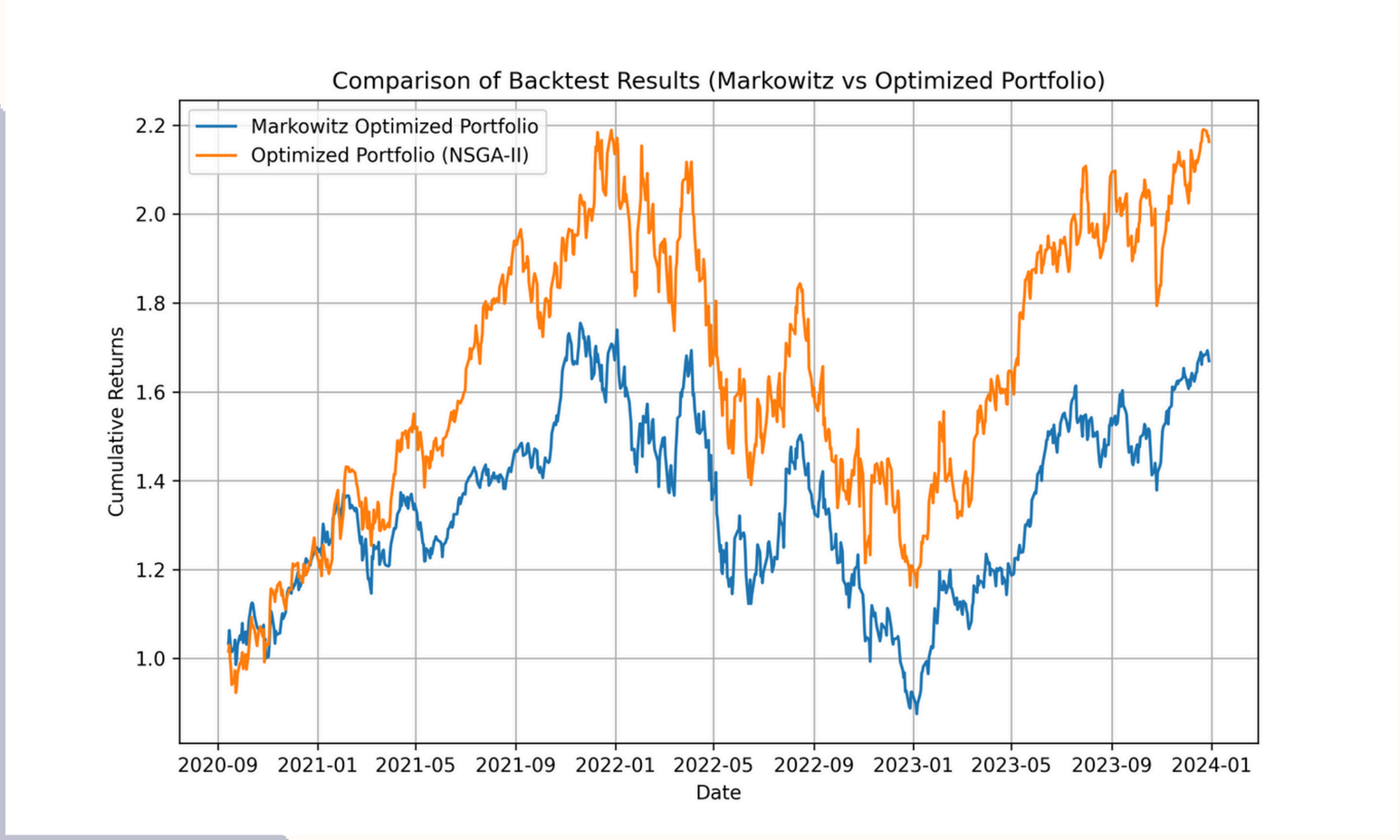


Back-Testing Results for Three Strategies After NSGA-II Portfolio Optimization:

- High Return
- Low Risk
- Moderate Risk, Moderate Return



Comparison of Back-Testing Results for Maximizing Sharpe Ratio: NSGA-II vs. Markowitz Theory



Conclusion

- Risk and Return Trade-Off:
  - Investors should choose the portfolio that best suits their individual risk tolerance, achieving optimal returns at different risk levels.
- Maximizing Sharpe Ratio:
  - For risk-neutral or risk-averse investors, selecting the portfolio with the highest Sharpe Ratio can achieve the best risk-adjusted return.
- Modern Needs and Multi-Objective Optimization:
  - As market complexity increases, single-objective optimization is no longer sufficient for all investors. NSGA-II offers a multi-objective optimization approach that adjusts the return-risk ratio based on individual risk preferences, making it suitable for modern investors.

Conclusion

- Future Prospects:
  - Explore the integration of reinforcement learning techniques with multi-objective optimization algorithms to adjust portfolios using real-time market data, achieving more flexible and efficient investment strategies.

Thanks!