High-dimensional portfolio optimization with an evolutionary multi-objective algorithm implemented in Python:

evMOGAportPy

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Introduction

Modern portfolio theory is evolving to meet investors' needs by integrating additional criteria — such as sustainability or diversification, and also by considering a broader array of risk measures.

Metaheuristic approaches like evolutionary multiobjective optimization algorithms have been used to improve complex portfolio optimization problems [1].

ev-MOGA has been developed by the Predictive Control and Heuristic optimization Group at Universitat Politècnica de València [3] and implemented for portfolio optimization in Garcia-Bernabeu et al. [2].

Objectives

- Develop **evMOGAportPy**, an open-source Python package that implements the evolutionary multi-objective genetic algorithm (ev-MOGA).
- Efficiently approximate the **Pareto front** in portfolio optimization problems involving more than two objectives.
- Provide a **flexible coding environment** and high-quality tool for **decision-making** in high-dimensional portfolio management.

ev-MOGA algorithm

1. **ev-MOGA** is an elitist multi-objective evolutionary algorithm based on the concept of epsilon dominance.
2. **ev-MOGA**, tries to obtain a good approximation to the Pareto Front in a smart distributed manner with limited memory resources.
3. **ev-MOGA**, adjusts the limits of the Pareto front dynamically.

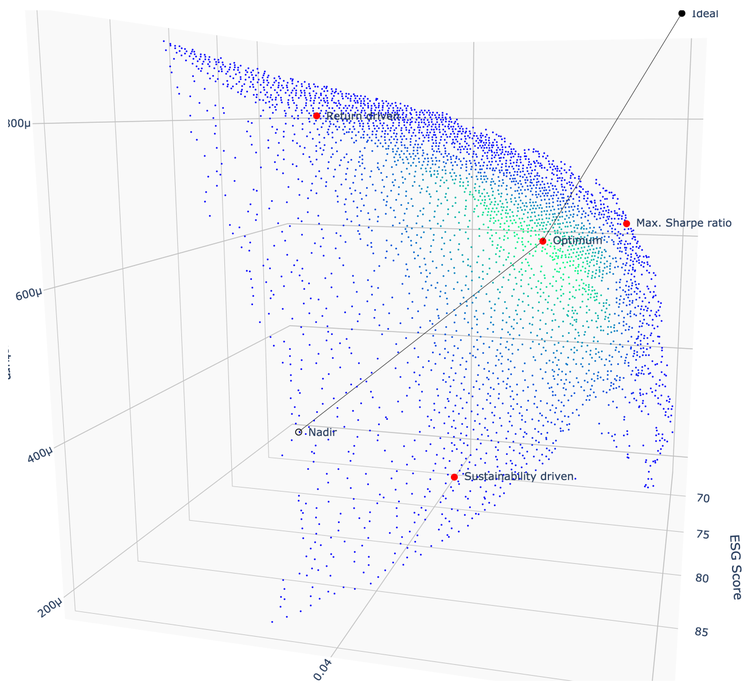

Figure 1. Mean–VaR–ESG approximate 3D Pareto front computed with ev-MOGA algorithm with optimum and key reference portfolios

Portfolio optimization problem

$$\min_{\mathbf{x}} \mathbf{f}(\mathbf{x}) \qquad \text{s.t.:} \quad \mathbf{x} \in S = \left\{\mathbf{x} \in \mathbb{R}^m : \mathbf{1}^T\mathbf{x} = 1\right\} \tag{1}$$

$$\mathbf{f}(\mathbf{x}) = \begin{bmatrix} -\boldsymbol{\mu}^T\mathbf{x} \\ \mathrm{VaR}_\varepsilon(\mathbf{x}) \\ -\boldsymbol{\rho}^T\mathbf{x} \\ -\mathrm{DR}(\mathbf{x}) \end{bmatrix} \tag{2}$$

Python code example

```
eMOGA = {
    'objfun': objective_function,

    'Generations': int(5000),
    'Nind_P': int(100000),
    'Nind_GA': int(200),
    'n_div': [200 for i in range(n_obj)],

    'param': {
        'esg': esg,
        'ret': returns,
        'mean_r': mean_r,
        'cov_Mtrx': cov_Mtrx,
        }
}

eMOGA = ev.MOGA(eMOGA)
```

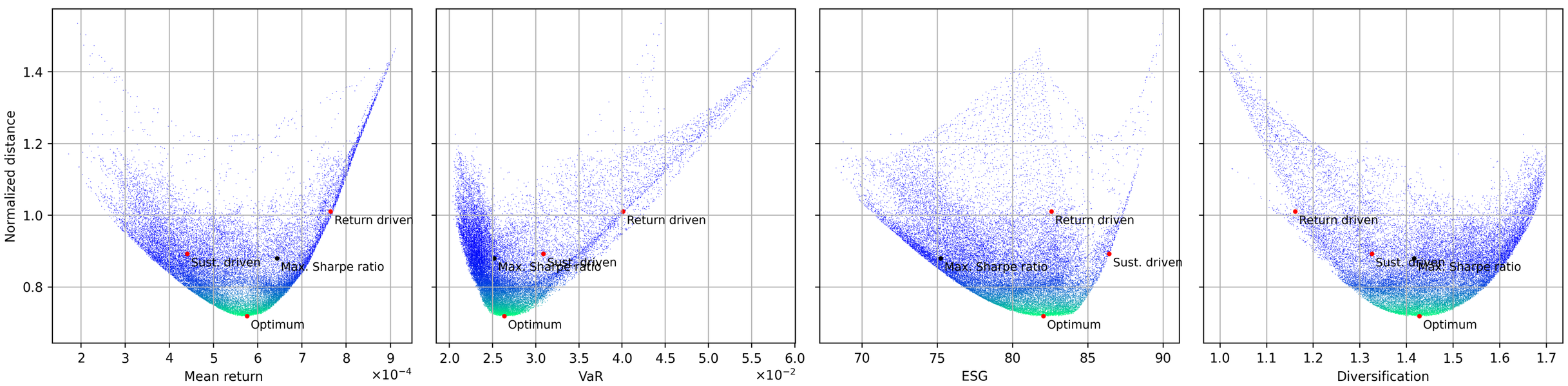

Figure 2. 2D Level Diagram Projections of the 4–Objective (Mean-VaR-ESG-Diversification) approximate Pareto Front. The "Normalized distance" is the Euclidean distance of each portfolio to the ideal point, each objective has been rescaled to the 0,1 interval. Reference portfolios: (i) the ideal portfolio, (ii) the portfolio with the maximum Sharpe ratio, (iii) a sustainability–driven solution that prioritizes ESG, and (iv) a return–driven solution that pushes mean return to its limit.

Experimental setup

- **Objectives**: Mean–VaR–ESG–Diversification problem
- **Dataset**: IBEX35 daily prices from Refinitiv-Eikon
- **Period:** 2016-2023
- **Algorithm parameters**: $N_{\mathrm{indP}} = 100\,000$, Generations = 5000

Conclusions

- **Open tool** – Publish evMOGAportPy, a free Python implementation of ev-MOGA.
- **Efficient Pareto Search** – Efficient and well distributed approximation of Pareto fronts with many objectives.
- **Better decisions** – Deliver a tailored aid for managing high–dimensional portfolios.

Bibliography

[1] Kyle Erwin and Andries Engelbrecht. "Meta-heuristics for portfolio optimization". In: *Soft Computing* 27 (Apr. 2023), pp. 19045–19073.

[2] Ana Garcia-Bernabeu et al. "ESG integration in portfolio selection: A robust preference-based multicriteria approach". In: *Operations Research Perspectives* 12 (2024), p. 100305. ISSN: 2214-7160.

[3] Juan M. Herrero. *ev-MOGA Multiobjective Evolutionary Algorithm*. MATLAB Central File Exchange. Recuperado 15 abril, 2025. 2025.