Benchmarking portfolio optimization with integer simulated annealing

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Abstract

The discrete portfolio optimization problem [1] is a combinatorial optimization problem that selects an optimal set of financial assets which tries to maximize expected returns, while keeping risks low. As such, many algorithms have been developed to tackle this problem, with quantum algorithms and machine learning approaches being proposed in recent years. In this work we show that the convexity of the problem makes it very well suited to be studied with a simple integer classical simulated annealing algorithm. We show how it is able to find optimal portfolios even for Hilbert spaces of dimension $\sim 2^{1000}$ and how it scales polynomially with the number of available assets and total budget P_0 by measuring the Time To Target (TTT) needed to compute optimal solutions [See Fig.1].
When we take into account transaction fees, such as linear costs t_l associated to the traded amount, the convexity of the problem is usually maintained and our algorithm keeps its polynomial scaling. However, transaction fees such as fixed costs t_f make the problem non convex. We show how, in the limit of low non convexity, which is the relevant regime in the financial sector, our algorithm is versatile enough to still find optimal portfolios. Taking these costs into account is specially relevant in the portfolio rebalancing problem, where we start with an initial portfolio and we seek to optimize it in periodical time windows. We show in Fig. 2 the result of rebalancing a portfolio each month within a year and compare the relative annual return when we compute the portfolios using simulated annealing against a greedy approach that is not able to take non convex transaction fees [2]. This also shows that our algorithm is competitive in an out-of-range real setup.

References

[1] H. Markowitz, Portfolio selection, The Journal of Finance 7, 77 (1952).a
[2] Martin, R. A.. PyPortfolioOpt: portfolio optimization in Python. Journal of Open Source Software, 6(61), 3066 (2021)

Figures

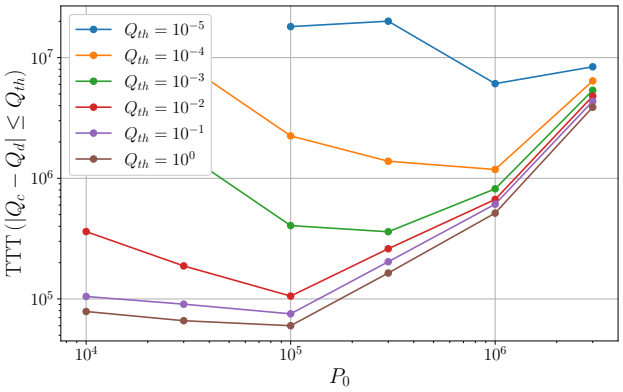

Figure 1: Time To Target for computing an optimal portfolio with quadratic utiliy below certain thresholds (different colors) against the total available budget P_0.

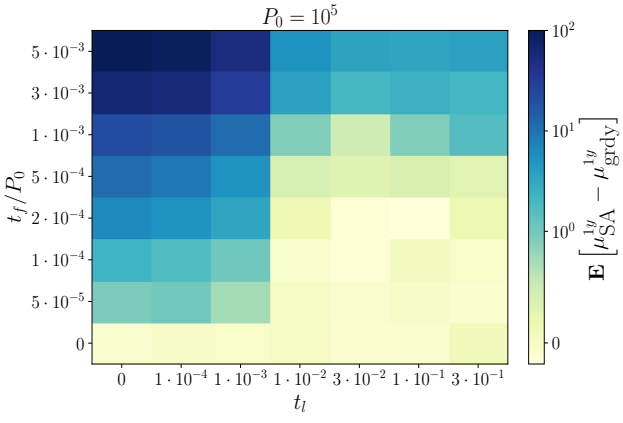

Figure 2: Absolute relative annual return of a portfolio monthly-rebalancing problem with different linear and fixed transaction costs using an integer simulated annealing computation against a greedy algorithm approach.