A multi-objective evolutionary algorithms for portfolio selection problems

Introduction

Portfolio selection problem is a problem where investor should select from number of assets, how much and which assets to invest on. This project explores the use of multi-objective evolutionary algorithms in portfolio selection.

One of the first and well-known approaches to this problem was proposed by Markowitz (1952) who introduced the mean-variance portfolio selection method. Mean-variance method utilizes two objective functions, and the purpose is to minimize the risk while maximizing the profit of portfolio.

When using large number of stocks, finding the solution using standard optimization tools might be difficult, by utilizing evolutionary algorithms, investor may be able to find better solutions. Also with evolutionary algorithms, it's possible to introduce additional objective functions and/or constraints, which can be tailored to the investor's preferences. To limit the computation time and scope, this project only considers optimization with the risk and profit objective functions and limited number of stocks.

All the source codes and instructions on running the tool that I have created can be found from Github: https://github.com/hkurhinen/portfolio-optimizer

Algorithm

In this project I'll test few evolutionary algorithms with the mean-variance portfolio selection method.

Mean-variance portfolio selection

Mean variance portfolio selection or modern portfolio theory (MPT) is algorithm introduced by Harry Markowitz in 1952. While it is not the only portfolio optimization algorithm, it is currently the most widely used one.

MPT aims to optimize investment portfolio in a way that investor can choose portfolio with minimum risk for the same returns. MPT also optimizes diverse portfolios, if highly varying assets are combined and they have little or no correlation with each other, they can form a portfolio with moderately low variance.

Implementation

First step of the implementation of this tool was to collect historical data on assets. Yahoo finance contains lot of data from different types of assets and thus this tool allows users to compare also portfolio which contain partly for example stocks and partly crypto currencies. Data is downloaded between start and end dates provided by the end user.
After data has been collected, I calculate covariance and correlation matrices from given portfolio. I used Pandas library for performing these calculations:

```
covariance = data.pct_change().apply(lambda x: np.log(1+x)).cov()
```

and

```
correlation = data.pct_change().apply(lambda x: np.log(1+x)).corr()
```

Log is used because log of the returns is additive time series, meaning that stock price decrease today and same increase tomorrow will yield the same stock value as it was in the past, and this would not be the case if computation would be done with percentages of change.

After the covariance and correlation have been calculated, I can calculate variance whole portfolio, it can be done with formula:

$$\sigma^2(Rp) = \sum i = 1^n \sum_{j=1}^{n} w_i w_j COV(R_i, R_j)$$

Where wi to wj represent weights of the assets i and j in the portfolio, meaning how much of each asset is acquired when building the portfolio. COV(Ri, Rj) represents the covariance between assets I and j. This will be the first objective function that will be used in the multiobjective optimization algorithm.

Second objective will be expected returns of the portfolio. This will simply be the sum of expected returns of each asset multiplied with the weight of the given asset

$$E(R_p) = w_1 E(R_1) + w_2 E(R_2) + \ldots . . w_n E(R_n)$$

Now that both objective functions have been modeled, I used RVEA and NSGAIII algorithms to run optimization where weights of each asset are used as decision variable and variance and return of the portfolio as objective functions. After that, found pareto front is returned to the user.

Tools

During the project I used Python programming language and few useful libraries, which I'll introduce in this chapter.

Desdeo

Desdeo contains multiple useful tools for multiobjective optimization. I used Desdeo for modeling the optimization problem with x number of decision variables, where x is the

number of assets that user has inputted, and with 2 objective functions where one is used to maximize the return of the investment and another to minimize risk. From Desdeo I also used the RVEA and NSGAIII algorithm implementations.

Pandas / Pandas – datareader

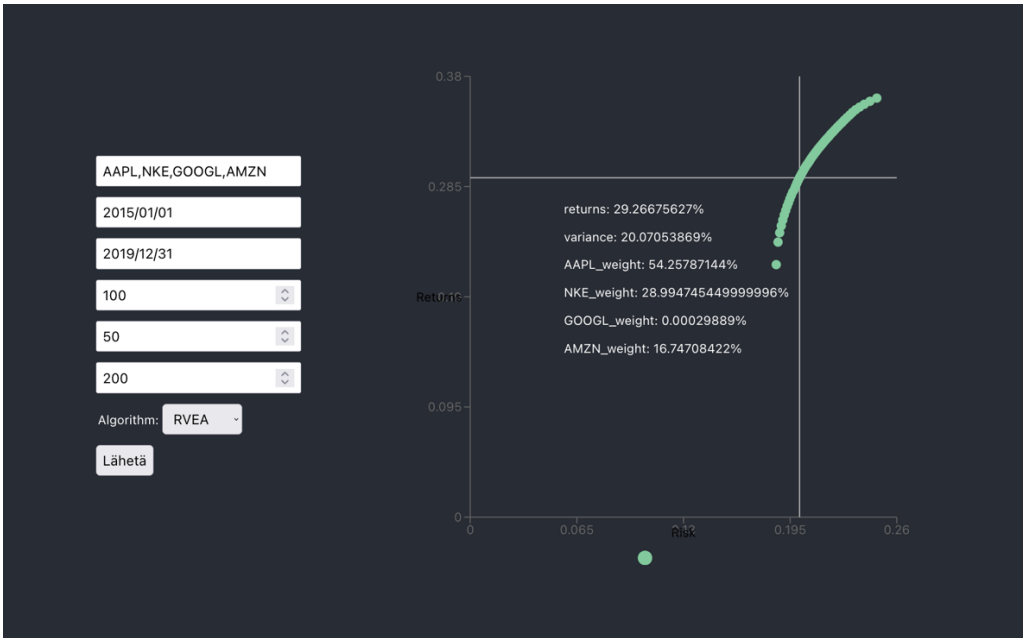
Pandas is a python data-analysis tool which I use in this project to hold and perform computations on financial data. Financial data used by this project is aquired from Yahoo finance, pandas-datareader is a extension to the Pandas library which automatically implements loading of stock data from Yahoo finance with specified filters.

Riskfolio-Lib

Collection of portfolio optimization methods and utilities which I'll used for comparing performance with my implementation and tools for plotting portfolio contents and allocations.

Results

I have developed a service where investor can get suggestions on how to improve their portfolio and get plot containing different versions of optimal weights of each asset containing risk level and expected returns. Tool contains separate front and backend; backend is built with python and frontend is built with react.



Conclusions

Algorithm was able to provide results that are (using MPT) the optimal versions of given portfolio, project had to be quite limited and there is still a lot of room for further development. With evolutionary algorithm optimizing the portfolio weights, it would be

interesting to introduce also additional constraints which could limit the assets for example to given industrial field, or other objective functions like time that it takes for certain asset to give some returns. Downsides are that running optimization with large amount of data and with high number of iterations, optimization process takes quite a long time and in web-based tool timeouts might become an issue in large-scale real-world usage.

References

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