Data driven simulation of a Portfolio Allocation Model

Abstract— A portfolio is a range of investments held by a person or organization. Optimal Portfolio management is the need of the hour, with a constant need for lucrative methods of investment. The optimum portfolio can be determined using the concept of sharpe ratio.

Keywords—Stock, portfolio, returns, covariance, volatility, sharpe ratio.

I. Introduction

A portfolio is a range of investments held by a person or organization. Portfolio management is the art and science of selecting and overseeing a group of investments that meet the long-term financial objectives and risk tolerance of a client, a company, or an institution. Portfolio management requires the ability to weigh strengths and weaknesses, opportunities and threats across the full spectrum of investments.

We all know that you should never put all your eggs in one basket. Hence, we try to build a portfolio consisting of different financial instruments. At the same time, you might develop different strategies to balance various measures such as risk, volatility, expected returns etc. The goal is to determine the best strategy. The normal answer, i.e., its return, is somewhat narrow in scope and does not help capture the big picture. Some strategies might be directional, some market neutral and some might be leveraged which makes annualized return alone a futile measure of performance measurement. Also, even if two strategies have comparable annual returns, the risk is still an important aspect that needs to be measured. A strategy with high annual returns is not necessarily very attractive if it has a high-risk component; we generally prefer better risk-adjusted returns over just ‘better returns’.

With this in mind, William Sharpe introduced a simple formula to help compare different portfolios and help us find the most feasible of them all.

Sharpe Ratio- It is a measure for calculating risk-adjusted return. It is the ratio of the excess expected return of investment (over risk-free rate) per unit of volatility or standard deviation.

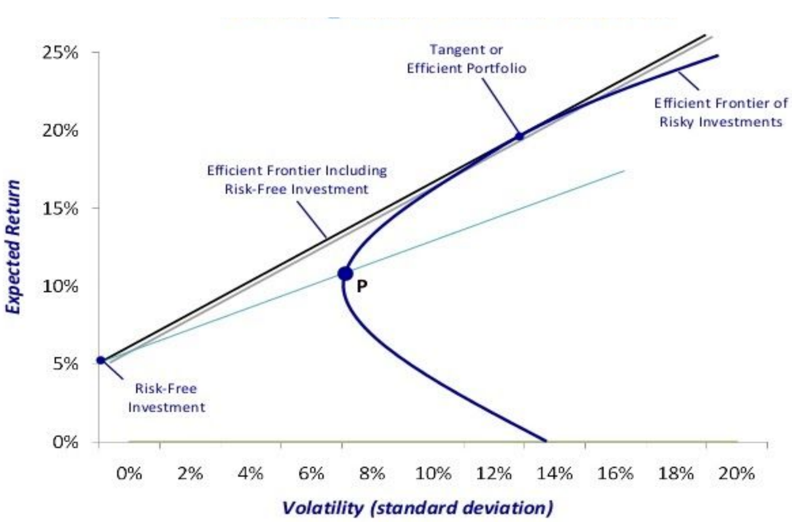
Subtracting the risk-free rate from the mean return allows an investor to better isolate the profits associated with risk-taking activities. The risk-free rate of return is the return on an investment with zero risk, meaning it's the return investors could expect for taking no risk. Generally, the greater the value of the Sharpe ratio, the more attractive the risk-adjusted return.

The Sharpe ratio is calculated as follows:

1. Subtract the risk-free rate from the return of the portfolio. The risk free rate could be a U.S. Treasury rate or yield, such as the one-year or two-year Treasury yield.
2. Divide the result by the standard deviation of the portfolio’s excess return. The standard deviation helps to show how much the portfolio's return deviates from the expected return. The standard deviation also sheds light on the portfolio's volatility.

The Sharpe ratio has become the most widely used method for calculating the risk-adjusted return. Modern Portfolio Theory states that adding assets to a diversified portfolio that has low correlations can decrease portfolio risk without sacrificing return. Adding diversification should increase the Sharpe ratio compared to similar portfolios with a lower level of diversification. For this to be true, investors must also accept the assumption that risk is equal to volatility, which is not unreasonable but may be too narrow to be applied to all investments.

The Sharpe ratio can also help explain whether a portfolio's excess returns are due to smart investment decisions or a result of too much risk. Although one portfolio or fund can enjoy higher returns than its peers, it is only a good investment if those higher returns do not come with an excess of additional risk.The greater a portfolio's Sharpe ratio, the better its risk-adjusted-performance. If the analysis results in a negative Sharpe ratio, it either means the risk-free rate is greater than the portfolio's return, or the portfolio's return is expected to be negative. In either case, a negative Sharpe ratio does not convey any useful meaning.



B. PROBLEM STATEMENT

Portfolio management involves building and overseeing a selection of investments that will meet the long-term financial goals and risk tolerance of an investor. This project aims to simulate the ideal portfolio allocation of stocks in various sectors of the industry.

C. OBJECTIVES

- Understand the theory and math behind portfolio management and the sharpe ratio
- Retrieve data from yahoo finance
- Operate on the stock data and perform simulations to determine optimum portfolio

II. LITERATURE SURVEY

The following papers were an inspiration to this project, and have therefore been listed here:

1. https://www.researchgate.net/publication/271068315_A_Monte_Carlo_simulation_technique_to_determine_the_optimal_portfolio
2. https://www.jstor.org/stable/3094492?seq=1
3. http://redfame.com/journal/index.php/aef/article/download/3376/3735

III. HARDWARE AND SOFTWARE REQUIREMENTS

A. SOFTWARE REQUIREMENTS-
    - Python3
    - Jupyter
    - Numpy
    - Pandas
    - Matplotlib

- Scipy

B. HARDWARE REQUIREMENTS-
- Identical to the hardware requirements of Python3

IV. METHODOLOGY

- **Portfolio Optimization: Monte Carlo Simulation**
- **Portfolio Optimization: Optimization Algorithm**

A. **Portfolio Optimization: Monte Carlo Simulation**

The Monte Carlo method is a stochastic (random sampling of inputs) method to solve a statistical problem, and a simulation is a virtual representation of a problem. The Monte Carlo simulation combines the two to give us a powerful tool that allows us to obtain a distribution (array) of results for any statistical problem with numerous inputs sampled over and over again. The methodology revolves around the concept that as we increase the number of portfolios, we will get closer to the actual optimum portfolio.

So for each portfolio, we must generate its return and risk. To do that, we retrieved the stock prices of each of the assets in the portfolio from yahoo finance.

The first step is to calculate the returns of the assets in the portfolio. For us to calculate the asset returns, we performed the following two steps:

1. We need to fetch the historical daily prices of the assets
2. Then we need to compute their geometric returns by calculating the following equation:

$$Return\ For\ Each\ Day\ =\ Log\left(\frac{Today's\ Price}{Yesterday's\ Price}\right)$$

The returns are generated so that we can standardised the stock prices so that they can be compared.

The asset returns which were computed above are all 2-dimensional as there is a time axis involved. We now need to compute a single number to represent the returns of the assets. One of the most common ways is to compute the mean of the returns which is known as the expected returns. To compute the asset expected mean return, we need the **mean** of the returns of each stock:

$$Asset\ Expected\ Return\ =\ \frac{Sum(Returns)}{Total\ Number\ Of\ Observations}$$

Now are ready to compute the expected return of the portfolio. The portfolio holds the assets together. The assets within the portfolio have been allocated a proportion of the total investment amount. From the asset expected return, we can compute the expected return of the portfolio. It is calculated by computing the weighted average:

$$\begin{aligned}&Expected\ Portfolio\ Return\\&\quad =\ Sum\ \ (Weight\ x\ Asset\ Expected\ Return) Of\ Each\ Asset\end{aligned}$$

The risk of an asset can be computed using a number of risk measures. One of these measures is the standard deviation which can inform us of how the price of an asset deviates from its mean. As an instance, some of the assets might be negatively correlated with each other, implying that as the value of the first asset moves down, the value of the negatively correlated asset increases. This shows us that the risk of a portfolio is not a simple sum of the risks of the individual assets.

The volatility of the portfolio is the risk of the portfolio. The volatility is computed by calculating the standard deviation of the returns of each stock along with the covariance between each pair of the stocks by using this formula:

$$Volatility = Square\ Root\ (Weights\ Vector * Covariance\ Matrix * Weights\ Vector\ Transposed)$$

Volatility in this instance is the standard deviation i.e. the total risk of the portfolio. Standard deviation measures the dispersion of the values around the mean.

The final step is to compute the Sharpe ratio of each of the portfolios. Sharpe Ratio is the amount of excess return over the risk-free rate as the relevant measure of risk:

$$Sharpe\ Ratio = \frac{Portfolio\ Expected\ Return - Risk\ Free\ Rate}{Portfolio\ Volatility\ (Standard\ Deviation)}$$

B. **Portfolio Optimization: Optimization Algorithm**

One thing to note is that guessing and checking is not the most efficient way to optimize a portfolio - instead we can use math to determine the optimal Sharpe Ratio for a given portfolio. To achieve this , we use the python scientific library- SciPy, whose built-in optimization algorithms to calculate the optimal weight for portfolio allocation, optimized for the Sharpe Ratio. The formulae used in this method are the same as mentioned above, but the data is fed into the scipy optimise function, which generates the optimum portfolio.

V. Result

We ran both simulations on a portfolio containing four stocks, namely, TCS, IRCTC, RELIANCE COM and IDEA. The output was an optimum portfolio, having sharpe ratio 1.87. The optimum portfolio is represented by the red dot in the scatter plot.

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Results of the Monte Carlo Simulation method-


Maximum Sharpe Ratio: 1.87
Expected returns of optimum portfolio: 77.94 %
Expected volatity of optimum portfolio: 41.77 %

The optimum allocation of assets using Monte Carlo Simulation are-

Weight of TCS.NS       is 32.50  %
Weight of IRCTC.NS     is 65.94  %
Weight of RCOM.NS      is 0.85   %
Weight of IDEA.NS      is 0.71   %
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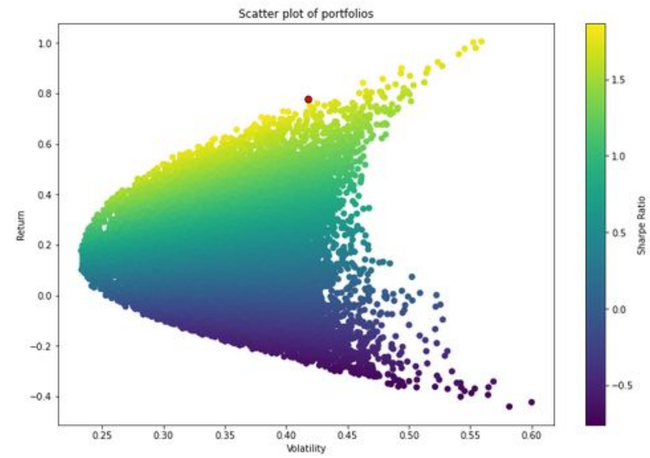


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Results of the Optimization Algorithm method-

The expected return is 76.99 %
The expected volitility is 40.79 %
The max sharpe ratio is 1.89

The return if all the stocks have equal Weightage is 17.03  %
The Volatility if all the stocks have equal Weightage is 32.58 %
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VI. Conclusion

Through this project, we demonstrated how the optimum portfolio management can be realised using historical data of the interested stocks. We managed to construct a simulation that takes in the stock data, processes it using the governing formulae and outputs the ideal portfolio.

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Authors and Affiliation

This report is a part of the mini-project for the course-Database Systems. The following are the members who contributed:

- Suraj Kulkarni, Roll no. 181EE248
- M Bharadwaj, Roll no. 181MT026
- Jai Mandal, Roll no. 181ME232

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3. http://downloads.hindawi.com/archive/2011/781760.pdf