Capstone Project 1

Portfolio Optimization

Springboard - Vincent Tseng

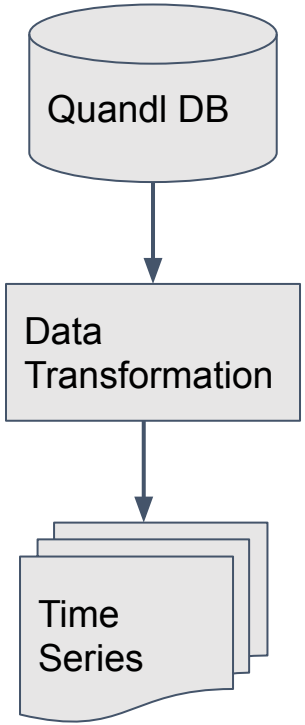
Goal for the project

- Get the optimal portfolio for my technology stocks by using Monte Carlo Simulation and Efficient Frontier.
- Apply statistical reference to get Alpha (α), Beta (β), Value at Risk for the optimal portfolio.

Contents

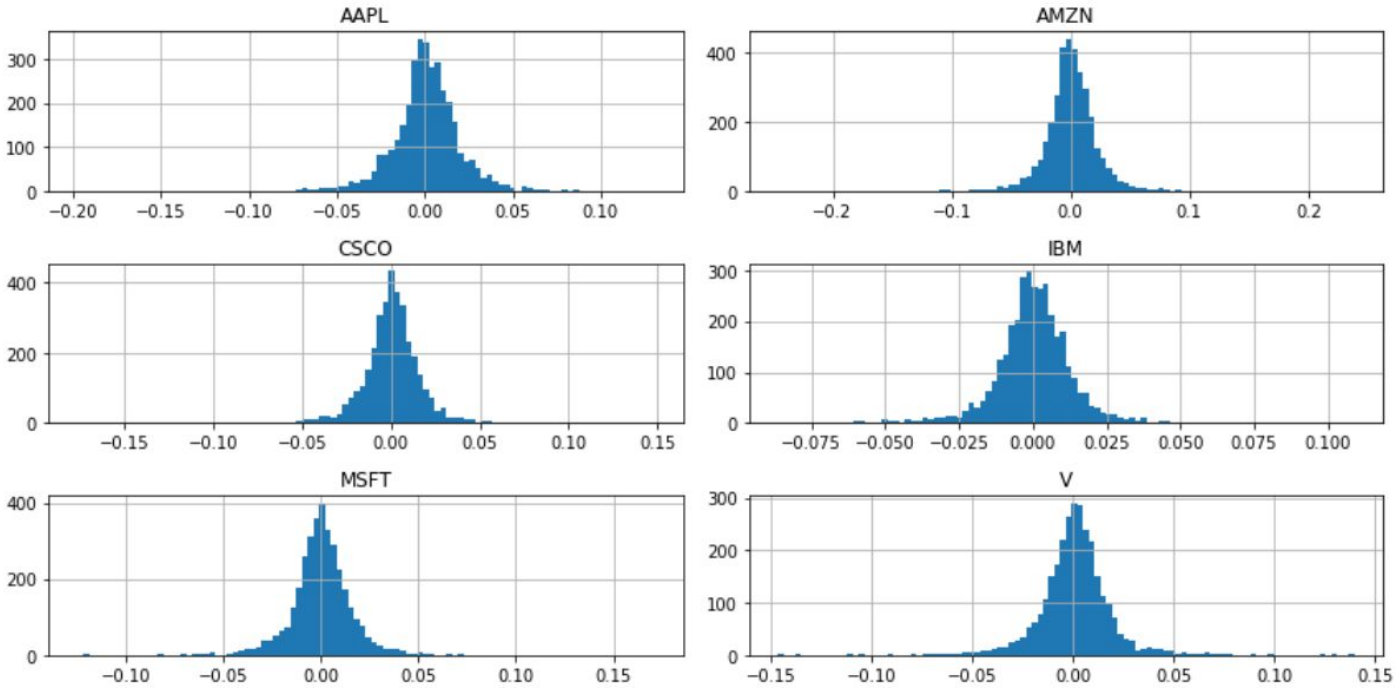
- **Data Preparation (Portfolio and Benchmark)**
  - Get stocks closing price from Yahoo finance
- **The Models and Solutions**
  - Monte Carlo Simulation
  - Efficient Frontier
  - Portfolio Beta(β)
  - Portfolio Alpha (α)
  - Portfolio Value at Risk (VaR)
- **Results**
  - Conclusion

Data Preparation



- Data Acquisition
  - ✔ Portfolio Stocks: Apple, Cisco, IBM, Amazon, Microsoft, Visa
  - ✔ Benchmark: VGT
  - ✔ Get "Adjusted closing price" from Yahoo Finance.
  - ✔ Data Range: 1/1/2006 to 12/31/2019
- Data Transformation
  - ✔ Calculate Log Return to detrend Time Series

Log Return of each stock in Portfolio



Methods and Solutions

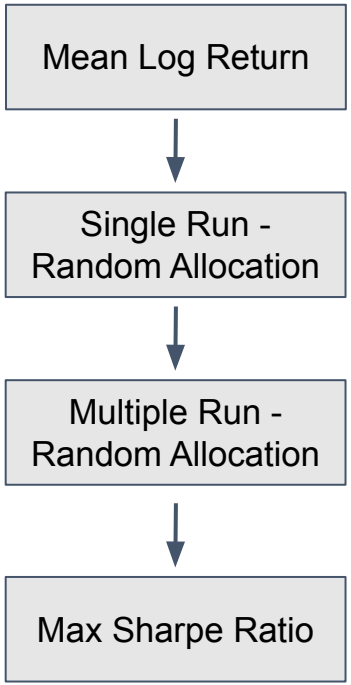
- Modern portfolio theory (MPT)
- Monte Carlo Simulation
- Efficient Frontier
- Sharpe Ratio

We start our approach by reviewing the notion of **MPT**

- Modern portfolio theory (MPT) is all about assembling a portfolio that maximizes expected return for a set level of risk.

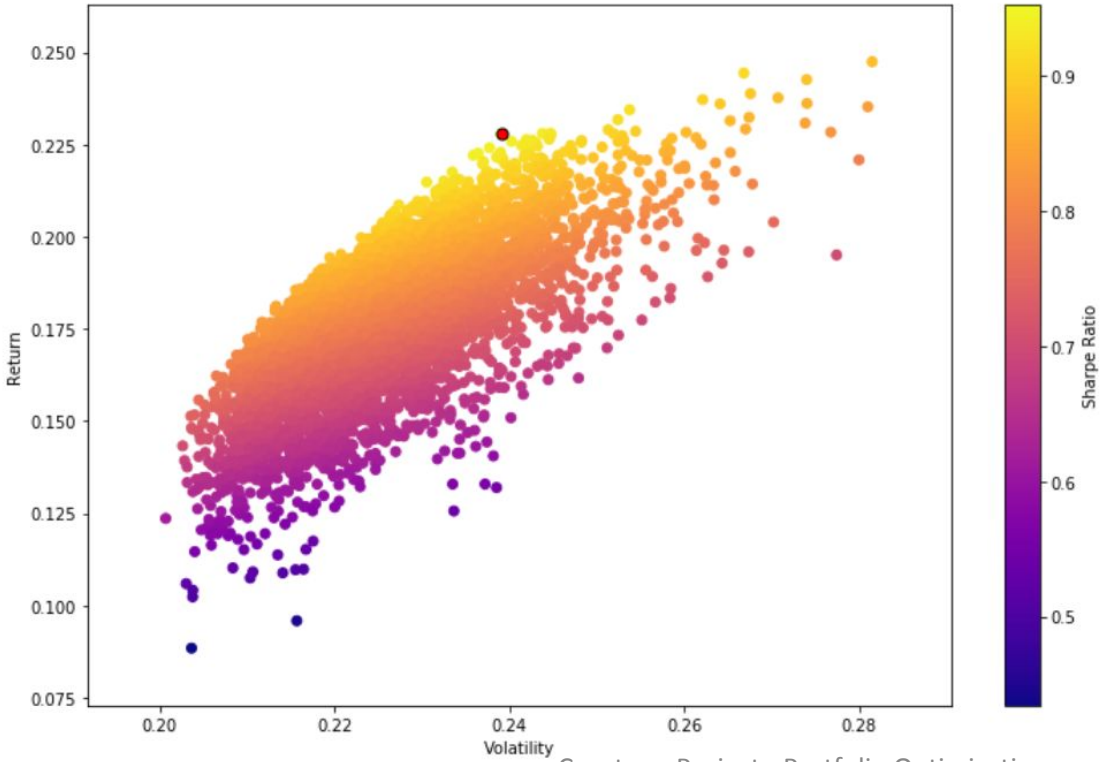
- Assumption of MPT
  - ✔ Investors are risk-averse, meaning that given two portfolios that offer the same expected return, investors will prefer the less risky one.
  - ✔ Thus, an investor will take on increased risk only if compensated by higher expected returns.

Apply Monte Carlo Simulation to get Sharpe Ratio



- Mean Return for each stock in the portfolio
  - ✅ Most technical analyses require detrending or normalizing the time series.
  - ✅ Using log returns is a nice way to do that.
- Single Run for Some Random Allocation
  - ✅ Randomly assign a weight to each security in our portfolio, then calculate its mean daily return and standard deviation of daily return.
- Repeat single run for thousands of times
  - ✅ This allows us to calculate the Sharpe Ratio for thousands of randomly selected allocations.
- Get the maximum Sharpe ratio

Monte Carlo – Multiple Random Runs



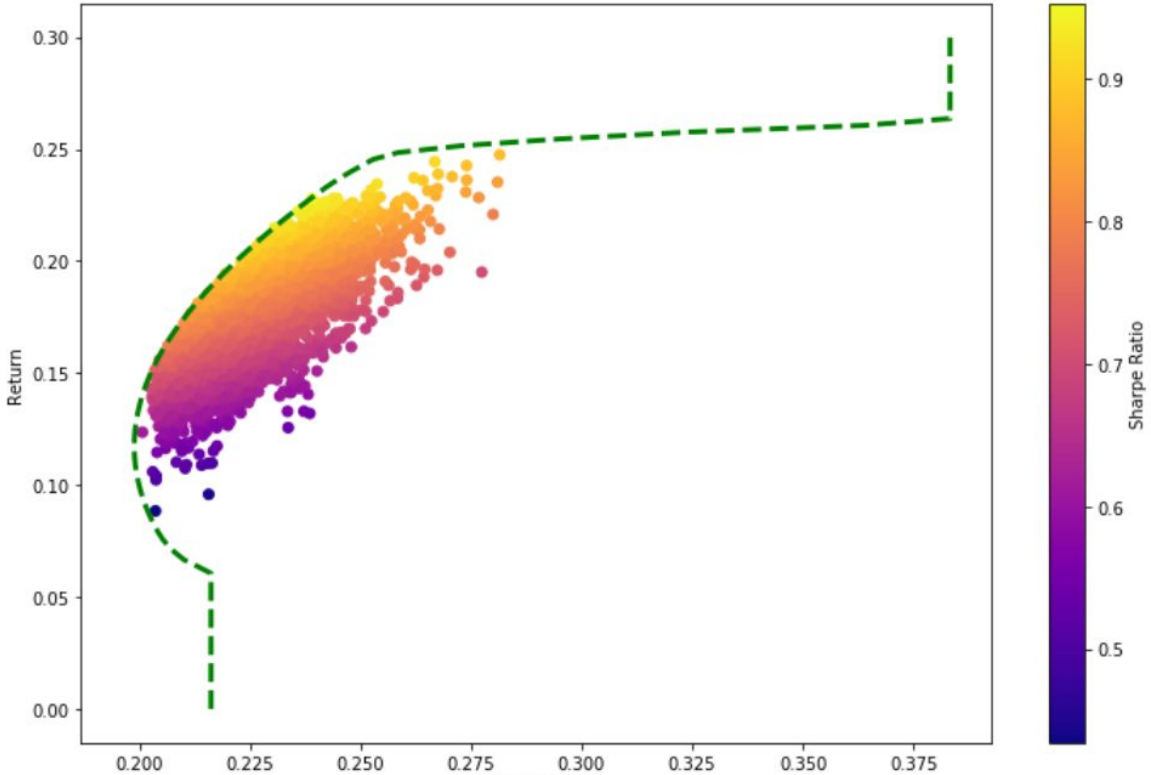
Use Efficient Frontier to find all Optimal Portfolios

- After we have done Monte Carlo Simulation with thousands of times of random allocations.
- Next, I will perform a mathematical optimization and get the Efficient Frontier.
- Efficient Frontier is a set of optimal portfolios that offers the highest expected return for the defined level of risk or the lowest risk possible for a given level of expected return.

- The most optimal weight for the portfolio

Stock	AAPL	AMZN	CSCO	IBM	MSFT	V
Optimal Weight	0.32	0.14	0.003	0.017	0.16	0.36

Efficient Frontier



Statistical Reference

- Calculate alpha, beta, and value at risk (VaR) by using statistical methods.

Beta (β) & Capital Asset Pricing Model (CAPM)

- CAPM is to evaluate whether a stock is fairly valued when its risk and the time value of money are compared to its expected return.
- $ERi=Rf+\beta i(ERm-Rf)$
  - ✔ ERi=expected return of investment
  - ✔ Rf=risk-free rate
  - ✔ βi=beta of the investment
  - ✔ (ERm−Rf) = market risk premium
- The beta of a potential investment is a measure of how much risk the investment will add to a portfolio that looks like the market. If a stock is riskier than the market, it will have a beta greater than one. If a stock has a beta of less than one, the formula assumes it will reduce the risk of a portfolio.

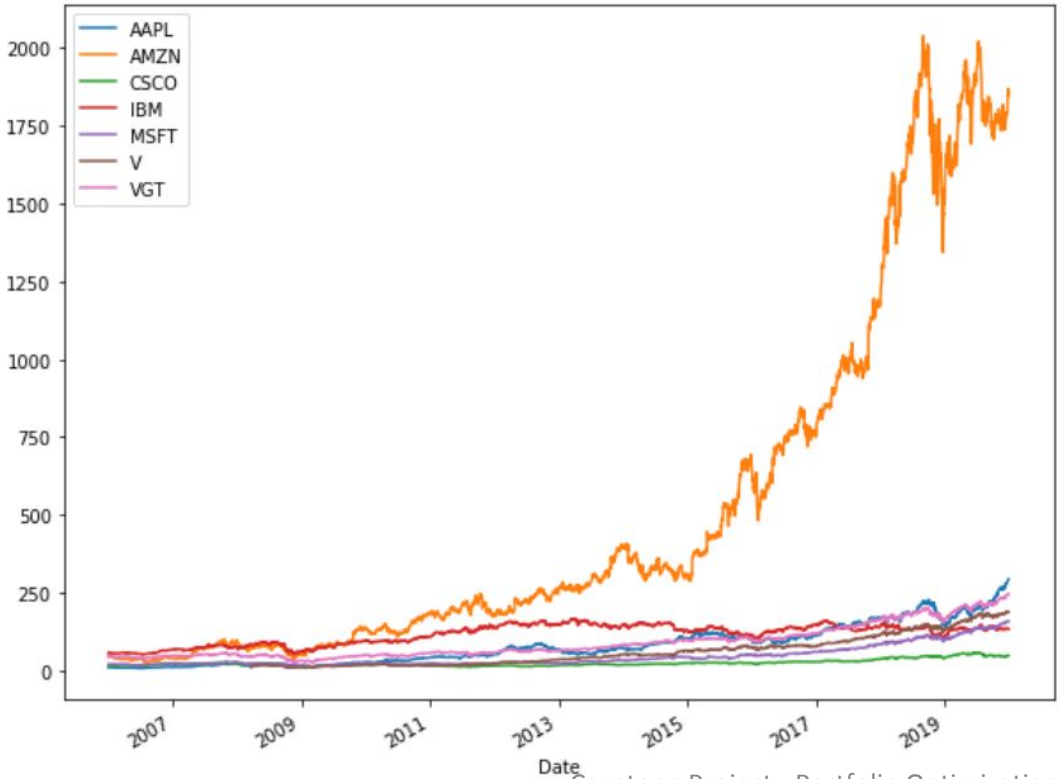
Alpha (α)

- Alpha (α) is a measure of the performance of an investment as compared to a suitable market index, such as the S&P 500.
  - $\alpha = 0$: the baseline value.
  - $\alpha > 0$: the return on the investment during a specified time frame outperformed the overall market average
  - $\alpha < 0$: an investment that is underperforming as compared to the market average
- The alpha of a portfolio is the excess return it produces compared to the index. Investors in mutual funds or ETFs often look for a fund with a high alpha in hopes of getting a superior return on investment (ROI).

Calculate Beta (β) and Alpha (α)

- Step 1: Calculate the portfolio daily return
- Step 2: Calculate the benchmark return
- Step 3: Check the correlation for the benchmark and portfolio
- Step 4: Since our portfolio returns are highly correlated to the benchmark returns, we can use the regression model to calculate the portfolio beta and the portfolio alpha.
- Step 5: Use the linear regression model to calculate the alpha and the beta

Benchmark & Portfolio Stock Movement



Portfolio and Benchmark Returns are Highly Correlated

Highly-Correlated Returns

↓

Use Regression Model to find α and β

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α =0.00048

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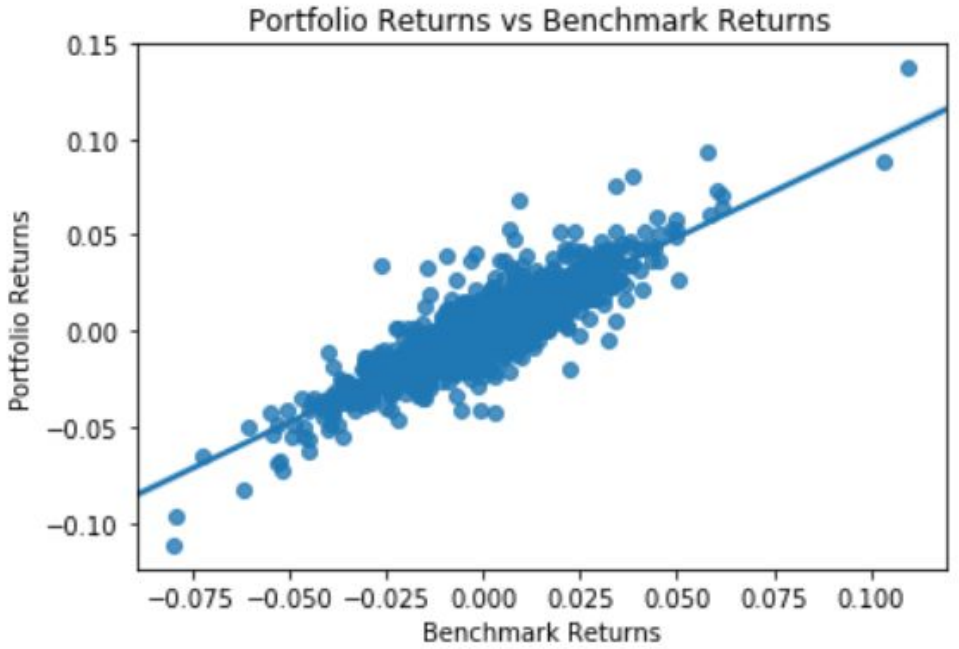
β = 0.9629



Value at Risk (VaR)

- VaR is a statistic used to try and quantify the level of financial risk within a firm or portfolio over a specified time frame.
- VaR provides an estimate of the maximum loss from a given position or portfolio over a period of time, and you can calculate it across various confidence levels.
- "We have a portfolio VaR of 250,000 USD over the next month at 95% confidence"
  - ✔ With 95% confidence, we can say that the portfolio's loss will not exceed 250,000 USD in a month.

Value at Risk (VaR) Assumption

- Normal distribution of returns - VaR assumes the returns of the portfolio are normally distributed. This is of course not realistic for most assets, but allows us to develop a baseline using a much more simplistic calculation. (Modifications can be made to VaR to account for different distributions, but here we'll focus on the standard VaR calculation)
- Standard market conditions - Like many financial instruments, VaR is best used for considering loss in standard markets, and is not well-suited for extreme/outlier events.

How to calculate VaR

- Assume Initial Investment is $1M.
- Step 1: Calculate periodic returns of the stocks in the portfolio
- Step 2: Create a covariance matrix based on the returns
- Step 3: Calculate the portfolio mean and standard deviation (weighted based on investment levels of each stock in portfolio)
- Step 4: Calculate the inverse of the normal cumulative distribution (PPF) with a specified confidence interval, standard deviation, and mean
- Step 5: Estimate the value at risk (VaR) for the portfolio by subtracting the initial investment from the calculation in step (4)

Portfolio VaR

Confidence Level	Value at Risk (VaR)
90%	$981,773
95%	$976,295
99%	$966,019

- Our Initial Investment is $1M USD
- With 95% confidence level, the maximum loss will be $976,295.
- With 5% probability, the minimum loss will be $976,295.

Conclusion

- From the stock performance, Amazon stock price increased from $47 to $2000 per share while other stocks prices increase to $200-250. However, the optimal weights shows only 14% for Amazon in our portfolio.

- Given the risk and volatility of investing in stocks, the optimal portfolio would choose the highest expected return under the defined level of risk