

MIE1622 Assignment 1 Report

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Implementation of Investment Strategies in Python

Initial portfolio value = \$ 1000070.06

Period 1: start date 01/02/2019, end date 02/28/2019

Strategy "Buy and Hold", value begin = \$ 1000070.06, value end = \$ 1121179.83

Strategy "Equally Weighted Portfolio", value begin = \$ 991124.38, value end = \$ 1097031.81

Strategy "Minimum Variance Portfolio", value begin = \$ 991702.28, value end = \$ 1057440.44

Strategy "Maximum Sharpe Ratio Portfolio", value begin = \$ 990119.39, value end = \$ 1016524.41

Period 2: start date 03/01/2019, end date 04/30/2019

Strategy "Buy and Hold", value begin = \$ 1126131.27, value end = \$ 1075001.89

Strategy "Equally Weighted Portfolio", value begin = \$ 1103260.47, value end = \$ 1188731.33

Strategy "Minimum Variance Portfolio", value begin = \$ 1055378.90, value end = \$ 1107930.67

Strategy "Maximum Sharpe Ratio Portfolio", value begin = \$ 1007118.16, value end = \$ 1076636.79

Period 3: start date 05/01/2019, end date 06/28/2019

Strategy "Buy and Hold", value begin = \$ 1070867.54, value end = \$ 969057.81

Strategy "Equally Weighted Portfolio", value begin = \$ 1181234.03, value end = \$ 1169139.09

Strategy "Minimum Variance Portfolio", value begin = \$ 1091907.85, value end = \$ 1099494.27

Strategy "Maximum Sharpe Ratio Portfolio", value begin = \$ 1060340.11, value end = \$ 1073413.37

Period 4: start date 07/01/2019, end date 08/30/2019

Strategy "Buy and Hold", value begin = \$ 976973.31, value end = \$ 933721.61

Strategy "Equally Weighted Portfolio", value begin = \$ 1179634.22, value end = \$ 1149869.96

Strategy "Minimum Variance Portfolio", value begin = \$ 1097336.69, value end = \$ 1129311.06

Strategy "Maximum Sharpe Ratio Portfolio", value begin = \$ 1071292.98, value end = \$ 1140352.70

Period 5: start date 09/03/2019, end date 10/31/2019

Strategy "Buy and Hold", value begin = \$ 922211.42, value end = \$ 1028337.74

Strategy "Equally Weighted Portfolio", value begin = \$ 1138167.02, value end = \$ 1252745.95

Strategy "Minimum Variance Portfolio", value begin = \$ 1115582.54, value end = \$ 1182495.62

Strategy "Maximum Sharpe Ratio Portfolio", value begin = \$ 1139167.02, value end = \$ 1246565.34

Period 6: start date 11/01/2019, end date 12/31/2019

Strategy "Buy and Hold", value begin = \$ 1037933.42, value end = \$ 1099403.03

Strategy "Equally Weighted Portfolio", value begin = \$ 1270461.87, value end = \$ 1373479.86

Strategy "Minimum Variance Portfolio", value begin = \$ 1184511.14, value end = \$ 1255872.45

Strategy "Maximum Sharpe Ratio Portfolio", value begin = \$ 1248640.31, value end = \$ 1370079.26

Period 7: start date 01/02/2020, end date 02/28/2020

Strategy "Buy and Hold", value begin = \$ 1112112.69, value end = \$ 900207.54

Strategy "Equally Weighted Portfolio", value begin = \$ 1396296.22, value end = \$ 1258330.19

Strategy "Minimum Variance Portfolio", value begin = \$ 1256164.22, value end = \$ 1159346.53

Strategy "Maximum Sharpe Ratio Portfolio", value begin = \$ 1379472.80, value end = \$ 1284770.75

Period 8: start date 03/02/2020, end date 04/30/2020

Strategy "Buy and Hold", value begin = \$ 924774.25, value end = \$ 856285.51

Strategy "Equally Weighted Portfolio", value begin = \$ 1312225.31, value end = \$ 1215208.23

Strategy "Minimum Variance Portfolio", value begin = \$ 1209653.03, value end = \$ 1077520.12

Strategy "Maximum Sharpe Ratio Portfolio", value begin = \$ 1340490.22, value end = \$ 1417345.41

Period 9: start date 05/01/2020, end date 06/30/2020

Strategy "Buy and Hold", value begin = \$ 822532.65, value end = \$ 875128.45

Strategy "Equally Weighted Portfolio", value begin = \$ 1171040.04, value end = \$ 1316082.51

Strategy "Minimum Variance Portfolio", value begin = \$ 1046783.13, value end = \$ 1081097.46

Strategy "Maximum Sharpe Ratio Portfolio", value begin = \$ 1357646.73, value end = \$ 1638005.29

Period 10: start date 07/01/2020, end date 08/31/2020

Strategy "Buy and Hold", value begin = \$ 852159.31, value end = \$ 852474.32

Strategy "Equally Weighted Portfolio", value begin = \$ 1307022.80, value end = \$ 1493983.95

Strategy "Minimum Variance Portfolio", value begin = \$ 1084116.26, value end = \$ 1242140.70

Strategy "Maximum Sharpe Ratio Portfolio", value begin = \$ 1699102.28, value end = \$ 2238611.66

Period 11: start date 09/01/2020, end date 10/30/2020

Strategy "Buy and Hold", value begin = \$ 857122.42, value end = \$ 795062.75

Strategy "Equally Weighted Portfolio", value begin = \$ 1504676.72, value end = \$ 1407362.52

Strategy "Minimum Variance Portfolio", value begin = \$ 1244341.51, value end = \$ 1193122.73

Strategy "Maximum Sharpe Ratio Portfolio", value begin = \$ 2285965.91, value end = \$ 2163817.00

Period 12: start date 11/02/2020, end date 12/31/2020

Strategy "Buy and Hold", value begin = \$ 811070.20, value end = \$ 972162.37

Strategy "Equally Weighted Portfolio", value begin = \$ 1419803.51, value end = \$ 1682239.09

Strategy "Minimum Variance Portfolio", value begin = \$ 1203779.19, value end = \$ 1273097.92

Strategy "Maximum Sharpe Ratio Portfolio", value begin = \$ 2161858.95, value end = \$ 2492620.00

Rounding procedure:

For rounding of stock shares, I used the `math.floor()` function in all of my strategies to round all shares computed down to the nearest integer. I chose to round stock shares down in order to prevent the cash account from becoming negative.

Validation procedure:

I wrote the following code as a validation procedure:

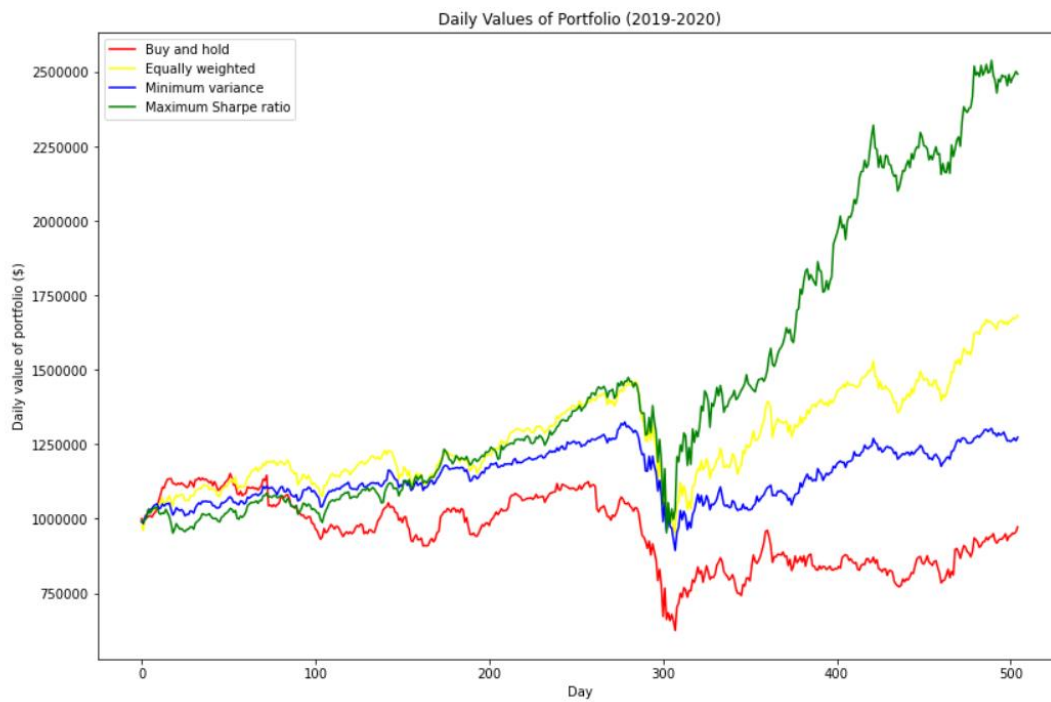
```
while cash[strategy, period-1] < 0:

    V_init = np.dot(cur_prices, curr_positions) + curr_cash
    x_normalized = x[strategy][period-1]/np.sum(x[strategy][period-1])
    cash_extra = abs(cash[strategy][period-1])*x_normalized
    x_extra = np.ceil(cash_extra/cur_prices)
    x[strategy][period-1] = x[strategy][period-1] - x_extra
    txn_cost = 0.005*np.dot(cur_prices, abs(x[strategy][period-1]-curr_positions))
    cash[strategy][period-1] = V_init - np.sum(cur_prices*x[strategy][period-1]) - txn_cost
```

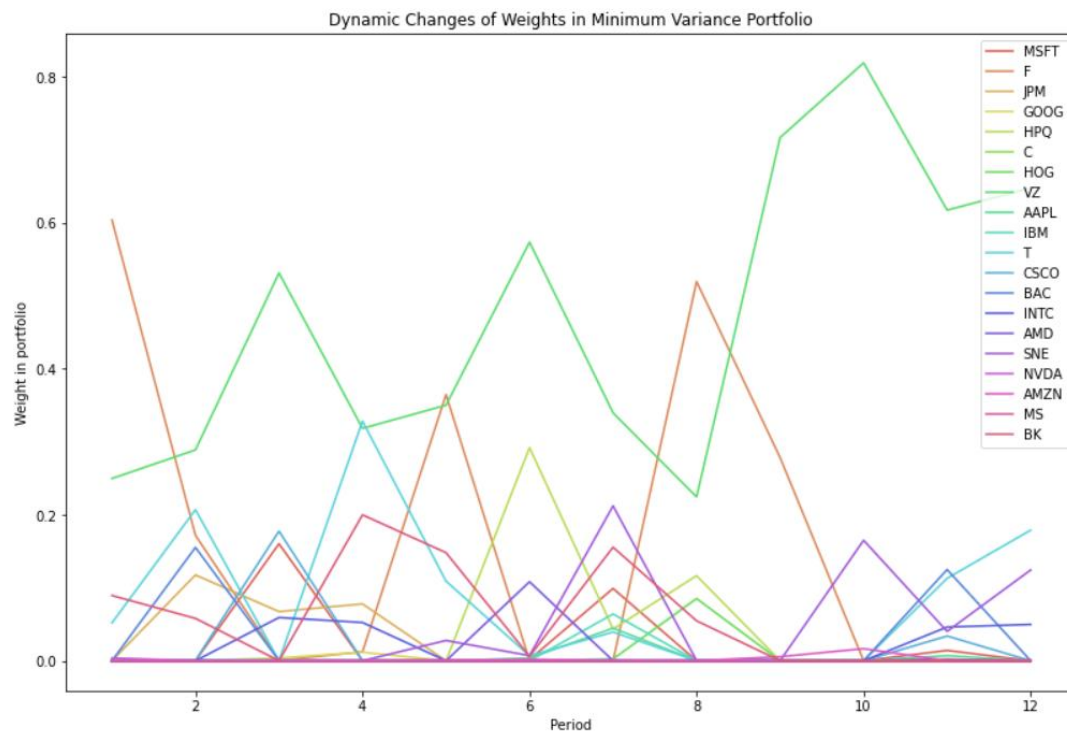
In the case where there is not enough budget to re-balance the portfolio for a specific period thus resulting in the cash account to be negative, the above algorithm will subtract an equal amount of shares from each stock until the cash account becomes non-negative again for that specific period.

Analysis of results

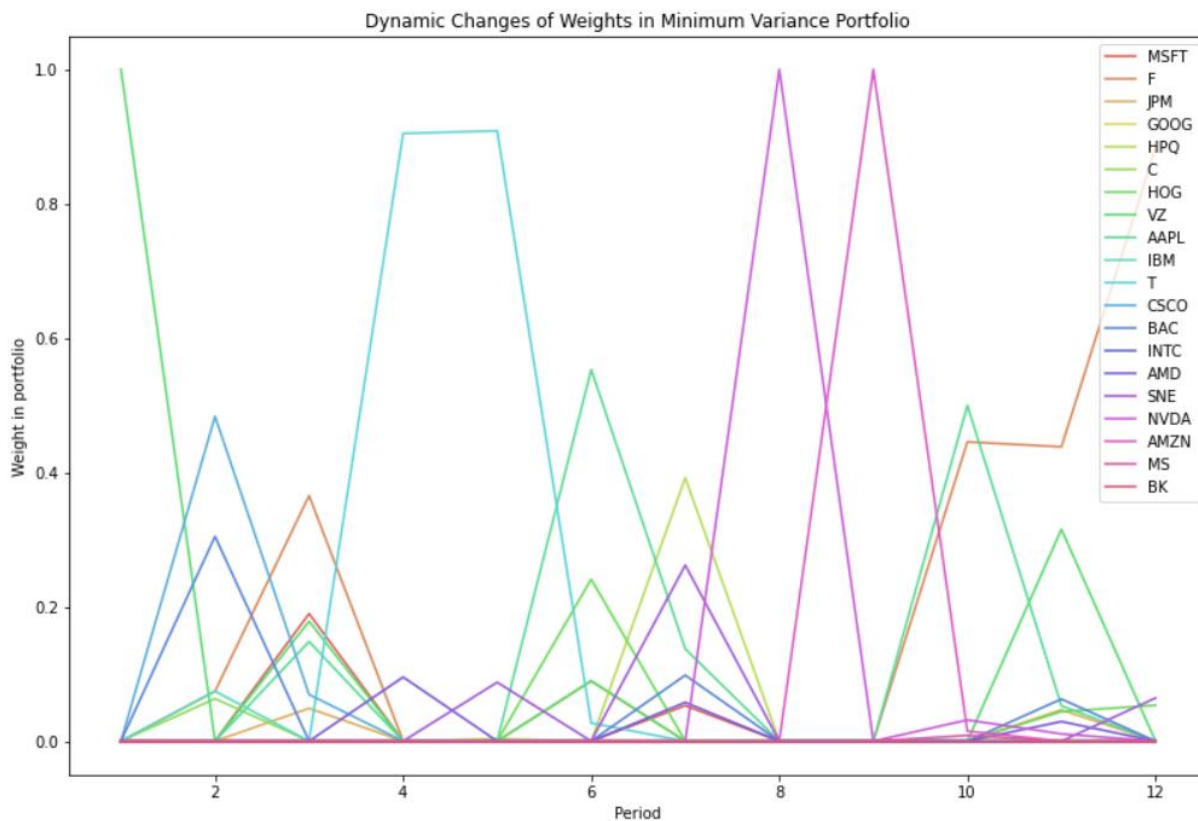
Daily values of portfolios plot:



Dynamic changes of weights in minimum variance portfolio plot:



Dynamic changes of weights in maximum Sharpe ratio portfolio plot:



Comparison of trading strategies:

Period 12: start date 11/02/2020, end date 12/31/2020

Strategy "Buy and Hold", value begin = \$ 811070.20, value end = \$ 972162.37

Strategy "Equally Weighted Portfolio", value begin = \$ 1419803.51, value end = \$ 1682239.09

Strategy "Minimum Variance Portfolio", value begin = \$ 1203779.19, value end = \$ 1273097.92

Strategy "Maximum Sharpe Ratio Portfolio", value begin = \$ 2161858.95, value end = \$ 2492620.00

Out of the 4 trading strategies used, the maximum Sharpe ratio strategy had the best performance in terms of portfolio value at the end of the 12 periods. The equally weighted strategy had the second highest portfolio value, while the minimum variance portfolio had the third highest portfolio value. The buy and hold strategy had the worst performance of the 4. I would personally want to use the maximum Sharpe ratio strategy to manage my own portfolio, since it gives the highest portfolio value out of all 4 strategies that were used in this assignment.

Discussion of improvements to trading strategies

I created 3 variations based on the strategies above. The first variation is an equal-weighted portfolio with buy and hold features. This means that we buy stock shares in period 1 such that each stock has a weight of $1/n$, and these shares are held for all subsequent periods. The second variation is a minimum variance portfolio with buy and hold features. Similar to the first variation, we buy stock shares in period 1 such that their weights will result in the least portfolio variance, and these shares are held for all subsequent periods. Finally, the third variation is a maximum Sharpe ratio portfolio with buy and hold features. These variations can be found in the Python notebook file *portf_optim_variations.ipynb*. The 12-period outputs for these strategy variations can be seen below.

Initial portfolio value = \$ 1000070.06

Period 1: start date 01/02/2019, end date 02/28/2019

Strategy "Buy and Hold", value begin = \$ 1000070.06, value end = \$ 1121179.83
Strategy "Equally Weighted Portfolio with buy and hold", value begin = \$ 1000070.06, value end = \$ 1105977.48
Strategy "Minimum Variance Portfolio with buy and hold", value begin = \$ 1000070.06, value end = \$ 1065808.21
Strategy "Maximum Sharpe Ratio Portfolio with buy and hold", value begin = \$ 1000070.06, value end = \$ 1026475.08

Period 2: start date 03/01/2019, end date 04/30/2019

Strategy "Buy and Hold", value begin = \$ 1126131.27, value end = \$ 1075001.89
Strategy "Equally Weighted Portfolio with buy and hold", value begin = \$ 1112519.43, value end = \$ 1198618.65
Strategy "Minimum Variance Portfolio with buy and hold", value begin = \$ 1068773.79, value end = \$ 1116497.29
Strategy "Maximum Sharpe Ratio Portfolio with buy and hold", value begin = \$ 1027189.40, value end = \$ 1041818.94

Period 3: start date 05/01/2019, end date 06/28/2019

Strategy "Buy and Hold", value begin = \$ 1070867.54, value end = \$ 969057.81
Strategy "Equally Weighted Portfolio with buy and hold", value begin = \$ 1191197.72, value end = \$ 1179661.37
Strategy "Minimum Variance Portfolio with buy and hold", value begin = \$ 1104168.02, value end = \$ 1086051.18
Strategy "Maximum Sharpe Ratio Portfolio with buy and hold", value begin = \$ 1029731.06, value end = \$ 1040736.55

Period 4: start date 07/01/2019, end date 08/30/2019

Strategy "Buy and Hold", value begin = \$ 976973.31, value end = \$ 933721.61
Strategy "Equally Weighted Portfolio with buy and hold", value begin = \$ 1190817.63, value end = \$ 1160875.08
Strategy "Minimum Variance Portfolio with buy and hold", value begin = \$ 1082494.08, value end = \$ 1087143.03
Strategy "Maximum Sharpe Ratio Portfolio with buy and hold", value begin = \$ 1032256.85, value end = \$ 1070364.57

Period 5: start date 09/03/2019, end date 10/31/2019

Strategy "Buy and Hold", value begin = \$ 922211.42, value end = \$ 1028337.74
Strategy "Equally Weighted Portfolio with buy and hold", value begin = \$ 1149267.41, value end = \$ 1263126.13
Strategy "Minimum Variance Portfolio with buy and hold", value begin = \$ 1080782.10, value end = \$ 1138910.48
Strategy "Maximum Sharpe Ratio Portfolio with buy and hold", value begin = \$ 1068176.81, value end = \$ 1123951.43

Period 6: start date 11/01/2019, end date 12/31/2019

Strategy "Buy and Hold", value begin = \$ 1037933.42, value end = \$ 1099403.03
Strategy "Equally Weighted Portfolio with buy and hold", value begin = \$ 1281870.27, value end = \$ 1394341.61
Strategy "Minimum Variance Portfolio with buy and hold", value begin = \$ 1148597.27, value end = \$ 1188857.98
Strategy "Maximum Sharpe Ratio Portfolio with buy and hold", value begin = \$ 1122109.35, value end = \$ 1141083.40

Period 7: start date 01/02/2020, end date 02/28/2020

Strategy "Buy and Hold", value begin = \$ 1112112.69, value end = \$ 900207.54
Strategy "Equally Weighted Portfolio with buy and hold", value begin = \$ 1420127.21, value end = \$ 1287767.44
Strategy "Minimum Variance Portfolio with buy and hold", value begin = \$ 1193090.80, value end = \$ 1038532.26
Strategy "Maximum Sharpe Ratio Portfolio with buy and hold", value begin = \$ 1134635.86, value end = \$ 1018095.23

Period 8: start date 03/02/2020, end date 04/30/2020

Strategy "Buy and Hold", value begin = \$ 924774.25, value end = \$ 856285.51
Strategy "Equally Weighted Portfolio with buy and hold", value begin = \$ 1344733.18, value end = \$ 1272461.40
Strategy "Minimum Variance Portfolio with buy and hold", value begin = \$ 1086406.90, value end = \$ 1019851.07
Strategy "Maximum Sharpe Ratio Portfolio with buy and hold", value begin = \$ 1076912.78, value end = \$ 1090832.66

Period 9: start date 05/01/2020, end date 06/30/2020

Strategy "Buy and Hold", value begin = \$ 822532.65, value end = \$ 875128.45
Strategy "Equally Weighted Portfolio with buy and hold", value begin = \$ 1227982.28, value end = \$ 1388057.25
Strategy "Minimum Variance Portfolio with buy and hold", value begin = \$ 999776.14, value end = \$ 1042994.12
Strategy "Maximum Sharpe Ratio Portfolio with buy and hold", value begin = \$ 1079168.36, value end = \$ 1047185.80

Period 10: start date 07/01/2020, end date 08/31/2020

Strategy "Buy and Hold", value begin = \$ 852159.31, value end = \$ 852474.32
Strategy "Equally Weighted Portfolio with buy and hold", value begin = \$ 1384168.32, value end = \$ 1667778.42
Strategy "Minimum Variance Portfolio with buy and hold", value begin = \$ 1034014.42, value end = \$ 1142730.83
Strategy "Maximum Sharpe Ratio Portfolio with buy and hold", value begin = \$ 1038531.60, value end = \$ 1137594.94

Period 11: start date 09/01/2020, end date 10/30/2020

Strategy "Buy and Hold", value begin = \$ 857122.42, value end = \$ 795062.75
Strategy "Equally Weighted Portfolio with buy and hold", value begin = \$ 1688450.64, value end = \$ 1532407.07
Strategy "Minimum Variance Portfolio with buy and hold", value begin = \$ 1146837.69, value end = \$ 1129546.24
Strategy "Maximum Sharpe Ratio Portfolio with buy and hold", value begin = \$ 1135502.23, value end = \$ 1105762.79

Period 12: start date 11/02/2020, end date 12/31/2020

Strategy "Buy and Hold", value begin = \$ 811070.20, value end = \$ 972162.37
Strategy "Equally Weighted Portfolio with buy and hold", value begin = \$ 1541002.18, value end = \$ 1800509.14
Strategy "Minimum Variance Portfolio with buy and hold", value begin = \$ 1139935.42, value end = \$ 1217555.60
Strategy "Maximum Sharpe Ratio Portfolio with buy and hold", value begin = \$ 1119414.09, value end = \$ 1139602.56

Variations 1 and 2 showed slight improvements compared to their original counterparts (no buy and hold features). Variation 3, however, had much worse performance compared to before. Finally, none of the three variations were able to achieve a higher performance than the original maximum Sharpe ratio strategy.

Additionally, I believe that some improvements can be made to the trading strategies that I have implemented:

- All of the implementations thus far unconditionally rounded stock shares down to the nearest integer. A better rounding strategy, such as one that is able to both round up and down depending on the situation, may improve the performance of these portfolios.
- The maximum Sharpe ratio strategy can be improved by using a more accurate daily risk-free rate. The current daily risk-free rate used is a constant value that is derived from the annual 2.5% risk free rate that was given to us. Using a variable daily-risk free rate that changed according to daily market changes may improve the performance of the maximum Sharpe ratio portfolio.
- The current method for calculating transaction costs is $0.5\% \times \text{traded volume}$. Using a more sophisticated method for calculating transaction costs may lead to better performance of all four strategies.