

Investment Policy Statement for COMS-W4995 group

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1. Scope and Purpose

- a. **Context:** JN enterprises combines the latest advances in machine learning with financial portfolio optimization methods to manage client assets with low risk and high rates of return. JN enterprises founder, John Nguyen, has his B.S in Electrical Engineering at Northeastern University, and is a candidate for his M.S in Computer Science at Columbia University. With his expertise and extensive experience in industry working at Siemens, Intel, Raytheon, and NASA, JN Enterprises specializes in the technology sector. JN's trading strategy seeks stocks with large market caps producing steady profits and growth, believing that this strategy has created substantial profit. As the prospective portfolio manager of the COMS-W4995 group, JN is entrusted to manage \$1 million in assets at their ultimate discretion.
- b. **Investor:** COMS-W4995 group is looking to invest \$1 million dollars at the complete discretion of a potential asset manager. They are evaluating multiple asset management firms within the computer science and finance program at Columbia university and will be ranking each potential manager according to their performance and their fundamentally sound investment management strategy. This investment policy statement governs the personal investment portfolios of COMS-W4995 group which has a financial philosophy centered around obtaining a high rate of return in tandem with low tolerance for risk.

2. Investment, Return, and Risk Objectives

- a. **Objective:** The overall investment objective of JN enterprises is to make a selection of 10-20 stocks using machine learning based portfolio optimization and stock selection methods. This is achieved through leveraging risk factor models, fundamental analysis and the powerful forecasting capabilities of machine learning algorithms. A position in each stock must be established in addition to a performance benchmark to measure against. The managed equity investment portfolio will begin on June 13, 2022 and run until July 1, 2022. Cash will not be sidelined and must not exceed 20% of the portfolio with bid and ask spreads not factored into the final portfolio computations. The investment program governed by this IPS is intended to diversify and supplement COMS-W4995 group's investing interests.
- b. **Return, distribution, and risk requirements:** JN Enterprises may invest in U.S. equity, U.S. fixed-income, and the U.S. money market, so long as they are not market indexes. The benchmarks selected for comparison

with the assets are the S&P500, the US Treasury 10 year index. As previously mentioned, the distribution and spending assumption policy governs that per the 10-20 stocks selected from the U.S exchange, each position, long or short, must be between 5% and 10% of the portfolio assets and the cash balance of the portfolio sidelined should not exceed 20% of the portfolio. The policy also assumes there are no fees, and does not take into account tax or inflation rates. These factors thus will not be factored into the assets under management computations. The asset allocation plan is subject to weekly review and rebalancing so long as the previously mentioned conditions are met under the sole authority of JN Enterprises. For the assets in the portfolio, a target allocation has been established that reflects the optimized asset allocation. The investment advisor JN is responsible for adhering and administering the asset allocation plan and for maintaining actual allocations to asset classes within the conditions established by COMS-W4995 group. At the end of the equity investing period, a report by the investment management team to COMS-W4995 group must confirm asset allocations and confirm that the allocations are within allowable ranges.

- c. **Risk tolerance:** COMS-W4995 group recognizes that risk and volatility is inevitable especially in the current market conditions. However JN is confident that they can minimize risk in their effort to generate investment returns. JN seeks to generate investment returns proportional to the risks assumed in the COMS-W4995 group portfolio. JN will implement an investment strategy that balances the needs of COMS-W4995 group and establish an absolute threshold that must be upheld within a time period of COMS-W4995 group's choosing. If the threshold has been incurred, policies and procedures to withdraw or minimize risk of further loss will be implemented by JN Enterprises.
- d. **Constraints:** JN Enterprises must provide a financial report at the conclusion of the vesting period and summarize if the performance objective were met. The investment advisor will also provide COMS-W4995 group metrics on the holdings (tickers) including cash, number of shares, trade price, close price, previous close price, value and weight in the portfolio for each holding, total AUM, AUM daily change (profit/loss) in dollars and percentages, cumulative return for portfolio (value and rate), benchmark value, benchmark daily change in dollars and percentages, and cumulative return for the benchmark. Furthermore, factory style analysis shall supplement the portfolio. There are no requirements for maintaining liquidity and tax considerations will not affect

investment decision making to any extent. The portfolio must adhere to all legal constraints and must be traded in the U.S. exchange market.

- e. **Considerations:** There are no special factor considerations or participation in securities lending programs. JN Enterprises, as investment adviser to the COMS-W4995 group, shall be responsible for voting all proxies in a timely manner in a way that maximizes the value of the group's underlying investments. Upon timely notification to JN Enterprises, the COMS-W4995 group of trustees may provide voting instructions to be executed.

3. Investment Strategy

- a. **Qualitative reasons for selection of each stock:** At the time of trading, the U.S exchange market has officially entered a bear market as of June 14, 2022. Bear markets are typically met with concerns of inflation, high interest rates which put downward pressure on stocks. Investors are paying more to borrow money which means they cannot invest as much for stocks that are inflated especially when bonds that are paying more in interest are a less risky option. However it is important to note that the bear markets always recover over time and prudent investors will reap the benefits. Thus the bear market presents an opportunity to establish a long position in companies for high returns especially within a large market capitalization stock and high growth potential. A high market capitalization is trademarked with low volatility/risk and is ideal for risk averse investors. With JN's specialization in the technology sector, they seek to find companies that meet these characteristics. JN will initially leverage financial metrics such as Beta and P/E ratios. JN will take a conservative investing approach by looking at stocks with proven performance, large market size, proven market leadership and perceived staying power meaning that it is less likely to be affected by economic downfall. After finding stocks that meet this criteria, JN will then deploy machine learning to narrow down the selection of stocks to 10 stocks that employ these characteristics for long term investing and are also trending short term to produce returns. Thus the 10 stocks will all be long positions.
 - i. To begin, JN will select stocks from the S&P500 and aim to make a "smarter" S&P500 with a smaller basket of stocks. The S&P500 represents the top 500 U.S companies with the largest market caps which fits the conservative investing strategy. Appendix A is a resourceful for more details about the S&P 500 including which stocks its consists of, their PE ratios, sector, and market cap.

- ii. Since JN is seeking high growth stocks, JN will further narrow the potential stocks in the S&P 500 to those within the technology sector. JN has a particular interest and expertise in this sector. Traditionally in bear markets, investors put money in sectors such as consumer staples, utilities, healthcare, since growth stocks generally tend to not perform as well. However, JN seeks to isolate the growth stocks in the technology sector during the bear market as they believe this is an opportune moment and ultimately the best strategy for long term growth. Below are the identified sectors of interest
 - 1. Technology Services
 - 2. Communications
 - 3. Electronic Technologies
 - 4. Health Technologies
 - iii. JN is seeking high growth and profitable companies therefore, they will eliminate any company without a PE ratio from consideration and also only select companies with a PE ratio larger than PE ratio of the monthly S&P sector (20) as shown in Appendix B.
 - iv. To further narrow down the list, JN will explore large cap stocks with over \$100 billion in market capitalization and this results in the 40 stocks shown in Appendix C.
- b. **Quantitative reasons for selection of each stock:** From the list of 40 stocks previously mentioned, JN aims to narrow down the list using machine learning to find the stocks that will have the highest returns for the next week. JN believes that the combination of short term returns with a long term outlook will most satisfy the risk averse client seeking high returns and success. The following steps are done and models are leveraged. Please reference the accompanying Jupyter Notebook for further technical analysis.
 - i. **Cross correlation matrix to avoid multicollinearity and portfolio diversity:** From Table E1 in Appendix E, and the accompanying Jupyter Notebook, the uncorrelated stocks are ['ORCL', 'AAPL', 'ABBV', 'IBM', 'RTX', 'AMGN']. This only produces six stocks, so JN also added to the initial exploration sample a mix of the stocks from each sector with highest market cap and the stocks from each sector with the highest PE Ratio. These are respectively, ['GOOGL', 'SYK', 'LRCX', 'GE', 'TMUS'] and ['NOW', 'T', 'NVDA', 'ISRG', 'HON']. Thus, JN has now identified 16 stocks.

- ii. **RNN prediction with positive returns to select predicted returns after 7 days:** With the 16 stocks, each stock is fitted to a LSTM Recurrent Neural Network. Lag period is 5 days, and the prediction period is 7 days out. Testing/training is done on the period start_date = '2022-05-01' and end_date = '2022-06-13' which is the month and a half leading up to the simulation training beginning. Min Max scaler is applied before reshaping the lag samples into the neural network. An example of the input data frame is shown in Table E2. From there a RNN is trained with a split of the first 80% of the dates and testing on the remaining split. Hyperparameter tuning finds the best model with the best shape (number of neurons per layer) and trial and epoch size of 10 and 100. An example of the training results and test results is shown in Table E1 where although the predicted price is a little bit off, the model is able to capture the general trends when the stock goes up, down, or neutral. After obtaining the best model, a prediction is done on the last 5 samples to predict the next day. This is repeated 7 times to find the prediction of the stock price after 7 days or one week which is when JN will examine potential rebalancing. This process is repeated for all 16 stocks and the 10 highest predicted stocks returns are ['ISRG', 'SYK', 'AAPL', 'HON', 'ABBV', 'GE', 'ORCL', 'T', 'RTX', 'NVDA'] as shown in Table E3 in Appendix E.
- iii. **Portfolio optimization to construct a weighted portfolio and determine asset allocation:** From the 10 stocks selected above, JN next constructs a portfolio to maximize the Sharpe Ratio. JN will leverage the “Python Portfolio Optimization” library to find the weights of the optimal portfolio subject to the constraints that a stock can only be 5 to 10 percent of assets under management. Optimizing with the objective to minimize variance will create the portfolio optimized in terms of risk and return and previous shows that global minimum variance portfolios often outperform mean variance optimized portfolios. To start a Ledoit-Wolf shrinkage covariance matrix is created and the capital asset pricing model returns are also used to define the efficient frontier of the max sharpe portfolio. Appendix F shows the portfolio weights, the portfolio expected performance, and the asset allocation. A weekly report is also generated with risk management metrics explored in the next section.

4. Risk Management

- a. **Evolution of portfolio and rebalancing:** In the “Weekly Report Final” excel file, sheet “Week_1”, attachment (screenshot in Appendix G), JN’s portfolio outperformed the S&P 500 by .18%. This is computed as the benchmark cumulative return minus the cumulative return of JN’s curated portfolio. While this is quite a small percentage, it represents a tremendous improvement in terms of risk aversion. JN was careful to select high performing long term growth stocks which encourage the client to hold onto these stocks. Since the net return of the portfolio is positive, and the portfolio is optimized to go long, JN deemed rebalancing unnecessary and will continue to hold onto these stocks. Given recent economic trends and downturn in the year 2022, to find two prong growth stocks with positive short term returns is ideal and JN recognizes the importance when constructing this portfolio. In practicality, the client will enjoy peace of mind with less frequent monitoring, and if deployed with trailing stop losses, be a safe portfolio. At the end of the simulation period, the benchmarks were recalculated and it turns out that JN’s portfolio underperformed compared to the S&P 500 by .45%. This is shown in the “Weekly Report Final” excel file, sheet “Week_2”, attachment. This is again quite a small margin and a bit disappointing, but it is important to keep in mind that this is a very small sample window of 2 weeks. JN is confident that the portfolio has better long term growth prospects and will continue to outperform the S&P 500 with more training. Unless drastic macroeconomic events occur, or the stock suddenly torpedoed, JN suggests and reiterates holding the position. JN also further suggests that to create a more fruitful performance comparison, compare portfolios after a longer time frame perhaps such as quarterly or annually.
- b. **Portfolio performance with the following statistics and risk measures:** See Appendix H, I, J or “Weekly Report Final” sheets “Final Benchmark”, “Final Performance Attribution”, “Final Fama French”. Below is a discussion of the aforementioned results. Note all calculations and formulas can be found in the attached spreadsheet
 - i. **Benchmarks:** As previously mentioned, JN’s portfolio outperformed the S&P 500 by .18% at the end of week one, and underperformed the S&P 500 by .45% by the end of the simulation period. Oftentimes, it is the goal of an investor to outperform this benchmark which is a tall task. Another noteworthy benchmark to examine is the Average Risk free rate (10-year Treasury Rate). The chart in Appendix H shows that the portfolio outperforms the benchmark and has lower volatility, both ideal indicators to have. In

terms of the capital asset model, JN sets the risk free benchmark rate as 3%. It is important to note that this number is based on the current rate that the Treasury would pay investors if purchasing a note today and this duration is a decade as opposed to the simulation which is essentially 10 business days or 2 weeks. Thus the total cumulative return is much lower than this benchmark. Thus the shape ratio is negative since JN's portfolio is not expected to outperform the benchmark in this period. Again, another apples to apples benchmark comparison would be to compare the benchmarks and the portfolio within the same time frame. Other key metrics computed are the alpha of $-.007$ and a Beta of $.723$, information Ratio of $-.248$, correlation of -0.11 . Beta is the performance of the portfolio relative to the market, and the portfolio Beta is lower than 1 which makes sense as from the predictions and the recent trends in the economy show a downward trend. Alpha is the excess return after adjusting for market-related volatility which is negative as a result of the factors mentioned. The correlation of the portfolio to the benchmark is a small negative number meaning they are not linearly correlated and trend in different directions.

- c. **Performance attribution:** Appendix I shows the results of the asset allocation vs stock selection. The total excess return of the portfolio is computed to be 4.81%. Excess return is the difference between the portfolio investment and the risk free rate and the positive excess return shows that the investment outperformed the benchmark of the S&P 500.
- d. **Factor style analysis using Fama French model:** Appendix J shows the computed Fama French Model using the last two weeks of May since the June factor data had not yet been published. The model has three factors; size of firms, book to market values, and excess returns and this helps show asset pricing taking into account size and risk factors to the risk factor of the market risk factor in the capital asset pricing model. The Fama French model considers the fact that value and small cap stocks will outperform the market and adjusts for this tendency. The calculations show all the factors generally trending downwards which then means that JN's performance was not due to these underlying factors and the results can be properly attributed to the stock prediction work conducted by JN Enterprises.

5. Analysis and Conclusion

- a. Q: *Which positions exceeded your expectations? What conditions caused this?*

A: The stocks that went up during the simulation were AAPL, ABBV, ISRG, ORCL, RTX, and T. More market research could potentially explain the trends. Apple stock was already down a bit since they just wrapped up their Worldwide Developers Conference. Historically Apple stock dips in the short term after this conference where Apple announces their newest products, and tech enthusiasts critique the new hardware/software. However Apple had tremendous growth and earnings so it is universally regarded as a great long term investment. Oracle shares also rose due to a better than expected earnings report. ABBV shot up immensely and outperformed its peers as they reported their revenue is up 71% over the last year. Similarly ISRG posted a positive ESP increase. Lastly RTX stock, a historic blue chip stock, has steadily been trending up since February after the Russian invasion of Ukraine and as NATO allies look to strengthen their defenses with Raytheon's Radar and Missile business units.

- b. Q: *Which positions underperformed for you? What factors created the performance gap?*

A: The stocks that went down during the simulation are GE, HON, NVDA, SYK. These are all primarily hardware companies which seem to not perform as well. These companies had small declines in performance except for NVDA. NVDA in particular had the largest drop and is plunging from their previous high due to the recent collapse in cryptocurrency. With the cost of mining not keeping up with the price of crypto, in addition to the looming release of Nvidia's next generation graphics cards scheduled to be released in the fall, sales have plummeted along with the stock.

- c. Q: *What are the key things you learned from your trading simulation? How will your trading simulation influence your personal investing in the future?*

A: There were many key takeaways from the trading simulation project. To begin with, the difficulty of choosing where to start. There are such a vast number of stocks on the market that it is often difficult to find a starting point. After several iterations of selecting stocks, I finally decided on selecting large cap stocks as these are the ones with the most proven performance and have desirable characteristics such as no debt, high earnings, high growth, market cap dominance, market sector dominance and company uniqueness/staying power. The rationale behind this is I would likely be an investor and in an effort to avoid close monitoring, paying for an advisor, and transaction fees, I would hold onto stocks long

term as opposed to speculation or day trading. Furthermore, I picked stocks within the technology industry since that is my background, and I have a lot of experience and knowledge in the industry having followed news and reports very closely and being familiar with the products or services personally. In another simulation, I would replicate my rationale and thought process on different sectors as well and I would have mini baskets of stocks similar to the S&P 500 except distinguished by sector which would be beneficial for transparency and diversification especially since stocks within sectors tend to be highly correlated. Some other technical aspects I learned are hyperparameter tuning with neural networks and the amount of effort/work that goes into data preparation which took up the bulk of my time. Some key takeaways/pits that I found myself in were using benchmarks. Choosing an effective benchmark is important especially in such a small window of time since it will directly show the client how well a portfolio is performing. I believe I made some mistakes in the benchmarks in comparing my portfolio to the Treasury which is not really fair since the economy is doing so poorly at the moment, hence the negative sharpe ratio. A better representation is a benchmark that more closely resembles the portfolio. My overarching takeaway is the importance of relativity. Comparing stocks and saying its doing well or doing poorly is relative, especially in the two week window we had to work with. The Fama French style analysis is an important tool to help put the relativity into perspective. A quarterly or annually vesting frame would be interesting to examine as the portfolio matures and ultimately see if the machine learning methods and portfolio optimization had a real effect. Overall I learned a lot from this project, including how to model data, gain insight from the data, marry excel and jupyter notebook, and strength my finance foundation having previously never taken a finance course.

6. Self Evaluation

- a. I believe that my investment rationale and coherence was foundationally solid and I merged what I knew from science and machine learning into an elegant solution. If I had more time, I would explore training my hyperparameters and for more epochs and trials with an even wider basket of stocks. Thus I graded myself 29/30 for these two categories. In terms of analytics, the portfolio performance benchmarks results did not quite make sense. I am still a little confused on how I obtained a negative Sharpe ratio but I explained the rationale behind it and stated my assumptions since I based my market risk free premium on 3% and benchmarks are relative. I took off two points for this since I did not get the chance to further explore the metric results. Lastly, I also took off one point from performance since ultimately the JN portfolio underperformed the S&P 500 by a small percentage but still had positive returns. Overall I believe that I learned a lot from this course and spent a significant amount of time on constructing a coherent and fundamentally sound portfolio which resulted in my final portfolio grade of 95%. Thank you for the semester!
- i. Investment rationale 30% → 29
 - ii. Data coherence 30% → 29
 - iii. Analytics 30% → 28
 - iv. Performance 10% → 9
 - v. Total 100% → 95/100 = 95%

Appendix A: Stocks by sector, market capitalization, & PE ratio

<https://www.liberatedstocktrader.com/sp-500-companies-list-by-sector-market-cap/>

Appendix B: Monthly PE ratio of S&P 500

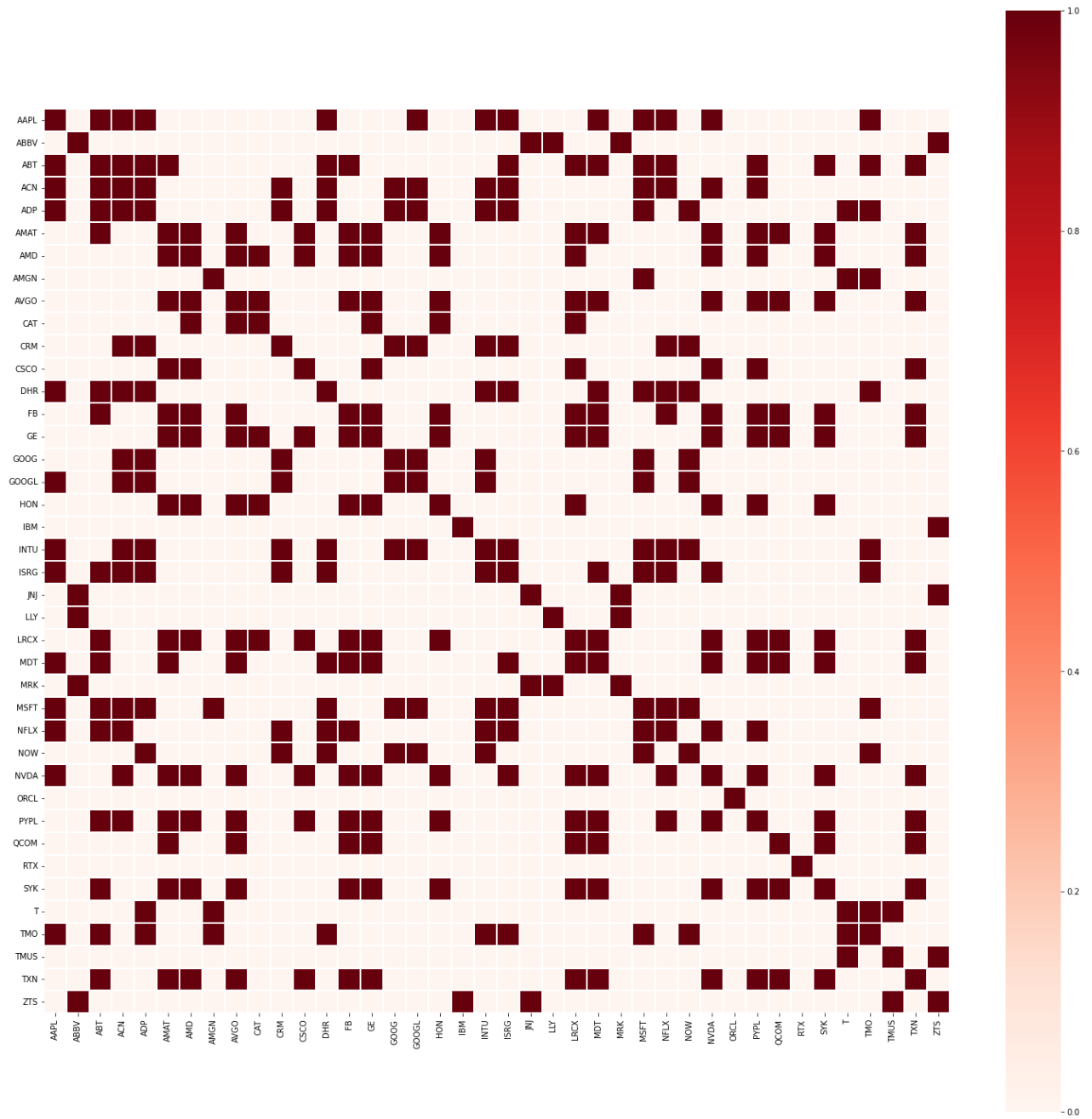
<https://www.multip.com/s-p-500-pe-ratio/table/by-month>

Appendix C: Tech Stocks Over \$100 billion Market Cap & PE Ratio of 20

Sector	Ticker	Company	Market Capitalization	PE Ratio
Producer Manufacturing	GE	General Electric Company	\$ 105,684,714,422.50	21.5
Producer Manufacturing	CAT	Caterpillar, Inc.	\$ 111,974,924,605.84	22.1
Health Technology	AMGN	Amgen Inc.	\$ 127,686,740,568.18	23.2
Electronic Technology	QCOM	QUALCOMM Incorporated	\$ 208,555,194,431.11	23.2

Sector	Ticker	Company	Market Capitalization	PE Ratio
Technology Services	CSCO	Cisco Systems, Inc.	\$ 266,384,018,596.41	23.6
Technology Services	FB	Meta Platforms, Inc.	\$ 941,736,878,229.62	24
Electronic Technology	TXN	Texas Instruments	\$ 176,024,068,559.83	24.2
Electronic Technology	LRCX	Lam Research Corporation	\$ 102,143,832,762.37	24.3
Producer Manufacturing	AMAT	Applied Materials, Inc.	\$ 142,099,923,764.55	24.5
Technology Services	IBM	IBM	\$ 122,000,723,501.00	25.3
Technology Services	ORCL	Oracle Corporation	\$ 234,732,290,724.48	25.3
Health Technology	JNJ	Johnson & Johnson	\$ 451,595,695,648.17	25.6
Producer Manufacturing	HON	Honeywell International Inc.	\$ 142,365,867,197.10	26.8
Health Technology	MRK	Merck & Company, Inc.	\$ 194,169,320,790.49	27.1
Technology Services	GOOGL	Alphabet Inc.	\$ 1,923,705,624,039.54	27.9
Technology Services	GOOG	Alphabet Inc.	\$ 1,927,101,773,229.48	27.9
Health Technology	MDT	Medtronic plc.	\$ 142,657,571,926.92	29.8
Health Technology	TMO	Thermo Fisher Scientific Inc	\$ 254,129,494,161.63	31
Electronic Technology	AAPL	Apple Inc.	\$ 2,986,128,347,290.24	31.7
Health Technology	ABBV	AbbVie Inc.	\$ 239,406,365,592.27	32.3
Health Technology	ABT	Abbott Laboratories	\$ 245,862,632,311.25	34.8
Technology Services	MSFT	Microsoft Corporation	\$ 2,513,296,516,647.36	37.6
Technology Services	ADP	Automatic Data Processing	\$ 102,821,918,705.62	39
Electronic Technology	RTX	Raytheon Technologies	\$ 130,174,753,742.42	39.2
Health Technology	DHR	Danaher Corporation	\$ 225,634,809,998.03	41.8
Health Technology	LLY	Eli Lilly and Company	\$ 259,934,839,379.61	42.2
Technology Services	ACN	Accenture plc	\$ 268,079,676,800.94	43.1
Communications	TMUS	T-Mobile US, Inc.	\$ 142,929,192,342.43	43.4
Electronic Technology	AVGO	Broadcom Inc.	\$ 273,867,545,687.41	44.4
Electronic Technology	AMD	Advanced Micro Devices, Inc.	\$ 181,431,389,863.09	44.5
Technology Services	PYPL	PayPal Holdings, Inc.	\$ 229,040,890,690.52	45.4
Health Technology	SYK	Stryker Corporation	\$ 101,258,755,071.66	53.8
Technology Services	NFLX	Netflix, Inc.	\$ 264,606,344,214.60	54.3
Health Technology	ZTS	Zoetis Inc.	\$ 110,725,636,030.92	58.8
Health Technology	ISRG	Intuitive Surgical, Inc.	\$ 128,509,998,075.81	77.6
Technology Services	INTU	Intuit Inc.	\$ 178,812,338,875.59	84.9
Electronic Technology	NVDA	NVIDIA Corporation	\$ 753,024,962,494.95	90.7
Technology Services	CRM	Salesforce.com Inc	\$ 251,628,104,835.17	140.1
Communications	T	AT&T Inc.	\$ 181,595,632,815.91	202.5
Technology Services	NOW	ServiceNow, Inc.	\$ 125,397,857,170.19	596.1

Appendix D: Cross Correlation Matrix



Appendix E: Recurrent Neural Network Training Results (ORCL)

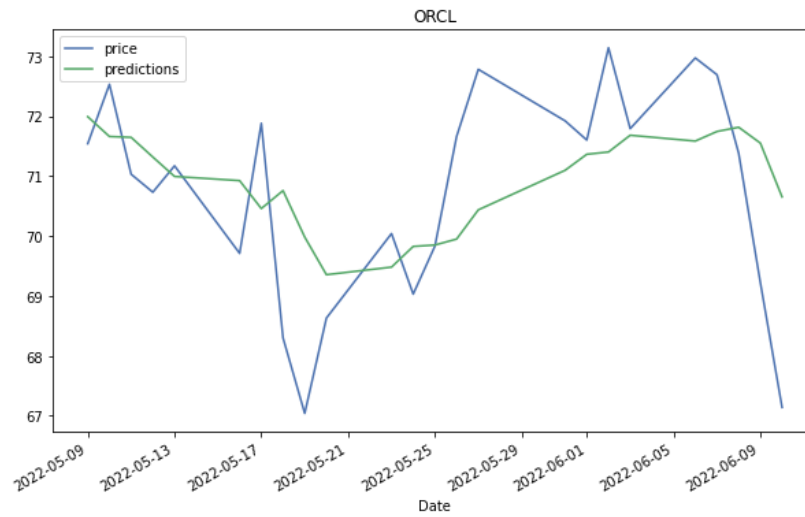


Table E1: Oracle Price vs Predictions during training

	lag_1	lag_2	lag_3	lag_4	lag_5	price	scaled price
Date							
2022-06-06	0.581395	0.746634	0.558139	0.597307	0.702570	72.970001	0.725826
2022-06-07	0.725826	0.581395	0.746634	0.558139	0.597307	72.690002	0.691555
2022-06-08	0.691555	0.725826	0.581395	0.746634	0.558139	71.379997	0.531211
2022-06-09	0.531211	0.691555	0.725826	0.581395	0.746634	69.220001	0.266830
2022-06-10	0.266830	0.531211	0.691555	0.725826	0.581395	67.139999	0.012240

Table E2: Input Data Frame for ORCL

```
In [829]: df_results.sort_values('7 day Return', ascending=False).head(10)
```

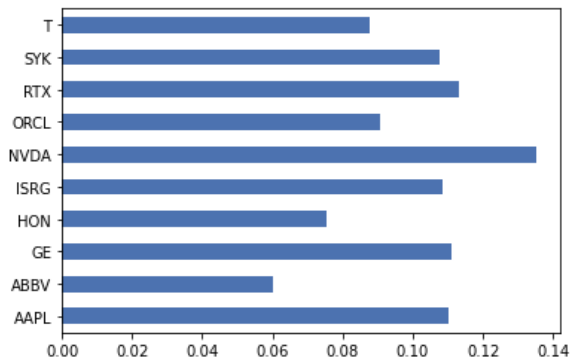
Out[829]:

	Stocks	7 day Return
14	ISRG	2.491180
7	SYK	1.553970
1	AAPL	1.407806
15	HON	1.046249
2	ABBV	0.689728
9	GE	0.478844
0	ORCL	0.320976
12	T	-1.468369
4	RTX	-4.668007
13	NVDA	-5.725082

Table E3: 5 Stocks Sorted by Highest/Lowest Predicted 5 day Return

Appendix F: Portfolio Optimization and Asset Allocation

```
In [900]: ▶ pd.Series(weights).plot.barh();
```



```
In [901]: ▶ ef.portfolio_performance(verbose=True);
```

Expected annual return: 79.4%
Annual volatility: 19.6%
Sharpe Ratio: 3.96

```
In [902]: ▶ latest_prices
```

```
Out[902]: AAPL    146.929993
          ABBV    155.210007
          GE      63.255001
          HON    173.229996
          ISRG   210.449997
          NVDA   156.529007
          ORCL    71.970001
          RTX     95.139999
          SYK    202.979996
          T       20.834999
          Name: 2022-07-08 00:00:00, dtype: float64
```

```
In [904]: ▶ from pypfopt import DiscreteAllocation
```

```
latest_prices = prices.iloc[-1]
da = DiscreteAllocation(weights, latest_prices, total_portfolio_value=1000000)
alloc, leftover = da.greedy_portfolio()
print(f"Discrete allocation performed with ${leftover:.2f} leftover")
alloc
```

Discrete allocation performed with \$49.33 leftover

```
Out[904]: {'NVDA': 863,
          'RTX': 1190,
          'GE': 1753,
          'AAPL': 749,
          'ISRG': 517,
          'SYK': 530,
          'ORCL': 1263,
          'T': 4201,
          'HON': 436,
          'ABBV': 389}
```


Appendix G: Week 1 Report Screenshot

				S&P 500				
Total AUM	Return \$	Return (%)	Cumulative Return	benchmark Value	benchmark return (\$)	benchmark return (%)	benchmark cumulative return	
				4101.23				
				4176.82				
				4108.54				
				4121.43				
				4160.68				
				4115.77				
				4017.82				
1000000				3900.86				
2 1000000	0	0.00%	100.00%	3749.63	-151.23	-4.03%	95.97%	
3 1002598.703	2598.70335	0.26%	100.26%	3735.48	-14.15	-0.38%	99.62%	
2 1016751.915	14153.2114	1.39%	101.39%	3789.99	54.51	1.44%	101.44%	
3 983310.5307	-33441.384	-3.40%	96.60%	3666.77	-123.22	-3.36%	96.64%	
4 987278.481	3967.95031	0.40%	100.40%	3674.84	8.07	0.22%	100.22%	

Appendix H: Performance Metrics

Note: see attached excel spreadsheet for calculations

	Portfolio	Benchmark
Arithmetic Average	0.131%	-0.250%
Geometric Average	0.118%	-0.270%
Total Cumulative Return	1.551%	-3.448%
Annualized Cumulative Return	34.764%	-49.346%
Total Volatility	0.01672	0.02031
Annualized Volatility	0.26540	0.32247
Sharpe ratio	-1.71579	
Alpha	-0.00715	
Beta	0.72392	
Active Risk	0.02770	
Information Ratio	-0.25806	
Correlation to Benchmark	-0.11093	

Appendix I: Performance Attribution

Note: see attached excel spreadsheet for calculations

Performance Attribution (2022/6/13 - 7/01)					
Asset Allocation					
	Portfolio weight	Benchmark weight	Excess weight	Benchmark return	Contribution
Stocks	97.05%	100%	-2.95%	1.55%	-0.05%
Cash	2.95%	0%	2.95%	0	0
Contribution of Asset Allocation					-0.05%
Stock selection					
	Portfolio performance	Benchmark performance	Excess performance	Portfolio weight	Contribution
Contribution of stock selection	1.55%	-3.45%	5.00%	97.05%	4.85%
Total excess return of portfolio					4.81%

Appendix J: Fama French Factor Data

Daily factor data pulled from the following link:

https://mba.tuck.dartmouth.edu/pages/faculty/ken.french/ftp/F-F_Research_Data_Factors_daily_CSV.zip

Fama French three factors analysis						
	Portfolio return	Mkt-RF	SMB	HML	RF	RP-RF
6/13/2022						
6/14/2022	0.26%	0.17000	1.28000	-1.22000	0.00001	0.259%
6/15/2022	1.41%	2.76000	0.89000	-2.20000	0.00001	1.411%
6/16/2022	-3.29%	-0.60000	-0.23000	1.33000	0.00001	-3.290%
6/17/2022	0.40%	2.14000	0.98000	-0.05000	0.00001	0.403%
6/21/2022	2.05%	-4.04000	0.22000	1.53000	0.00001	2.054%
6/22/2022	-0.05%	-0.34000	0.47000	-0.80000	0.00001	-0.047%
6/23/2022	0.49%	-0.05000	-0.11000	-0.18000	0.00001	0.492%
6/24/2022	3.21%	1.74000	-1.07000	1.29000	0.00001	3.205%
6/27/2022	-0.50%	-1.23000	-0.94000	1.84000	0.00001	-0.506%
6/28/2022	-2.28%	1.22000	0.78000	0.21000	0.00001	-2.280%
6/29/2022	-0.36%	2.18000	0.20000	-0.63000	0.00001	-0.361%
6/30/2022	-0.23%	2.58000	0.35000	-1.30000	0.00001	-0.234%
7/1/2022	0.59%	-0.71000	-0.49000	0.44000	0.00001	0.590%