Analyzing Multiple Stock Portfolios utilizing Signal Frontier Analysis

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Abstract

In this case study, we are looking at stocks across different industries, using Signal Frontier Analysis and Sharps Ratios for determining the best strategy, i.e. Holding period vs momentum, for three (3) stock portfolios: Financial, Technology, and Balanced. This study is an extension of work previously conducted by the authors of *Python for Data Analysis, Data Wrangling with Pandas, NumPy, and IPython,* McKinney [1].

Introduction

Gone are the days where a potential investor calls up his local stock broker and places an order to purchase shares of XYZ company's stock. The investor and/or their broker would review the company's financials, growth potential, and current market outlook to decide if a stock was worth buying. Investors worked on the assumption of a 'Free Market', where supply and demand determined pricing of commodities, in this case stocks. Profits or losses were driven by difference in expectations of future performance of said companies. This all changed at the beginning of the 21st century with the advent of computers, more precisely computer trading. At first, computers were used as tools to assists investors/brokers in making buy/sell decisions and speed up the processing of orders. Today, most buy/sell orders are executed utilizing algorithms, without any human interaction. Today in the US, between 80 – 90 percent of all trades are computer generated.
Stock portfolios are grouping of different stocks from within an industry sector or a conglomeration of stocks from multiple industry sectors.

Signal Frontier Analysis and the Sharpe Ratio allow us to look at three different portfolios, with three different risk profile and determine a holding period, as well as quantify risk-adjusted performance for each portfolio. The Balanced portfolio includes stocks from multiple sectors; Starbucks, Facebook, Johnson & Johnson, Delta Airlines, Bank of America, and General Electric.
The Financial Sectors portfolio include banks and investment firms; Morgan Stanley, JP Morgan Chase, Goldman Sachs and more. The final portfolio consists of Technology sector stocks; Intel, Apple, Google, Facebook, IBM and Adobe Inc. With technology moving in the picture we are now able to put statistical reasons behind our buy/hold/sell decisions.

Methods- Signal Frontier Analysis

Signal Frontier Analysis uses time series forecasting to analyze a basket of securities and find the optimal holding and look-back periods. Portfolios with higher risk adjusted returns have higher Sharpe Ratios. Modern portfolio analysis considers back testing as a common practice to test various algorithms and their risk-adjusted returns. While this method is by no means perfect and any investment advisor will tell you that 'past returns aren't indicative of future performance', it is an accepted method of analyzing portfolio performance.

Sharpe Ratio

Using Signal Frontier Analysis, it is possible to analyze a basket of securities and find the optimal holding and lookback periods, which yields the highest Sharpe Ratio. The goal of portfolio management is the maximization of return and the minimalization of risk. We can quantify this goal with the Sharpe Ratio. The Sharpe Ratio was developed by Nobel laureate William F. Sharpe and is

used to help portfolio managers understand the return of an investment, while taking risk into consideration [2].

Figure 1 – Sharpe Ratio

$$Sharpe\ Ratio = \frac{R_p - R_f}{\sigma_p}$$

Where:

- Rp = Return of portfolio. Can be measured in any frequency (i.e. daily, monthly, or annually), as long as they are normally distributed.
- Rf = Risk-Free rate, normally defined as a U.S T-Bill. Determines if you are being properly compensated for your risk. You may adjust risk-free instrument to your holding period.
- σp = Standard deviation of the portfolio's excess return

Sharp Ratio – Interpretation

Interpretation and example of the Sharpe Ratio:
The prudent portfolio manager considers risk to be just as an important factor as return. The goal of portfolio management is to maximize return and minimize risk. Previewing the equation for the Sharpe Ratio Figure 1, we can see that this satisfies risk-adjusted return in a way we can quantify. Assume you have a portfolio of stocks with an expected return of 10 percent, consider a one-year holding period for this example. The risk-free rate, Treasury Bill, is paying 3 percent. Let's further assume that the portfolio carries a 0.05 standard deviation.

Sharpe Ratio for the portfolio:
(0.10 – 0.03)/0.05 = 1.4 ~ for every point of return, you are assuming 1.4 units of risk.

Analysis

Our analysis contains three different portfolios designed to generate three different variations of Sharpe Ratios. For our analysis, an analysis time window of Jan 4, 2016 to present was chosen.

Balanced Portfolio

Balanced Portfolio ~ This portfolio is composed of seven different stocks from six different industries, Table 1. In world of portfolio management, this would be referred to as a balanced, or diversified portfolio. The goal of a balanced portfolio is to diversity risk and give a return with less volatility.

Stocks in the balanced portfolio:

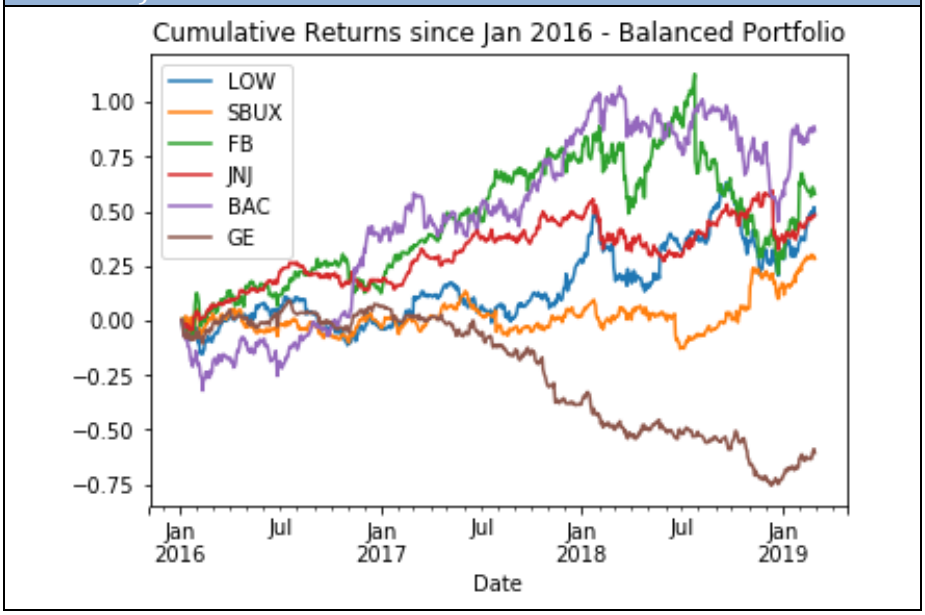
Table 1 – Portfolio Stocks (Balanced)

Stock	Industry

Starbucks	Consumer Discretionary
Facebook	Technology
Johnson and Johnson	Pharmaceuticals
Bank of America	Financial Services
GE	Industrials
Lowes	Retail

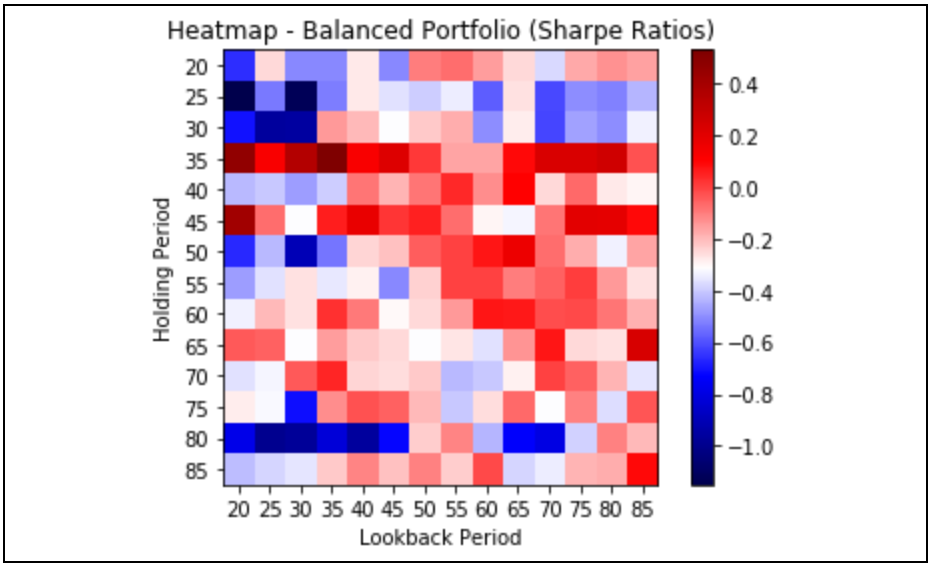
Cumulative Returns percentages for the Balanced portfolio are depicted in Figure 2. Within this portfolio, it is evidient that substantially differing returns were present. The best performing was Bank of America (+80% return) while the worst was General Electric (GE) -60% return.

Figure 2 – Cumulative Returns Jan 2016-Present (Balanced Portfolio)



Portfolio returns can vary dramatically depending on the amount of time an individual retains a stock (Holding Period) relative to momentum of stock portfolio for a given timeframe prior to obtaining the stocks (Lookback Period). A heatmap of Sharpe Ratios versus various Holding Period and Lookback Periods for the Balanced Portfolio, Figure 3, shows a relative consistent positive performance with a 35-day holding period.

Figure 3 – Heatmap Sharpe ratio over various lookback and holding periods (Balanced Portfolio) – Higher is better



Financial Stock Portfolio

Financial Services Portfolio ~ This portfolio is composed of six different stocks and they are all from the financial services sector, Table 2. Financial services companies are typically considered less volatile, lower Sharpe Ratio, for two reasons. One, they reinvest or payout their excess earnings in the form of a quarterly dividend and two, they are more tightly regulated by state and federal agencies.

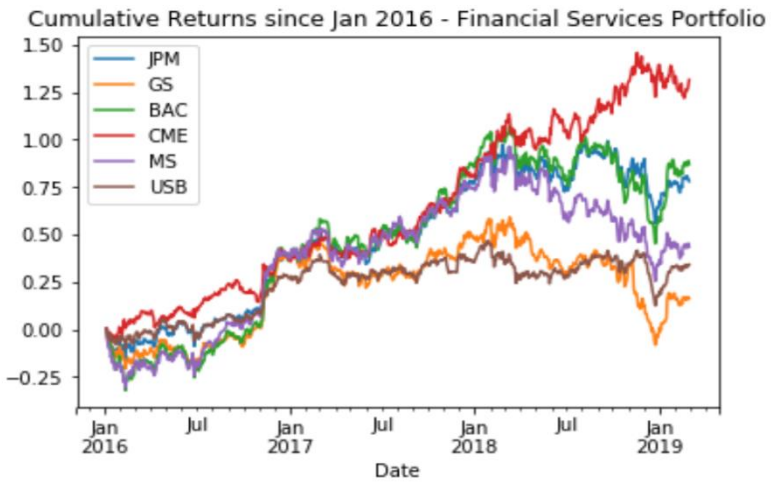
Stocks in the Financial Services portfolio:

Table 2 – Portfolio Stocks (Financial Services)

Stock	Industry
JP Morgan Chase	Financial Services
Goldman Sachs	Financial Services
Bank of America	Financial Services
CME Group	Financial Services
Morgan Stanley	Financial Services
US Bancorp	Financial Services

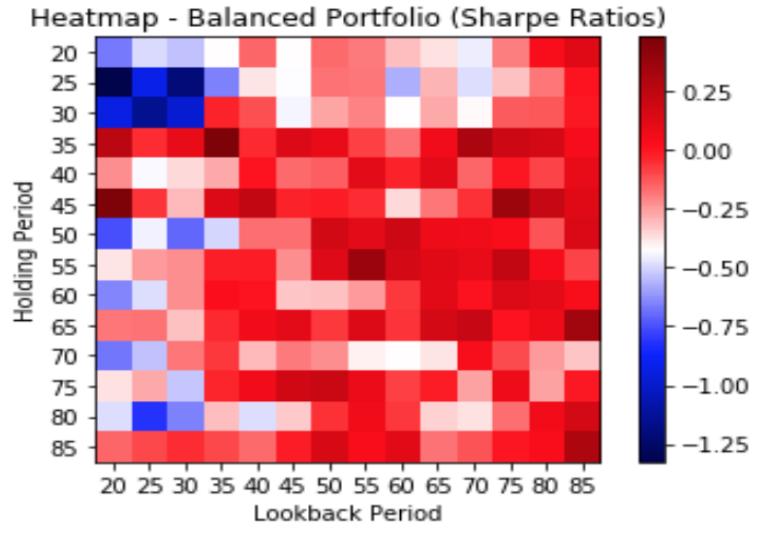
Cumulative Returns percentages for the Financial portfolio are depicted in Figure 4. Within this portfolio, it is evidience that substantially differing returns were present as well. The best performing was CME Group (CME), ≈+140% returns, while the lowest returns were Goldman Sachs (GS), ≈20% returns.

Figure 4 – Cumulative Returns Jan 2016-Present (Financial Services)



A heatmap of Sharpe Ratios over various Holding Period and Lookback Periods for the Financial Portfolio, Figure 5.

Figure 5 – Heatmap Sharpe ratio over various lookback and holding periods (Financial Services)



Technology Stock Portfolio

Technology Portfolio ~ This portfolio is composed of six different stocks and they are all from the technology sector, Table 3. Most of these companies do not pay dividends, are opaque with regards

to how they generate revenue and are in an industry that is, comparatively speaking, lightly regulated.

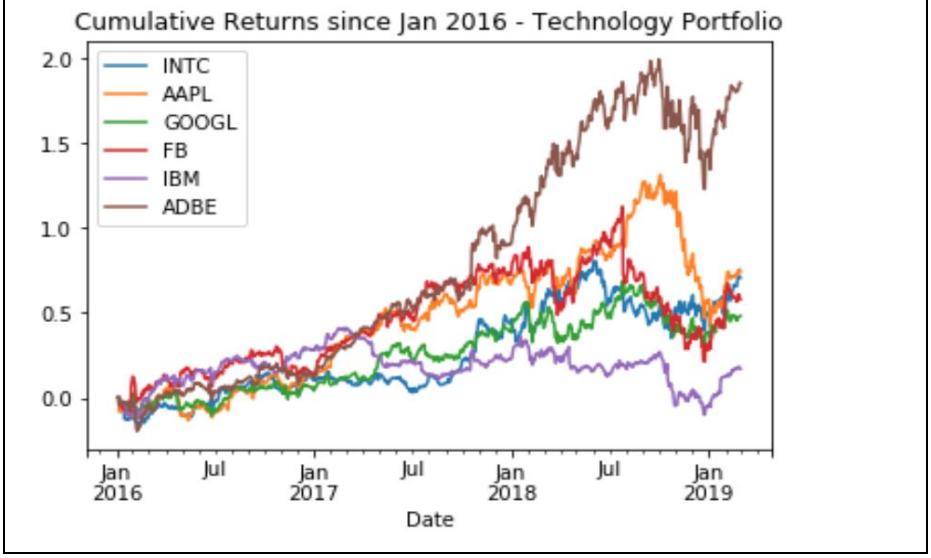
Stocks in the Technology portfolio:

Table 3 – Portfolio Stocks (Technology)

Stock	Industry
Intel Corporation	Technology
Apple	Technology
Google	Technology
Facebook	Technology
IBM	Technology
Adobe Inc.	Technology

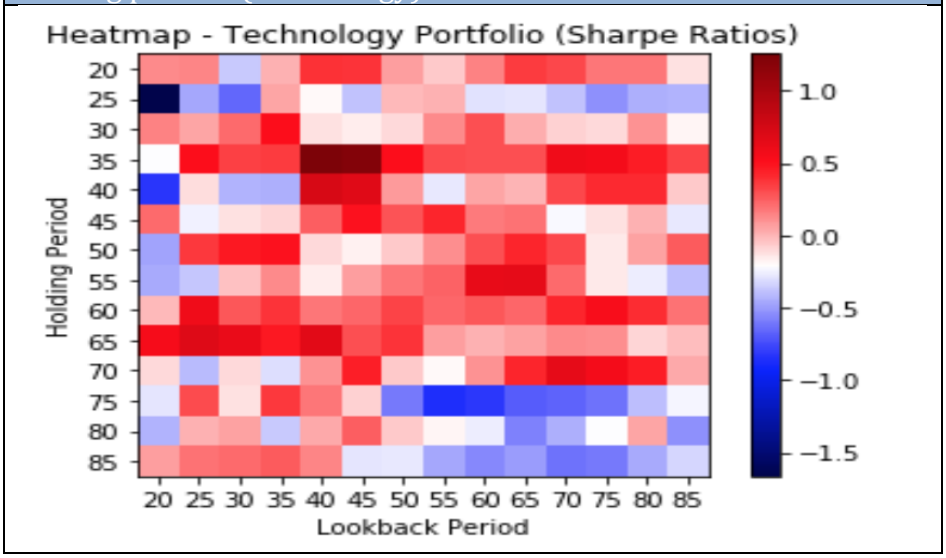
Cumulative Returns percentages for the Technology portfolio are depicted in Figure 6. With the overwhelming attention being given to technology stocks as a 'fool-proof' way of making exadurated returns, there is still evidience that not all technology stocks are 'golden eggs'. Some bell weather stocks did not perform as well, IBM with ≈20% returns, while non-mainstream stocks were stars, Adobe Inc. with ≈+180% returns, over this time period.

Figure 6 – Cumulative Returns Jan 2016-Present (Technology)



A heatmap of Sharpe Ratios over various Holding Period and Lookback Periods for the Technology Portfolio, Figure 7.

Figure 7 – Heatmap Sharpe ratio over various lookback and holding periods (Technology)



Portfolio Analysis Summary

Signal Frontier Analysis and the Sharpe Ratio allow us to look at three different portfolios, with three different risk profile and determine a holding period, as well as quantify risk-adjusted performance for each portfolio. Looking at the Table 4, the reasoning becomes apparent as to why we have different risk profiles. You see a stark contrast in performance and a holding period that may be counter intuitive. The aggressive portfolio manager would choose the technology portfolio to maximize performance and be mindful of the risk he/she is assuming. A more conservative portfolio manager is going to choose the balanced portfolio. Further research would go more in depth as to the holding periods generated by our model. In the world of High Frequency Trading, we have the option of using milli-seconds as a holding period.

Table 4 – Portfolio Sharp Ratios

Sector	Max Sharpe Ratio	Holding Period	Min. Sharpe Ratio	Holding Period
Balanced	0.5319	35	-1.1505	25
Financials	0.5621	20	-1.7930	80
Technology	1.2544	35	-1.6634	25

Future Work

The subject of financial analysis is extensive enough to author numerous case studies. Anticipated future work shall be closely related to the original case study.

Different Time Frame

Additional analysis over different timeframes are recommended, to determine if the patterns hold up or if they vary substantially with time.

Different Sectors

Financial markets are made up of numerous sectors and subsectors (Utilities, Industrial Goods, Basic Materials, Consumer Goods, etc.). Conducting similar analysis on other sectors, to discover if similar patterns could be observed, would be informative. With additional sectors analyzed, it may be possible to determine which sectors' performances are correlated with each other.

Different Asset Classes

Analysis on different asset holding, electronic traded funds (ETFs) for example might be informative. ETFs have become a very popular among individual investors to diversify holdings. ETFs are securities that tracks a stock index, a commodity, or a basket of assets. They are often concentrated on a certain sector of the market (financials, utilities, energy, etc.). Utilizing ETFs to represent sectors may improve analysis results by muting the volatility that can be inherent from a single stock and providing more of an overall view of the sector.

Discussions

Automated/Algorithmic trading systems (ATS) are computer programs that create and submit orders directly to market exchanges without human interaction. ATSs automatically generate orders based on predefined rules, which are often based on technical analysis and/or macroeconomic indicators. ATSs are often used in conjunction with automated/electronic market exchanges like Nasdaq (National Association of Securities Dealers Automated Quotations) which today boast a market cap of over $10 trillion dollars [3]. ATSs and electronic market exchanges can execute tasks (buys/sells/…) hundreds or even thousands of times a second, orders of magnitude greater than any transaction involving humans.

With such rapid trading, traditional safeguards and risk controls, previously performed by humans, are ill-equipped to properly perform, leading to market turmoil on more than one occasion. "A machine is making a decision based on the fact that we reached a level to buy or sell," Hogan said. "The problem with that is everyone's algorithms are pretty much the same, they key on the same trigger points. That's causes really fast momentum swings."[4] It is a self-fulfilling prophecy.

Recent ATS inspired market disruptions:

May 6, 2010 Flash Crash: The Dow Jones Industrial average dropped nearly 1,000 points (≈9%) and recovered those losses within minutes. The drop appeared to be a rapid sell-off of securities exacerbated by ATS's utilizing pre-defined trading triggers selling off large volumes at an incredibly rapid pace. At one point, over $1 Trillion dollars in equity value was lost, before regaining 70% by the end of the trading session.

Aug 1, 2012 Knight Capital Group (KCG): KCG lost 4 times its 2011 net income in 30 minutes of trading. The massive loss was due to a bug in one of KCG's trading algorithms the submitted erroneous orders to exchanges for nearly 150 different stocks, nearly collapsing KCG.
Other incidents include: 2015 NYSE Flash Crash; Aug 22, 2013 Nasdaq computer failure; ….

Financial regulatory agencies are concerned by the proliferation and fragility of ATSs, and high frequency trading (HFT). US regulation authorities, The Financial Industry Regulatory Authority (FINRA) and the Securities and Exchange Commission (SEC) have enacted several risk mitigation/controls that aim to limit the impact of such market disruptions. While some of the policies enacted, such as market stop authority 'circuit-breakers', are steps in the right direction, there is no 'foolproof' policy that will eliminate the increased risks of ATSs altogether.
FINRA is also tasked with identifying cross-market and cross-product manipulation of equity prices. Manipulation are usually performed through abusive trading algorithms by closing and opening positions at favorable prices by overwhelming the normal supply-demand market; thus, artificially raising or lowering the position's price. Such strategies include "momentum ignition strategies" where one entity places a bogus order on one side of the market, usually above the offer or below the bid, to entice other entities to react to the bogus order and then trade with another opposing order.
While ATSs and HFT systems algorithms are proprietary, most of them are based on the same principles that have worked in the past. This leads to a bit of 'in-breeding' between the different system's algorithms, making the threat of manipulation and coercion even more dangerous. What affects one algorithm will most likely affect numerous others. Due to the proprietary nature of the algorithms, little to no oversight into how they are created exists.

Ethics:

With this level of automation controlling the financial market, decoupling the equity pricing from market fundamentals, how easy would it be to manipulate prices in one party's favor, using ATSs? Some experts have said that the presence of ATSs means that the individual investor cannot compete. ATSs ingest massive amounts of data and make split-second trading decisions, much faster than a human could. Large trading firms, like JP Morgan and Goldman Sachs, have an unfair advantage over an average investor, making the stock market 'rigged' in their favor.

Terrorist/Malicious Attacks on world financial structures. With an ever increasingly 'connected' world, it becomes easier for individuals, groups, and/or nation-states to malicious attack the financial systems. Gone are the days of robbing banks, now financial institution can be attacked from thousands of miles away, with virtually no chances of being brought to justice. Institutions must be vigilant to guard against cyber-attacks. No system is fool-proof and criminals are always coming up with ever ingenious ways of infiltrating financial systems. Threats of these types of attacks must be acknowledged and sharing of 'lessons-learned' must be required, to help prevent future attacks.

Should FINRA, SEC be allowed to use a 'kill' switch to disconnect an ATS that is malfunctioning or grossly manipulating market conditions? This seems like a no-brainer but there are numerous repercussions that would have to be addressed prior to a government agency have the power to step-in and shut-down a private institution's business transaction(s). Who would have the authority? What type of activity would warrant a 'kill' activation? If parties are negatively affected

by the action, how will this be handled (repayment, cancellation of orders, etc.). Because of all the open issues, an Individual 'kill' switch operated by the regulatory agencies will not be something that will be implanted soon.

Conclusion

The prudent portfolio manager considers risk to be just as an important factor as return. The goal of portfolio management is to maximize return and minimize risk. Gone are the days where a potential investor calls up his local stock broker and places an order to purchase shares of XYZ company's stock. Most equity transactions are executed using sophisticated algorithms analyzing stocks using numerous financial indicators, to determine if a stock/portfolio is worth buying.

Signal Frontier Analysis allows us to look at three different portfolios (Balanced, Financial Services, Technology), with three different risk profile and determine a holding period, as well as quantify risk-adjusted performance for each portfolio. A stark contrast in performance and holding period were evident between the three portfolios (Table 4). The analysis highlights the different strategies that may be employed by different portfolio managers relative to their management style. The aggressive portfolio manager would choose the technology portfolio while a conservative manager might choose the balanced portfolio.

References

[1] McKinney, Wes; from: "Python for Data Analysis, Data Wrangling with Pandas, NumPy, and Ipython" O'Reilly ©2013
[2] https://www.investopedia.com/terms/s/sharperatio.asp
[3] https://www.thestreet.com/investing/what-is-nasdaq-14812837
[4] https://money.cnn.com/2018/02/06/investing/wall-street-computers-program-trading/index.html
https://en.wikipedia.org/wiki/Automated_trading_system

Appendix A


CaseStudy8_Rev1.pdf

Python 3.6 Code

```
# coding: utf-8

# # Financial and Economic Data Applications
# Original from Wes McKinney (https://github.com/wesm/pydata-book/tree/1st-edition)
#
# Updated and edited for Python circa 2018 by R. D. Slater
#
# MSDS 7333 - Quantifying the World - Case Study 8
# Signal Frontier Analysis
# Team Members: Jeffery Lancon, Manisha Pednekar, Andrew Walch, David Stroud
# Date: 03/05/2019
#

# In[1]:


from __future__ import division
from pandas import Series, DataFrame
import pandas as pd
from numpy.random import randn
import numpy as np
pd.options.display.max_rows = 12
np.set_printoptions(precision=4, suppress=True)
import matplotlib.pyplot as plt
plt.rc('figure', figsize=(12, 6))


# In[2]:


get_ipython().run_line_magic('matplotlib', 'inline')


# In[3]:


import os
```

```
currentDir = get_ipython().run_line_magic('pwd', '')
os.chdir(currentDir)


# In[4]:


pwd


# ## Signal frontier analysis

# ### Balanced Portfolio
# LOW - Lowes Home Improvement
# SBUX - Starbucks
# FB - Facebook
# JNJ - Johnson & Johnson
# BAC - Bank of America Corporation
# GE - General Electric

# In[5]:


import datetime
import pandas as pd

start_dt=datetime.datetime(2016,1,4)
end_dt=datetime.datetime(2019,2,27)
from pandas_datareader import data as web
#stock='AAPL'
#px=pd.DataFrame({'AAPL':web.get_data_yahoo(stock, start_dt, end_dt)['Adj Close']})
#names=['GOOG','MSFT', 'GS','INTC', 'MS', 'BAC', 'C']
stock='LOW'
px=pd.DataFrame({'LOW':web.get_data_yahoo(stock, start_dt, end_dt)['Adj Close']})
names=['SBUX','FB','JNJ','BAC', 'GE']
for stock in names:
   while True:
      try:
         px[stock]=web.get_data_yahoo(stock, start_dt, end_dt)['Adj Close']
         break
      except:
         print('Unable to read stock: {0}'.format(stock))
         print('trying again')


# In[6]:
```

```
#px = pd.read_csv('ch11/stock_px.csv')


# In[7]:


plt.close('all')


# In[8]:


px = px.asfreq('B').fillna(method='pad')
rets = px.pct_change()
((1 + rets).cumprod() - 1).plot()
plt.title('Cumulative Returns since Jan 2016 - Balanced Portfolio')


# In[9]:


def calc_mom(price, lookback, lag):
    mom_ret = price.shift(lag).pct_change(lookback)
    ranks = mom_ret.rank(axis=1, ascending=False)
    demeaned = ranks.subtract(ranks.mean(axis=1), axis=0)
    return demeaned.divide(demeaned.std(axis=1), axis=0)


# In[10]:


compound = lambda x : (1 + x).prod() - 1
daily_sr = lambda x: x.mean() / x.std()

def strat_sr(prices, lb, hold):
    # Compute portfolio weights
    freq = '%dB' % hold
    port = calc_mom(prices, lb, lag=1)

    daily_rets = prices.pct_change()

    # Compute portfolio returns
    port = port.shift(1).resample(freq).first()
    returns = daily_rets.resample(freq).apply(compound)
```

```
    port_rets = (port * returns).sum(axis=1)

    return daily_sr(port_rets) * np.sqrt(252 / hold)


# In[11]:


strat_sr(px, 70, 30)


# In[12]:


from collections import defaultdict

lookbacks = range(20, 90, 5)
holdings = range(20, 90, 5)
dd = defaultdict(dict)
for lb in lookbacks:
    for hold in holdings:
        dd[lb][hold] = strat_sr(px, lb, hold)

ddf = DataFrame(dd)
ddf.index.name = 'Holding Period'
ddf.columns.name = 'Lookback Period'


# In[13]:


import matplotlib.pyplot as plt
def heatmap(df, portfolio,cmap=plt.get_cmap('seismic')):
    fig = plt.figure()
    ax = fig.add_subplot(111)
    axim = ax.imshow(df.values, cmap=cmap, interpolation='nearest')
    ax.set_xlabel(df.columns.name)
    ax.set_xticks(np.arange(len(df.columns)))
    ax.set_xticklabels(list(df.columns))
    ax.set_ylabel(df.index.name)
    ax.set_yticks(np.arange(len(df.index)))
    ax.set_yticklabels(list(df.index))
    ax.set_title("Heatmap - {} Portfolio (Sharpe Ratios)".format(portfolio))
    plt.colorbar(axim)
```

```
# In[14]:


heatmap(ddf,'Balanced')
plt.show()


# In[15]:


# max for each row
maxForRow = ddf.max(axis=0)
globalMax = maxForRow.max()
# https://stackoverflow.com/questions/23271575/printing-bold-colored-etc-text-in-ipython-
qtconsole/46934204
print('\x1b[4;1;34m'+'Portfolio - Balanced'+'\x1b[0m')
print ("Max Sharpe Ratio is: %f" % globalMax)
ddf[ddf.values==globalMax]


# In[16]:


# min for each row
minForRow = ddf.min(axis=0)
globalMin = minForRow.min()
print('\x1b[4;1;34m'+'Portfolio - Balanced'+'\x1b[0m')
print ("Min Sharpe Ratio is: %f" % globalMin)
ddf[ddf.values==globalMin]


# ---

# ### Financial Services Portfolio
# JPM - JP Morgan Chase
# GS - Goldman Sachs
# BAC - Bank of America
# CME - CME Group
# MS - Morgan Stanley
# USB - US Bancorp

# In[17]:


stock='JPM'
pxFin=pd.DataFrame({stock:web.get_data_yahoo(stock, start_dt, end_dt)['Adj Close']})
```

```
namesFin=['GS', 'BAC','CME', 'MS', 'USB']
for stock in namesFin:
   while True:
      try:
         pxFin[stock]=web.get_data_yahoo(stock, start_dt, end_dt)['Adj Close']
         break
      except:
         print('Unable to read stock: {0}'.format(stock))
         print('trying again')


# In[18]:


plt.close('all')
pxFin = pxFin.asfreq('B').fillna(method='pad')
rets = pxFin.pct_change()
((1 + rets).cumprod() - 1).plot()
plt.title('Cumulative Returns since Jan 2016 - Financial Services Portfolio')


# In[19]:


strat_sr(pxFin, 70, 30)


# In[20]:


lookbacks = range(20, 90, 5)
holdings = range(20, 90, 5)
ddFin = defaultdict(dict)
for lb in lookbacks:
   for hold in holdings:
      ddFin[lb][hold] = strat_sr(pxFin, lb, hold)

ddfFin = DataFrame(ddFin)
ddfFin.index.name = 'Holding Period'
ddfFin.columns.name = 'Lookback Period'


# In[21]:


heatmap(ddfFin,'Financial Services')
```

```
plt.show()


# In[22]:


# max for each row
maxForRow = ddfFin.max(axis=0)
globalMax = maxForRow.max()
print('\x1b[4;1;34m'+'Portfolio - Financial'+'\x1b[0m')
print ("Max Sharpe Ratio is: %f" % globalMax)
ddfFin[ddfFin.values==globalMax]


# In[23]:


# min for each row
minForRow = ddfFin.min(axis=0)
globalMin = minForRow.min()
print('\x1b[4;1;34m'+'Portfolio - Financial'+'\x1b[0m')
print ("Min Sharpe Ratio is: %f" % globalMin)
ddfFin[ddfFin.values==globalMin]


# ---

# ### Technology Portfolio
# INTC - Intel Corporation
# AAPL - Apple
# GOOGL - Alphabet Inc Class A - Google
# FB - Facebook
# IBM - International Business Machine
# ADBE - Adobe Inc.

# In[24]:


stock='INTC'
pxTech=pd.DataFrame({stock:web.get_data_yahoo(stock, start_dt, end_dt)['Adj Close']})
namesTech=['AAPL', 'GOOGL','FB', 'IBM', 'ADBE']
for stock in namesTech:
   while True:
      try:
         pxTech[stock]=web.get_data_yahoo(stock, start_dt, end_dt)['Adj Close']
         break
```

```
    except:
        print('Unable to read stock: {0}'.format(stock))
        print('trying again')


# In[25]:


plt.close('all')
pxTech = pxTech.asfreq('B').fillna(method='pad')
rets = pxTech.pct_change()
((1 + rets).cumprod() - 1).plot()
plt.title('Cumulative Returns since Jan 2016 - Technology Portfolio')


# In[26]:


strat_sr(pxTech, 70, 30)


# In[27]:


lookbacks = range(20, 90, 5)
holdings = range(20, 90, 5)
ddTech = defaultdict(dict)
for lb in lookbacks:
    for hold in holdings:
        ddTech[lb][hold] = strat_sr(pxTech, lb, hold)

ddfTech = DataFrame(ddTech)
ddfTech.index.name = 'Holding Period'
ddfTech.columns.name = 'Lookback Period'


# In[28]:


heatmap(ddfTech,'Technology')
plt.show()


# In[29]:
```

```
# max for each row
maxForRow = ddfTech.max(axis=0)
globalMax = maxForRow.max()
print('\x1b[4;1;34m'+'Portfolio - Technology'+'\x1b[0m')
print ("Max Sharpe Ratio is: %f" % globalMax)
ddfTech[ddfTech.values==globalMax]


# In[30]:


# min for each row
minForRow = ddfTech.min(axis=0)
globalMin = minForRow.min()
print('\x1b[4;1;34m'+'Portfolio - Technology'+'\x1b[0m')
print ("Min Sharpe Ratio is: %f" % globalMin)
ddfTech[ddfTech.values==globalMin]
```